# DAYLIGHT PERFORMANCE IN SOUTH FACING ROOMS OF RESIDENTIAL APARTMENTS IN RESPECT OF CURRENT BUILDING CODE (2008): RELATION BETWEEN OBSTRUCTION DISTANCE AND OPENING SIZE

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**Abstract**

Dhaka, the capital city of Bangladesh is one of the highly dense cities in the world. Demand of residence is increasing with the increasing number of population. Orientation of building and microclimate of surrounding varies a lot in this city. In tropical region where daylight is plenty in amount, south facing room gets blessing of sunlight almost fulltime in a day. What happen when surrounding situation changes because of following rules, building code (Floor Area Ratio, Set Back)? One size of land is selected to evaluate its daylight performance, where building volume and height is fixed. The experiment is done by computer simulation. The study was also based on the comparative analysis of the difference of opening size with the change of the building surroundings. The simulation was done by Eco-Tech software and no field survey was conducted. The research result concluded that the lighting condition of south facing room at different condition could control by changing the opening size. With the change of the percentage of opening can do better lighting environment at interior space.

**Keywords:** South facing room, Lighting Performance, Opening size, FAR, Set back, urban residence

## 1. Introduction

It is acknowledged that by maximising of the use of natural lighting (daylight) a significant reduction in artificial lighting and thus primary energy consumption can be achieved (Crisp, Littlefair, Cooper, and McKennan, 1998). A good provision of daylight is now considered to be highly desirable in terms of building occupants well-being and productivity (Heschong, 2002). The goal of making good use of daylight provision however needs to be tempered by the need to prevent the undue occurrence of very high levels of daylight luminance since these are associated both with visual discomfort and the likelihood of excessive solar gain (i.e. increased cooling loads) (Mardaljevic, 2008).

We are blessed by daylight almost all daytime around the year but temperature and humidity is always major important issues for our climate. Building orientation and indoor environment always dominated by solar heat gain. Therefore main concern about designing a building is reducing heat gain and beside increase daylight in indoors spaces. For south facing room, the opening penetrated daylight and the amount reduce with the increase of the depth of the room. Therefore, daylight performance of the room depends on the opening size, surrounding condition and the depth of the room (Marsh, 2010).

In Dhaka city, residences are designed by following FAR (Floor Area Ratio), Set back and some other issues. The orientation of the buildings governs the indoor day light conditions. With the location of the road and other buildings, every residence gets some constant urban situation. These are the cause of the difference of lighting performance. It also varies with the height of the building. This study tries to find out the optimum performance of indoor daylight environment at different conditions. It also tries to establish a general volumetric ratio of a room with opening size and depth of the room.

## 2. AIMS AND OBJECTIVE:

The study focuses on daylight strategies on Residential buildings of Dhaka Bangladesh, which follows latest building code and proposes some design guidelines. Particular emphasis has been given on increasing daylight inclusion to the south facing rooms. The objectives of the study are as follows:

- To explore the nature of the luminous environment of south facing rooms through literature survey.
- To identify parameters that can help to improve the luminous environment of south facing rooms by daylight inclusion in residential buildings under current building code.

• To recommend some opening configuration to increase daylight inclusion in rooms through simulation study.

• To prepare a basis for further study to investigate the consequences of daylight inclusion.

## 3. BACKGROUND STUDY:

### 3.1 Climate of Bangladesh and the City of Dhaka

Bangladesh lies between 20º 34′ N to 26º 33′ N and 88º 01′ E to 92º 41′ E, and is in the Indo-Malayan Realm. The climate of Bangladesh is based on the widely used classification by Atkinson (Koenigsberger, 1973) is categorized as warm-humid.

Dhaka city has mainly three different seasons (Trip Advisor, 2011). These are:

1. The hot dry season (March-May)
2. The hot humid season (June- November)
3. The cool dry season (December- February)

April is considered as hottest month and temperature varies 30.3$^0$C to 34.8$^0$C, January is considered as coldest month and temperature ranges 9 $^0$C to15.2 $^0$C (BBC, 2011).

Table 1: Sky condition with respect to Days with clouds for year (Joarder, AR, 2007)

| Type of sky | Hot dry | Warm humid | | Cool dry Dec-Feb | Total Days |
|---|---|---|---|---|---|
| | Pre-monsoon March-May | Monsoon on June-Sept | Post-monsoon Oct-Nov | | |
| Clear sky | 62 | 38 | 39 | 77 | 215 |
| Overcast sky | 30 | 84 | 22 | 14 | 150 |
| Total days | 92 | 122 | 61 | 90 | 365 |

### 3.2. Present scenario of energy consumption:

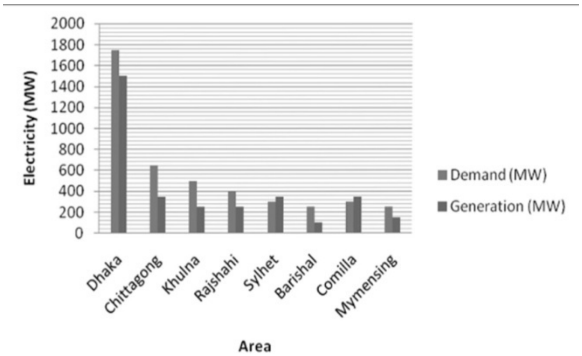



Fig. 1 Maximum demand and generation in area wise peak hour

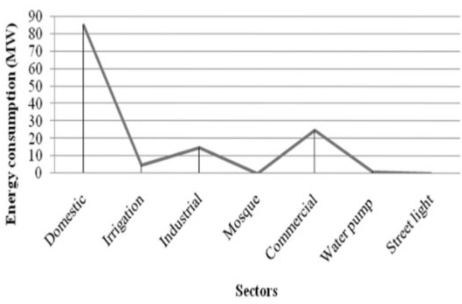



Fig. 2 Electric energy consumption pattern in various sector

Fig. 1 represents electricity demand and generation scenario in peak hour of eight main cities in Bangladesh. From Fig. 1 it can be seen that there is a big difference of energy demand and generation in Dhaka city with others. (Dhaka Power Development Board, Bangladesh, 2010)

Fig. 2 represents electric consumption pattern in various sectors of Dhaka city. In Fig. 2 it is seen that in domestic sector the highest energy consumption is happened at Dhaka city, Bangladesh. (Dhaka Power Development Board, Bangladesh, 2010)

### 3.3 Studies on LEED:

Leadership in Energy and Environmental Design (LEED) is a suite of rating systems for the design, construction, operation, and maintenance of green buildings, homes and neighborhoods, developed by the U.S. Green Building Council (USGBC). Rating systems are groups of requirements for projects that want to achieve LEED certification and each group is geared towards the unique needs of a project or building type. Within each of the LEED credit categories, projects must satisfy prerequisites and earn points (USGBC, 2013). The number of points the project earns determines its level of LEED certification. Main credit categories are Sustainable sites, Water efficiency, Energy & atmosphere, Materials & resources, Indoors environmental quality. Energy & atmosphere credits promote better building energy performance through innovative strategies.

For daylight and view, LEED credit has 2 points, where more credit can earn through minimise energy consumption.

### 3.4 Required light for residence:

RESIDENCES

| AREAS -ACTIVITIES | TYPE OF WORK | Recommended Lux - (Minimum Lux) |
|---|---|---|
| Reception areas (living rooms) | (General) | 150 |
| | (Localized: reading, writing, etc) | 1000 – (500) |
| Kitchens | (General) | 150 |
| | (Localized: sink, table) | 500 – (250) |
| Bedrooms | (General) | 150 |
| | (Localized: mirrors, children beds) | 200 – (70) |
| Corridors – staircases– garage | (General) | 150 |
| | (Localized) | 500 – (250) |

**Source: Internet**

### 3.5 About Daylight in design:

Design guidelines recommend daylight provision in terms of the long-established daylight factor (Cannon-Brookes,1997). Formulated in the UK over fifty years ago, the daylight factor is simply the ratio of internal luminance to unobstructed horizontal luminance under standard CIE overcast sky conditions. It is usually expressed as a percentage, so there is no consideration of absolute values. The luminance of the CIE standard overcast sky is rotationally symmetrical about the vertical axis, i.e. about the zenith. And, of course, there is no sun. Thus for a given building design, the predicted DF is insensitive to either the building orientation (due to the symmetry of the sky) or the intended locale (since it is simply a ratio).

## 4. EXPERIMENTAL METHOD:

This research is developed through a computer simulation of the model house. The resultant indoor daylight condition of south facing room is compared with different opening condition as well as different surrounding condition. Surrounding condition has been developed by future prediction of a typical site under present building code (2008). According to the modelling considerations the daylight factor & natural lighting level were calculated with the help of Autodesk Ecotect Analysis software (Building performance software). The comparative lighting performance evaluation was made on the basis simulation result.

The entire computer simulation was carried out for daylight conditions under Overcast sky conditions. The sample rooms having similar floor area, floor to ceiling height identical glazing (area and glass combination), glazing height and identical wall, floor and ceiling reflectance were taken into consideration in this study. Climate-based daylight modelling (CBDM) was carried out using computer simulation techniques.

### 4.1 Sample:

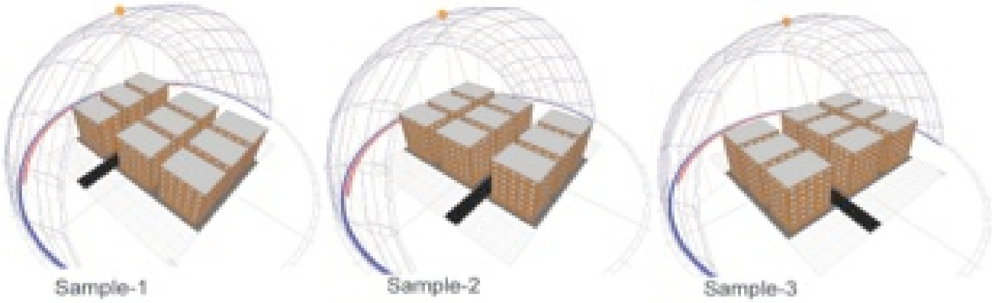
Three types of samples are modelled in terms of 3 different surrounding situations. For all cases 5 katha (3600 sft) land with all same type of land around the sample plot is taken. 20’ wide adjacent road is considered. Floor area Ratio (FAR), Set Back, and Maximum Ground Coverage (MGC) is counted by following BNBC 2008. Here total floor area 12600sft (FAR 3.5), Maximum ground coverage 2250sft (MGC 62.5%). Total building height is 7 stories where ground floor is parking. Three possible arrangements have been taken as sample for evaluating daylight performance at south facing room.

**Sample-1:** 1$^{st}$ model has 20’ wide road at south side and same size plot with building after the road. Therefore building-to-building distance is 32’.

**Sample-2:** At 2$^{nd}$ model, south is rear side of the plot. It has plot with building at rear side. Therefore building distance is 15’ by set back calculation.

**Sample-3:** At 3$^{rd}$ model, south is at one side of the plot. It has plot with building at side. Therefore building distance is 10’ by set back calculation. Road at east side.

In residential building, generally we use two types of living spaces. One is private zone which is bed rooms and another is common spaces like dinning, family living, living spaces. In this study 12'x12' room is taken as sample which is like bed rooms and 20'x20' room as common spaces. For both types of spaces, opening size is identified for optimum lighting level at different conditions.




**4.2 Instruction and conditions:**

At any given arrangement, room at lower height get less daylight rather than upper story rooms in a dense urban situation like Dhaka. Typically most of the residential apartments use their ground floor as car parking. Therefore 1st floor is being considered critical in case of daylight performance. Room at corner of the building plan has opportunity to use opening in multi-direction that bring better daylight performance. This study considered only rooms at middle position (which has opportunity to provide opening only one side) of 1st floor to evaluate optimum size of the window to ensure adequate daylight.

- 150 lux is considered as adequate light.
- Room size 20'x20' and 12'x12' are used as sample.
- Firstly typical opening height is being considered, i.e. most commonly used 4.5 feet window. (From 2.5' seal level to 7' lintel level). Opening width has been taken simultaneously.
- Secondly vertical type windows also considered 7' height (where 1' seal level to 8' lintel level).
- Lowest size of the opening for 150 lux at rear end of the room is marked.
- 15'' shading device is considered every time
- Exterior and interior is plaster and 5'' wall room.
- Glazing window with aluminium frame is considered.
- Surrounding building considered as brick surface (Exterior), road is pitched and outside is normal exposed ground.

- Properties of inner surface, glazing and shading device and the U Value (Coefficient of heat transmission) of the construction materials:

| Item | Material | U Value ($W/m^2\ ^0C$) | Solar Absorption $Wm^{-2}$ | Thermal Decrement |
|---|---|---|---|---|
| Wall | 110mm brick (4.33”) with 10mm (0.4”) plaster in both sides | 2.620 | 0.418 | 0.7 |
| Window | Single panel of glass with aluminium frame (no thermal break). | 6.000 | 0.94 | 1.74 (refractive index of glass) |
| Roof | Concrete Roof Asphalt | 0.896 | 0.9 | 0.58 |
| Floor | 100mm thick (3.94”) concrete slab on ground | 0.880 | 0.467 | 0.3 |
| Shading device | Concrete Roof with plaster | 0.896 | 0.9 | 0.58 |

## 5. RESULTS AND FINDINGS:

After completion of simulation and analysis of data, the following outcomes are observed:

**<u>For 20’x20’ room:</u>**

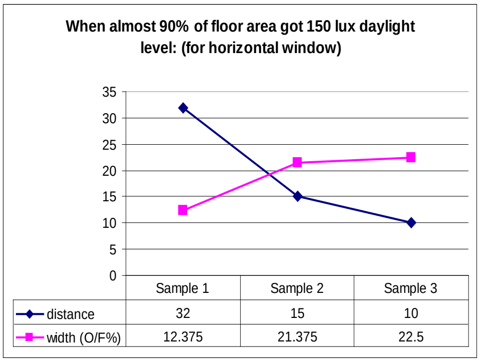
### 1.1. When almost 90% of floor area got 150 lux daylight level: (for horizontal window)

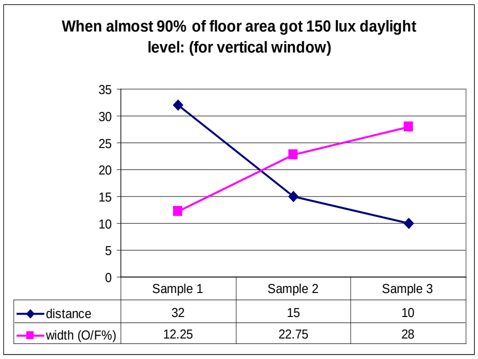
| Sample | Building to building distance | Width of window (where height is 2.5’ to 7’) feet | Window area Square feet | Opening % (of floor area) | Opening % (of surface area) | Remarks |
|---|---|---|---|---|---|---|
| Sample 1 | 32’ | 11’ | 11x4.5=49.5 | 12.375% | 24.75% | Lighting level is from 773 lux to 130 lux |
| Sample 2 | 15’ | 19’ | 19x4.5=85.5 | 21.375% | 42.75% | Lighting level is from 1597 lux to 140 lux |
| Sample 3 | 10’ | 20’ | 20x4.5=90 | 22.5% | 45% | More length may require |

### 1.2. When almost 90% of floor area got 150 lux daylight level: (for vertical window)

| Sample | Building to building distance | Width of window (where height is 1' to 8' feet) | Window area Square feet | Opening % (of floor area) | Opening % (of surface area) | Remarks |
|---|---|---|---|---|---|---|
| Sample 1 | 32' | 7' | 7x7=49 | 12.25 | 24.5% | Lighting level is from 773lux to 130lux |
| Sample 2 | 15' | 13' | 13x7=91 | 22.75 | 45.5% | Lighting level is from 1597lux to 140lux |
| Sample 3 | 10' | 16' | 16x7=112 | 28 | 56% | More length may require |

### Comparison of building-to-building distance and floor-opening ratio:




From the figure it is revealed that required opening, floor area and and window ratio for target daylight level is **inversely proportionate** with building to building distance for both horizontal and vertical opening.

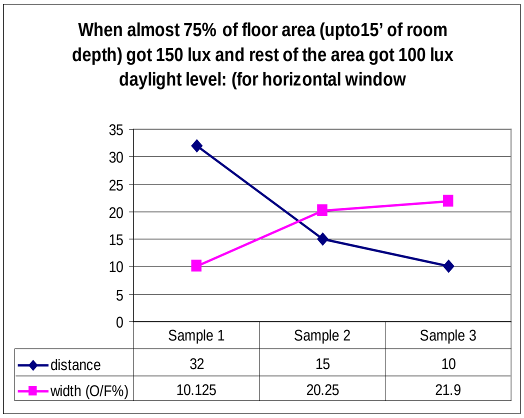
### 2.1 When almost 75% of floor area (upto15' of room depth) got 150 lux and rest of the area got 100 lux daylight level: (for horizontal window)

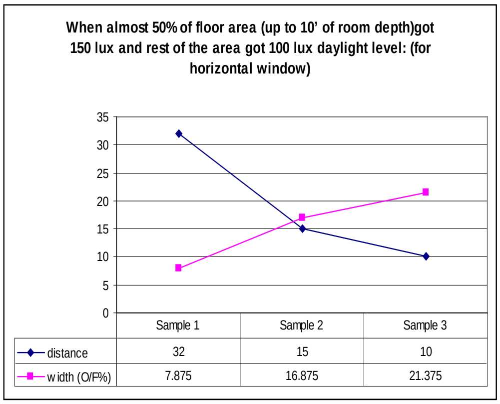
| Sample | Building to building distance | Width of window (where height is 2.5'to7') feet | Window area Square feet | Opening % (of floor area) | Opening % (of surface area) | Remarks |
|---|---|---|---|---|---|---|
| Sample 1 | 32' | 09' | 09x4.5=40.5 | 10.125% | 20.25% | Lighting level is from 704lux to 117lux |
| Sample 2 | 15' | 18' | 18x4.5=81 | 20.25% | 40.5% | Lighting level is from 1568lux to 127lux |
| Sample 3 | 10' | 19.5' | 19.5x4.5=87.75 | 21.9% | 43.875% | Lighting level is from 854lux to 127lux |

### 2.2. When almost 50% of floor area (up to 10' of room depth) got 150 lux and rest of the area got 100 lux daylight level: (for horizontal window)

| Sample | Building to building distance | Width of window (where height is 2.5'to7') feet | Window area Square feet | Opening % (of floor area) | Opening % (of surface area) | Remarks |
|---|---|---|---|---|---|---|
| Sample 1 | 32' | 07' | 07x4.5=31.5 | 7.875% | 15.75% | Lighting level is from 652lux to 103lux |
| Sample 2 | 15' | 15' | 15x4.5=67.5 | 16.875% | 33.75% | Lighting level is from 1534lux to 107lux |
| Sample 3 | 10' | 19' | 19x4.5=85.5 | 21.375% | 42.75% | Lighting level is from 854lux to 120lux |

### Comparison of building-to-building distance and floor-opening ratio




From the figure above it is revealed that required opening, floor area and window ratio for target daylight level is **inversely proportionate** with building-to-building distance for different amount of daylight inclusion.

### <u>For 12'x12' room:</u>

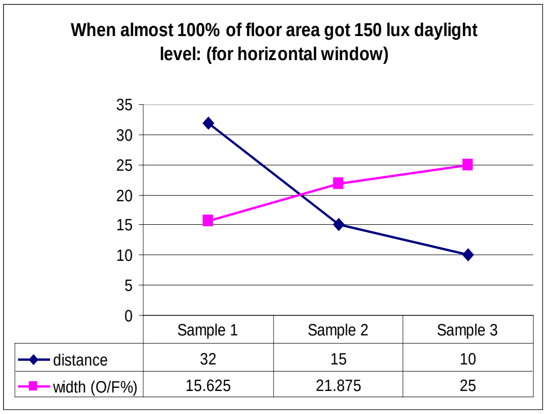
### 1. When almost 100% of floor area got 150-lux daylight level: (window is horizontal type)

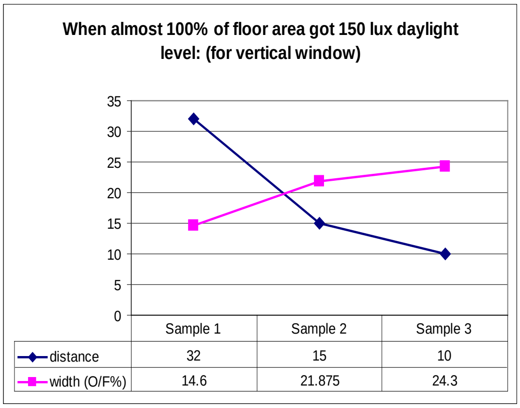
| Sample | Building to building distance | Width of window (where height is 2.5'to7') feet | Window area Square feet | Opening % (of floor area) | Opening % (of surface area) | Remarks |
|---|---|---|---|---|---|---|
| Sample 1 | 32' | 5' | 5x4.5=22.5 | 15.625% | 18.75% | Avg value-317.5 lux |
| Sample 2 | 15' | 7' | 7x4.5=31.5 | 21.875% | 26.25% | Avg valu-321.5 |
| Sample 3 | 10' | 8' | 8x4.5=36 | 25% | 30% | Avg value-259 lux |

**2. When almost 100% of floor area got 150-lux daylight level: (window is vertical type)**

| Sample | Building to building distance | Width of window (where height is 1'to8' feet) | Window area Square feet | Opening % (of floor area) | Opening % (of surface area) | Remarks |
|---|---|---|---|---|---|---|
| Sample 1 | 32' | 3' | 3x7=21 | 14.6% | 17.5% | Avg value - 242.9 lux |
| Sample 2 | 15' | 4.5' | 4.5x7=31.5 | 21.875% | 26.25% | Avg value – 289.5 lux |
| Sample 3 | 10' | 5' | 5x7=35 | 24.3% | 29.16% | Avg vale - 280.3 lux |

**Comparison of building-to-building distance and floor-opening ratio:**




From the figure above it is revealed that required opening, floor area and window ratio for target daylight level is **inversely proportionate** with building-to-building distance for both horizontal and vertical opening

1. These analyses show that building-to-building distance has great impact on daylight penetration of building. Obstructions in front of opening decrease the lighting level. More distance gives better daylight inclusion at fewer apertures.
2. Present building code gives better inclusion of daylight at roadside rooms. At other three sides, it needs almost 1.5-time large opening for same amount of daylight inclusion.
3. For large space in depth of 20', vertical window can give better daylight inclusion than horizontal windows.
4. At distance after 10' from opening, daylight performance changes relatively slow with the change of opening size. At 15' depth, it is

moderate. Therefore more than 15’, it is not easy to penetrate daylight with close distance obstruction. It may need supplementary lighting for better luminous environment.

5. For bed room (100 to 150 sft rooms), both horizontal and vertical windows with same area gives same type of daylight inclusion at interior space, therefore for large area, vertical window gives better performance.

## 6. SCOPE AND LIMITATIONS:

This analysis specially focused on day light level at south facing room. Solar radiations also penetrate with daylight. Different types of window and different orientation like north, east and west can consider at time of research. Further study can be held on over all lighting and thermal comfort solution at urban residential building. Different urban situation and microclimate affect differently in indoor environmental lighting quality.

## 7. CONCLUSION:

It can be concluded that the rooms at south can be blessed by natural light through proper design of opening. This analysis can give designer some proportion of opening at different orientation at city environment. Basic guideline of suitable opening size can be derived. Therefore a building should be designed with proper orientation of living spaces for better indoor environment. Different urban situation affects our living space. Over growing settlement and development increase density. Therefore we should conscious to improve our urban planning and microclimate for our better city condition.

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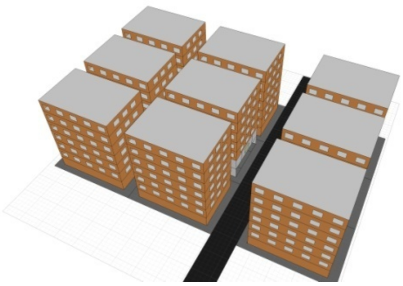
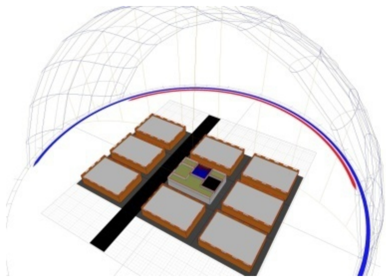
## 09. APPENDIX

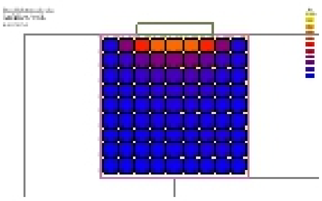
Lighting Simulation environment and simulation plane



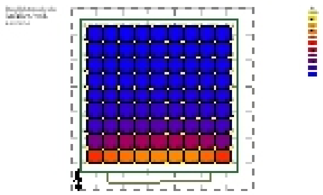


## For 20'x20' room:

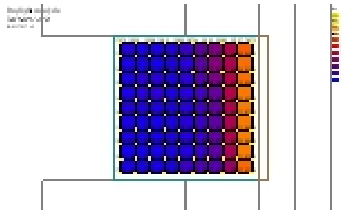
1.1. When almost 90% of floor area got 150 lux daylight level: (for horizontal window)



Sample-1

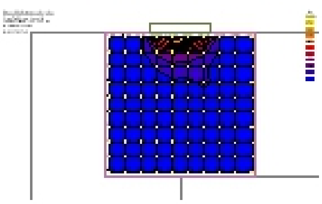


Sample-2

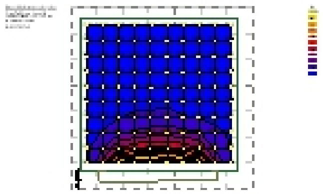


Sample-3

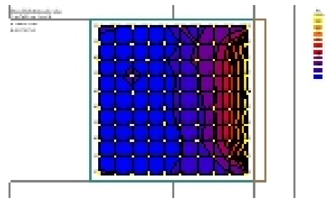
1.2. When almost 90% of floor area got 150 lux daylight level: (for vertical window)



Sample-1

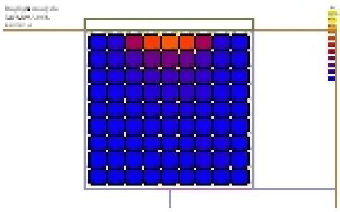


Sample-2

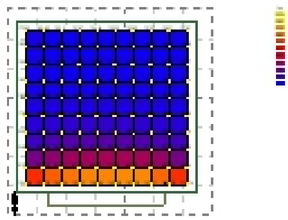


Sample-3

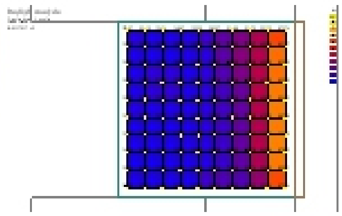
2.1 When almost 75% of floor area (upto15' of room depth) got 150 lux and rest of the area got 100 lux daylight level: (for horizontal window)



Sample-1

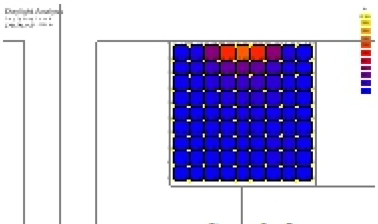


Sample-2

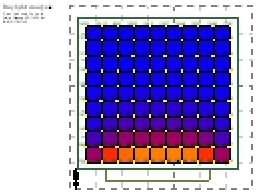


Sample-3

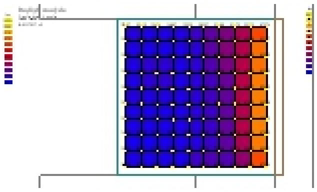
2.2. When almost 50% of floor area (up to 10' of room depth) got 150 lux and rest of the area got 100 lux daylight level: (for horizontal window)



Sample-1



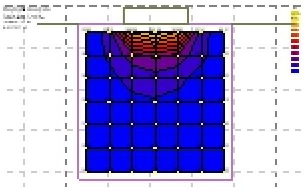
Sample-2



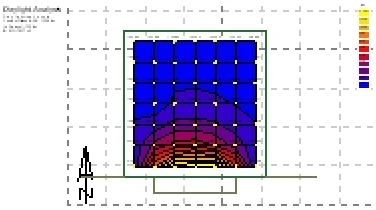
Sample-3

## For 12'x12' room:

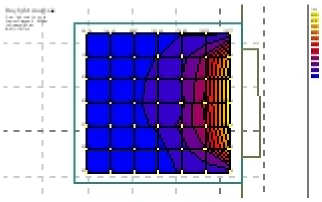
**1. When almost 100% of floor area got 150 lux daylight level:** Here window is horizontal type



Sample-1

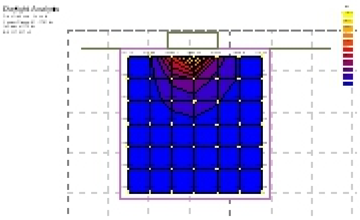


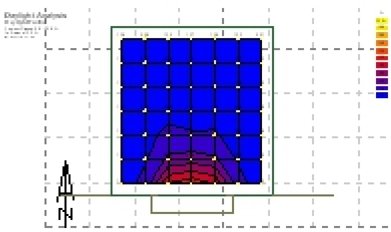
Sample-2



Sample-3

**2. When almost 100% of floor area got 150 lux daylight level:** Here window is vertical type





Sample-1

Sample-2