MARKET OPPORTUNITIES FOR ADVANCED VENTILATION TECHNOLOGY

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BARRIERS TO THE INTEGRATION OF CLADDING AND BUILDING SERVICES

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Synopsis

This paper briefly exams the role of the building envelope in determining the internal environmental conditions in buildings and the scope for holistic design of building services and building envelope. It then looks at how holistic design may be undertaken, the barriers to be overcome to enable this to happen and the incntives that are necessary.

1.0 THE FUNCTION OF THE BUILDING ENVELOPE

The building envelope fulfils many functions including environmental control. The design may be dominated by other considerations than building physics, for instance aesthetics or structure. Even the design for internal comfort and energy use may be governed by a single aspect of comfort such as noise reduction across the façade.

The design of the whole building envelope in every aspect of its performance is complex and invariably a compromise. It is probably the most difficult engineering aspect of any building because of the large number of parameters that can be changed and the large number of conflicting performance requirements. Figure 1 shows the many things to be considered in façade design.

Too often facades are designed without full consideration of their contribution to the internal climate of the building. The façade design will define the basic internal climate that is to be moderated by heating, cooling and ventilation plant.

1.1 Air leakage

The building envelope will be the sole controller of air infiltration and exfiltration. Historically this was considered on a component by component basis if at all. Standards for air leakage through windows were conducted on a product, often

COST

- **Capital costs**
  - - -
- **Whole life costs**
  - Energy
  - Maintenance
  - - -
- **Environmental costs**
  - - -

MATERIAL

- **Glass**
  - Annealed
  - Toughened
  - Laminated
  - Tinted
  - - -
- **Metals**
  - Aluminium
  - Bronze
  - Titanium
  - - -
- **Sealants**
  - - -
- **Gaskets**
  - - -
- **Finishes**
  - - -
- **Stone**
  - - -
- **Insulation**
  - - -

PERFORMANCE

- **Weather**
  - Water leakage
  - Wind resistance
  - Air leakage
  - - -
- **Thermal**
  - U-value
  - Solar gain
  - - -
- **Moisture**
  - Condensation
  - Mould
  - - -
- **Acoustics**
  - - -
- **Security**
  - - -
- **Light**
  - - -

QUALITY

- **Workmanship**
  - Factory
  - Site
- **Durability**
  - - -

APPEARANCE

- **Finishes**
  - Colour
  - Gloss
  - Texture
  - - -
- **Fit**
  - Tolerance
  - Flatness
  - Alignment
  - - -
- **Materials**
  - Texture
  - Consistency
  - - -

Figure 1. Scope of façade engineering (This is a partial diagram indicating the breadth of this area)

excluding ancillary components such as cills or joining mullions. Doors were not covered by these Standards simply because they were not capable of providing the same degree of sealing. All of this ignored the gross air leakage that may occur at the interface between components and between components and the wall into which they are fixed.

1.2 Ventilation

The building envelope is the route for ventilation, whether this is natural or forced ventilation. The use of naturally ventilated buildings is being pursued in the interests of reducing energy use and providing a good indoor air quality. However, the use of natural ventilation may conflict with the needs to:

- Reduce noise transmission through the wall.
- Remove pollutants from the ventilation air.
- Exclude insects and vermin from a building.

1.2 Conduction loss/gain

Heat loss and gain resulting from conduction through the building envelope is one often the greatest source of energy transfer into or out of the building, particular for envelopes of low transparency. The insulation of walls can be very good but too often an elemental approach is applied to the calculation of U-values. This creates no incentive to develop or use highly insulated envelope components or to allow trade-off between components. For instance a highly insulated façade may allow a trade off against increased ventilation/air leakage.

1.3 Solar gain

The inward transfer of energy as a result of solar gain is totally governed by the building envelope, either solely by its transparency/opacity or by its reaction to incoming solar energy through shading devices.

1.4 Comfort

The building envelope also contributes to comfort in a building through its thermal mass acting as a moderator of the internal temperatures and through other considerations such as glare.

2.0 BUILDING ENVELOPE DESIGN

The building envelope is the only engineered element of the building for which the design is constrained at an early stage by non-engineers. The envelope gives the building its aesthetic that is set at an early stage of the design process. This often forms part of the planning permissions required for construction of the building and is difficult to change at a latter stage. Similarly the client may have a view of the form of building that they wish to construct and occupy, for instance a glass box, a building incorporating photovoltaics, a traditional brick building with many opening windows, and so on.

Only in the following stages of design are the building envelope and building services designed in detail. At this stage the building envelope is seldom redesigned, but merely detailed, such that the building services alone are required to moderate the internal climate.

To achieve the successful performance and economic performance it is necessary to have a better understanding of building physics at the early design stage and to design holistically throughout the process.

2.1 Initial design

At the early design stage buildings are too often designed without a clear knowledge of the art of the possible. Different styles of window have characteristic air leakage rates and some, such as sliding windows, cannot be sealed as well as others. Similarly the outline design of wall may presume a jointing technology, or number of joints, that will create an inherently leaky building.

The purpose of the building envelope is to provide a controlled filter between the internal and external environments. Designs with large numbers of penetrations through the envelope will be difficult to seal and maintain. Yet building are designed with the structural frame external to the envelope. Clearly the view taken by designers at the initial design stage is that all problems can be solved latter in the design process, or at the construction stage. All too often in the construction industry one designer introduces a problem for another designer to solve, at a cost, later in the project.

2.2 Envelope design

Envelope procurement has become largely based on performance specification over the last twenty years. This places responsibility for design of the envelope on the specialist sub-contractor. This is done in the belief that specialist sub-contractors have specific knowledge of their construction techniques. However there are two consequences of this trend.

Firstly the façade is often comprised of a number of different forms of construction. These are often packaged into separate contracts let to different contractors. The problem is assignment of responsibility for the interfaces between the different sections of the wall. This is a particular problem where separate layers of the wall, for instance a rainscreen cladding, are detailed, supplied and constructed by different contractors. Frequently this form of construction will entail the employment of three different contractors to install the blockwork inner wall, outer rainscreen and windows respectively.

Secondly the specialist sub-contractor has little scope to do other than comply with the performance specification. They have limited ability to influence the adjacent construction to which they must seal. There is seldom an opportunity for a specialist sub-contractor to provide an enhanced wall that, although possibly costing more, wold deliver overall cost, energy and comfort benefits to the whole project.

2.3 Holistic approach to design

Holistic design implies that all aspects of the building performance are considered concurrently in the design process.

Holistic design would consider alternative building designs, taking account of cost, comfort, energy use, quality, appearance and so on. A full list of façade performance consideration is given in Figure 1. Time and cost considerations prohibit the full development of more than one design or the iteration and improvement of a full design. Therefore a linear approach is taken to design with different aspects being designed one after the other and with specialist designers often only involved after the outline design has been locked.

There is a need to bring more specialist knowledge of facades and building services to the early stages of building design.

2.4 Detailed envelope design

Joints are required in the building envelope to:

- Allow construction taking account of;
  - the use of different materials and components
  - the upper dimensional limits of materials and components
- Allow construction of the envelope as separate contractual packages
- Allow opening components for;
  - Comfort ventilation
  - access
  - cooling ventilation

Permanently sealed (non-opening) joints within a single contractual package can be successfully made as sealant joints, gasket joints or welded/bonded joints as both halves of the joint are detailed by a single contractor. Similar joints between adjacent envelope packages are more difficult to detail. Traditionally these joints have been overlooked in detail design with drawings labeled ‘joint by others’ and so on. Often these details are agreed on site, if the need is recognised.

At the detail design stage little can be done to improve issues such as excess solar gain. It is virtually impossible at this stage to change the thermal mass of the envelope and the only possibility is to avoid cold bridging at details as the cladding materials have largely been selected at the initial design stage.

3.0 VENTILATION AND AIR LEAKAGE

Buildings in the UK achieved average air leakage in excess of 20 $m^3/hr/m^2$ with many having air leakage well in excess of this. The draft UK Building Regulations 2002 require buildings to achieve and overall air leakage of 10 $m^3/hr/m^2$ at 50Pa.

Glazing screens, curtain walling and similar forms of construction can achieve air tightness of 1.5 $m^3/hr/m^2$ at 600Pa, equivalent to 0.28 $m^3/hr/m^2$ at 50Pa, for fixed light construction. The introduction of opening lights for ventilation requires the use of opening joints which, although sealed with gaskets, are inherently more difficult to seal. Furthermore, the air leakage is related to the length of opening joint. Measurement shows that it is also related to the number of corners in each joint as these are weak points that allow greater air leakage. The length of joint per unit area is determined at an early stage of the envelope design when aesthetics, and possibly natural ventilation, are the major considerations.

Walling and window systems are frequently used to construct the building envelope. Although these are standard systems, for which air leakage rates have been measured, the air leakage rate achieved will depend on the configuration and size of components. Configurations using smaller dimension components will require a better performing system to achieve the same air leakage rate.

4.0 HEAT TRANSFER

The U-value of a wall will depend on the area of opaque (insulated) panels and area of glazing. The frame also has a significant effect and the overall U-value achievable may be constrained at an early stage by the outline design of the building.

As with air leakage a system of components may perform well in some configurations yet give too large a U-value in configurations that contain large proportions of frame.

5.0 RELIABILITY OF BUILDING ENVELOPE PERFORMANCE

As a result of poor detailing at interfaces, as a result of both design and workmanship, worst case assumptions have been made in the past. This basis for design of building services delivers plant that can always cope with the heat transfer through the envelope but it leads to gross oversizing of plant. This plant may be optimised during commissioning but will never run as efficiently as correctly sized plant optimised at the design stage.

With improved design of cladding and the introduction of whole building air leakage tests it is possible to have greater confidence in the air leakage achieved by the building envelope. The introduction of thermal imaging can show up poor workmanship in the fitting of insulation and again confidence in the achieved U-value is enhanced.

The only remaining unknown is the long-term performance of the building envelope. Currently most façade components are designed for a service life of 20-30 years while the primary components are designed for a life of 60 years. This is generally comparable with the service life of the mechanical plant. The principal concern is the gradually increased air leakage that may occur through gaskets of opening joints. This will arise where lower grade polymers have been used for gasket manufacture.

Deterioration of some insulation material has occurred in the past but this has generally been due to total breakdown of the structure of the insulation material and is likely to cause problems whatever rational approach is taken to oversizing of service plant.

6.0 CHANGING ROLE OF THE BUILDING SERVICES ENGINEER

The increasing need to calculate energy loss for buildings and take account of cooling loads and solar gain has placed a greater emphasis on the design of the building envelope and the building services. Architects have looked to building services engineers to specify the environmental performance of glass and the U-values to be achieved by different areas of the building envelope. An analogy can be found in the use of structural engineers to check the integrity and safety of the building envelope.

Experience at the Centre for Window and Cladding Technology shows that building services engineers are not experienced at calculating the thermal performance of complex metal walls constructed as thermally broken, yet often bridged, highly insulated constructions.

Furthermore the services engineer is seldom aware of the art of the possible in façade construction. They are unlikely to use leading technology but to rely on U-values that have been used in the past and can be easily achieved today.

The use of adaptive facades with controllable blinds or variable transmission glass require a greater input from the services engineer. The use of natural ventilation requires awareness of the technology for opening and controlling windows. Here the services engineer may be aware of what is possible but less likely to know what is appropriate and what can be afforded on any given project.

7.0 COMBINING BUILDING ENVELOPE AND BUILDING SERVICES PERFORMANCE

It is topical to talk of whole building performance where the client simply specifies budget, spaces for activities, interconnectivity, services, internal environments, running costs, green issues and so on. This may be fine from the point of view of the client. However, it changes the demands made on all of the designers and constructors involved in the design and commissioning of a building.

In order to respond to a whole building performance specification it is necessary to have people with many skills in the initial design team. Some of the leading practices are already working in this environment but many will have to change radically to adjust to these methods of working. Some projects now involve a main contractor at the early design stage and a few main contractors have set up pre-contract design groups.

Façade contractors and HVAC contractors are seldom involved in the early design discussions. This arises partly because neither wishes to give their knowledge to a project on which they may not eventually be the contractor and largely because there is no design fee for this element of the design. This approach to holistic design also fails because few specialist contractors take an interest in technology outside of their own sphere. Generally only the largest specialist contractors can make an in-depth contribution at the initial design stage.

Attempts have been made to let the cladding and HVAC contracts as a single package but these have foundered for the reasons given above. Each of the specialist contractors has simply worked at their own specialism with little attempt at holistic design or design trade-off. This has arises because neither contractor has an interest in the running costs but only the initial cost, and in particular their share of it.

8.0 WAYS FORWARD

Holistic design of the building envelope and the building services requires not only the right mix and level of skills but also a financial or equivalent driver, for instance client insistence on an improved approach to design. Clearly any financial driver has to relate to whole life costs.

8.1 Façade engineers

Façade engineers first appeared as consultants when concerned clients realised that building envelopes frequently leaked water as a result of poor design and workmanship. These consultants employed directly by the client to monitor the performance of designers and contractors alike. Today, many multi-disciplinary consultancy practices include façade engineering teams and there are many small specialist façade engineering practices. Increasingly these façade engineering groups work as part of the clients design team rather than directly for the client, Figure 2. However, these consultants and designers still focus largely on the construction, materials, durability and weather sealing of building envelopes, Ledbetter (2001).

Specialist design offices are employed by building envelope contractors to undertake detail design of wall and roofing systems. To date these companies have become skilled at construction and weather sealing but have limited ability to understand the building physics of walls.

8.2 Building physicists

With few exceptions building services consultancies do not have people who understand the performance and contribution of the façade. This is the scenario that will lead clients to directly employ building physicists as consultants to oversee the design of building services and building envelope and ensure that together these two major elements of any building deliver optimum performance.

8.3 Design Build Operate (DBO) contracts

These contracts take several forms. In the UK they have become popular as Private Finance Initiative (PFI) contracts. Under these contracts a consortium, normally including a main contractor, undertakes to construct and operate a building for a given period in return for payment from the client. These contracts are complex and take many forms but frequently place responsibility for energy and maintenance costs on the consortium constructing the building.

8.4 Package management

Often the building envelope is constructed as separate contract packages undertaken by different specialist cladding contractors. In this case the main contractor, or client, may insist that one sub-contractor acts as the lead contractor for all of the building envelope and assumes responsibility for all interfaces and sealing, Figure 3.

Sometimes a package manager is appointed with sole responsibility of coordinating the separate specialist contractors. Increasingly main contractors are developing in-house skills to undertake this role themselves. It is only a short step to apply this to integration of the cladding and building services. The key to this happening will be clearly defined benefits and the availability of adequately trained individuals with knowledge of building services, building envelope and above all building physics.

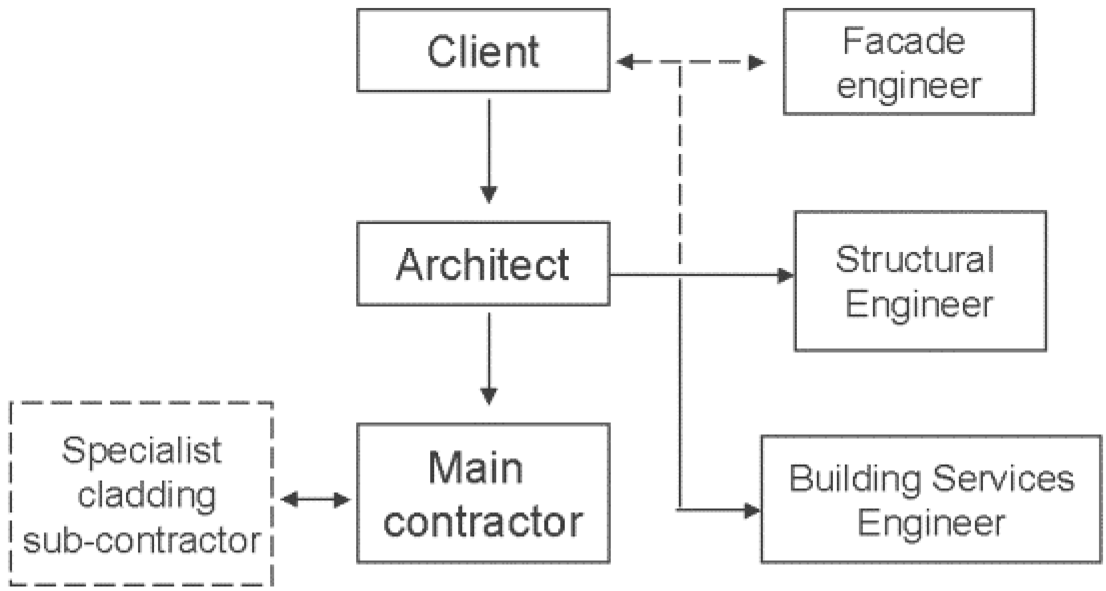

Figure 2. Role of the façade engineer

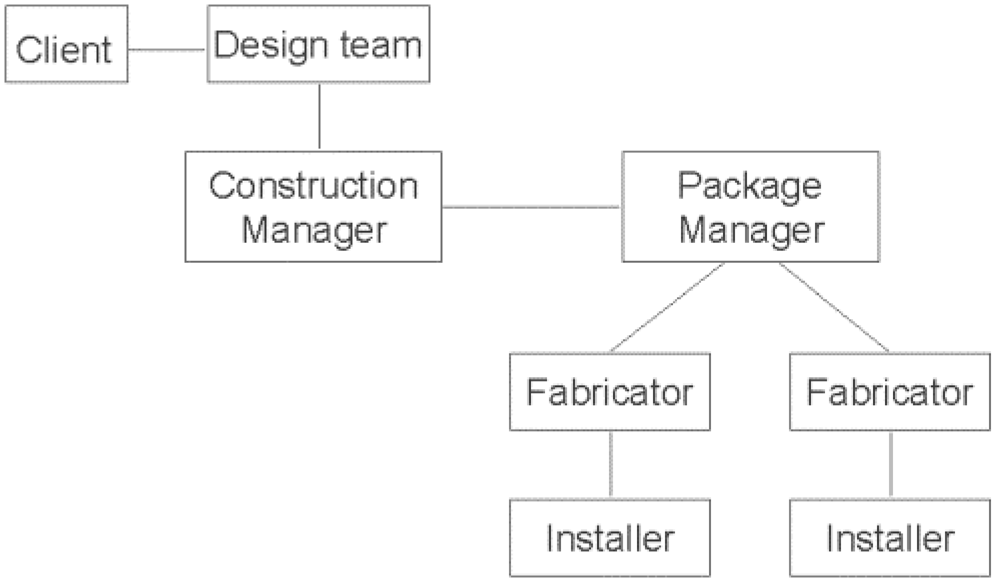

Figure 3. Role of a package manager

8.0 DOMINANCE OF THE WALL

Architects and leading curtain wall designers are starting to design buildings in which the dominance of the wall over the internal climate is clearly identified from the outset, Colomban (1997). This can only be achieved if the architects have greater knowledge of building envelope performance and its effect on the internal climate. This requires a knowledge of what is possible and a willingness to involve façade contractors in the very early stages of design. Steps are being taken to make architectural case studies available to illustrate the possibilities, Pollais and Colomban (2001).

Beyond this there is considerable work being undertaken to develop reactive walls that have varying light transmission and ventilation characteristics, Skelly (2000). These developments require greater changes to the design and procurement processes set out above. They require not only integrated design but a willingness for clients and occupiers to accept the operational and maintenance implications of such systems. This resistance may be overcome by the use of DBO contracts if the economic advantages can be demonstrated. This will probably require the establishment of a link between comfort and economic benefit, Kragh (2001).

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