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Contribution of Each Facade Towards Daylight Penetration

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***Abstract*: Major changes in climate have been noticed lately and it is an architect's job to be sensitive about this matter and reduce fossil fuel consumption in response to these changes in climate. In order to do so, minimizing the consumption of artificial light can make major contributions to it. In this study, the contribution of each façade towards light penetration was analyzed with the objective of providing an idea of how light is penetrating indoor environment to the designers.**

***Keywords*: Daylight Penetration**

1. Introduction

The sun delivers an incredible amount of energy to us each day, and that's why it is a dominating influence on climates. Sun is a very important part of our life as nature feeds on the sun's radiations. From photosynthesis to water cycle everything depends on the sun. As the rays travel all the way to the earth's atmosphere only 50% of this energy reaches to the ground. These radiations travel through the earth's atmosphere and get reflected or diffused in the atmosphere. Figure 1 shows the passage of solar radiation through the earth's atmosphere. The sun releases an estimated 3.846x1026watts of energy in the form of light and other forms of radiation. The upper reaches of our atmosphere, the energy density of solar radiation is approximately 1368W/m^2 and that at earth's surface is reduced to approximately 1000W/m^2 for a surface perpendicular to the sun's rays at sea level on a clear day. (University of Tennessee, Institute of agriculture).

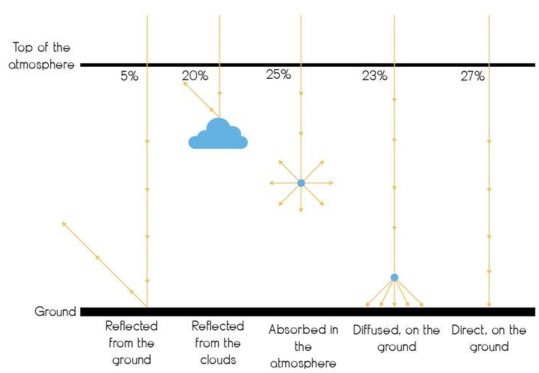

Fig. 1. Passage of radiation through the atmosphere

Daylighting is the controlled admission of natural light, direct sunlight and diffused-skylight into a building to reduce electric lighting, saving energy and to create visually stimulating productive visual environment for building occupants (Daylighting by Gregg D. Ander, FAIA, WBDG). From previous studies, findings revealed that tropical skies are not consistent and therefore allows for more sunlight which also in turn generates more heat gain and glare.

There is no common solution for daylight in all climates due to its dynamism; and the tropical climate, in general, is associated with intensive heat gain and solar radiation. Energy efficiency is achieved when there is a balance between heat gain and daylight penetration (Daylight penetration in buildings: Issues in tropical climate by Pela Ogheneyoma, Pirisola Heritage).

Harnessing this light energy (sun light or daylight) is an important part of a good architectural design. Architecture deals with the smart and effective use of this natural light in a building so that no space is left dark. From historical periods, various observations are made on different use of natural light in different types of buildings. Passive use of solar radiation functions without the need for technical systems. In it, the building itself makes direct use of solar energy by virtue of placement, geometry, material and building elements. This is the easiest and most effective form of solar architecture.

Ancient architectural works never ignored the importance of light, associating it with human health, well-being and positive energy. Description of light deities is seen in many mythologies. Studies show that human work efficiency is more in natural light than it is in artificial light, which makes it very important to admit light in spaces like schools, offices and hospitals. But direct sunlight must be excluded from buildings partly for thermal reasons and partly as it would unavoidably create glare, which makes it a challenge to admit light without heating up the space and providing a comfortable work environment. Admission of light always affects heating and cooling loads as much as it affects electric lighting loads. Thus, smart architecture is that which suggests a solution to admit light with maintaining internal thermal comfort.

Although, modern works of architects like Le Corbusier and Luis I Kahn show various example of daylight design, but many projects were entirely dependent on artificial lighting. As the technology is offering flexible artificial lighting solutions, designers are attracted more towards electronic fixtures of lighting. This, no doubt, provides an aesthetically enhanced environment, but increases the use of electricity at the same place making it expensive and non-green solution. Here comes a term ‘light pollution’ into play. Light pollution is the presence of excessive and misdirected use of artificial light especially at night which leads to disruption of circadian rhythm, affects the environment, energy resources, wildlife, humans and astronomy research as well. Thus it is very important for the engineers and architects to carefully design lighting systems and solutions for ecologically effective design.

In this era of social media, every one of us is aware of environmental changes and hazards around the world. Everyone has come across the fires in amazon forests and how global environment is changing drastically and the most important aspect is that no one is doing anything about it. These changes in the environment occur due to human interferences mostly. The main reason behind this is industrial revolution; it brought different manufacturing processes, new and different kinds of requirements which ultimately brought us to mechanized factory systems that used a large amount of electricity. Everything we gained from industrial revolution from the way to make our food to the way we should be wearing clothes, emits a certain amount of energy and greenhouse gases majorly carbon dioxide. A good way to balance out these emitted gases is to plant as much as trees possible as trees take carbon dioxide from the environment and give oxygen. But human cut-down trees for their needs which further led to deforestation. And due to lack of awareness, this problem is increasing rapidly every day.

The electric power we use in our house is also a ‘present’ that industrial revolution gave us. We all know how large amount of resources like fossil fuels are burnt down to make this energy. The requirement of this power is maximum in industries and educational buildings. Reduction in power consumption is a very important change to be made while construction and operation of the building although, power cut in a factory while manufacturing may cause loss to the owner of the factory for which maximum use of natural sources of energy is required. Due to malpractice in India, when factories are designed, these aspects are not taken under consideration which has worsened the current condition. Since sun is the biggest source of energy which is free to all, it is not a very difficult task to harness this energy but it comes with glare and heat. A precaution is to be made so that indoor thermal and visual comfort is maintained.

In this study, certain percentages and ratios are calculated and analysed through computer simulation to provide a thumb rule for daylight design in commercial and educational buildings in Indore, Madhya Pradesh, 22.71^0N, 75.85^0E. A specific room of size 10mx6m is taken assuming there are no external light barriers like buildings or trees close to it. The study is carried out in Indore, Madhya Pradesh taking weather data from Indian Society of Heating, Refrigerating and Air-Conditioning Engineers (ISHRAE) New Delhi, India. The simulations are carried out using Daysim, Radiance and Energy Plus through Diva.

2. Comfortable ranges

A. *Determining Visual Range*

Guide for Daylighting of Buildings *[CED 12: Functional Requirements in Buildings] (IS: 2440-1975)*, Code of Practice for Interior Illumination, *Part 2: Schedule of Illumination and Glare Index [ETD 24: Illumination Engineering and Luminaries] (IS 3646-2-1966)* were referenced during this study to determine standard comfortable lux level that is required in an office or school.

The study is carried out in Indore, having coordinates of 22.71^0N, 75.85^0E. IS: 2440-1975 assumes exterior illumination to be 8000 lux. In Table 1, IS: 2440-1975, solar altitudes are given by;

IS 3646-2-1966 gives indoor illumination level for different industrial and commercial activities. In this study only commercial activities are taken under consideration the minimum value of illuminance is required in areas like corridors, garage, passenger and goods lifts etc. which is 70 lux. Maximum value of illumination is required while sewing and darning of the value 700 illumination lux. In areas like reception and accounts, writing rooms, reading rooms, cash desk, study area etc. a value of 300 illumination lux is required. Other areas like dining, staircase or toilet required an illumination lux of 100units whereas areas like dressing, laundry, kitchen or workshops require illumination lux of 200units.

Taking in account these lux levels, a range of 200 to 700 lux is taken as comfortable range to perform a house hold or reading task. This range is taken during the computational simulation to analyze the illuminance of a specific room assuming it does not have any barrier of light surrounding it like trees or buildings.

Table 1

	June 22						Mar 21 Sep 23						Dec 22					
	7:00	8:00	9:00	10:00	11:00	12:00	7:00	8:00	9:00	10:00	11:00	12:00	7:00	8:00	9:00	10:00	11:00	12:00
	17:00	16:00	15:00	14:00	13:00		17:00	16:00	15:00	14:00	13:00		17:00	16:00	15:00	14:00	13:00	
10^0N	18	31	45	58	70	77	15	30	44	59	72	80	9	23	35	46	53	57
13^0N	19	32	46	60	72	80	15	29	44	58	70	77	8	21	33	43	51	54
16^0N	20	33	47	61	74	83	14	29	43	56	68	74	7	19	31	41	48	51
19^0N	21	34	48	62	75	86	14	28	42	55	66	71	5	18	29	46	45	48
22^0N	22	35	49	62	76	89	14	28	41	53	64	68	4	16	27	36	42	45
25^0N	23	36	49	63	76	88	13	27	40	52	61	65	3	14	25	34	39	42
28^0N	23	36	49	63	76	88	13	26	39	50	59	62	1	13	23	31	37	39
31^0N	24	37	50	62	75	82	13	25	37	48	56	56	-	11	21	28	34	36
34^0N	25	37	49	62	75	79	12	25	36	46	55	56	-	9	18	26	31	33

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Table 2

S. No.	Buildings and Processes	Illumination Lux
	Hotel	
a.	Entrance Halls	150
b.	Reception and accounts	300
c.	Dining rooms (tables)	100
d.	Lounges	150
e.	Bedrooms:	
	General	100
	Dressing tables, bed head, etc.	200
f.	Writing rooms (tables)	300
g.	Corridors	70
h.	Stairs	100
j.	Laundries	200
k.	Kitchens	200
l.	Goods and passenger lifts	70
m.	Cloakrooms and toilets	100
p.	Bathrooms	100
	Restaurants	
a.	Dining rooms:	
	Tables	100
	Cash desks	300
b.	Self-carrying counters	200
c.	Kitchens	200
d.	Cloakrooms and toilets	100
	Shops and Stores	
a.	General areas	150 to 300
b.	Stock rooms	200
	Homes	
a.	Kitchens	200
b.	Bathrooms	100
c.	Stairs	100
d.	Workshops	200
e.	Garages	70
f.	Sewing and Darning	700
g.	Reading (casual)	150
h.	Homework and sustained reading	300

3. Contribution of Each Façade for Daylight Penetration

A. Determining size of the module

According to IS 3646-2-1966, a maximum amount of illumination is required for works like sewing and darning, homework and sustained reading. Therefore, a module of 10m by 6m is taken with a height of 3m, as this is a general size of a classroom as seen in various buildings. In this module opening is placed on the shorter side so as to analyze light penetration through the length of the module.

In this chapter, one wall of the module was deleted and then simulation was carried out rotating it in each direction so as to analyze the initial amount of light penetrating in the module without any barrier. The results are given in percentage in the range of 200 to 700 illumination lux.

B. Calculating contribution of each façade towards light penetration

The module was placed in four permutations, facing each direction one-by-one with one shorter wall deleted so the total amount of light penetration form that direction can be simulated.

1) East facing façade

For the module facing east direction, 100% of floor area is day lit with a mean daylight factor throughout the year of 8.7%. The illumination lux goes from 98% to 75% through the length. (Figure 3).

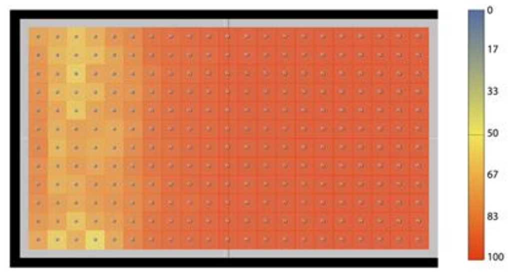

Fig. 2. East facing module without wall in east direction

2) South facing façade

For the module facing South direction, 100% of floor area is daylit with a mean daylight factor throughout the year of 8.7%. The illumination lux goes from 98% to 78% through the length. (Figure 4).

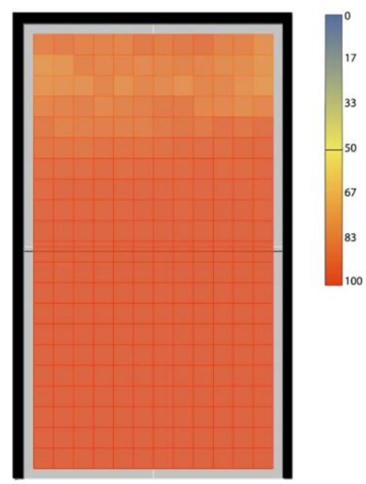

Fig. 3. South facing module without wall in South direction

3) West facing façade

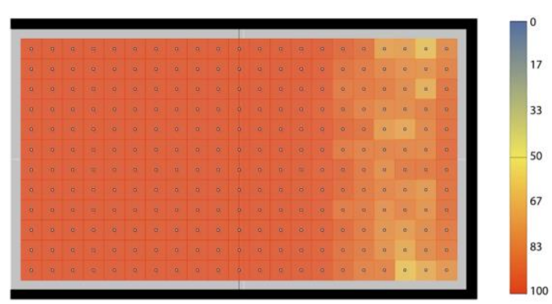

Fig. 4. West facing module without wall in west direction

For the module facing West direction, 100% of floor area is daylit with a mean daylight factor throughout the year of 8.7%. The illumination lux goes from 98% to 75% through the length. (Figure 5).

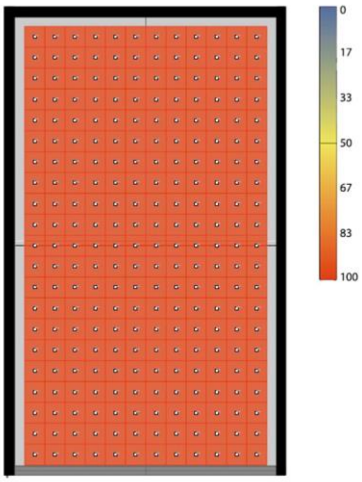

Fig. 5. North facing module without wall in North direction

C. *Comparing the results*

Direction	Daylit Area (%)	Annual Daylight Factor (%)	Illumination (%)	
			Min.	Max.
East	100	8.7	75	98
South	100	8.7	78	98
West	100	8.7	75	98
North	100	73.3	85	98

The module behaved similarly in east and west directions, although the results in south and north were different. 100% of the floor area was lit in all the four cases but the penetration was from 98% to 75% in east and west, on the other hand it was from 98% to 78% in south and it was uniform throughout the length in north.

Also, the mean daylight factor throughout the year for east south and west is the same of 8.7% but it increases to 73.3% in north because of the constant penetration of light in the module.

4. Calculation for openings

A. *Determining geometry of the opening*

In this sction, an opening of 1.4m height and 3.2m width was created 0.9m above floor level which is about 8.3% of the carpet area; on one wall of the module. According to a thumb rule given in time saver standards, the total area of openings should be minimum 25% of the carpet area of the room, assuming that there will be an opening planned on three sides of this module with the remaining side having door one-third of 25% is to be provided on one wall hence 8.3% of the carpet area.

B. *Calculating contribution of each façade towards light penetration*

1) East facing opening

For the module facing east direction, 38% of floor area is daylit with a mean daylight factor throughout the year of 2.5%. The illumination lux goes from 98% to 0% through the length. (Figure 7)

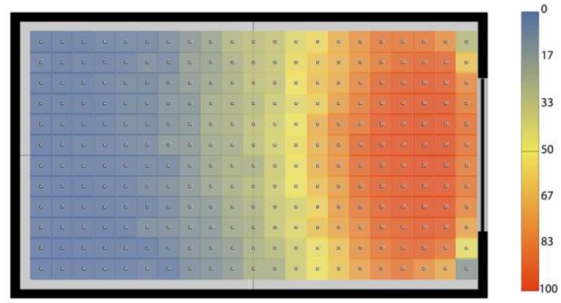

Fig. 6. East facing module with opening in east direction

2) South facing opening

For the module facing South direction, 44% of floor area is daylit with a mean daylight factor throughout the year of 2.5%. The illumination lux goes from 98% to 0% through the length. (Figure 8).

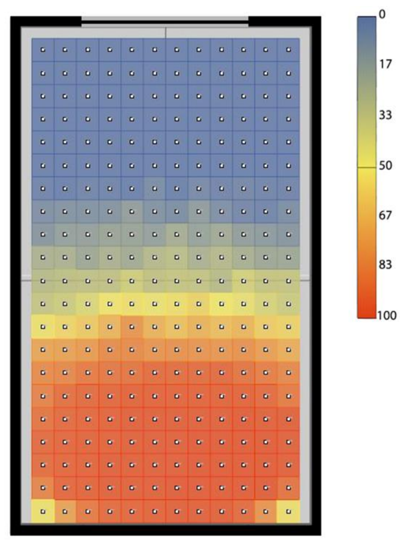

Fig. 7. South facing module with opening in South direction

3) West facing opening

For the module facing West direction, 40% of floor area is daylit with a mean daylight factor throughout the year of 2.5%. The illumination lux goes from 98% to 0% through the length. (Figure 9).

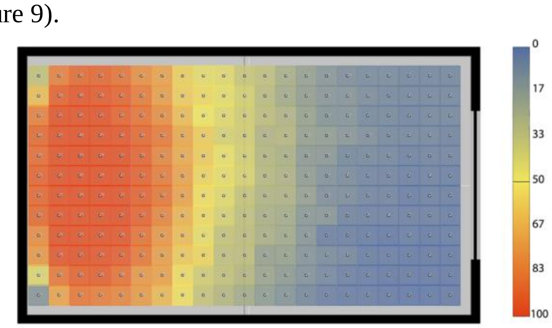

Fig. 8. West facing module with opening in west direction

4) North facing opening

For the module facing North direction, 30% of floor area is daylit with a mean daylight factor throughout the year of 2.5%. The illumination lux goes from 98% to 0% through the length. (Figure 10).

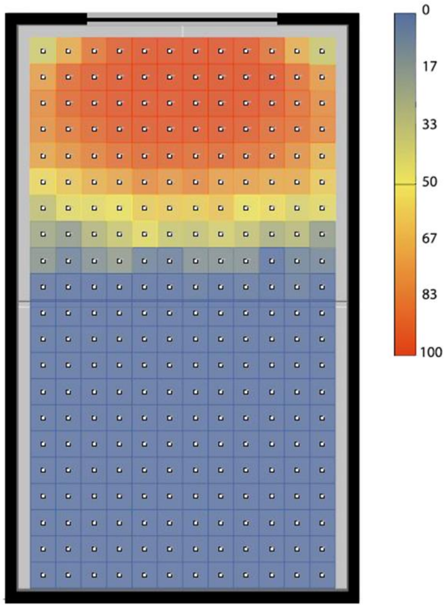

Fig. 9. North facing module with opening in North direction

C. Comparing the results

Direction	Daylit Area (%)	Annual Daylight Factor (%)	Illumination (%)	
			Min.	Max.
East	38	2.5	0	98
South	44	2.5	0	98
West	40	2.5	0	98
North	30	2.5	0	98

The module behaved differently in all directions, although the mean daylight factor was same in all directions being 2.5%. 38% of the floor area was lit in east, 44% of the floor area was lit in south, 40% of the floor area was lit in west and 30% of the floor area was lit in East. All the four cases had the penetration from 98% to 0% throughout the length.

In the same geometry of the opening, the best results were given from south providing illumination to maximum floor area (viz. 44%) then west (40%) then east (38%) and the least was 30% provided in the north direction.

5. Conclusion

In the first exercise, the best results were given in north with annual daylight factor of 73.3% and uniform light penetration through the length. But in second exercise, north presented poor results with minimum floor area illumination. Looking at these results, this can be concluded that although light is uniform in north, it needs larger opening in order to provide comfortable illumination. This proves that the 1/8th of floor area for opening are is not sufficient in north direction.

The light penetration in south east and west were similar in the first exercise but in second exercise, south had maximum illuminated area, then west and then east although the differences in these areas were not too much. These results show that 1/8th of floor area for opening area is sufficient in these three directions.

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