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EVALUATION OF DAYLIGHT PERFORMANCE OF CLASSROOM SPACES IN AHMEDABAD

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Abstract
The study uses building energy simulation tools to analyze the conceptual models representative of existing classroom spaces in Ahmedabad, to study the daylight performance. The existing classroom spaces are documented with field studies, analyzed and the best representative classroom spaces are simulated to check the annual performance.Different dynamic and climate-based daylight metrics are evaluated. The data generated from parametric simulation run are analyzed.The approach is to check how the existing typical classroom space perform when tested in terms of various daylight metrics. Following this approach, we can conclude that from the cases that we tested, one of the case performs the best in terms of daylight factor and daylight autonomy but also faces glare issues. Uniform Daylight Index is the metric that will work best in case of classrooms if in future we wish to evaluate the space or design them as it defines a range of illuminances that can be said to constitute useful levels of illumination, however, the upper and lower limit illuminance values are incorporated, while also fixing compliance intervals integrating the concept of target ranges.

Keywords: Daylight in Schools, Building simulation, Annual performance, Illumination, Daylight performance

1 Introduction

Natural lighting has been the main source of lighting in buildings for centuries until the late nineteenth century when artificial lighting got invented. Also, artificial light was not used widely in buildings during the daytime until the 1950s (Phillips, 2004). During the last quarter of the 20th century, architects and designers have considered the importance of natural lighting within buildings (Brain, 2015). Daylight is the amount of desirable diffuse natural light in a particular space (Ander & FAIA, 2016). Direct sunlight might be too intense and produce glare conditions and excessive heat gain. Daylighting is the practice of using natural light to provide illumination in interior environments. Fifty years ago, practically all schools and workplaces used daylight as the primary illumination source (Heschong & Roger , 2002). Ample and pleasant view out of a window, that includes vegetation or human activity and objects in the far distance, support better outcomes of student learning (Wymelenberg, 2014). Classrooms with the most amount of daylighting are seen to be associated with a 20% to 26% faster learning rate. (Park, 2017).

The study here examines typical classrooms in the municipal buildings at Ahmedabad to determine how they perform in terms of daylight when compared with best practice and what the impact of parametric variation on daylight is. The research would benefit architects and designers who will in future design any classroom space to achieve the specific daylight metric or if they need to evaluate any space to access the daylight performance within the scope of the research.

1.1 Objectives

- To understand how the existing classroom of Ahmedabad performs in terms of daylight.
- To understand the role of daylight design in terms of the performance of the building.
- To understand how different daylight metric helps in analysing daylight performance.

1.2 Scope and limitations

The foremost limitation of the study is that it analyses computer-generated models through the process of virtual simulation techniques. Parametric analysis studies can only be done with the help of computer simulation. Understanding the performance of a building over a year needs annual data that can be easily generated by simulation using the weather file of a place. The space selected for this research is specific to Ahmedabad and all schools which are taken into consideration comes under Municipal Corporation of Ahmedabad. The study and its results are subjected to identified methods. The methodology can be used to carry out a similar approach for a different case.

2 Literature Review

2.1 Building energy performance and daylight

The Architectural Energy Corporation has stated (Architectural Energy Corporation, 2006) that "Daylighting can drastically improve the energy efficiency of space with adequate control of electrical lighting and solar heat gain" (Architectural Energy Corporation, 2006). Buildings are responsible for almost 40% of the world's energy consumption, including up to 65% of electrical energy. Moreover, lighting is a major portion of the electrical energy consumption of non-residential and commercial buildings (Baldwinet, 2015). Hence, in recent years one of the key strategies for this sector is increasing energy efficiency by reducing the energy used for lighting (Kaminska & Ozadowicz, 2018). Daylight is not only good for children's overall health and wellbeing but that it can also significantly improve academic performance (Shishegar & Boubekri, 2016).The biggest challenge faced while implementing daylight is glare and visual discomfort. Glare is created when areas that are too bright are located within the field of view, or when the contrast ratio is high (Osterhaus, 2005).

2.2 Daylight in schools

Lighting is one of the most important of all building systems, according to the National Lighting Bureau (DiLouie, 2011). Every school relies on lighting to provide an effective learning environment, which is one of the most critical physical characteristics of the classroom (Edwards & Torcellini, 2002). Gelfand (2010) claimed that natural lighting in classrooms can connect students to nature and also directly promote the mood of children and teachers (Gelfand & Freed , 2010). Daylight promotes the mental well-being of teachers and students. Knez (1990) and Veitch (1997) claimed that lighting influences people's moods and attitudes (Cardellino, 2013). The amount of lighting has an important mental function in educational facilities. The lack of windows causes stress on people (Jeffrey , Baglioni Jr., & Cooper, 2013). Furthermore, Heschong (2002) examined 8000 students in 450 classrooms and results showed that natural light directly affects children's performance.A study found a high correlation between schools that reported improvements in student test scores - upwards of 10 percent - and those that reported increased daylight in the classroom (Heschong L. , Daylighting in Schools An Investigation into the Relationship Between Daylighting and Human Performance Condensed Report, 1999).Children in daylit classrooms promoted by 20 % compared with children in non-daylit classrooms (Heschong & Roger , 2002). Hathaway (1994) found a good correlation between lighting and student attendance (Boyce, Hunter, & Howlett, 2003). More than 21,000 students' test scores about reading and math were analyzed, and found that the California students 20% to 26% increase in academic performance, while children in Seattle and Fort Collins showed about 7% to 18% developments (Heschong L. , 1999). When compared with maximum daylight classrooms with minimum daylight classrooms, students in maximum daylight classrooms improved math by 20% and reading by 26%. Learning areas at schools with maximum window areas were related to 19% and 20% better reading and math test scores (Boubekri & Wang, 2012).

2.3 Daylight performance indications and simulation tools

Illuminance is the measure of the amount of light received on the surface. It is typically expressed in lux (lm/m2). Illuminance levels can be measured with a luxmeter, which helps in calulating daylight (Velux, 2017). Dynamic daylight performance metrics are based on time series of illuminances or luminances within a building. Daylight Autonomy (DA) now commonly referred to as dynamic daylight metrics, is represented as a percentage of annual daytime hours that a given point in space is above a specified illumination level of 300 lux (DA300). It also has the power to relate to electric lighting energy savings if the user-defined threshold is set based upon electric lighting criteria (New Buildings Institute , 2020).Useful Daylight Illuminance (UDI) is a modification of Daylight Autonomy conceived by Mardaljevic and Nabil in 2005 (Mardaljevic & Nabil, 2005).This metric bins hourly time values based upon three illumination ranges, 0-100 lux, 100-2000 lux, and over 2000 lux. It provides full credit only to values between 100 lux and 2,000 lux suggesting that horizontal illumination values outside of this range are not useful. There is significant debate regarding the selection of 2,000 lux as an 'upper threshold' above which daylight is not wanted due to potential glare or overheating (New Buildings Institute , 2020). Daylight Factor is a ratio that represents the amount of illumination available indoors relative to the illumination present outdoors at the same time under overcast skies. LEED rating system originally required a DF ≥ 2 for at least 75% of the critical visual task zones to achieve indoor environment credit 8.1.BS 8206-2 requires DF ≥ 2 or 5 depending on electric lighting requirements to support human well-being

(Mardaljevic, Heschong, & Lee, Daylight metrics and energy savings, 2009). Spatial Daylight Autonomy (sDA) describes how much of space receives sufficient daylight. It describes the percentage of floor area that receives at least 300 lux for at least 50% of the annual occupied hours. It describes the proportion of a building space that is fully illuminated by daylight for a certain portion of the year (Heschong M. , 2012)Annual Sun Exposure (ASE) describes how much space receives too much direct sunlight, which can cause visual discomfort (glare) or increase cooling loads.ASE measures the percentage of floor area that receives at least 1000 lux for at least 250 occupied hours per year (Heschong M. , 2012).
The impact of daylight on the lighting performance of a building can be examined through daylighting simulations.Energy simulation programs of buildings can be very effective tools at the design stage to evaluate the daylighting performance by generating parametric studies varying the features of windows and shading devices to optimize the energy performance of a building (Loutzenhiser, Maxwell, & Manz, 2007). There are various simulation tools such as Radiance, Daysim, Rhino, Ecotect, Velux, etc., to analyze the illumination levels (Velux, Daylighting Simulation tools, 2017).

2.4 Climatic data of Ahmedabad

Ahmedabad is at 23°3'N, 72°38'E, 56 m (185 ft), has a subtropical steppe/ low-latitude semi-arid hot climate (Köppen-Geiger classification: BSh). According to the Holdridge life zones system of bioclimatic classification, Ahmedabad is situated in or near the subtropical dry forest biome (Climatemps, 2017). The temperature here averages 27.3 °C | 81.1 °F. About 753 mm | 29.6 inch of precipitation falls annually. Most of the precipitation here falls in July, averaging 271 mm | 10.7 inch (Climate-Data, 2017).

3 Methodology

The methodology used for the study here is divided into four major sections which have been described in detail below:
Literature Review involves study of secondary data to undertand the current senario and validate the need of the study.Pilot Study would deal with the workability of the system designed for analysing daylight performance of the existing classroom space and how different parameters can be fixated to strengthen the process.
Case Study: The case study incorporates a survey based method with documentation of 20 different existing classroom spaces in Ahmedabad. The classroom selected for the study are taken from the schools under the Municipal Corporation of Ahmedabad. All these classrooms are documented, analyzed and the best representative classrooms are taken ahead and tested through simulations. In figure 2, a detailed flow of documentation process is showed.
Simulation: This portion of the study demands the use of simulation tools like Ecotect with help of additional built-in connections like radiance and daysim, which help further to visualize results. Ecotect is majorly used for creating the prototype of classroom space, to assign characteristic like material, color, external obstruction, climatic data, etc and further test them. Radiance and Daysim are used for simulation for specific analysis and time period. The performance of space will be evaluated based on annual data. In figure 3, a detailed flow of simulation process is showed.

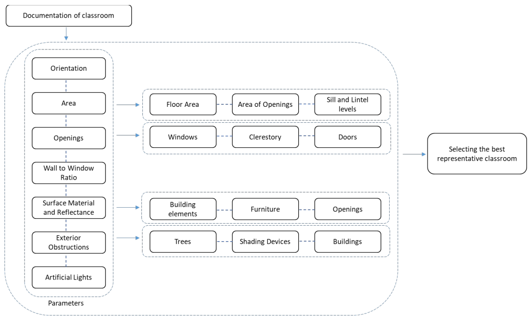


Figure 1. Process for documentation of classroom

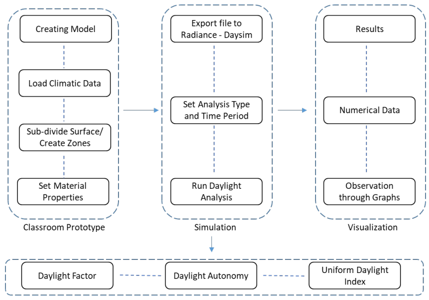


Figure 2. Simulation process

4 Case Study and analysis

4.1 Details of the case study

The study is conduted through a survey based method for existing classroom spaces in Ahmedabad, documenting them and collecting the required data. The classrooms selected for the study are the Middle School Prototype Projects selected from the schools that comes under Municipal Corporation (Department of Education); which are also known as Nagar Prathamik Shiksha Samiti Kendra of Ahmedabad. A prior permission was taken in written from the municipal corporation department to visit these schools and collect data. Private schools are not considered for the study because it was difficult to take out the common features from multiple schools and the design of classroom spaces were modified as per the requirement for each school. The classroom occupancy hours considered for the study are between 8:00 a.m. to 6:00 p.m for all 365 days. 20 classrooms from twenty different schools are surveyed and documented for the study.
Based on the data collected from survey, a comparative chart has been made to futher identify common parameters, and the best representative classrooms can be taken ahead and analyzed in detail. Further, the conceptual models representative of existing classroom spaces has been built to analyze the daylight performance. In **Figure 3**, a comprehensive information reagrding these case studies are depicted and is attached at the end of the paper after citations.

4.2 Observations through study

This chapter describes the analysis of all the twenty cases and interpretations made after analysis, which mainly constitute the area of the classroom, wall window ratio, window, and clerestory area.

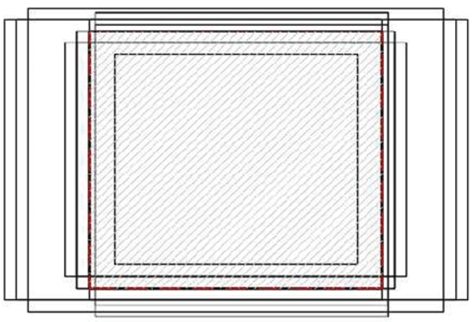


Figure 4. Area of the classroom

The above diagram shows the layout of all twenty classrooms to get an idea about the layout structure of the space and also about the dimensions. While considering the floor dimensions, the most common dimensions of length lie between 6.0m-6.5m and for width, lies between 5.5 m - 6.5 m; except for few cases.

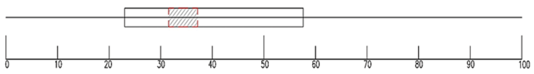


Figure 5. Range of the area of classrooms

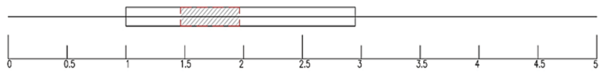


Figure 6. Wall window ratio.

The area of the classroom space ranges from 22.5 m^2 to 57 m^2, which tell us about the extreme areas, but this is generally seen in a case or two. The common range lies between 33 m^2 to 36 m^2. The range for wall window ratio lies from 9 % - 23 % but when seen the most commonly WWR considered in these cases lies from 10 % - 19 %.

The area of the window lies between 1.4 m^2 - 1.8 m^2 (in most cases the height of the window is the same; 1.2 m). While the overall window area ranges from 1.0 m^2 to 2.9 m^2.

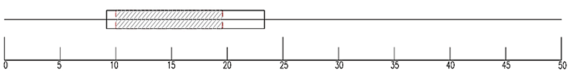


Figure 7. Area of openings

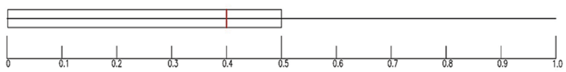


Figure 8. Area of clerestory

The area of the clerestory is 0.4 m, which considered in maximum cases (the height of the clerestory is almost the same in each case; 0.4 m). The worst scenario is the cases that do not have a clerestory. The maximum area goes up to 0.5 m^2 which can be seen in just one case.

4.3 Analysis of the case study

The primary goal of the study was to get an idea about typical municipal classroom spaces in Ahmedabad. Following this approach, more detailed knowledge of the layout of the classrooms was construed.

- Only two classrooms are on the second floor, seven on the ground floor and eleven on the first floor.
- While considering the floor dimensions, the most common dimensions of length lie between 6.0 m - 6.5 m and for width, lies between 5.5 m - 6.5 m; except for few cases.
- The area of the window lies between 1.4 m^2 -1.8 m^2 (in most cases the height of the window is the same); the area of the clerestory is 0.4 m^2 and the area of the door is 2.1 m^2.
- Sill height in 90 % of the cases is considered to be 0.8 m.
- The wall window ratio lies between 10 % - 20 %.
- The working plane for students is situated at a height of 0.8m above the floor level.
- Regarding the surface material and reflectance; the walls are usually painted in 2 colors, which in most cases are yellow, cream, white, blue, and brown. The floor has finished with Kota stone tiles. The window and doors have wooden shutters painted blue/brown. The furniture is made out of metal and painted black and the desk has a blue laminate on top.
- Exterior obstructions are taken into account like shading devices, tress, and building surrounding the classroom. In most of the classroom, there are no shading devices installed.
- There are no blinds in the windows.

Three best repesentative cases were selected out of twenty cases that were documented.These cases were selected on the basis of most similar parameters observed in all cases, which shall cover all aspects of other cases.Figure 10 and 11 shows the details of these cases and how they differ from each other.

Name of the school	Location	Floor		Window		Clerestory		WWR	Material and Surface Reflectance					Exterior Obstruction			Light	
		Length	Width	Area	No	Area	No		Wall	Floor	Window	Board	Furniture	Shading device	Trees	Buildings	Tube light	On/off
Ellisbridge – 14	First floor	6.0	6.5	1.7	2.0	0.4	2.0	11	Yellow and blue	Light brown tiles	Wooden shutters painted blue	Black	Brown wooden desk and metal chairs (black)	N	Y	N	4	On
Vasna - 8	Ground floor	6.0	6.0	1.9	2.0	0.4	2.0	13	Yellow and blue	Kota stone tiles	Wooden shutters painted blue	Black	Brown wooden desk and metal chairs (black)	N	Y	N	4	Off
Vasna - 3/4	First floor	6.0	5.5	1.9	3.0	0.0	0.0	17	White and light brown	Kota stone tiles	Wooden shutters painted light brown	Black and white	Blue laminate on desk and metal chairs (black)	N	Y	N	4	Off

Figure 9. Details of cases selected

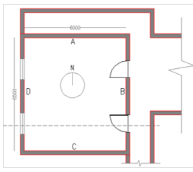
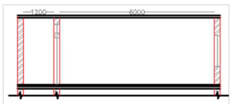
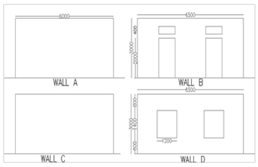
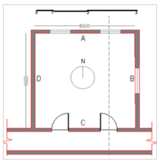
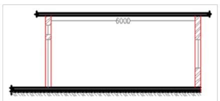
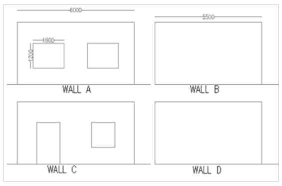
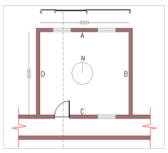
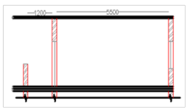
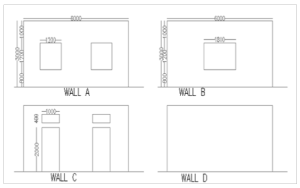
Name of the school	Layout	Section through passage	Elevations	Remarks
Ellisbridge – 14				The classroom has two windows located on the west wall with an area of 1.7 m^2. The south wall is shared with other classroom and the north wall has been covered by the passage. The east wall has doors and clerestory windows and is shared with the passage area.
Vasna - 8				The classroom has two windows, one located on the north wall and one on the east wall. The west wall is shared with other classroom and the east wall has been shared with a passage. The south wall has doors and clerestory windows and is shared with the passage area.
Vasna - 3/4				The classroom has three windows; two of them located on the north wall and one on the south wall. The west wall is shared with other classroom and the east wall has been shared with a passage. The north wall has doors and is shared with the passage area

Figure 10. Analysis of the cases selected

5 Simulation

5.1 Simulation for the base case

The prototypes of representative models are built, which depicts the conceptual model of real classroom. The model will be tested for various daylight metrics to know how the existing design performs under real senario.The paramters considered for each case has been mentioned below.

5.1.1 Simulation for Case 1

The representative model of the classroom built, is located on the first floor of the building. The classroom has two windows located on the west wall with an area of 1.7 sq.m. The south wall is shared with other classroom and the north wall has been covered by the passage. The east wall has doors and clerestory windows and is shared with the passage area.

Table 1. Parameters considered while doing simulation for case 01

Location: First Floor	Electric Lights: 4
Dimensions: 6.0 M X 6.5M	Artificial light : On/Off: Off
Floor Area: 39 M^2	Material and Reflectance-
Sill Height: 0.8 M	Floor: Light brown Tiles – 0.40
Window Area: 1.7 M^2	Wall: Yellow - 0.70
No of Windows: 2	Celling: White – 0.80
Clerestory Area: 0.4 M^2	Exterior Obstruction-Yes
No of Windows: 2	Shading Device: No
Door Area: 2.1 M^2	Trees: Yes
No of Doors: 2	Buildings: No
WWR: 11%	Blinds: N/A

5.1.2 Simulation for Case 2

The representative model of the classroom shown built, is located on the ground floor of the building. The classroom has two windows, one located on the north wall and one on the east wall. The west wall is shared with other classroom and the east wall has been shared with a passage. The south wall has doors and clerestory windows and is shared with the passage area.

Table 2. Parameters considered while doing simulation for case 02

Location: Ground Floor	Electric Lights: 4
Dimensions: 6.0 M X 6.0 M	Artificial light : On/Off: Off
Floor Area: 36 M^2	Material and Reflectance-
Sill Height: 0.8 M	Floor: Kota Stone Tiles – 0.30
Window Area: 1.9 M^2	Wall: Yellow - 0.70
No of Windows: 2	Celling: White – 0.80
Clerestory Area: 0.4 M^2	Exterior Obstruction - Yes
No of Windows: 2	Shading Device: No
Door Area: 2.1 M^2	Trees: Yes
No of Doors: 2	Buildings: No
WWR: 13%	Blinds: N/A

5.1.3 Simulation for Case 3

The representative model of the classroom built, is located on the first floor of the building. The classroom has three windows; two of them located on the north wall and one on the south wall. The west wall is shared with other classroom and the east wall has been shared with a passage. The north wall has doors and is shared with the passage area.

Table 3. Parameters considered while doing simulation for case 03

Location: First Floor	Material and Reflectance-
Dimensions: 6.0 M X 5.5 M	Wall: White – 0.8
Floor Area: 33 M^2	Floor: Kota Stone Tiles – 0.30

Window Area: 1.9 M²	Celling: White – 0.80
Door Area: 2.5 M²	Exterior Obstruction - Yes
WWR: 17%	Trees: Yes
Sill Height: 0.8 M	Blinds: N/A
No of Windows: 3	Shading Device: No
No of Doors: 1	Buildings: No
Electric Lights: 4	Artificial light : On/Off: Off

5.2 Result analysis for base case

5.2.1 Analysis for Case 1

- Daylight Factor (DF) Analysis: 42% of all illuminance sensors have a daylight factor of 2 or higher.
- Daylight Autonomy (DA) Analysis: DA requirements (300 lux or more) are met over the total area for 53 % of total annual analysis hours.
- Useful Daylight Index (UDI) Analysis: The Useful Daylight Index are UDI<100=13%, UDI100-2000=40%, UDI>2000=47% .

5.2.2 Analysis for Case 2

- Daylight Factor (DF) Analysis: 36% of all illuminance sensors have a daylight factor of 2 or higher.
- Daylight Autonomy (DA) Analysis: DA requirements (300 lux or more) are met over the total area for 65 % of total annual analysis hours.
- Useful Daylight Index (UDI) Analysis: The Useful Daylight Index are UDI<100=100%, UDI100-2000=0%, UDI>2000=0%.

5.2.3 Analysis for Case 3

- Daylight Factor (DF) Analysis: 62% of all illuminance sensors have a daylight factor of 2 or higher.
- Daylight Autonomy (DA) Analysis: DA requirements (300 lux or more) are met over the total area for 87 % of total annual analysis hours.
- Useful Daylight Index (UDI) Analysis: The Useful Daylight Index are UDI<100=12%, UDI100-2000=9%, UDI>2000=79%

The representative model of the For the base case scenario, when the classroom spaces are model as per real case:
- Daylight Factor (DF) Analysis: None of the space has daylight factor of 2 for 75% of the space.
- Daylight Autonomy (DA) Analysis: DA requirements (300 lux or more) are met over the total area for 53 % and 65% of total annual analysis hours which seems to be adequate while in case 3 the requirement is getting met by 87%., hence fulfilling the criteria.
- Useful Daylight Index (UDI) Analysis: Only in the third case scenario, space will have glare problems.

6 Conclusion

The primary goal of the study was to get an idea about how the typical classroom spaces in Ahmedabad perform in terms of daylight. Following are the main conclusions of the study:
Considering the cases studied for schools of Ahmedabad, the metrics worked in the following manner:

- Daylight Factor (DF) Analysis: None of the classroom space will achieve daylight factor of 2 for 75% of the space.
- Daylight Autonomy (DA) Analysis DA requirements (300 lux or more) are met over the total area for at least 75 % of total annual analysis hours are fulfilled by 6 cases.
- Useful Daylight Index (UDI) Analysis: The amount of daylight (2000 lux or more) penetrating inside the classroom will be higher (more than 60%) in 6 cases that might lead to glare conditions, thus visual and thermal discomfort.

For schools of Ahmedabad, the appropriate metric would be UDI because it helps in determining the occurrence of daylight illuminances in ranges. The useful daylight illuminance approach uses hourly sky and sun conditions for an entire year to assess illuminance on work planes. Instead of focusing on a single target illuminance level, the useful daylight illuminance approach draws on a range of useful levels derived from existing research. If the daylight illuminance is too small (i.e. below a minimum), it may not contribute in any useful manner to either the perception of the visual environment or in the carrying out of visual tasks. Conversely, if the daylight illuminance is too great (i.e., above a maximum), it may generate visual or thermal discomfort or both. Illuminances that fall within the bounds of minimum and maximum are potentially useful illumination for the occupants of the space

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SNO	NAME OF THE SCHOOL	LOCATION	FLOOR			SILL	WALL		WINDOW		CELESTORY		DOOR		WWR
			LENGTH	WIDTH	AREA		AREA-1	AREA-2	AREA	NO	AREA	NO	AREA	NO	
1	Ellisbridge – 10	Ground Floor	6.0	5.5	33.0	0.8	18.0	16.5	1.0	3.0	0.2	1.0	2.4	1.0	9
2	Ellisbridge – 4	Second Floor	7.0	5.0	35.0	1.0	21.0	15.0	1.1	4.0	0.0	0.0	1.9	1.0	12
3	Ellisbridge – 12	First Floor	6.5	5.0	32.5	0.8	19.5	15.0	2.5	2.0	0.5	2.0	2.1	2.0	18
4	Ellisbridge – 22	Ground Floor	6.0	6.0	36.0	0.8	18.0	18.0	1.4	2.0	0.4	2.0	2.1	2.0	10
5	Ellisbridge – 14	First Floor	6.0	6.5	39.0	0.8	18.0	19.5	1.7	2.0	0.4	2.0	2.1	2.0	11
6	Vasna - 7	Second Floor	6.0	6.5	39.0	0.8	18.0	19.5	2.2	2.0	0.0	0.0	2.1	1.0	12
7	Vasna - 8	Ground Floor	6.0	6.0	36.0	0.8	18.0	18.0	1.9	2.0	0.4	2.0	2.1	2.0	13
8	Vasna - 5/6	Ground Floor	6.0	5.5	33.0	0.8	18.0	16.5	1.9	3.0	0.0	0.0	2.1	1.0	17
9	Vasna - 3/4	First Floor	6.0	5.5	33.0	0.8	18.0	16.5	1.9	3.0	0.0	0.0	2.5	1.0	17
10	Ellisbridge – 6	First Floor	5.0	4.5	22.5	0.8	15.0	13.5	2.2	4.0	0.0	0.0	2.1	1.0	23
11	Narangpura -1	First Floor	6.5	5.5	35.8	0.6	19.5	16.5	2.2	3.0	0.4	2.0	2.1	2.0	20
12	Narangpura -6	Ground Floor	6.0	9.5	57.0	0.4	18.0	28.5	1.6	4.0	0.0	0.0	2.1	1.0	14
13	Ellisbridge – 7	First Floor	6.0	5.0	30.0	0.8	18.0	15.0	1.8	2.0	0.0	0.0	2.1	2.0	11
14	Ellisbridge – 17	Ground Floor	6.0	9.0	54.0	0.8	18.0	27.0	2.2	4.0	0.0	0.0	2.1	2.0	14
15	Ellisbridge – 26	First Floor	6.0	5.5	33.0	0.8	18.0	16.5	1.4	2.0	0.4	2.0	2.1	2.0	11
16	Ellisbridge – 2	First Floor	6.0	5.5	33.0	0.8	18.0	16.5	2.9	2.0	0.4	2.0	2.1	2.0	19
17	Ellisbridge – 29	First Floor	6.5	8.5	55.3	0.8	19.5	25.5	1.8	2.0	0.4	2.0	2.1	2.0	10
18	Vejalpur- 1/2	Ground Floor	6.5	5.5	35.8	0.8	19.5	16.5	1.8	2.0	0.4	2.0	2.1	1.0	12
19	Vejalpur- 3/4	First Floor	6.0	5.5	33.0	0.8	18.0	16.5	2.7	1.0	0.0	0.0	2.1	1.0	15
20	Narangpura -4	First Floor	6.0	5.5	33.0	0.8	18.0	16.5	1.7	2.0	0.4	2.0	2.1	2.0	12

SNO	MATERIAL AND REFLECTANCES												EXTERIOR OBSTRUCTION				ELECTRICITY	
	WALL	REFLECTANCE	FLOOR	REFLECTANCE	WINDOW	REFLECTANCE	DOOR	REFLECTANCE	BOARD	REFLECTANCE	FURNITURE	REFLECTANCE	SHADING DEVICE	TREES	BUILDINGS	BLINDS	LIGHTS	ON/OFF
1	CREAM AND BLUE	0.75	KOTA STONE TILES	0.3	BROWN PAINTED METAL SHUTTERS	0.57	BROWN PAINTED METAL SHUTTERS	0.57	GREEN	0.22	BLUE LAMINATE ON DESK AND METAL CHAIRS(BLACK)	0.4	Y	Y	N	N/A	4	ON
2	YELLOW AND BLUE	0.7	KOTA STONE TILES	0.3	WOODEN SHUTTERS PAINTED BLUE	0.45	WOODEN SHUTTERS PAINTED BLUE	0.45	BLACK AND GREEN	0.15-0.22	BLUE LAMINATE ON DESK AND METAL CHAIRS(BLACK)	0.4	Y	Y	N	N/A	4	OFF
3	WHITE	0.8	KOTA STONE TILES	0.3	WOODEN SHUTTERS PAINTED BLUE	0.45	WOODEN SHUTTERS PAINTED BLUE	0.45	BLACK	0.15	BLUE LAMINATE ON DESK AND METAL CHAIRS(BLACK)	0.4	Y	Y	Y	N/A	4	OFF
4	YELLOW AND BLUE	0.7	KOTA STONE TILES	0.3	WOODEN SHUTTERS PAINTED BLUE	0.45	WOODEN SHUTTERS PAINTED BLUE	0.45	BLACK	0.15	BLUE LAMINATE ON DESK AND METAL CHAIRS(BLACK)	0.4	N	Y	N	N/A	4	OFF
5	YELLOW AND BLUE	0.7	LIGHT BROWN COLOR TILES	0.4	WOODEN SHUTTERS PAINTED BLUE	0.45	WOODEN SHUTTERS PAINTED BLUE	0.45	BLACK	0.15	BROWN WOODEN DESK AND METAL CHAIRS(BLACK)	0.2	N	Y	N	N/A	4	ON
6	YELLOW AND BROWN	0.7	BEIGE COLOR VITRIFIED TILES	0.4	SLINDING GLASS SHUTTERS	0.1	WOODEN SHUTTERS PAINTED BROWN	0.57	BLACK	0.15	BLUE LAMINATE ON DESK AND METAL CHAIRS(BLACK)	0.4	N	N	N	N/A	4	OFF
7	YELLOW AND BLUE	0.7	KOTA STONE TILES	0.3	WOODEN SHUTTERS PAINTED BLUE	0.45	WOODEN SHUTTERS PAINTED BLUE	0.45	BLACK	0.15	BROWN WOODEN DESK AND METAL CHAIRS(BLACK)	0.2	N	Y	N	N/A	4	OFF
8	WHITE AND LIGHT BROWN	0.8	KOTA STONE TILES	0.3	GLASS WINDOW WITH WOODEN SHUTTERS	0.1	WOODEN SHUTTERS PAINTED BROWN	0.57	GREEN	0.22	BLUE LAMINATE ON DESK AND METAL CHAIRS(BLACK)	0.4	N	N	N	N/A	4	ON
9	WHITE AND LIGHT BROWN	0.8	KOTA STONE TILES	0.3	WOODEN SHUTTERS PAINTED LIGHT BROWN	0.57	WOODEN SHUTTERS PAINTED LIGHT BROWN	0.57	BLACK AND WHITE	0.15 - 0.8	BLUE LAMINATE ON DESK AND METAL CHAIRS(BLACK)	0.4	N	Y	N	N/A	4	OFF
10	CREAM AND BLUE	0.75	CONCRETE FLOORING	0.4	WOODEN SHUTTERS PAINTED BLUE	0.45	WOODEN SHUTTERS PAINTED BLUE	0.45	BLACK	0.15	BLUE LAMINATE ON DESK AND METAL CHAIRS(BLACK)	0.4	N	N	N	N/A	4	OFF
11	YELLOW AND BLUE	0.7	KOTA STONE TILES	0.3	WOODEN SHUTTERS PAINTED BLUE	0.45	WOODEN SHUTTERS PAINTED BLUE	0.45	BLACK	0.15	BLUE LAMINATE ON DESK AND METAL CHAIRS(BLACK)	0.4	N	Y	N	N/A	4	ON
12	WHITE AND BLUE	0.8	KOTA STONE TILES	0.3	LIGHT BROWN PAINTED METAL SHUTTERS	0.57	LIGHT BROWN PAINTED METAL SHUTTERS	0.57	BLACK	0.15	BLUE LAMINATE ON DESK AND METAL CHAIRS(BLACK)	0.4	N	N	N	N/A	4	OFF
13	YELLOW AND BLUE	0.7	MOSAIC TILE	0.3	WOODEN SHUTTERS PAINTED BLUE	0.45	WOODEN SHUTTERS PAINTED BLUE	0.45	BLACK	0.15	BLUE LAMINATE ON DESK AND METAL CHAIRS(BLACK)	0.4	N	Y	N	N/A	4	ON
14	CREAM	0.75	KOTA STONE TILES	0.3	SLINDING GLASS SHUTTERS	0.1	WHITE PANEL WITH METAL FRAME	0.8	BLACK	0.15	BLUE LAMINATE ON DESK AND METAL CHAIRS(BLACK)	0.4	N	N	N	N/A	4	OFF
15	CREAM AND BLUE	0.75	KOTA STONE TILES	0.3	WOODEN SHUTTERS PAINTED BLUE	0.45	WOODEN SHUTTERS PAINTED BLUE	0.45	BLACK	0.15	BLUE LAMINATE ON DESK AND METAL CHAIRS(BLACK)	0.4	N	N	N	N/A	4	OFF
16	WHITE AND GREEN	0.8	CONCRETE FLOORING	0.4	WOODEN SHUTTERS PAINTED YELLOW	0.6	WOODEN SHUTTERS PAINTED YELLOW	0.6	GREEN	0.22	BLUE LAMINATE ON DESK AND METAL CHAIRS(BLACK)	0.4	N	N	N	N/A	4	OFF
17	CREAM AND BLUE	0.75	KOTA STONE TILES	0.3	WOODEN SHUTTERS PAINTED BLUE	0.45	WOODEN SHUTTERS PAINTED BLUE	0.45	BLACK	0.15	BLUE LAMINATE ON DESK AND METAL CHAIRS(BLACK)	0.4	Y	N	N	N/A	4	OFF
18	WHITE AND GREY	0.8	KOTA STONE TILES	0.3	LIGHT BROWN PAINTED WOODEN SHUTTERS	0.57	LIGHT BROWN PAINTED WOODEN SHUTTERS	0.57	GREEN	0.22	BROWN WOODEN DESK AND METAL CHAIRS(BLACK)	0.2	N	N	N	N/A	4	OFF
19	CREAM AND BLUE	0.75	LIGHT BROWN VITRIFIED TILES	0.4	WOODEN SHUTTERS PAINTED BLUE	0.45	WOODEN SHUTTERS PAINTED BLUE	0.45	GREEN	0.22	BLUE AND YELLOW AND BROWN COLOR ON DESK AND METAL CHAIRS(BLACK)	0.4-0.6-0.2	N	N	N	N/A	4	OFF
20	CREAM AND BLUE	0.75	KOTA STONE TILES	0.3	WOODEN SHUTTERS PAINTED BLUE	0.45	WOODEN SHUTTERS PAINTED BLUE	0.45	BLACK	0.15	BLUE LAMINATE ON DESK AND METAL CHAIRS(BLACK)	0.4	N	Y	N	N/A	4	OFF

Figure 3. Comparison chart for all cases