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Daylight retrofitting for a school in Pune

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ABSTRACT
Daylighting is an optimal illumination of building using natural sunlight . The utilization of daylight can significantly affect building aesthetic , energy efficiency, as well as occupant's comfort,*productivity and health.*Another purpose of day lighting is to save energy by reducing artificial lighting. In this study existing daylight pattern in school building is studied. Few retrofitting strategies like introduction of skylight, windows alteration and redesigning of the interior space are suggested to get the benefit of optimal daylight. Evaluation of daylighting after retrofitting is done by using Ecotect simulation .After retrofitting considerable increase in daylight performance is observed.Retrofitting suggested here also provides better ventilation with minimized energy consumption.However it should be noted that though retrofitting improves internal illuminance, surrounding structures limits the solar penetration .
Keywords: Day lighting, Retrofitting, School building

I. INTRODUCTION

Natural light has great impact on the interior and exterior forms of buildings and on those who dwell in them. Students spent their one third time of day in the school .There are many studies which showed that daylight is good for health and well being of children as well as for their academic performance .[1,2]

Most of the Indian school buildings rely on electricity for lighting. Use of artificial light during day is in the paradox when there is abundance of natural light for illumination.Artificial light causes some physiological and psychological problem of occupants and productivity issues.[3]

The total annual energy use in office buildings varies in the range of 100–1000 kWh/m^{2}yr, depending on the geographic location, use and type of office equipments, operational schedules, use of HVAC systems etc.[4] In such office buildings, lighting generally constitutes about 20–45% of electrical demand but it varies from one building to another.[5] It is also found that 23% of all energy-saving opportunities could be achieved by just improving lighting system. Daylight releases less heat than artificial light hence use of daylight will reduce energy spent on cooling.[6]

Nowadays many buildings are designed on basis of concept of Green buildings. Green buildings means development of sustainable design by conservation of resources, energy efficiency, passive design, use of renewable energies with improved air quality and minimal adverse effects on occupant's health.But many institutional buildings are built before introduction of sustainability.Hence existing buildings must be subjected to a process of retrofit to create the intended ecological impact.

This paper attempted to provide retrofitting options for daylighting improvement in a secondary School using findings from the actual on-site lighting audit and results of a simulation software.

II. METHODS AND MATERIAL

Aims And objectives :

1. Conduct an audit of the existing lighting and daylighting at school
2. Prioritize retrofit applications according to the site's needs.
3. Identify suitable strategies and technology options
4. To simulate daylight penetration using Ecotect simulation software.
5. Measure and verify results before and after retrofitting

This is study of daylight retrofitting of existing school building located in Pune, India..Pune has a hot semi-arid climate average temperatures ranging between 19 to 33 °C and experiences three seasons: summer, monsoon, and winter.(Fig 1)

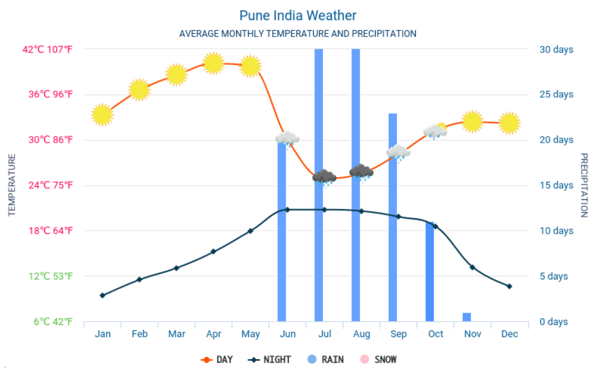

Figure 1:Yearly weather chart , Pune (India)

The concerned school building was previously in use for some other purpose. The same building is now used for School purpose after some modifications, hence ours is a case of "Change of User". There was poor daylight in school.Only peripheral area of the building is illuminated by daylight while core area depends on artificial light which is consuming lots of energy.The occupancy pattern is uniform across the buildings with estimated 2700 total occupants The observed working hour pattern approximately ranges between 8am to 3pm Indian Standard Time (IST).

To propose daylight retrofitting strategies, the workspace is studied.The school building studied is presented in Fig.2, 3, 4 .

Figure 2:External view of school Building

This particular G+2 school building is accessible by six meter wide road abutting along the west side of the building. On north side open space between the school and G+2 residential building is just three meters.

Figure 3:Abutting G+2 residential building on north side

A huge municipal storage tank of twenty meter height is overshadowing the school building on eastern side. On south side G+1 residential building is just three meters away from the school.

Fig 4 : Huge Municipal water storage tank on eastern side

A field study was performed on-site. Passive design features of the building were studied .The in-situ measurement is taken. Three spaces are covered under this –ground floor, First Floor, Second Floor. For this study purpose we focused only on class rooms for daylight calculations, however the spaces like passages, toilets, service areas were not taken into account. Yet care has been taken to illuminate these areas to receive optimum daylight after retrofitting.Actual measurements of illuminance were conducted on the work plane level which is approximately 80 cm above the floor level.

For receiving daylight and ventilation retrofitting is suggested in the form of extending the existing fenestrations and creating new punctures in the slab.lighting.

The structural grid and strength ,characteristics of daylight,annual daylight pattern of Pune,daylight requirement of the spaces were considered while making the alterations.Illumination pattern before and after retrofitting is calculated using Ecotect simulation

ZONE	AVERAGE LUMINANCE IN LUX								
ROOM NO	1	2	3	4	5	6	7	8	9
GROUND FLOOR	175	84	62	5	115	58	-	-	-
FIRST FLOOR	56	9	42	29	6	466	270	117	78
SECOND FLOOR	288	50	358	747	533	631	659	-	-

III. RESULTS

Existing scenario: Existing built up area per floor is measured as shown in Table no 1 .

TABLE 1. EXISTING BUILT UP AREA PER FLOOR

Existing built up	Area
Ground floor	620sqmteter
First floor	620sqmteter
Second floor	600sqmteter

Existing daylight illuminance measured manually by using LUXMETER on site is mentioned in Table 2.

TABLE 2. Existing daylight profile (USING LUXMETER)

ZONE	AVERAGE LUMINANCE IN LUX								
ROOM NO	1	2	3	4	5	6	7	8	9
GROUND FLOOR	175	84	62	5	115	58	-	-	-
FIRST FLOOR	56	9	42	29	6	466	270	117	78
SECOND FLOOR	288	50	358	747	533	631	659	-	-

Daylight profile of existing building by using ECOTECT simulation is shown in Table 3.

TABLE 3. Existing daylight profile (ECOTECT SIMULATION)

ZONE	AVERAGE LUMINANCE IN LUX								
ROOM NO	1	2	3	4	5	6	7	8	9
GROUND FLOOR	1188.20	926.95	1040.41	738.79	1223.60	1182.73	-	-	-
FIRST FLOOR	1020.01	601.03	982.58	607.50	331.36	640.68	978.35	375.57	1045.22
SECOND FLOOR	1104.10	763.90	1155.95	1191.99	493.5	1202.83	1407.12	-	-

Passive fenestration System is a key building design aspect as it cuts recurring energy costs associated with lighting load in building. The building is able to largely achieve the objectives with respect to day lighting by passive fenestration .The seasonal solar penetration noted using Sun Path Diagram is shown in table 4 to 7.

TABLE 4. Solar penetration First Term (Morning Session)

DAYS	VERTICAL ANGLES	
	8AM	11AM
21 JUNE	74^{0}	49^{0}
28 JULY	73^{0}	48^{0}
27 AUG	70^{0}	47^{0}
25 SEPT	65^{0}	43^{0}
20 OCT	58^{0}	38^{0}
17 NOV	48^{0}	33^{0}

TABLE 5. Solar penetration Second Term (Morning session)

DAYS	VERTICAL ANGLES	
	8AM	11AM
22 DEC	18^{0}	45^{0}
26 JAN	22^{0}	48^{0}
25 FEB	25^{0}	58^{0}
21 MAR	28^{0}	65^{0}
16 MAR	32^{0}	70^{0}

TABLE 6. Solar penetration First Term (Afternoon Session)

DAYS	VERTICAL ANGLES	
	1PM	3PM
21 JUNE	74^{0}	49^{0}
28 JULY	73^{0}	48^{0}
27 AUG	70^{0}	47^{0}
25 SEPT	65^{0}	43^{0}
20 OCT	58^{0}	38^{0}
17 NOV	48^{0}	33^{0}

TABLE 7. Solar penetration Second Term (Afternoon Session)

DAYS	VERTICAL ANGLES	
	1PM	3 PM
22 DEC	45^{0}	29^{0}
26 JAN	48^{0}	33^{0}
25 FEB	58^{0}	38^{0}
21 MAR	65^{0}	43^{0}
16 APR	70^{0}	47^{0}

The building has a wall window ratio (WWR) less than 40 %.To get the maximum benefit of light for interior spaces, retrofitting of the existing building is proposed .For retrofitting following strategies are proposed .

1) Use of sky light
2) Alterations of windows
3) rearrangement of interior spaces

1. Use of sky light

a. Court yards provided for sky lighting by making punctures in slabs (Drawing Sheet no 4,5,6,) measuring measuring (3.67X4.57)m2, (3.67X4.57)m2,(3.67X3.97) m2

b. Raised acrylic pyramid shaped skylight open at base for ventilation is introduced.(Drawing Sheet no 7)

2. Alteration of windows :

Changing the sizes of windows : Altered WWR after changing the size of windows is shown in table 8 and 9.

TABLE 8. Existing WWR

ZONE	WALL WINDOW RATIO (WWR) %								
ROOM NO	1	2	3	4	5	6	7	8	9
GROUND FLOOR	13.33	20	20	-	20	-	-	-	-
FIRST FLOOR	18	12	13.33	10	-	40	23	23	23
SECOND FLOOR	23	23	23	23	23	23	40	-	-

TABLE 9. WWR After retrofitting

ZONE	WALL WINDOW RATIO (WWR) %								
ROOM NO	1	2	3	4	5	6	7	8	9
GROUND FLOOR	50	50	50	50	50	50	-	-	-
FIRST FLOOR	50	50	50	50	50	50	50	50	50
SECOND FLOOR	50	50	50	50	50	50	50	-	-

IV DISCUSSION

A significant percentage of newer buildings is still not designed in a way that lighting energy is utilized efficiently. It is also found that 23% of all energy-saving opportunities could be achieved by just improving the energy efficiency of the lighting system.

From literature we know that performances of students increase by a good visual environment.[7,8] The proper introduction of natural light in building has aesthetic ,physiological ,psychological and economic benefits . Vision is the main role of lighting in architecture.

Given the importance of designing a proper lighting system for energy savings and occupancy comfort in work environment, the study was conducted at Anjali English School ,Pune .

Geography and climate play a lead role in the context of day lighting in built environments. Pune is located in the Maharashtra state. The geographical coordinates of the city are 18.55° latitude and 73.52° longitude.

Neighborhood : Layout of buildings is significant in determining the daylight availability inside. External obstructions such as adjacent buildings reduce the sky component and also daylight availability inside the space. The obstructions at a distance of three times their height or more from window facade are not significant and may be ignored. As the separation between window facade and opposite building is reduced, there is progressive reduction in daylight indoors due to reduction of sky components.

In our case, neighboring buildings and water tank obstructs the daylight penetration into the interior spaces.Considering climatic data of Pune and adjacent neighboring structures, sunlight penetration pattern at Anjali English School is plotted term wise.It was observed that daylight is hampered due to overcasting by tank and residential buildings during school working hours.

On site readings taken manually by Luxmeter at various spots shows insufficient daylight at ground floor, first floor and second floor .

In order to get a good lighting concept, knowledge of the different tasks in classrooms is important. Each task needs its own light conditions. During the day there are a number of different visual tasks in a classroom. So, high requirements for the light quality are important.

As per BIS code, glare free daylight integration should be achieved in all living spaces. Daylight factor as recommended by Bureau of Indian Standards BIS) should be met.[9]Daylight factors for interiors as per Bureau of Indian Standards SP are as in following table.

TABLE 10

Day light factors as per BIS

Sl. No.	Location	Daylight Factor (%)
1	**Dwellings**	-
	Kitchen	2.5
	Living room	0.625
	Study room	1.9
	circulation	0.313
2	**Schools**	
	classroom	1.9-3.8
	laboratory	2.5-3.8
3	**Offices**	
	general	1.9
	Drawing ,typing	3.75
	enquiry	0.625-1.9
4	**Hospital**	
	General ward	1.25
	Pathology lab	2.5-3.75
5	**Libraries**	
	Stack room	0.9-1.9
	Reading rooms	1-9-3.75
	Counters	2.5-3.75
	Catalogue rooms	1.9-2.5

Learning requires visual tasks (writing reading observing) for both students and teachers. For young children learning to read the faces and the bodies around them is as important as learning to read text. Successful daylighting engages the entire space of the classroom, not just in work surface.

The Education (School Premises) Regulations 2012 stipulate minimum standards for school premises. Schools and colleges are also covered by the Workplace (Health, Safety and Welfare) Regulations 1992, which outline provisions that must be made in relation to the work environment. Provisions that are covered by these regulations include: toilet facilities, fire, staff rooms, weather protection, noise, lighting, heating, temperature, ventilation and water supply.

In all workplaces, each room must be appropriately lit by natural and/or artificial light. Under the Education (School Premises) Regulations, the illumination of teaching accommodation must be 300 lux or more at any point on the work surface - this is usually appropriate in classrooms, libraries and halls. However, the illumination must not be less than 500 lux where visually demanding tasks are carried out, for example, in laboratories.

For all educational establishments, the Workplace (Health, Safety and Welfare) Regulations state that every workplace should have suitable lighting (wherever possible by natural light), which means that the type and level of lighting must be compatible with the nature of the work undertaken. Consequently, specialized lighting may be required in certain areas.

Classrooms of the concerned school show an average value in Lux which is less than the required.Hence we decided to retrofit school building to improve the physical and mental health of students.

After introducing the skylight, altering the window sizes and rearranging the internal spaces it is observed

I. The actual reading of existing school building measured by Luxmeter on sight shows very poor daylight intensity because of overcasting effect of the neighbouring structures.

II. Simulation software readings for existing school building shows higher values, as it does not consider the effect of adjacent structures.

III. Simulation software readings for school building after retrofitting shows much higher values which indicates the improvement in daylight intensity after retrofitting.

IV. Even after retrofitting during the winter morning slot the adjacent municipal water storage tank on East side overcasts the school building limiting the day light performance.

In a Library building of a research block in IIT, Kanpur also observed that due to daylighting there is much improvement in luminance level day time even with artificial lights off.

Daylight is not cost free, and factors such as the control of sunlight, heat gain and loss, the association of windows with ventilation and the question of whether the windows should open or the building be sealed, are all problems which need to be addressed; but these need to be equated with the human desire for association with the natural environment, as well as the possible savings in electricity and cost.

At Druk White Lotus School lacated at Shey, Ladakh, India; the classrooms are designed for optimum daylight. In the wider Nursery and Kindergarten Building, the light from the direct solar gain windows is balanced by top lighting from north- and south-facing clerestories and a splayed ceiling. No electric lighting is typically used in the classrooms.

Daylighting is an excellent strategy not only for classrooms, but also for administrative offices, gymnasiums, and meeting rooms. Whenever possible, any lighting renovation should start by using daylighting as much as possible and reducing electric lighting accordingly.

Although a complete redesign of a lighting scheme to incorporate daylighting may be too costly for most renovation projects, some measures can be cost-effective like introduction of skylight, windows alteration and redesigning of interiors.

V C0NCLUSION

By introducing simple methods like creating the aperture, window alteration and redesigning the interior spaces leads to greater daylighting benefits. The surrounding structures play an important role in acquiring the daylight into interior spaces .Even after implementing retrofitting such structures limits the daylight to some extent.

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