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A Research on Construction Systems of Double Skin Facades

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Abstract

Applications of double skin facade systems developed to reduce energy consumption in buildings and scientific researches on this subject have been increasing recently. In the context the aim of this study is to make energy efficient facade design more understandable as functional, conceptual, and technical by indicating the importance of current architecture and to reveal the responsibility of architects. In this study, facade construction details of 16 sample buildings, having double skin façade system are analyzed and presented in tables. It has been reached the result of the research by evaluating the working principles, the advantages and the disadvantages of facade systems.

1. INTRODUCTION

Environmental challenges increasing in recent years and future anxiety have caused to make provisions against energy consumption. As a consequence of particularly having deliberated the relationship between architecture and environment, it is concluded that energy is a factor leading design process in architecture. This conclusion has resulted in speeding up developments in building industry and yielding new technologies. Today buildings have started to turn into comfortable environments that are designed so as to provide optimum conditions by utilizing minimum energy against changing climatic conditions, being ventilated naturally, in which solar radiation can be controlled by householders, being environment-friendly, and in which the use of mechanical systems is minimized. These developments emerging in building design assign the task to balance between indoor and outdoor climate particularly to the building envelope as part of energy efficiency. This task leads to the development of a new system and new materials on facades including a large part of the building envelope [1]. These new facade systems enhanced on the purpose of energy efficiency designs take parts in literature as “energy-efficiency double skin façade systems”, “ventilated facades”, and “double glass façade”…etc. Facade systems that make contributions to energy conservation and enable solar power, a renewable energy source to be used in buildings as part of sustainable and ecological design play a significant role in forming and developing today’s architecture. In the literature, there are many researches related to introduction, development, and performance of these facade systems. For instance, in his book, Poirazis reveals double skin facade systems in details making use of examples and scrutinizing relevant researches [2]. Wigginton and Harris analyze double skin facade systems of sample buildings in their book by touching upon development process of intelligent facade systems as part of energy efficient and passive design [3]. Loncour et al. in their researches examines ventilation models and their features by considering examples while categorizing double skin facade systems that contains ventilation systems [4]. Oesterle et al. in their book analyzes double skin facade systems within the context of building physics, construction, ventilation and economic viability [5]. Ayçam and Sağıroğlu in their researches examines the changing parameters of double skin facade examples that

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have been implemented in four different climate types all around the world. [6]. In this study, the double skin facade systems that prevail in energy efficient and sustainable architecture patterns are analyzed in terms of functionality, conceptuality, and technical aspects. Within this framework, facade construction details and operation principles of building samples with different double skin facade systems are studied.

2. DOUBLE SKIN FACADE (DSF) SYSTEMS

Double skin facades are formed placing a second skin onto a single skin facade. A certain cavity must accordingly exist between two skins. Both skins of the facades can be designed in transparent form and are named "double-skin glass facades". Figure 1 simply displays components forming double skin facade installation and operation principles of the facade system. On such facades, clean air taken through the bottom opening into the space placed between two skins rises as it warms and is exhausted through building-high shafts or canals fixed up on each floor level without causing thermal disturbance. As a result of providing a buffer zone by the air in the space during the periods of heating and cooling, and ventilating the space in a controlled manner, energy conservation is achieved [7].

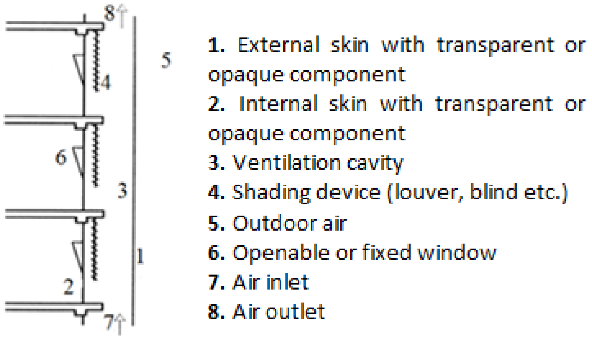

Figure 1. *Double skin facade structure [8]*

The ventilation cavity in the facade performs some critical functions such as cleaning, maintenance-repair, and prevention of exterior factors by placing solar control elements. Selection of the cavity width depends on some conditions including performance level expected from the system and usage area, climate data, etc. It varies from 20 to 200 cm [9]. The cavity depth, glass type, type and location of solar control elements, size and location of internal and exterior gaps in the cavity, and ventilation system have effects on properties of air in the cavity. In a double skin facade system, air circulation can be provided in 5 different ways in an installed cavity [5].

Outdoor air curtain (1): In this type of ventilation, air in cavity is supplied from outside and then exhausted outside.

Indoor air curtain (2): Air in cavity comes from inside the room and then goes into the room. This circulation occurs automatically or is carried out by means of ventilation systems.

Air supply (3): Ventilation of facade is performed with the help of air outside. Fresh air supplied from outside automatically blows or is taken into room by means of ventilation systems.

Exhaust air (4): Dirty air aspirated from indoors of building is exhausted outside through facade cavity.

Buffer zone (5): Each of double facade layers is airtight and cavity between layers is not ventilated so that a buffer zone is provided between indoor and outdoor.

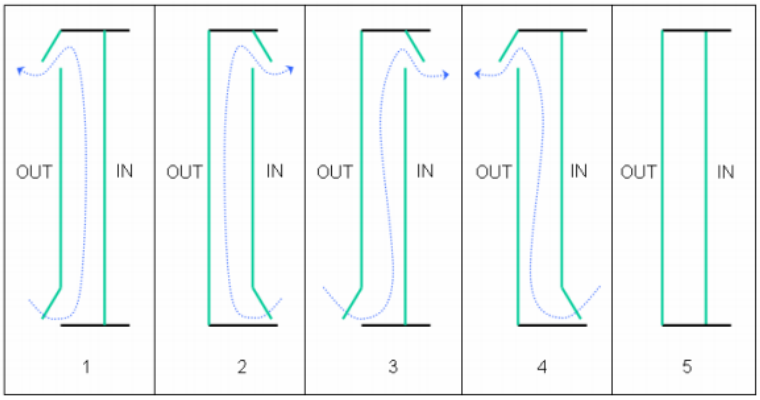

Figure 2. *The five main ventilation mode of DSF [4]*

2.1. Classification of DSF

Double skin energy efficient facades are categorized in 4 types by considering the types of ventilation cavity partition [4].

- Building-high DSF

In this facade system, air cavity provided between exterior and internal skin horizontally and vertically has no cut. Passive heat gain is provided by means of solar power in the building-high cavity [10]. In the ventilation cavity functioning as air well, dirty air warms and rises and is exhausted through the outlet on the top of building [11]. Throughout the cavity in the facade, catwalks that do not prevent ventilation are planned for staff to carry out cleaning and maintenance-repair. For the ventilation way in building-high facades, outdoor air curtain and buffer zone are generally preferred. Such facades provide an efficient acoustical performance and a thermal isolation [4].

- Storey-high DSF

This facade system, commonly used in double skin facade systems, is also called “corridor facades” in the literature. The story-high air cavity in the system is formed as an intermediate zone travelling around the building. Air ducts through which fresh air enters and dirty air goes out are placed on the wall near the ground floor and the ceiling so that all stories are ventilated separately. In order to prevent dirty air that comes out from a story from entering through air ducts into another story, the staggered duct installation is required. In case air cavity that is placed throughout each story increase sound transmission between indoors in the story, sound isolation required on inner surface of building have to be provided [10]. Such facades also prevent fire from spreading between stories.

- Box Window DSF

In this facade system, air cavity placed between exterior and interior skin is partitioned into horizontal modules at floor level and vertical modules at window level. Each story has its own outlet and inlet ducts that provide natural ventilation and are founded in window modules. As in story-high double skin facade systems, vertical-staggered duct installation is required in order to prevent dirty air that comes out from a story from entering through air ducts into another story. Such facade systems have an effect on fire insulation between stories [12].

- Shaft Box DSF

Operation principles of such facade systems are a combination of principles of building-high double skin facade systems and story-high double skin facade systems. Building-high air cavity is partitioned by a central vertical shaft that enables to exhaust dirty air. There is story-high cavity connected with the shaft and available on both sides of the vertical shaft. Warming dirty air is transmitted into central vertical shaft through the story-high cavity. Dirty air that rises due to chimney effect in shaft is exhausted outside from outlet on the top [12].

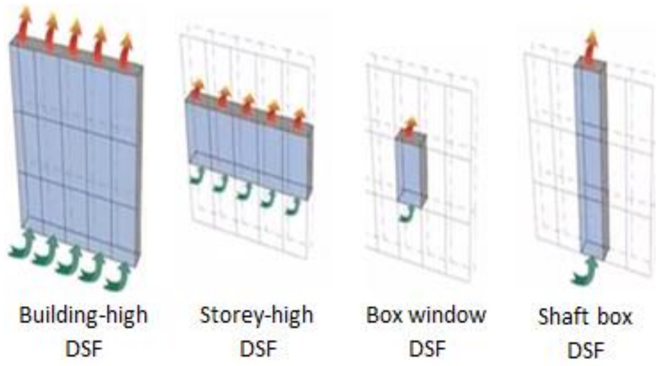

Figure 3. *Fresh and warm air flows of DSF Systems [13]*

3. METHOD

For this study, 34 samples of buildings that display one of 4 types of energy efficient facade systems [building-high, story-high, box-window, and shaft box] and that have taken places in the literature due to their sustainable structural features are determined. However, due to page limitation related to the article, analyses concerning 16 sample buildings in total - 4 samples for each type – are presented. ID cards prepared for sample buildings are available in Appendix of the study. After that, inquiry-based analysis tables are edited in order to determine the features of energy efficiency façade constructions.

There is a table of analysis of each type of façade in the article. The titles relating to these analysis tables are identification of façades, façade function, façade ventilation type, façade ventilation form, façade construction, size and type of openings in air shafts, direction of air flow in shafts, shading element used, maintenance and repair of façade, HVAC systems (heating, ventilating and air conditioning).

3.1. Analysis of DSF Construction

Information regarding facade types and buildings of which facade construction analyze is carried out is available in Table 1. Beside this, detailed construction analyzes concerning facade type of 4 sample buildings which are randomly chosen are also presented in tables (Table 2, 3, 4, 5).

Table 1. *Building samples with analysis of facade construction*

		TYPE 1	TYPE 2	TYPE 3	TYPE 4
SAMPLES		**Building-high DSF**	**Storey-high DSF**	**Box window DSF**	**Shaft box DSF**
	1	GSW Headquarters	Deutsche Messe AG Administration	Kista Science Tower	ARAG 2000
	2	Victoria Life Insurance	High Tech Centre Helsinki	Eurotheum	Photonics Centre
	3	Occidental Chemical Centre	Galeries Lafayette	RWE AG	Building Research Establishment
	4	Martela Business Centre	Düsseldorf City Gate	Print Media Academy	Halenseestrabe

Table 2. *Facade construction analysis of GSW Headquarters building [14]*

Facade system	**Type: Building-high DSF**	
	Number of building facade - Number of DSF facade: 4 – 2	
	Total size (m^2): No information	
Function of DSF	Energy efficiency, Optimum air-conditioning, External noise control, Efficient usage of daylight	
Ventilation type of DSF	**Natural** ✓	Air that enters through gaps from eastern facade circulates inside place and then automatically flows back into place by passing through western facade cavity.
	Mechanical	
	Hybrid (Mechanical +Natural)	
	Outdoor air curtain	

Ventilation mode of DSF	**Indoor air curtain** ✓		Fresh air coming from outside is drawn into western facade cavity flowing through indoor spaces. After ventilating western facade, it returns inside.
	Supply air		
	Exhaust air		
	Buffer zone ✓		
Construction of DSF	**Internal skin construction (single-layer)**	**First layer:** 8 mm Low-E glass 14 mm air cavity 8 mm clear glass (low-ferrous flat glass)	
		Frame type: 1,8×1,9 m openable aluminium frame	
	External skin construction (single-layer)	**First layer:** Fixed, 10mm tempered glass	
		Frame type: 1,8×3,3 m aluminium frame	
	Air cavity	**Narrow (10–20 cm)**	There is 90 cm air cavity between exterior and interior skins.
		Wide (20–200 cm) ✓	
Open junctions type of DSF	On the topside and underside of ventilation space, air intake & vent grates exist. When the grilles are closed, a buffer zone is formed.		
Air flow direction through the cavity	**Vertical**	✓	Air that is drawn into inside from eastern front gaps is transferred into western front cavity and so a vertical air flow is provided.
	Diagonal		
	Horizontal		
Shading device	**Position**	**In the middle of air cavity**	
		Inside air cavity, near-internal skin	
		Inside air cavity, near-external skin	✓
		Outside of external skin	
		Indoor	
	Type	0,6×2,9 m, entirely collapsible aluminium louvre blind	
	Control system	Manually and mechanically	
Service and maintenance of DSF	Maintenance of interior front and ventilation cavity is conducted through service hallways located on each floor level in the cavity.		
Hvac (Heating, Ventilating and Air Conditioning sys.)	Office spaces are naturally ventilated by means of cross - ventilation. In the case that energy-efficiency facade systems are not sufficient in winter, HVAC systems are activated.		

Table 3. *Facade construction analysis of Deutsche Messe AG building [15]*

Facade system	**Type: Storey-high DSF**		
	Number of building facade - Number of DSF facade: 4–4		
	Total size (m^2): ~6800		
Function of DSF	Energy efficiency, Optimum air-conditioning, Efficient usage of daylight		
Ventilation type of DSF	**Natural** ✓		Air is drawn into facade and then exhausted outside through vertical grates on each floor level.
	Mechanical		
	Hybrid (Mechanical +Natural)		
Ventilation mode of DSF	**Outdoor air curtain** ✓		When air intake & vent grates on facade are open, warming air continuously circulates in each floor. Beside this, a cross-ventilation is provided as a result of opening windows.
	Indoor air curtain		
	Supply air ✓		
	Exhaust air ✓		
	Buffer zone ✓		
Construction of DSF	**Internal skin construction (single-layer)**	**First layer:** 4 mm laminated glass 16 mm air cavity 6 mm laminated glass	
		Frame type: steel frame, sliding, openable	

<table>
<tr><td rowspan="3"></td><td rowspan="2">External skin construction (single-layer)</td><td colspan="3">First layer: 8mm laminated glass
16mm air cavity
8mm laminated glass</td></tr>
<tr><td colspan="3">Frame type: Fixed, steel frame</td></tr>
<tr><td>Air cavity</td><td colspan="2">Narrow (10–20 cm)
Wide (20–200 cm) ✓</td><td>There is 56 cm air cavity between exterior and interior skins.</td></tr>
<tr><td>Open junctions type of DSF</td><td colspan="4">In cavity on exterior wall in each floor, 8 metal stripe grates, 3m-high, exist.</td></tr>
<tr><td rowspan="3">Air flow direction through the cavity</td><td>Vertical</td><td>✓</td><td colspan="2" rowspan="3">Flow direction of air drawn into cavity each floor level is provided vertically and horizontally. Fitted into cavity, floor slabs prevent air from transmitting into other floors.</td></tr>
<tr><td>Diagonal</td><td></td></tr>
<tr><td>Horizontal</td><td>✓</td></tr>
<tr><td rowspan="7">Shading device</td><td rowspan="5">Position</td><td colspan="3">In the middle of air cavity</td></tr>
<tr><td colspan="3">Inside air cavity, near-internal skin</td></tr>
<tr><td colspan="3">Inside air cavity, near-external skin ✓</td></tr>
<tr><td colspan="3">Outside of external skin</td></tr>
<tr><td colspan="3">Indoor ✓</td></tr>
<tr><td>Type</td><td colspan="3">Aluminium louvre blind in the air cavity, roller blind indoor</td></tr>
<tr><td>Control system</td><td colspan="3">Manually and mechanically</td></tr>
<tr><td>Service and maintenance of DSF</td><td colspan="4">By means of service hallway and gaps opening into ventilation cavity, maintenance service of cavity is carried out.</td></tr>
<tr><td>Hvac (Heating, Ventilating and Air Conditioning sys.)</td><td colspan="4">When indoor windows are open, offices can be ventilated in summer and in the case that the system is insufficient in winter, in-floor heating and cooling systems are activated.</td></tr>
</table>

Table 4. *Facade construction analysis of Kista Science Tower [2]*

<table>
<tr><td rowspan="3">Facade system</td><td colspan="3">Type: Box window DSF</td></tr>
<tr><td colspan="3">Number of building facade - Number of DSF facade: 4–4</td></tr>
<tr><td colspan="3">Total size (m²): 6000</td></tr>
<tr><td>Function of DSF</td><td colspan="3">Energy efficiency, Optimum air-conditioning, Efficient usage of daylight</td></tr>
<tr><td rowspan="3">Ventilation type of DSF</td><td colspan="2">Natural</td><td rowspan="3">Fresh air is taken from grates on each floor level. Beside this, mechanical systems also contribute air flow.</td></tr>
<tr><td colspan="2">Mechanical</td></tr>
<tr><td colspan="2">Hybrid (Mechanical +Natural) ✓</td></tr>
<tr><td rowspan="5">Ventilation mode of DSF</td><td colspan="2">Outdoor air curtain ✓</td><td rowspan="5">When air intake & vent grates of box window modules on facade are open, warming air continuously circulates in each floor. When they are closed, a buffer zone is formed.</td></tr>
<tr><td colspan="2">Indoor air curtain</td></tr>
<tr><td colspan="2">Supply air</td></tr>
<tr><td colspan="2">Exhaust air</td></tr>
<tr><td colspan="2">Buffer zone ✓</td></tr>
<tr><td rowspan="5">Construction of DSF</td><td rowspan="2">Internal skin construction (single-layer)</td><td colspan="2">First layer: 4 mm clear glass
12 mm air cavity
4 mm clear glass</td></tr>
<tr><td colspan="2">Frame type: Fixed, storey-high steel frame</td></tr>
<tr><td rowspan="2">External skin construction (single-layer)</td><td colspan="2">First layer: 10 mm fixed clear glass</td></tr>
<tr><td colspan="2">Frame type: Storey-high box frame</td></tr>
<tr><td>Air cavity</td><td>Narrow (10–20 cm)
Wide (20–200 cm) ✓</td><td>There is 70 cm air cavity between exterior and interior skins.</td></tr>
</table>

Open junctions type of DSF	Mechanical ventilation grates are on topside and underside of box windows, on exterior wall, on each floor in cavity, and on roof level.		
Air flow direction through the cavity	**Vertical**	✓	Air drawn into cavity on each floor vertically rises and is exhausted outside through grates on other box window modules. Thus, air flow is vertically and horizontally performed. As a result that there is no air circulation area on floor levels between floors, inter-story air flow does not exist.
	Diagonal	✓	
	Horizontal		
Shading device	**Position**	**In the middle of air cavity**	✓
		Inside air cavity, near-internal skin	
		Inside air cavity, near-external skin	
		Outside of external skin	
		Indoor	
	Type	Aluminium louvre blind	
	Control system	Mechanically	
Service and maintenance of DSF	Maintenance of interior wall is conducted through service hallway in ventilation cavity while that of exterior wall is by means of service lifts hanging from roof.		
Hvac (Heating, Ventilating and Air Conditioning sys.)	Because the windows on interior facade can not be opened, indoors are ventilated mechanically and are heated with radiators.		

Table 5. *Facade construction analysis of Halenseestrabe [2]*

Facade system	**Type: Shaft box DSF**		
	Number of building facade - Number of DSF facade: 2–1		
	Total size (m^2): ~1200		
Function of DSF	Energy efficiency, Optimum air-conditioning, External noise control		
Ventilation type of DSF	**Natural**	✓	Air taken into vertical air-hole located on the corners of building from roof level gets dirty while passing throughout floors and is exhausted outside from vertical shaft located in the center.
	Mechanical		
	Hybrid (Mechanical +Natural)		
Ventilation mode of DSF	**Outdoor air curtain**	✓	Air drawn into shaft through air doors on roof ventilates indoors by means of gaps while heading towards in horizontal ducts throughout floors. When air doors on the roof are closed, a buffer zone is provided.
	Indoor air curtain		
	Supply air	✓	
	Exhaust air	✓	
	Buffer zone	✓	
Construction of DSF	**Internal skin construction (single-layer)**	**First layer:** Openable, sliding laminated glass	
		Frame type: Aluminium	
	External skin construction (single-layer)	**First layer:** Fixed 12 mm clear glass	
		Frame type: Frameless curtain wall	
	Air cavity	**Narrow (10–20 cm)**	There is 85 cm air cavity between exterior and interior skins.
		Wide (20–200 cm) ✓	
Open junctions type of DSF	In the shaft, air is in taken by means of air doors on roof level that are operated mechanically and passes through ducts heading on floor level throughout story.		
Air flow direction through the cavity	**Vertical**	✓	Air taken into shaft from roof level is vertically referred to floors and then the air warming here is referred to the central shaft through horizontal pipes in air cavity. Finally the dirty air rises in the shaft and is exhausted here.
	Diagonal		
	Horizontal	✓	

Shading device	**Position**	**In the middle of air cavity**
		Inside air cavity, near-internal skin
		Inside air cavity, near-external skin ✓
		Outside of external skin
		Indoor
	Type	Louvre blind
	Control system	Mechanically
Service and maintenance of DSF	Maintenance of the cavity is carried out by means of windows on interior wall.	
Hvac (Heating, Ventilating and Air Conditioning sys.)	When glass doors on interior wall are opened, indoors are ventilated by cross-ventilation method. In winters when the system is insufficient, mechanical ventilation system is activated.	

4. FINDINGS

In this section, data obtained as a result of analyzing facade systems of 16 sample buildings in order to determine the specific construction features of each facade type and to compare 4 double skin facade systems with each other is presented in Table 6. Inquiry parameters that are used to create the assessment table are; Double Skin Facade Function, Facade Number, Facade Ventilation Type, Interior Facade Construction, Exterior Facade Construction, Interior Windows, Exterior Windows, Air cavity in Facade, Gap Types in Air Cavity, Flow Direction in Air cavity, Type of Shade Element, Location of Shade Element, Maintenance Opportunity, HVAC Systems [heating, ventilating, and air conditioning].

As is seen from the study including the comparison of the sample buildings that have the four types of double skin facade construction, the buildings provide energy efficiency and optimum air conditioning functions. On the other hand, noise control and efficient usage of daylight are preferred functions depending on the intended purpose and location of the buildings. Beside this, it is seen that natural ventilation is used as ventilation form of façade cavity and thus indoor space for almost all types of façades. In case of insufficient natural ventilation, mechanical ventilation is additionally activated.

For the large majority of the sample buildings, air circulation in facade system is provided through the principle consisting of outdoor air curtain, air supply, air exhaust, and buffer zone. As for glass types used for internal and external skin constructions, low-e and laminated glass is mostly preferred for internal skin clear glass (low-ferrous flat glass) and laminated glass with high solar radiation transmittance for external skin.

Considering the different types of the double skin facades of the sample buildings analyzed, it is seen that the most of the windows in the inner skin are designed as opening while those in the outer skin are as fixed windows. Beside this, the analysis suggests that the windows in the inner skin of the buildings with double skin facade, building-high, are also designed as fixed windows in order to provide a buffer zone.

On the other hand, considering the dimensions and geometry of the air well, it is seen that they are designed as a wide air well (20-200cm) for all the 4 types of the energy efficiency facades. Air flow in the well is vertically oriented in all the sample buildings. Only for the sample buildings with box-window double-skin façade, cross air flow exists additionally in order to prevent mixing of dirty air with clean air. Preferred as shading elements for the most of the sample buildings, jalousies are placed rather into facade cavity. For almost all of the sample buildings, service & maintenance opportunity is provided depending on the design of the facade system.

In case of being insufficient in providing climatic comfort conditions, HVAC systems (heating, ventilating and air conditioning) are used as supportive agent for all the façade types.

Table 6. *Comparative analysis of DSF systems of sample buildings*

FACADE TYPES		**TYPE 1**				**TYPE 2**				**TYPE 3**				**TYPE 4**			
NUMBER OF SAMPLES		**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Function of DSF	Energy efficiency	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Optimum air-conditioning	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Noise control	x	x			x								x	x		
	Efficient usage of daylight									x	x	x	x				
Number of DSF	DSF at all facades	x	x	x		x	x	x	x	x	x	x		x			
	DSF at some facades	x								x				x	x	x	
Type of ventilation	Natural	x	x	x		x	x	x	x	x	x			x	x	x	
	Mechanical																
	Hybrid	x								x	x			x			
Ventilation mode of facade	Outdoor air curtain	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
	Indoor air curtain	x															
	Supply air	x				x	x	x	x	x	x	x		x	x	x	x
	Exhaust air	x				x	x	x	x	x	x	x		x	x	x	x
	Buffer zone	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Pane type of internal skin	Clear glass					x				x							
	Tempered glass	x	x														
	Laminated glass	x	x			x	x			x	x	x		x			
	Low-E glass					x								x	x	x	
Pane type of external skin	Clear glass	x				x				x	x			x	x	x	
	Tempered glass									x							
	Laminated glass	x				x	x			x				x			
	Low-E glass	x	x			x											
Windows of internal skin	Fixed	x	x	x						x							
	Openable	x				x	x	x	x	x	x	x		x	x	x	x
Windows of external skin	Fixed	x	x			x	x	x	x	x	x	x	x		x	x	x
	Openable	x	x											x			
Air cavity of facade	Narrow (10-20 cm)																
	Wide (20-200 cm)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Open junctions of facade	Grate	x	x	x		x	x			x	x	x		x	x		
	Duct					x	x			x	x	x					
	Window	x															
	Damper	x				x				x				x	x		
Air flow direction through the cavity	Vertical	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Diagonal									x	x	x	x				
	Horizontal					x								x			
Type of shading device	Venetian blind	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x
	Roller blind					x	x										
Position of shading device	At external skin													x			
	Inside the air cavity	x	x	x		x	x	x		x	x	x	x	x	x	x	
	At internal skin	x				x	x	x									
Service-maintenance possibility	Available	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
	Non-available									x							
HVAC	Available	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Non-available																

Positive and negative features of double skin facade systems are summarized in Table 7 based on analyzes carried out as part of the study and the literature.

Table 7. *Positive and negative features of DSF systems*

POSITIVE FEATURES	**Natural Ventilation**: In all types of DSF, user comfort is enhanced by providing natural ventilation by means of air cavity designed in facade.
	Heat Insulation: Of all types of DSF systems, exterior skin makes contribution to heat insulation by reducing heat transmission resistance. Beside this, air cavity designed in facade minimalizes heat loss on glass surface of interior facade by balancing temperature difference between indoor and outdoor.
	Sound Insulation: Particularly building-high DSF reduces sound transmission from outdoor to indoor in areas where noise ratio is high due to intense traffic flow. However, noise pollution may occur between stories of building with such a facade because there is no separating layer along the building height. On the other hand, other types of DSF including story-high, box-window, and shaft enable to dramatically reduce inter-floor sound transmission because air cavity is not continuous.
	Night Ventilation: It is most likely that indoor temperature readily increases during summer months in DSF systems. Moreover, indoor outfits and construction elements are not allowed to accumulate heat by way of natural ventilation conducted when mechanical ventilation systems are off at night so that daytime indoor thermal comfort is enhanced.
	Energy Conservation and Reduction of Environmental Factors: Owing to natural ventilation in DSF systems, energy conservation is provided as a result of reducing usage of mechanical air conditioning systems. Double skin system protects building against external factors.
	Visual Communication: wide glazing area ratio in double skin glass facades enhances visual communication between users and outdoor, and increases indoor lighting level.
	Reduction of Wind Effect: When the windows installed in buffer zone between two skins in DSF systems are opened, wind pressure on the exterior surface can be reduced by transmitting into center section.
	Protective Effects of Shading and Lighting Elements: Damages that may occur due to external climatic changes are prevented as a result of installation of shading- lighting elements into facade cavity.
NEGATIVE FEATURES	**Overheating Problems:** Overheating DSF cavity may have a negative effect on indoor comfort. For this reason, it is so critical to properly design air cavity, air flow way there and also exterior and interior gaps that contribute air flow.
	Daylight Problems: In DSF systems, transmission of sun radiation from external skin to indoor may reduce quantity of daylight.
	High Construction Cost: As compared to other types of facade systems, DSF systems cost higher due to the material used. However, they soon have an advantage owing to energy conservation that is provided in operating process.
	High Air Flow Speed in Cavity: In high-rise buildings with DSF systems, air flow speed in facade cavity may rise. Unbalanced air flow speed may cause failure in function that facade is supposed to conduct.
	Fire Problems: In building-high DSF systems, a fire breaking out on a lower floor may easily spread to upper floors as a result of rising throughout the facade cavity. Required technical preventions including fire insulation must be taken. In story-high and box-window types of DSF systems, this problem does not exist because the cavity is partitioned.
	Problems Related To Mechanical System: Problems that occur based on mechanically controlling air vents and solar control elements used in these facade systems may have a negative effect on indoor comfort requirements.

5. RESULT

Usage rate of energy efficiency double skin facades is increasing as days pass due to its favorable features such as; minimizing heat loss in buildings, benefiting from the sun in a controlled manner, establishing optimum balance between inner and outer climate, therefore drawing more advantages from the space near the window, making a contribution to sound insulation, providing the opportunity of natural ventilation particularly on the top floors of high-rise buildings, bringing innovations to architecture and building sector. Some parameters that must be primarily considered in design process of double skin facade systems for system efficiency, reduction in building-operating cost, and energy conservation can be summarized as follows;

- Building's Function [affecting selection of type and design of double skin facade],
- Climatic Features, Geographical Location, Topographic Structure of Construction Area [affecting selection of type and design of double skin facade],
- DSF Direction [affecting heat loss and gain on facade],
- Cavity Geometry and Dimensions of Facade Construction [affecting air temperature and flow in cavity],
- Ventilation Way in Cavity [affecting indoor thermal comfort],
- Selection of Material Used in Double Skin Facade Systems [physical, technical etc. features of glazing and shading elements affect natural ventilation and users' visual comfort],
- Position and Design of Window Openings Planned on Exterior and Interior Facade [affecting air flow format, speed, and direction in cavity].

In this regard, it is certain that technical data and experience are required to determine the most optimal facade system in designing buildings with double skin facade (thermo-physical properties of materials chosen for inner and outer skins, air flow and thermal changes in facade cavity, measurement of temperatures in inlet/outlet air ducts, building thermal performance, heat recovery from indoor solar radiation, and in facade cavity etc.).

In the early of design process, conducting analyzes of buildings including CFD Analyzes [Computational Fluid Dynamics] and Heating & Cooling Load Analyzes by energy simulation programs will make contributions to enhancement in system efficiency, energy conservation, determination of optimal facade system for a project. Building patterns with double skin facade systems prevail around the world. In our country which thermal solar capacity is quite high in and is located on the temperate climate zone, the number of double skin facade systems that have been practiced is so few. Therefore it is necessary to increase the number of patterns which are properly designed and can make positive contributions to building energy management.

*This article was based on Esra Lakot Alemdağ's MSc Thesis 'The Study Of Analysis About The Position And Performance In The Current Architecture Of Energy Efficient Double Skin Building Façade Designs In The Content Of Ecologic And Sustainable Architecture'.

CONFLICT OF INTEREST

No conflict of interest was declared by the authors

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APPENDIX

***Table 1.** ID Cards of Sample Buildings With Building-High DSF and Storey-High DSF*

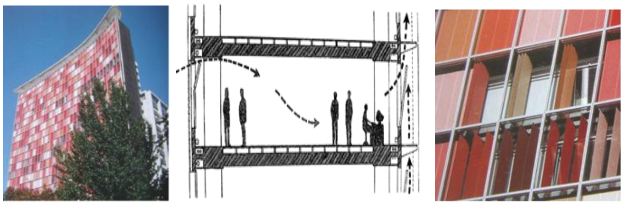
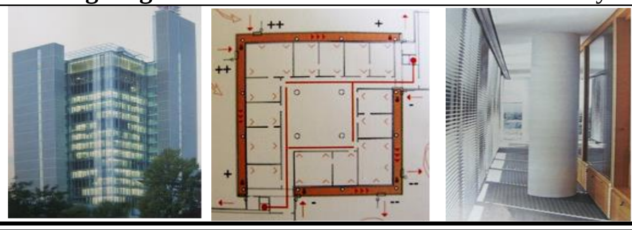
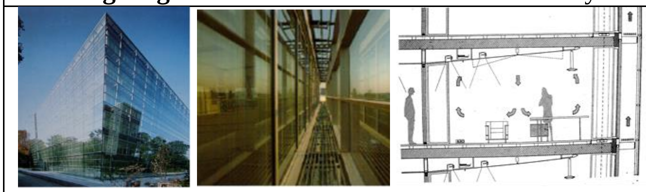
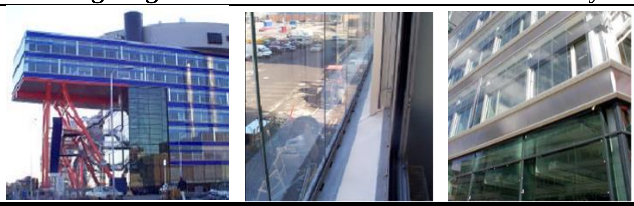
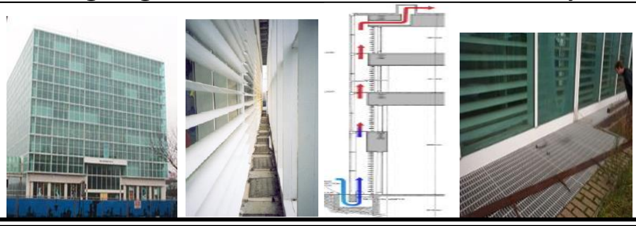
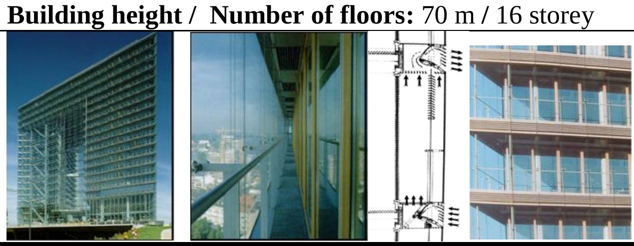
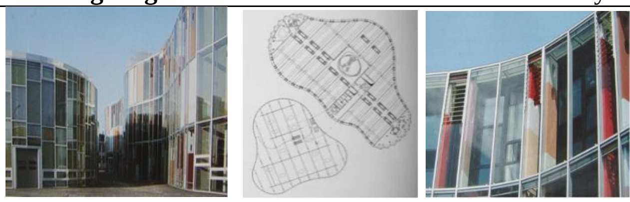
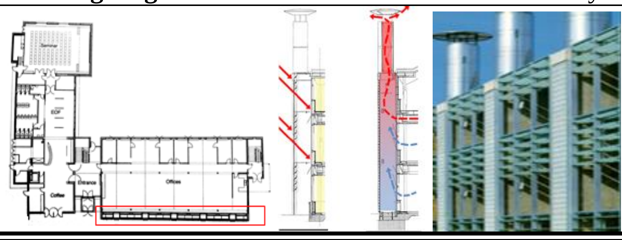
SAMPLES OF BUILDING-HIGH DSF	SAMPLES OF STOREY-HIGH DSF
Sample 1. GSW Headquarters Building	**Sample 1**. Deutsche Messe AG Building
Architect: Sauerbruch Hutton **Location / Year:** 1999 / Germany **Function:** Office building **Building height / Number of floors:** 65 m / 19 storey	**Architect:** Thomas Herzog **Location / Year:** 2000 / Germany **Function:** Office building **Building height / Number of floors:** ~ 70 m / 20 storey
	
Sample 2. Victoria Life Insurance Building	**Sample 2**. High Tech Centre Helsinki Building
Architect: T. Valentyn ve A. Tillman **Location / Year:** 1996 / Germany **Function:** Office building **Building height / Number of floors**: 22 m / 6 storey	**Architect:** Kai Wartiainen, Evata Finland **Location / Year:** 2001 / Finland **Function:** Office building **Building height / Number of floors:** ~ 35 m / 8 storey
	
Sample 3. Occidental Chemical Centre Building	**Sample 3**. Galeries Lafayette Building
Architect: Mark R. Mendell **Location / Year:** 1980 / New York **Function:** Office building **Building height / Number of floors:** 42 m / 9 storey	**Architect:** Jean Nouvel **Location / Year:** 1995/ Germany **Function:** Shopping center **Building height / Number of floors:** ~ 30 m / 7 storey
	
Sample 4. Martela Business Centre Building	**Sample 4**. Düsseldorf City Gate Building
Architect: Tommila Oy **Location / Year:** 2001 / Finland **Function:** Showroom **Building height / Number of floors:** ~ 14 m / 4 storey	**Architect:** Petzinka Pink **Location / Year:** 1997 / Germany **Function:** Office building **Building height / Number of floors:** 70 m / 16 storey
	

Table 2. ID Cards of Sample Buildings With Box window DSF and Shaft box DSF

SAMPLES OF BOX WINDOW DSF	SAMPLES OF SHAFT BOX DSF
Sample 1. Kista Science Tower Building	**Sample 1.** ARAG 2000 Building
Architect: White Architecture **Location / Year:** 2003 / Switzerland **Function:** Office building **Building height / Number of floors:** 128 m / 32 storey	**Architect:** Norman Foster **Location / Year:** 2000 / Germany **Function:** Office building **Building height / Number of floors:** 125 m / 32 storey
	
Sample 2. Eurotheum Building	**Sample 2.** Photonics Centre Building
Architect: Novotny Mähner **Location / Year:** 1999 / Germany **Function:** Office and housing **Building height / Number of floors:** 110 m / 31 storey	**Architect:** Sauerbruch Hutton **Location / Year:** 1998 / Germany **Function:** Research center **Building height / Number of floors:** ~ 10 m / 3 storey
	
Sample 3. RWE AG Administration Building	**Sample 3.** Building Research Building
Architect: Ingenhoven Overdiek **Location / Year:** 1997 / Germany **Function:** Office building **Building height / Number of floors:** 120m /31 storey	**Architect:** Fielden Clegg Bradley **Location / Year:** 1997 / UK **Function:** Research center **Building height / Number of floors:** ~ 10 m / 3 storey
	
Sample 4. Print Media Academy Building	**Sample 4.** Halenseestrabe Building
Architect: Schroder Architect **Location / Year:** 2000 / Germany **Function:** Office building **Building height / Number of floors:** 50 m/ 12 storey	**Architect:** Hilde Leon, Konrad Wohlhage **Location / Year:** 1996 / Germany **Function:** Office building **Building height / Number of floors:** ~ 40 m / 10 storey