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Light and Ventilation Analysis for Infrastructure in an Urban Region- A Case Study

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Abstract

Pressure on infrastructure due to over population has deteriorated the indoor environment causing various health issues. It has also contributed to the sick building syndrome making huge monetary burden to economy. Public health department of the country has taken many actions to mitigate these issues however; design of the building was not taken into consideration. Optimum quantities of light and proper ventilation express the quality of indoor environment. Also, the use of natural light and ventilation is definitely an advantage with the raising concerns regarding the cost and environmental impact of energy use. Natural light and ventilation can reduce building construction and operation costs and reduce the energy consumption. Moreover it would also ensure safe, healthy and comfortable living conditions. Therefore, it is very important to assess indoor environment before implementing new construction or building. This provides theoretical guidelines and basic calculations for understanding a green infrastructures and the factors related to it. In this paper, a building has been studied in an urban city of India where the percentage area of light and ventilation were analyzed. Analysis showed the percentage of light is thrice and ventilation is twice the prescribed limits by Indian Green Building Council (IGBC). It has been found that building under study fulfills the given criteria by IGBC. This analysis can be useful while constructing a new infrastructure to improve the standard of living as 90% time is spent indoors.

Keywords: glazing factor; IGBC; carpet area

1. Introduction

Habitat is described as an adequate space with security, accessibility, lightening, heating, ventilation and basic infrastructure within the affordable cost (Bonnefoy, 2007). However, building designs these days mostly rely on the structure and maintenance charges of the infrastructure ignoring the health of occupants. Migration causes population explosion in an urban region (Islam *et al*., 2014; WUP, 2014). More population demands more habitats resulting in a massive growth in construction and developmental field (Meerow and Newell, 2017; Nan and Sansavini, 2017). Furthermore, for the faster monetary benefit, many areas have buildings built illegally without any compliance with current planning and building regulations (Dana, 2011). This subsequently results in the immediate next door construction blocking the circulation of the pollutants enclosed within the compact structures which eventually deteriorates the air quality indoors, causing a negative impact on occupants. (Carlet, 2015; Tzoulas *et al*., 2007; Zellner *et al*., 2016). There is important role for light and ventilation in habitat for human beings (Thirumal and Saraswathy, 2010).

Indoor Air Quality (IAQ) is the quality of air inside the building and its near surrounding and is represented by the concentration of pollutants and the comfort parameters like thermal (temperature and relative humidity) conditions that affect the health and performance of occupants (Boleij and Brunekreef, 1982; OSHA, 2011). It is an important environmental health concerns as people spend 60-90 % of their life in indoor environments like houses, offices, schools, etc. (Mohammed and Srinivas, 2011). Wide range of sources emanate indoor air pollutants like combustion of kerosene, tobacco, coal etc., volatile organic, compounds emitted by building materials, biological contaminants. Outdoor pollution is also the major contributor in indoor air pollution. Poor IAQ leads to the 'Sick Building Syndrome' where rapid increase in the amount of pollutants result in defiled air leading to discomfort (Hedge and Erickson, 1997; Kalimeri *et al*., 2016). Proliferation of the pollutants is majorly due to the inadequate ventilation and a significant lack of natural daylight. Annually air pollution leads to 3.7 million deaths precisely in an urban area (WHO, 2014).

Several positive impacts of natural sunlight and ventilation has been studied and depicted worldwide. Light and ventilation are one of the major components considered while designing a green infrastructure and determining the indoor air quality. Moreover, before the development of antibiotics, ventilation, natural sunlight and cleanliness were the three pillars of infection control and were considered key in preventing diseases spreading in buildings (Dancer and Path, 2013). Sunlight induces Vitamin D production (Edwards and Torcellini, 2002), stimulates the hormonal system (Wurtman, 1975) synchronizes the body's biological rhythms. A lack of exposure to sunlight will lead to a gradual degeneration of the body (Braun, 2008). Natural Ventilation provides thermal comfort by providing a heat transport mechanism (Kleiven, 2003; U.S. EPA, 1990). It dilutes the indoor pollution concentration and also renders electric energy consumption (Jomehzadeh *et al*., 2017). The only disadvantage of natural ventilation is as it dilutes the indoor air pollution, it may also let the filthy outdoor air in.

Thus, it becomes an important issue to stimulate the reliance on green infrastructure. Encouraging the resilience on sustainable infrastructure and strategically gaining equilibrium between economy and sustainability are the prime agenda of ecologists. To drag construction companies towards eco-sensitive zone, Indian Green Building Council (IGBC) has been established for the regulation of Green Building. Green Buildings are the structures that ensure efficient use of natural resources like building materials, water, energy and other resources with minimal generation of non-degradable waste promoting quality environment. The development of IGBC Green Homes Rating System is another important step in this direction (IGBC, 2012).

Numerous studies have been conducted to integrate natural daylight and ventilation into the building design decision. Research included both software related analysis as well as calculations based analysis. To mention one, software TRNSYS_LIGHT, was used that allows static and dynamic simulation of rectangular rooms and the results are calculated by the illumination in Lux at the floor. (Schweizer *et al*., 1998). Chandra (1987) calculates natural ventilation in building using building pressure coefficient. The main limitations of the program are that only rectangular rooms are permitted and that neither the surrounding of the simulated room nor atria situations can be considered (Chandra, 1987).

Additional studies has also been carried out for developing green infrastructure spatial planning considering many factors such as storm water management, social vulnerability, green space, air quality, urban heat island amelioration and landscape connectivity (Meerow and Newell, 2017). An indoor air quality assessment by Kalimeri *et al*. (2016) showed the positive outcomes and increased productivity was noted in school students and office staff. Country wise assessment using AERMOD was done to study the indoor air pollutants and their effects (Kunkel and Kontonasiou, 2015). Also, to calculate indoor air quality as a whole, software tools has been designed by United States National Institute of Standards and Technology (NIST) like Indoor Air Quality Design Tool (IAQDT) to aid in contaminant-based design of ventilation systems. The other is CONTAM (ver. 2.4), is a computer program for a multizone airflow and indoor air quality and ventilation analysis that predicts the concentration of contaminants and the airflows in a building under study (Muller and Stanley, 2007).

The overall objectives of the study are to highlight the importance of daylight and natural ventilation and also to design a basic and not so complicated procedure for their evaluation. Economically, India is a weak country, cost cutting ideas has to be lateral with the development. Hence, the undertaken study would analyze the factors in a limited time without much tools, software and expertise unlike the other related studies.

2. Materials and Methods

2.1 Study area

Congestion is mostly seen in urban cities and hence the urban area was selected for the study (Fig. 1). A thirty stories building in a Mumbai city was studied as shown in Fig. 2. The building consists of 1 and 2 BHK flats and a refuge area. Most of the flats faced towards north west and south east side. Refuge floors are on 7^{th}, 11^{th}, 16^{th}, 21^{st}, 26^{th} floor. Different parameters like carpet area, number and area of windows, glass type used, type of ventilation, total openable area including doors etc. were studied. Mathematical calculation was done based on the ratios of openable area, floor area and carpet area etc. to check the accessibility for the proper light and ventilation.

2.2 Methodology

As mentioned earlier, both the factors have various evaluation methods and procedures depending upon the aim and objectives of the research, however, IGBC Green Homes norms-Reference Guide has been prepared to help the Indian developer and planner in

Figure1. Location of study area: Mumbai

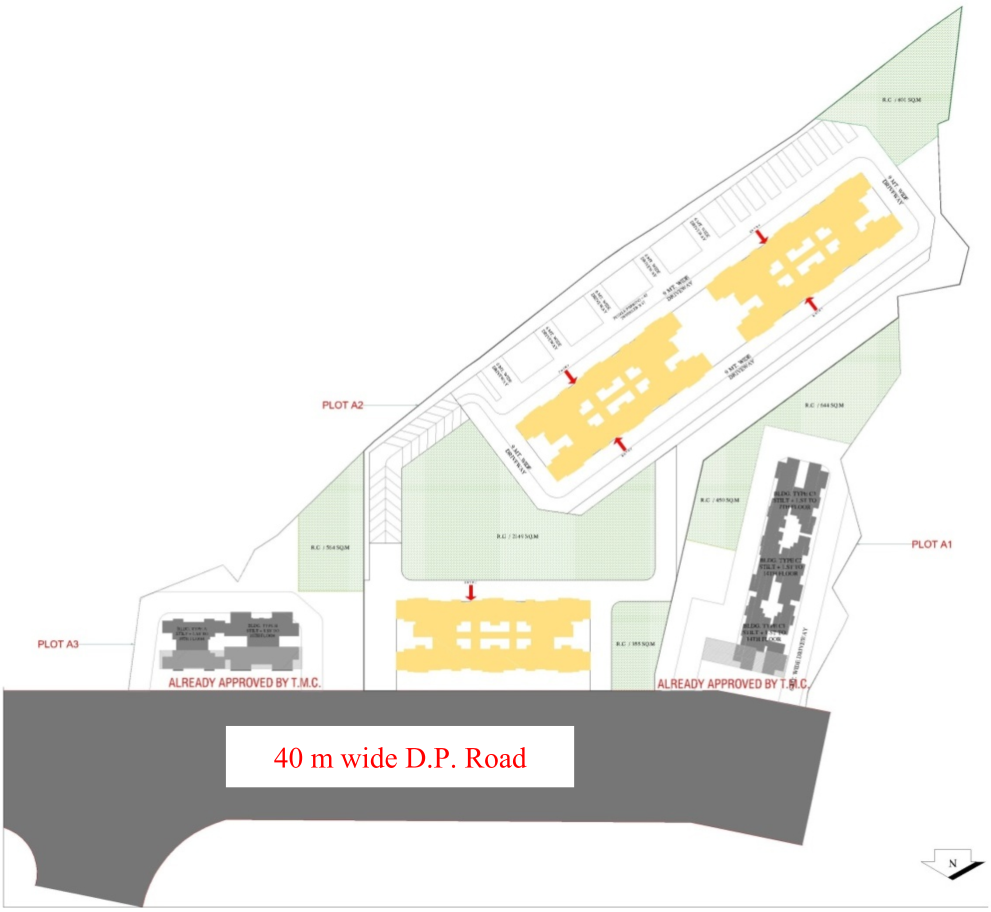

Figure 2. Building layout

Table 1. Glazing factors for Regularly Occupied Spaces (IGBC, 2012)

Type of Regularly Occupied Spaces	Glazing Factor (GF)*
Living / Bedroom	1
Study Room	2
Kitchen	2

the terms of sustainability in India (2012). Daylight analysis is done using the prescriptive approach whereas ventilation analysis is done using analysis for naturally ventilated spaces.

IGBC norms manifest separate procedures for individual residential and multi dwelling residential units for both the analysis. Units are made according to the area of the flats. All the flat with one bedroom, a hall and a kitchen (1 BHK) was considered as Unit 1, all the flats with two bedrooms, a hall and a kitchen (2 BHK) was considered as Unit 2, Refuge area was considered as Unit 3. While studying multi dwelling residential unit for daylight analysis, the minimum glazing factor in regularly occupied spaces (by area) in each dwelling unit should be achieved. Each unit should satisfy the criteria listed in Table 1.

A minimum glazing factor of 1.0 should be achieved for other regularly occupied spaces which are not listed in Table 1. Glazing Factor calculation is done using equation 1 as given below (IGBC, 2012):

$$\text{Glazing Factor} = \frac{\text{Window Area [sq.m]}}{\text{Floor Area [sq.m]}} \times \text{A V T G} \times \text{constant} \times 100 \quad \text{Eq. (1)}$$

Where, AVTG is actual visible transmittance of glazing and constant values are taken 0.2 and 1 for windows on wall and windows on roof respectively. Light transmission (ATVG) for this study has been taken based on thickness of glass (Heschong Mahone Group, 1998). This study executed light transmission value for various glass types and thickness (Table 2).

Ventilation in an air conditioned spaces should be of 5 cfm/second for each unit. Naturally ventilated spaces were considered for this study, where the installation of openable area of windows or doors in living spaces, kitchens and bathrooms should meet the criteria as outlined in Table 3.

Actual openable area calculation is done using equation 2, 3 and 4 as given below (IGBC, 2012). Considering two third windows are openable and door are openable for only half of the time, the factors ⅔ and ½ are used.

$$\text{Openable area} = \text{Area of doors} + \text{Area of windows} \quad \text{Eq. (2)}$$

$$\text{Actual openable area} = \text{Openable area} * 2 / 3 \text{ (for Living room and Kitchen)} \quad \text{Eq. (3)}$$

$$\text{Actual openable area} = \text{Openable area} / 2 \text{ (for bath room)} \quad \text{Eq. (4)}$$

The analysis was conducted using the software Autodesk AutoCAD 2013 and MS-Office Excel 2007. The following steps are involved in this analysis:

1. On the basis of the architectural drawings provided, the building is divided into unit based on the area of rooms.

2. The openable window area to carpet area ratios is determined for daylight analysis, and the openable window + door area to carpet area ratio is determined for ventilation analysis using the formula given.

Table 2. Light transmission with respect to the thickness of window glass (Heschong Mahone Group, 1998)

Substrate	Light Transmission (%)
2mm Clear	91
3mm Clear	90
4mm Clear	90
5mm Clear	90
6mm Clear	89
8mm Clear	88
10mm Clear	87
12mm Clear	87
15mm Clear	85
19mm Clear	84

Table 3. Design criteria for openable windows and doors (IGBC, 2012)

Space Type	Openable Area as % of Total Carpet Area
Living Spaces	10%
Kitchens	8%
Bathrooms	4%

3. The window orientation of the living space of each residential unit is scrutinized to be in at least two different orientations.

3. Results and Discussion

The present study was done as per the norms laid by IGBC Rating System. The building under study has Ground (Gr.) + 30 floors with 1 BHK, 2 BHK flats and Refuge areas and were divided according to the area as Unit 1, Unit 2, Unit 3 respectively. Glazing Factor for light and the openable area for ventilation for each unit was calculated and compared to the rating system given by IGBC South side of the building has no constructions so far whereas three other directions has residential construction that are not placed right beside the project. Hence way of ventilation is not being blocked. Likewise, the position of the building under study is such that the surrounding projects would not be blocking the way of sunlight too. Moreover, the height of surrounding buildings is way too less than the study area.

3.1 For daylight analysis

Glazing factors for the regularly occupied spaces such as living room, study room, kitchen etc. has been provided as 1, 2, and 3 respectively. Glazing factors obtained for Unit 1was found to be thrice the given limit for both living and Kitchen (Table 4). In Unit 2 and 3, glazing factor was four times greater for living area and is double for the kitchen area.

Table 4. Daylight analysis for Unit 1, 2 and 3

Unit 1(1BHK)					
Room	Floor Area	Window Area	Actual Visible Transmittance of Glazing	Constant	Glazing factor
Living + dining	14.0	4.4	0.89	0.20	5.61
Bedroom 1	8.8	3.15	0.89	0.20	6.34
Bedroom 2	22.80	3.9	0.89	0.20	3.01
Total living	5.9	1.42	0.89	0.20	4.28
Kitchen	14.0	4.4	0.89	0.20	5.61
Unit 2(2BHK)					
Room	Floor Area	Window Area	Actual Visible Transmittance of Glazing	Constant	Glazing factor
Living + dining	18.3	4.4	0.89	0.20	4.28
Bedroom 1	10.8	3.78	0.89	0.20	6.25
Bedroom 2	9.3	3.15	0.89	0.20	6.03
Total living	38.38	11.33	0.89	0.20	5.25
Kitchen	7.0	1.42	0.89	0.20	3.64
Unit 3(Refuge Area)					
Room	Floor Area	Window Area	Actual Visible Transmittance of Glazing	Constant	Glazing factor
Living + dining	18.3	4.4	0.89	0.20	4.28
Bedroom 1	10.8	3.78	0.89	0.20	6.25
Bedroom 2	9.3	3.15	0.89	0.20	6.03
Total living	38.38	11.33	0.89	0.20	5.25
Kitchen	7.0	1.42	0.89	0.20	3.64

3.2 For ventilation analysis

For good ventilation, IGBC has provided minimum openable areas in percentage as 10% for living room and bedroom, 8% for kitchen and 4% bathroom (Table 5). According to the analysis carried out for the proposed study area, the actual openable areas for all the spaces in all the Units were found to be more than the prescribed minimum openable areas.

4. Conclusions

Green infrastructure is the need of this generation as the use of chemicals has increased tip to toe. Therefore, to keep an eye check on indoor air pollution and to bridge economy, development and health altogether, a computable study for the amount of light and ventilation in a closed structure is undertaken. Results indicate the exceptional amount

Table 5. Ventilation analysis for unit 1, 2 and 3

Unit 1 (1BHK)					
Room	Area (m^2)	Natural ventilation W/D opening area	Actual openable area (m^2)	Actual openable area (%)	Minimum openable area requirement
Living	14.0	4.56	3.0	26.0	10%
Bedroom	8.8	3.87	2.5	38.0	10%
Total living	22.80	8.43	5.6	31.0	10%
Kitchen	5.9	1.42	0.9	16.0	8%
Bathroom	3.1	3.97	2.6	90.0	4%
Bathroom	2.6	1.47	0.9	43.0	4%
Total bath	5.7	5.44	3.6	68.0	4%
Unit 2 (2BHK)					
Room	Area (m^2)	Natural ventilation W/D opening area	Actual openable area (m^2)	Actual openable area (%)	Minimum openable area requirement
Living + dining	18.3	4.6	3.0	16.5	10%
Bedroom 1	10.8	3.5	2.3	21.7	10%
Bedroom 2	9.3	3.8	2.5	27.3	10%
Total living	38.38	11.89	7.9	20.64	10%
Kitchen	7.0	1.42	0.9	13.6	8%
Bathroom	2.61	2.12	0.7	27.0	4%
Bathroom	3.14	1.47	0.4	15.6	4%
Total bath	5.75	3.59	1.1	9.2	4%
Unit 3 (Refuge Area)					
Room	Area (m^2)	Natural ventilation W/D opening area	Actual openable area (m^2)	Actual openable area (%)	Minimum openable area requirement
Living + dining	18.3	4.6	3.0	16.5	10%
Bedroom 1	10.8	3.5	2.3	21.7	10%
Bedroom 2	9.3	3.8	2.5	27.3	10%
Total living	38.38	11.89	7.9	20.64	10%
Kitchen	7.0	1.42	0.9	13.6	8%
Bathroom	2.61	2.12	0.7	27.0	4%
Bathroom	3.14	1.47	0.4	15.6	4%
Total bath	5.75	3.59	1.1	9.2	4%

*W/D is window/door.

of light and ventilation received fulfilling the criteria enlisted. Building design ensures the proper light and air circulation which would improve the quality of air indoors and cut short the electricity expenses. The study also aimed to encourage the need of light and ventilation. Inclusion and assessment of numerous factors related to green building design has been gaining attention. Similar research was done using various other factors viz. daylight factor, luminance and illuminance factor, building pressure coefficient etc. Unlike the methods noted previously on light and ventilation, this study doesn't use any software or tools which excludes the necessity of the expertise. Also, the evaluation method is simply an area based calculation and doesn't require any intricate formulas. Standardized yet simple, and financially beneficial procedure would only encourage the introduction of light and ventilation analysis while designing an infrastructure. Indian Green Building Council encourages environmentally and sustainably sound infrastructures and hence should be made mandatory certification. Though the method followed here is simple mathematical calculations still software like Revit, Ecotect, and AutoCAD Flow Design can be used for user friendly results.

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