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Double Skin Facades in Use, A Study of Configuration and Performance of Double Skin Façade, Case Studies some Office Buildings

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Abstract

This paper will survey the various types of double skin façades and their features, functioning followed by a review of examples, both constructed and proposed. The building facade plays an important role in achieving energy conservation. The aim of this report is to describe the concept of Double Skin Façades based on different sources of literature. Its complexity and adaptability to different climatic conditions increase the need for careful design. Since the construction types can differ from one location to another, it is obvious that the comparison of different literature sources is not always relevant. Since the concept of Double Skin Facades is complicated and its use and function affects different parameters of the building, the literature studied is from different fields. as a conclusion the designed system is crucial for the performance of buildings. Due to technological advances, transparency and the use of glass has become an attractive envelope option in architectural design. Designing buildings with all glass facades provide external views and potential for an excellent level of natural light as well and natural ventilation.

Keywords: Double skin façade, Energy in building, Ventilation, Office buildings

Introduction

The building facade plays an important role in achieving energy conservation. Due to technological advances, transparency and the use of glass has become an attractive envelope option in architectural design. Designing buildings with all glass facades provide external views and potential for an excellent level of natural light as well and natural ventilation.

In general, multiple-skin facades are recommended for their potentially high energy savings and environmental benefits, their high acoustical performance, the sheltering from the urban pollution, the excellent thermal comfort and the possibility of integrating natural ventilation. Also, their capability for solar energy utilization and solar control are regularly put forward as important advantages. (Saelens, 2002)

Double skin façades have been used on a larger scale since the nineties for technical and aesthetic reasons in “innovative” office buildings in addition to renovations. Due to the recent pervasive design of transparent building envelopes, various publications have been distributed since then (Leão et al, 2008)

History

Traditional envelope design regarded the external skin as a barrier between the variable outdoor climate and the highly controlled interior environment. (McClintock and John,2000)

Crespo, claims that, the first instance of a Double Skin Curtain Wall appears in 1903 in the Steiff Factory in Giengen, Germany. Le Corbusier had used a second skin glazing system in his Villa Schwob in his home town of La Chaux de Fonds in Switzerland in 1916. He even envisioned ”respiration exacte” and “murs neutralists” , which was a carefully controlled mechanical ventilation system and which would have ‘walls envisaged in glass, stone or mixed forms, consisting of a double membrane with a space of a few centimeters between them.(Boake et al, 2001)

In 1978, Cannon design in association with HOK designed the Occidental Chemical Centre, also called the Hooker Office building. It can be regarded as the first modern instance of a glazed double skin façade incorporating Le Corbusier’s ideas in ventilation. ‘The 8- inch cavity houses a system of louvers, grouped in banks. On each bank, a louver has a solar cell that registers when the sun hits it and reacts by tilting the whole bank out of the sun The louvers collect radiative energy as the bank bounces the sunlight back. This results in a stack effect where warm air rises to the top where it is collected in cold weather and discarded on warm weather (Boake et al, 2001)

John Perry and Maurya McClintokk façade engineers in Arup identify the possibilities and challenges of applying ‘green’ strategies to cooling dominated high-rise office buildings in the more tropical climates of Australasia. (Yellamraju, 2004)

Table 1.History Evaluation of Double Skin Facades

	Time	Highlighted Buildings/Architect	Where	How
History Evaluation of Double Skin Facades	ANCESTORS	Window Switzerland	When humans realized the benefits of unheated spaces surrounding the main accommodation on space	• Main house was facing the south • The rest of the departments were performing as buffer zones against the north facade • Trees were used to control the wind flow, minimize wind's energy and shade the buildings. • In winter the windows are closed on while in summer the windows are opened to ventilate naturally the space
		16-17th Century Hayiati or Liakoto (Balkans)	In Greece and Iran: Balkans in general, an attached volume on the basic volume of the building on the second floor. Made by wood and clay	
	1850-1882	Greenhouses	The Gardeners Chronicle in the UK, Jacob Forst suggested that south facing glass walls creating sunspaces	• Circulate the air warmed by the greenhouse effect • An exterior glass layer, a metallic sheet behind it and the masonry wall of the building. • Maximizing daylight as making natural light, and taking into consideration the local climate consisting of strong wind and cold weather
		Early from of Tromb wall	The first solar wall by an American botanist Edward Mors Felix Trombe German toy factory Margarete Steiff AG	
	1903	Toy Factory Margarete Steiff AG (Germany)	The concept of the double skin was used on the skylight in Vienna Le Corbusier	-
	1910 -1930	Otto Wagner Post Office savings bank in Vienna	In 1916,villa schwob 1929, cite de,Paris 1928,centrosouz worker's housing , Moscow 1932, Narkomfin worker's housing Ginzburg's & Milinis	• DSF concept that he offered a 40 % cut of the budget for the project for Cite de Refuge • Second skin on the south facade comprising two layers of large windows with wooden casements and heating pipes between them
		Le Corbusier		
	1957,1967	Ekono, 1 airflow window patent Sweden	In Scandinavia the first studies on airflow windows were published in 1950's Little or no progress was made in double skin glass construction until the late 70s, early 80s.	• Improve the energy efficiency and the thermal comfort of residential fenestration

Definition

Double skin façade design is a system that has taken its present form over a number of years of its application. Predominantly seen in the European countries, the concept is now picking up in the USA and also other Australasian countries. (Boake et al, 2001) Newer concepts of facade design look at the building facade as a filter which moderates between the external and internal environment. (McClintock and John,2000)

Designing according to the climate, with indigenous materials, using passive design strategies to reduce energy consumption in buildings. There are a number of strategies that are being developed to use the potential of the facade as a major energy saving component in building design. (McClintock and John,2000) The exact definition of a double skin varies with different situations and these can be classified according to the form in which the intermediate space is divided and the nature of air flow within the space. (Saelens, 2002)
The main components of the multiple-skin façade system are external glazing, internal glazing, and an air cavity. The exterior glazing is usually a hardened single glazing. (Ozdeniz et al, 2011)

Advantages of the Double Skin Facade

One of the objectives of Double Skin Facades is to reach a satisfying indoor climate with a reasonable energy consumption for the building. In order to reach that objective several indoor climate and energy aspects must be taken into account. (Hendriksen And Sørensen,2004)
The advantages of the Double Skin Facade are that it provides acoustic insulation, thermal insulation, and the reduction of the effects of wind pressure; this approach allows natural or fan-supported ventilation and the possibility of rehabilitating existing single-skin facades by the addition of a second skin. The disadvantages of the system are its higher cost, the lack of practical information on fire protection, the reduction of available space for offices, and less room-to-room or floor-to-floor sound insulation. (Ozdeniz et al, 2011)

- Energy Savings and Ecological Responsibility

Providing a low solar factor and low U-value minimizes the load of adjacent spaces. It is claimed that Double Skin Facades (DSF) save natural resources by reducing energy consumption during the operational life of the building (Yellamraju, 2004)

- Solar shading

One of the important benefits of Double Skin Facades is protection of solar shading devices against rain, wind and degradation. Table 4 lists solar shading factors. Maintenance issues for protected solar shading devices is often seen as the prior technical reason for a Double Skin Facade. (A.N, 1996)

- Lighting

Due to the additional pane, the light transmission of multiple-skin facades diminishes by 10 up to 20% compared to traditional facades. The additional effective room depth, the framing of the exterior surface and shading equipment result in an additional decrease of the daylight factors. As compensation for the lower overall transmittance, typically a higher glass to wall ratio is used.

- Natural Ventilation

DSF is a common solution for allowing windows to be operable in a windy zone because of the buffering effect of placing a fixed plane of glass outside the operable window (Yellamraju, 2004)

- Cost Savings

Overall value is dependent not only on the façade skin itself, but also for the variety of components used. These could include walkways, integrated shading, motorized blinds, motorized louvers and/ or dampers, as well as the associated costs for wiring and controls. Indicative costs for double skin façades vary greatly from e1400 to e2700 dependent on configuration used, as compared to typical unitized single skin façades which would typically cost in the region of e850 to e1100. (Morrison, Walshe, 2007)
It is necessary to note that it is three times more expensive to cool a building as it is to heat one. Therefore a Double-Skin Façades behavior as a thermal buffer utilizing the stack effect to remove excessive heat in summer decreases the cooling loads significantly and in turn building operational costs. (Yellamraju, 2004)

- Social Costs

The goal of these systems is not only to be environmentally "responsible" but also to greatly improve working conditions for the occupants of these buildings through access to day lighting, natural ventilation and greater control over the workplace atmosphere. (Boake & Harrison,2003)

- Noise Reduction

DSFs are now specifically being used for reduction of noise in urban settings. The degree of noise reduction increases with use of glazing that reflects sound and varies with specific details and operation of the facades. (Yellamraju, 2004)

Increased space between glazing layers will result in increased noise reduction values, especially for low frequent noise, e.g. traffic from heavy vehicles. This is relevant for Double Skin Facades with a certain air gap between the layers because it is often hard to reduce low frequent noise with traditional window facades. (Tombazis, 1996)

Due to the addition of an external skin, it is possible to achieve the same degree of acoustic insulation with the windows open as you can with the windows closed in conventional single-skin façade construction.(URL2)

- User Control and Comfort

The temperature of the inside surface of glazing systems needs to be taken into consideration, as this surface is a source of infrared radiation during summer and a heat sink during winter. User comfort is also linked with the aspect of being able to control the light with louvers/shades and the ability to control air movement with operable windows. (Yellamraju, 2004)

- Occupant Comfort/Productivity

As occupants are able to control light penetration with louvers or shading devices and to regulate air movement and temperature with operable windows, the overall building comfort levels are increased. In turn, due to increased environmental control and comfort levels, work productivity is increased. (URL1)

- Security

Double-Skin Façades provide a relatively unobtrusive method of achieving building security due to a continuous glazing layer with small ventilation grilles as opposed to project opening with bars or vents. (URL1)

The additional skin of the façade makes it almost a transparent physical barrier increasing the feeling of security psychologically. Also it allows the windows being open in the inner skin, which also improves the security of the building in comparison to directly exposed operable windows. (Yellamraju,2004)

Disadvantages of the Double Skin Facade

The construction of DSF is however more of an architectural decision than part of an energy concept. One of the widely known advantages of these constructions is the increased acoustic performance, however, the direct or indirect energy saving potentials is not evident. (GELESZ and Reith, 2011)

- Noise

A disadvantage is internal noise distribution between rooms facing a Double Skin Facade. A further disadvantage of external noise is openings which are needed for venting. In order to decrease external noise these openings should be silenced, but still have a very low pressure drop. (Tombazis, 1996)

- fire

Double Skin Facades can increase the spread of a fire. If a fire occurs in a room or compartment facing the Double Skin Facade and smoke is intended or unintended removed via the Double Skin Facade and if the smoke is cooled and reaches a certain temperature it can lead to explorers and extended spread of fire. (Tombazis, 1996)

When Double Skin Facades are designed. Furthermore, fire safety conditions play an important role in the design of these facades. (Hendriksen And Sørensen,2004)

- cold climates concerns

The potential for condensation in the air space and on elements/surfaces within that space.

The ventilated cavity :

The rapid removal of humid air that escapes from the interior, either to the exterior or to the interior HVAC system return air, depending on the particular system design. (Boake,2003)

Functioning of Double Skin Facades in seasons

A multiple-skin facade is an envelope construction that consists of two transparent surfaces separated by a cavity. The extra skin can reduce both cooling demand in summer and heating demand in winter. Solar radiation entering through the outer skin on the south face of the building will heat the air in the cavity. Depending on whether there is a demand for heating or cooling, this preheated air can either be drawn into the interior spaces or ventilated out of the building.(Ozdeniz, 2011)

Results from our simulations showed that the DSF window was more energy efficient than a double glazing window in summer regardless of the cavity open or closed. Such energy advantages were more due to the additional pane of the DSF window to reduce the solar transmittance than due to ventilation of the cavity. Although ventilation is beneficial in summer, the annual energy gain may be limited. (He, Shu, Zhang, 2011)

This function can be seen in The Royal Library, Amager, Copenhagen, Denmark, The Double Skin Facade has an air gap of 30 cm and perforated louver blinds to guarantee visual contact with the surroundings. The cavity is used as a buffer zone in the heating season to reduce heat loss and cold down draught. The extract of air from the offices are lead through gaps below the sliding doors and are further extracted via outlets in the horizontal division. In the summer period automatic opening of windows in the outer layer and the sliding doors are used for supplementary venting of the offices, (Byggeindustrien, 1999). (Tombazis, 1996)

Totally a double skin façade in the cooling season operate the way below:

The cavity Carry away heat that would be otherwise accumulated in the cavity and be partially transferred into the adjacent occupied space.

Temperature of the inner membrane kept lower than without the airflow. This reduces conduction, convection and radiation from the occupied space within. Thus, less heat is transferred from outside to the inside, and less energy is required to cool the space. (Yellamraju, 2004)

Different types of Double Skin Facades

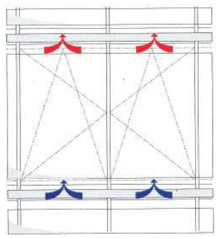
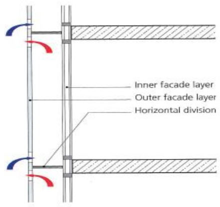
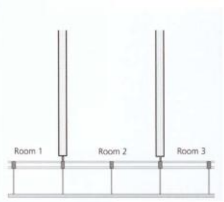
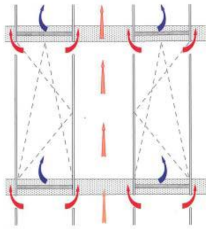
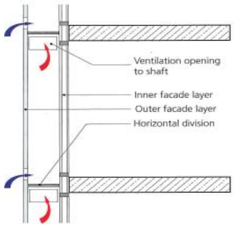
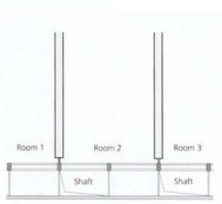
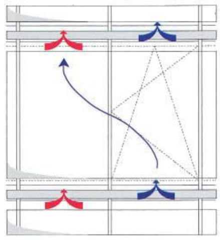
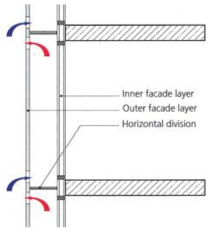
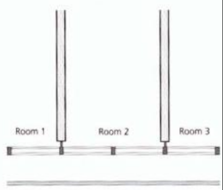
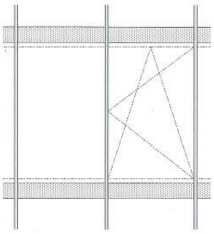
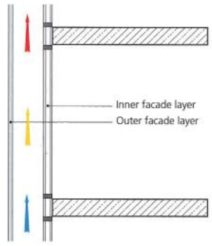
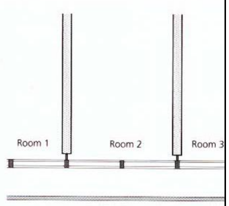
Double Skin Facades can be classified into various categories based on the major working principles: (Saelens, 2002)

The formed categories depend on different criteria in all cases. The most common classification on is according to their geometry, their operation and their air flow type. (Panagiotis, 2014)

If the multiple-skin facade extends over the entire height and width of the building the term facade is appropriate. When the facade is divided into smaller units, three main categories can be defined. If the partitioning consists of vertical ducts, the expression shaft facades is adopted. When the facade is horizontally partitioned, usually the term corridor facade is employed. If the facade is both horizontally and vertically subdivided, the multiple-skin facade is called window or box. The term windows can be used for systems in which the windows act as multiple-skin facades. The term box is more appropriate for entirely transparent envelopes with horizontal as well as vertical partitioning. (Saelens, 2002)

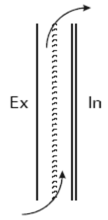
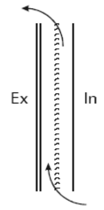
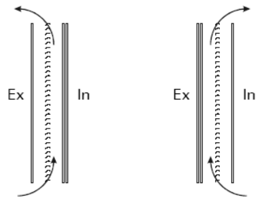
In a “shaft-box window”, the air space is divided into vertical compartments along the height of the facade with a tall ventilation shaft place near it. These box windows are connected to the vertical shafts on the facade, which provide a stack effect. This is suitable in high noise areas where a high level of sound insulation is required inside the buildings. In a “corridor facade”, the air space is divided into horizontal compartments, usually at the level of each storey. In some cases, vertical dividers are added for fire and sound protection. The corridor is accessible and is wide enough to be used as service platform. In a “multi-story Double Skin Facade”, there is no horizontal or vertical partitioning between the two skins; instead, the air cavity is ventilated via large openings near the base and roof of the building. (Ozdeniz et al, 2011)

Table 2. Different types of Double Skin Facades Based on the geometry, (Panagiotis, 2014)

Type	Elevation	Section	Plan	Construction type	Ventilation
Box window				Vertically and horizontally partitioned	Through the horizontal and vertical partitioning
Shaft-box facades				Mix partitioning mode	Stack effect
Corridor facades				Horizontally partitioned	Horizontal partitioning is realized for ventilation reasons
Multi story façade				Multi-Story	Through the large openings near the floor and the roof of the building

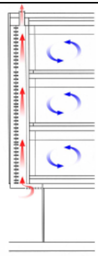
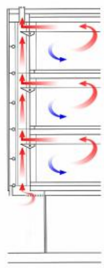
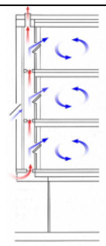
The origin of the airflow is an important characteristic because it largely influences the eventual average cavity temperature. Three airflow concepts are possible:

Table 3. Different origin of the airflow into the intermediate space, (Saelens, 2002)

	Performance	Diagram
Supply	Fresh outside air flows into the cavity	
Exhaust	Inside air flows through the cavity to outside	
Air curtain	Air leaves the cavity the same side it came in; there is no exchange between the air outside and inside (exterior and interior air curtain)	 c. exterior air curtain d. interior air curtain

There are 4 basic types of double skin systems According to ventilation:
• Buffer Façade
• Extract-Air Façade
• Twin-Face Façade
• Hybrid Façade (Boake,2003)

Table 4. different types of Double Skin Facades Based on the ventilation

Name	Diagram	Benefits	Layer	Performance
Buffer Façade		Maintain daylight into buildings while increasing insulating and sound properties of the wall system.	Use two layers of single glazing spaced 250 to 900 mm apart	Sealed and allowing fresh air into the building through additional controlled means.
Extract-Air Façade		The outer layer of insulating glass minimizes heat-transmission loss.	Air space between the two layers of glazing Layers of glass ranges from around 150 mm to 900 mm	Fresh air is supplied by HVAC and precludes natural ventilation. Insulating glass minimizes heat-transmission Loss
Twin-Face Façade		The internal skin offers the insulating properties to minimize heat loss	Normally have an interior space of at least 500 to 600 mm to permit cleaning	Allow for natural ventilation
Hybrid Façade	Combination of, or variation on, any of the previous three DSF types	Reduce the energy consumption of both the HVAC and lighting systems of the building	An additional layer (none glazed as a shader) and the interior skin of the building(glazed)	The external layer have been positioned off the glazed facade to reduce solar heat gain and glare while still admitting daylight to the interior of the building

- Buffer Façade

Dates back some 100 years

Predate insulating glass and were invented to maintain daylight into buildings while increasing insulating and sound properties of the wall system.

use two layers of single glazing spaced 250 to 900 mm apart, sealed and allowing fresh air into the building through additional controlled means – either a separate HVAC system or box type windows which cut through the overall double skin.

Shading devices can be included in the cavity

Modern example of this type is the Occidental Chemical/Hooker Building in Niagara Falls, New York (Boake,2003)

- Extract-Air Façade

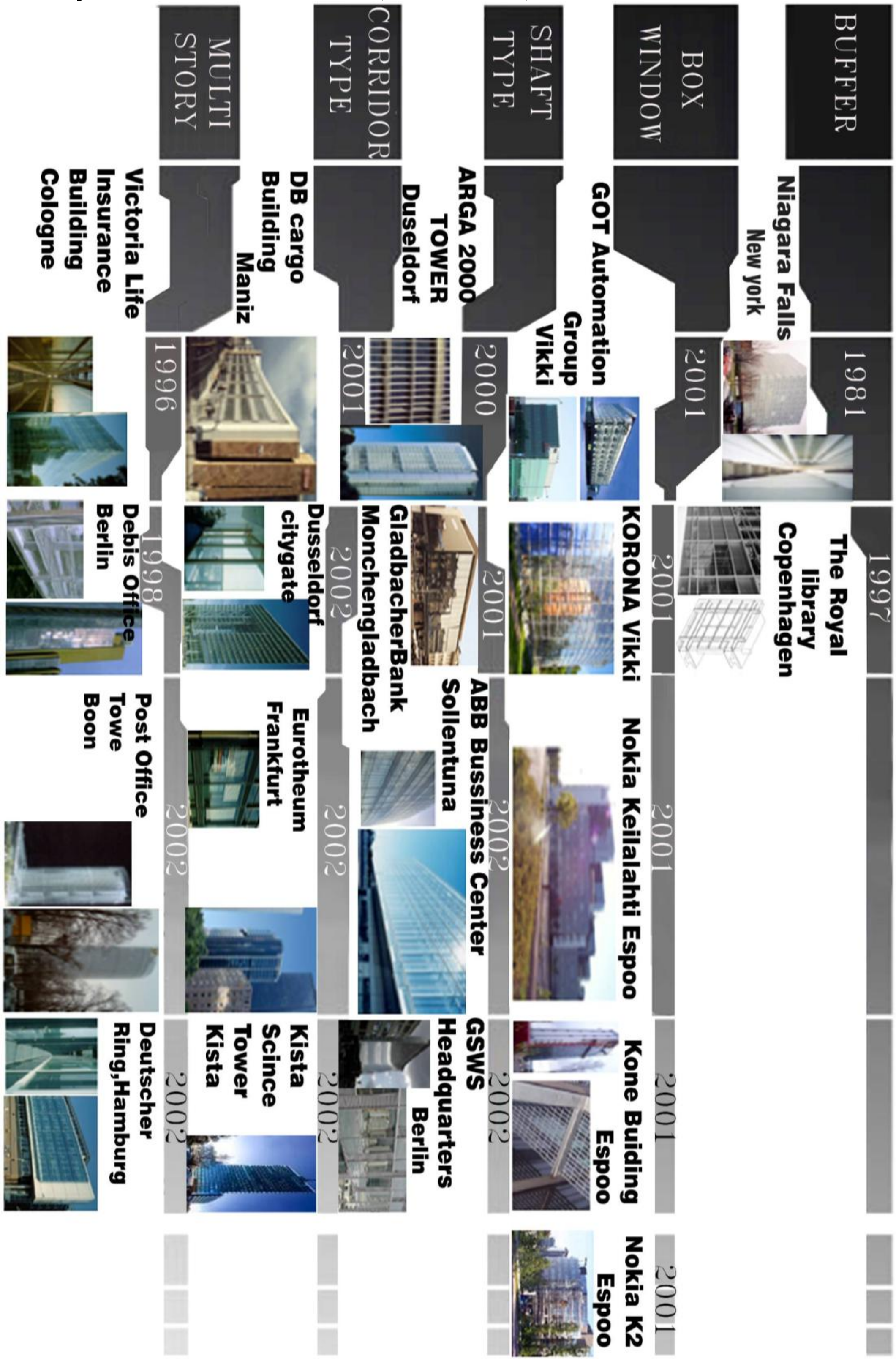
Comprised of a second single layer of glazing placed on the interior of a main façade of double-glazing (thermo pane units)

the air space between the two layers of glazing becomes part of the HVAC system. The heated "used" air between the glazing layers is extracted through the cavity with the use of fans and thereby tempers the inner layer of glazing while the outer layer of insulating glass minimizes heat-transmission loss.
fresh air is supplied by HVAC and precludes natural ventilation. (Boake,2003)
The air contained within the system is used by the HVAC system. these systems tend not to reduce energy requirements as fresh air changes must be supplied mechanically. Occupants are prevented from adjusting the temperature of their individual spaces. Shading devices are often mounted in the cavity. Again the space between the layers of glass ranges from around 150 mm to 900 mm and is a function of the space needed to access the cavity for cleaning as well as the dimension of the shading devices. This system is used where natural ventilation is not possible (for example in locations with high noise, wind or fumes). (Boake and Harrison, 2003)
Twin-Face Façade
Consists of a conventional curtain wall or thermal mass wall system inside a single glazed building skin. Outer glazing may be safety or laminated glass or insulating glass. Shading devices may be included normally have an interior space of at least 500 to 600 mm to permit cleaning distinguished from both Buffer and Extract Air systems by their inclusion of openings in the skin to allow for natural ventilation single-glazed outer skin is used primarily for protection of the air cavity contents (shading devices) from weather. The internal skin offers the insulating properties to minimize heat loss. (Boake,2003)

- Hybrid Façade

The hybrid system combines various aspects of the above systems and is used to classify building systems that do not “fit” into a precise category. Such buildings may use a layer of screens or non-glazed materials on either the inside or outside of the primary environmental barrier. The Tjibaou Center in New Caledonia by Renzo Piano may be used to characterize this type of Hybrid system. (Boake & Harrison,2003)
The hybrid façade is a system that combines one or more of the basic characteristics of the 3 main typologies to create a new system.
Renzo Piano’s Tjibaou Cultural Center in New Caledonia would be an example of this type. (Boake,2003)

Some case study of Double Skin Facades (Poirazis, 2004)



Conclusion

So what is this review and examination of DSF results? Well firstly there is a limited amount of literature on this subject 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 the actual performance and facts about DSF. It is only through new, detailed research and study that our knowledge and understanding of DSF will develop.

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 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 can also bring glare unless the daylight is carefully controlled and moderated. It is important that we question the desire for all glass facades and select the most appropriate design strategy for each situation. Of course all details have significant roles to catch a goal and meet needs of using DSFs, but as a future research, the most important view is how we can Improve to explore what is the best result.

References

Boake, Terri Meyer . Harrison, Kate. Collins, D. Balbaa,T. Chatham, A. Lee, R. Andre, B. (2001). TheTectonics of the Double Skin: Green Building or Just More Hi-Tech Hi-Jinx, What are Double Skin Facades and How Do They Work?. University of Waterloo (2001).

Boake, Terri Meyer. (2003). The tectonics of the double skin: understanding double facade systems. University of Waterloo.

Boake, Terri Meyer. Harrison, Kate. (2003). Understanding the General Principles of the Double Skin Façade System. 1-18

Gelesz, Adrienn. Reith, András.(2011). Classification And Re-Evaluation. 17th Urban Energy Conference. Building Services, Mechanical and Building Industry Days. Hungary. 13-14 October 2011.65-72

He, Guoqing. And Shu, Lifang. And Zhang, Sanming. (2011). Building Thermal, Lighting, And Acoustics Modeling. Building Simulation. 4 (2011). 283-291

Hendriksen, Ole J. Sørensen, Henrik(2004) . Double Skin Facades-Fashion or A Step Towards Sustainable Buildings. https://ptp.irb.hr.

Leão, Marlon. Borges, Érika. Panyu Zhu, Leão. Aklan, Aymen. Huckemann, Volker. (2008). Heating Energy In Double Skin Façade Buildings.

McClintock, Maurya. Perry, John. (2000). The challenge of green buildings in asia. https://bath.ac.uk. University of Bath.

Morrison, Andrew and Walshe, David.(2007). Products & Technology, Double Skin Facades. Graphs courtesy of IN2 Engineering Design Partnership.

Ozdeniz, Halil Z. Alibaba and Mesut B. (2011). Thermal comfort of multiple-skin facades in warm climate. http://www.academicjournals.org/SRE. 8 September 2011.

Panagiotis, Koukaroudis. (2014). Properties And Design Guidelines For Double-Skin Facades In Sweden. Master Of science Thesis in Chalmers University Of Technology.2013-2014

Poirazis, Harris.(2004). Department of Construction and Architecture, Lund Institute of Technology.Lund University, 2004.

Saelens, Dirk. (2002). Energy Performance Assessment of Single Storey Multiple Skin. https://bwk.kuleuven.be/bwf/PhDs/PhDSaelens. Katholieke Universitit Leuven. September 2002.

Tombazis, AN. On double elements in bioclimatic.(1996). 26-29.

Yellamraju,Vijaya. (2004). Evaluation And Design of Double-Skin Facades for Office. Master Of science Thesis in Texas A&M University. May 2004

URL1: www.Autodesk.com

URL2: www.stwarchitects.com/data/sketchbook/research/stw

.