

An Experimental Study for Performance Evaluation of the Box type Double Skin Façade System

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ABSTRACT: The purpose of this study is to evaluate the environmental performance of the box type double skin facade (DSF) system. The results of this study are as follows; (1) the peak of air temperature within the air cavity appeared 1 hour later after the peak time of outdoor temperature. It appears that the air cavity had a time delay effect. (2) There was about 3 °C temperature difference between the upper zone and the lower zone in case3. It appears that the sun control window films could reduce the solar radiation. (3) The difference of sound pressure level (SPL) between case1 and case4 was up to 32.4dB, at least 17.3dB in each frequency band. it appears that sound insulation effect of DSF system would be approximately 39dB (4) The difference of the illuminance level between separation distance, 1m, and separation distance 5m, was up to approximately 1350lx, at least approximately 250lx. It appears that it would not be necessary to use artificial lighting within 3m from window side because of the natural lighting being through the window and light shelf.

Keywords: Box type Double Skin Façade (DSF) system, Air Cavity, Sound Insulation, Light Shelf

1. INTRODUCTION

Recently, since there was been a growing concern about health and energy savings in buildings, various methods to make comfortable indoor environments and energy saving have been developed.

In the middle of those, especially the application of the double skin facade system has been adopted in newly-built buildings. This method corresponds with ecological concept. Already, in case of developed countries, various types of DSF system have been used. On the other hand, in the case of

Korea, the study on DSF system has only been performed recently. Besides, almost of them were the Curtain wall type DSF. Thus, it is necessary to evaluate and apply the other types. This study quantitatively performed the field measurements to evaluate the performance in summer and winter of the box type DSF system adopted in Kolon Construction Technology Research Institute in Yongin-si, Korea.

For this purpose, thermal environment, acoustical environment and luminous environment were evaluated by measuring the window surface · air temperature, the sound pressure level (SPL) and the illuminance level according to adopting box type DSF system.

2. THEORY STUDY

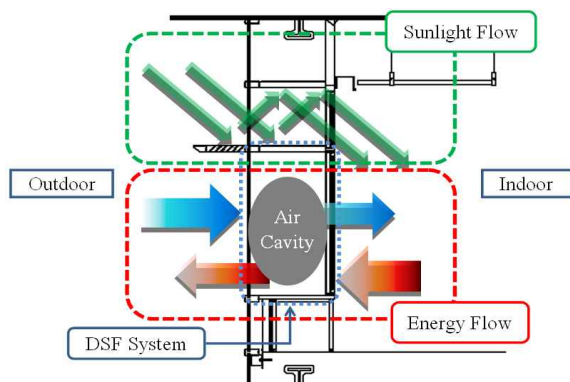


Figure 1: The concept of box type DSF system

2.1 Overview of DSF System

DSF system is able to provide a thermal buffer zone, solar preheating of ventilation air, energy savings, sound protection, wind protection, pollutant protection with open windows and nocturnal cooling. The concept of the box type DSF system is shown in Figure 1.

2.2 Types of DSF System

The double skin facade (DSF) system can be classified by the space separation method and the ventilation method; Box type DSF, Corridor type DSF and Curtain wall type DSF. They are shown in Table 1.

3. OUTLINE OF FIELD MEASUREMENTS

3.1 Measurement object

The Kolon Construction Technology Research Institute's office space used in this study was located in Youngin-si, Keonggi-do, Korea. It faced southwest. The box type DSF system was adopted on the south facade of this building.

Measurement periods were from August 6, 2007 to September 10, 2007 and from January 13, 2008 to February 9, 2008.

The cooling or heating system was being operated and some residents were in the building during the measuring period.

Table I: Type of DSF System

Story high cavity		Hybrid cavity	Multistory high cavity	
Box type	Corridor type	Shaft-box type	Shaft type	Whole type

3.2 Evaluation parameters and measurement methods

3.2.1 Evaluation of thermal environment

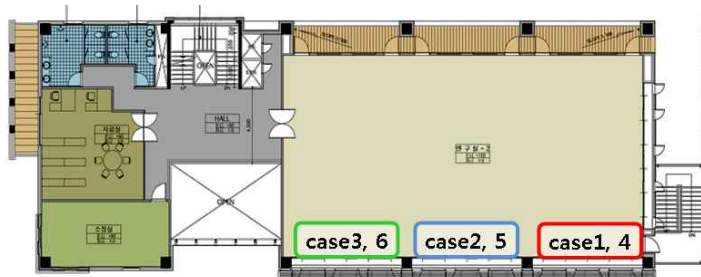
The box type DSF system consisted of three units on each floor. The dimensions of one unit were 7100mm(L) × 750mm(W) × 1200mm(H). The measurement space was divided into six cases to evaluate the thermal performance.

This was done by comparing and contrasting the results of the six cases according to the operating openings or blades and applying the sun control window film.

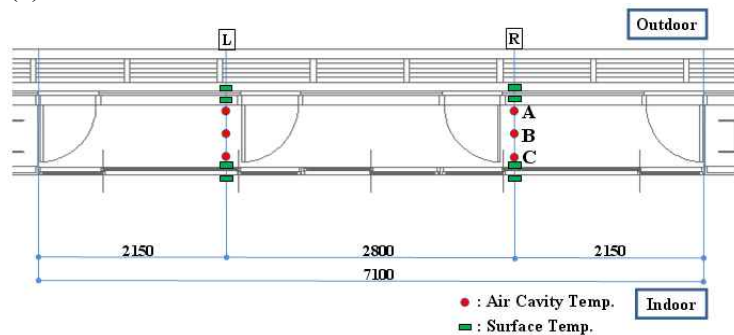
The measurement was performed that case1, 2, 3 were in summer and case4, 5, 6

Table II: Details of the cases (thermal environment)

Summer	case1	case2	case3
Openings	Open	Closed	Closed
Sun control window film	Not applied	Not applied	Applied
Winter	case4	case5	case6
Blades	Closed	Open	Open
Sun control window film	Not applied	Not applied	Applied



(a) Sectionalized cases



(b) Horizontal location of T-type thermocouples

were in winter, respectively, on same floor to minimize measurement errors.

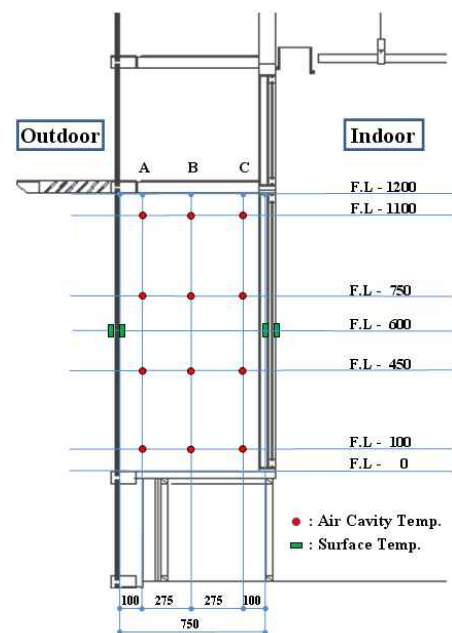
Figure 2 shows the locations of the T-type thermocouples that measure the window surface and the air temperature within the air cavity of DSF system.

The temperature data was regularly monitored every 1 minute. Measurements were performed in the right zone and the left zone in each case.

The horizontal locations of T-type thermocouples for the air temperature within the air cavity were classified by the distance from the inside surface of the external window; 100mm (A), 375mm (B) and 650mm (C), respectively.

On the other hand, the vertical locations of thermocouples were classified by the distance from the bottom of the air cavity; 100 mm, 450 mm, 750 mm and 1100 mm, respectively.

So, the numbers of the measurement points within the air cavity were 24 (12 points×2) points in each case. The surface temperature data of the internal and external



(c) Vertical location of T-type thermocouples

Figure 2: Outline of measurement for air & surface temperature

window was monitored in 8(4×2) points being apart from the bottom, 600mm, in each case.

Also, the indoor and outdoor air temperature was measured together.

The thermal infrared imaging camera was used to measure qualitatively the surface temperature of the external window.

The sun control window film was applied to the inside surface of the external window in case3, 6. It was designed to cut heat transmission through a window pane. And it can reflect 97% of infrared rays, 99.9% of ultraviolet rays and 50% of visible rays, respectively. Consequently, it can reduce energy consumption and relieve imbalance of indoor air temperature.

3.2.2 Evaluation of acoustical environment

In order to evaluate the sound insulation performance according to applying the box type DSF system, Sound pressure level (SPL) was measured by Sound level meters.

The measurement case was classified into four cases according to controlling the external and internal windows. The external window was a double glazed window and the internal window was the single glazing window.

The measurement was performed by the elements method based on ISO 140-5 (Field measurements of airborne sound insulation of facade elements and facade).

A speaker was used as the sound source. SPL was measured in central frequency 50 Hz~10 KHz of 1/3 octave band at 4 points.

A formula of weighted apparent sound reduction index (R'_{45W}) was as follows.

$$R'_{45W} = L_{1,S} - L_2 + \log\left(\frac{S}{A}\right) - 1.5$$

A 106dB noise was generated on the spot being 5 m from the receiving room. By applying the equivalent noise level ($=L_{eq}$), measurement value, it was measured from 4 points for 30 seconds and was averaged in each case.

3.2.3 Evaluation of luminous environment

To evaluate the performance of the light shelf in the DSF, an illuminance level was measured by a digital illuminance meter at intervals of two hours from 9 to 19. The measurement location of the illuminance level is shown in Figure 3.

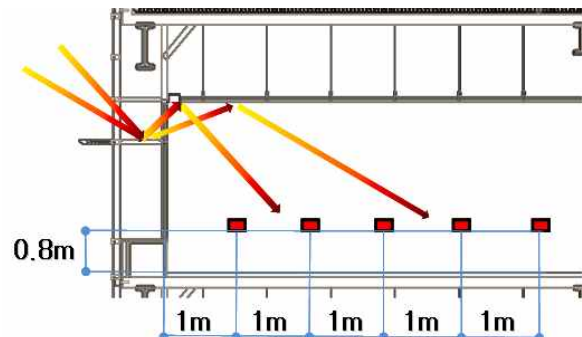


Figure 3: Measurement location of illuminance level for performance of the light shelf

4. MEASUREMENT RESULTS AND ANALYSIS

4.1 Thermal environment (The summer season)

4.1.1 Selecting Representative Day

Above all, the Representative Day must be selected to analyze results measured for about a month. Since outdoor air temperature has an effect on indoor air temperature, the Representative Day was selected on the basis of August outdoor air temperature data furnished by the Korean Meteorological Administration (KMA).

As a result of comparing outdoor temperature data during the field measurement, August 23 was decided as Representative Day, because the day's mean

Table III: Details of the cases (acoustical environment)

	Internal window	External window
caseA	Closed	Closed
caseB	Open	Closed
caseC	Closed	Open
caseD	Open	Open

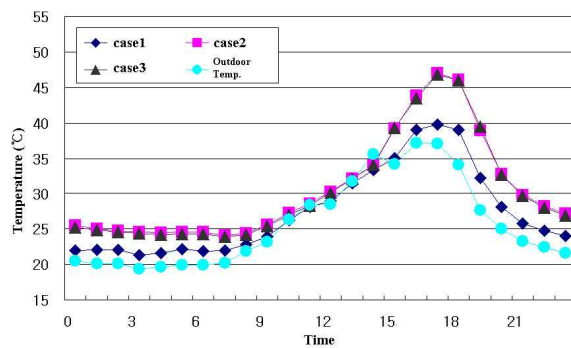


Figure 4: Change of air cavity temp. & outdoor air temp. in August 23

outdoor air temperature 25.7°C was similar to the mean outdoor air temperature 25.2°C of weather data in August.

Also, the relative humidity was 72% for the day. These values appeared to show the typical summer weather condition.

4.1.2 Measuring results

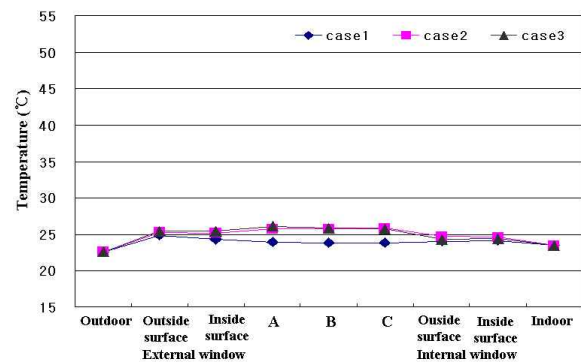
Figure 4 shows the change of mean air temperature within the air cavity of box type DSF system on August 23. It appears that the temperature in the air cavity was higher than the outdoor air temperature, approximately 1~2°C in case1 and 5~10°C in case2, 3. The air temperature in case1 was lower than the others, approximately 6~7°C. It because of the solar radiation in the air cavity was exhausted by ventilation through the openings.

The peak of outdoor air temperature was measured at 16. The peak air temperature within the air cavity was measured one hour after the peak time of outdoor air temperature in all cases. It appears that the air cavity of box type DSF would have the time delay effect.

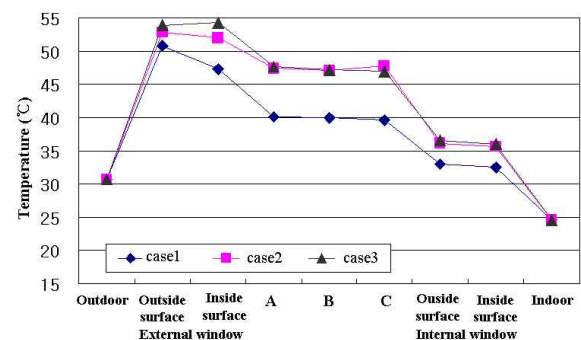
Figure 5 presents the comparison among the outdoor, window surface, air cavity, and indoor temperature at 9 and 17.

It appears that the outdoor air temperature was 23°C, the external window surface temperature was 25°C and the air cavity temperature was 24~26°C at 9, similar with each other.

The surface temperature of the external window was higher, up to 20°C than the



(a) At 9



(b) At 17

Figure 5: Outdoor, window surface, Air cavity, and indoor temp.

outdoor air temperature and about 15~18°C than the surface temperature of the internal window at 17, the peak time.

The A, B, C were the mean air temperature of the air cavity. The air temperature in case1 was lower than case2 and 3, approximately 6~7°C at this point. case3's surface temperature was higher than case2's, approximately 2~3°C. On the other hand, case3's air temperature within the air cavity was lower than case2, approximately 1~2°C. This was because of the heat absorption by the sun control window films.

4.2 Thermal environment (The winter season)

4.2.1 Selecting Representative Day

The Representative Day was selected by the same process at the summer season.

February 1 was decided as Representative Day, mean outdoor air temperature was -2.3°C and the relative humidity was 53%.

4.2.2 Measuring results

Figure 6 shows the change of mean air

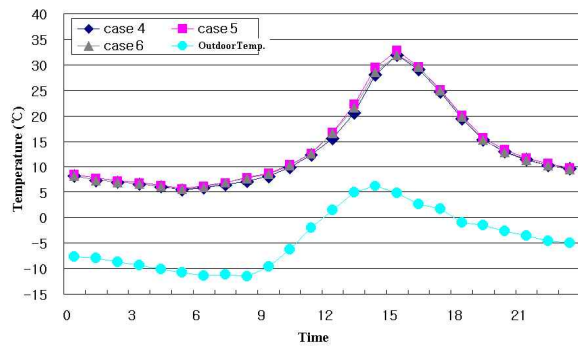
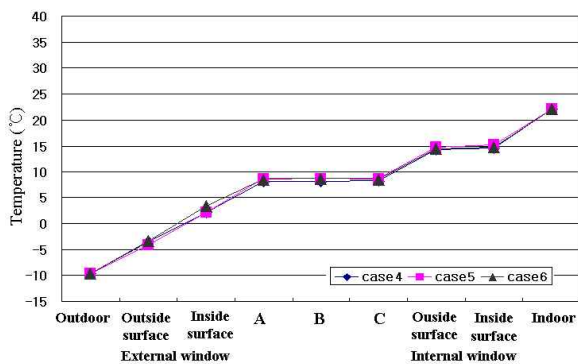
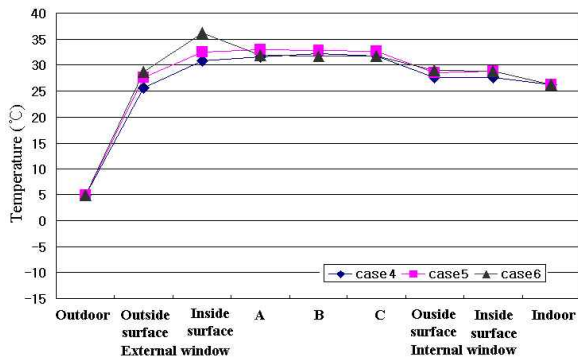


Figure 6: Change of air cavity temp. & outdoor air temp. in February 1



(a) At 9



(b) At 15

Figure 7: presents the comparison among the outdoor, window surface, air cavity, and indoor temperature at 9 and 15.

temperature within the air cavity of box typeDSF system on February 1.

It was the peak time of air temperature in the air cavity at 15.

It appears that the temperatures in the air cavity were similar each other and higher than the outdoor air temperature, approximately 15~28°C. This shows that the blade was not efficient to reduce solar radiation because of the low solar altitude in winter.

The peak of air cavity temperature was measured one hour after the peak time of outdoor air temperature in all cases, same as summer season.

Figure 7 presents the comparison among the outdoor, window surface, air cavity, and indoor temperature at 9 and 15.

It appears that the outdoor air temperature was -10°C, the external window surface temperature was -4°C and the air cavity temperature was 8°C at 9, similar with each other. When the peak time of air cavity temperature at 15, the outdoor air temperature was 5°C, the external window surface temperature was 25~28°C and the air cavity temperature was 31~33°C, 20~23°C and 26~28°C higher than the outdoor's, respectively.

4.3 Acoustical environment

The sound pressure levels (SPL) and the single-number quantities are displayed in Table IV.

The difference of SPL between caseA and caseD was up to 32.4dB, at least 17.3dB in each frequency band. Thus, it appears that sound insulation effect of DSF system would be approximately 39dB.

Table IV: Sound pressure level (SPL) & single-number quantities

	Sound pressure level (SPL) [dB]					Single-number quantities
	125Hz	250Hz	500Hz	1KHz	2KHz	R'_{45W}
caseA	31.7	35.6	36.9	34.6	41.8	39
caseB	28.8	26.1	27.9	24.1	34.9	29
caseC	26	27.5	21.7	19.3	20.8	20
caseD	14.4	11.7	7.6	4.2	9.4	0

The difference in SPL between caseB and caseC was up to 14.1dB, at least 1.4dB in each frequency band. It appears that the sound insulation effect could be changed according with controlling the internal window and the external window in each frequency band on DSF system.

In case of single-number quantities, caseB was higher than caseC approximately 9dB. It appears that sound insulation effect would be more effective when the double glazing window is used.

4.3 Luminous environments

The patterns of the internal illuminance levels according to each different separation distance are shown in Figure 8. In summer season, except for at 19, the difference of the illuminance level between separation distance 1 m and 5 m was up to approximately 1350lx, at least approximately 250lx.

If the illuminance level on the desktop is 300lx and working hours are from 9 to 18, it

seems that it would not be necessary to use artificial lighting within 3m from the window side, as natural lighting through the window and the light shelf. Alternatively, in the case of a separation distance above 4m, it would be necessary to use artificial lighting except for in certain hours of the afternoon.

In winter season, the internal illuminance levels were higher than summer in whole measurement points at 13. Especially, it was higher in the measurement points over 3m, every time.

It appears that the influx range of solar irradiance was increased, but the general influx amount of solar irradiance reduced as compared with summer because of the low solar altitude in winter.

The analysis results indicate that a lighting effect would be present under the DSF system by adopting the light shelf, given this building's window direction was facing southwest.

5. CONCLUSION

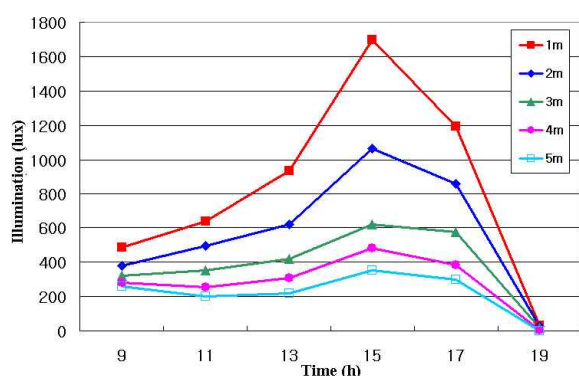
For the purpose of analyzing the environmental performance of the box type DSF system, field measurements were performed.

A summary of the general findings of this study is as follows;

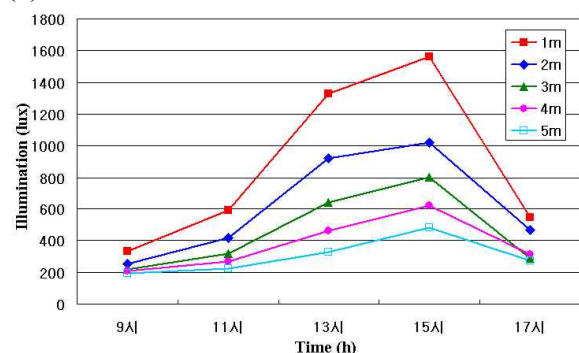
(1) In the summer season, the temperature in the air cavity was higher than the outdoor temperature approximately 1~2°C in case1 and up to 10°C in case 2 and 3. It appears that heat was accumulated in the air cavity.

In the winter season, the temperatures in the air cavity were similar each other and higher than the outdoor air temperature, approximately 15~28°C. This shows that the blade was not efficient to reduce solar radiation because of the low solar altitude in winter.

Also, the peak of air temperature within the air cavity appeared 1 hour late after the peak time of the outdoor air temperature.



(a) In summer season



(b) In winter season

Figure 8: The patterns of the internal illuminance levels

It appears that the air cavity had the time delay effect. Accordingly, it would be effective on saving energy.

(2) The difference of SPL between caseA and caseD was up to 32.4dB, at least 17.3dB in each frequency band. Thus, it appears that sound insulation effect of DSF system would be approximately 39dB.

Also, the difference of SPL between caseB and caseC was up to 14.1dB, at least 1.4dB in each frequency band. It appears that a sound insulation effect could be changed according with controlling the internal window or the external window in each frequency band on the double skin system.

In case of single-number quantities, caseB was higher than caseC approximately 9dB. It appears that a sound insulation effect would be more effective when the double glazing window is used.

(3) In summer season, the difference of the illuminance level between the separation distance of 1m and the separation distance of 5m was up to approximately 1350lx, at least approximately 250lx.

If the illuminance level on the desktop is 300lx and working hours are from 9 to 18, it seems that it would not be necessary to use artificial lighting within 3 m from the window side, as natural lighting through the window and the light shelf. Alternatively, in the case of a separation distance above 4 m, it would be necessary to use artificial lighting except for in certain hours of the afternoon.

In winter season, the influx range of solar irradiance was increased, but the general influx amount of solar irradiance reduced as compared with summer because of the low solar altitude in winter.

The analysis results indicate that a lighting effect would be present under the DSF system by adopting the light shelf, given this building's window direction was facing southwest.

In conclusion, the box type DSF system could reduce thermal load in the summer. This can be achieved by adopting the sun control window film and opening the openings of the window. And, its sound insulation effect is effective.

It is necessary to evaluate the performance of the box type DSF system in winter and to study the other DSF type system.

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