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Evaluation of Double Skin Facades

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Abstract

Double-skin facades used in intelligent buildings provide natural light, heat and solar control, noise isolation and most importantly, natural ventilation. This study aims to evaluate the double skin facade systems according to design criteria and helps the designers and builders to take the right decision for double-skin facade system selection. The evaluation has been done to the multi-storey, corridor-type, shaft-type and box-type facade systems. The criteria affecting system selection in double-skin facade systems are identified as noise and heat conductivity, day lighting, wind and fire resistance, cost, aesthetics, and construction process. A survey was prepared to evaluate the double-skin facade systems and design criteria. The survey was sent out to 34 individuals, but the responses of only 21 individuals with prior experience in similar construction and project activities were evaluated. Architects and engineers actively working at construction yards answered the survey questions. Facade systems are evaluated for each design criteria (noise and heat conductivity, day lighting, fire and wind resistance, cost, aesthetics, construction process). Also, design criteria are evaluated. The results of the study are then offered to designers and builders as a source of information for taking the right decision with regard to double-skin facade system selection.

Keywords

Double-skin facade, design criteria for double skin facades, multi-storey facade, corridor type facade, shaft-type facade, box-type facade.

1. Introduction

Diminishing energy resources, the excessive use of fossil fuels, and the pollution released into the air, water, and soil as a result of material production, building construction, and management processes have made it necessary to consider energy demand and environmental requirements when designing buildings. Designers now adopt approaches that minimize energy consumption and maximize energy efficiency; double-skin facade systems are one such approach.

This study aims to evaluate the double skin facade systems according to design criteria and helps the designers and builders to take the right decision for double-skin facade system selection. The study proceeds as follows:

- Identifying types of double-skin facades and the design criteria influencing the selection of double-skin facade systems,
- Preparing a questionnaire with data obtained from the literature study,

o Carrying out a survey and evaluating the results obtained from the survey data.

2. Double-Skin Facade Systems

Double-skin facades in intelligent buildings provide natural light, heat and solar control, noise isolation and, most importantly, natural ventilation. By using natural energy resources, the need for mechanical systems is reduced and energy consumption is minimized. Double-skin facades serve as regulating elements between the internal and external environments in order to meet the comfort requirements of users. In this type of facade design, a cavity connected to the external environment is retained between the two skins. The air trapped in the cavity between the two skins provides heat insulation during winter and a buffer zone during summer, and also contributes to sound insulation (Goksal, 2005).

An important criteria for the classification of glass facades is the way in which they divide the cavity between outer and inner layers. The cavity may be undivided, or it may be partitioned by walls, glazing, wings, or other design techniques. This determines the functional characteristics of the facade, such as its heat and sound insulation, as well as the means of fire protection used within the structure (Lang and Herzog, 2000). In this study, the evaluation has been done to the multi-storey, corridor-type, shaft-type and box-type facade systems.

2.1. Multi-Storey Double-Skin Facade

The cavity in this type of facade acts as a chimney for exhaust air. Hot and exhaust air rises up through the cavity, which consists of a central vertical shaft, due to the chimney effect and is discharged at the highest point of the structure. The natural ventilation of the building is in general guaranteed because the air in the shaft never descends even when there is very little air current outside. However, for a certain building height, the pressure is reversed, and hot air can come back inside from the cavities in the storey height. This phenomenon varies with the building height, but also with the prevailing wind etc. (Essiz and Ozgen, 2004). Figure 1 shows a schematic diagram of the partitioning in this type of facade.

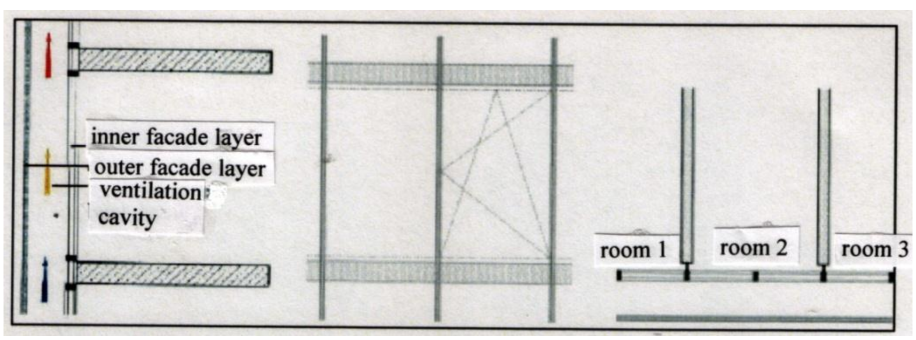

Figure 1: A Schematic Diagram of Multi-Storey Double-Skin Facade (Oesterle et al., 2001)

2.2. Corridor-Type Double-Skin Facade

The corridor-type double-skin facade is commonly used. Every storey is fitted with a fresh air intake and foul air outlet ducts; the cavities in every storey are arranged on top of each other. This type of facade is more complex than uninterrupted double-skin facades because of the series of ventilation cavities and dividers present on every storey. It reduces excessive heat and sound transfer as well as smoke and fire propagation (Essiz and Ozgen, 2004). Figure 2 shows a schematic diagram of the partitioning in this type of facade.

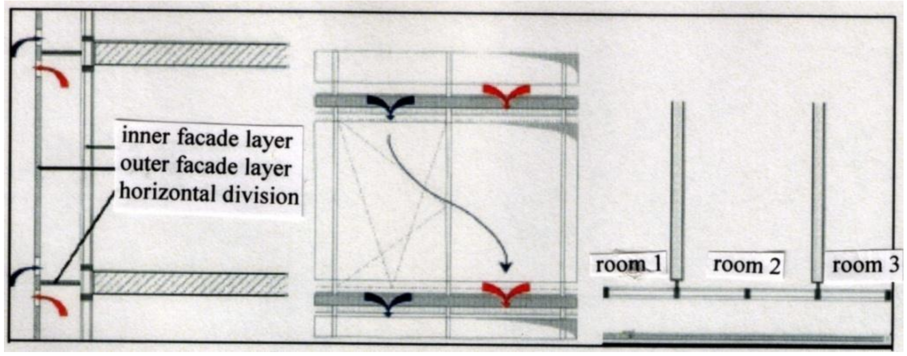

Figure 2: A Schematic Diagram of Corridor-Type Double-Skin Facade (Oesterle et al., 2001)

2.3. Shaft-Type Double-Skin Facade

A shaft-type facade is a combination of a double skin facade with a building-high cavity and a double-skin facade with a storey-high cavity. The full-height cavity forms a central vertical shaft for exhaust air. On both sides of this vertical shaft and connected to it via overflow openings are storey-high cavities. The warmed, exhaust air flows from the storey high cavity into the central vertical shaft. There it rises, due to the stack effect and escapes into the open at the top. The buoyancy in the shaft supports this flow at the level of the lower floors in that as the trapped air is warmed it is drawn upwards (Poirazis, 2004). When compared to other double-skin facade systems, the shaft-type double-skin facade has disadvantages such as low fire protection and the mixing of fresh and foul air. Figure 3 shows a schematic diagram of the partitioning in this type of facade.

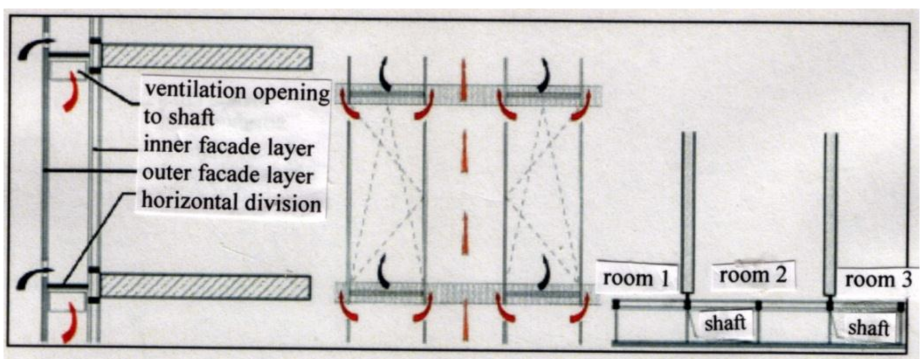

Figure 3: A Schematic Diagram of Shaft-Type Double Skin Facade (Oesterle et al., 2001)

2.4. Box-Type Double-Skin Facade

Box-type double-skin facades are stockwise ventilated facades with horizontal partitions on each floor and vertical partition on each window. The inlet and outlet vents are placed at each floor. Hence the lowest degree of air heating and therefore the most effective level of natural ventilation is to be expected (Poirazis, 2004). A type of “Diagonal Streaming of Air” ventilation configuration inside this type of cavity is described both by Uuttu and the journal “Space Modulator”. In box double-skin facades, a special sash called a “fish-mouth” designed to admit and exhaust outside air is often built in between storeys. This “fish mouth” has air inlets and outlets. The outside air from the intake “fish-mouth” is warmed inside the doubleskin and diagonally ascends to be exhausted from the outtake “fish mouth” at the neighbouring sash. If both the “fish mouths” are laid out vertically, a large part of the exhausted air would have been reabsorbed. This system also prevents fire from spreading to other levels (Poirazis, 2004), (Uuttu, 2001). Figure 4 shows a schematic diagram of the partitioning in this type of facade.

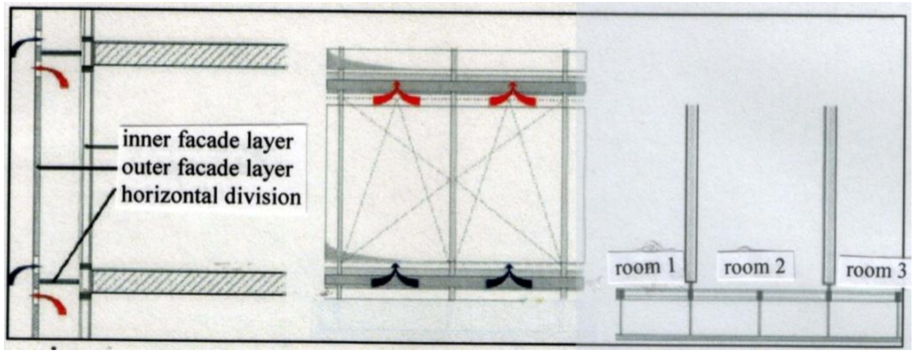

Figure 4: A Schematic Diagram of Box-Type Double-Skin Facade (Oesterle et al., 2001)

3. Criteria for the Selection of Double-Skin Facade Systems

3.1. Noise Conductivity

The outer skin screens external noise, so the noise level in the intermediate cavity is low. Comfort conditions can then be met in internal areas; the noise level remains low even when the windows on the internal skin are opened. Double-skin facades are effective against the constantly increasing traffic noise in city centers, and in particular provide more sound insulation than single-skin facades. The open spaces in the facade skin have a direct effect on the skin's noise screening. The screening effects of the outer skin can be used to reduce the sound insulation requirements of the inner skin. When noise is screened effectively by the outer skin, the windows on the inner skin can be opened without concerns about noise (Oesterle et al., 2001).

3.2. Heat Conductivity

An external skin provides effective heat insulation during both summer and winter. If the location of the building does not allow for sun breakers, the installation of sun breakers in the intermediate cavity of the double-skin facade can directly enhance heat insulation. Double-skin facades provide thermal insulation for the building during winter. The double-skin facade also reduces the cooling energy used during summer days because of the cold air stored in the intermediate cavity during the nights, which is not possible with a single-skin facade (Oesterle et al., 2001).

3.3. Day Lighting

A glass facade minimizes the energy required for artificial lighting. However, it is also important that the brightness level of the natural light in the internal space does not negatively affect comfort conditions (Cetiner, 2002). The demand for natural light is the same for double-skin and single-skin facades. However, there are some basic differences in this respect between double-skin and single-skin facades, which stem from the reduced quantity of light transmitted through the outer layer and the additional glass facade. If the additional layer is single-glazed, the decrease is at least 10%. However, if a special glazing with high transparency is used, the decrease can be in the range 7-8%, which is an acceptable value. If the thickness of the glazing is increased because of structural reasons, the quantity of light transmitted inside loses its importance. The transparency percentage of the glass used to coat the facade is in direct proportion to the percentage of light transmitted inside. As we move from the outer facade to the inner sections of the building, the daylight transmission rate and the possibility of seeing the sky decrease (Oesterle et al., 2001)

3.4. Fire Resistance

Fire causes an increase in the temperature, leading to changes in glass. These changes reduce its mechanical strength and vary according to the characteristics of the glass, the degree of temperature increase, and the duration of the fire. The joints between glass panels and other components are as important as the characteristics of the glass in determining the fire resistance of a glass facade. The fire resistance of the facade can be enhanced by using fire-proof materials and by designing the joints between the facade and the carrier system so as to prevent the propagation of fire or smoke from one storey to another (Cetiner, 2002).

3.5. Wind Resistance

The concept of wind includes in this context all air currents inside the building and those blowing towards the inside of the building. In some cases, air currents can affect the structure of the building; for example, the increased wind loads in wind tunnels or on tall buildings can affect static calculations. Identifying the active wind direction and the velocity and the points at which air passes in and out of the intermediate cavity are two important aspects of the design phase (McGee, 2005). Adequate resistance to wind loads can be achieved in a glass facade system by sizing carrier profiles and glass panes according to their deflection under wind loads. It is thus also necessary to take into account the wind load due to the height of the building. Wind resistance is also vital to the energy efficiency of the facade. Wind creates pressure on the facade surface and increases the speed at which rain enters through windows or through the joints of the facade panels, and thus leads to heat losses either through decreases in the thermal resistance or through air leakage (Cetiner, 2002).

3.6. Cost

Double-skin facades have lower heat transfer coefficients than traditional glass facades. Hence, double-skin facades decrease the overall heating load of buildings in cold periods. Further, reducing the wind pressure by adding a second glass skin makes it possible to open windows even in the highest storey of the building and enables the natural ventilation of the building. Thus the need to use air conditioning systems is reduced, a lower total lifecycle cost is obtained, and the energy consumption of the building is lowered (Cetiner, 2002).

3.7. Aesthetic

Double-skin facades do not differ much in appearance from traditionally coated single-skin facades. Although the aesthetic value of glass-coated facades is subjective, the addition of a second facade to an old single-skin facade to create a double-skin facade improves and renovates traditional single-skin buildings suffering from an outdated appearance or external facade problems. (Unal, 2006).

3.8. Construction Process

Technological developments in the building sector mean that the building construction process is able to produce higher quality buildings. However, the scarcity of resources limits the building production process, which makes it necessary to use resources rationally. A delivery date for construction is usually determined by the architect, the property owner, and the building contractor. By consulting high-level professionals during this process, the long-term utilization of the investment is increased and small details such as guest needs, personnel work areas, and storage can be identified. After the construction phase is completed, businesses may be forced to pay additional fees for repairs and changes. Such costs can be minimized through professional support, particularly by proceeding according to the feasibility study conducted before construction. The objectives should be shaped around the expectations of the investor, and the content and location should be selected according to these objectives and the income sources.

4. Evaluation of Double-Skin Facades

A survey was prepared for the evaluation of double-skin facade system. The responses to survey questions were evaluated digitally. The survey was sent out to 34 individuals, but the responses of only 21 individuals with prior experience in similar construction and project activities were processed. Architects and engineers actively working at construction yards answered the survey questions. As taking part in the survey, 19% were project managers, 10% were general directors, and 71% were architects and engineers. 19% had experience in educational buildings, 10% in health-related buildings, 14% in industrial buildings, and 57% in civil buildings. 10% worked with 0 to 10 personnel, 57% with 10 to 50 personnel, and 33% with 50 to 100 personnel. 14% had included multi-storey double-skin facade systems, 33% corridor-type systems, and 53% box-type systems in their projects. The content of the questions in the survey was determined by carrying out a literature study.

Table 1 shows the results for the rankings by the respondents of the criteria affecting their selections of double-skin facade systems, according to the degree of importance from 1 to 8 (with 8 the highest value and 1 the lowest value), and the arithmetic mean of the results.

Table 1: The Survey Results for the Criteria Affecting the Selection of Double-Skin Facade Systems

		8	7	6	5	4	3	2	1	arithmetic mean
1	noise conductivity	2	2	1	0	0	4	5	7	1.81
2	heat conductivity	2	2	6	6	3	0	2	0	3.11
3	day lighting	1	1	0	1	8	0	4	6	1.83
4	fire resistance	3	1	0	4	4	5	4	0	2.50
5	wind resistance	1	0	3	0	2	7	2	6	1.81
6	cost	6	8	1	3	0	0	3	0	3.64
7	aesthetic	4	5	5	2	0	4	1	0	3.36
8	construction process	1	2	5	5	4	2	0	2	2.81

The criteria for selection of double-skin facade systems are evaluated and it is found that the cost is the most important of the criteria, followed by the aesthetics. These criteria are followed in order of importance by heat conductivity, construction process and fire resistance. Of the eight factors, the least important for system selection is found to be the wind resistance, day lighting and noise conductivity criteria are ranked equally (Figure 5).

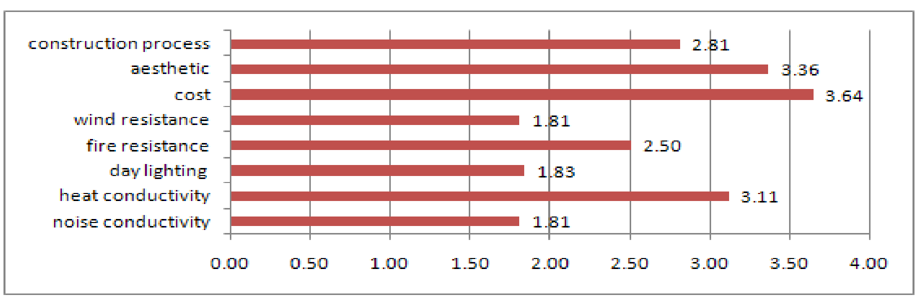

Figure 5: Evaluation of Design Criteria

By using the selection criteria of noise conductivity, heat conductivity, day lighting, fire and wind resistance, cost, aesthetics and construction process, the respondents evaluate the multi-storey, corridor-type, shaft-type, and box-type double-skin facade systems on a scale of 1 to 9 (with 1 the lowest value and 9 the highest value). The results of the evaluation for each facade system by the respondents and the arithmetic mean of the results are shown in Table 2.

Table 2: Survey Results for the Evaluation of Double-Skin Facades According to Design Criteria

	multi-storey double-skin facade						corridor-type double-skin facade						shaft-type double-skin facade						box-type double-skin facade					
	9	7	5	3	1	arithmetic mean	9	7	5	3	1	arithmetic mean	9	7	5	3	1	arithmetic mean	9	7	5	3	1	arithmetic mean
noise conductivity	0	1	3	8	9	1.67	0	1	3	10	7	2.36	0	3	7	6	5	3.16	5	11	5	0	0	5.88
heat conductivity	0	3	1	9	8	2.44	0	2	4	5	10	2.36	3	4	7	5	2	4.28	9	7	5	0	0	6.20
day lighting	11	8	2	0	0	6.60	8	7	3	1	2	5.64	1	3	2	10	5	3.00	3	3	8	6	1	4.28
heat resistance	0	1	2	4	14	1.72	0	1	8	8	4	3.00	0	0	1	6	14	1.48	4	13	4	0	0	5.88
wind resistance	0	2	0	10	9	2.12	0	0	8	7	6	2.68	0	2	7	7	5	3.00	3	14	4	0	0	5.80
cost	3	8	5	1	4	4.60	2	10	2	5	2	4.60	0	5	5	7	4	3.40	6	0	0	8	7	3.40
aesthetic	6	8	4	2	1	5.48	7	7	5	1	1	5.64	0	1	5	5	10	2.28	6	4	3	4	4	4.52
construction process	3	8	2	3	5	4.28	1	4	9	6	1	4.04	4	1	4	4	8	3.32	4	1	0	13	3	3.40

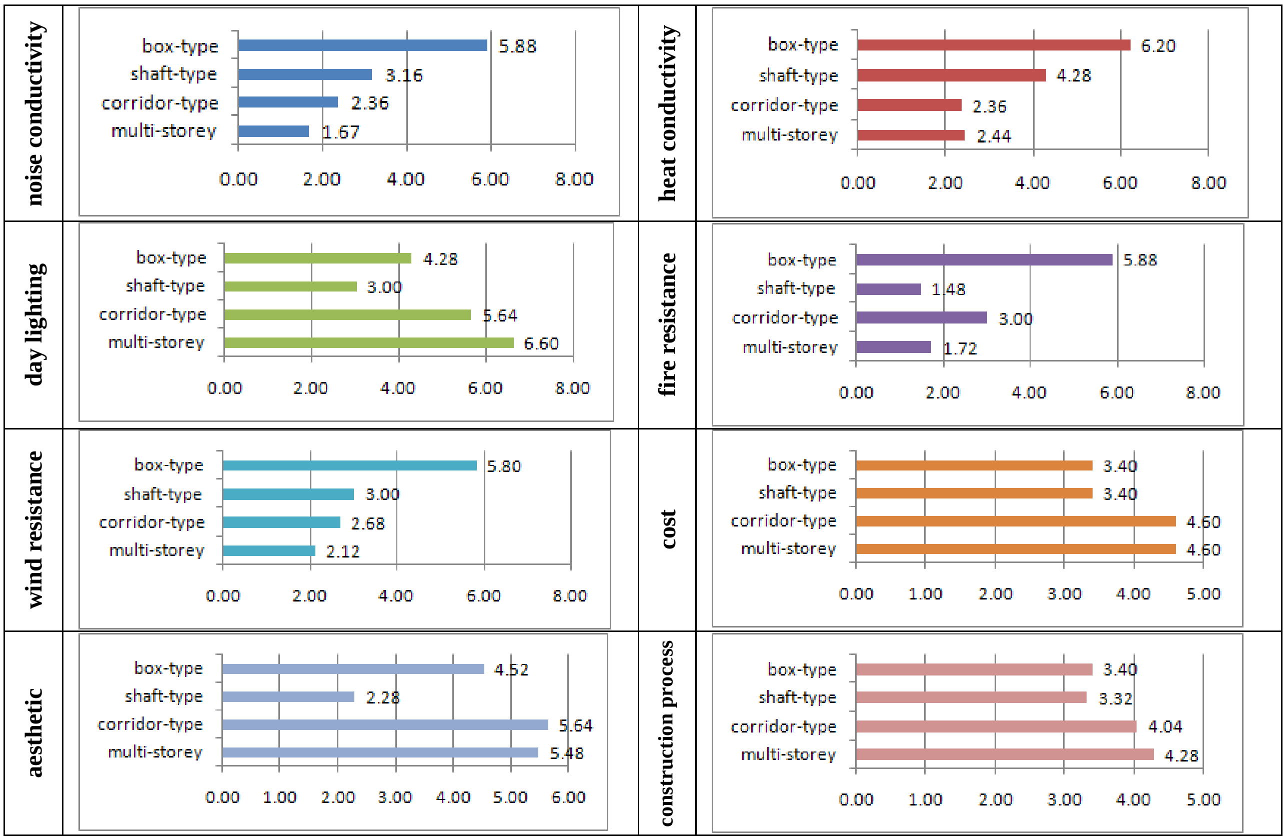

Figure 6: Evaluation of Double-Skin Facades According to Design Criteria

Double-skin facade systems are evaluated according to each design criterion. The best facade system according to the noise conductivity criterion is found to be the box-type system, followed by the shaft-type and corridor system and lastly the multi-storey system. When evaluated according to the heat conductivity criterion, the best facade is found to be the box-type system. The shaft-type system is found to be the second best, followed by the multi-storey system, and lastly the corridor-type system. According to the day lighting criterion, the best facade is found to be the multi-storey system. The corridor-type system is found to be the second best, followed by the box-type system, and lastly the shaft-type system. According to the fire resistance criterion, the best facade is found to be the box-type system. The corridor-type system is found to be the second best, followed by the multi-storey system, and lastly the shaft-type system. According to the wind resistance criterion, the best facade is found to be the box-type system. The shaft-type system is found to be the second best, followed by the corridor-type system, and lastly the multi-storey system. According to the cost criterion, the best facade is found to be the multi-storey and corridor systems are ranked equally, followed by the box-type and shaft-type systems are ranked equally.

According to the aesthetic criterion, the best facade is found to be the corridor-type system. The multi-storey system is found to be the second best, followed by the box-type system, and lastly the shaft-type system. According to the construction process criterion, the best facade is found to be the multi-storey system. The corridor-type system is found to be the second best, followed by the box-type system, and lastly the shaft-type system. (Figure 6)

5. Results and Discussion

It is important to transform buildings into comfortable environments that provide the optimum conditions with minimum energy consumption under changing climate conditions, with natural ventilation, user-enabled solar radiation control, and minimal use of mechanical systems. The building skin has the role of balancing the external and internal climates within the context of energy efficiency, which has led to the development of new systems and materials in the facades that constitute a large proportion of building envelopes.

In this study, a survey was prepared to evaluate the double-skin facade systems and design criteria. Facade systems are evaluated for each design criteria and design criteria are also evaluated. When the best facade system according to the noise conductivity, heat conductivity, fire resistance and wind resistance criteria is found to be the box-type system, according to day lighting criterion is found to be the multi-storey system. Although corridor and multi storey facades have points close to each other according to aesthetics and construction process criteria, corridor type is found the best according to aesthetics and multi-storey type is found the best according to the construction process criterion. According to the cost as the most important criterion, the best facade is found to be the corridor-type and multi-system which are ranked equally. The criteria for selection of double-skin facade systems are evaluated, too. It is found that the cost is the most important of the criteria, followed by the aesthetics. These criteria are followed in order of importance by heat conductivity, construction process and fire resistance. Of the eight factors, the least important for system selection is found to be the wind resistance, day lighting and noise conductivity criteria are ranked equally. The results of this study are provided to designers and builders as a source of information for decision-making in the double-skin facade system selection process.

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