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ENVIRONMENT DESIGN GUIDE

DOUBLE SKIN FAÇADES – MORE IS LESS?

Brett Pollard

Summary of

Actions Towards Sustainable Outcomes

Environmental Issues/Principal Impacts

- In the search for ways for reducing energy use in buildings, addressing thermal loss and thermal gain through facades provides a major opportunity.
- Double-skin facades (DSF) offer the potential to improve energy performance for buildings. They can also offer increased daylighting, and opportunities for natural ventilation.
- The growth of DSF to date has predominantly been in the colder climates of the Europe and North America. As there is now increased use of DSF in warmer climates of Asia, the Middle East and Australia, practitioners need to understand the potential value and issues of DSF.

Basic Strategies

In many design situations, boundaries and constraints limit the application of cutting EDGe actions. In these circumstances, designers should at least consider the following:

- Consider and question the desire for buildings that have all glass facades, as these make controlling solar gain and glare a major design issues.
- Consider the local climate as well as the orientation of each of the different facades of a building to ensure that the proposed facade design addresses and responds to the different constraints and opportunities it faces.
- Well designed single skin facades with appropriately orientated, sized and shaded windows can perform as well as DSF.
- Increase access to daylight whilst minimising and controlling potential glare.
- Increase potential for use of natural ventilation in high-rise buildings.
- Consider and address the potential for heat build up in the cavities of DSF, specially in the upper levels.

Cutting EDGe Strategies

- The potential exists for DSF to be used to allow for 'night purging' (passive cooling) of taller builders without wind and rain related issues that normally restrict these opportunities.
- Utilising the 'stack effect' created by rising warm air with the cavity of the DSF can reduce HVAC energy use and potentially allow for natural ventilation without mechanical energy.
- The potential to use a combination of single and double skin facades allows for buildings to have an appropriate design response for each individual façade; one that is customised to maximise the efficiency of each facade.

Synergies and References

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The use of double skin façades has increased significantly over the last 10 to 15 years, primarily due to the benefits attributed to them in regard to increased energy efficiency and improved day lighting. There remains debate, however, about whether these benefits would be more effectively provided by a well designed, traditional, single skin façade system. This paper discusses the various types of double skin facades systems, exploring their features and function. The paper then reviews recent research and examples to attempt to reach a conclusion as to whether with a double skin façade, more really is less.

Keywords:
buffer DSF, daylight, double skin façade, DSF, energy efficiency, extract air DSF, high-rise, hybrid DSF, lighting, natural ventilation, office building, twin face DSF

Figure 1: SA Water House, Adelaide
View of Northern facade (left), and western hybrid double skin facade (right). (Source: Hassell. Photographer: Trevor Mein)

1.0 INTRODUCTION

The term double skin façade (DSF) covers a wide range of façade systems and types from narrow fully sealed assemblies to systems with fully operable external louvres or shading devices. All of them have one thing in common, the outer and usually the inner skin are highly glazed. According to Bestfacade, a European Union project set up to review and develop best practice guidelines for DSF, the first DSF was proposed in the mid 1800's with a number of other examples being constructed during the early part of the 1900's. Interest in DSF was revived briefly during the oil crises of the 1970's and 1980's. However, the use of DSF, particularly for commercial and public buildings, has increased significantly in Europe and North America over the last 10 to 15 years, primarily due to the benefits attributed to them in regard to increased energy efficiency and improved daylighting. There is now an increasing number of DSF being built in warmer climates such the Middle East and Australia.

There remains debate, however, about whether these benefits would be more effectively provided by a well designed, traditional, single skin façade system. Indeed in 1999 a German professor of building physics, Dr Karl Gertis concluded that: *"It becomes apparent that DSFs (Double Skin Facades) - apart from special cases –*

are unsuitable for our local climate (German) from the building physic's point of view. Moreover, they are much too expensive. If they are nevertheless designed in order to keep up with architectural fashion, building physics support is indispensable."

2.0 POTENTIAL BENEFITS

Primary Benefits

The primary benefits attributed to DSF in the literature reviewed for this paper are their ability to save energy and enhance daylighting of the internal spaces of buildings. In regard to the reduction in energy use, DSF are credited with the ability to mitigate the impact of the prevailing external climatic conditions on the interior of a building, thereby allowing a reduction in the size, extent and operation of a building's Heating, Ventilation and Air Conditioning (HVAC) systems. In some cases DSF have been credited with eliminating the need for air conditioning altogether. Battle McCarthy, a United Kingdom based engineering and landscape architectural practice, state on their website that *"…double skin buildings are able to reduce energy consumption by 65 per cent, running costs by 65 per cent and cut carbon dioxide emissions by 50 per cent, in the cold temperate climatic prevalent in the United Kingdom when compared to advanced single skin building."*

Specifically, DSFs are reported as achieving reductions in energy use by:

Reducing heating demand – DSF achieve this in a number of ways. When sealed, the cavity between the inner and outer skin forms an additional layer of insulation to the building, reducing heat loss from the interior of the building. As well, air within the cavity which is warmed by sunlight and heat radiated from the building, can be used to preheat fresh air being introduced into the building for ventilation. When extensive glazing is provided in facades, it allows direct sunlight to be used for passive heating of the interior of the building.

Controlling solar gain – In warmer months and climates, the cooling demand of buildings can be very high due partially to solar gain through windows and the fabric of buildings. DSFs can reduce the impact of solar gain by allowing shading devices, such as blinds and solid louvres, to be installed in the cavity between the two skins, preventing sunlight from reaching the building's interior. Such interlayer shading devices are normally adjustable to ensure that views through highly glazed façades are retained as much as possible. Warm air trapped within the cavity can be expelled by natural and/or mechanical ventilation to prevent the transfer of heat to the interior of the building. The cavity protects the shading devices from rain and wind, especially on tall buildings, as well as providing access for maintenance of these devices.

Allowing natural ventilation – Natural ventilation provided by operable windows can reduce the load on, or eliminate the need for HVAC systems during periods of mild weather by providing fresh air and comfort cooling for occupants of a building. DSF can permit natural ventilation, even in high rise buildings, when the outer skin is used to provide wind and rain protection for ventilation openings in the inner skin. Ventilation of the cavity either by mechanical means or through the creation of the 'stack effect' within the cavity can improve cross ventilation and purge hot air from the building interior.

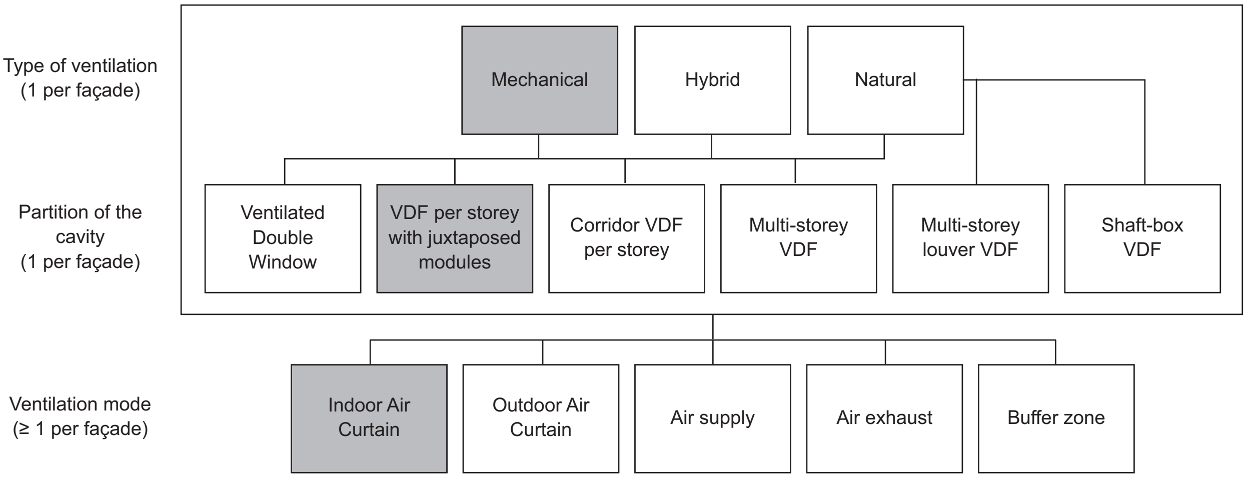


Figure 2: Bestfacade DSF Classification Diagram

In the diagram above VDF stands for Ventilated Double Facade which is the same term as Double Skin Facade

(Source: Bestfacade Best Practice Guidelines for Double Skin Facades - WP1 Report)

The enhanced daylighting of building interiors attributed to DSF is a direct result of the extensive areas of glazing incorporated into buildings with DSF. While extensive areas of glazing are possible with single skin facades, DSF are able to use glass with higher visible light transmission properties because of the ability to incorporate extensive shading devices to control sunlight penetration at critical times during the day. The specific benefits of enhanced daylighting are:

Reduced artificial lighting requirement – Daylight can significantly reduce the requirement for artificial lighting within a building. Daylight can potentially become the major source of lighting for the perimeter zones of a building's interior with artificial lighting being used to supplement daylight when necessary. Typically in commercial buildings this involves the use of automatic daylight controls such as light sensors and dimmers that switch on, or adjust the artificial lighting when the incoming daylight is insufficient to provide the required internal light levels. This reduces electricity consumption.

Improved occupant comfort – Access to daylight, without glare, is seen as an important component of occupant comfort and is considered to contribute to improved productivity, reduced eye strain and reduced stress levels.

Other Potential Benefits

In addition to these two primary benefits, there are a number of other potential benefits ascribed to DSF including:

Acoustic protection – DSF have been used to provide acoustic protection for buildings located near roads and railway lines. In theory, the outer skin provides a barrier to noise while allowing windows in the inner skin to be opened for natural ventilation.

Views – As buildings with DSFs generally have highly glazed facades, the occupants can have increased access to views. This is considered to improve occupant wellbeing through greater connection with the outside world and reduced eyestrain.

Enhanced security – DSF have been used to improve security due to the presence of an additional layer of building fabric that can impede unauthorised entry through the façade of the building. A secure outer skin can allow internal windows to be opened to permit natural ventilation in high security buildings, and also at night when the building is unoccupied.

Pollution barrier – In much the same way as the acoustic and security protection, DSF are claimed to allow natural ventilation in polluted locations with the outer glazed skin screening pollutants permitting windows in the inner skin to be opened.

Emergency egress – If maintenance walkways are present in the cavity between the two skins they could potentially be integrated into the emergency egress path.

3.0 DOUBLE SKIN FAÇADE TYPES

There is no accepted standard for grouping or defining the different types of DSF. The literature reviewed for this report found a multitude of ways to classify them. For example, the researcher Harris Poirazis in his comprehensive review of DSF (2004), found more than six different ways of classifying them. Bestfacade (Schiefer, 2008) developed a classification system for DSF based on their extensive review of the literature and built examples.

The BestFacade system is based on three sets of criteria:

- the type of ventilation of the building interior
- the ventilation mode of the cavity; and
- the partitioning of the cavity

While extremely comprehensive this system does allow for a large number of potential system variations and too many to describe and provide examples of in this paper.

In 2000, the architects and academics Werner Lang and Thomas Herzog defined three basic types of DSF. This classification has been adapted and developed by Terri Boake of the University of Waterloo's School of Architecture (2002). While relatively basic, it does allow for easy understanding of the different DSF types

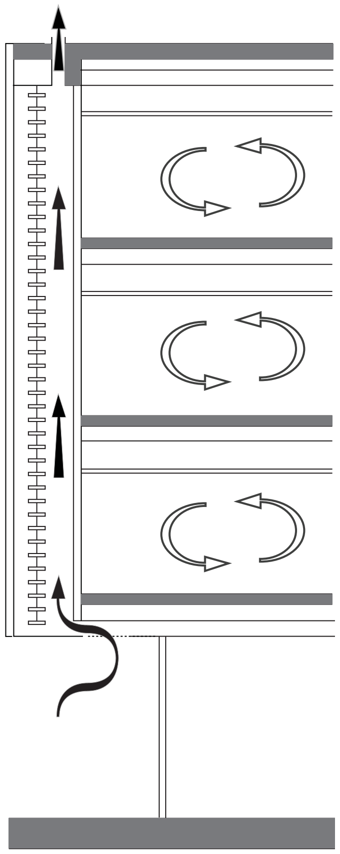
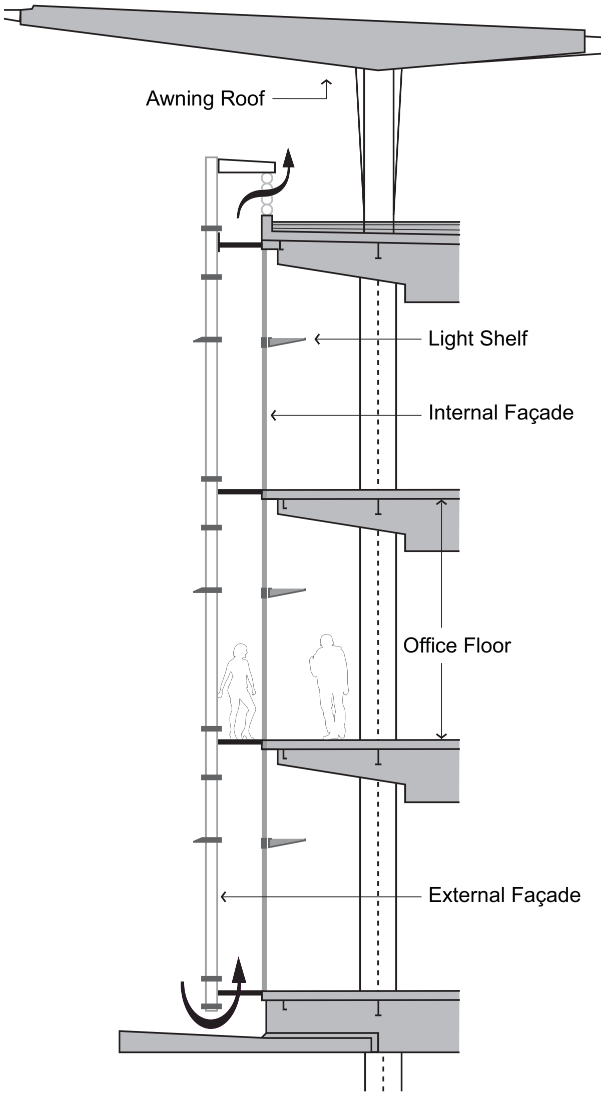


Figure 3: Buffer double-skin facade
(Source: adapted from Terri Boake, University of Waterloo)

View from street

Maintenance platform between facades



Thermal buffer wall section

Figure 4: Seattle Justice Centre
(Source: NBBJ Architects)

and was considered the most suitable classification system for this paper. The different types of DSF are:

- the Buffer
- the Extract Air
- the Twin Face; and
- the Hybrid System

In addition to these 4 basic types there is one additional distinction between DSF, whether the cavity is continuous or divided into compartments, usually on a floor by floor basis. These categories are described below.

3.1 Buffer Double Skin Facade

As the name suggests this type of DSF provides a buffer between the external conditions and the interior of the building. The cavity essentially functions as an insulating layer with the added benefit that any heat that builds up in the cavity can be expelled in the warmer months, usually by ventilation created by the 'stack effect' (i.e. warm air rising through convection draws further air). There are no openings in the internal skin and none in the external skin apart from ventilation inlets at the base of the DSF and outlets at the top. Typically the ventilation inlets are controlled by automatic dampers and exhaust fans can be installed to assist with removal of the heated air from the cavity. There is no natural ventilation of the interior of the building through the DSF, with the building's HVAC system being completely separate from the DSF. However, in some buildings heated air is extracted from the top of the cavity and is used for pre-heating supply air for the HVAC system, thus reducing energy loads.

It is suggested by Lang and Herzog that both skins of buffer facades are typically single glazed but it has become more common for the outer skin to be single glazed and the inner skin to be double glazed. Automatic blinds are usually installed within the cavity between the facades to reduce solar gain in summer and to control glare at different times of the day. It is typical for this type of DSF to run continuously for the full height to the façade with the only horizontal interruptions within the cavity being mesh access ways for maintaining the glass. The width of the cavity is typically about 1 m to allow for safe maintenance access. If narrower cavities are used, maintenance access is usually provided by making the internal glazing operable. The disadvantage of this is the disruption that can occur to the building occupants when access is required to clean windows.

An example of the Buffer DSF is the Seattle Justice Centre, Washington USA designed by NBBJ.

3.2 Extract Air Double Skin Facade

Extract Air DSF use the cavity between the two facades as an exhaust and or return air path for the conditioned air from the building interior. In colder climates this allows the heat of this already warmed return air to warm the cavity space and enhance its insulating effect. The air is then expelled at the top of the DSF, usually after the heat has been extracted by heat exchangers for reuse in the HVAC system. As the cavity is effectively acting as a return air duct, it is usually continuous for the full height of the building's facade. The width of the cavity can be narrow or wide with similar access provision as for the Buffer DSF. The Extract Air DSF typically uses single glazing in the outer skin and insulated double glazing for the inner skin.

In the warmer months heat gain to the building interior is moderated by the continuous extraction of the warm air in the cavity, usually through the use of mechanical ventilation fans linked to the building's HVAC system. Additional outside air can be introduced at the base of the DSF, if the volume of air moving through the cavity needs to be increased to assist with reducing the heat build up in the cavity. Solar heat gain to the interior of the building can be further reduced by using shading devices located in the cavity. This type of DSF is reliant upon a building's HVAC system and so could potentially use more energy than a naturally ventilated DSF. Although not stated in the literature reviewed, it may be possible to use the stack effect created in DSF to extract air from the building's interior without use of the HVAC System.

An example of the Extract Air DSF is the Museum of Cotemporary Art Denver, Colorado USA designed by Adjaye Associates and Davis Partnership Architects.

3.3 Twin Face Double Skin Facade

These types of DSF are categorised by having two skins that are able to be opened to permit natural ventilation of both the cavity and the building's interior. Typically, the outer skin is single glazed and the inner skin is double glazed. The extent of openings in the skins can vary significantly depending on the ventilation strategy to be employed. This can range from a series of small operable windows to a fully louvered external facade. The outer skin can act as a wind and rain shield to allow the windows in the internal skin to be opened to permit ventilation and/or night cooling of the building's interior regardless of the wind conditions or height of the building. During winter months, when the DSF is required to assist with insulation against the cold, the external and internal openings can be closed to allow it to function like that of a Buffer DSF. However, if the outer skin is unable to be effectively sealed due to the number of openings or the window system being used (i.e. glass louvres) it may not function as well as a Buffer DSF, in the colder months. Therefore this DSF tends to be built in locations without an extensive and prolonged heating requirement unless the insulation performance of the inner skin is increased.

An advantage of this DSF over Buffer and Extract Air DSF is that it is able to more easily discharge hot air that can build up within the cavity. This is especially the case when the external skin has numerous openings that allow high volumes of outside air to ventilate the cavity and remove unwanted hot air.

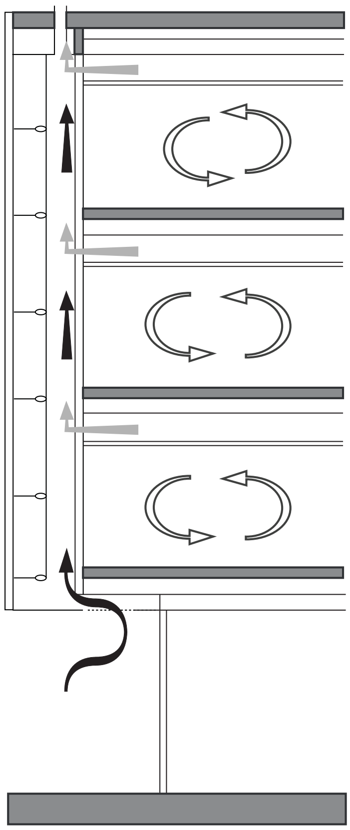


Figure 5: Extract air double-skin facade
(Source: adapted from Terri Boake, University of Waterloo)

Figure 8: Aurora Place / Macquarie Apartments building
The very wide cavity of the DSF is very wide and compartmentalized both horizontally and vertically with the cavity acting as the balcony for each apartment.

(Source: Renzo Piano Building Workshop. Photo: courtesy Denancé Michel)

The range of potential variations of this type of DSF is large, with the cavity width being either narrow or wide, and the cavity can be continuous or compartmentalised. Shading devices, such as blinds and louvres can also be installed within the cavity.

An example of the Twin Face DSF is the Daimler Benz Debis Building in Berlin, Germany designed by the Renzo Piano Building Workshop (Figure 8).

3.4 Hybrid Double Skin Facade

Hybrid DSFs can be a combination of, or variation on, an of the previous three DSF types. This can include layered sun control on externally mounted glazing to adjustable louvre systems that combine solid and clear elements.   . An example of this type of DSF is the façade of the New York Times building in New York, designed by the Renzo Piano Building Workshop and Fox and Fowle (Figures 9 and 10). While not strictly a DSF, it can be seen as a Hybrid DSF on the basis that an additional layer (skin) has been added to the glazed walls of what is essentially a fully glazed building. Here, a layer of carefully spaced light redirecting ceramic rods have been positioned off the glazed facade to reduce solar heat gain and glare while still admitting daylight to the interior of the building (Figure 10). The design goal was to reduce the energy consumption of building by reducing the cooling load on the HVAC system and the need for artificial lighting. Extensive studies were undertaken by the consultant team in partnership with the Environmental Energy Technologies Division (EETD) of the Lawrence Berkeley National Laboratory to develop both the external skin and the automated internal blinds that make up the other half of the daylight control system. The project has only been recently completed and will be studied by EETD to determine whether the predicted US$20,000/floor/year energy savings are achieved.

Another example of the Hybrid DSF is the western facade of SA Water House in Adelaide, designed by Hassell (Figure 1). In this case a fully glazed second facade has been used to reduce the solar gain on the building's interior from low angle western sunlight while permitting views from the building. A series of frit patterns on the external skin of glass as well as horizontal maintenance walkways within the cavity between the two facades provide shading. Heat build up within the cavity, which can be extreme during the summer months in Adelaide, is addressed in two ways. Firstly, the outer skin is not sealed against the inner facade on the top, bottom or sides of the facade and thus maximising the ability of hot air to be removed from the cavity. Secondly, the outer facade is raked in section, with the cavity at the bottom and top of the facade being wider than the middle section to further increase the ability for hot air to escape from the cavity.

4.0 DESIGN CONSIDERATIONS

As with all building systems and technologies there are a number of additional considerations that need to be addressed other than just benefits and system functionality. The literature reviewed for this paper indicates that the following issues need to be considered when designing DSF (please note that many of these considerations also apply to the design of single skin facades):

Floor area – The 1 to 0.3 metre wide cavity required for the DSF can reduce the available floor area for occupation or leasing by the building owner (i.e. Net Lettable Area). This is especially the case if the building is located in an inner city area where land costs are high and it is not normally possible to build beyond the site boundaries to compensate for the usable floor area lost to the DSF cavity.

Floor plan shape & HVAC Energy Requirements – The prevailing climatic and solar conditions primarily impact upon the interior spaces of a building that are located directly adjacent to the glazed facades of a building. These spaces are commonly known as the **perimeter zone** and typically extend 3.5 to 4.5 meters into the building. The interior spaces located away from the perimeter zone are typically called the **centre zone**. The HVAC heating and/or cooling loads within the perimeter zone are primarily influenced by the prevailing climatic conditions while within the centre zone the heating and cooling loads are caused by internal factors such as the lighting systems and the number of computers and occupants. . As DSF affect the energy use of the perimeter zone, building floor plates which have a greater ratio of perimeter zone to central zone are going to have a greater potential of energy saving from using DSF.

Floor plan shape & lighting energy requirements – In addition to HVAC loads the floor plan shape also influences the percentage of the building floor area that has access to good daylight. As previously mentioned, good daylighting design can reduce the amount of energy required to light the interior of a building as fewer luminaires are required and/or these can be switched off for periods of the day when daylight is adequate. A general rule of thumb for daylighting is that areas within 6-8 metres of a glazed facade will have acceptable levels of daylight. Typically narrow floor plates tend to have greater total percentages of floor area with good natural daylight than do buildings that have deep and/or square floor plates. Once again in floor plates with a greater length of façade, using DSF will potentially allow for a larger reduction in lighting requirement.

Heat build up in cavity – The air in the upper sections of a continuous DSF cavity can become quite hot due to solar gain. This can cause overheating in the adjacent internal spaces even in the cooler months. This potential for heat build up needs to be considered in the design and detailing of a DSF. Some methods to address this include providing additional mechanical air extraction to the cavity to remove the heated air or providing operable windows or ventilation openings in the outer skin.

Glare control – As DSF are usually highly glazed, the issue of glare within and around the building needs to be addressed. Daylight controls such as internal blinds and screens will be required as well as consideration given to the placement and orientation of work spaces to ensure that glare from the daylight doesn't adversely impact on the building occupants. Similarly, potential outward reflections need to be addressed by either the use of special coatings or films and/or careful orientation and positioning of glazing relative to sun angles.

Additional façade cost – The capital cost of a DSF is higher than single skin facade because of the additional glazing, structure and framing that is required. A 2003 report by researchers Stribling and Stigge put the additional cost of a DSF compared to a conventional curtain wall at approximately 50 per cent more in New York, 40 per cent more in the UK and 20 per cent more in Germany. However, they also reported that the cost savings from the reduction in HVAC energy use attributed to a DSF could payback the additional facade cost within 20 to 95 years depending upon energy costs.

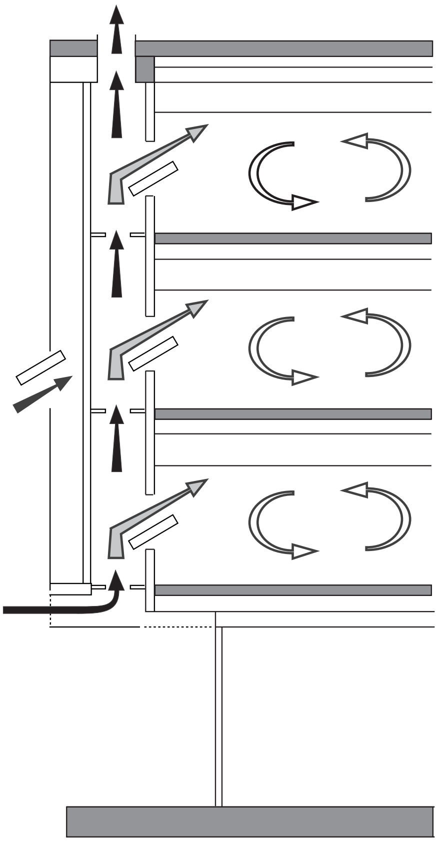


Figure 7: Twin face double-skin facade
(Source: adapted from erri Boake University of Waterloo)

Maintenance requirements – DSF, especially wide cavity types, can have much higher maintenance requirements than single skin façade. This is because there are four glass surfaces rather than two that may require cleaning. While maintenance walkways can be provided within the cavity to clean the glass and maintain blinds, access to the outer face of the glass is still required, with this normally being provided by a separate access system as per single skin facades.

Smoke management impact – DSF can impact on the smoke management system of a building in a number of ways. DSF make it difficult to use the façade of building to expel smoke as the cavity will fill with smoke and may spread to other floors if windows are open. This can certainly occur with single facade buildings but the situation is exacerbated in DSF buildings because the smoke is unable to be dispersed by wind. Using the cavity of an Extract Air DSF as a smoke exhaust duct or path would require significant fire engineering input.

Figure 8: Daimler Benz Debis Building, Berlin
(Source: Renzo Piano Building Workshop. Photo: Enrico Cano)

5.0 CLIMACTIC SUITABILITY

Until recently DSF have been used predominantly in northern parts of Europe and North America because of their perceived ability to reduce heating energy use and enhance daylighting, especially during long cold winters. In recent years DSF have begun to be used on buildings in warmer climates such as Australia, the Middle East and Asia because of the perception that DSF can reduce cooling energy use while increasing daylight and views for building occupants.

Research for this paper indicates that there are several major differences between DSF in colder and warmer climates. Instead of encouraging the penetration of direct sunlight, DSF in warmer climates concentrate on excluding direct sunlight through the use of shading devices located in the cavity between the two skins. Another difference is that, unlike in colder climates where air in the sealed cavity is intended to be warmed by the sun as well as insulate the building in order to reduce load on the heating systems, the cavities in warmer climate DSF are designed to be very well ventilated. This ventilation, either by mechanical or natural means (i.e. 'stack effect' mentioned above) is to reduce the potential for heat build up, especially at the top of the cavity which can cause over heating of the building interior and increase the demand on the cooling systems within the building

As the use of DSF in warmer climates is not as extensive in colder climates, the number of independent reviews and academic research papers on the functioning and performance of DSF in warmer climates is somewhat limited. Researchers Matthias Haase and Alex Amato (2006) have reported on the DSF that they have analysed in Hong Kong and have concluded that ventilated Buffer DSF offer the best ability to reduce external heat loads for buildings with HVAC system. They did not report on whether DSF have been used for natural ventilation of interior spaces of buildings.

A Masters thesis written in 2004 by Vijaya Yellamraju of Texas A&M University investigated the suitability of using of DSF on office buildings in India. The report was based upon building energy simulation of theoretical buildings located in Hyderabad and New Delhi. Various arrangements of the DSF were modelled to find optimal designs. The report found that on the faces of the building with high solar exposure there was extensive heat build up in the cavity and that this led to increased temperatures within the building. It did find that loads could be slightly reduced with shading and increased ventilation of the cavity. The report recommended that the best performing system was achieved by decreasing the amount of glazing to about 50 per cent of the façade and introducing masonry for the remainder.

6.0 CONCLUSION

There is a limited amount of literature on the subject of DSF as many of the articles and reports reviewed for this report all had similar reference lists. This gives weight to the various authors' calls for more research into DSF including the study and reporting on actual performance of DSF in a range of climates. Certainly the increasing number of DSF that have been recently completed or are currently under construction in Australia, Asia and the Middle East will provide researchers with the opportunity to undertake 'real world' studies to confirm whether these buildings are actually delivering on the predicted benefits such the energy savings and increased daylighting. It is only through new, detailed research and study that the knowledge and understanding of DSF will fully develop and allow determination of whether more facade means less energy used in buildings.

In regard to some of the attributed benefits such as pollution barriers, emergency egress, acoustic protection and future proofing, the effectiveness of DSF is not able to be confirmed through the literature reviewed for this paper. As to whether the energy saving benefits attributed to DSFs are correct or not, it is certainly the case that DSF can play a role to reducing heat loss in colder climates where a façade is fully glazed. However, well designed, high performance glazing such as double and triple glazing can achieve similar results. Fully glazed façades can definitely provide an abundance of daylight for some of the interior spaces of a building but they can also introduce unwanted glare unless the daylight is carefully controlled and moderated.

In warmer climates, the use of DSF can be more problematic due to the need to cool the interior spaces of buildings rather than warm them and to reduce solar heat gain. Unshaded, fully glazed facades are probably the wrong design choice in such climates if the goal is to save energy. The recently completed Council House 2, a medium rise office building in Melbourne, designed by the City of Melbourne (Mick Pearce) and DesignInc, took the approach that each facade needs to be separately addressed and designed to deal with the prevailing conditions rather than adopting a uniform approach and then applying it to all four facades. Its western façade uses a hybrid DSF to shield the building from unwanted solar gain, allowing views to be gained when shading is no longer required. As the cavity is easily able to be naturally ventilated there is little or no heat build up. It is these types of creative responses that take building technology, examine it, understand it, adapt it and develop it, rather than blindly replicating it. It is important that we question the desire for all glass facades and select the most appropriate design strategy for each situation rather than follow architectural fashion. This is how we could see the greatest gains made in our quest for low or zero net energy buildings.

ACKNOWLEDGEMENT

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BIOGRAPHY

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