Effect of external shading device materials on air temperature of perimeter zones of commercial buildings with glazed facades

Fariha Seraj

Abstract— Commercial buildings of Dhaka city are characterized by excessive use of glazing. The glass surfaces create indoor thermal discomfort by increasing solar gain and the consequence is extensive use of air conditioning systems. It requires high energy demand and use of natural resources to satisfy comfort requirements. Shading device as a major element of building fenestration plays a significant role to reduce the solar heat gain. Among the variables of shading design, e.g. height, width, depth, material, material is less considered or considered for aesthetic rather than a key variable to control indoor air temperature. To reduce the cooling and lighting energy demand, effective shading design is necessary. The purpose of this study is to evaluate the performance of external shading device types and materials on controlling indoor air temperature. The three dimensional model of the two case spaces were created in Autodesk Ecotect Analysis 2011 to perform simulation. Indoor air temperature and the surface temperature of the shading devices for south and west oriented facades were observed for different shading typology and materials by simulation. Results show the relationship between orientation, typology and material. Most efficient shading devices are- horizontal louvers on horizontal plane and egg crate for south and west façade respectively. It was also found that the material with high thermal mass performs better than the low thermal mass materials.

Index Terms— Air temperature, Commercial building, External shading devices, Perimeter Zone, Shading materials.

1 Introduction

Skin and skeleton technology allows building with large glazing area which offers transparency, daylight in the visual environment as well as increase the amount of solar heat gain. These vertical surfaces of glass also act as heat trap. The thermal effect of these glass facades depends on the shading provided and spectral properties of glass [1]. Use of shading devices can ensure thermal comfort and reduce the cooling load by decreasing the amount of solar heat gain. Thermal benefits of shading devices are observed in many researches and its use is highly recommended [2], [3]. Baklah, Ismail and Rahman [4] found that indoor air temperature remain lower than the outdoor from 9am to 9pm by using a shading device while the time duration is 9am to 6pm in case of no shading device. This may be happen because of the direct exposure to solar radiation and the influence of heat transfer through external building envelop and the effect of delay time.

Spaces near the glazing area or the perimeter zones are critical area in case of ensuring thermal comfort for the occupants. It receives both the direct solar radiation from the sun and the inward heat flow from the absorbed solar radiation of the fenestration elements. Perimeter zones experience the largest fluctuations in temperature and human comfort. In case of both summer and winter, higher temperature difference between indoor air and glass surface create discomfort due to radiant temperature asymmetry and increased (summer) and decreased (winter) operative temperature [5]. Effective use of external shading devices can improve thermal comfort conditions in perimeter zones.

Most common studies on shading devices are limited to the orientation, configuration or geometry. Experiment related to thermal properties and surface properties of the exterior shading device is rare. The objectives of this study is to investigate the thermal performance of different fixed external shading devices with commonly used materials in Dhaka during the last ten years and find the relation between orientation, typology and material.

2 Climate Of Dhaka

Based on Koenigsberger's climate classification of tropical climate, Bangladesh has a warm humid climate. Dhaka, the capital of Bangladesh lies between 23°40′N and 23°55′N north latitudes and 90°20′E 90°30′E east longitudes. There are three distinct seasons in Bangladesh: a hot, humid summer (March to June); a humid warm rainy monsoon season (June to October); and a cool, dry winter (October to March). In Dhaka, maximum summer temperatures are observed during the hot- humid season and it ranges from 30°c to 40°c. April is observed as the hottest month of hot- humid season [6].

3 Perimeter Zone

Perimeter zone is the spaces near the facades of a building. Depth of the perimeter zone is defined as 2700 mm from the maximum width of a workstation including secondary circulation space and an office cubicle.

• *Author Fariha Seraj is currently pursuing masters degree program in Architecture in Bangladesh University of Engineering & Technology, Bangladesh, PH-01717559593. She is also a lecturer in Architecture Department at Dhaka University of Engineering & Technology, Gazipur, Bangladesh. E-mail: fariha.seraj@gmail.com*

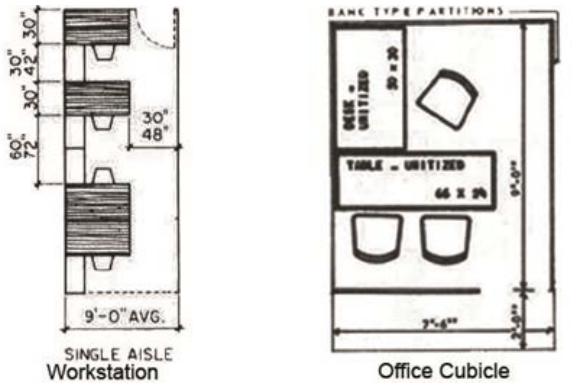


Fig. 1. Space Standards for Office cubicle & Work Station [7]

4 External Shading Devices- Typology & Materials

Shading devices can be divided into two broad categories- interior and exterior. Exterior shading devices are 30- 35% more effective than interior shading devices [8]. Shading devices are broadly classified into three categories based on its integration with the window. They are: retractable or removal, movable or adjustable and fixed shading device [9]. Fixed shading devices are of three types based on their physical forms.They are horizontal shading device, vertical shading device and combination of the two (eggcrate) [10].

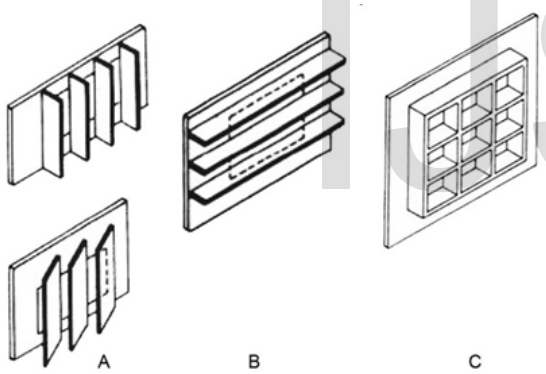


Fig. 2. Types of External Shading Device- A. Vertical, B- Horizontal, C- Eggcrate [10]

Orientation, typology, physical dimensions, materials are variables for designing an exterior shading device. Indoor thermal environment and occupants comfort depend on these variables of exterior shading design. Gutierrez, G. C. R and Labaki, L. C [11] conducted experiments to find relation between orientation, typology and material of external shading device. Among concrete and wood, concrete presents the best performance as it has high thermal mass. Concrete with its high thermal mass and capacitance absorb and retain short-wave solar radiation during the day and released the stored heat to the atmosphere and its immediate surroundings later in the day as long-wave radiation. The study only focus on concrete and wood, but other frequently used exterior shading device materials e.g. brick, aluminium should be tested.

5 Methodology

South and west oriented facades are more critical than the others in terms of solar gain. One south and one west oriented fully glazed facades with no obstruction are taken as study element. Indoor air temperature and surface temperature of the shading devices are measured for different combination of shading device typology and materials during hot- dry and warm- humid season.

The field survey was conducted to investigate the material and construction details. 3D model of the two study spaces are created in Autodesk Ecotect Analysis 2011. Whole day simulations were conducted for two months: April (Hot- Dry) and June (Warm- Humid). The range of indoor air temperature and surface temperature of the shading device were measured from the simulation. The thermal performance of the different shading devices and materials were compared for two randomly selected days: 17th April and 23rd June. The best possible combination of shading device typology and its material is chosen by comparing the models.

6 Simulation Study

Both the buildings have been selected for getting optimum solar exposure without any obstruction throughout the day. Both the buildings have blue tinted glazed facades with different shading devices and materials. Horizontal louvers, vertical fins, horizontal louvers on horizontal plane, egg crate; made of concrete and aluminium composite panels (ACP) were tested on the study spaces.

6.1 Simulation Material Specifications

In engineering and architectural analysis of materials, thermal property is an important material property. Chowdhury. S 2014 [12] in his study measured and compared the thermal properties of different building envelope materials with other standards. Material properties that were set before the Ecotect simulation are listed below in Table- 1.

TABLE 1
PROPERTIES OF MATERIALS FOR SIMULATION

Materials	Thickness (m)	Conductivity (W/m- K)	Density (kg/m3)	Specific Heat (J/ kg-K)
R. C. C	0.1016	1.34	2487.667	669.44
1st Class Brick	0.127	0.48	1690.108	1338.88
6mm Standard Glass	0.006	0.9	2300	836
Plaster	0.0063	0.43	2374.417	753.12
Aluminium	0.006	0.15	1370	879.23
Air (For Air Gap between Al Panels)	0.15	5.56	1.3	1004

6.2 Simulation of Case Space-1

Case space- 1(Fig. 3) is the 10th floor of NCC Bank Building at Toyenbee Circular Road, Motijheel, Dhaka. The perimeter zone of an office room of the South- east corner has been selected for simulation study as there was no obstruction on both south and east side. The overhang is 750mm and there are 2slats of ACP (Aluminium Composite Panel) with air gap at 1050mm interval.

Simulation has been done for three types of shading devices and two types of materials. Indoor air temperature of the test zone and the shading device temperature were measured for the month of April and June. From the simulation it is clear that the material properties play a significant role on the indoor air temperature as well as the shading device temperature. The findings from the experiments are listed in Table- 2.

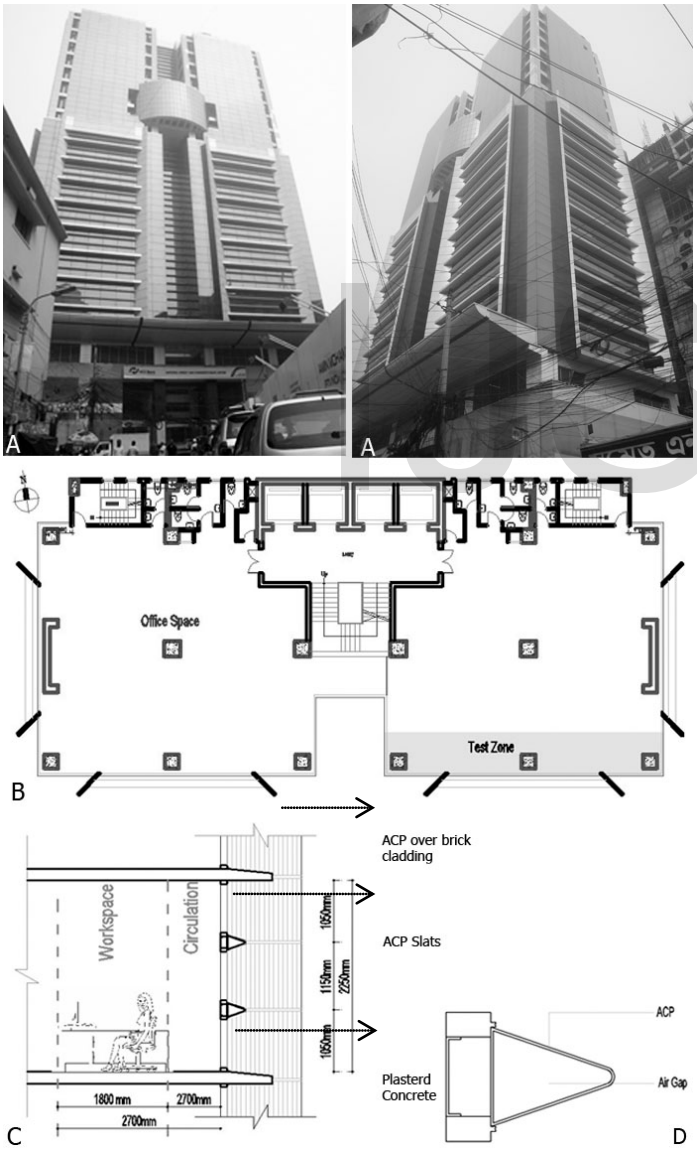


Fig. 3. Case Space- 1; A- Exterior view of Case Space-1, B- Plan of the space (10th Floor), C-Section of Test Zone, D- Section of the Shading Device (ACP Slats).

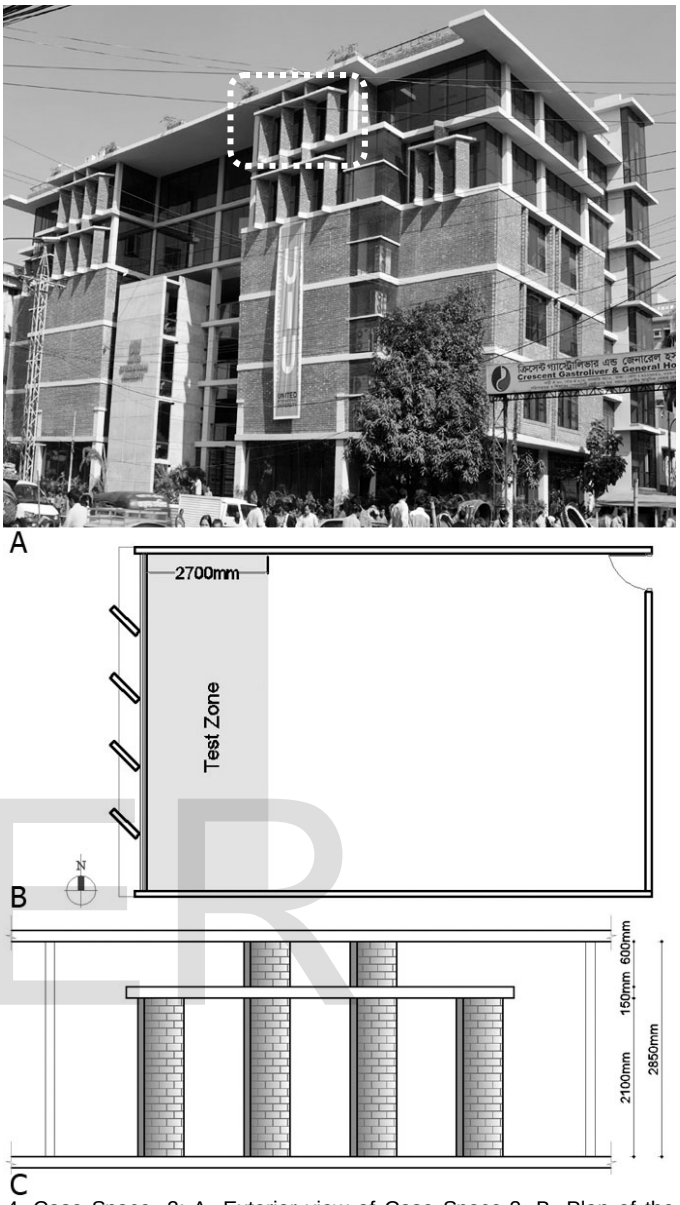


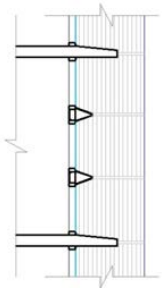
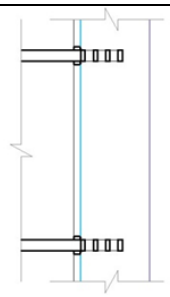
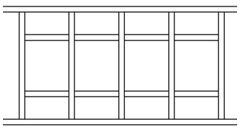
Fig.4. Case Space- 2; A- Exterior view of Case Space-2, B- Plan of the space (6th Floor), C- Elevation of Test Zone.

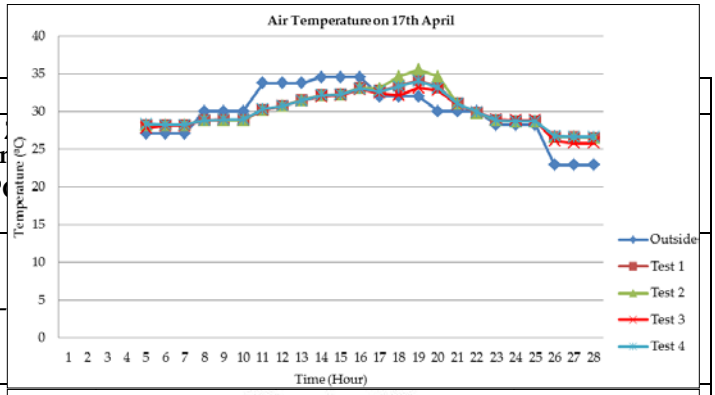
6.3 Simulation of Case Space-2

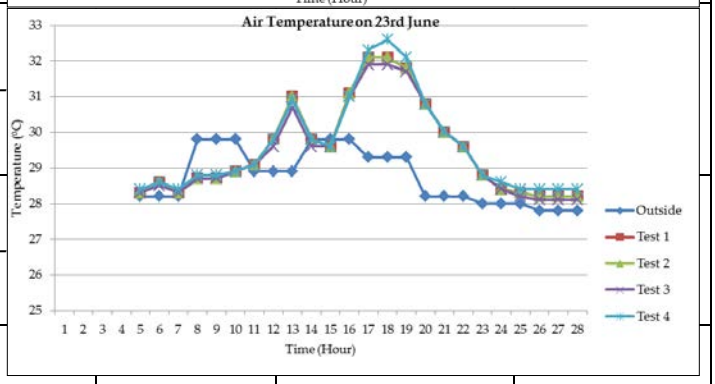
Case space- 2 (Fig. 4) is the 5th floor of UIU's (United International University) Building at Satmasjid Road, Dhaka. The perimeter zone of an office room of the South- west corner has been selected for simulation study as there was no obstruction on west side. The overhang is 450mm and there are vertical fins of 750mm width placed at 45**°** angle. The vertical fins are of exposed bricks.

Simulation has been done for two types of shading devices and three types of materials. Indoor air temperature of the test zone and the shading device temperature were measured for the month of April and June. The findings from the experiments are listed in Table- 3.

TABLE 2
SUMMARY OF EXPERIMENTAL RESULT FOR MONTH OF APRIL & JUNE

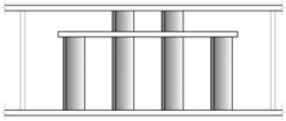
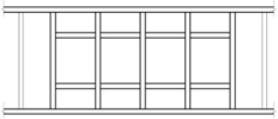
Shading Device Typology & Material		Test Zone Temp. (°C)			
	Test 1: Horizontal with 2slats in middle (Aluminium)	25.8-			
	Test 2: Horizontal with 2slats in middle (Concrete)	24.9-			
	Test 3: Horizontal Louvers in Horizontal Plane (Concrete)	20.6-			
	Test 4: Horizontal Louvers in Horizontal Plane (Aluminium)	41.6- 22.8	25.3- 35.2	24.1- 42.6	28.4- 30.7
	Test 5: Egg crate (Aluminium)	21.5- 35.4	23.5- 34.8	22.2- 34.6	28.1- 31.7
	Test 6: Egg crate (Concrete)	20.7- 35.2	29.3- 34.5	22.8- 34.6	29.1- 30.5





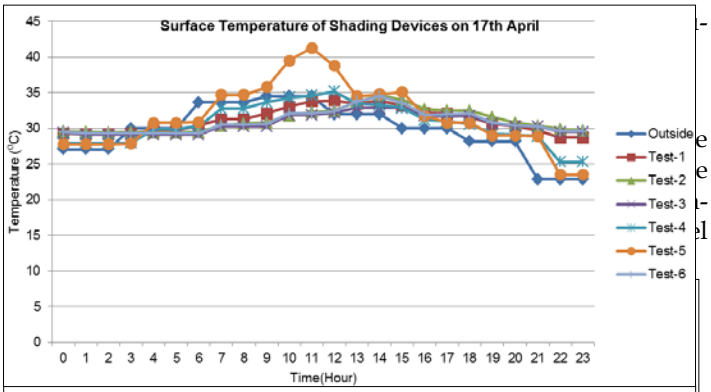
(CASE SPACE-1)

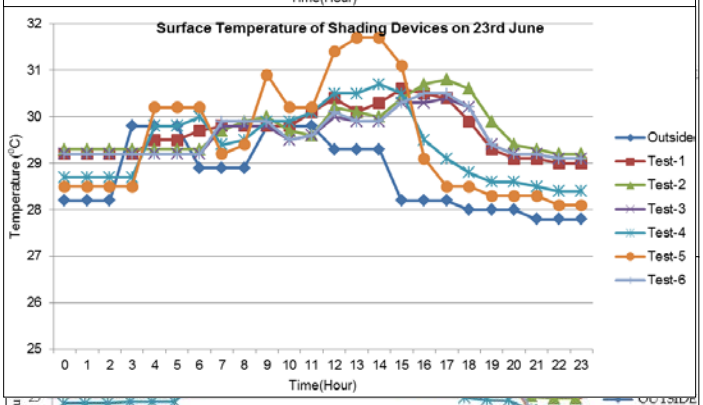
TABLE 3
SUMMARY OF EXPERIMENTAL RESULT FOR MONTH OF APRIL & JUNE (CASE SPACE-2)

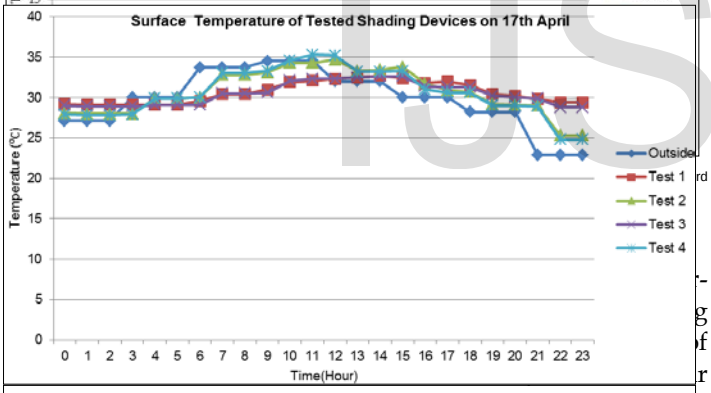
Shading Device Typology & Material		April		June	
		Test Zone Temp. (°C)	Shading Device Temp. (°C)	Test Zone Temp. (°C)	Shading Device Temp. (°C)
	Test 1: Vertical Fins (Exposed Brick)	26.5- 34.1	29.1- 32.7	28.2- 32.1	29- 30.3
	Test 2: Vertical Fins (ACP)	26.5- 35.5	25.3- 34.7	28.2- 32.1	28.4- 30.6
	Test 3: Egg Crate (Concrete)	25.8- 33.1	28.8- 32.6	28.1- 31.9	28.9- 30
	Test 4: Egg crate (ACP)	26.6- 34	24.8- 34.6	28.4- 32.6	28.2- 30.4

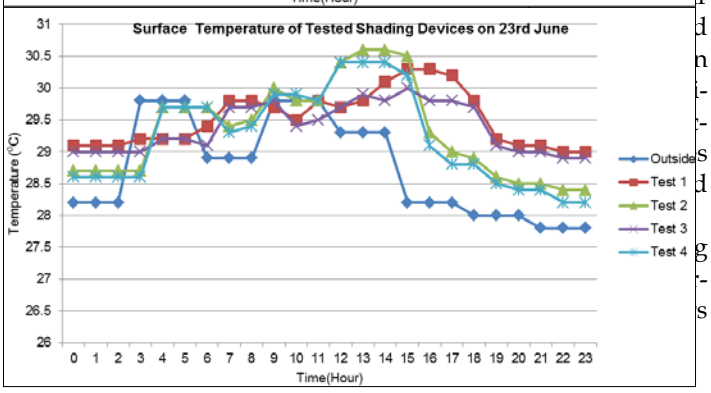
7 RESULTS

Graphs (Figure 5- 8) show the results for the experimental devices on South and West façade of the N.C.C Bank building (Case-1) and UIU Building (Case-2) respectively, for randomly









for its thermal properties.

Fig.6. Outside & inside air temperature for west façade on 17th April & 23rd June

7.2 Results for Surface Temperature of Shading Devices

Orientation, typology and material property has influence on the surface temperature of the shading devices. Among the two types of materials concrete performs better than the other type- ACP.

Results show that, for the south orientation (Fig.7), the horizontal louvers in horizontal plane and egg crate with concrete performs better than the other combination of devices and materials. Performances of these two devices are almost similar, but the former give smoother curve during 12pm- 3pm in April and 3pm- 6pm in June than the other. Performance of the horizontal louvers in horizontal plane with ACP is the worst because of its low conductivity. It gives two picks in April and three picks in June along the day.

In case of west oriented façade (Fig.8), performance of the egg crate device with concrete shows the best performance. It gives the smoother curve along the day in both hot- dry and warm- humid period than the others. Although vertical fins and egg crate with ACP give the lowest temperature in night the egg crate with concrete gives lower temperature in the occupancy period (9am to 5pm).

8 Discussion

The most efficient shading devices in terms of thermal performance are horizontal louvers on horizontal plane with concrete for south façade and egg crate with concrete for west façade among the tested devices in this experiment. The performances of the devices with ACP are worse because of the thermal properties of ACP.

Fig.7. Surface temperature of shading devices for south façade on 17th April & 23rd June

Fig.8. Surface temperature of shading devices for west façade on 17th April & 23rd June

The experiment only considers the effects of the devices on indoor air temperature but the other variables of thermal comfort- air flow, humidity can also be influenced by different shading devices. Other factors- air flow, humidity and also energy consumption can be studied for different fixed and operable external and also internal shading devices. Parametric studies can be done to obtain design guidelines for dimensions and shading mask.

9 Conclusion

The experiments show the relationship between orientation, typology and materials of the tested devices. It is clear that different kinds of devices with different materials but same shading mask do not perform equally. The most efficient performance was obtained by concrete because of its thermal mass. The materials with high thermal mass and conductivity performs better than the low conductivity material.

Acknowledgment

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