A Study on the Thermal Performance of Embossing Surface Sandwich Panel

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Key words: Embossing surface sandwich panel, Flat surface sandwich panel, Thermal performance, Heat transfer rate, Thermal conductivity, Effective resistance

Abstract

The purpose of this research is to investigate the thermal performance of embossing surface sandwich panel and flat surface sandwich panel. To do this research, thermal performances in summer season at the six points of embossing surface sandwich panel and flat surface sandwich panel are investigated focusing on the temperature. Three kinds of embossing surface sandwich panel and one kind of flat surface sandwich panel are used for this research. At the same size of sandwich panel, the average temperature differences of flat surface sandwich panel between average temperature at the 0.5 mm below copper plate and average outside air temperature and surface temperature are higher than those of embossing surface sandwich panel. The average heat transfer rate of flat surface sandwich panel is higher than that of embossing surface sandwich panel.

More study will be needed about the size of diameter and height of embossing, and materials of embossing surface sandwich panel.

Nomenclature

- A : Area of material [m^2]
- k : Thermal conductivity of material [w/m · ℃]
- q : Heat transfer rate [w]
- $Rair$: Thermal resistance of air [℃ · m^2/w]
- Rcu : Thermal resistance of copper [℃ · m^2/w]
- $Reff$: Effective thermal resistance [℃ · m^2/w]
- ΔT : Temperature difference [℃]

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1. Introduction

Recently, the flat surface sandwich panels are used as architectural materials according to the preference of light weight materials. These flat surface sandwich panels have some problems of sliding at the time of its construction, and leaking and exfoliated phenomena. The developing sandwich panel should have high quality of thermal ability solving economical problem.

The object of this research is to examine the thermal performance of embossing surface sandwich panel. Three kinds of embossing surface sandwich panel and one kind of flat surface sandwich panel are used for this research. Using the results of this research, new kinds of sandwich panel that have excellent thermal ability and economical aspect will be developed.

2. Description and characteristic of experimental apparatus

2.1 Description of experimental apparatus

It is necessary to prepare the data for designing new sandwich panel including suitable shape and depth, and thermal performance of the panel. Thus, this research should include thermal performance and the range of useable panel as well as the characteristic of shape. To do this, thermal performance of three kinds of embossing surface sandwich panel and one kind of flat surface sandwich panel should be evaluated. It is also necessary to decide suitable type of panel considering theoretical size, shape, and thermal performance of developing panel.

The new sandwich panels that have embossing and connecting passway are expected to contribute the architectural development of housing, storage, and other kinds of building.

2.2 Characteristic and size of experimental apparatus[1]

To compare and evaluate the thermal performance of experimental apparatus, three kinds of embossing surface sandwich panel and one kind of flat surface sandwich panel are used for this research.

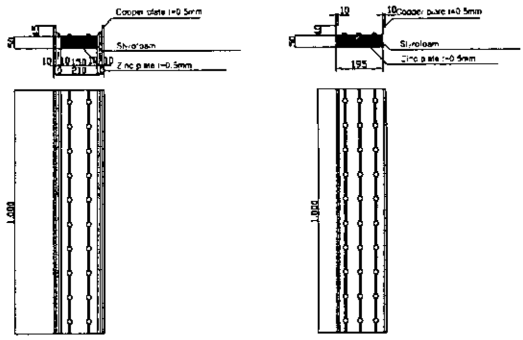


Fig. 1 EP1-1 and EP1-2.

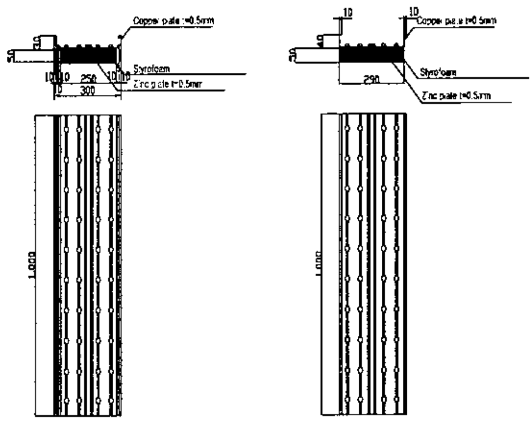


Fig. 2 EP2-1 and EP2-2.

2.2.1 EP type sandwich panel (embossing panel)

The experimental apparatus of EP type sandwich panel have EP1, EP2, and EP3 series as in the Table 1. Each of panel has three apparatus. Thus, 18 apparatus are made for this

Table 1 EP type sandwich panel

Test No.	Width × length (mm)	Diameter of embossing (mm)	Insulating material used
EP1-1	190 × 1000	Diameter: 20 mm Height: 5 mm	Copper plate thickness: 0.5 mm Styrofoam: 50.0 mm Zinc plate: 0.5 mm
EP1-2	190 × 1000		
EP2-1	290 × 1000		
EP2-2	290 × 1000		
EP3-1	490 × 1000		
EP3-2	490 × 1000		

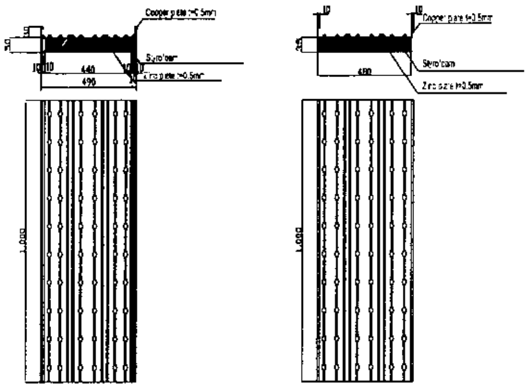


Fig. 3 EP3-1 and EP3-2.

research. These three types of experimental apparatus have the same characteristic of material and surface condition except the shape of connection part. Although the connection parts of EP1, 2, 3-1 series have one curve, the connection parts of EP1, 2, 3-2 series have 90 degree angle. As in the Figure 1, 2, and 3, EP1, EP2, and EP3 have the same length, the same distance and height of embossing except width.

2.2.2 FP type sandwich panel (flat panel)

The experimental apparatus of FP type sandwich panel have FP1-1, FP2-1, and FP3-1 series as in the Table 2.

Each of panel has three apparatus. Thus, 9 apparatus are made for this research. These three types of experimental apparatus have the same characteristic of material and surface condition except the triangle shape of connection part. As there are no embossing at the surface of the FP series panel, their thermal performances can be compared with those of EP series panel. As in the Figure 4, FP series have the same length, the same flat surface except width.

Table 2 FP type sandwich panel

Test No.	Width × Length (mm)	Insulating material used
FP1-1	190×1000	Copper plate thickness: 0.5 mm
FP2-1	290×1000	Styrofoam: 50.0 mm
FP3-1	490×1000	Zinc plate: 0.5 mm

The shape of connection parts of FP series panel is triangle. There are no embossings at the surface of FP series panels. Their surfaces are flat.

3. The characteristic of thermal performance of EP type and FP type sandwich panel

3.1 Installation and measurement of experiment apparatus

Using six sensors and Remote Scanner (NEC) Potable Environment Meter, the temperatures at the EP and FP types sandwich panels are measured. From one o'clock to two o'clock

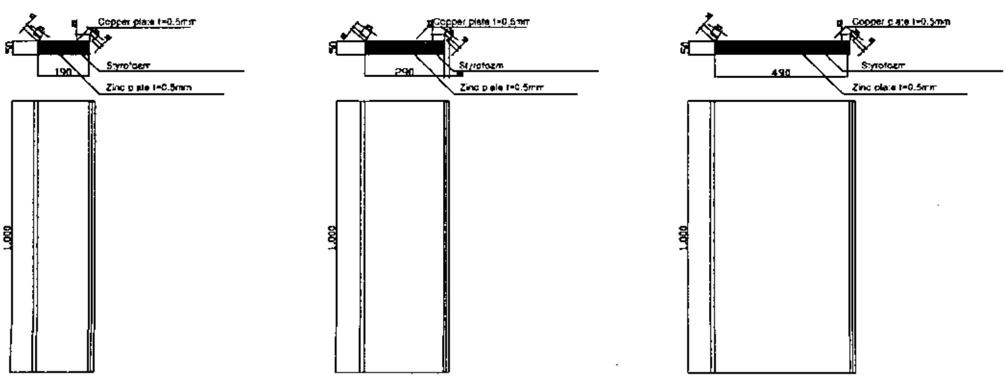


Fig. 4 FP1-1, FP2-1, and FP3-1.

Table 3 Sensor position of test type

Sensor \ Tool	Remote-Scanner (NEC) portable environmental meter					
Position No.	1	2	3	4	5	6
Distance (mm)	0.0	0.5	25.0	50.0	−100.0	100.0
Sensor position	outside surface	below copper	inside material	inside surface	outside space	inside space

afternoon at the summer time, 120 times, 30 seconds interval, the measurements are conducted. When experiments are conducted, the same measuring environments are used.

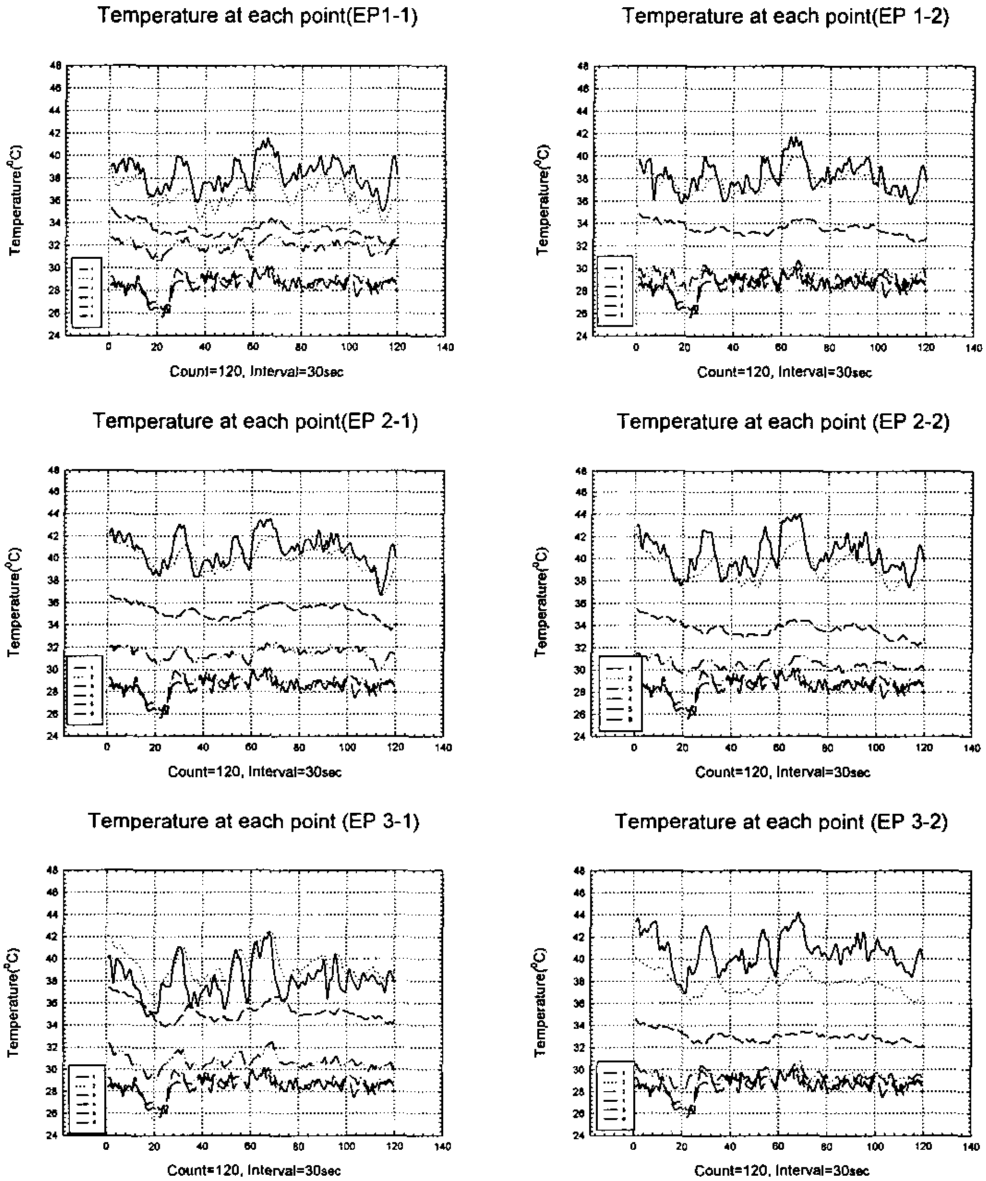


Fig. 5 Temperature at each point.

3.2 Comparison and evaluation of temperature at the each measurement point

During one hour experimental period, as Figure 5 and Figure 6, the average, highest, and lowest outside temperatures are 28.4℃, 30.1℃, and 25.7℃, respectively.

3.2.1 Average outside surface temperature at the each type of sandwich panel

During one hour, 120 times, 30 seconds interval, the measured average surface temperatures at the point 1 are in the Table 4. As in the table, measured average surface temperature differences at the point1 located at the EP1-1 and EP1-2, EP2-1 and EP2-2, and EP3-1 and EP3-2 are 0.1℃, 0.3℃, and 2.6℃, respectively. Also as in the Table 4, the average surface temperature differences at the point 1 located at the FP1-1 and FP2-1, FP1-1 and FP3-1, and FP2-1 and FP3-1 are 3.1℃, 2.8℃, and 0.3℃, respectively.

Depending on the results, it seems that average surface temperature difference is not affected by the shape of connection part of sandwich panel. Additionally, average outside surface temperature at the FP type sandwich panel is higher than that of EP type sandwich panel.

3.2.2 Average temperature at the point of 0.5 mm below copper

During one hour, 120 times, 30 seconds interval, the measured average temperatures at

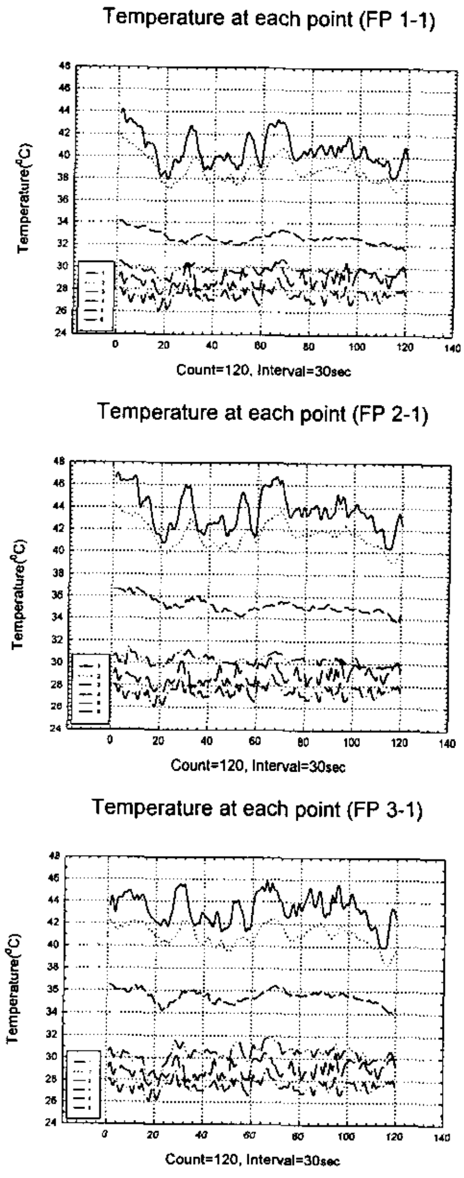


Fig. 6 Temperature at each point.

Table 4 Average outside surface temperature

	EP1-1	EP1-2	EP2-1	EP2-2	EP3-1	EP3-2	FP1-1	FP2-1	FP3-1
Average outside surface temperature (℃)	38.3	38.2	40.7	40.4	38.1	40.7	40.6	43.7	43.4

Table 5 Average temperature at the 0.5 mm below copper plate

	EP1-1	EP1-2	EP2-1	EP2-2	EP3-1	EP3-2	FP1-1	FP2-1	FP3-1
Average temperature at 0.5 mm below copper plate (℃)	36.7	37.7	40.0	39.2	39.3	37.8	38.8	41.5	41.0

the point of 0.5 mm below copper are in the Table 5. As in the table, measured average surface temperature differences at the point 2 located at the EP1-1 and EP1-2, EP2-1 and EP2-2, and EP3-1 and EP3-2 are 1.0℃, 0.8℃, and 1.5℃, respectively. Also as in the Table 5, the average temperature differences at the point 2 located at the FP1-1 and FP2-1, FP1-1 and FP3-1, and FP2-1 and FP3-1 are 2.7℃, 2.2℃, and 0.5℃, respectively.

Depending on the results, the average temperature at point 2 located at the FP type sandwich panel is higher than that of EP type sandwich panel.

3.2.3 Temperature difference between average outside surface temperature and average outside air temperature

Temperature differences between average outside surface temperature and average outside air temperature are in the Table 6. As in the Table 6, the temperature differences between average outside surface temperature and average outside air temperature are not greatly affected by the shape of connection part. The temperature difference between average outside surface temperature and average outside air temperature at the FP type sandwich panel is higher than that of EP type sandwich panel.

Table 6 Temperature difference between average outside surface temperature and average outside air temperature

	Average surface temperature (℃)	Average outside temperature (℃)	Temperature difference (℃)
	(a) Panel size 190 mm × 1,000 mm		
EP1-1	38.3	28.5	9.8
EP1-2	38.2	28.5	9.7
FP1-1	40.6	28.9	11.7
	(b) Panel size 290 mm × 1,000 mm		
EP2-1	40.7	28.5	12.2
EP2-2	40.4	28.5	11.9
FP2-1	43.7	28.9	14.8
	(c) Panel size 490 mm × 1,000 mm		
EP3-1	38.1	28.5	9.6
EP3-2	40.7	28.5	12.2
FP3-1	43.4	28.9	14.5

3.2.4 Temperature difference between average outside air temperature and average temperature at the 0.5 mm below copper plate

Temperature differences between average outside air temperature and average temperature at the 0.5 mm below copper plate are in the Table 7. As in the Table 7, the temperature difference between average outside air temperature and average temperature at the 0.5 mm below copper plate at the FP type sandwich panel is higher than that of EP type sandwich panel.

3.2.5 Temperature difference between average surface temperature and average temperature at the 0.5 mm below copper plate

The temperature differences between average

Table 7 Temperature difference between average outside air temperature and average temperature at the 0.5 mm below copper plate

	Average measured temperature (℃)	Average outside temperature (℃)	Temperature difference (℃)
	(a) Panel size 190 mm × 1,000 mm		
EP1-1	36.7	28.5	8.2
EP1-2	37.7	28.5	9.2
FP1-1	38.8	28.9	9.9
	(b) Panel size 290 mm × 1,000 mm		
EP2-1	40.0	28.5	11.5
EP2-2	39.2	28.5	10.7
FP2-1	41.5	28.9	12.6
	(c) Panel size 490 mm × 1,000 mm		
EP3-1	39.3	28.5	10.8
EP3-2	37.8	28.5	9.3
FP3-1	41.0	28.9	12.1

Table 8 Temperature difference between average surface temperature and average temperature at the 0.5 mm below copper plate

	Average surface temperature (℃)	Average measured temperature (℃)	Temperature difference (℃)
EP1-1	38.3	36.7	1.6
EP1-2	38.2	37.7	0.5
FP1-1	40.6	38.8	1.8
EP2-1	40.7	40.0	0.7
EP2-2	40.4	39.2	1.2
FP2-1	43.7	41.5	2.2

surface temperature and average temperature at the 0.5 mm below copper plate are in the Table 8. As in the Table 8, the temperature difference between average surface temperature and average temperature at the 0.5 mm below copper plate at the FP type sandwich panel is higher than that of EP type sandwich panel.

3.2.6 Heat transfer rate between panel surface and 0.5 mm below copper plate[2,3,4,5]

Using average surface temperature, average temperature at 0.5 mm below copper plate, and one dimensional heat transfer equation, the heat transfer rate between panel surface and 0.5 mm below copper plate can be analyzed.

Fourier law, $q = -kAdT/dx$ are used. Thermal conductivity of copper, k is 385.0 w/m · ℃, and thermal conductivity of air, k is 0.024 w/m · ℃.

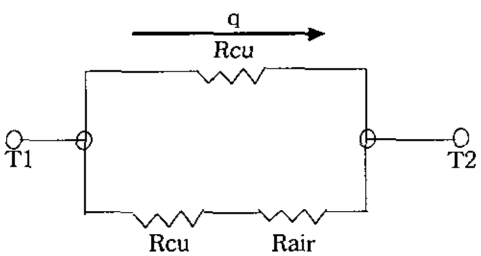
The depth of copper plate is 0.0005 m, and the depth of air inside of the EP type panel is 0.0005 m. The copper plate areas of the EP1-1, EP1-2, EP2-1, EP2-2, FP1-1, and FP2-1 are 0.19 m^2, 0.19 m^2, 0.29 m^2, 0.29 m^2, 0.19 m^2, and 0.29 m^2, respectively. The air passway areas of the EP1-1, EP1-2, EP2-1, and EP2-2 are 0.06 m^2, 0.04 m^2, and 0.08 m^2, respectively. The temperature differences between average surface temperature and average temperature at the 0.5 mm below copper plate are in the Table 8. One dimensional heat flow electrical analogs through EP type panel (a) and FP type panel (b) are in the Figure 7.

In the Figure 7, the effective resistance of embossing sandwich panel (a)

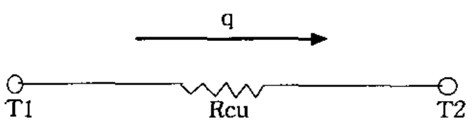
$$Reff = \frac{1}{\frac{1}{Rcu} + \frac{1}{Rcu + Rair}},$$

and the effective resistance of flat surface sandwich panel (b), $Reff = Rcu$. Heat transfer rate, $q = \frac{\Delta T}{Reff}$. The heat transfer rate between panel surface of EP type panel and FP type panel and 0.5 mm below copper plate are in the Table 9.

Average heat transfer rate at the FP type panel is higher than average heat transfer rate at the EP type panel. This is because thermal



(a) Embossing surface sandwich panel



(b) Flat surface sandwich panel

Fig. 7 Electrical analog.

Table 9 Heat transfer rate between panel surface and 0.5 mm below copper plate

	Heat transfer rate (w)		Heat transfer rate (w)
EP1	153,615.0	EP2	212,135.0
FP1-1	263,340.0	FP2-1	491,260.0

conductivity of the copper is higher than that of the air.

4. Conclusions

The aim of this research was to examine the thermal performance of embossing surface sandwich panel. Three kinds of embossing surface sandwich panel and one kind of flat surface sandwich panel were used to examine the thermal performance. Using the results of these research, new kinds of sandwich panel that have excellent thermal ability and economical aspect could be developed.

The thermal performance of the developed embossing surface sandwich panel can be summarized as follows.

(1) The average surface temperature difference is not affected by the shape of connection part of sandwich panel. Additionally, average outside surface temperature at the FP type sandwich panel is higher than that of EP type sandwich panel.

(2) The average temperature at the 0.5 mm below copper plate located at the FP type sandwich panel is higher than that of EP type sandwich panel.

(3) The temperature differences between average outside surface temperature and average outside air temperature are not greatly affected by the shape of connection part. The temperature difference between average outside surface temperature and average outside air temperature at the FP type sandwich panel is higher than that of EP type sandwich panel.

(4) The temperature difference between average outside air temperature and average temperature at the 0.5 mm below copper plate at the FP type sandwich panel is higher than that of EP type sandwich panel.

(5) The temperature difference between average surface temperature and average temperature at the 0.5 mm below copper plate at the FP type sandwich panel is higher than that of EP type sandwich panel.

(6) The average heat transfer rate at the FP type panel is higher than average heat transfer rate at the EP type panel. This is because thermal conductivity of the copper is higher than that of the air.

The average heat transfer rate at the flat surface sandwich panel is higher than that of embossing surface sandwich panel. More study will be needed about the size of diameter and diameter and height of embossing, and materials of embossing surface sandwich panel.

Acknowledgements

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References

1. Son, C. S., 1999, Development of Sandwich panel in roof and wall, Consortium final report, Keimyung Unverssity, pp. 31-74.
2. Eugene, H., 1996, Physics: Calculus, Brooks/Cole Publishing Company, California, pp. 585-591.
3. Stein, B., Reynolds, J. S. and McGuinness, W. J., 1992, Mechanical and Electrical Equipment for Buildings, 8th ed, John Wiley & Sons, New York, pp. 115-125.
4. McQuiston, F. C. and Parker, J. D., 1988, Heating, Ventilating, and Air Conditioning, 3rd ed., John Wiley & Sons, New York, pp. 131-172.
5. Holman, J. P., 1986, Heat Transfer, 6th ed., McGraw-Hill Book Company, New York, pp. 27-42.