ISSN: 1999-1630

SEU Journal of Science and Engineering, Vol. 13, No. 2, December 2019

The Influence of Orientation, Opening, and Shading Devices on the Thermal Performance of Classrooms in the Warm-Humid Climate

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Abstract
Building orientation may be a significant design consideration, mainly concerning solar radiation and wind. In predominantly warm humid regions like Bangladesh which receives sunlight all year round, buildings should be oriented to minimize solar gain and maximize natural ventilation. This paper describes an investigation into the effect of classroom orientation because of solar radiation absorptance of the exterior wall and the effect of shading device with openings on the thermal performance for classrooms in the tropical region. Three classrooms were selected from Southeast University permanent campus located at Tejgaon, one facing the west and the other two facing the south direction. The differences between in/outdoor air temperature and humidity of both rooms were measured from the field directly using the 'Thermo Hygrometer'. This data have been analyzed and investigated. The results show that west windows have a more obvious effect on increasing indoor air temperature than north/south windows despite having shading devices and thus it will be helpful research for planning classrooms with proper orientation in the same site.

Keywords: *Classroom, Opening, Orientation, Shading Device*

I. Introduction

Architecturally, the warm and humid region is one of the hardest climates to ameliorate through design. This is due to the high humidity and daytime temperatures that result in high indoor temperatures. The openings need protection against overheating and sun glare in a tropical region, especially when it faces east or west direction. In Bangladesh, for example, the east and west façade is exposed to direct sun radiation every morning and evening, and the south façade is exposed to the sun during midday thus this façade also gains much heat during day time. Therefore building orientation, particularly in the tropical region should be seriously considered according to its interaction with solar radiation as well as wind direction. In warm humid regions, the provision of effective cross ventilation under the local wind direction is the major factor that may affect the building orientation. Air movements inside a building depend not only on external wind velocity but also largely on the architectural parameters. Architectural means for achieving this aim include conventional design elements such as position and orientation of the building, roof shape, balcony/veranda configuration, type and location of windows, partition, and furniture arrangement.

II. Aim and Objectives

To ensure maximum comfort in classrooms without artificial measures, in terms of temperature and humidity

III. Objectives

To explore and compare the differences in indoor and outdoor temperature and humidity between classrooms in different orientations and with or without shading device and cross-ventilation.

IV. Methodology and Description of the Case Study

The method used in this study is experimental and quantitative. It focuses to study the influences of orientation, natural ventilation, and the use of shading devices on indoor environmental performance. Three classrooms were selected from Southeast University's permanent campus, located at Tejgaon. The campus has two buildings (buildings 1-2, shown in Figures 1-2 respectively).

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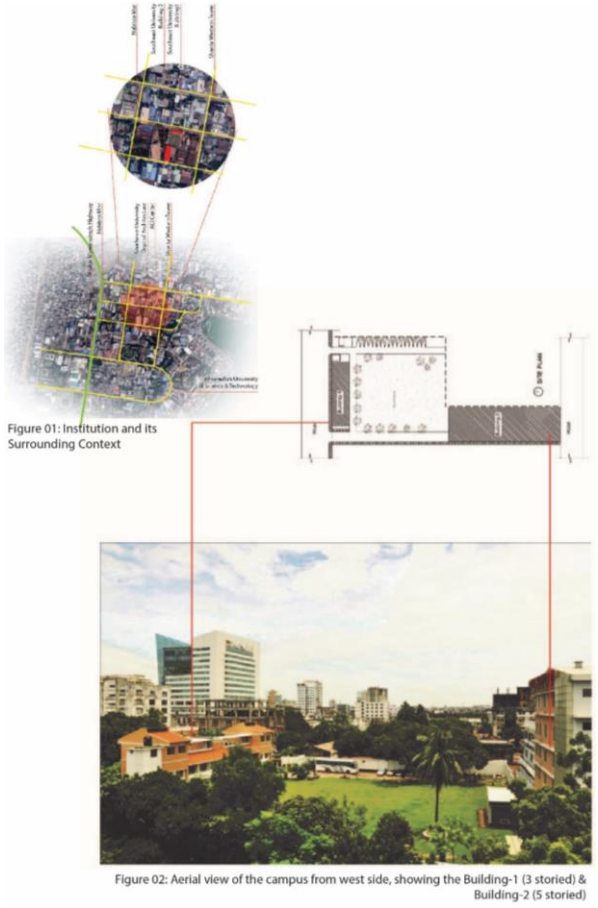

Figures 1 and 2: Institution and it's surrounding context (figure.1), Aerial view of the campus from the west, showing building 1 and building 2 (figure.2)

The classrooms fall into three categories. They are discussed below:

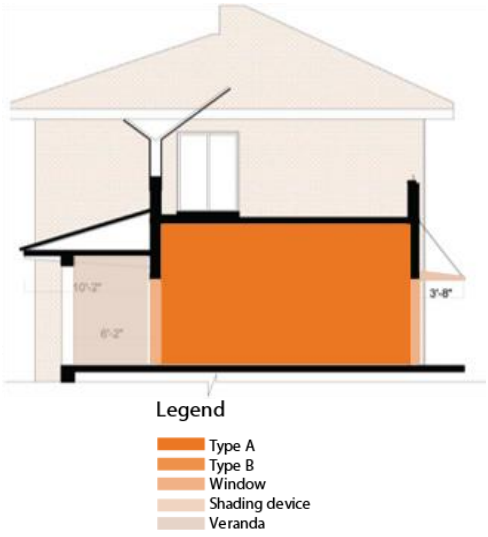

Figure 3: Section of Type 'A' Classroom

Building 1: Type A: With Veranda, With Cross-Ventilation (South facing having single-loaded corridor).

Building 1, consists of two stories, the type A and B classrooms were chosen were on the first floor and no effects of outdoor shading like trees were found, both facing South orientation.

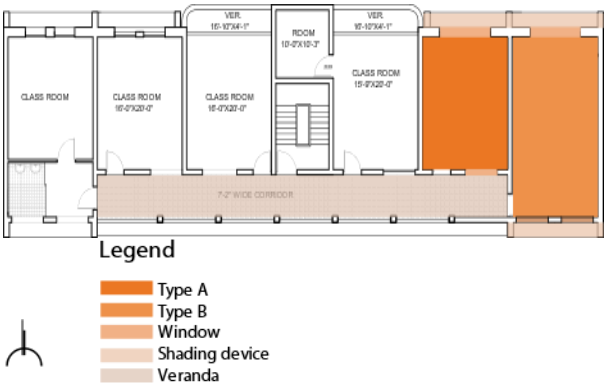

Figure 4: 1st Floor Plan of Building 1

Figure 5: Building 1 (View from South)

Building 1: Type B: Without Veranda, with Shading and with Cross-ventilation (South facing having single-loaded corridor)

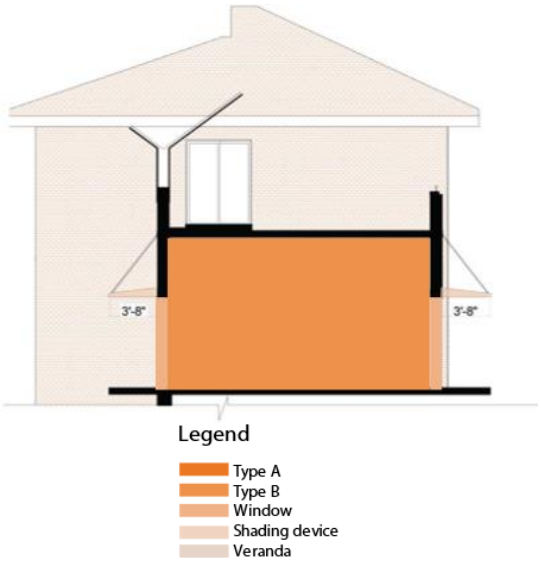

Figure 6: Section of Type 'B' Classroom

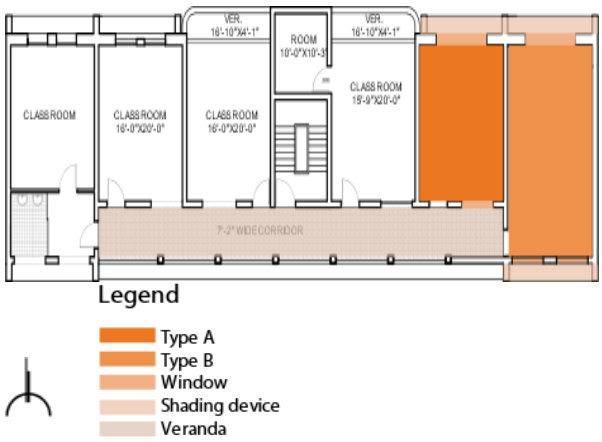

Figure 7: 1st Floor Plan of Building 1

Figure 8: Interior of Type 'B' and Type 'A' Classroom (From left to right)

Though the façade at the south orientation is heated almost all day, for the summer breeze this façade needs to get openings with shading. Building 1 is oriented in such a way that openings have mainly been exposed to the north and south directions.

Building 2: Type C: Without Veranda, with Shading, without cross-ventilation (West facing having double-loaded corridor).

Figure 9: Interior of Type 'C' Classroom

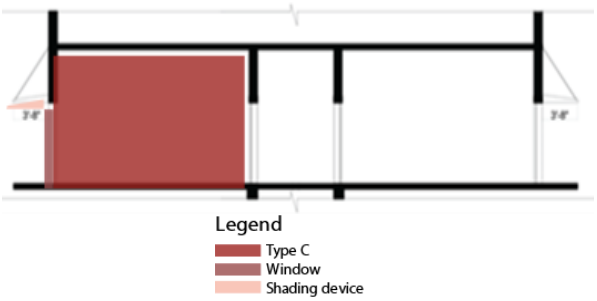

Figure 10: Section of Type 'C' Classroom

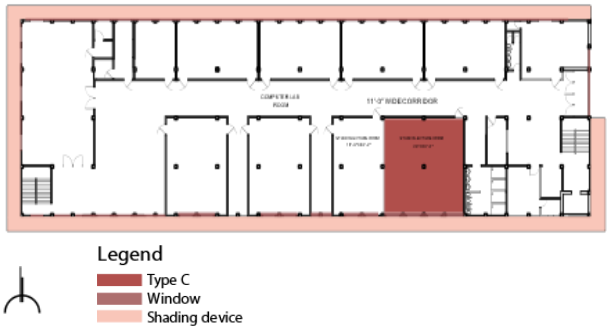

Figure 11: 4th t Floor Plan of Building 2

The 3rd classroom in Building 2 was facing West orientation as the typical worst-case orientation scenario in the tropics in terms of direct solar radiation in the afternoon hours. Building 2 is oriented in such a way that openings have mainly been exposed to the east and west directions.

V. Collection of Data

The data was collected with the help of students who collected data using the 'Thermo hygrometer', starting from 10:00 am to 5:00 pm (class hour) at 8 instances. At each instance, three readings were taken and the average reading is considered.

Building 1: Type A: With Veranda, With Cross-Ventilation (South facing having single-loaded corridor).

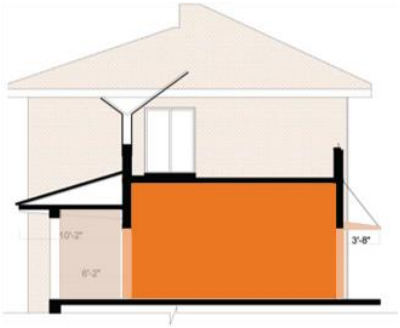

Table 1: Temperature and Relative Humidity Profile for Type 'A' classroom in Building 1

Time	Indoor				Outdoor			
	Temperature (°C)		Relative Humidity (%)		Temperature (°C)		Relative Humidity (%)	
	Reading	Avg.	Reading	Avg.	Reading	Avg.	Reading	Avg.
10:00 am	30	30.6	78	80	29	32	84	85
	30.9		82		28.8		85	
	31		80		29		86	
11:00 am	30.1	30	78	78.6	29	31	81	82
	30		78		30.1		82	
	29.9		80		30		83	
12:00 pm	23.2	24.3	65	65.3	30	31	66	66
	24.8		64		30		67	
	25.0		67		30.1		65	
01:00 pm	28.2	28.2	66	66.5	31	32	69	68
	28.1		67		31		68	
	28.3		66		31		67	
02:00 pm	28.3	28.4	72	60	31	31.8	71	70
	28.5		71		30.8		69	
	28.6		72		30.8		70	
03:00 pm	29.9	30.06	76	72	31.8	33	74	74
	30.1		75		31.8		74	
	30.2		75		31.5		74	
04:00 pm	25.8	25.9	84	84.5	31.8	33	85	86
	25.9		85		31.5		86	
	26.1		84		31.5		87	
05:00 pm	28	28.4	76	77	30	32	85	85
	29.2		78		30.5		84	
	28		76		30		86	

Building 1: Type B: Without Veranda, with Shading and with Cross-Ventilation (South facing having single-loaded corridor).

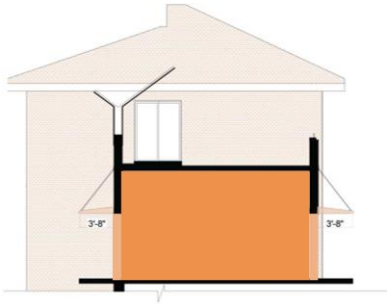

Table 2: Temperature and Relative Humidity Profile for Type 'B' classroom in Building 1

Time	Indoor				Outdoor			
	Temperature (°C)		Relative Humidity (%)		Temperature (°C)		Relative Humidity (%)	
	Reading	Avg.	Reading	Avg.	Reading	Avg.	Reading	Avg.
10:00 am	31.4	31.45	74	74.5	29	28	81	80
	31.5		75		28.8		80	
	31.5		75		29		79	
11:00 am	31.8	31.8	76	72	29	30	74	75
	31.9		74		30.1		75	
	31.7		74		30		76	
12:00 pm	29.2	29.7	84	70	30	30	77	78
	29.5		85		30		78	
	29.8		86		30.1		79	
01:00 pm	30.1	30.7	53	65	31	31	67	68
	30.5		55		31		68	
	30.9		54		31		69	
02:00 pm	30.3	30.4	56	75	31	30.9	70	70
	30.4		55		30.8		69	
	30.5		54		30.8		71	
03:00 pm	31	31.1	71	80	31.8	31.7	75	76
	31.1		70		31.8		77	
	31.2		71		31.5		76	
04:00 pm	28.7	28.5	78	85	31.8	31.7	81	80
	28		76		31.5		80	
	27.4		78		31.5		79	
05:00 pm	30.2	30.3	74	74.5	30	30.3	73	74
	30.4		75		30.5		74	
	30.4		74		30		75	

Building 2: Type C: Without Veranda, With Shading and without Cross-Ventilation (West facing having double-loaded corridor)

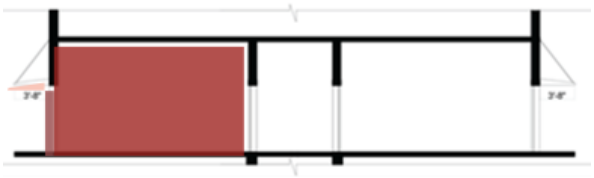

Table 3: Temperature and Relative Humidity Profile for Type 'C' classroom in Building 2

Time	Indoor				Outdoor			
	Temperature (°C)		Relative Humidity (%)		Temperature (°C)		Relative Humidity (%)	
	Reading	Avg.	Reading	Avg.	Reading	Avg.	Reading	Avg.
10:00 am	27.5	27.7	66	68	30	29.5	75	75
	27.9		70		29		77	
	27.6		68		29		76	
11:00 am	26.9	27.1	70	71	30	30	75	75
	27		70		30.1		75	
	27.6		72		30		75	

12:00 pm	25	30	72	73	30.5	30.3	80	80
	26		74		30		79	
	26.9		74		30.1		81	
01:00 pm	25	32	66	70	32	31.7	69	70
	25		66		31.8		70	
	25		65		31.5		71	
02:00 pm	27	32.5	57	75	31	31.8	70	70
	27.8		56		31		70	
	27		57		31.8		70	
03:00 pm	28.7	34	68	70	31.8	32	63	62
	28		68		31.5		61	
	29		68		31.5		62	
04:00 pm	30.4	33	72	70	31	31.3	78	78
	30.6		69		31		79	
	30.9		68		31.5		77	
05:00 pm	31.1	31.3	70	71	31	30.9	73	74
	31		70		30.9		74	
	30.9		72		30.8		75	

VI. Observation

Comparison of collected data

Temperature and humidity of indoor and outdoor were plotted in time vs. temperature and time vs. humidity graph. These graphs helped to compare the changes between the indoor and outdoor temperature and humidity.

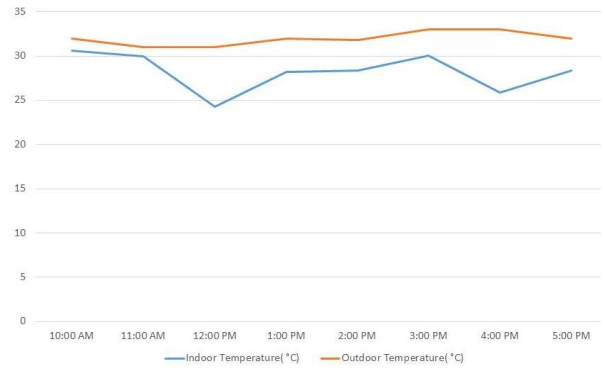

Figure 12: Type A Classroom, Indoor – Outdoor Temperature Comparison

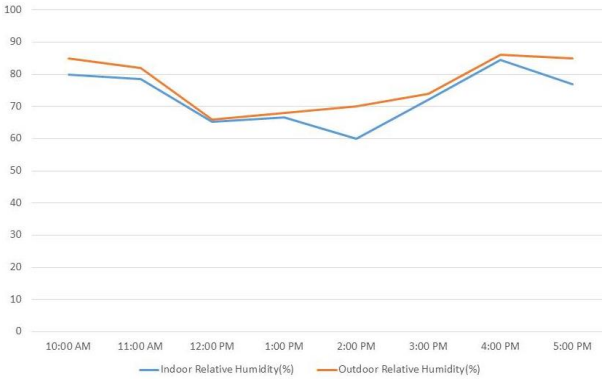

Figure 13: Type A Classroom, Indoor – Outdoor Humidity Comparison

From figure 12, for Building 1: Type A: With Veranda, with cross-ventilation (south-facing having single-loaded corridor). We find that the indoor temperature is reasonably lesser than the outdoor temperature from 10 am to 5 pm (class hour) and there is no intersection of temperatures in the graph (figure 12).

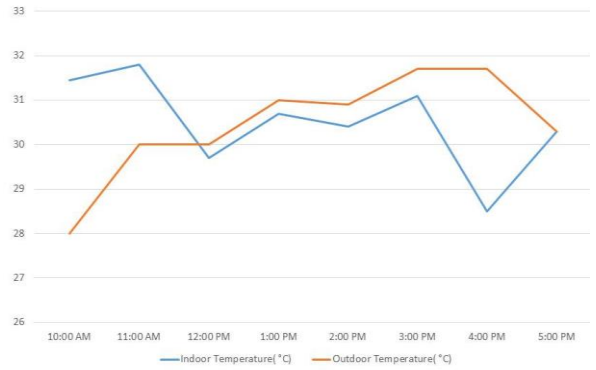

Figure 14*:* Type B Classroom, Indoor – Outdoor Temperature Comparison

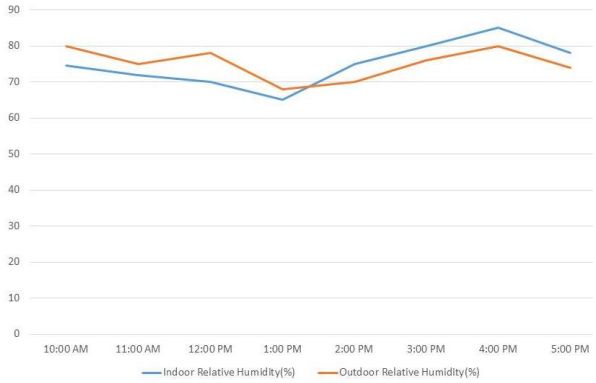

Figure 15*:* Type B Classroom, Indoor – Outdoor Humidity Comparison

From figure 14, Building 1: Type B: Without Veranda, With Shading and With Cross-Ventilation (South facing having single-loaded corridor). We find that the indoor temperature is reasonably higher than the outdoor temperature before mid-day. The lines intersect at noon and the temperature gradually falls but at 5 pm the lines intersect again.

From figure 16, Building 2: Type C: Without Veranda, with Shading, without cross-ventilation (West facing having double-loaded corridor). We find that, before noon, the indoor temperature is lesser than the outdoor temperature. The lines intersect in between at 12 pm-1 pm and then the indoor temperature gradually increases than the

outdoor temperature. At 3 pm, the indoor temperature reaches its highest and then it gradually falls but still, the indoor temperature line in the graph does not fall below the outdoor temperature. At 5 pm it intersects with the line representing outdoor temperature.

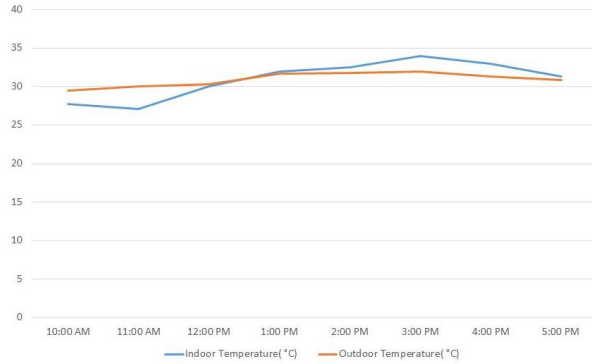

Figure 16: Type C Classroom, Indoor – Outdoor Temperature Comparison

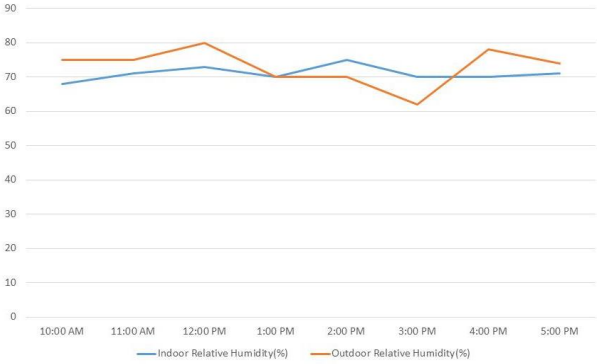

Figure 17: Type C Classroom, Indoor – Outdoor Humidity Comparison

From figures 13, 15, and 17, we find that type 'A' classroom has less indoor relative humidity than outdoor relative humidity. Type 'B' classroom has less indoor humidity too but between 1 pm-2 pm the line intersects and the indoor relative humidity starts increasing and at 5 pm still the graph shows the indoor relative humidity is relatively higher than outdoor relative humidity. Type 'C' classroom has less humidity before 1 pm but later the humidity increases and again drops at 4 pm.

VII. Conclusion

The main findings of this paper are summarized as follows:

West orientation is more sensitive to solar radiation. The west rooms are always hotter than those in the south direction, and even by applying a shading device, the average differences in indoor or outdoor air temperature and humidity in west rooms are higher, comparing with the south rooms. Lack of cross ventilation is another reason (Figures 10 and 11).

South oriented room without veranda but with shading device and cross ventilation (Type B) have better performance than Type 'C' classroom. (Figures 6 and 7).

South oriented room with veranda on the south with east-west wall blocked having single-loaded corridor and cross ventilation (Type A) have the best performance than Type 'B' and 'C' classroom (Figure 3 and 4).

More care should be taken in the primary stage of design to avoid any opening in the east or west direction unless there is a need for that. In this case, intensive consideration should be taken like Selecting a proper shading device. The need for applying mechanical ventilation is necessary to improve the occupier's thermal comfort.

References

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