

Study on Using Double-Skin Facade and Its Effects on Urban Landscape Aesthetic

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Abstract: Today, the facade is an essential part of urban landscape. Facades have become real procedure, while they are not just a bearer structure. Facade as the outermost view of building plays a major role in aesthetic structure of city, but this main feature nowadays has become more important due to advancement of technology and modern construction technologies and features have been added to it such as structural role, sound insulation, heating and ventilation. With the advancements of construction industry in today's world, it is possible to design and execute a smart facade in addition to its structural role using double-skin facades in order to control and regulate heat, cold, light, wind, and outdoor noise as well as provide comfort of residents without energy waste. Facades are less used and considered due to their modernity as well as their low performance in Iran. In this paper, we analyze the specific features of double-skin facades; also, we investigate the aesthetic impact of double-skin facades from urban landscape perspective.

Keywords: double-skin facades; urban aesthetics; new technologies; construction industry

1. Introduction

The study investigates the quantitative and qualitative status of double- skin facades and their effects on Iranian urban landscape. The idea that double- skin facades can be promoted as an important factor in aesthetic aspect of urban landscape is discussed because these facades are less used in Iran for urban landscape aesthetics.

The facades and walls of city affect urban environment from various aspects and dimensions, including: semantic and cultural aspects, ecological aspects and visual aspects. Facade form and shape are influenced by visual aspects constituent elements. It is essential to consider buildings and city facades and walls as part of city's landscape in order to prevent the ever-expanding facade patterns and construction volumes that form without semantic, ecological and ecological support and provide a heterogeneous mix of street and city walls. Pay attention to this issue requires knowledge of facade elements whose overlook will undermine the visual and aesthetic quality of walls and buildings in urban landscape (Atarod & Kashi, 13: 2013).

Nowadays, environmental and energy crises are major issues of human life. Architecture is not an exception, because consumed energy amount in buildings has huge impact on environment. On the other hand, increased use of glass facades makes necessary an efficient method in order to control the environmental conditions of buildings. The glass facades are extremely inaccessible due to their low insulating properties. Creating a skin that is independent of glass facade can control the amount of heat, light and ventilation into space. To do this, mentioned skin acts like a living organism. As a result, using smart components in architecture can reduce energy consumption of buildings due to compatibility with different environmental conditions. One of these important elements is smart facade. (Ahmadinejad Karimi and Hekmatian Asl, 2014).

Double-skin facade technology is often designed for buildings with the aim of optimizing energy consumption, sustainability and green architecture. The number of such buildings is increasing due to optimal use of daylight and integrated, beautiful facade. The identification method of this paper is descriptive-analytical. The field and library methods were used in order to collect data for theoretical foundations of this study. The main question is "what is the position of double-skin facades in contemporary Iranian architecture and urban planning and to what extent are they advantageous in urban design and architecture? Case studies have been used in order to achieve this aim.

In Iran, energy consumption of country's buildings as a non-productive sector accounts for the largest share of all consumption percentages. According to country's annual balance sheet, more than 40% of energy consumption is directly spent on needs of this sector. While most studies show that more than half of this amount is wasted for various reasons. In fact, we can provide comfort of buildings by half of this amount of energy through optimizing and improving energy efficiency, modifying operation model and addressing buildings. (Gholami et al., 2018)

The building skin is the boundary between controllable indoor and uncontrollable outdoor spaces and this boundary is exactly where the maximum energy loss occurs. So, the energy loss can be greatly reduced through controlling the amount of energy transmittance from exterior skin. Further analysis on building exterior skin leads to its aesthetics consideration, since the building body is among the influential factors of urban landscape. The beauty has direct effect on observers' sense of peace.

2. Double- skin facade

Double- skin facade is distinguished from other facades by at least two membranes between living space and outside environment. There is a path for air movement between two membranes. Shading devices are often used in the distance between two membranes (Moqtadainejad and Khan Mohammadi 12: 2015)



Figure 1: Double- skin facade details (Behling, Sophia et al., 2011)

The double-skin facade is a glass structure consisting of two transparent plates separated by a cavity. This cavity is used as an air duct. (Saelens, 2003) Double-skin facade can be defined as a traditional single-layer facade, which is essentially two-layered inside or outside with a second glass facade. Double-skin facade is a system where air flows through a cavity between two glass skins. Minimum depth of cavity between two layers is 20 cm and maximum depth is 2 meters. The cavity can be ventilated by a variety of methods, including natural, mechanical, or hybrid ventilation. Apart from ventilation inside cavity, the source and destination of air varies based on climate conditions, functional type, location and hours of building use. (Poirazis, 2004)

3. Double- skin facade systems (DSF)

Double- skin facade is distinguished from other facades by at least two membranes between living space and outside environment. There is a path for air movement in the distance between two membranes. The movement of air through facade is its priority over double-glazed windows. Also, shading devices are used in the distance between two membranes. The seasons change is effective for facade performance. The air blown out in facade slot removes the heat stored during hot seasons; therefore, the middle membrane temperature is kept low theoretically, which reduces heat conduction, convection and transfer from interior glass surface to living space. Since the radiation temperature of space is lowered, residents will feel more comfortable. In other words, as the indoor air gets warmer, the suction effect gets stronger and cool air is drawn to interior space of facade more quickly. As a result, sun heat paradoxically lowers facade temperature. Shading devices act as passive cooling devices like adjustable horizontal shutters and absorb or reflect sun's energy. The absorbed heat by shading devices is repelled through air movement and convection; thereby, reduced load on cooling devices leads to energy saving. (Moqtadainejad and Khan Mohammadi 12: 2015)

One can use a wide variety of properties in classifying double- skin facades, the most important of which are mentioned below.

4. Classification of double- skin facades

A) Airway Route Design: Three types of ventilation are suggested for this facade:

- Indoor Ventilation (A) Mechanical Air Flow Ventilation (AFW)
- Outdoor Ventilation (B) Double Skin Ventilation (DSF)
- Composite Ventilation - (C-D) Mechanical Window Storage Ventilation (SUP) (Moqtadainejad & Khan Mohammadi 13: 2015)

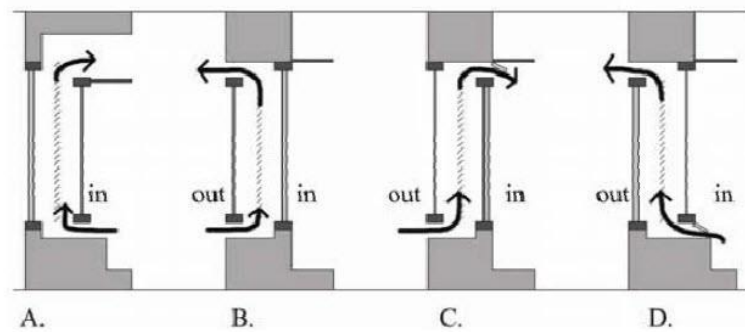


Figure 2: Plot of air travel path (Saelens, 2003)

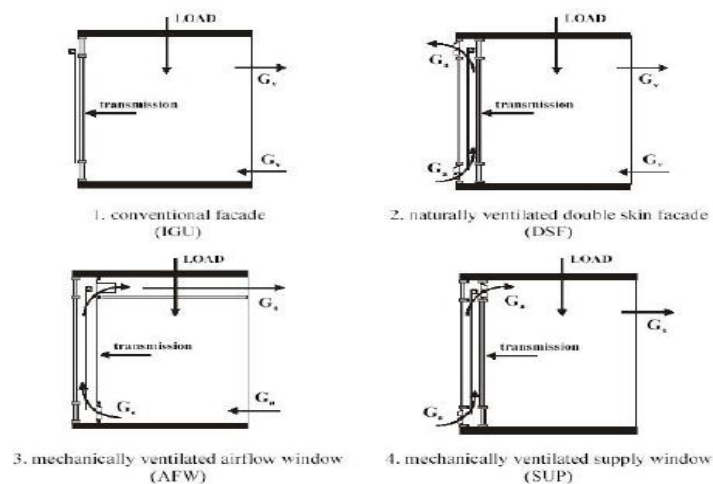


Figure 3: Different Multi-skin facades diagram (Saelens, 2003)

In a facade with indoor ventilation, air enters from interior space into slot and outlet air returns to facility. In a facade with outdoor ventilation, air enters slot from outside and drains out. In a facade with composite system, air enters the facade slot from inside or outside the building and exits the opposite direction. (Moqtadainejad and Khan Mohammadi 13: 2015)

B) Hybrid Air Layers:

There is a great variety of materials for this type of facade. Smoked glass can be used either with low energy consumption or resistant glass in various ways. One can use smoked glass either with low energy consumption or resistant glasses in various ways. Canopies can be metal and plastic in colored, glossy, lattice or solid forms. The arrangement of layers depends on air route design. If air is ventilated outside, the inner glass is insulated and a glass is installed outside. On the other hand, if there is indoor ventilation, the insulated glass is used on outer skin. (Moqtadainejad and Khan Mohammadi 14: 2015)

C) Facade depth:

Facade depth varies widely. Facade depth range of existing buildings is usually between 133 and 2133 mm, as face to face between inner and outer skin. There are three dominant styles for this depth. The distance between two skins of compact style is between 133 and 133 mm. In the second style, the distance is adjusted so that it is possible to clean surfaces between slots. The third or wide style wide is about one meter or more. In this style, it is possible to use the slot space as exit corridor for water. In fact, third or wide style creates an atrium-like space. (Oesterle, 2000)

D) Horizontal slot width:

Horizontal slot width refers to distance between facade components. Facade slot is divided by its inner blades. (Moqtadainejad and Khan Mohammadi 14: 2015)

E) Vertical slot width:

Vertical slot width refers to distance between slot's air supply location and the farthest outlet from slot. If this distance is multilevel and distance between two membranes are deep, this space will form an atrium and, if it is narrow, it will act like a chimney. (Moqtadainejad and Khan Mohammadi 14: 2015)

F) Opening of facade:

In the case of double-skin facades, the interior glass is often movable and can be opened by occupants or auto mechanic vehicles. In some cases, the interior glass is opened and full access is provided to exterior glass and mid space. The shape and capability of interior is varied. In some cases, openings are in the form of hinged windows that are designed as fully heightened, smaller in size or sliding. Full height sliding windows create a much stronger feel of natural ventilation through creating an opening as long as entire room height due to entry and exit of equal air volume near floor and ceiling. (Moqtadainejad and Khan Mohammadi 14: 2015)

G) Materials:

The glass frame materials of this facade are very diverse like other windows. It is worth noting that materials used for interior skin are somewhat negligible in terms of type because it is protected by outer skin, but material selection for exterior skin must be precise due to contact with outside climate. (DiMiao, 2001)

Advantages of double skin facades:

A - Buildings with double skin facades save money through reducing power consumption due to reduced energy consumption, size of mechanical installations and dependence on artificial light.

B- Ability to open windows in inner skin of facade, which is easily possible even in high-rise buildings where the bodies are exposed to high wind pressure. This type of facade is used to reduce noise pollution.

C - Canopy can be used in this facade even in adverse weather conditions (wind, rain and polluted air).

D- Achieve a much more transparent architecture compared to conventional methods and make better use of surrounding environment.

E- Use natural and night ventilation instead of mechanical ventilation

F- Escape from fire

G - Use of solar energy annually (Esmaili 2016: 11)

Disadvantages of double skin facades:

A - High construction costs compared to normal facades

B- Excess maintenance costs

C- Welding problems

D - Increased structural heat (Esmaili 2016: 11)

5. History and construction of buildings with double skin facades in Iran

Simple double- skin domes were built in rainy areas of Iran before Timurid and Safavid double- skin buildings; perhaps the intention of builders was to keep the airflow between double- skin facades and protect inner skin from moisture and damage. One of double- skin domes was built in Qabus ibn Wushmagir tomb in Gonbad Kavus city. Another dome is related to Lajim Tower in Mazandaran, which is considered as Al Ziyar period monument. The third dome is related to Rosegate Tower in northern Iran and beginning of fifth century AH. The inner cover of this building is circular and its outer cover is almost turnip. Iran domes are made of double- skin: 1- inner skin 2- outer skin. (Pirnia 1973: 136-137)

6. Architectural aesthetics

Beauty perception is a multidimensional phenomenon that can activate our inner, outer senses, reason and intuition. A series of studies by Gestalt psychologists and other groups, such as architects, designers and environmental psychologists show that beauty perception is multidimensional phenomenon; secondly, symbolic quality of environment is most important factor in beauty perception. Thirdly, there is an intrinsic connection between formal and symbolic beauty. According to these studies, Alan Dizak considers several features effective in beauty perception of environment. (Tabbaz, 1998)

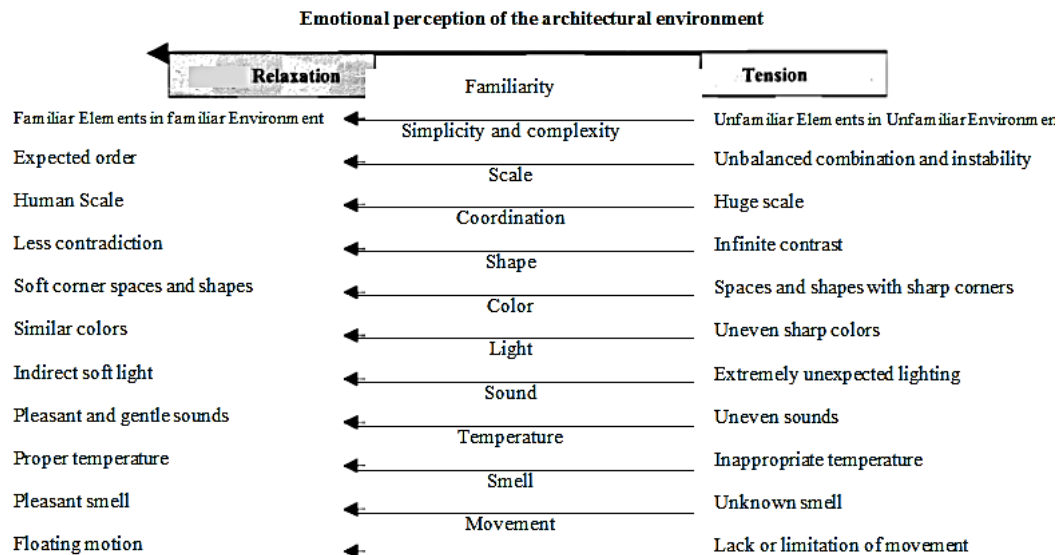


Figure 4: Effective characteristics on beauty of environment perception (Lang, 1987, pp. 191)

7. Aesthetics of double skin facades

Aesthetically, using this technology enhances aesthetic and architectural features. Using double skin facade in Qazvin Engineering Organization building illustrates an image of technology and aesthetic principles. Also, double skin facade enhances transparency of facade design and building walls. These facades are physically and thermally dependent on mechanical systems, along with all outlined benefits. So, facades design must be carefully studied in order to better understand the interaction between these two systems and their effects on reduced size of mechanical installations. (Emami Tabrizi 2013)



Figure 5: Two-skin facade in Qazvin Engineering Organization building (Johari & Masoudinejad 2017: 5)

8. Beauty and variety of double-skin facades

A key element of describing double-skin facade is the possibility of using extensive transparency in facade that preserves both functional properties and transparency idea of architecture. The addition of "high-tech" feel to building plays important role in its beauty. Since architects and engineers of other disciplines have to work closely together in double-skin facade system, the particulars and innovations created in beauty of building have an intrinsic effect. Using hybrid systems in such facades will change the appearance of building and constant and uniform facades in all seasons. Diversity can be an important element of beauty in building; such as our own workplace or home environment which we occasionally make changes in order to avoid homogeneity and diversify or adapt to seasonal changes (Qasemi, Navidoufar Qasemi 2016: 13).

9. Materials and Methods

9.1 Cambridge Public Library structure Analysis (Raven, 2009):

In this section, we analyze the functional structure of Cambridge Public Library that was finished in 2009 and will be familiarized with function, components and implementation of dual- skin facade. (Qasemi and Qasemi 2016: 17)

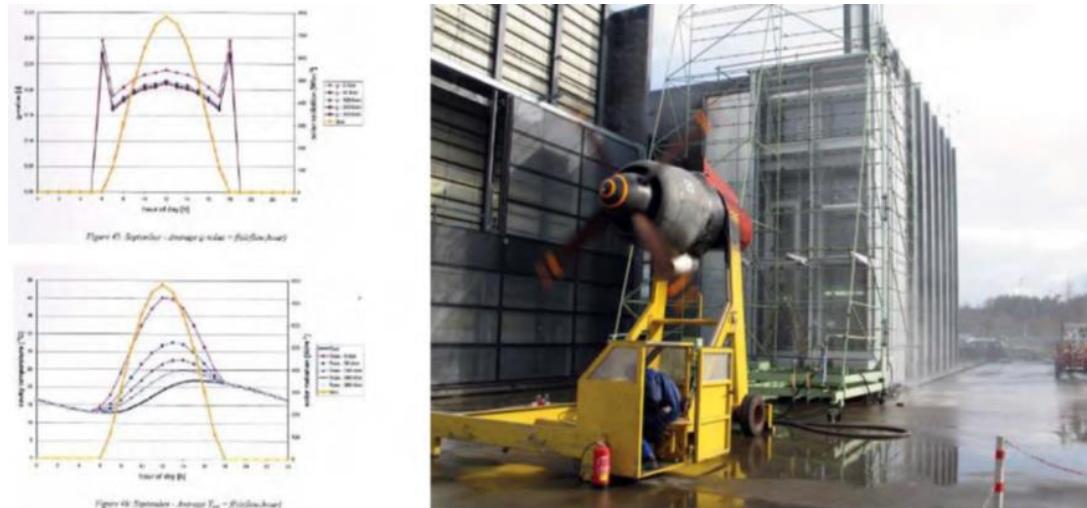


Figure 6: The facade in right was built in Gundelfingen, Germany by Josef Gartner, GmbH. They built a real-scale model of facade before real construction and carried out experiments of air, pressure, water, and earthquake based deformations. Left image is thermal diagram provided by Arup FacadeEngineering (London office). (Qasemi and Qasemi 2016: 17)

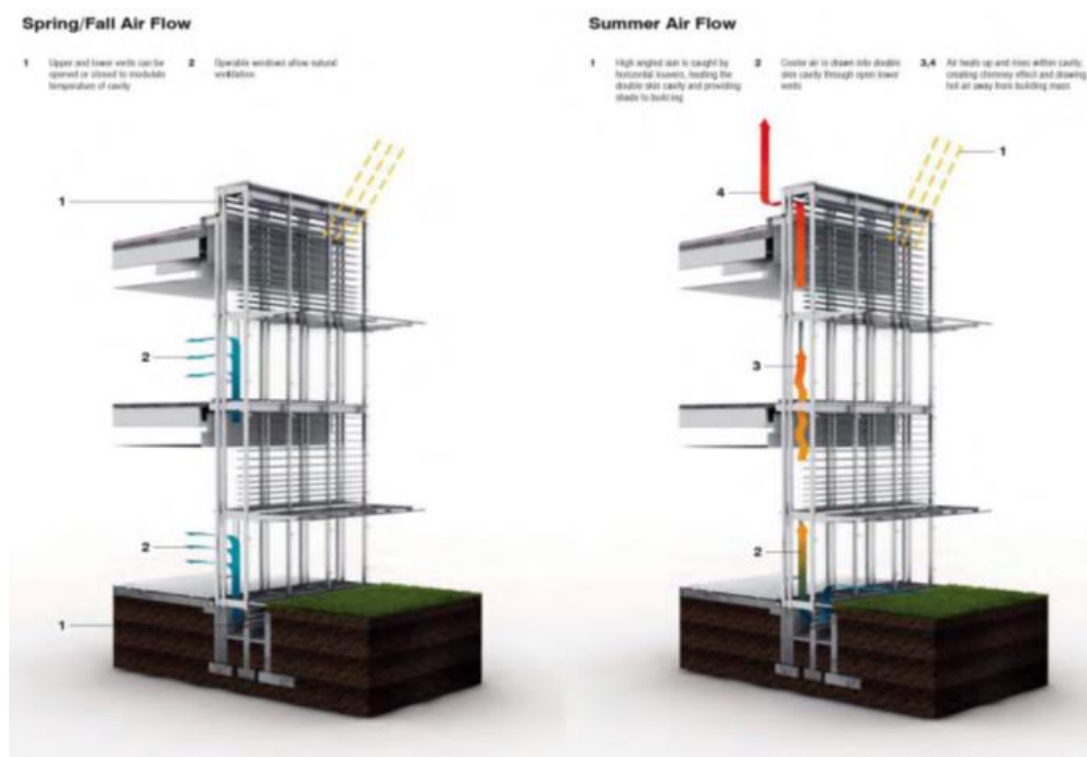


Figure 7: Structure and components of air conditioning in spring and summer (Qasemi and Qasemi 2016: 17)

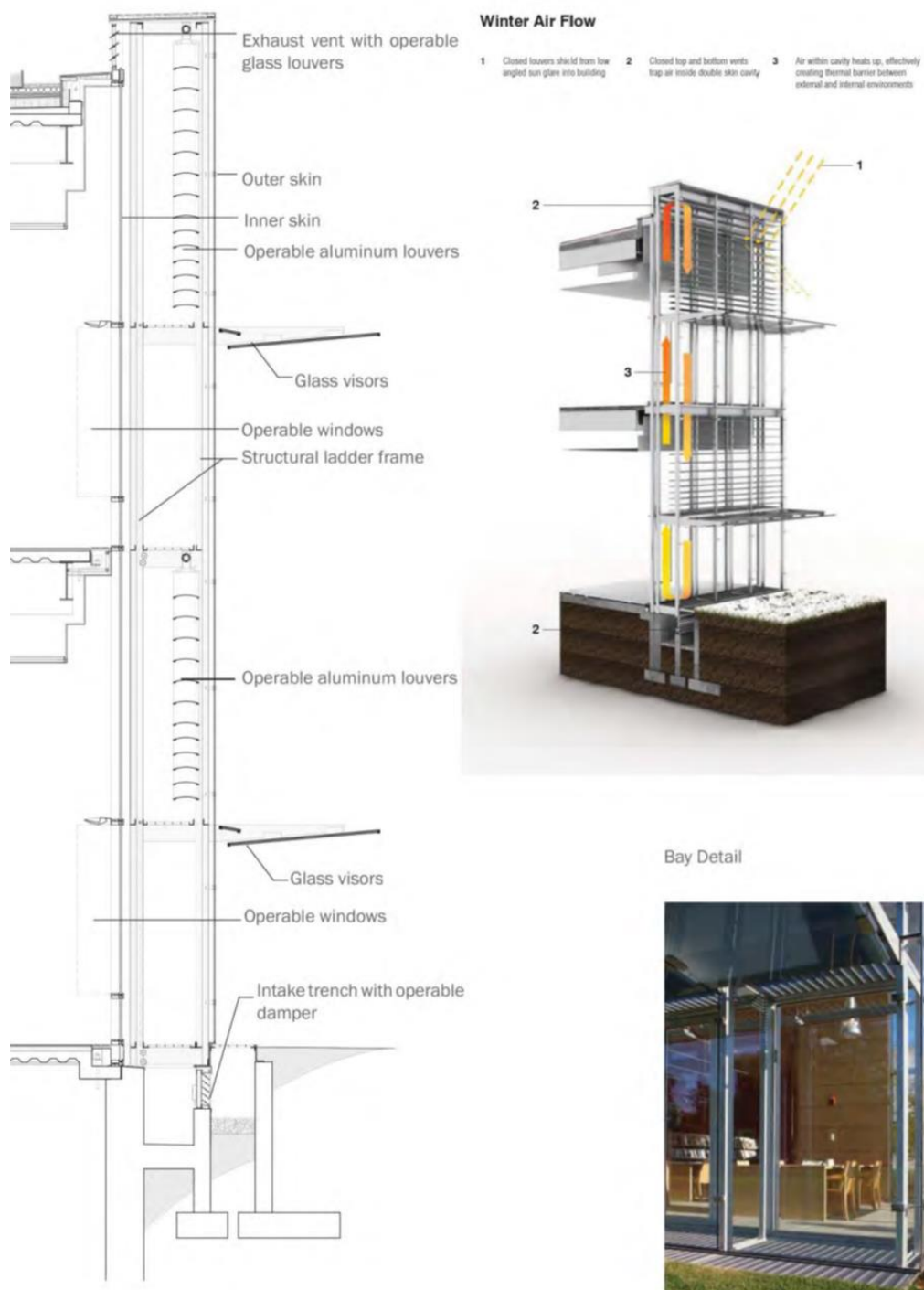


Figure 8: Structures and components involved in winter air flow and ventilation (Qasemi and Qasemi 2016: 18)

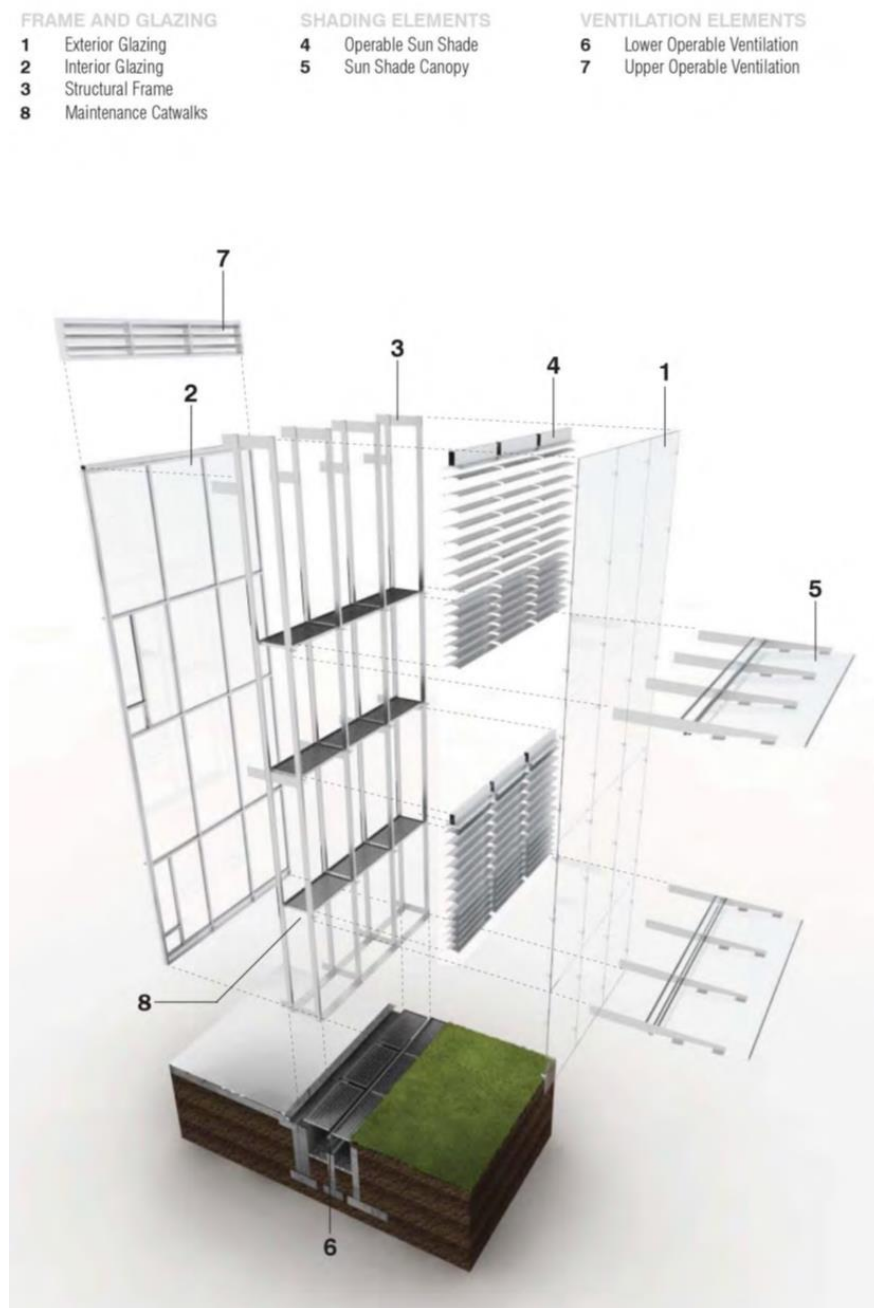


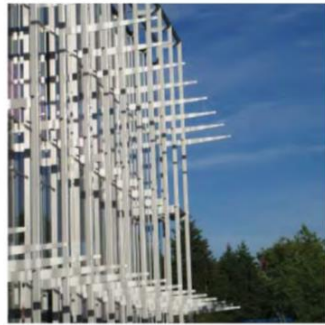
Figure 9: The main components of double- skin facade (Qasemi and Qasemi 2016: 19)



Structural ladder frame erection



Glass visor installation



Structural ladder frame



Inner glass skin installed



Structural ladder frame



Outer glass skin installed

Figure 10: How to run double- skin facade (Qasemi and Qasemi 2016: 20)



Figure 11: View from inside the library (Qasemi and Qasemi 2016: 21)

10. Case study

Nykredit bank in Copenhagen is an interesting example of design approach with public service function which is formed from a synergy with renewable energy sources in order to increase energy efficiency. Double- skin facade of building is made up of large three-layer glasses attached to an iron frame (Figure 12). The glass facades have

different color patterns. These colors protect against harmful solar radiation. They are split between two floors that are horizontally aligned and a low-width air-conditioning mechanism is fixed by louver in some places. There is a space of about 70 cm between two facade layers, which protects the building from external factors. Features of this approach include natural ventilation of indoor offices, better sound insulation, improved night time cooling using natural air circulation, which is formed indoors due to openings in facade and exterior openings on roof. Also, the building is equipped with roof-mounted photovoltaic cells that produce more than 80,000 kWh per year; water needed for flash tanks and part of HVAC system is provided by rainwater harvesting system (Figure 13). All of these features are part of building's useful efficiency in reducing energy consumption that led to annual energy consumption reduction of 70 kWh. The value is very low (Schmidt) and even it is less than 25% of Denmark's current legal standard. The building, known as "Crystal", was completed in 2010 and received many awards, including European Steel Design Award in 2011 or IABSE Denmark's Structuxre Award in 2013. (Qasemi and Qasemi 2016: 14)



Figure 12: Exterior facade of Nykredit Bank Building (Qasemi and Qasemi 2016: 14)

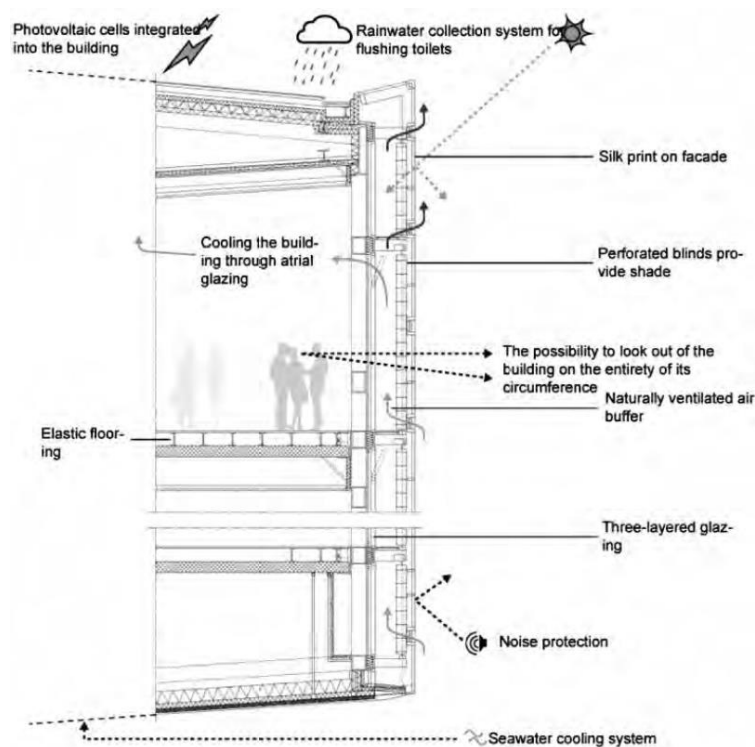


Figure 13: Cross section of Nykredit Bank building (Schmidt)



Bayer Headquarters,
Leverkusen, Germany



Post Tower,
Bonn, Germany



Helicon,
London, England



ARAG 2000,
Dusseldorf



Sparkasse
Dusseldorf



Seestern,
Dusseldorf



Stadttor,
Dusseldorf



ARUP Offices,
London



Victoria Ensemble,
High Rise - type 1



Victoria Ensemble,
Low rise - type 2



Victoria House,
Cologne

Figure 10: Successful examples implemented as a double- skin facade (Qasemi and Qasemi 2016:16)

11. Conclusion

In this study, we analyze the double- skin facades and different aspects of them. As stated in this paper, double-skin facades have positive effects on buildings energy under different water conditions; this improvement is due to thermal behavior of building. Another important aspect of double- skin facades is their beauty from urban and psychological viewpoint of viewers; it is an important issue from urban designers and architects perspective and has always been a challenge. Obviously, the construction industry must always expect new ideas in order to improve technologies and materials that improve the quality of life in cities.

New materials and technologies use has positive impact on different economic, social and environmental sectors of society. New materials and technologies are economically profitable through reducing energy of different sectors, extending the lifespan of buildings, producing positive psychological impacts on people socially and enhancing the beauty of urban landscape environmentally. Technology development in construction industry can improve double-skin facades function through combining these facades with green ones as well as using solar cell technology and maximize the effect of such facades from various aspects. As stated, facades form the main skin and boundary between indoor and outdoor (urban space). For this reason, more attention must be paid to facades and their improvements that have positive effect on economic, social and cultural sectors of city.

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