Studying the association between structural factors and tuberculosis in the resettlement colonies in M-East ward, Mumbai

Final Report

Doctors For You

July 2018

DOCTORS FOR YOU
THERE TO CARE

MMR ENVIRONMENT IMPROVEMENT SOCIETY

Contents

Executive Summary

The building architecture and site planning seems to play a big role in creating a healthy atmosphere in the urban resettlement colonies as is projected by the various reports on research carried out in different countries (1-14). High burden of TB results in sizeable economic and social costs making it a critical issue to address. Hence, it is worthwhile to study if the urban resettlement colonies in M-East ward also show similar trends. Further, it is important to consider if the Development Control Regulations (DCRs) for resettlement buildings need to be changed in order to ensure that the health of the families residing in these buildings is not compromised due to any design and layout faults. Through this study, *we aimed to investigate and establish the strength of association between structural factors of slums resettlement colonies buildings and the incidence pattern of tuberculosis.* For this, we performed a cross sectional study using household survey to find architectural and socioeconomic details of the household, computational modelling of sunlight and ventilation access based on house design and layout of the Lallubhai compound, Natwar Parekh compound and PMG colony and validation of these models by actual measurements of air velocity and daylight.

Results: Computation modelling has shown that lower floors do not have access to sufficient light (Fig. ES1) and ventilation in the living area. These results were compared to the results obtained from statistical analysis of household survey data and both were found to be in sync. The survey brought out the following correlations:

Floor – Low floor have more number of cases probably because they have poor ventilation and sunshine access.

Window design and usage – Households not having openable windows and/or using the closed windows as storage spaces have high likelihood of having a TB patient.

Exhaust fans – Lack of exhaust fans are strongly correlated to TB prevalence, indicating towards lack of mechanical ventilation, one of the risk factors for TB prevalence and transmission.

Sky view factor, daylight autonomy, ventilation – All colonies show poor sky view factors, daylight autonomy and ventilation which may be likely cause of high TB in this area. Low daylight autonomy and ventilation may be because of poor design of the houses and compact stacking of the building next to each other.

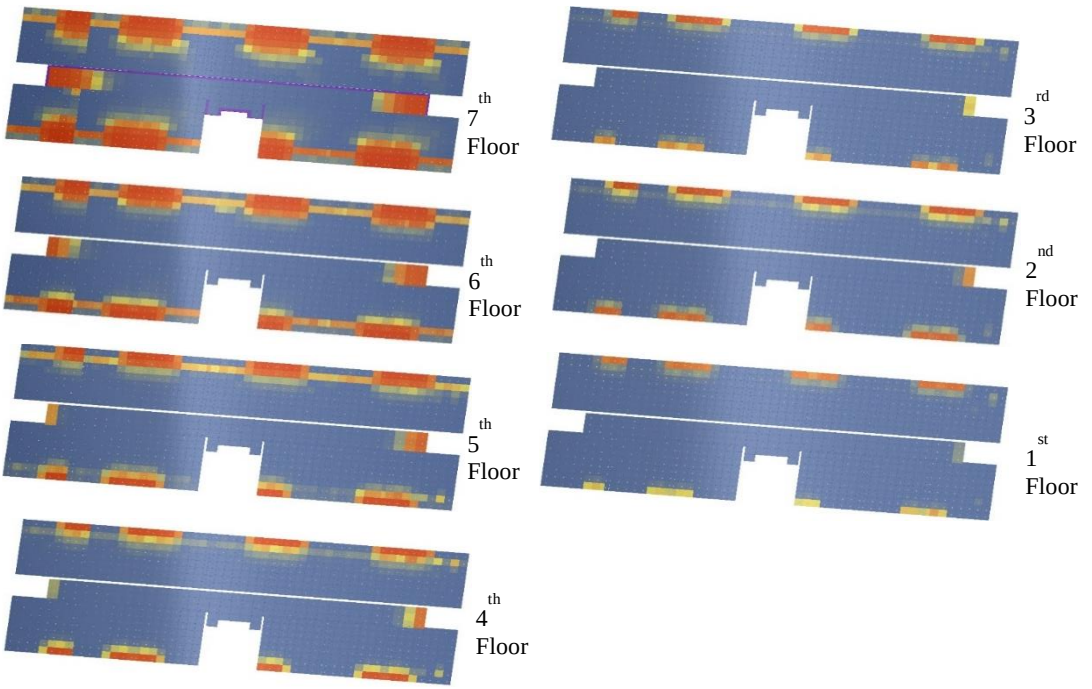


Fig. ES1. Simulation of floor-wise Daylight Autonomy due to impact of nearby buildings in Lallubhai colony

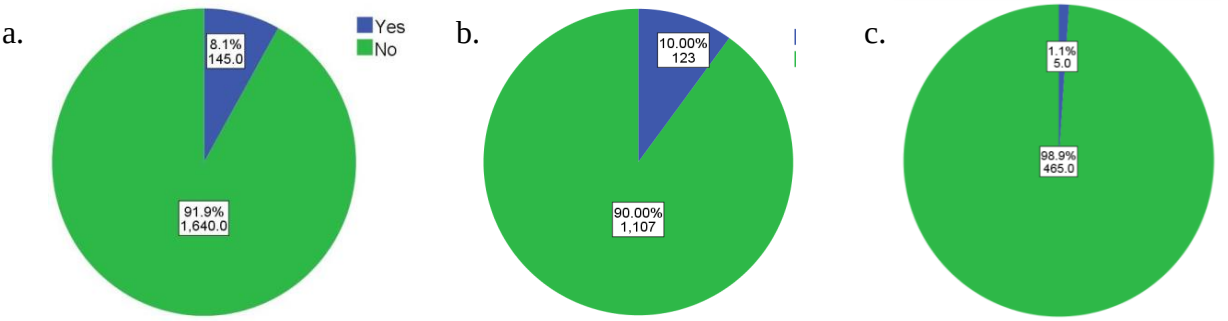


Fig ES2. Households having at least a TB patient in the three colonies: a). Lallubhai colony, b) Natwar Parekh colony, c) PMG colony

Conclusion and Recommendations: The results show that the occurrence of TB in Natwar Parekh and Lallubhai compounds is strongly associated with the built environment of the houses and the layout of the buildings in both the colonies. In contrast, occurrence of tuberculosis is least in PMG colony which is associated with better built environment and the layout characteristics. This explains that, efficient provision of daylight and natural ventilation strategies within a

particular space may act as a factor in improving human health condition, whereas poor sunlight access and natural ventilation may be major risk factors for the deadly TB disease.

Table ES2. Statistical analysis of Household survey data to find correlation between TB and house design

At least one member of the household is suffering from TB		B	Std. Error	t statistics	Sig.
Yes	Intercept	-5.523	0.605	-9.130	0.000
	House hold size	0.152	0.021	7.364	**0.000**
	Number of the floors in the building in which the respondent is residing	-0.056	0.028	-2.005	**0.045**
	Number of exhaust fans	-0.222	0.132	-1.686	**0.092**
	Not openable Window	2.823	0.583	4.846	**0.000**

Planners have long known the relationship between the city's built form and public health. A detailed study of the layout of these resettlement colonies and the Development Control Regulations (DCRs) reveal that there is huge disparity between the housing provided by the government and that built by the private firms. This study strongly suggests that the SRA and PAP project developers must follow the National Building Codes for the resettlement colonies without any dilution of the strict norms. Also, there should be no separate rules and regulations for public and private housing, in order to maintain a healthy locality and a hence, healthy country. It is imperative to roll back on the norms that are detrimental to the health of the public.

In the era of climate change, climatically sensitive design is necessity for survival of the lower income classes that cannot depend on costly mechanical solutions for air conditioning and ventilation. Public housing that is being built is expected to last at least for the next 30 years and should be built after due deliberation of built form and livability standards. The city government must take necessary actions bring improvements in built from, livability and avert a public health crisis.

In the areas where the population has already been affected by poor access to natural ventilation and sunlight, structural and social interventions can be made retrospectively, in order to increase the air flow in the houses and help the residents avail of the clean air and open surroundings. In populations that are particularly vulnerable to certain diseases like TB, special measures need to be taken to prevent the occurrence of disease in them.

Introduction

Tuberculosis (TB) is the leading cause of deaths due to infectious diseases. *Mycobacterium tuberculosis*, the causative agent of TB remains viable in damp and cool environment and is transmitted through aerosols generated by coughing and sneezing. According to WHO estimates, there were 1.4 million deaths due to TB and 10.4 million new cases reported in 2015 (1). India has the highest burden of TB with more than 25% of the cases worldwide (1). Tuberculosis has been named as the disease of poverty. Lack of hygiene, large family size, crowding, unhealthy food leading to low immunity, non-compliance of dose regimen, HIV co-infection are among the major factors contributing to the spread of TB.

With rapid urbanization taking place, people from rural and poor areas are migrating towards metro cities in search of livelihoods. Mumbai being the commercial capital of the country, has become a hub of slums populated with migrant workers. These slums are temporary dwellings which lack in hygiene and sanitation facilities. Municipal Corporation of Greater Mumbai (MCGM) has tried to accommodate the slum dwellers in concrete settlements with the amenities of electricity, water and attached lavatories. However, the problems of access to sunshine and ventilation persist.

The building architecture and site planning seems to play a big role in creating a healthy atmosphere in the urban resettlement colonies as is projected by the various reports on research carried out in different countries. In the urban quarters of Hong Kong, it was found that there is a positive correlation between height of the building and tuberculosis. The lower floors had more TB cases as they had less access to sunlight and fresh air (2)(3). In an ecological study carried out in Birmingham, it was established that TB spread more during winter season when there was less exposure to sunlight as compared to that in summer season (4). A similar study in Peru associated TB incidence with the potential risk factors like crowding of the houses, hours of sunlight exposure and vitamin D deficiency (5). Also, in Bern, Switzerland, a study found a positive correlation between TB mortality and crowding and lack of sunlight. TB mortality decreased with the introduction of improved housing conditions and public health measures, over many years (6).

With the established correlation of TB morbidity and mortality with building architecture and housing conditions, as discussed above, it is worthwhile to study if the urban resettlement colonies in M-East ward also show similar trends. Further, it is important to consider if the Development Control Regulations (DCRs) for resettlement buildings need to be changed in order to ensure that the health of the families residing in these buildings is not

compromised due to any design and layout faults. It is interesting to note that the DCRs for private buildings and those for public housing schemes may differ so as to allow more crowding which could prove to be a health risk. With these principles in mind, the current study was undertaken.

Aim

"To investigate and establish the strength of association between structural factors of slums resettlement colonies buildings and the incidence pattern of tuberculosis"

The study would try to understand the epidemiology of TB in these resettlement colonies and investigate if structural factors of the buildings have a role to play in the profile of TB cases.

Objectives

Primary objective:

To compare the architectural parameters like building height, distance between two buildings, sky view factors, air exchange rates of the three colonies and draw their correlation to the number of TB cases in the residents of these resettlement colonies

Secondary objectives:

To determine the health parameters and socioeconomic status of the population residing in resettlement colonies

To find good architectural and structural parameters for resettlement colonies which are cost effective but at the same time do not compromise the health of the residents.

Researchers associated in the Project

Sr No	Researchers Associated	Qualification	Affiliation
1	Dr Ravikant Singh	MBBS & MD Public Health KEM Hospital Mumbai	Doctors For You
2	Dr Peehu Pardeshi	M.Sc Microbiology PhD IIT Bombay	Doctors For You
3	Prof. Ronita Bardhan	B.Arch, MCP, PhD	Centre for Urban Science & Engineering, IIT Bombay
4	Ms Namrata Kapoor	M. Arch., M City Planning, UC Berkeley	KRVIA, Mumbai
5	Dr Balram Jadhav	BAMS,MPH KLE	Doctors For You
6	Mr Siddharth David	MSW TISS Mumbai	Doctors For You
7	Dr Nabhojit Roy	MBBS, MS, MPH John Hopkins University USA	BARC & NHSRC Govt. of India
8	Dr Arnab Jana	B.Tech, PhD	Centre for Urban Science & Engineering, IIT Bombay

Methodology

A. Study area-

Households in two resettlement colonies in which Doctors For You provides health services along with the MMRDA, in the M East Ward (A and B) (Fig. 1a and 1b) and households from another resettlement colony with better ventilation and spacious building design (C) (Fig. 1c) were selected for the house hold survey. The sample was approximately 12,000 households with a population of about 70,000. The approximate number of households in the three colonies are given below.

A. Lallu Bhai Compound, Govandi West: 36 Buildings; 4,890 occupied rooms
B. Natwar Parekh Compound, Shivaji Nagar, Govandi West: 59 Buildings; 4,800 occupied rooms
C. PMG colony (Ambedkar Nagar, MHADA), Mankhurd: 16 buildings; 2,100 occupied rooms

a.  b.  c. 

Fig. 1 Snapshots of top view of: a. Lallubhai compound, b. Natwar Parekh compound, and c. PMG colony

B. Study population-

Persons residing in the houses in the three resettlement colonies (Natwar Parekh, Lallubhai Compound and PMG colony) were considered for the data collection and questionnaire based interviews.

C. Study Design-

The study design consisted of a household survey in the three colonies to gather information on various indicators of TB as well as housing conditions, followed by computational modelling and simulations to study the architecture houses and layout of the buildings. The computational models were further validated by actual measurements in the households. The detailed design and method of the study is given below:

i) Household survey

This is a cross-sectional study based on **house-to-house survey**. (Questionnaire attached in Annexure I). Sampling technique used was systematic random sampling, using which at least 1/3rd of the households on each floor of every building were interviewed. Further, detailed field visits and informal open-ended interviews of the residents of all the colonies were taken, in order to understand the reasons behind some of the habits and patterns observed in the colonies.

For conducting this survey, a team was formed as given below:

Research team: Research officer, field supervisor, data entry operator and data collectors

Recruitment and training of data collectors:

For the household survey, data collectors who belonged to Lallubhai compound and Natwar-Parekh compound were recruited. The recruitment was based on personal interview conducted by the Research officer. The candidates who had a prior experience of working in healthcare settings and survey area were selected. A total of 8 data collectors were appointed. Workshop for explaining the questionnaire and consent forms was conducted at the Doctors For You office. Also, intermittent training and revision was conducted every week to understand the problems faced during survey and to reiterate the important points to be considered during the interview. A pilot study for the survey was conducted with 40 households over two days, in order to ensure the robustness of the questionnaire. Fig. 2 shows some data collectors starting on their first visit to houses for survey at Natwar-Parekh compound.

Fig. 2. Six of the eight data collectors along with the research officer, at the Doctors For You office on their first day of survey

For the survey, the questionnaire in English and Hindi formats (Annexure I) was given to the data collectors along with the consent forms (Annexure II). Participants were approached personally at their residence and were explained about the nature of study and tool. The consent form was explained to them and their signature was sought. Data collectors interviewed the participants and filled the forms according to the information provided (Fig 3).

In total, about 10,000 households were considered for the study out of which more than 40% were sampled for the survey. The survey started at 10.30 am and ended at 5pm with a lunch break from 1-2 pm, on all working days.

The parameters monitored in the survey were as follows:

a. Socioeconomic and demographic details – Name, age, gender, house number, building number, number of occupants in the house, time since occupying the house, occupation of the respondent, family income

b. Morbidity details – Whether any family member suffered TB in the past or present, any other disease or disorder

c. Housing conditions and practices – windows and doors opening habits, electricity consumption, layout of windows in the house, using windows as storage space, time spent in the house.

However, data pertaining to life style, food habits and other dietary habits were not inquired. No blood samples or any physical measurements were undertaken during the survey.

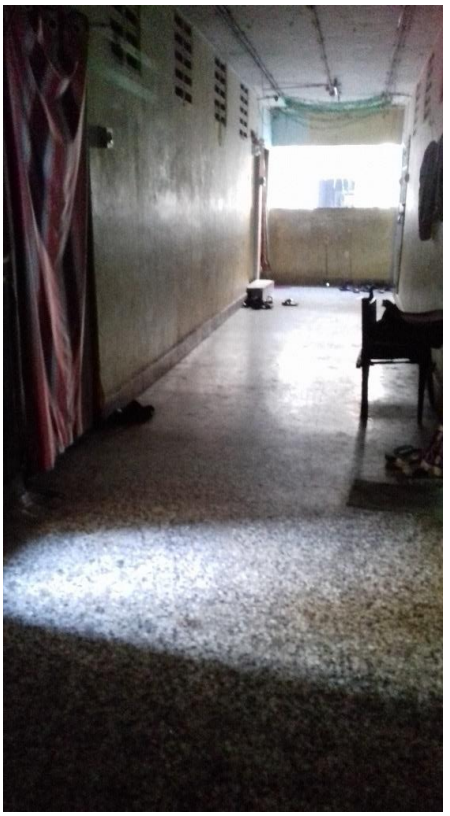
The information in the questionnaires filled by the data collectors was compiled by the data entry operator in the form of Microsoft excel sheets which were further subjected to statistical analysis.

A total of 4,080 households were surveyed. Number of households surveyed in each colony are mentioned below:

Name of the colonies	Number of Households Surveyed
Natwar Parekh Compound	1797
Lallubhai Compound	1785
PMG colony (Ambedkar Nagar)	498

Data analysis has been performed using SPSS software, on the household survey data and the secondary data. The main areas of analysis and comparison were: age group affected, floors wise distribution of TB patients in each colony, gender wise distribution, type of infection and time of incidence of TB after shifting into the colony. For further statistical analysis, all the samples were pooled and incomplete samples with missing data were deleted. Post data cleaning, the sample size reduced to 4,019 (Table 2).

a.



b.

c.

d.

Fig. 3. Snapshots of a dark corridor in one of the buildings of Lallubhai compound (a) and data collectors interviewing various households (b, c, d).

ii) Computational Models using building drawings

Computational modelling and simulations were used to prepare models of age of air in the house, daylight autonomy and sky view factor for the three colonies. These models are based on the floor plans and section maps of the buildings in the three colonies (Attached in Annexure III), procured from MMRDA and MHADA by Ms. Namrata Kapoor, Urban Planner, KRVIA. The computation facility at IIT Bombay was used for this purpose under the guidance of Dr. Ronita Bardhan and Dr. Arnab Jana, C-USE, IIT Bombay. The software used for these experiments were: ESRI 2011. ArcGIS Desktop: Release 10.5. Redlands, CA: Environmental Systems Research Institute. Autodesk® Revit® 2017 Autodesk, Inc., Autodesk® AutoCAD® 2017 Autodesk, Inc.,Rhinoceros 5 Rhinoceros. Inc. and DIVA 4.0.2.9 for Rhino Sustainable Design (G(SD)2) research group Solemma LLC.

The factors studied through modelling are explained below:

Sky view Factor

Theoretically, 'the sky view factor (SVF) is a geometrical concept that describes the fraction of the overlying hemisphere occupied by the sky'. The SVK is a dimensionless parameterisation of the quantity of visible sky at a given point. It is a graded value between zero and one. Increasing the height of flanking objects obstructs the vision of the sky, which leads to a decreasing SVF value, reaching the value of zero at its lowest. In contrast, by decreasing the height of flanking objects to when the entire hemisphere is clearly visible, the SVF value will equal one. (Fig. 17, 18, 24, 25, 31 and 32)

Daylight Factor

Daylight factor (DF) is the most common metric used in actual practice and/or guidelines, which is the ratio of internal illuminance to external horizontal illuminance under an overcast sky defined by the CIE (International Commission on Illumination) luminance distribution.

1. The CIE standard overcast sky is merely an idealist sky model: Overcast sky type is not unique. The CIE overcast sky is applicable when the complete sky canopy is covered with uniform dark clouds representing heavy overcast sky only.
2. DF is assessed under overcast conditions, no account is made of illuminance from sun and non-overcast skies, and so the daylight factor is invariant to building orientation and the location of the room.

Daylight autonomy was preferred over Daylight factor.

Daylight Autonomy

Daylight autonomy (DA), on the other hand, is a climate-based Daylight performance metric which factors in the daylight climate of the building site and facade orientation. DA is represented as a percentage of annual daytime hours that a given point in space is above a specified illumination level. It is a major innovation since it encompasses specific weather conditions of the geographic location on an annual basis. DA uses work plane illuminance as an indicator of whether sufficient daylight is rendered in a space so that an occupant can work by daylight alone.

Natural Ventilation

Exchange of air between indoor and outdoor environment without reliance on mechanical support like fans and other cooling sources is known as natural ventilation. Natural ventilation not only improves thermal comfort but also provide healthier indoor environment by boosting indoor air quality within a particular space. Efficient provision of natural ventilation strategies into building spaces can significantly reduce energy consumption as well as monetary concerns due to its negligible cost and low energy consumption in comparison to mechanical modes of ventilation. This strategy can be more useful in the hot and humid or subtropical climate dominant countries where air conditioners are major elements for energy consumption. Therefore, it is essential to study natural ventilation in residential buildings in order to increase benefits.

The LIG settlements, particularly in Mumbai, are characterized by lack of airflow path in the living spaces leading to poor indoor air quality, higher indoor temperature and lack of sanitation and hygiene. The relationship between health and built environment majorly focuses on Household Air pollution (HAP).

The interior layouts of tenement units for each of the colonies were studied. A mixed mode research methodology was involved in this study which included i) Measurement of temperature and air velocity for 10 minutes in 60 households and ii) and airflow in each of the tenement units were computed using Computational Fluid Dynamics(CFD) simulations. The recorded values of air velocity from field survey were taken as input boundary conditions for CFD simulations.

CFD simulation

The 2015 version of the CFD software ANSYS coupled with FLUENT interface, was used to carry out the simulations. This is well known and well-established tool for simulating and analyzing fluid flow, air velocity and has been used worldwide by researchers to predict airflow characteristics in different ventilation scenarios.

The airflow in the tenement units was assumed to enter through window (inlet) and escape through door (outlet). Only unidirectional flows were considered in the simulation. The window was assumed as velocity inlet while the door as pressure outlet. The middle of the window and door was assumed at a constant atmospheric temperature of 305 K (21 deg C). Pressure was considered

constant across inside and outside boundaries of the tenement unit. Therefore, ventilation was assumed to be completely wind driven. The details of boundary conditions are shown in Table 1. The monitoring point was taken at the mid bed position at a height of 0.7 m from the ground level.

Table 1 Summary of boundary conditions used for natural ventilation simulation

Part of Computational Domain	**Boundary Conditions**	
Door	Pressure outlet	Gauge pressure = 0; T = 300 K, Hydraulic diameter= 1.26 (authors' computation) ; Turbulence intensity = 10%
Window	Velocity inlet	Gauge pressure = 0; T = 300 K, Hydraulic diameter= 1.09 (authors' computation); Turbulence intensity = 10%, Velocity (authors' computation)
Wall- room	Wall	Stationary wall; No slip

These models were validated by actual measurement of daylight, air velocity and sky view factor of the three colonies these factors using luxmeter (Fig 4a), anemometer (Fig 4b) and Fish eye lens camera, respectively, in the colony premises.

Further, a detailed study of DCRs governing the built form of resettlement and rehabilitation colonies like PMG Colony, Lallubhai Colony and Natwar Parekh Compound was performed.

a. b.

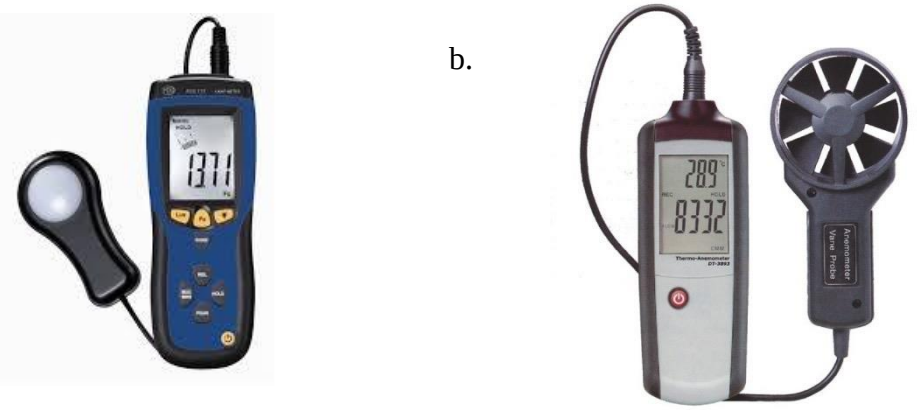


Fig. 4. Representative images of a Luxmeter (a) and an Anemometer (b)

Results

Simulations and calculations

Using the building maps, models of the three building designs were built and simulated for air velocity, sky view factor and daylight autonomy.

Sky View Factor

SVF simulations for Lallubhai and Natwar Parekh compounds showed that these colonies have poor sky view between the buildings indicating crowding which could be detrimental to the well-being of their residents. PMG colony was found to be a better colony with open corridors and better sky view (Fig 5, 6, 13, 14, 21, 22). Actual measurements show that an open corridor in PMG colony has a SVF of 0.3, whereas widest spaces in Lallubhai and Natwar Parekh compound could reach only upto a SVF of 0.1 and 0.2. These measurements validated the observations made by simulations and thus indicate that Lallubhai and Natwar Parekh compounds do not provide access to sunshine and open sky in their buildings.

Daylight Auntomy

Lallubhai compound:

Daylight Factor (DF) Analysis: 19% of all illuminance sensors have a daylight factor of 2% or higher. Assuming that the sensors are evenly distributed across 'all spaces occupied for critical visual tasks', the investigated lighting zone does **not** qualify for LEED-NC 2.1 daylighting credit 8.1.
Daylight Autonomy (DA) Analysis: The mean daylight autonomy is 26% for active occupant behavior. The percentage of the space with a daylight autonomy larger than 50% is 28% for active occupant behavior.
Continuous Daylight Autonomy (DA) Analysis: The mean continuous daylight autonomy is 44% for active occupant behavior. The percentage of sensors with a DA_MAX > 5% is 10% for active occupant behavior
Useful Daylight Illuminance (UDI): The percentage of the space with a UDI<100-2000lux larger than 50% is 45% for active occupant behavior. (Fig.7, 8)
A yearly occupancy schedule was used for the simulations in which the occupied hours were considered to be from 8 AM to 6 PM for the months of Jan, Feb, Nov, Dec and 7 AM to 5 PM in rest of the months this was done considering the daylight availability.

Natwar Parekh compound:

Daylight Factor (DF) Analysis: 44% of all illuminance sensors have a daylight factor of 2% or higher. Assuming that the sensors are evenly distributed across ‘all spaces occupied for critical visual tasks’, the investigated lighting zone does **not** qualify for LEED-NC 2.1 daylighting credit 8.1.
Daylight Autonomy (DA) Analysis: The mean daylight autonomy is 60% for active occupant behavior. The percentage of the space with a daylight autonomy larger than 50% is 65% for active occupant behavior.
Continuous Daylight Autonomy (DA) Analysis: The mean continuous daylight autonomy is 76% for active occupant behavior. The percentage of sensors with a DA_MAX > 5% is 31% for active occupant behavior
Useful Daylight Illuminance (UDI): The percentage of the space with a UDI<100-2000lux larger than 50% is 58% for active occupant behavior. (Fig 15, 16)

PMG colony model type 1:

Daylight Factor (DF) Analysis: 28% of all illuminance sensors have a daylight factor of 2% or higher. Assuming that the sensors are evenly distributed across 'all spaces occupied for critical visual tasks', the investigated lighting zone does not qualify for LEED-NC 2.1 daylighting credit 8.1.
Daylight Autonomy (DA) Analysis: The mean daylight autonomy is 38% for active occupant behavior. The percentage of the space with a daylight autonomy larger than 50% is 40% for active occupant behavior.
Continuous Daylight Autonomy (DA) Analysis: The mean continuous daylight autonomy is 51% for active occupant behavior. The percentage of sensors with a DA_MAX > 5% is 22% for active occupant behavior
Useful Daylight Illuminance (UDI): The percentage of the space with a UDI<100-2000lux larger than 50% is 45% for active occupant behavior. (Fig 24, 25)

PMG colony model type 2:

Daylight Factor (DF) Analysis: 25% of all illuminance sensors have a daylight factor of 2% or higher. Assuming that the sensors are evenly distributed across 'all spaces occupied for critical visual tasks', the investigated lighting zone does **not** qualify for LEED-NC 2.1 daylighting credit 8.1.
Daylight Autonomy (DA) Analysis: The mean daylight autonomy is 36% for active occupant behavior. The percentage of the space with a daylight autonomy larger than 50% is 39% for active occupant behavior.

Continuous Daylight Autonomy (DA) Analysis: The mean continuous daylight autonomy is 48% for active occupant behavior. The percentage of sensors with a DA_MAX > 5% is 20% for active occupant behavior

Useful Daylight Illuminance (UDI): The percentage of the space with a UDI<100-2000lux larger than 50% is 42% for active occupant behavior. (Fig 27, 28)

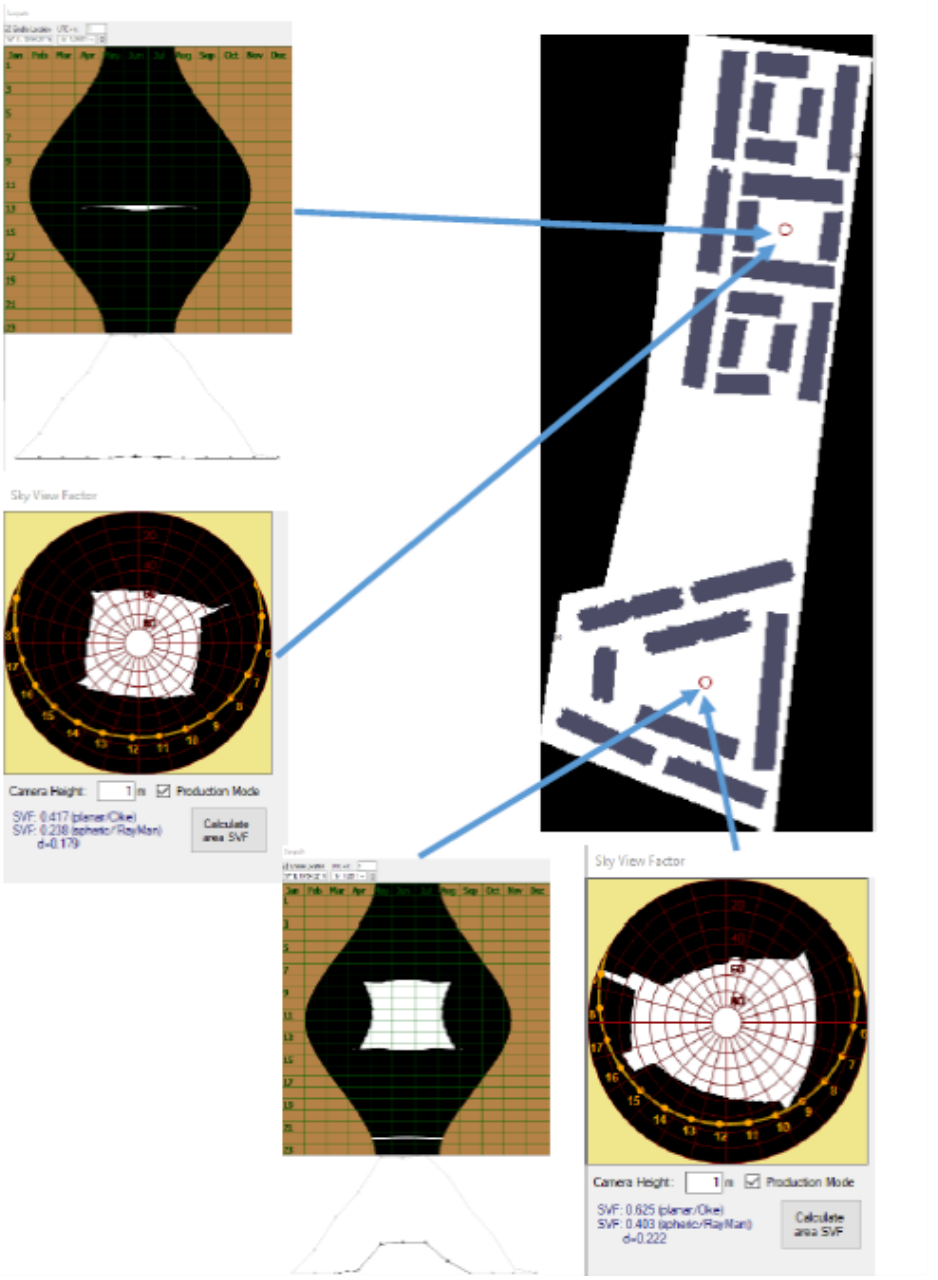


Fig 5. Sky view factor calculation for Lallubhai compound. (Camera height – 1m above ground)

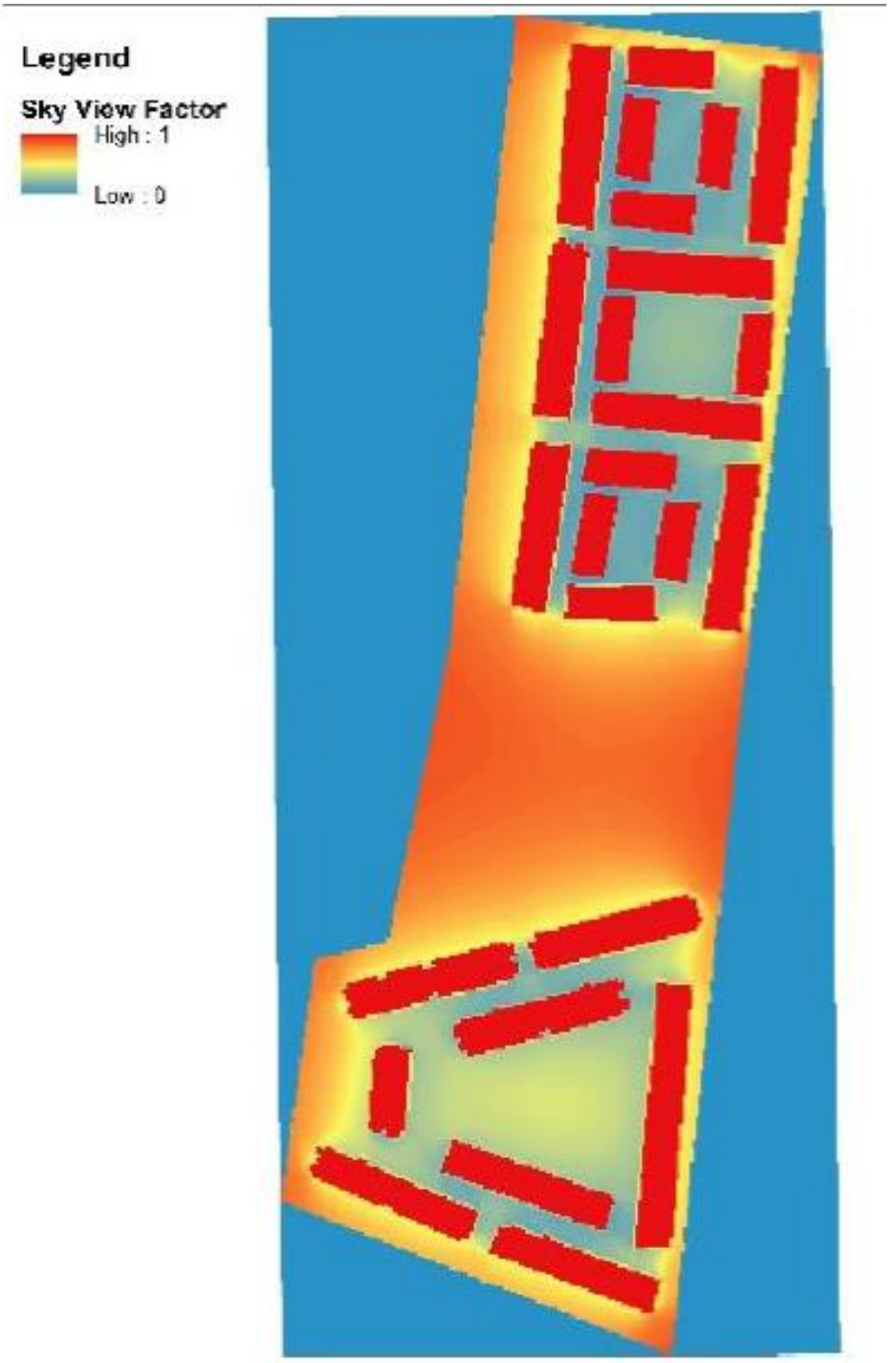


Fig 6. Simulated model for Sky view factor of Lallubhai compound

Table 2. Daylight simulation report for Lallubhai compound

Daylit Area (DA_{300lux}[50%])	28% of floor area
Mean Daylight Factor	1.4%
Occupancy	3650 hours per year

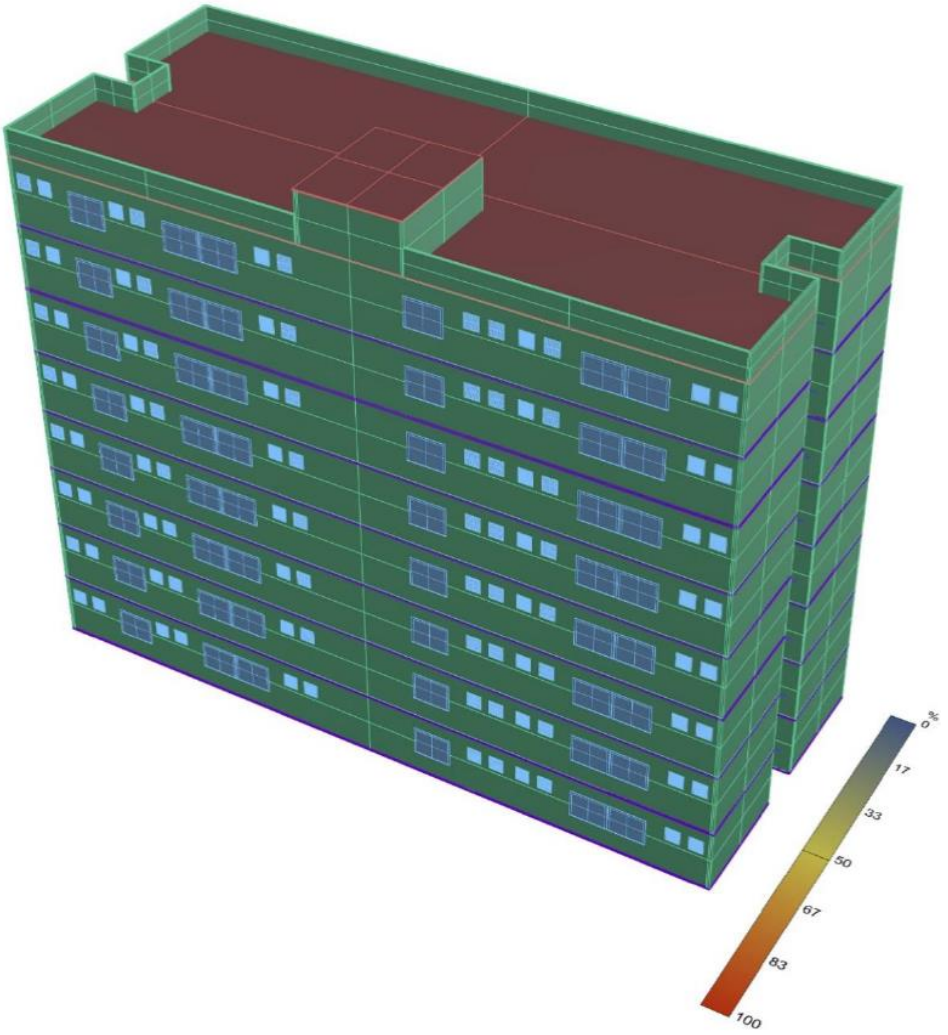


Fig 19. Building model for Lallubhai compound

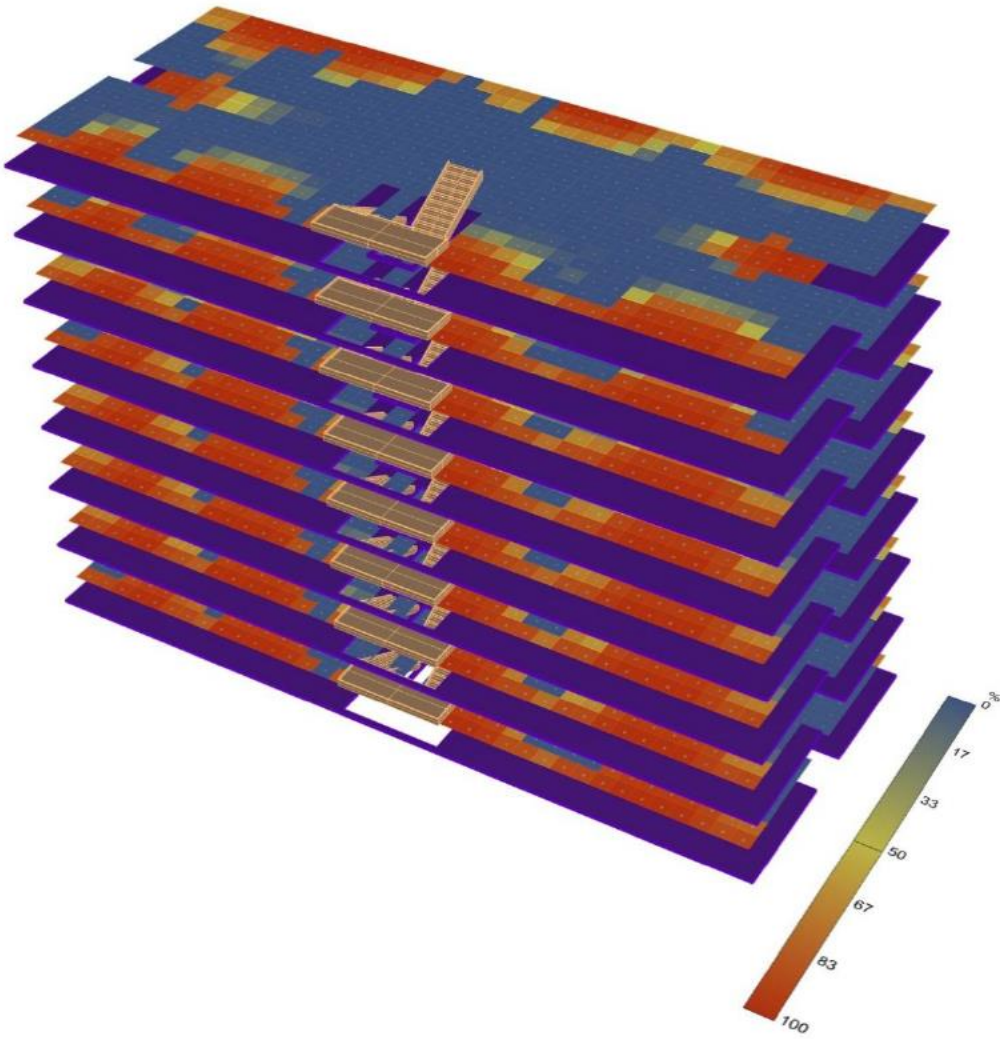


Fig 7. Daylight autonomy of all floors in Lallubhai compound

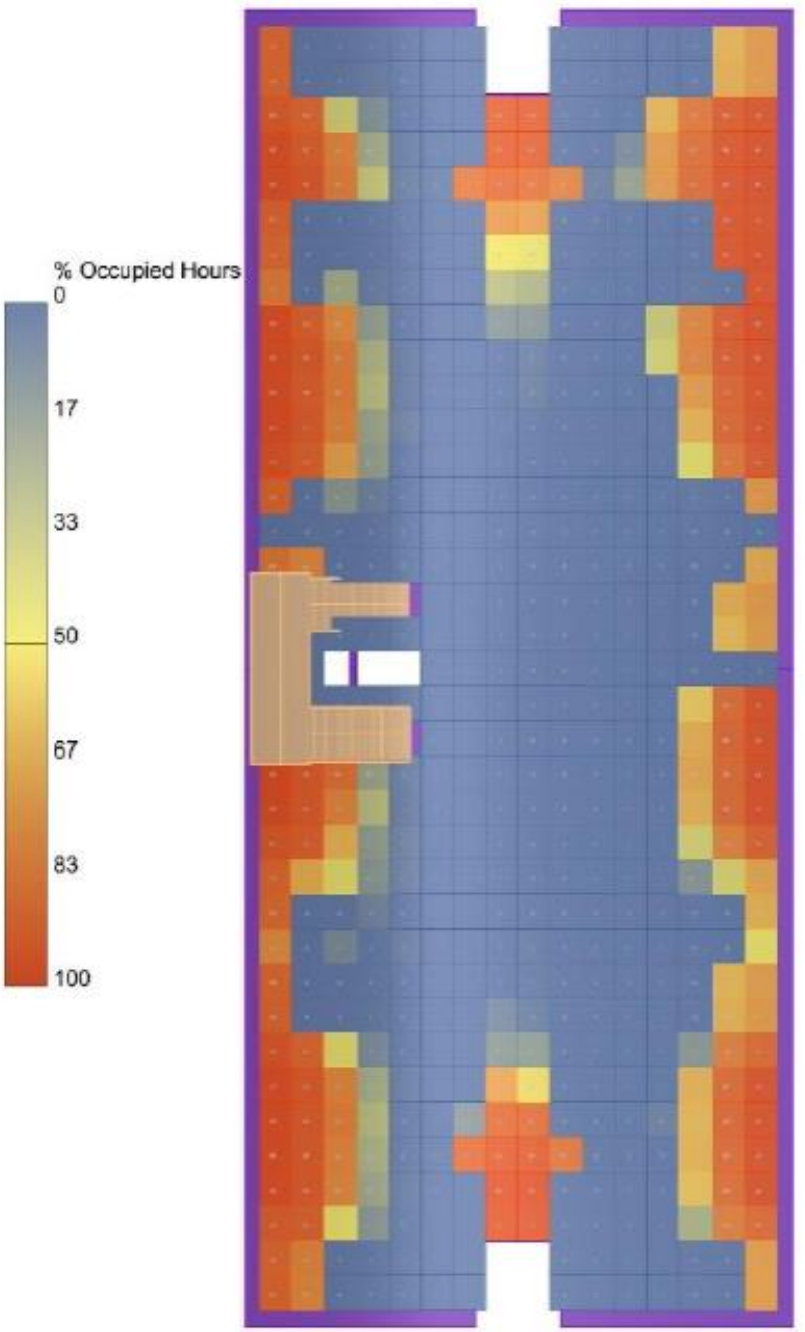


Fig 8. Floor with maximum Daylight autonomy in Lallubhai compound

Daylight autonomy calculation considering impact of nearby buildings.

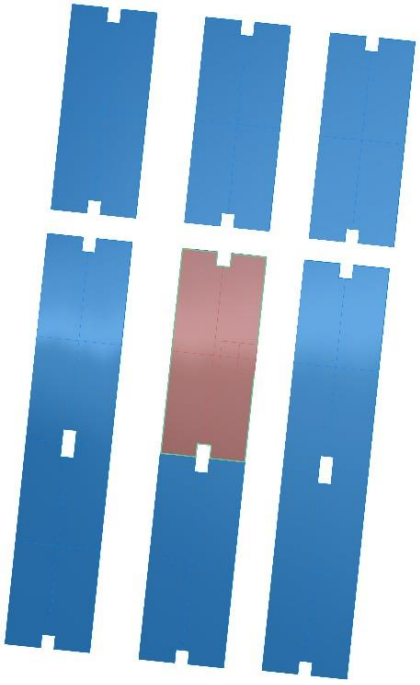


Figure 9 Building used for DA calculation in Lallubhai compound

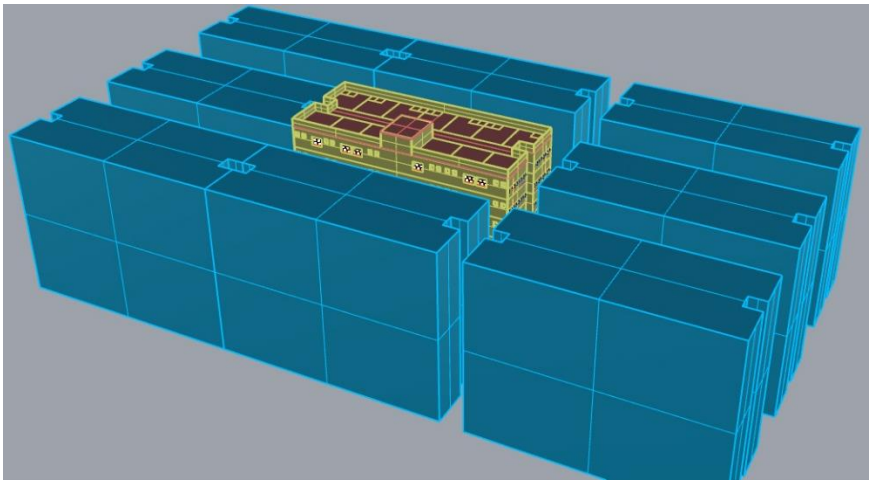


Figure 10 Building model with surrounding building cover in Lallubhai compound

Table 3. Daylight simulation report for Lallubhai compound – impact of stacked buildings

Daysim Simulation Report

Daylit Area (DA_{300lux}[50%])	12% of floor area
Mean Daylight Factor	0.7%
Occupancy	3650 hours per year

Daylight Factor (DF) Analysis: 7% of all illuminance sensors have a daylight factor of 2% or higher. Assuming that the sensors are evenly distributed across 'all spaces occupied for critical visual tasks', the investigated lighting zone does **not** qualify for LEED-NC 2.1 daylighting credit 8.1.

Daylight Autonomy (DA) Analysis: The mean daylight autonomy is 12% for active occupant behavior. The percentage of the space with a daylight autonomy larger than 50% is 12% for active occupant behavior.

Continuous Daylight Autonomy (DA) Analysis: The mean continuous daylight autonomy is 24% for active occupant behavior. The percentage of sensors with a DA_MAX > 5% is 7% for active occupant behavior

Useful Daylight Illuminance (UDI): The percentage of the space with a $UDI_{<100\text{-}2000lux}$ larger than 50% is 18% for active occupant behavior.

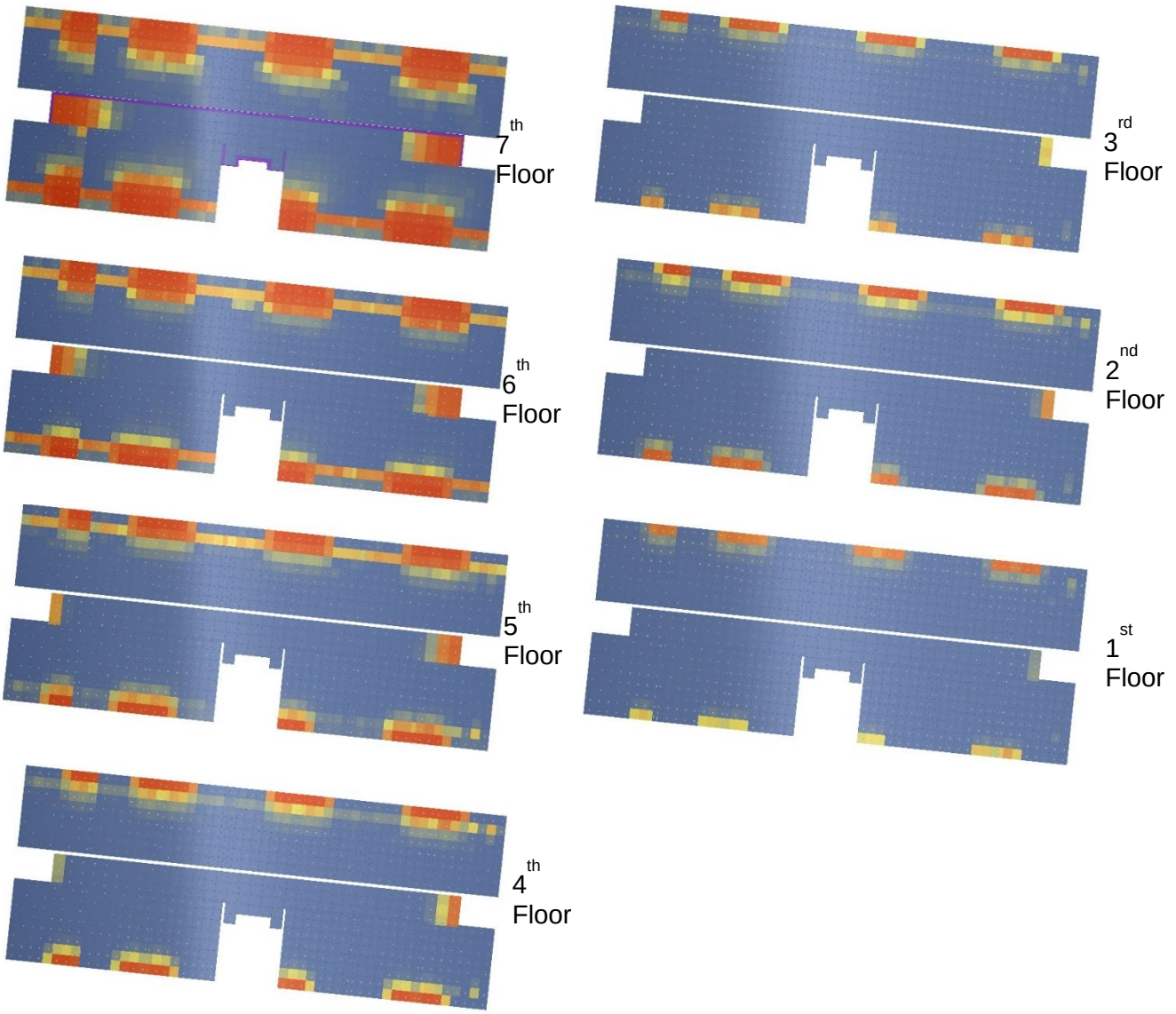


Figure 11 Floor wise DA results in Lallubhai Compound

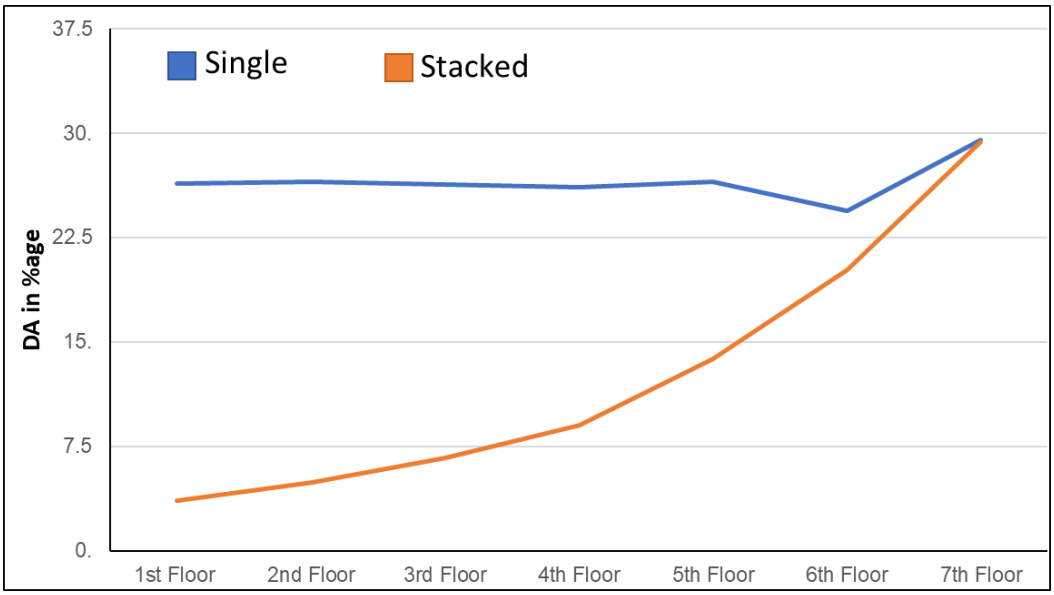


Figure 12 Change in DA of building with and without surrounding buildings in Lallubhai compound

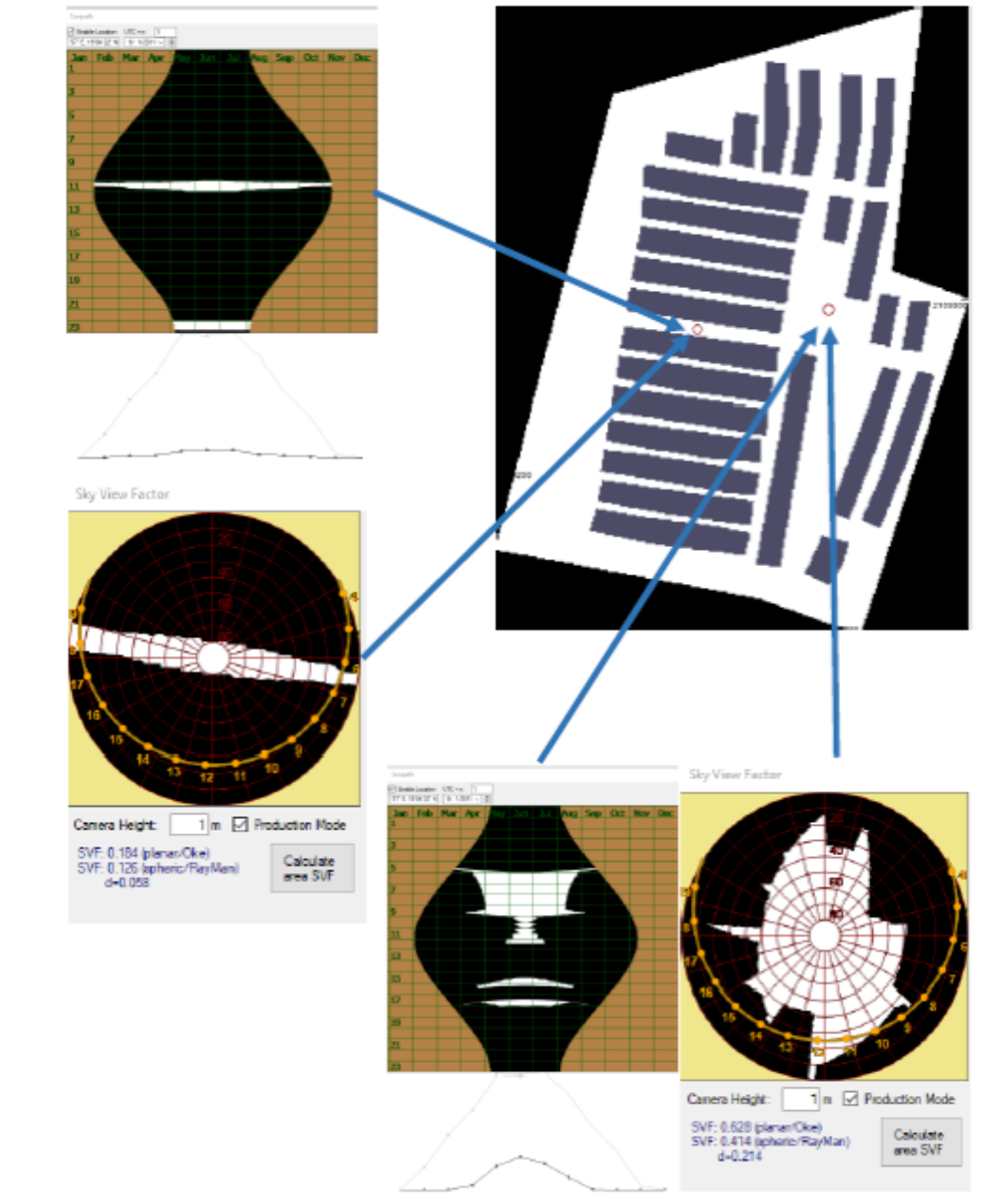


Fig 13. Sky view factor calculation for Natwar Parekh compound

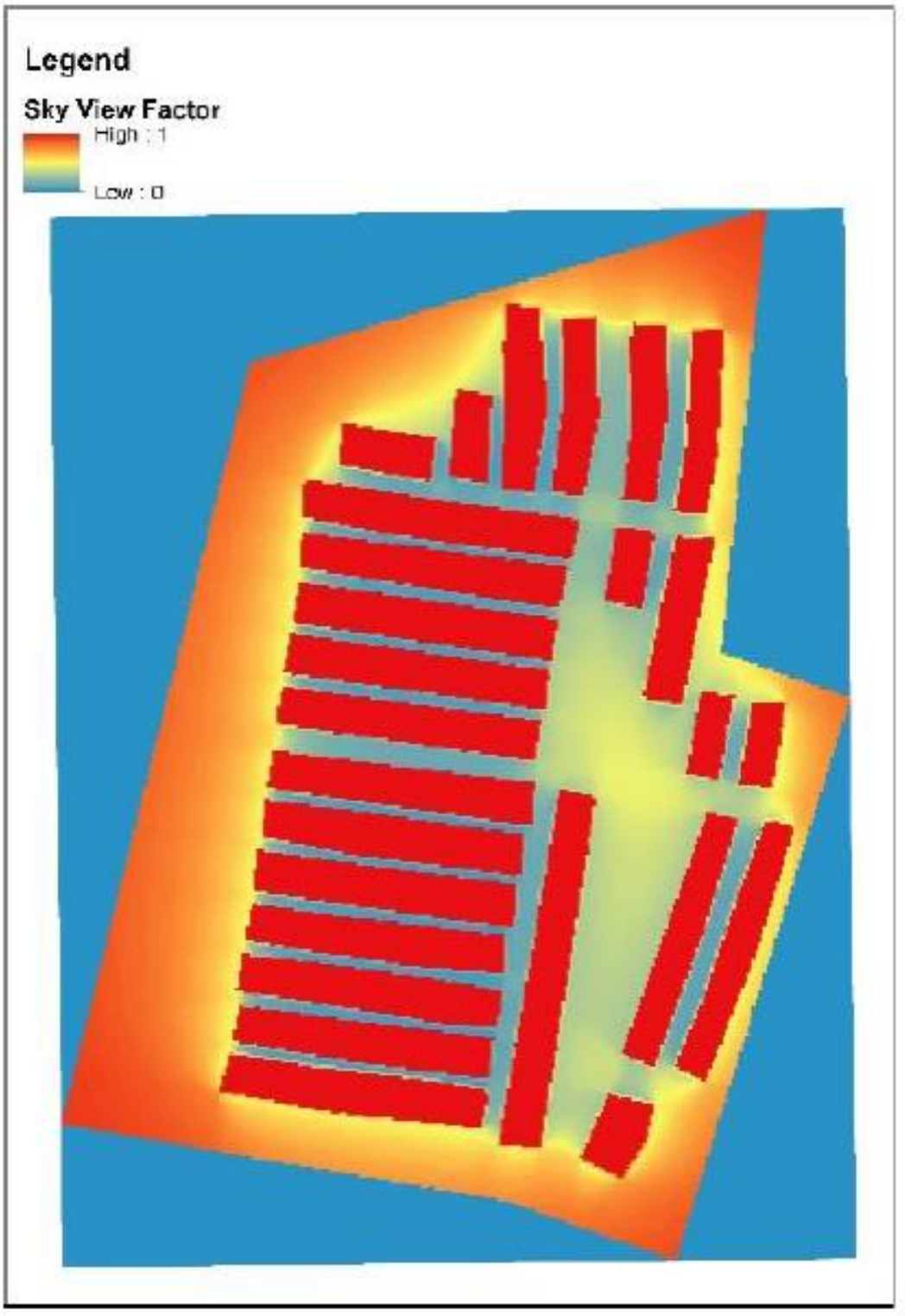


Fig 14. Simulated Sky view factor for Natwar Parekh compound

Table 4. Daylight simulation report for Natwar Parekh compound

Day lit Area (DA_{300lux}[50%])	65% of floor area
Mean Daylight Factor	6.3%
Occupancy	3650 hours per year

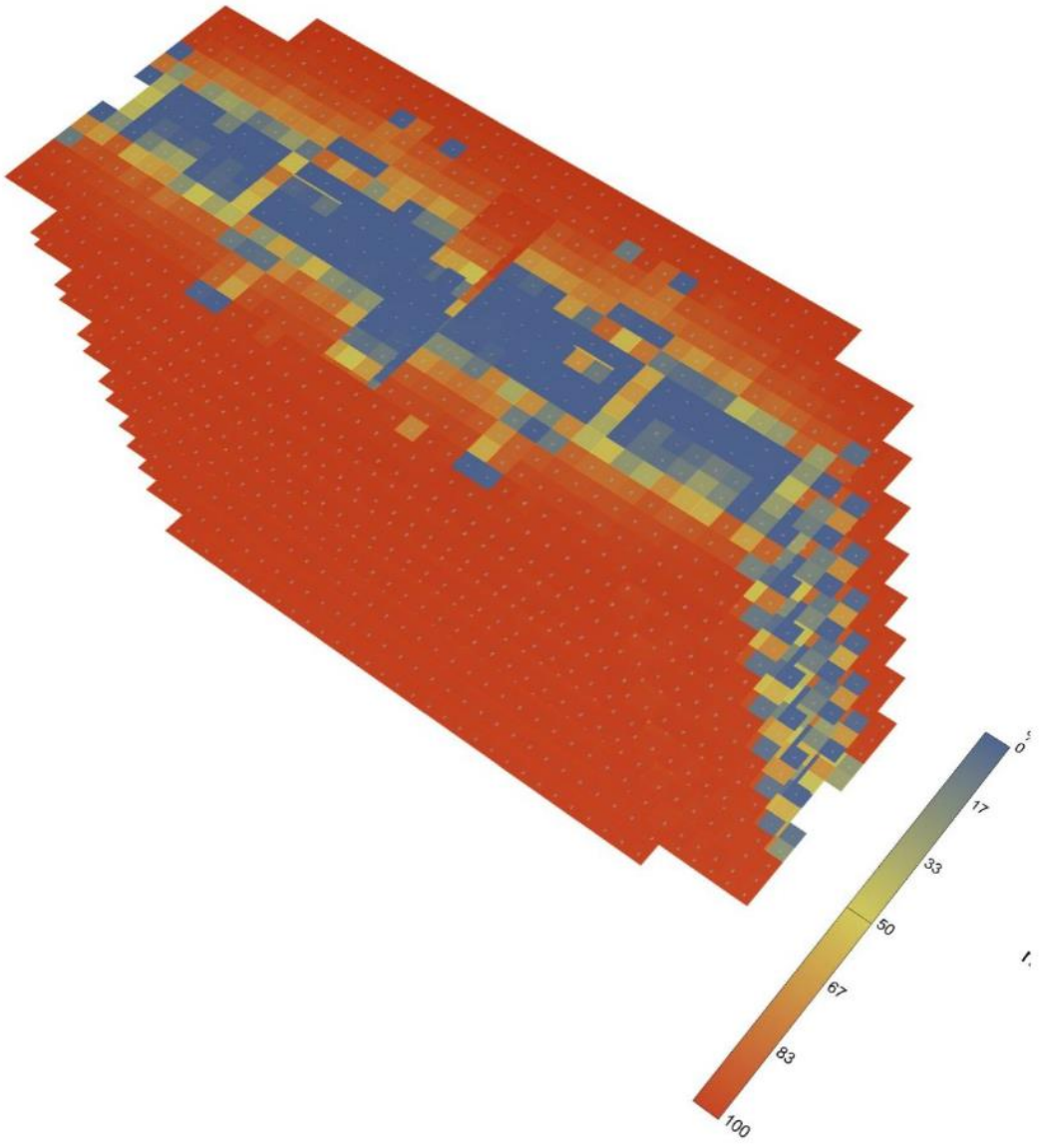


Fig 15. Daylight autonomy of all floors in Natwar Parekh compound

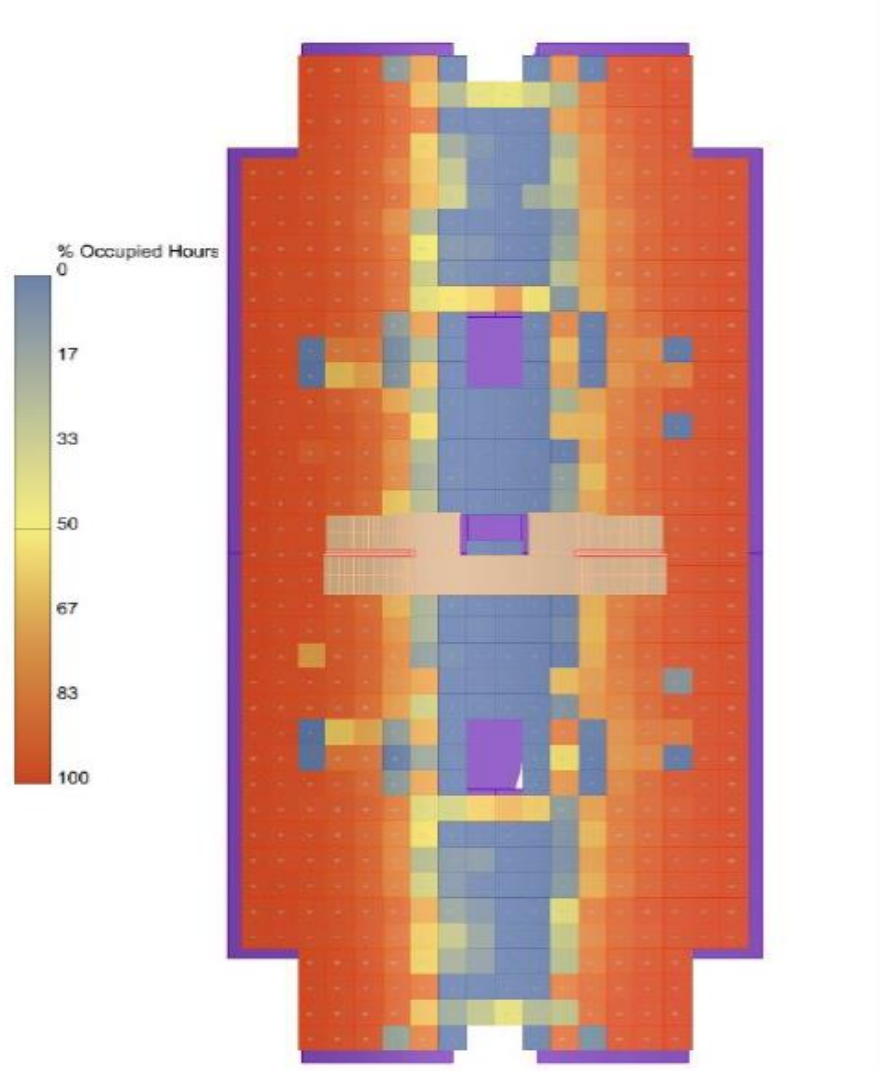


Fig 16. Floor with maximum Daylight autonomy in Natwar Parekh compound

Daylight Autonomy calculation considering impacts of nearby buildings

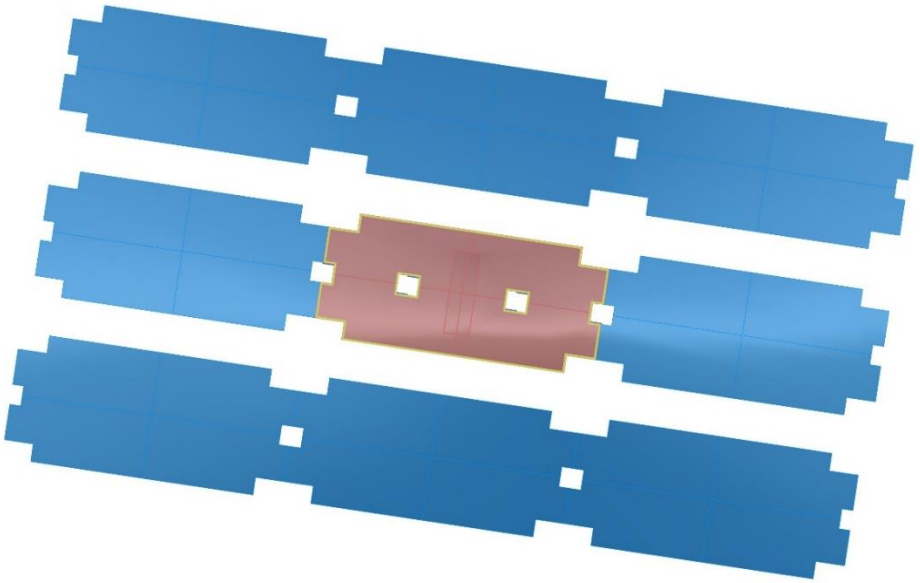


Figure 2 Building used for DA calculation

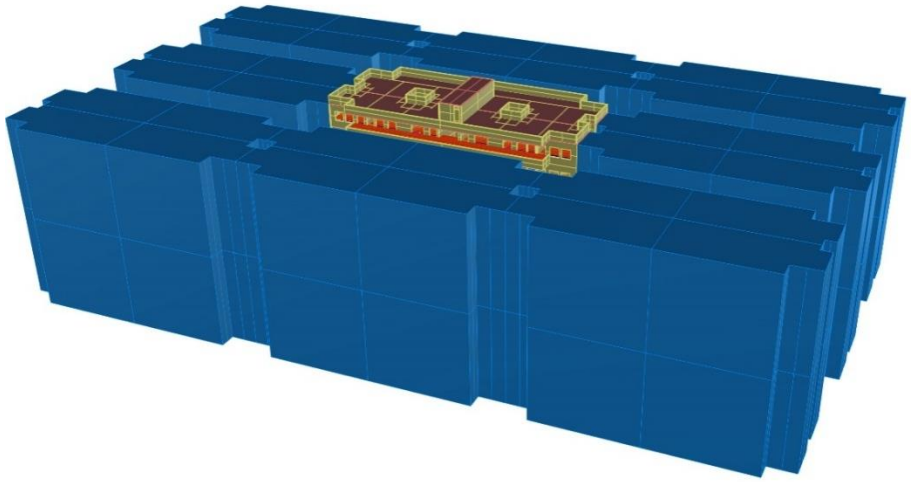


Figure 3 Building plan with surrounding building cover.

Table 5. Daylight simulation report for Natwar Parekh compound – impact of stacked buildings

Daysim Simulation Report	
Daylit Area (DA_{300lux}[50%])	31% of floor area
Mean Daylight Factor	2.8%
Occupancy	3650 hours per year

Daylight Factor (DF) Analysis: 21% of all illuminance sensors have a daylight factor of 2% or higher. Assuming that the sensors are evenly distributed across 'all spaces occupied for critical visual tasks', the investigated lighting zone does **not** qualify for LEED-NC 2.1 daylighting credit 8.1.
Daylight Autonomy (DA) Analysis: The mean daylight autonomy is 31% for active occupant behavior. The percentage of the space with a daylight autonomy larger than 50% is 31% for active occupant behavior.

Continuous Daylight Autonomy (DA) Analysis: The mean continuous daylight autonomy is 43% for active occupant behavior. The percentage of sensors with a DA_MAX > 5% is 18% for active occupant behavior

Useful Daylight Illuminance (UDI): The percentage of the space with a $UDI_{<100\text{-}2000lux}$ larger than 50% is 30% for active occupant behavior.

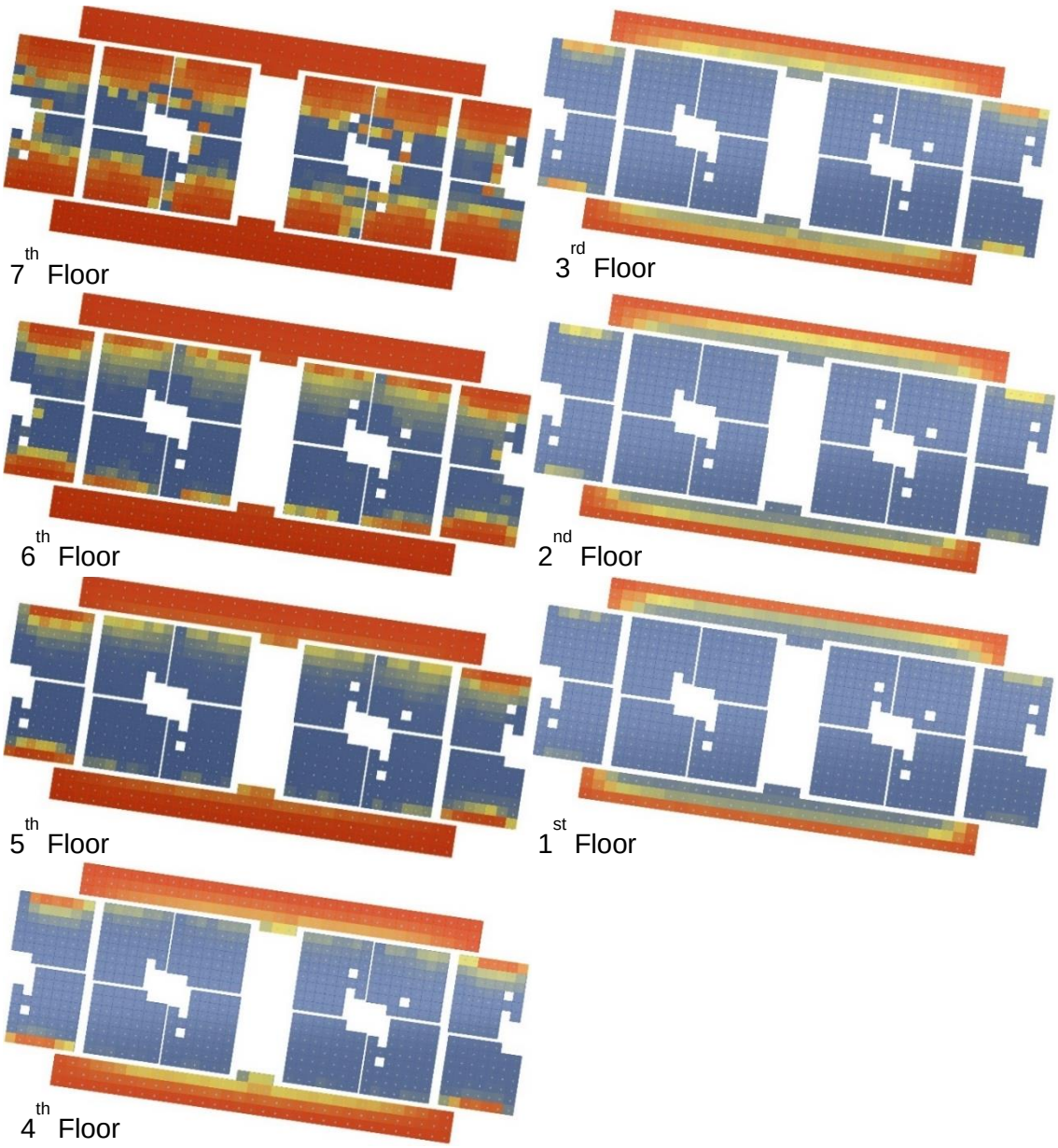


Figure 4 Floor wise DA of Natwar Parekh compound

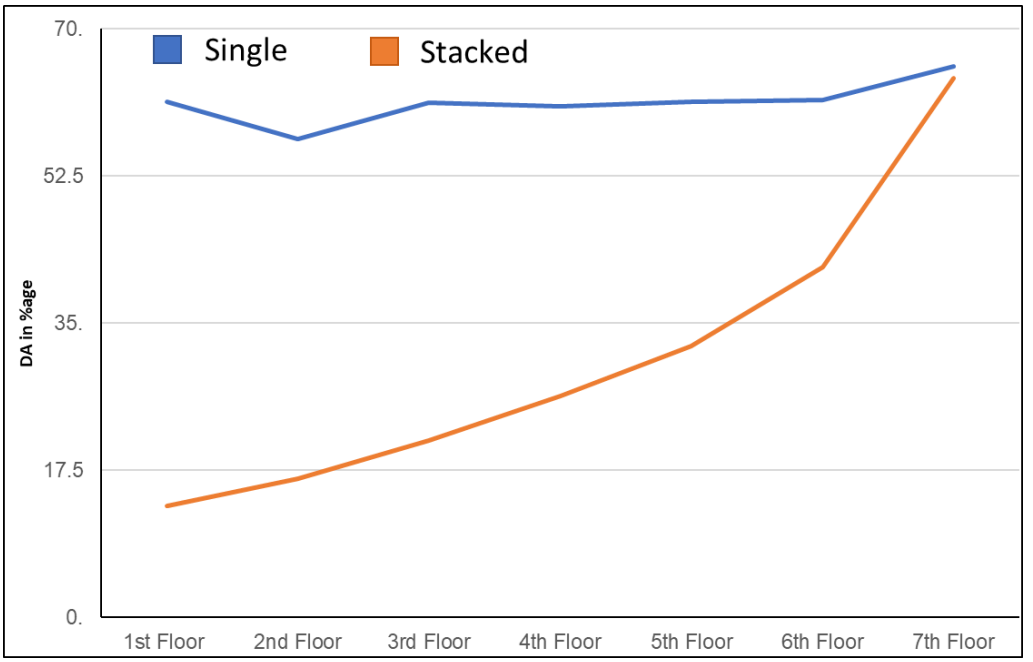


Figure 5 Change in DA of building with and without surrounding buildings.

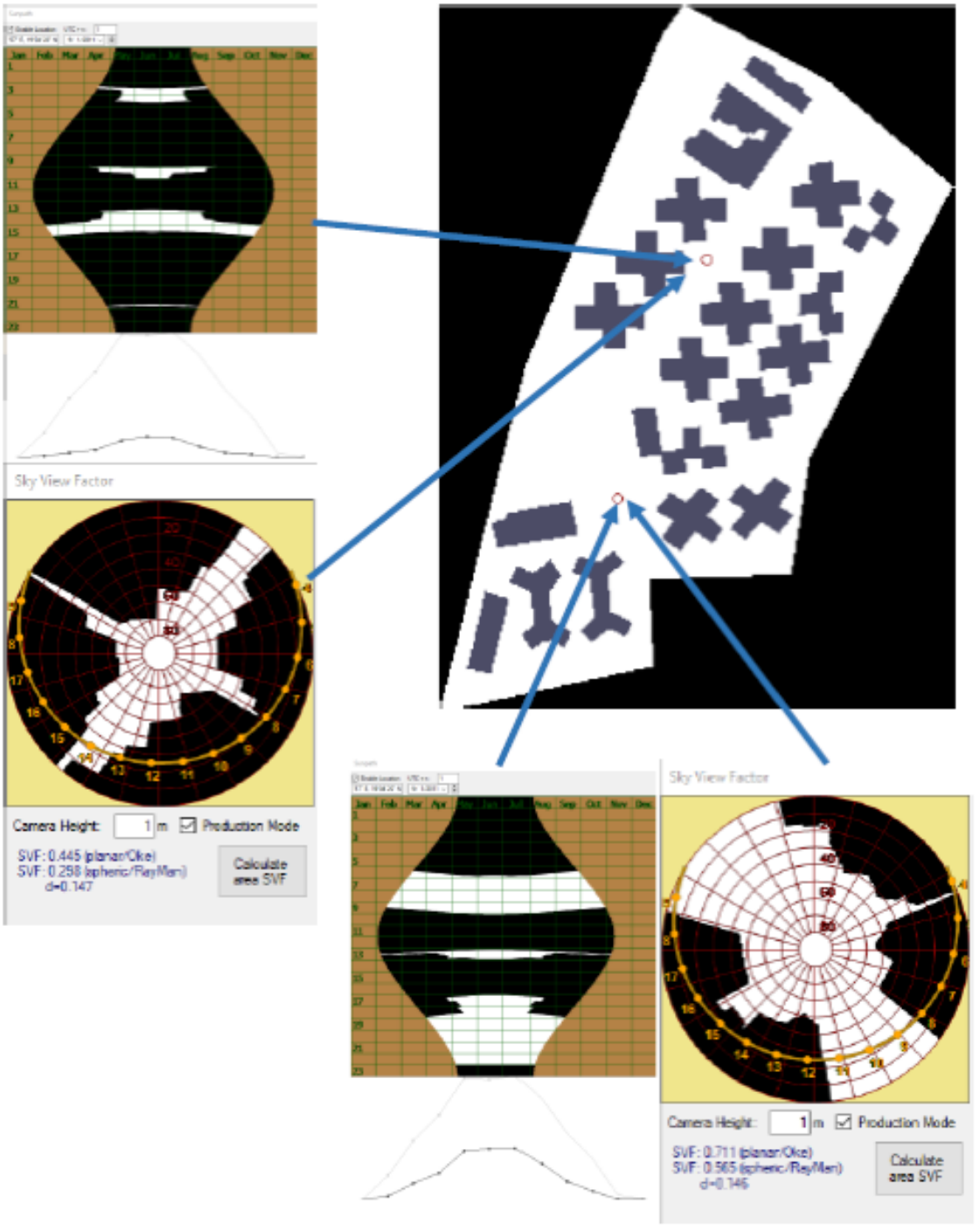


Fig 21. Sky view factor calculation for PMG colony

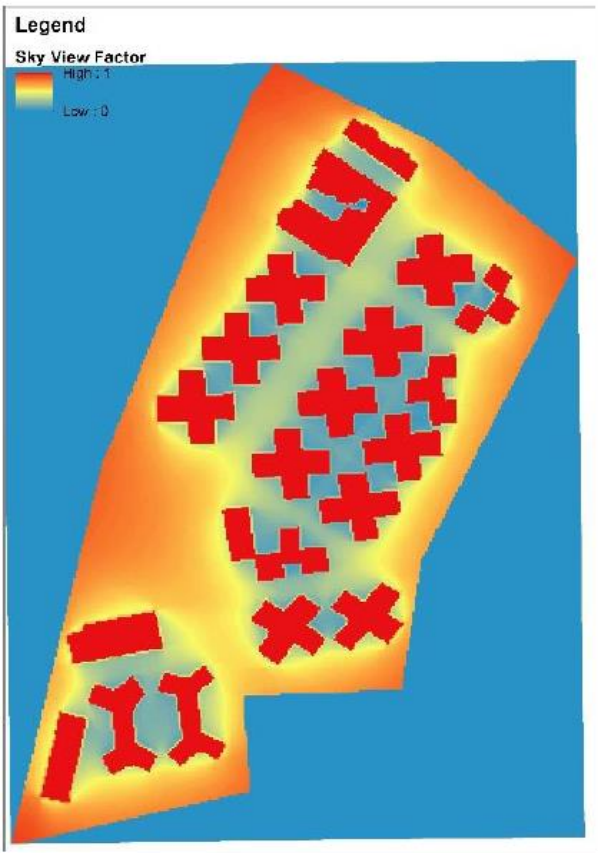


Fig 22. Simulated Sky view factor for PMG colony

Table 6. Daylight Simulation report for PMG colony type I

Daylit Area (DA_{300lux}[50%])	40% of floor area
Mean Daylight Factor	2.4%
Occupancy	3650 hours per year

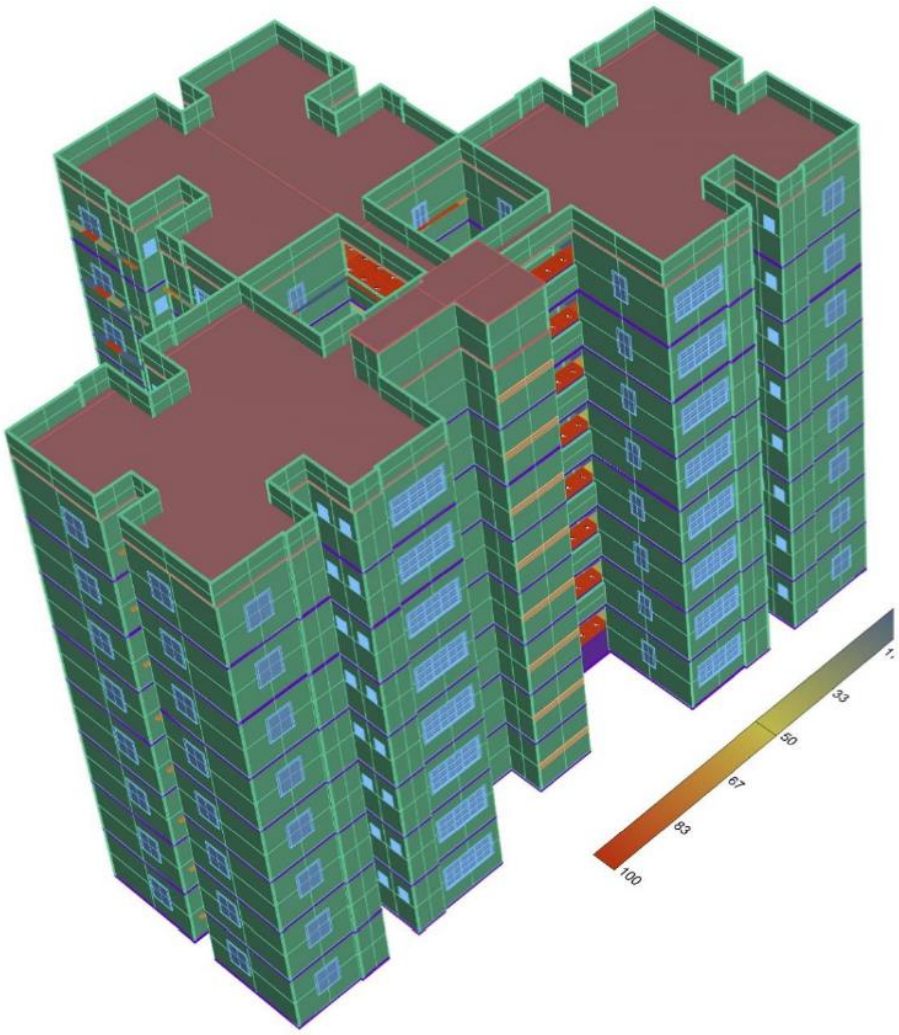


Fig 23. Type 1 Building model type 1for PMG colony

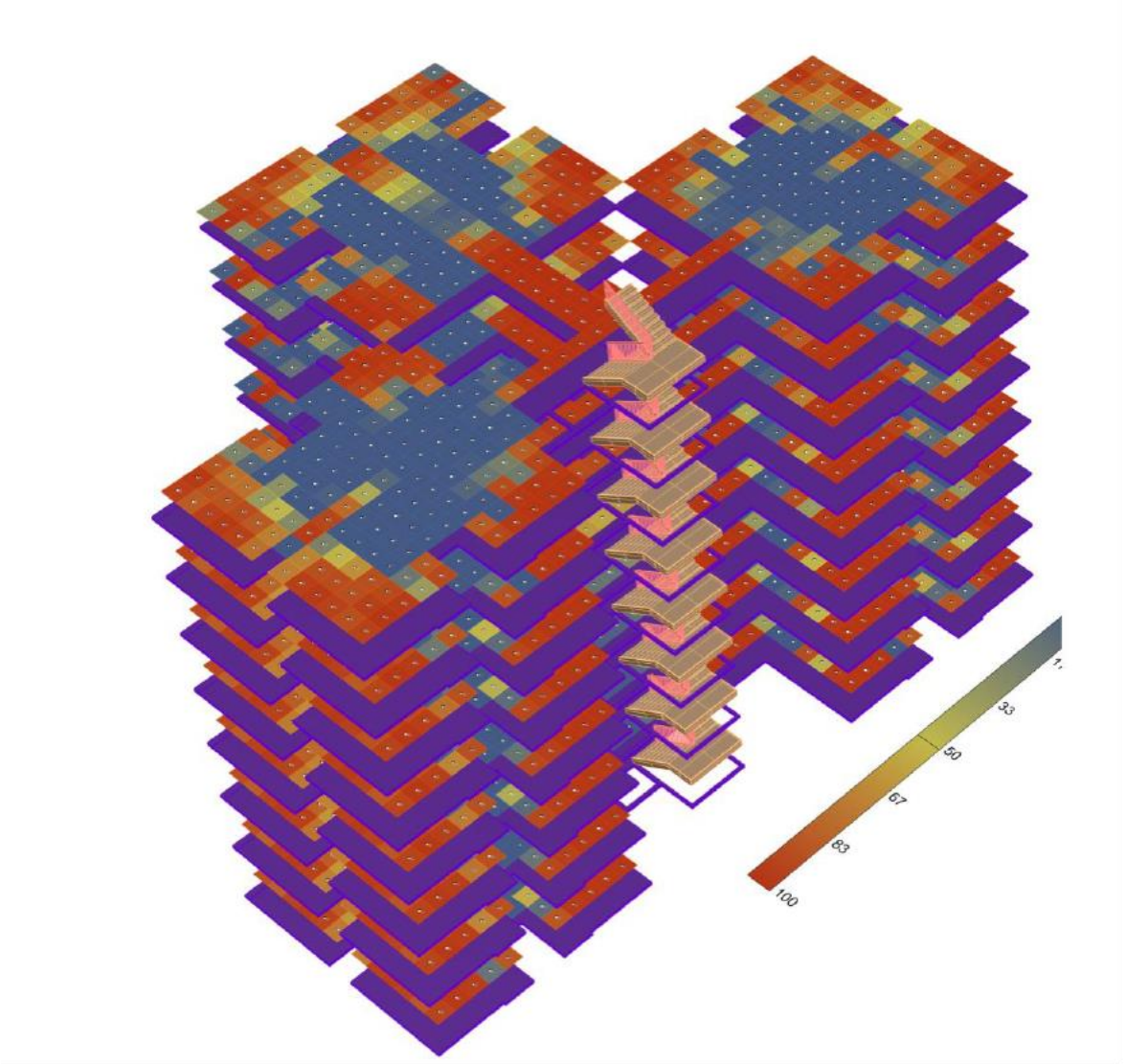


Fig 24. Daylight autonomy of all floors in PMG colony type 1

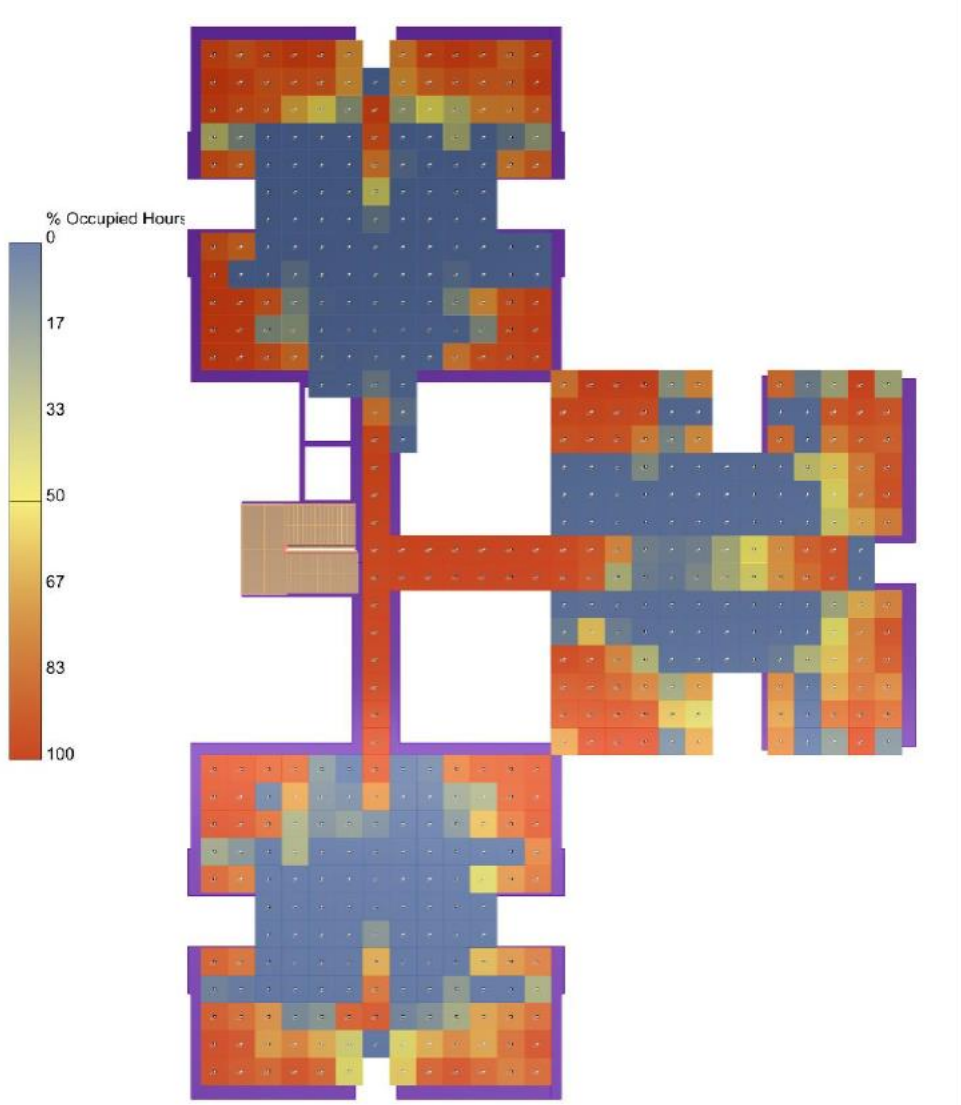


Fig 25. Floor with highest Daylight autonomy in PMG colony type 1

Table 7. Daylight simulation report for PMG colony type 2

Daylit Area (DA_{300lux}[50%])	39% of floor area
Mean Daylight Factor	2.2%
Occupancy	3650 hours per year

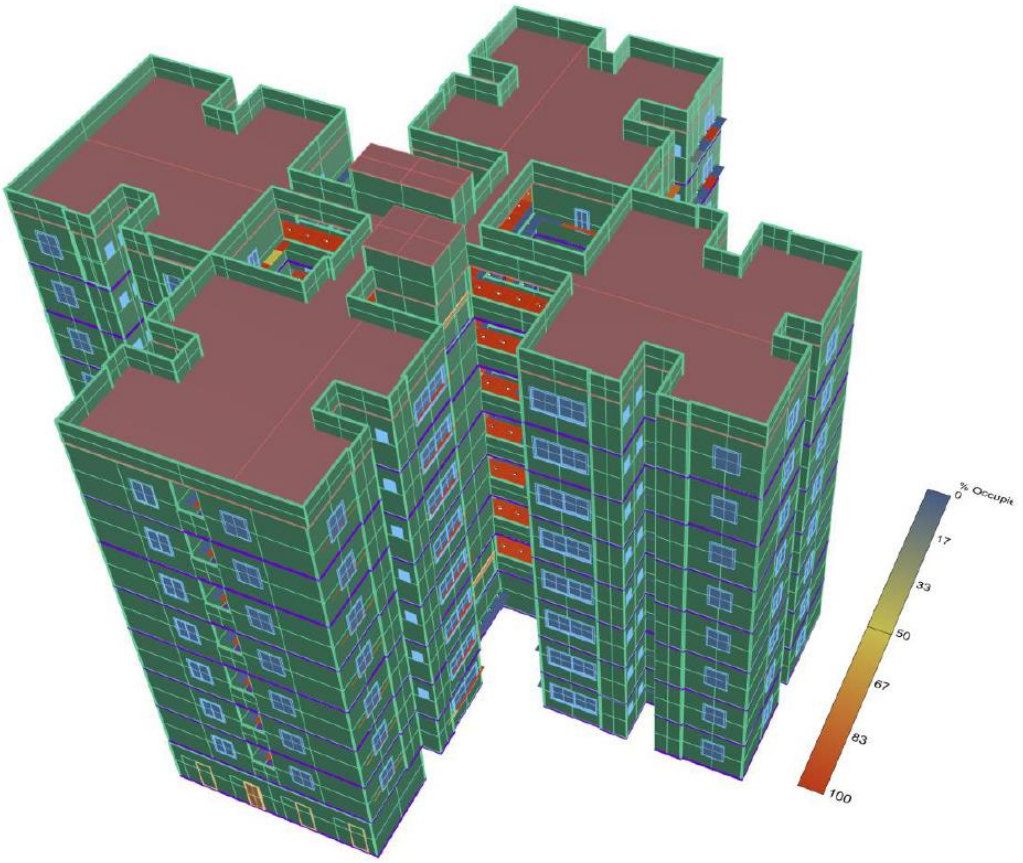


Fig 26. Type 2 Building model type 1for PMG colony

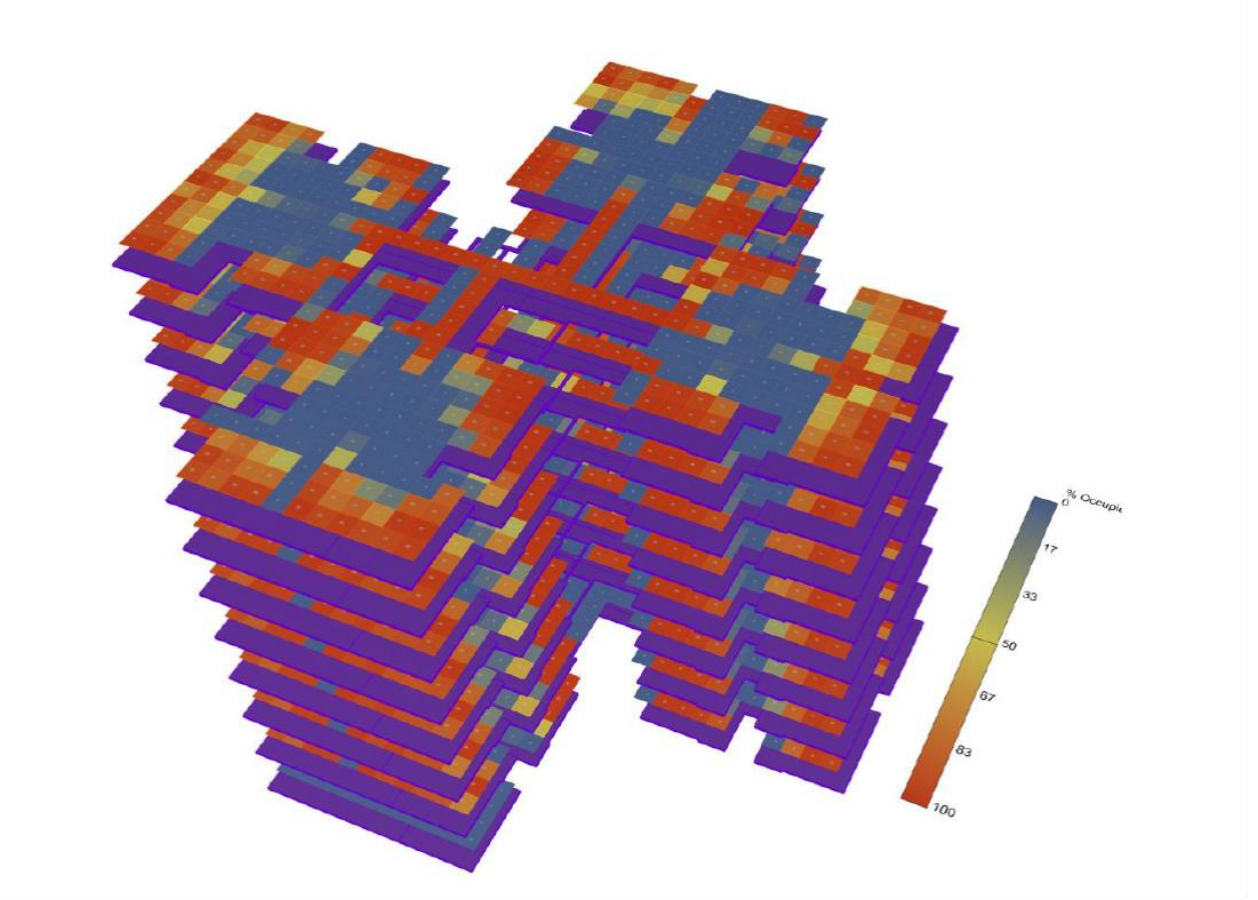


Fig 27. Daylight autonomy of all floors in PMG colony type 2

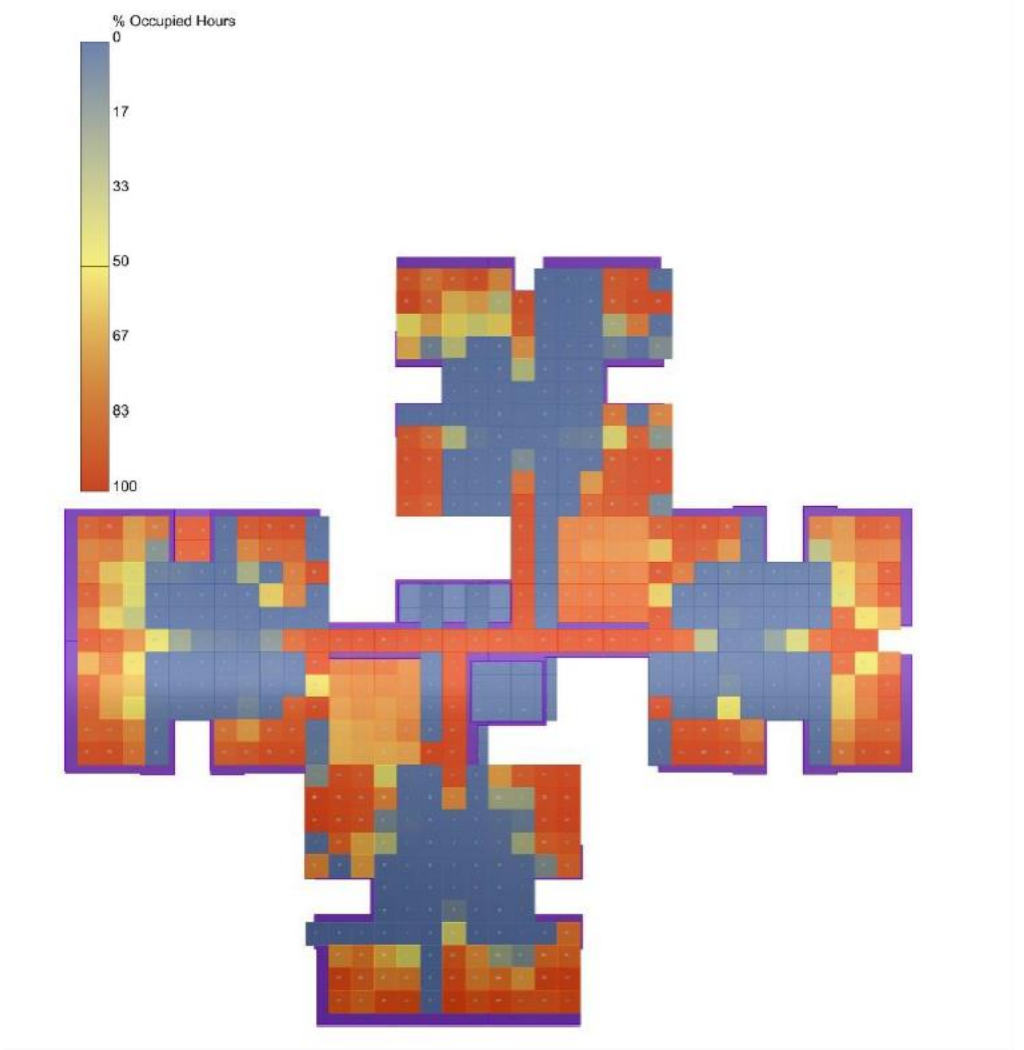


Fig 28. Floor with highest Daylight autonomy in PMG colony type 1

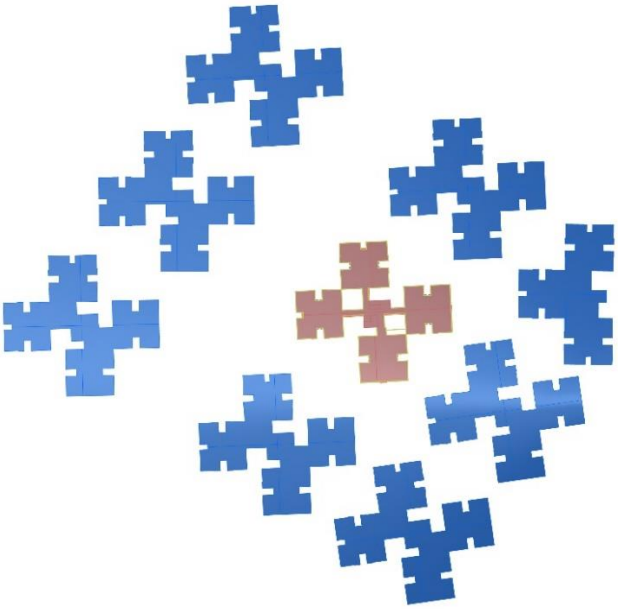


Figure 29 Building used for DA calculation

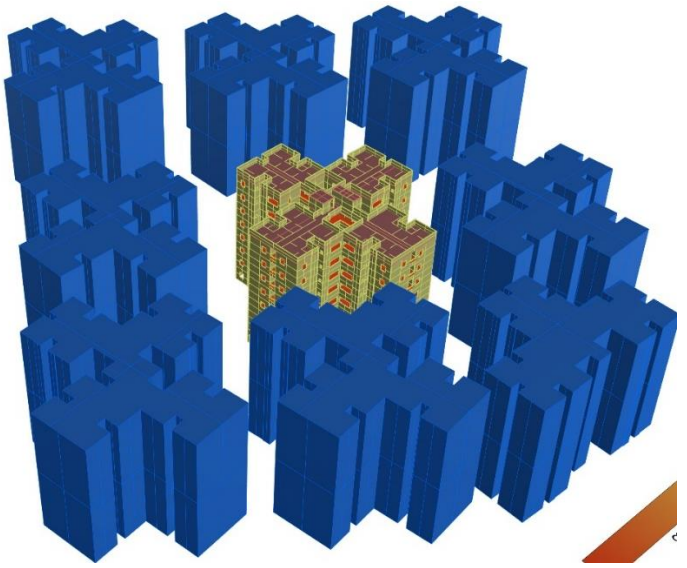


Figure 30 Building plan with surrounding building cover.

Table 8. Daylight simulation report for PMG colony – impact of stacked buildings

Daysim Simulation Report

Daylit Area (DA_{300lux}[50%])	36% of floor area
Mean Daylight Factor	2.0%
Occupancy	3650 hours per year

Daylight Factor (DF) Analysis: 23% of all illuminance sensors have a daylight factor of 2% or higher. Assuming that the sensors are evenly distributed across 'all spaces occupied for critical visual tasks', the investigated lighting zone does **not** qualify for LEED-NC 2.1 daylighting credit 8.1.

Daylight Autonomy (DA) Analysis: The mean daylight autonomy is 34% for active occupant behavior. The percentage of the space with a daylight autonomy larger than 50% is 36% for active occupant behavior.

Continuous Daylight Autonomy (DA) Analysis: The mean continuous daylight autonomy is 48% for active occupant behavior. The percentage of sensors with a DA_MAX > 5% is 19% for active occupant behavior

Useful Daylight Illuminance (UDI): The percentage of the space with a $UDI_{<100\text{-}2000lux}$ larger than 50% is 42% for active occupant behavior.

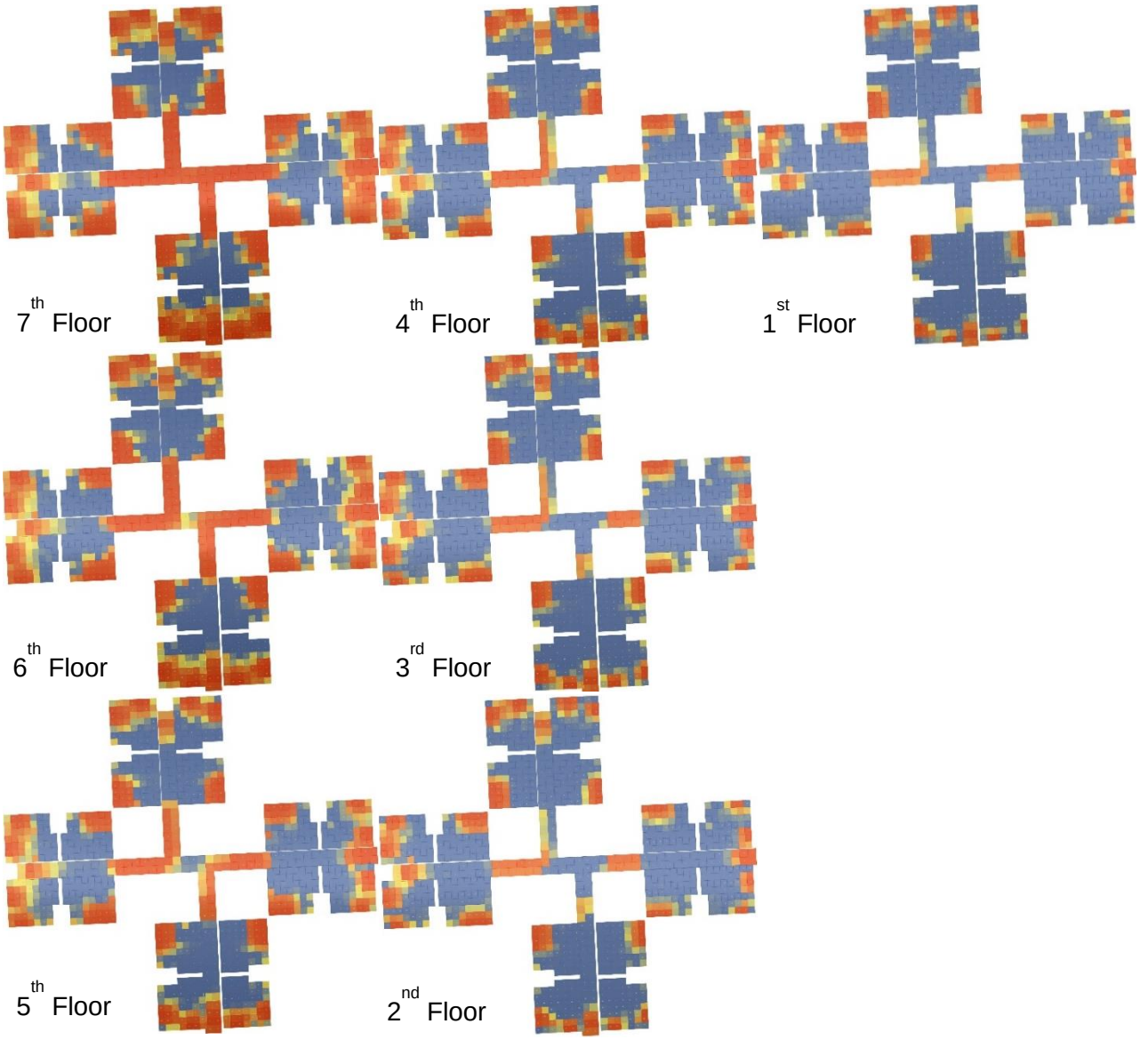


Figure 31 Change in DA of floors.

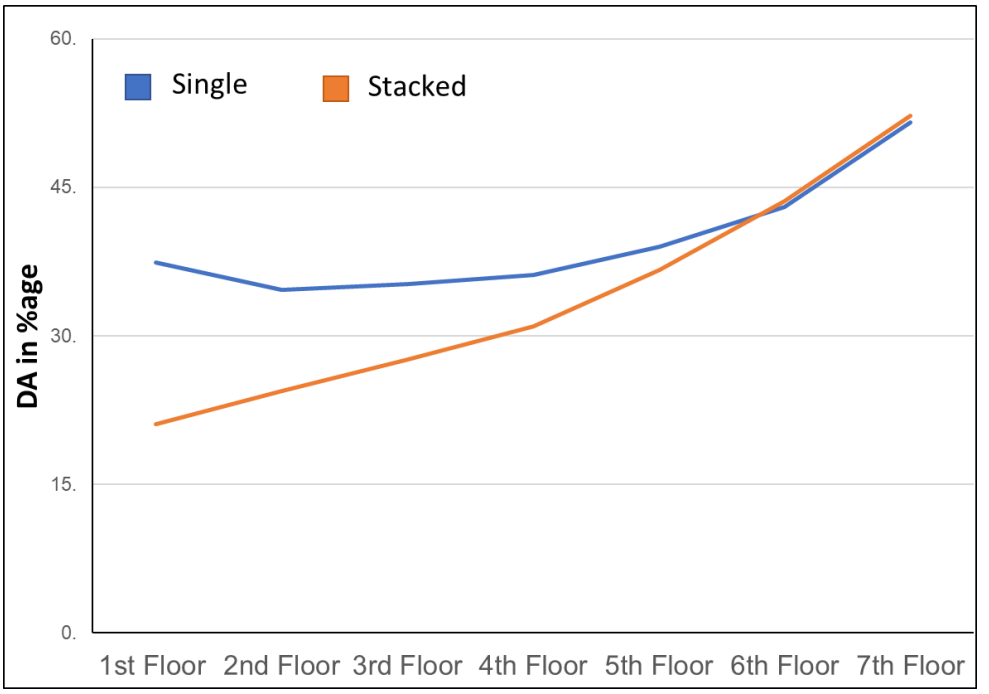


Figure 32 Change in mean DA of Building with and without surrounding buildings

Natural ventilation

This study has focused on the performance of single sided naturally ventilated multifunctional tenement units of three different housing typologies. It was observed that in Lallubhai compound, due to the presence of window and door on the opposite faces, cross ventilation occurs which generates an airflow path with a velocity of 0.8m/sec. However, there is no airflow in the living zone. The velocity in other parts ranges from 0 to 0.1 m/sec (Fig 35, 36).

In Natwar Parekh compound, the corner plot has better airflow within the room than that of the apartments beside the staircase. The air velocity near the windows is 0.9m/sec. However, there is no airflow in the living space (0 to 0.3m/sec). This simulation has been performed when windows are fully open. This velocity can be even reduced on manual controlling of window opening schedule (Fig. 37, 38, 39). In PMG colony, due to the presence of three windows on different wall surfaces which are acting as air inlets, there is airflow with a velocity of 0.8-1m/sec in the living and sleeping area. However, there is no natural ventilation in the kitchen (Fig. 40, 41).

Hence, from the CFD simulations it is observed that Natwar Parekh and Lallubhai compound lack sufficient airflow within the room due to lack of cross ventilation design facilities.

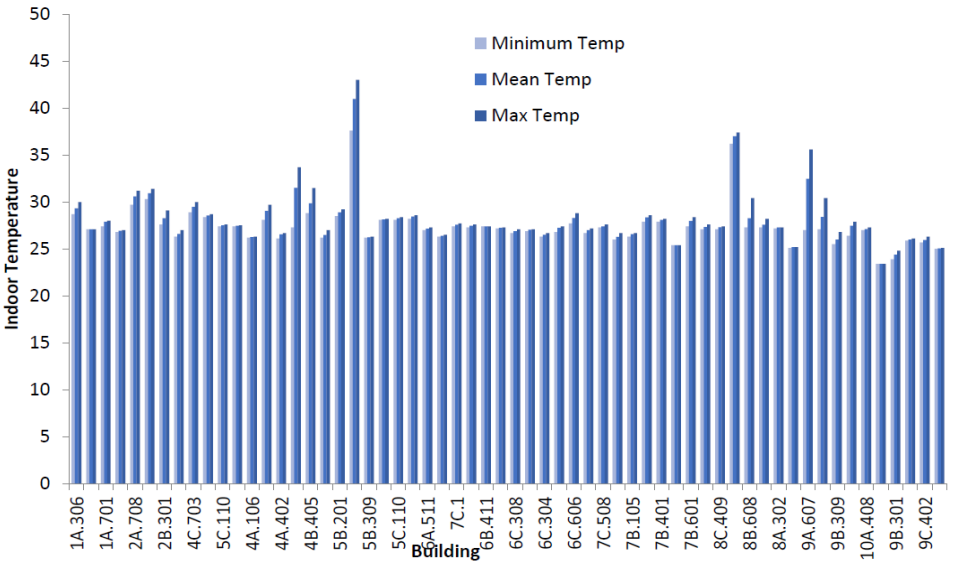


Fig 33. Temperature profile of tenements in Natwar Parekh compound

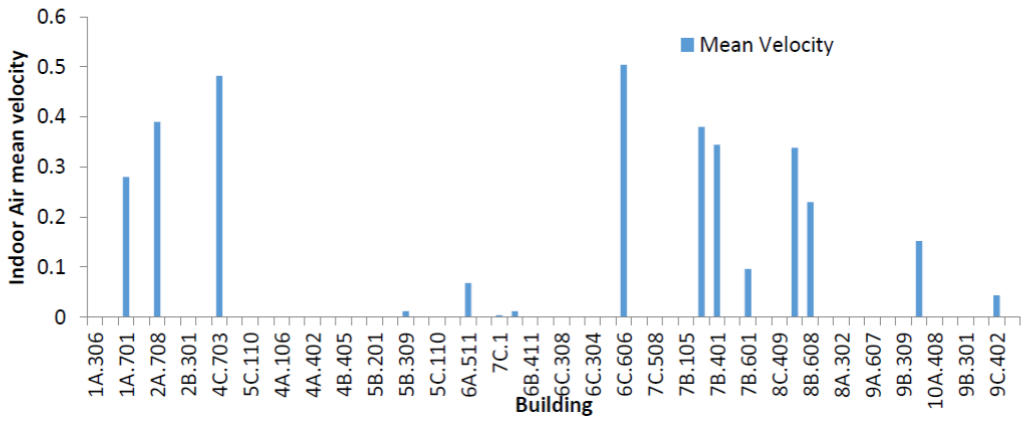


Fig 34. Air velocity profile of tenements in Natwar Parekh compound

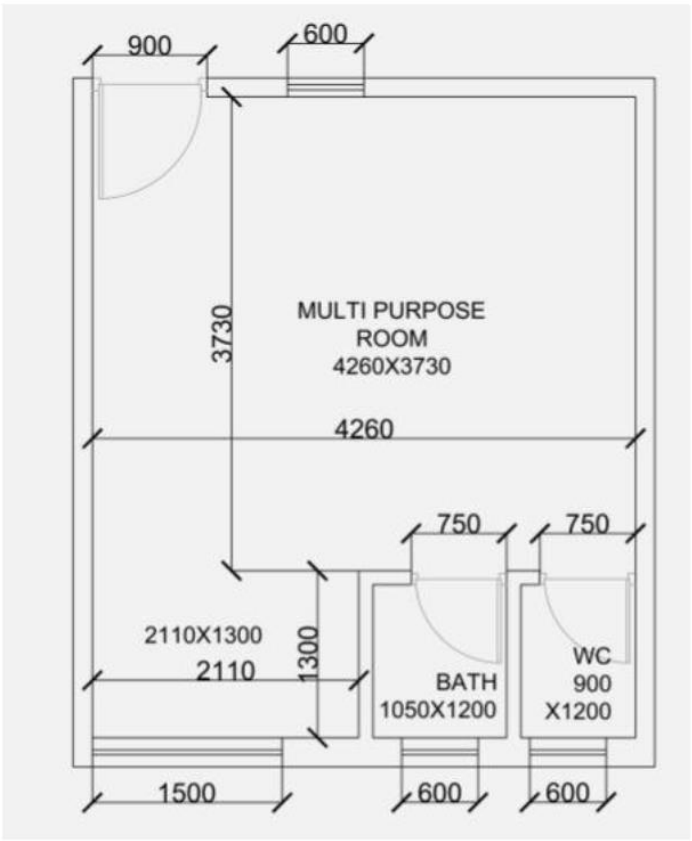


Fig 35. Floor plan of a house in Lallubhai compound

a. b.

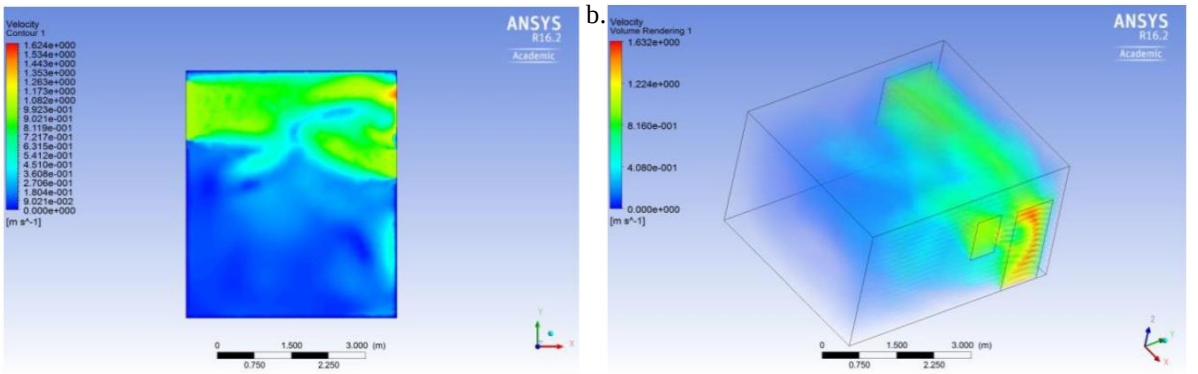
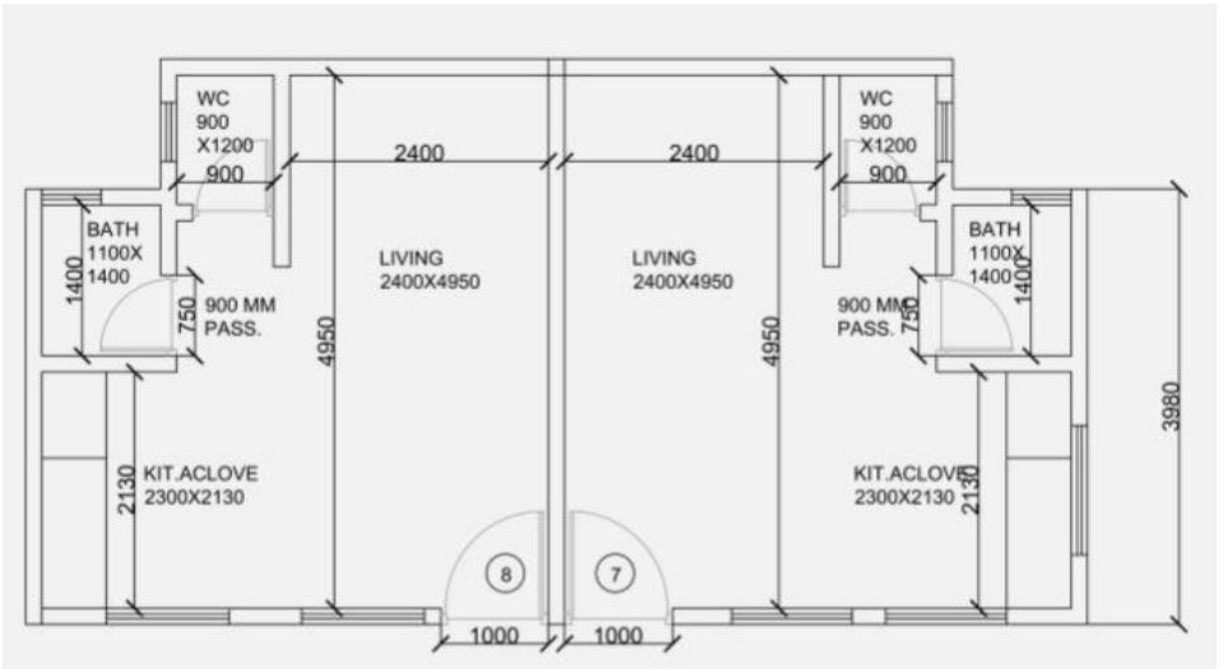


Fig 36. Velocity contour (a) and Volume rendering (b) of air velocity within the room in Lallubhai compound



House near the stairwell

House at the corner

Fig 37. Floor Plan of tenement in Natwar Parekh compound

a. b.

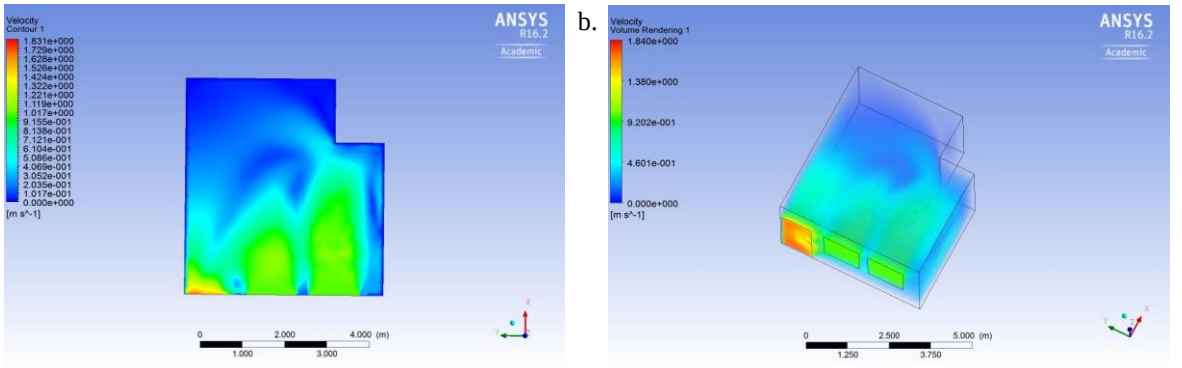


Fig 38. Velocity contour (a) and Volume rendering (b) of air velocity within the apartment beside the stairwell in Natwar Parekh compound

a. b.

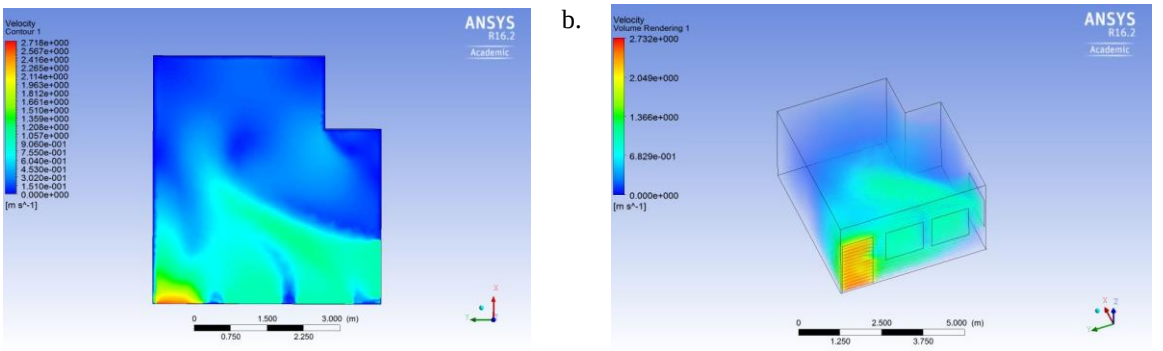


Fig 39. Velocity contour (a) and Volume rendering (b) of air velocity within the corner apartment in Natwar Parekh compound

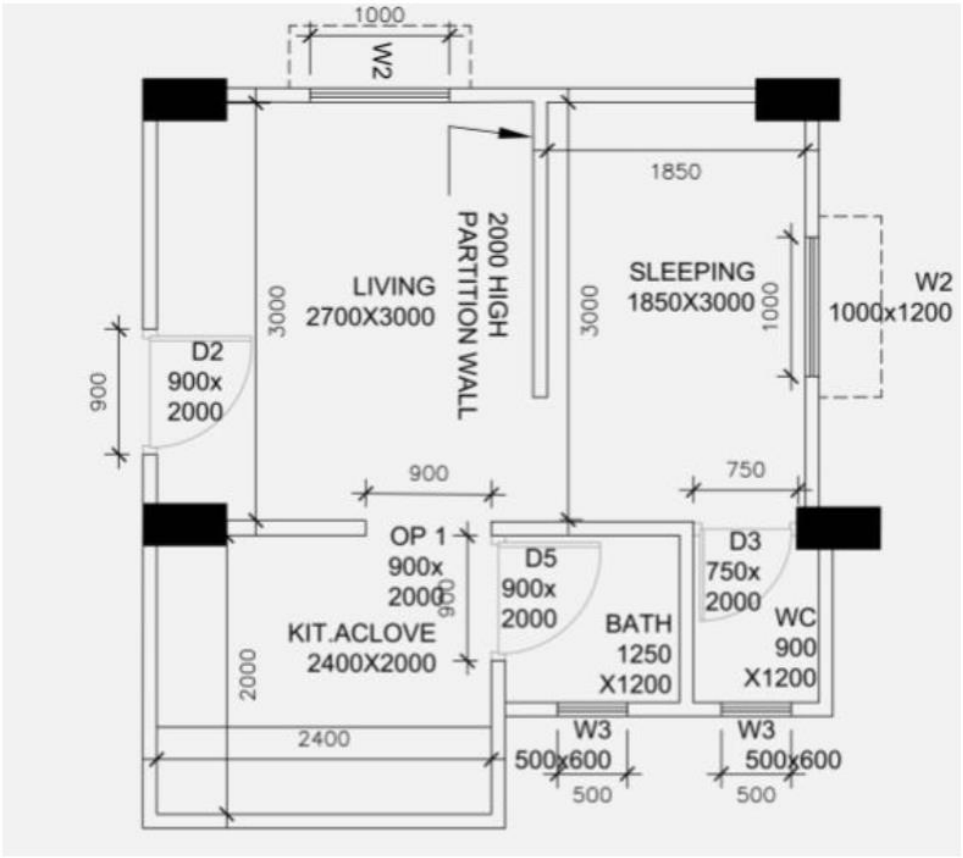
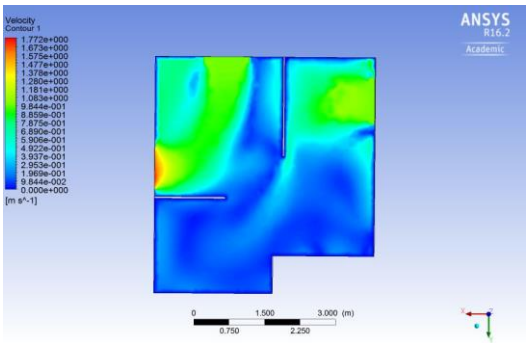


Fig 40. Floor Plan of a tenement of PMG colony

a.



b.

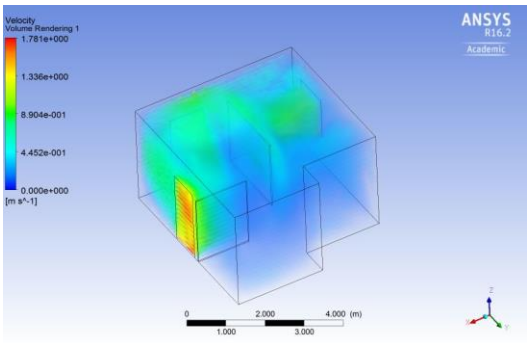


Fig 41. Velocity contour (A) and Volume rendering of air velocity within the room in PMG colony

Household survey

According to TB India 2017 report, the incidence of TB in India was 217 per 100,000 persons. However, in some pockets of Mumbai like the resettlement colonies of M-East ward, the incidence is remarkably higher than the national average as indicated by our records (Fig. 42). These facts make M-East ward in general and Lallubhai and Natwar Parekh compounds in particular, interesting cases for studying TB burden and its association with various housing conditions.

The household survey has brought to attention a variety of problems affecting the residents of Lallubhai and Natwar Parekh colonies. The field visits and informal interviews revealed that Natwar Parekh and Lallubhai compounds were very filthy and were almost always waterlogged during heavy rains. Due to these, there was dirty water around the buildings giving out foul smell which forced the residents to keep their windows closed. This was aggravated by the fact that large amount of garbage was thrown off the balconies and windows by the people staying on the upper floors which accumulated on the open spaces between the buildings. Important quantitative findings from the related to tuberculosis patient distribution are as follows:

- In Lallubhai and Natwar Parekh colonies, about 8-10% of the households have reported at least one TB patient. In contrast, in PMG colony 1% of the households reported a TB patient (Fig. 43). This indicates that Lallubhai and Natwar Parekh compounds have been rich breeding grounds for TB bacterium. This rate of TB prevalence is much higher than the national average.

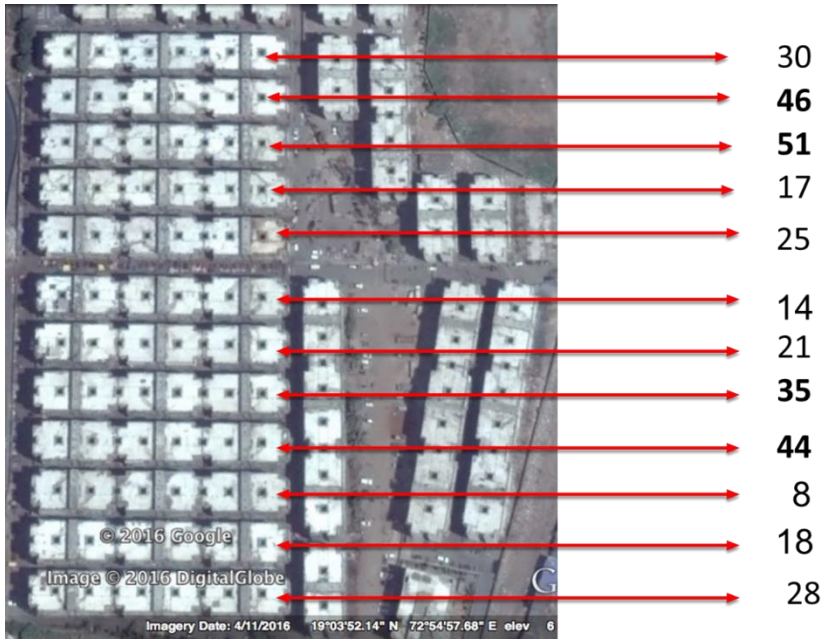
- In Lallubhai and Natwar Parekh colonies, most of the TB patients got their infection after they started living in the colony, indicating that the infection hotspot may be lying inside the colony itself (Fig. 44).

- The percentage of families having TB patients was greater where there were more members in the household (Fig. 45), indicating that overcrowding of the houses may be associated with prevalence and spread of TB. Even in PMG colony the families with higher number of members had higher incidence of TB (Fig. 45c).

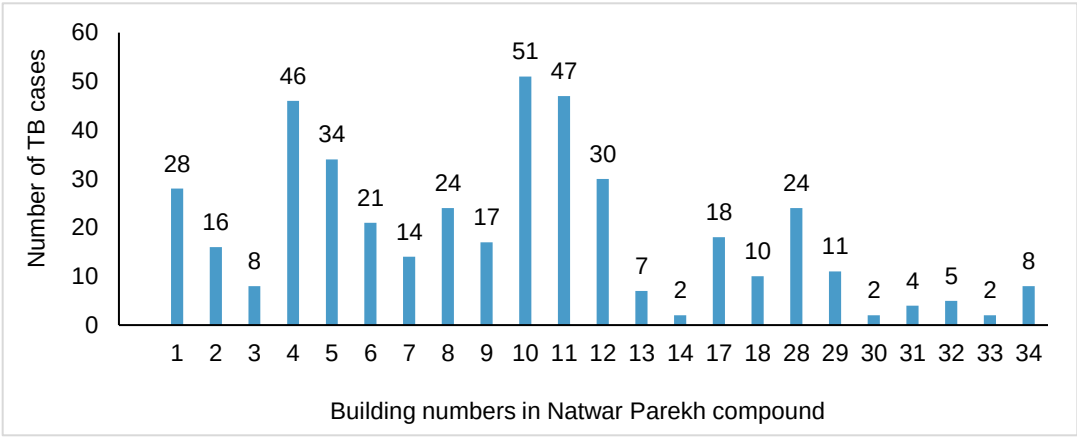
Further, the analysis of pooled and cleaned data was done to find the possible association between household factors and TB morbidity. Of 4019 respondents, 74.5% were female. Only around 12.2% of the respondents have shifted to these residents in last one year. However, 60% of the residents have been living in these tenements for more than five years.

The households: The average family size in these tenements was found to be 5.27, which is higher than Mumbai (4.56 as per census 2011). In 40.1% households there is at least one child below five years of age. The mean house hold income was found to be INR 11500/- approximately, whereas the median income was found to be less than INR 10,000/- (Fig. 47).

a.



b.



c.

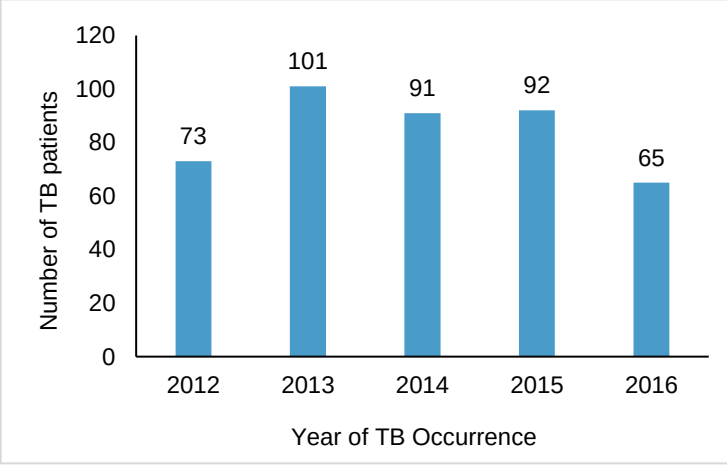


Fig 42. TB cases in densely clustered buildings in Natwar Parekh compound from 2011 to 2016 (5 years data), as recorded by the DOTS center run by Doctors For You (a and b); Year-wise distribution of TB cases in Natwar Parekh compound (c).

Occurrence of TB (the analysis is based on the direct reported patients): Analysis revealed that around 60% of the respondents who reported TB are between age group 20 to 40 (Fig. 46), while 65% of the affected respondents belonged to lower income group (household income less than INR 10,000). Importantly, most of the people suffering from TB are under medication. Most of the patients suffering from TB talked about lack of cleanliness and unhealthy environment.
In order to determine probable factors that might be affecting the occurrence of TB and with respect to the type of survey data collected, we estimated two models, based on the responses on the occurrence of TB. In the following sections, results of two binary logistic regression are presented:

Model A: Only for the patients who reported TB directly. (Table 10, 11)

Model B: At least one of the household member is suffering from TB. (Table 12, 13)

For both models the correlation between occurrence of TB and the existence of one of the possible risk factors was calculated statistically. The B value indicates the strength of the correlation. Higher the magnitude stronger the correlation. Negative B values indicate that there is negative correlation between the two variables tested. The values in the extreme right column (Sig.) indicate whether the correlation is statistically significant or not. Values below 0.1 indicate that there are chances of 10% error in the correlation with the current sample size, i.e. there is at least 90% confidence that the correlation is true. If the value is below 0.05, it means that there are chances of 5% error, i.e. there is 95% confidence that the correlation is significant. The regression analyses thus performed, showed the following correlations:

Model A states that the occurrence of TB is more likely in crowded spaces, occupied by more number of household members. Households having exhaust fans and openable windows are less likely to be affected.

Model B states that as the occurrence of TB is more likely in crowded spaces, occupied by more number of household members. The likelihood decreases as one goes higher up in the upper floors. Households having exhaust fans and openable windows are less likely to be affected (Table 13).

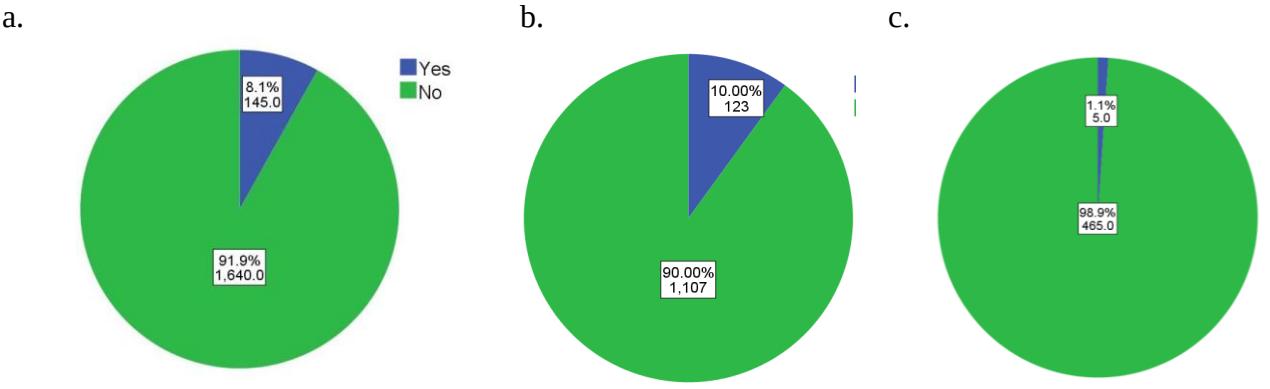
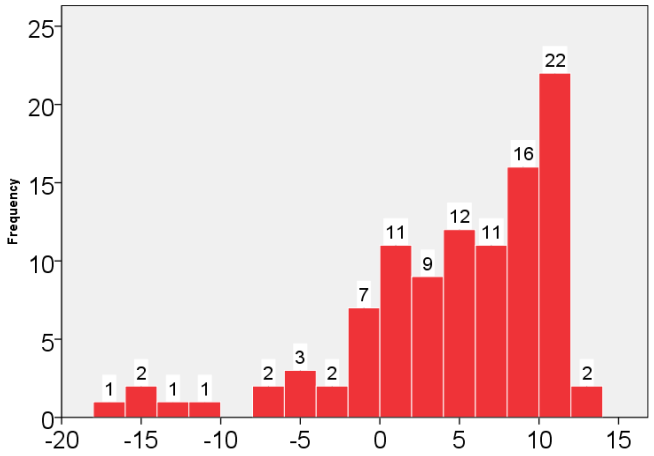
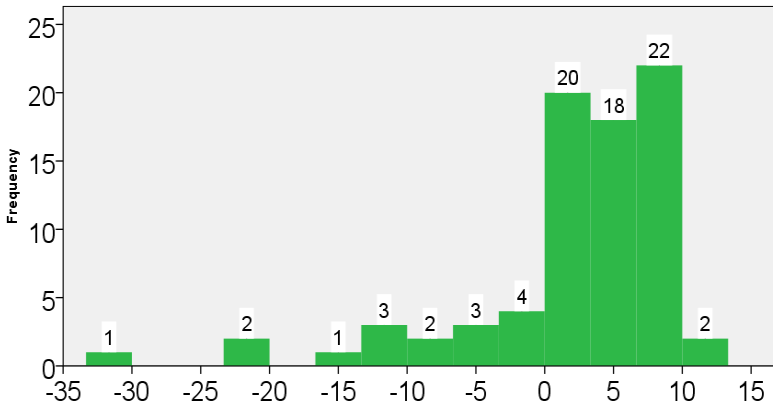


Fig 43. Households having at least a TB patient in the three colonies: a). Lallubhai colony, b) Natwar Parekh colony, c) PMG colony

a.



b.



c.

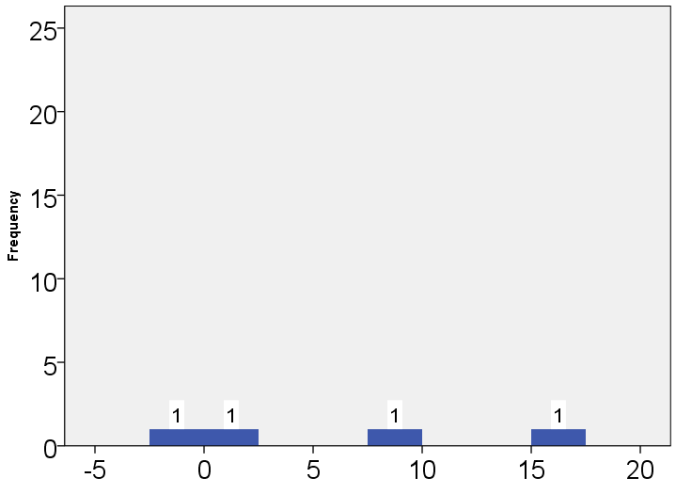
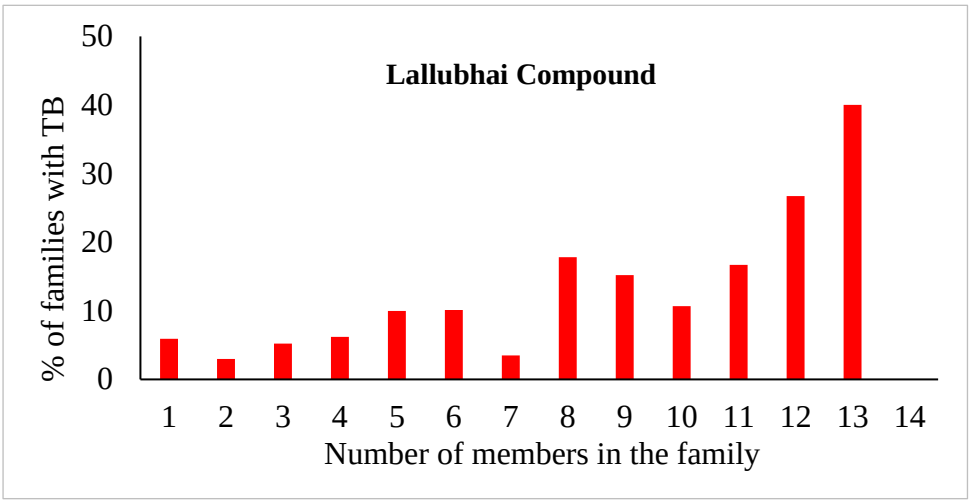
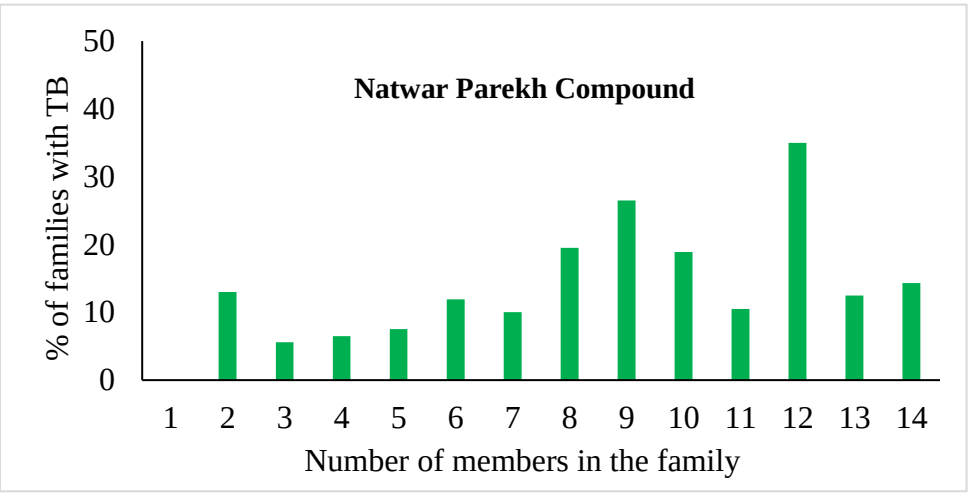


Fig. 44 Distribution of TB patients according to time of infection after shifting into Lallubhai colony (a), Natwar Parekh colony (b) and PMG colony (c)

a.



b.



c.

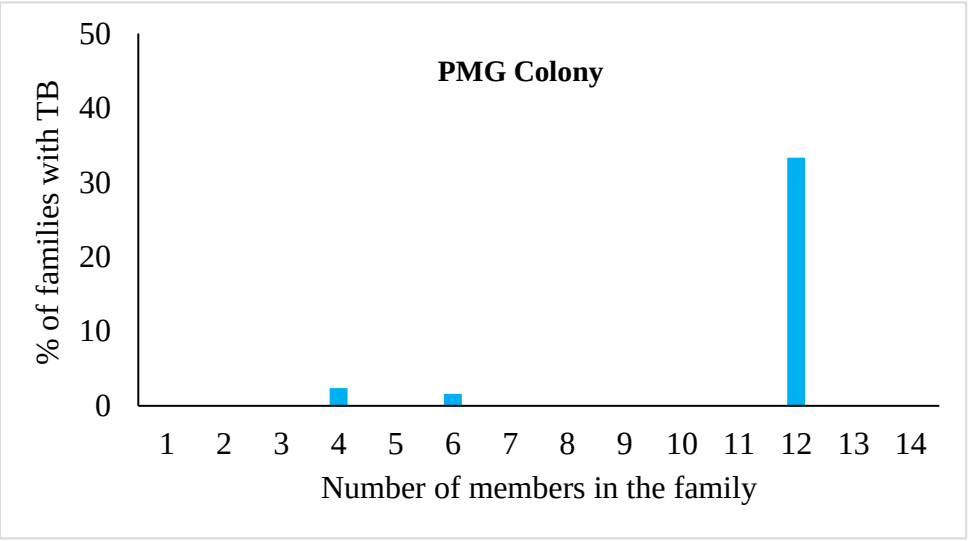


Fig. 45. Distribution of TB affected households in Lallubhai compound (a), Natwar Parekh compound (b), PMG colony (c). The graphs show that larger families had more chances of having a TB patient in the family.

Table 9. Survey data used for correlation analysis

Name of the location	Total Sample collected	%age	Samples analyzed	%age
PMG Colony	498	12.2	471	11.7
Lalu Bhai	1,785	43.8	1,770	44.0
N P Compound	1,797	44.0	1,778	44.2
Total	4,080		**4,019**	

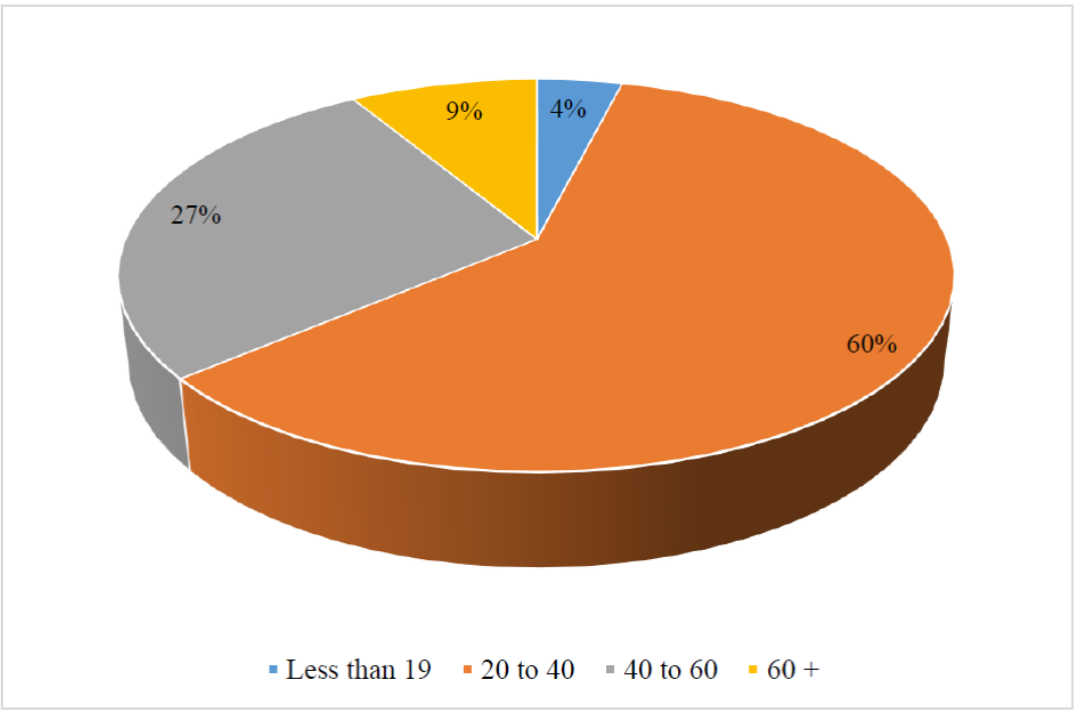


Fig 46. Age of TB patients (based on direct reported patients)

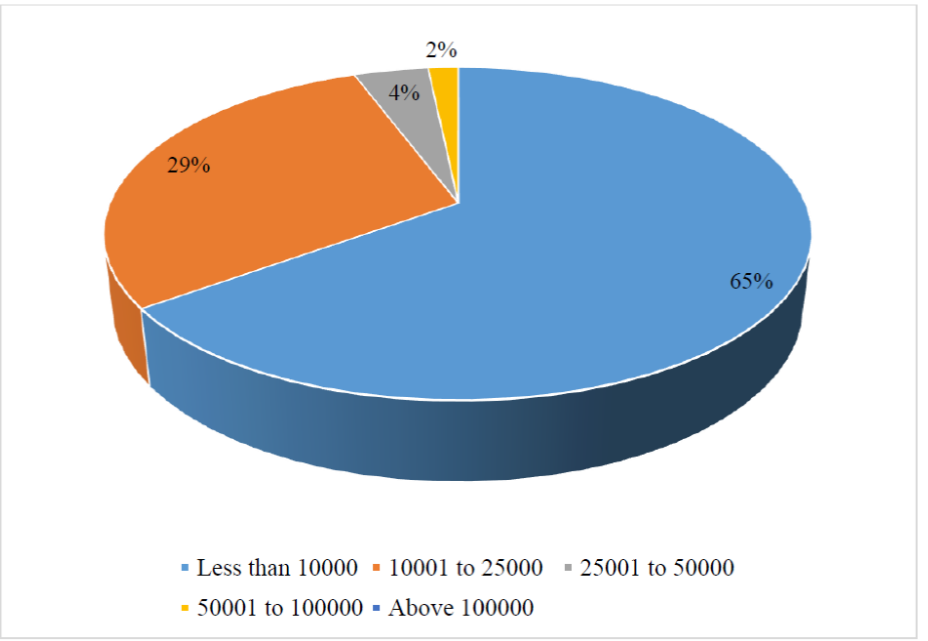


Fig 47. Income distribution of the reported TB patient households

Table 10 Statistical analysis of Model A

		N	Percentage
If the respondent is suffering from TB	No	3,890	97.0%
	Yes	122	3.0%
Does the windows have openable shutter?	No	3,562	88.8%
	Yes	450	11.2%

If the respondent is suffering from TB		B	Std. Error	t statistics	Sig.
Yes	Intercept	-6.291	1.090	-5.769	0.000
	House hold size	0.083	0.036	2.308	**0.021**
	Number of exhaust fans	-0.573	0.255	-2.249	**0.025**
	Duration of stay in the current residence (in months)	0.003	0.002	1.471	0.141
	Not openable Window	2.917	1.013	2.881	**0.004**
	Openable	0[b]			
a. The reference category is: Not suffering from TB					
b. This parameter is set to zero because it is redundant.					

Table 11. Segmented models for 2 colonies in Model A

Model A1 – Natwar Parekh compound - reported TB directly

If the respondent is suffering from TB	B	Std. Error	t statistics	Sig.
Intercept	-3.261	0.145	-22.489	0.000
Number of exhaust fans	-0.750	0.381	1.969	**0.049**

Model A2 – Lallubhai compound - reported TB directly

If the respondent is suffering from TB		B	Std. Error	t statistics	Sig.
	Intercept	-3.963	0.326	-12.156	0.000
	House hold size	0.126	0.054	2.333	**0.020**

Table 12. Statistical analysis of Model B parameters

		N	Percentage
At least one member of the household is suffering from TB	No	3,638	90.5%
	Yes	381	9.5%
Does the windows have sliding shutter or openable shutter?	No	3,568	88.8%
	Yes	451	11.2%

At least one member of the household is suffering from TB		B	Std. Error	t statistics	Sig.
Yes	Intercept	-5.523	0.605	-9.130	0.000
	House hold size	0.152	0.021	7.364	**0.000**
	Number of the storey in the building in which the respondent is residing	-0.056	0.028	-2.005	**0.045**
	Number of exhaust fans	-0.222	0.132	-1.686	**0.092**
	Not openable Window	2.823	0.583	4.846	**0.000**
	Openable	0[b]			

Table 13. Segmented models for 2 colonies in Model B

Model B1 – Natwar Parekh compound – at least 1 TB patient

At least one member of the household is suffering from TB		B	Std. Error	t statistics	Sig.
	Intercept	-2.704	0.270	-10.015	0.000
	House hold size	0.151	0.027	5.593	**0.000**
	Storey of the apartment	-0.097	0.039	-2.487	**0.012**
	Duration of stay at the current apartment (in months)	0.003	0.002	1.500	0.138

Model B2 – Lallubhai compound – at least 1 TB patient

At least one member of the household is suffering from TB		B	Std. Error	t statistics	Sig.
	Intercept	-3.170	0.246	-12.886	0.000
	House hold size	0.134	0.035	3.829	**0.000**
	Duration of stay at the current apartment (in months)	0.003	0.002	1.500	**0.085**

Study of Development Control Regulations

The Government of Maharashtra passed the Slum Rehabilitation Act 1995 (SRA) to rehabilitate eligible slum dwellers and resettle project affected slum dwellers. The SRA policy was adopted to provide eligible slum dwellers formal housing, free of cost, on or close to the site of their existing slums. For this purpose, the policy offers developers incentive FSI to build market rate housing in exchange for free housing for slum dwellers.

Health and hygiene is an important aspect of quality of life and through redevelopment, the government must have sought to provide housing that lifts slum dwellers from unhygienic environment of slums. However, this study shows that the environment of rehabilitated buildings is detrimental to the health of its residents. Specifically, the study establishes a strong correlation between the built form of SRA buildings and the incidence of Tuberculosis (TB).

As mentioned in the previous sections - households in the three colonies belong to the same socio economic group, yet there is a high burden of TB in Lallubhai Compound and Natwar Parekh Compound. These include cases of multi drug resistant TB (MDR) and extremely drug resistant TB (XDR). A negligible number of TB cases were found in the PMG Colony.

Study of design factors, namely access to daylight (Day light autonomy, Sky view factor), natural ventilation (Air velocity) shows that buildings in Natwar Parekh Compound and Lallubhai Compound severely lack natural light and ventilation especially on the lower floors. Comparatively light and ventilation conditions are better in the PMG Colony.

Following the adoption of the SRA policy, a separate set of regulations was added to the Development Control Regulations (DCR) of Greater Mumbai in 1997 to enable Slum Rehabilitation. One of the major deviations from the DCR 1991 in this set of regulations pertained to minimizing the distance between buildings. The built form of Lallubhai Compound and Natwar Parekh Compound is designed using these special regulations under DCR 33(10) that apply to R&R and slum rehabilitation buildings as well.

Comparatively, PMG Colony has generous open spaces between and around buildings as it is perhaps designed using previous building regulations. It also has negligible number of TB cases. The adverse outcomes for Lallubhai Compound and Natwar Parekh compound could be attributed to the provisions in the special SRA DCRs related to natural light and ventilation of buildings.

This section shall examine regulations regarding ‘setbacks’, ‘distance between buildings’, design of openings and density and see how it has affected the built form and in turn the environment in the three rehabilitation colonies.

The summary Table 14 given below provides a comparison of special DCRs pertaining to Rehabilitation & Slum Redevelopment buildings with the norms for general residential development and National Building Codes (NBC). The comparison with NBC norms shows a relaxation of norms related to unit density, marginal open space and distance between buildings for rehabilitation and resettlement (R & R) and slum redevelopment buildings. Table 2 shows how regulations are reflected in the design of the three buildings.

Table 14: DCR Comparisons:

DCR Categories	Resettlement & Rehabilitation of PAP 33(13) DCR 1991 & Subsequent Amendments	Slum Redevelopment 33(10) DCR 1991 & Subsequent Amendments	General Residential Development DCR 1991 & Subsequent Amendments	National Building Codes 2016
Permissible FSI	2.5 FSI for plots that are not being redeveloped DCR 33(10) applies for the plots where rehabilitation is happening using redevelopment	Proportion of Rehab: Incentive FSI Island city- 1 : 0.75 Suburbs- 1 : 1 Difficult Areas- 1 : 1.33	Island city = Total 1.8 (1.33 Base FSI x 0.35 Premium) + 1.33 Base FSI Suburbs = Total 2.7 (1 Base FSI + 1 max TDR) + (1 Base FSI + 1 max TDR) 0.35 Premium FSI = 2. 7	Prescribes an FAR of 2 Consumption of FAR subject to other restrictions on height and setbacks
Insitu FSI Consumption & TDR	For plots not under redevelopment: 2.5 FSI rehabilitation in situ 2.5 TDR as compensation to developer of Rehab DCR 33(10) applies for the plots where rehabilitation is happening using redevelopment	Insitu FSI may exceed 3 if existing dwelling units (DU) on site between 500 DU/ha - 650 DU/ha Insitu may exceed 4 if existing DU/ha more than 650 Du/ha Rest floated as TDR	Insitu consumption for general plots: Island city = May exceed 1.8 Suburbs = May exceed 2.7 TDR floating permitted for some conditions	-
Density DU/ Min	500 DU/Net Ha	500 DU/Net ha for regular slum redevelopment 650 DU/net ha for Dharavi Redevelopment Plan	For plots 1 ha and above: Island City 267 Du/Net Ha/FSI Suburbs 200Du/Net Ha/FSI	-

DCR Categories	Resettlement & Rehabilitation of PAP 33(13) DCR 1991 & Subsequent Amendments Slum Redevelopment 33(10) DCR 1991 & Subsequent Amendments	General Residential Development DCR 1991 & Subsequent Amendments	National Building Codes 2016
Density DU/Max	No limit mentioned	600 DU/Net ha per FSI Island City (1.33) 450 Du/Net ha per FSI Suburbs (1)	For low income housing - 15sqm in size in 4 storied walkups, without possibility of incremental growth- 500 DU/ha is maximum density prescribed Otherwise 125 - 150 DU/gross ha for metropolitan housing
Height	No limit (But until now the buildings have not been taller than 24m i.e. G+7. However there are plans to increase building heights for future)	The height of a building shall not exceed one and half times the total of the width of the street on which it abuts and the required front open space. Unless high rise permitted by Commissioner in accordance with min street widths mentioned in DCR (min street width 9m for building 32 m in height.. onwards)	15 m for low income housing i.e G+4
Setbacks and Step backs	**Front and side setback:** 1.5m for building up to 24m height 6m for buildings above 24m. 3m where plot abuts DP road 18.3m wide No separate regulations for Stepbacks	**Front:** Varies from 7.5 to 3 m depending on street width **Side and Rear:** Width between internal buildings not less than a third of the height of that building above the ground level, rounded to the nearest decimeter subject to a maximum of 20 m. Minimum being 3.6 m. Different for detached buildings and row houses Step Backs allowed on upper floors for taller buildings This norm is separate and distinct for each building/wing	**Front -** 1.5 m to 6 m depending on street width **Side Open Space:** For buildings above 10 m in height = Height/3 till the height of 30 m then +1 m for every 5 m height increase subject to a maximum of 20 m. **Rear open space:** Average width of 3.0 m and at no place measuring less than 1.8 m Step backs allowed on the upper floors for taller buildings This norm is separate and distinct for each building/ wing
Area between buildings	3m min	Width between internal buildings not less than a third of the height of that building above the ground level for each building, rounded to the nearest decimeter subject to a maximum of 20 m. This norm is separate and distinct for each building and wing	H/3 till the height of 30 m then +1 m for every 5 m subject to a maximum of 20 m. Sizes also provided for ventilation shafts for kitchens and toilets This norm is separate and distinct for each building and wing

DCR Categories	Resettlement & Rehabilitation of PAP 33(13) DCR 1991 & Subsequent Amendments Slum Redevelopment 33(10) DCR 1991 & Subsequent Amendments	General Residential Development DCR 1991 & Subsequent Amendments	National Building Codes 2016
Rehab Unit Size/ Unit Size	Used to be 20.9sqm changed to 25sqm in 2008 A multi purpose room shall be allowed with size upto 12.5 sqm with a minimum width of 2.4 m Each house abuts common passages 2 m min Kitchen can be an alcove no size restrictions Bathroom no size restrictions	No limit to unit size Min habitable room size 9.5 sqm - min width 2.4 m	Min habitable room size 9.5 sqm - min width 2.4 m Multipurpose single room should be at least 12.5 sqm with minimum width of 2.5 m
Windows size and design	One or more apertures, excluding doors, with area not less than one-sixth of the floor area of the room, with no part of any habitable room being more than 7.5 m. away from the source of light and ventilation Habitable Room: At least a window not less than 1 sqm in area, opening directly on to an interior or exterior open space, but not into a shaft Kitchen Window: No Window / direct ventilation requirement - mechanical light an ventilation is fine Bathroom Window: No Window / direct ventilation requirement - mechanical light an ventilation is fine	One or more apertures, excluding doors, with area not less than one-sixth of the floor area of the room, with no part of any habitable room being more than 7.5 m. away from the source of light and ventilation At least a window not less than 1 sqm in area, opening directly on to an interior or exterior open space, but not into a shaft For towers external windows on a floor shall be not less than 2 1/2 per cent of the floor area Bathroom openings (windows, ventilators, louvers) not less than 0.3 sqm in area or 0.3 m in width.	1/6th of the area of room should be window area for warm and humid - 25% higher window area for kitchen If a window is partly fixed, only the openable area shall be counted. No portion of a room shall be assumed to be lighted, if it is 7.5 m away from building
Open Space Requirement	8% min on ground level	For plots over 1001 sqm depending on area of Plot 15% - 25% of open space shall be reserved	Layout/plot measuring 0.3 ha or more for recreational purposes which shall as far as possible 15 percent of the area of the layout, or b) 0.3 to 0.4 ha/1 000 persons; for low income housing

Table 15: Comparison of three colonies under current study

	PMG Colony	Lallubhai Compound	Natwar Parekh
Year of approval as per building approval drawings	1997	2003 and 2007	2008
FSI for entire plot area	2.5	2.5	2.5 consumed 2.44
Net Study Area* (After removing Roads on municipal sheets and built up amenity area)	1.75	5.75	5.05**
Number of Units in Study Area (including shops)	1600	6318	5568
Density DU/ net ha in Net Study Area	914	1099	1103**
Area of window for multipurpose room	12%-20% of room area (6% to 10% after accounting for shut pane of sliding window)	10% of room area (5% after accounting for shut pane of sliding window)	16% of room area (8% after accounting for shut pane of sliding window
Window Design Features	Cross ventilated.	Not Cross ventilated.	Not Cross ventilated and opens to a common passage
Height	G+7 = 24 m	G+5 = 18 m	G+7 = 24 m
Distance between buildings	Mediated through courts measuring 10x10 to 16x16 m. Each building has 4 light wells measuring 5x5m	3 m min distance	3 m min distance
Open Space Requirement	15%	15%	15%
Room Size	21 sqm	21 sqm	21sqm

***NOTE 1:**

- *The Net Study Area is different from total plot area mentioned in the municipal drawings. Study areas are the areas of the Colony where the TB study was mostly concentrated.
- Google Maps was used to approximate the study areas for the three colonies
- Number of units were derived from the Municipal Drawings – They include vacant units and shops.

**** NOTE 2:** The study area of Natwar Parekh compound is smaller in the Municipal Drawings than shown in the Google map. If that areas is used net density of Natwar Parekh Compound goes up significantly

A detailed section discussing the DCRs and design of buildings is presented below.

Net Study Area

PMG Colony

Net Study Area = 1.75
Total Number of Units = 1600
Density/ Net ha = 914 du/ net ha

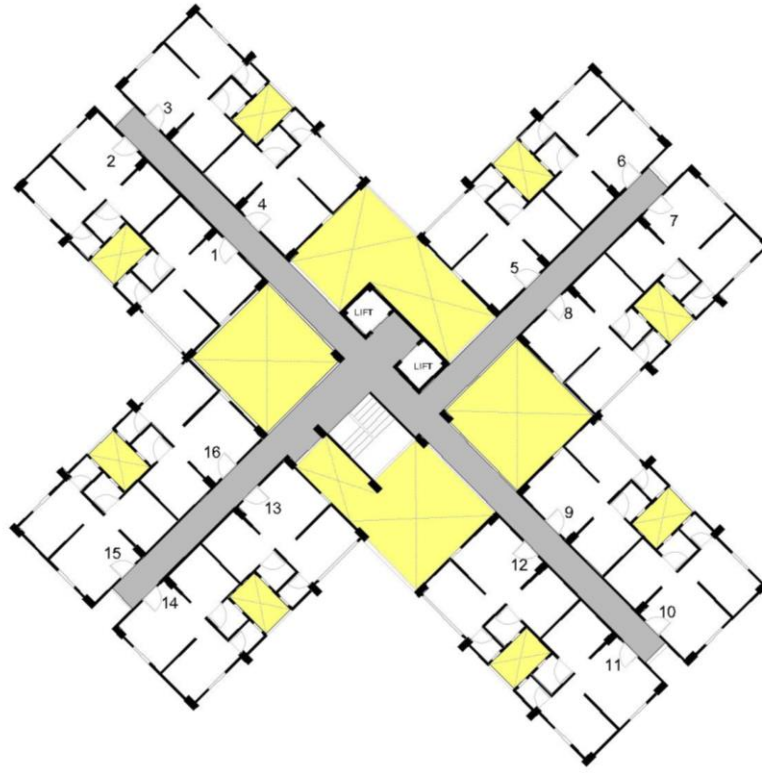
Lallubhai Compound

Net Study Area = 5.75 ha
Total Number of Units = 6318
Density/ Net ha = 1099 du/ net ha

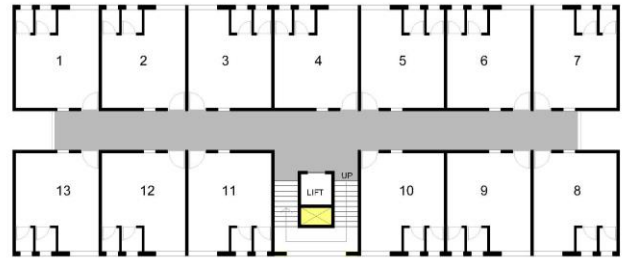
Natwar Parekh Compound

Net Study Area = 5.05 ha
Total Number of Units =5568
Density/ Net ha = 1103 du/net ha

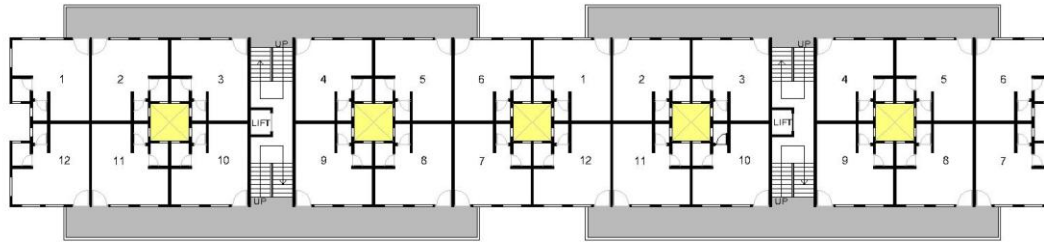
The number of units include shops and vacant buildings
Net study area excludes roads and built up amenities but includes adjoining recreational open space



PMG Colony Building Layout Plan



Lallubhai Compound Building Layout Plan

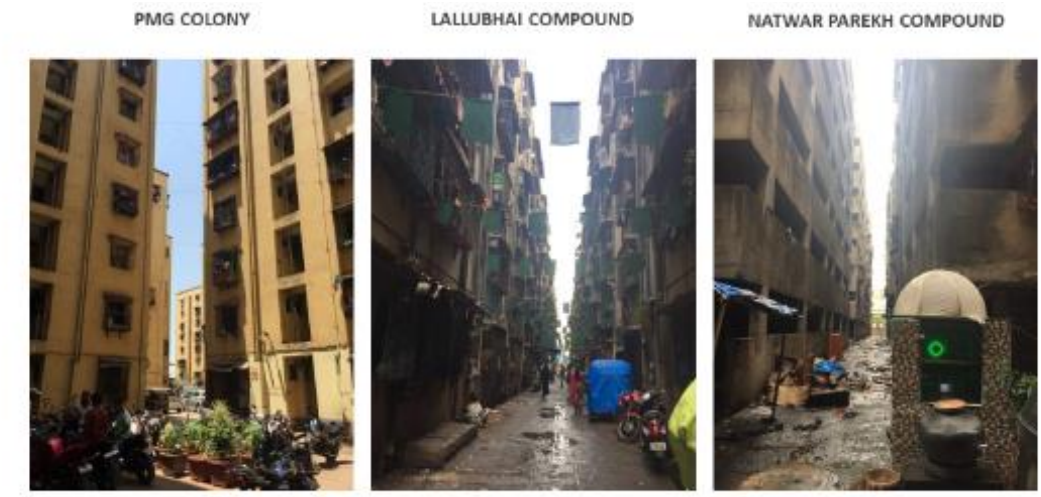


Natwar Parekh Compound Building Layout Plan

Discussion on regulations:

Floor Space Index:
As per the municipal drawings submitted to the building plan department, all three colonies have a permissible FSI of 2.5.
In order to accommodate a higher number of formal dwelling units on the site, the insitu consumption of FSI on a plot has been increased since 1991 to 2015 years from 2.5 to 4. In order to consume this FSI, buildings on the plot are going taller, but the marginal open space and distance between the buildings is fixed at 1.5m and 3m respectively.

Marginal open space and distance in-between buildings:
Close stacking of the buildings in Natwar Parekh Compound and Lallubhai Compound has led to poor light and ventilation, especially on the lower floors in these buildings. The special DCRs for SRA permit this close stacking.



Buildings higher than 10m in height and less than 40 m in length, having habitable rooms that derive light and ventilation on the side and rear faces, the provisions for side and rear setbacks have the following provisions:

- **As per National Building Code (NBC):** Part 3 Development Control Rules and General Building Requirements. DCR 8.2.3 and DCR 8.2.6 for Exterior Open Space and Joint Open Air Space respectively, (page 35 & 36) norms are as follows:

  "The open spaces shall be separate or distinct for each building and where a building has two or more wings, each wing shall have separate or distinct open spaces for the purposes of lighting and ventilation of the wings..."

  Buildings of height above 10 m, the open spaces (side and rear) shall be as given in Table 4– It states: for building height (H) up to 30 m, side and rear open space to be left around buildings is H/3. After 30 m height, for every 5 m increase in building height, 1 m shall be added to rear and side open space up to distance of 20 m.

  For joint air space (area in-between buildings) the NBC code says;

"If such interior or exterior open air space is intended to be used for the benefit of more than one building belonging to the same owner, the width of such open air space shall be the one specified for the tallest building as specified in 8.2.3 abutting on such open airspace…"

- **As per General DCRs of Greater Mumbai 1991:** DCR 28(b) for application of setbacks and open space and DCR 29 for Open Space Requirement, Compilation of Development Control Regulations up to 1st January 2015 for Mumbai, (Page 73):

"Side and rear open space in relation to the height of the building for light and ventilation-(1) Residential and Commercial Zones; (a) Building having length, depth up to 40 m.- The open spaces on all sides except the front side of a building shall be of a width not less than a third of the height of that building above the ground level, rounded to the nearest decimeter subject to a maximum of 20 m., the minimum being 3.6 m. for a residential building and 4.5 m. for a commercial building…"

The same, calculated for each building, applies for distance between two buildings

- **As against these the special provision in DCR 33 (10) :**Appendix 4, Section 6.11 and 6.14 - Relaxation in building and other requirements, Compilation of Development Control Regulations up to 1st January 2015 for Mumbai, (page 316) is as follows:

"For building having height up to 24 m in the rehab component or composite building, the front and marginal open space shall be 1.5 m for these buildings. Provided however, that in case of buildings having height more than 24 m the minimum marginal open space shall be 6.0 m or as may be prescribed by CFO…
The distance between any two rehab/composite buildings shall not be less than 3 m."

Building comparisons with respect to marginal open space and distance in between buildings (joint air space):
In essence the desirable setback is H/3 for individual building or 2(H/3) i.e. H/1.5 as the distance between two buildings of equal height. As against this the SRA rule implies setback of a mere 1.5 m (which translates to H/16 for 24 m tall buildings) or distance between two buildings of 3 m (which translates to H/8 for 24 m tall buildings). Hence, the distance between buildings in Lallubhai Compound and Natwar Parekh compound is as small as 3m. PMG Colony on the other hand is spaced with courts measuring between 10x10 m up to 16mx16m and has better conditions of light and ventilation.

Window size and design:
Light and ventilation conditions also depend upon the window size and design

- **As per NBC codes** - Part 3 Development Control Rules and General Building Requirements. DCR 20.1.2 on lighting and ventilation (page 57 & 58):

"Rooms shall have, for the admission of light and air, one or more openings, such as windows and ventilators, opening directly to the external air or into an open Verandah …, the minimum aggregate area (see Notes 1 to 3) of such openings, excluding doors inclusive of frames, shall be not less than… one-sixth (17%) of the floor area for warm-humid climate…;

Note:
1. If a window is partly fixed, the openable area shall be counted.
2. No portion of a room shall be assumed to be lighted, if it is more than 7.5 m away from the opening assumed for lighting that portion."

- **According to General DCRs of Greater Mumbai 1991:** DCR 42 for Light and Ventilation, Compilation Of Development Control Regulations up to 1st January 2015 for Mumbai, (page 176):

  "All parts of any room shall be adequately lighted and ventilated. For this purpose every room shall have -One or more apertures, excluding doors, with area not less than one-sixth of the floor area of the room, with no part of any habitable room being more than 7.5 m. away from the source of light and ventilation..."
  And
  "An opening with a minimum area of 1 sq. m. in any habitable room including a kitchen, and 0.3 sq. m. with one dimension of 0.3 m. for any bathroom, water closet or store;"

- **SRA rules** do not have separate regulations pertaining to windows for multipurpose rooms. However, Appendix 4, Section 6.3 - Relaxation in building and other requirements, Compilation Of Development Control Regulations up to 1st January 2015 for Mumbai, (page 315) states that:

  "for bathroom, water closet or kitchen, there shall be no stipulation of one wall abutting open space, etc. as long as artificial light and ventilation through any means are provided".

Building Comparisons with respect to Window Size and Design:
Windows in Lallubhai compound are smaller than the prescribed percentage of 17%. Windows for the multipurpose room for Lallubhai Compound are up to 10% of room area[1]. Natwar Parekh Compound fares better in this aspect - here the windows are up to 16% but opens to a passage. As a result some residents keep curtains drawn for privacy blocking ventilation. PMG Colony has some homes that have up to 20% window area and another type that has 13%.

However the windows have ½ sliding shutters, as a result of which half the opening remains shut at all times blocking ventilation. If the windows had 1/3 sliding shutters or open able windows they would have bigger openings. Rooms in PMG Colony are also cross-ventilated through two windows on adjacent walls. Natwar Parekh Compound and Lallubhai Compound are not cross-ventilated.

In addition, because homes are small, some households use windows for storage thus further blocking ventilation. Also, bad maintenance has led to filthy common areas in some parts of these colonies. As a result many people on ground floor and first floor chose to keep their windows closed completely shutting off the ventilation.

Density:
As stated in the report above, in the resettlement colonies, larger families had more chances of having a TB patient in the family. In other words, more the number of people sharing a space, higher the probability of TB. The SRA norms promote higher density development. A review of these norms is as given below.

[1] Note in the calculation for windows the small window provided into the common doubly loaded corridor is not counted as it doesn't open up to the external wall.

- **For density, the provisions for density in the NBC are as follows:**
  As per Part 3 Development Control Rules and General Building Requirements. DCR
  In the case of group housing[2] DCR 9.6.2 (page 41 and 42)

  "No limit to floors and height shall be applicable, but the coverage and floor area ratio for various densities may be as given in Table 6 unless provided otherwise in the Master Plan and local development control rules"

  Table 6 prescribes a density of 100 Dwelling Unit (DU)/net ha for FSI of 1 which proportionately rises up to 400Du/net ha for an FAR of 4.

  In case of low income housing the Annex C (page 137) of NBC further states that:

  "In case of developments with per dwelling unit covered area of 15 m2, four storeyed walk ups without future incremental growth with maximum densities of 500 dwelling units per hectare shall be permissible. In case of four storeyed walk ups, having two roomed dwelling unit where one room is for future expansion, maximum density of 400 dwelling units per hectare shall be permissible".

  In other words the norms suggest a maximum DU/ha density of 500 but allow master plans to tweak the density norms as per its city's requirements.

  Provisions pertaining densities in the General DCRs Section 32, Table 14 on Floor Space Indices and Tenement Density, Compilation Of Development Control Regulations up to 1st January 2015 for Mumbai, (page 87) is as follows:

	FSI	Maximum	Minimum (applicable only to plots of I ha and above and subdivided plots each of I ha and above from larger layouts or sub-division)
(A) Island City	1.33	600	267
(B) (iii) Suburbs	1	450	200

  Further, the DCRs prescribe that the tenement density should be relatively increased as per the increase in FSI. The densities can go even higher in the case in sites allocated for Public Housing/High Density Housing (PH/HDH). As per DCR 32 note on (page 93):

  "number of maximum tenement density is prescribed, but the minimum density will be 325 per net hectare for FSI of 1.00. However, in zones in which the FSI is less or more than 1.00 the minimum density of PH/HDH sites will be reduced or increased in proportion to the FSI permissible"

[2] 2.43 Housing for more than one dwelling unit, where land is owned jointly (as in the case of cooperative societies or the public agencies, such as local authorities or housing boards, etc) and the construction is undertaken by one Agency.

- **As per the provisions in the special DCRs for SRA:**
  Appendix 4 Section 3.12 Minimum Density On The Plot Including Non-Residential Units and Section 3.13, Compilation Of Development Control Regulations up to 1st January 2015 for Mumbai, (Page 312):

  "The minimum density of rehabilitation component on plot shall be 500 tenements per net hectare, that is, after deducting all reservations actually implemented on site including the land appurtenant thereto, but not deducting the recreational/amenity open space on the remaining area. If the number of tenements to be provided to the hutment dwellers is less than the minimum, the balance shall be handed over free of cost to the Slum Rehabilitation Authority. The Authority shall use them for the purpose of transit or Project-affected persons or pavement-dwellers or slum dwellers from other slums".... Further it states .. "All non-residential built-up areas shall be included in the computation of minimum density but on the scale of 20.90 sq. m. of carpet area being one tenement"

Building Comparisons with respect to density:
Average number of people per household in resettlement colonies is 5.3 as compared to 4.6 in the rest of the city. This increases the people density in these neighbourhoods as compared to the rest of the city.

The number of units per hectare is larger in Natwar Parekh and Lallubhai Compound as compared to PMG Colony. The number of units/net ha in Natwar Parekh is approximately 1103 units/net ha while in Lallubhai Compound it is approximately 1099 units/net ha. In PMG Colony density is approximately 914 units/net ha. These densities are not drastically different from each other. However, the difference in built form and bad maintenance creates an environment that breeds TB pathogen in Lallubhai compound and Natwar Parekh compound.

Thus we see that dark and damp surroundings due to poor design and maintenance make these colonies a breeding ground for the TB pathogen. High people density and poor ventilation brings a large number of people in contact with the pathogen increasing the risk of contagion.

Discretionary powers:
Its important to note that although, as per Section 63 on Discretionary powers (Compilation Of Development Control Regulations up to 1st January 2015 for Mumbai, page 236), it is stated that:

"in specific cases where a clearly demonstrable hardship is caused, the Commissioner may for reasons to be recorded in writing, by special permission permit any of the dimensions prescribed by these Regulations to be modified"
The section only allows relaxations
"…provided that the relaxation will not affect the health, safety, fire safety, structural safety and public safety of the inhabitants of the building and the neighborhood".

It could thus be seen that health and safety of occupants is of paramount importance. Therefore while devising separate set of regulations as well, health and safety of residents should not be compromised. So far, the rule has been used to provide concessions to the marginal and joint open space for all buildings. This should be stopped. In the light of the TB study findings, relaxations to the norms related to light and ventilations amount to a violation of the provisions in Section 63, as these relaxations are detrimental to the health of the inhabitants.

Discussion

Building indoor environment plays a significant role in modifying health of occupants. Efficient provision of daylight acts a contributing factor in maintaining health and hygiene of occupants. Similarly, in naturally ventilated multifunctional tenement units, airflow network depends on building parameters like windows. Literature has established that windows or openings have a sincere effect on daylight and natural ventilation strategies in compact high-rise apartments. This helps in refreshing the indoor environment by easier and faster removal of household air pollution. Also, it has been reported that sunlight and natural ventilation help in controlling airborne infections like TB. Natural ventilation has been preferred over mechanical ventilation for a better exchange of gases and dilution of infectious agents (8).

Further, direct sunlight is involved in killing of mycobacteria, whereas diffused light has not been found as efficient. Also, direct sunlight exposure leads to production of Vitamin D in the body which is important for prevention as well as cure of TB (8)(9)(10)(11). A study in a district in Indonesia has reported that risk of TB disease is high at lower floor of residential buildings as well as under conditions of overcrowding, lack of sunlight and/or natural ventilation (12). Similar studies have been reported for public housing colonies in Hong Kong (3). Even in school settings with lack of ventilation, the school children have been found to be at high risk of being infected with TB (13). In hospital-like settings, it has been reported that the treatment of spaces with UV radiation and the air with ionizer could prevent air-borne transmission of TB (14). Sky view factor has been defined by personnel working in the field of building design, in order to compare the sunshine access and distance between any group of buildings. The values of SVF can range from 0 to 1. According to the literature, any value below 0.6 is a potential risk for TB prevalence and transmission (2). Thus, poor building design and layout pose many health risks to its residents, risk of airborne infection being major one of them. Access to natural ventilation and sunlight may, then, prove to be important public health measures in controlling drug resistant TB where the antibiotics have failed to cure the disease.

The M-East Ward of Mumbai has been found to be one of the hotspots for incidence and spread of drug resistant TB, worldwide (7). This area contains mainly slums, SRA colonies and PAP resettlement colonies. The low income high-rise urban settlements under current study (eg. Natwar Parekh compound, Lallubhai compound and PMG colony) have developed many health risks for PAP families. Increased risk or incidence of tuberculosis due to lack of efficient daylight and natural ventilation is one of the leading examples. In this study, sky view factor, daylight autonomy and natural cross ventilation were investigated extensively using various computational simulation models, physical household survey as well as real time measurements of these parameters inside the tenements.

Under the simulated conditions, PMG colony performed better in comparison to Natwar Parekh and Lallubhai compounds from the perspective of provision of daylight, because of enough space available between two buildings of PMG colony. In all the three cases, the living areas within the units lacked enough natural ventilation. However, due to the presence of windows on opposite external walls,

PMG colony performed better than Natwar Parekh and Lallubhai compound as far as natural ventilation is considered. These findings corroborate with the observations from the field studies using different experimental tools and setups.

For comparison of simulated results to the real-life scenario in the resettlement colonies, the analysis of the survey data was performed using binary logistical regression for different cases such as 'if the respondent reported of having TB' or 'at least one of the member of the household was affected with TB'. Household and individual characteristics, together with built-up characteristics were included in the analysis. Segmented models were estimated for different study areas separately. Statistical analysis of the survey data revealed that the occurrence of TB is more likely in crowded spaces, occupied by more number of household members. Households having exhaust fans and openable windows are less likely to be affected. Moreover, the likelihood decreases as one goes higher up in the upper floors. Detailed field visits and informal interviews revealed that even the fully openable windows were kept closed in many houses in order to keep out the foul smell from the surroundings. Also, the windows were kept closed to maintain privacy and avoid theft. Further, the portion of the sliding windows that was permanently closed was used as a storage space thus blocking any entry of light from that area.

Thus, the results derived from the simulations are found in sync with the household survey results, which show that the occurrence of TB in Natwar Parekh and Lallubhai compounds is strongly associated with the built environment of the houses and the layout of the buildings in both the colonies. In contrast, occurrence of tuberculosis is least in PMG colony which is associated with better built environment and the layout characteristics. Also, PMG colony was found to be much cleaner than the other two colonies, which helped the residents to keep their windows open. This explains that, efficient provision of daylight and natural ventilation strategies within a particular space may act as a factor in improving human health condition, whereas poor sunlight access and natural ventilation may be major risk factors for the deadly TB disease.

A detailed study of the layout of these resettlement colonies and the Development Control Regulations (DCRs) reveal that there is huge disparity between the housing built for slum dwellers and project affected people using DCR 33(10) rules and housing built using general regulations. The people displaced from slums are allotted tenements in the resettlement colonies mostly based on a lottery system and often have no choice in selecting the location of their house. Thus, these families are doomed to suffer various health risks which are present in these colonies by design, as has been shown in the current study and supported by the reports in the literature.

This study strongly suggests that the SRA and PAP project developers must follow the National Building Codes for the resettlement colonies without any dilution of the DCR norms. Also, there should be no separate rules and regulations for public and private housing, in order to maintain a healthy locality and hence, a healthy country. In the areas where the population has already been affected by poor access to natural ventilation and sunlight, structural and social interventions can be made retrospectively, in order to increase the air flow in the houses and help the residents avail of the clean air and open surroundings. In areas where ventilation is a problem, fully openable windows should be installed, instead of sliding windows. In populations that are particularly vulnerable to certain diseases like TB, special

measures need to be taken to prevent the occurrence of disease in them. As shown, in the current study, females of productive age group are specifically affected by TB. Hence, it is essential to provide possible interventions structurally and socially, so as to maintain the health of the society as a whole.

Recommendations

In the light of this study two sets of recommendations are suggested:

A. Changes to DCRs :

The findings suggest that relaxation in building standards for slum rehabilitation and redevelopment are detrimental to the health of the poor who inhabit these homes and must be amended. Hence -

1. Exceptions made in DCR 33(10) – Appendix 4, Section 6.11 and 6.14 on marginal open space and area between two buildings should be removed and general DCRs should be followed for the same.

2. Adoption of these regulations may not make it possible to attain the minimum requirement for densities. Hence it is recommended that regulations pertaining to minimum density in SRA buildings should also be removed.

3. For windows, we recommend that General DCR 42 be changed to read as: "All parts of any room shall be adequately lighted and ventilated. For this purpose every room shall have - One or more apertures, excluding doors, **with openable area** not less than one-sixth of the floor area of the room, with no part of any habitable room being more than 7.5 m. away from the source of light and ventilation."
   This DCR should be applied to DCR 33(10) without exceptions.

4. Do not allow authorities to provide concessions that compromise the light ventilation of homes, especially in low income and slum rehabilitation colonies as residents cannot afford the costs of artificial light and ventilation.

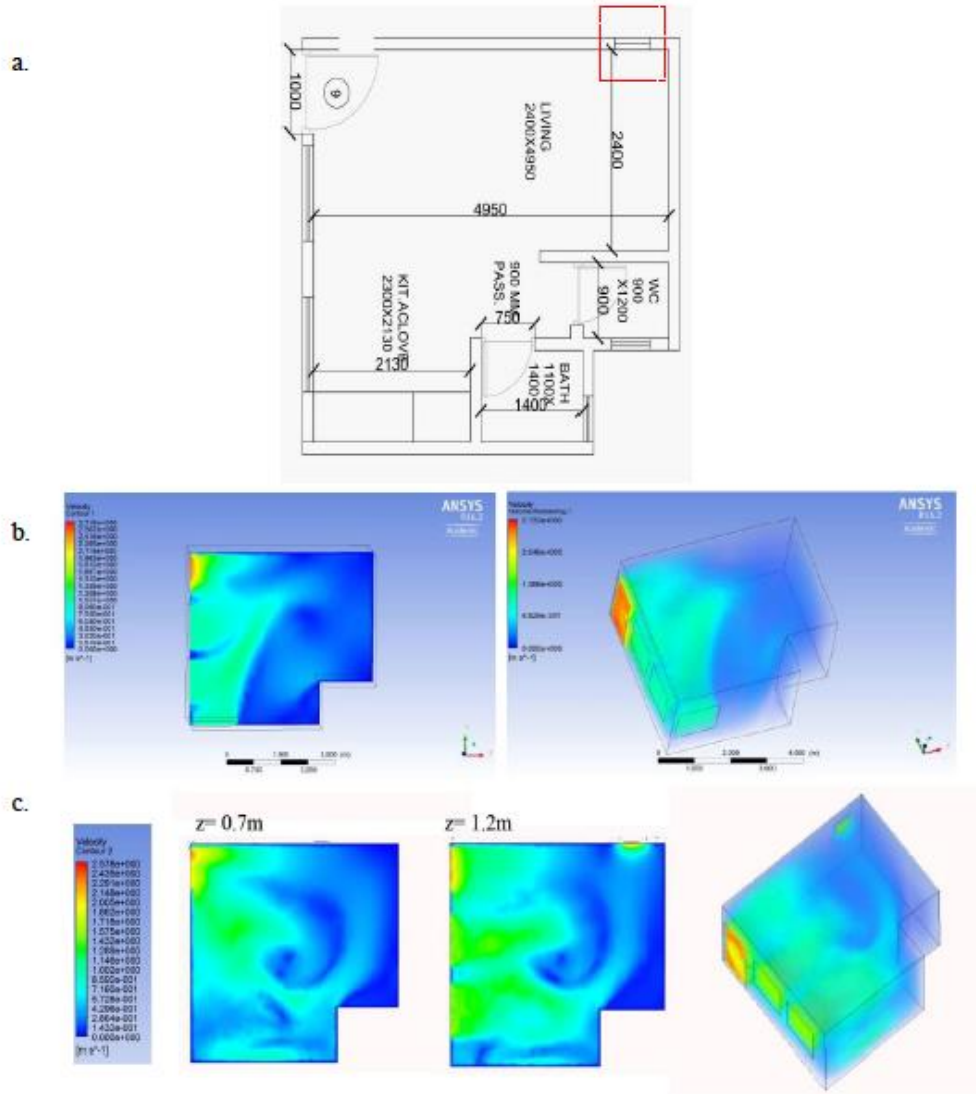
B. Retrofitting of Existing Buildings:

To improve the light and ventilation conditions in SRA buildings already constructed under existing regulations, it is recommended that the following retrofitting measures be undertaken:

- All existing SRA buildings that have problems of ventilation should be retrofitted with appropriately placed exhaust fans.
- Three-leaf sliding windows or fully openable windows should replace the existing two-leaf sliding windows for better ventilation
- Ventilators on the wall/door: One of the scenarios – _an extra window in the living area of a tenement of Natwar Parekh compound- was modelled and simulation experiments were performed in order to see the possible impact of the intervention on the natural ventilation in the house (see fig below). It was observed that by addition of this extra window, the air velocity in the living area increased considerably because of the cross ventilation. Since, none of the houses in this Colony have any windows for cross ventilation, this intervention may help in maintaining a healthier atmosphere in the house.

C. Study of Layout Design:

Well designed layouts can make a difference to final conditions of light and ventilation. Further modeling studies, similar to the ones carried out in this report, could be conducted to see the effect of light and ventilation in the rooms using the step back methods of building and different building and open space layouts.



Simulation studies for a model with an extra window introduced in a house in Natwar Parekh compound. a. The design of the simulated house. Red box shows where the window was introduced, b. Velocity contour and volume rendering of the house before introducing the extra window, c. Contour and Volume rendering of the air velocity in the modelled house with the new window.

Conclusions and Future Prospects

Planners have long known the relationship between the city's built form and public health. The first planning interventions and regulations were implemented by the Bombay Improvement Trust in the aftermath of the plague of 1896. However, over time, in a bid to provide formal housing for maximum number of people on high value land, the DCRs have compromised on the basic standards for livability for the poor. Our planning norms are now aiding a public health disaster. It is imperative to roll back on the norms that are detrimental to the health of the public.

In the era of climate change, climatically sensitive design is necessity for survival, especially for those who cannot depend on costly mechanical solutions for air conditioning and ventilation. Public housing that is being built is expected to last at least for the next 30 years and should be built for these future needs. The city government must take necessary actions to bring improvements in housing and avert a public health crisis.

Summary of the findings

Design and layout of the house/colony:

Floor – Almost all floors are equally affected. Top floors have lesser number of cases probably because all the other floors have poor ventilation and sunshine access.

Window design and usage – Households not having openable windows and/or using the closed windows as storage spaces have high likelihood of having a TB patient.

Exhaust fans – Lack of exhaust fans are strongly correlated to TB prevalence, indicating towards lack of mechanical ventilation one of the risk factors for TB prevalence and transmission.

Sky view factor, daylight autonomy, ventilation – All colonies show poor sky view factors, daylight autonomy and ventilation which may be likely cause of high TB in this area. In literature, Sky view factor less than 0.6 has been associated with TB prevalence. PMG colony has the highest SVF among these colonies, although all the three colonies show SVF from 0-0.4 indicating that Lallubhai and Natwar Parekh colonies are acting like culture medium/breeding ground for the TB bacteria. Low daylight autonomy and ventilation may be because of poor design of the houses and compact stacking to the building next to each other.

Thus, this study suggests that the architectural factors and layout of the colony is an important risk factor for TB prevalence and transmission. Thus, the parameters followed for the building of the new resettlement colonies in the future must conform to the National Building code without any dilution. No separate DCRs should be made specifically or SRA and PAP colonies.

In the already existing buildings, installing ventilators and exhaust fans might reduce the risk of occurrence of TB, while decongesting the living spaces might aid in reducing the risks. This is substantiated by the observations that lesser number of people are affected by TB residing in the higher floors of these high-rise low income urban habitats. It can be concluded from the study that window position plays a very important role in modifying natural ventilation strategies within the room. A detailed study needs to be conducted to frame effective design guidelines for constructing high rise housing for low income groups incorporating better air circulation and ventilation to improve air exchange rate.

Socio economic indicators:

Age – 20-40 years – productive age group

Gender – Female – maybe because of being bound to house and Income – Low income groups more affected

Family size – Bigger the family higher are the chances of finding a TB patient in that household.

These factors indicate that for the well-being of the population residing in the resettlement colonies, urgent measures and a targeted approach to ascertain the health of the particularly vulnerable population i.e. females of productive age group, need to be taken.

Further, to ascertain that TB is being transmitted within the colony and households and to track the path of transmission, genetic identification of the strain of the bacteria infecting various individuals is needed. Also, a detailed qualitative analysis along with patient and family interviews are needed to understand and address the problems faced by the TB patients and their family members. Further, quality of external atmosphere needs to be tested and efforts to improve the quality of air in the locality need to be taken.

References

1. WHO. Global tuberculosis report 2016. WHO press;

2. Lai P, Low C, Tse WC, Tsui C, Lee H. Risk of tuberculosis in high-rise and high density dwellings : An exploratory spatial analysis. Environ Pollut. 2013;183:40–5.

3. Low C, Lai P, Tse WC, Tsui C, Lee H, Hui P. Exploring tuberculosis by types of housing development. Soc Sci Med. 2013;87:77–83.

4. Koh GCKW, Hawthorne G, Turner AM, Kunst H, Dedicoat M. Tuberculosis Incidence Correlates with Sunshine : An Ecological 28-Year Time Series Study. PLoS One. 2013;8(3):1–5.

5. Wing T, Schumacher SG, Sandhu G, Tovar MA, Zevallos K, Baldwin MR, et al. The Seasonality of Tuberculosis , Sunlight , Vitamin D , and Household Crowding. J Infect Dis. 2014;210:774–83.

6. Zürcher K, Ballif M, Zwahlen M, Rieder HL, Egger M, Fenner L. Tuberculosis Mortality and Living Conditions in Bern, Switzerland, 1856-1950. PLoS Genet. 2016;11(2):1–11.

7. Central TB Division R. TB India 2017 Annual Status Report. 2017. 1-173 p.

8. Hobday RA, Dancer SJ. Roles of sunlight and natural ventilation for controlling infection : historical and current perspectives. J Hosp Infect. 2013;84(4):271–82.

9. Ritu G, Gupta A. Vitamin D Deficiency in India: Prevalence, Causalities and Interventions. 2014;729–75.

10. Desai N, Tukvadze N, Frediani J, Kipiani M, Sanikidze E, Nichols MM, et al. Effects of Sunlight and Diet on Vitamin D status of pulmonary tuberculosis patients in Tbilisi, Georgia. Nutrition. 2013;28(4):362–6.

11. Ralph AP, Lucas RM, Norval M. Vitamin D and solar ultraviolet radiation in the risk and treatment of tuberculosis. Lancet Infect Dis. 2013;13(1):77–88.

12. Solihah Q, Djapawiwi M. Relationship between House Condition and Tuberculosis Incidence in Timor Tengah Utara District. 4531:344–9.

13. Richardson ET, Morrow CD, Kalil DB, Bekker L, Wood R. Shared Air : A Renewed Focus on Ventilation for the Prevention of Tuberculosis Transmission. 2014;9(5):1–7.

14. Escombe AR, Moore DAJ, Gilman RH, Navincopa M, Ticona E, Sheen P, et al. Upper-Room Ultraviolet Light and Negative Air Ionization to Prevent Tuberculosis Transmission. 2009;6(3).

Form no.: Date: Name of data collector:

Association between structural pattern in habitation of resettlement colonies and Tuberculosis in Mumbai

1. Colony कॉलोनी _____ 2. Building No. बिल्डिंग नं ._____ 3.Floor मंज़िल नं . ____
4.House No. घर नं _____

5. House proximity to stairs घर की सीढ़ियों से निकटता - 1L/2L/3L/1R/2R/3R

6. Respondent Name उत्तरदायी का नाम _____

7. Staying in the house since years/months कितने वर्ष / महीनों से इस घर मे रह रहे हैं?_____
8. Total no of members currently staying वर्तमान में रहने वाले सदस्यों की कुल संख्या ___
9. Family structure परिवार संरचना:
   a. Children below 5 years, 5 वर्ष से कम उम्र के बच्चे
   b. Children 5-12 years, 5-12 साल के बच्चे
   c. 12-18 years, 12-18 साल के बच्चे
   d. 18 yr and above, 18 साल और उससे ऊपर

10. Where did you stay before shifting to this house? Was that house smaller or bigger? How many members were there in previous house ?
इस कॉलोनी में आने से पहले आप कहाँ रहते थे? घर छोटा या इससे बड़ा था? उस घर में कितने सदस्य थे?_____

11. Age of respondent उत्तरदायी की उम्र _____
12. Occupation of respondent उत्तरदायी का व्यवसाय _____
13. Family income परिवार की महीने की आय _____
14. Do you have any of the following? क्या आपको निम्न में से कोई भी है?

High BP उच्च बीपी /Low BP कम बीपी /Diabetes डायबिटीज/Fever बुखार/Lethargy थकान/Tobacco consumption/smoking/paan-gutkha chewing तम्बाकू खाने की आदत / धूम्रपान / पान-गुटखा चबाने की आदत ।

15. **Have you been diagnosed with TB? Yes/No** क्या आपको टीबी है?
a. Yes हाँ, Since When? कब से?

b. No नहीं

Has any of your family member diagnosed with TB? Since When?
क्या आपके परिवार के किसी सदस्य को टीबी है? कब से? _____

If yes, did you avail treatment. From which hospital/health center?
यदि हां, तो क्या आपने उपचार का लाभ उठाया? किस अस्पताल / स्वास्थ्य केंद्र से? _____

Sign of data collector:

Form no.: Date: Name of data collector:

A. If On treatment:

Type of TB- a. P_____ b. EP_____

i. Duration_____ a. Intensive phase b. Curative phase

ii. Sputum Status:

a. First Sputum Negative period_____

b. Second sputum_____

iii. Diseases Treatment category:

a. Cat I_____ b. CatII_____ c. MDR_____ d. XDR_____

iv. Treatment outcome:

B. Previously cured

(Note: In case there are more than one, a new sheet should be filled for each individual)

Type of TB- a. P_____ b. EP_____

Category: a. Cat I_____ b. CatII_____ c. MDR_____ d. XDR_____

Total duration of treatment- Date: From_____ To_____

Duration since cured_____

Relapse- Yes/NO/NA If yes

details_____

_____

Default- Yes/NO/NA If yes

details_____

_____

Failure- Yes/NO/NA If yes

details_____

_____

Death- Yes/NO/NA If yes

details_____

_____

C. Suspected Case

(Note: Clinical history taking should be started revising the consent of study)

i.The one who is having cough since more than 14 days_____

ii. Weight loss since few months /weeks_____

iii. evening rise in fever_____

iv. Loss of appetite

v. History of hospital visits

16. How much time do all members spend in the house together? सभी सदस्य एक साथ घर में कितना समय बिताते हैं?

a. Less than 6 hours 6 घंटे से कम

b. 6-12 hours 6-12 घंटे

c. More than 12 hours 12 घंटे से अधिक

Sign of data collector:

Form no.: Date: Name of data collector:

17. Do you keep the door open during cooking? क्या खाना पकाने के दौरान दरवाजा खुला रहता है?

a. Yes हाँ

b. No नहीं

Observation based

18. Does the house have cross ventilation between windows? क्या घरों में खिड़कियों के बीच आर-पार हवा का प्रवाह है?

a. Yes हाँ
b. No नहीं

19. Does the house have cross ventilation between the window and door? क्या घर में खिड़की और दरवाज़े के बीच आर-पार हवा का प्रवाह हैं?

a. Yes हाँ

b. No नहीं

20. Does the window have sliding shutter or openable shutter? खिड़की में शटर खुलने वाला या फिसलने (स्लाइडिंग) वाला है?

a. Sliding फिसलने वाला (स्लाइडिंग)
b. Openable खुलने वाला

21. If sliding, shutter how much of the window gets permanently shut? यदि खिड़की में स्लाइडिंग शटर है, तो कितना हिस्सा हमेशा बंद रहता है?

a. 50%
b. 30%
c. 25%

22. Is the window being used to store things? क्या खिड़की को चीजों को रखने करने के लिए इस्तेमाल किया जा रहा है?

a. Yes हाँ

b. No नहीं

Sign of data collector:

Form no.: Date: Name of data collector:

23. How much of the window is shut due to storage? चीजों को रखने के कारण कितनी खिड़की बंद है?
a) 10%
b) 30%
c) 50%
d) 70%
e) 90% or more

24. What kind of mechanical ventilation system is available in the house? How many? घर में हवा के प्रवाह के लिए किस तरह की यांत्रिक प्रणाली उपलब्ध है? कितने?

a. Ceiling fan पंखा _____
b. Exhaust fan निकास पंखा _____
c. Table/stand fan टेबल /स्टैंड पंखा _____

25. What is your monthly electricity bill (in Units or Rs.)? आपका मासिक बिजली बिल क्या है?

Oct 17

Sept 17

August 17

July 17

June 17

May 17

April 17

March 17

Feb 17

Jan 17

26. How much time do you spend outside the house? घर के बाहर आप कितने समय बिताते हैं?_____

27. Remarks/comments टिप्पणियां _____

Sign of data collector:

Consent Form

Introduction and Informed Consent Form

Dear Sir/ Madam

DFY is a medical humanitarian organization in India, working in the field of medical relief, sustainable healthcare services, capacity building and risk reduction activities during crisis and non-crisis situations. The organization during the short period of its existence, it has been able to established a creditable reputation with regards to the quality of its work and the ethical principles that have guided such work.

Purpose of the Study: We are conducting a study in Mumbai to understand the association of structural factors in resettlement colonies with the spread of tuberculosis. This study will help us to suggest possible solutions for better architecture of the resettlement colonies.

Nature of Participation: We would like to request your consent to participate in the study. If you agree to participate, you will be asked to fill a small questionnaire to measure the health status and your socio-economic status as well as physical parameters in the house.

Risks and Discomforts: Some of the questions may make you feel uncomfortable. To protect you from this sense of discomfort, you do not have to answer any question you do not want to. The study will ensure complete confidentially of your information.

Benefits: Although you will not receive an immediate benefit from this study, you and others from the humanitarian field may benefit from this in the future, if this research succeeds in finding ways to improve the secondary stress among humanitarian workers.

Duration of the procedures: The questionnaire may take 15-20 minutes to fill up.

Compensation: There will be no monetary compensation for your participation in the study.

Confidentiality: To make sure that no one learns about any information shared by you in this study, your name will not appear on any document or other materials associated with the project. Each questionnaire would be given a unique code. The filled forms will be kept in a safe place under lock and key and only accessible authorized persons designated by us in Mumbai. The identity of the interviewee will always remain confidential. Your name will be removed from all records.

Right to refuse or withdraw: Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time.

If you have questions about the research: The project staff is willing to answer any questions you may have concerning the procedures described. If you have any questions about the research, you may contact DFY (address)

Participants' consent: I have read and understood this entire consent form and any questions I have, have been answered to my satisfaction. I agree to participate in the study and to respond to the questions. I understand the purpose, nature, and length of my involvement in the study. I understand that I may choose not to participate at the beginning of the project or at any time during the project without penalty.

_____ _____

Date Signature of Respondent

सहमति पत्र

परिचय और सूचित सहमति फ़ॉर्म

प्रिय महोदय / महोदया

डीएफवाई भारत में एक चिकित्सा मानवीय संगठन है, जो चिकित्सा राहत, टिकाऊ स्वास्थ्य सेवा, क्षमता निर्माण और संकट और गैर-संकट स्थितियों के दौरान जोखिम कम करने की गतिविधियों के क्षेत्र में काम कर रहा है | अपने अस्तित्व की छोटी अवधि के दौरान संगठन, अपने काम की गुणवत्ता और नैतिक सिद्धांतों के संबंध में एक प्रतिष्ठा स्थापित करने में सक्षम हो गया है, जो इस तरह के काम को निर्देशित करते हैं।

अध्ययन का उद्देश्य: हम टीबी के फैलाव के साथ पुनर्वास कालोनियों में संरचनात्मक कारकों के संघटन को समझने के लिए मुंबई में एक अध्ययन का आयोजन कर रहे हैं। यह अध्ययन हमें पुनर्वास कालोनियों के बेहतर आर्किटेक्चर के लिए संभावित समाधानों का सुझाव देने में मदद करेगा।

भागीदारी की प्रकृति: हम अध्ययन में भाग लेने के लिए आपकी सहमति का अनुरोध करना चाहते हैं। यदि आप भाग लेने के लिए सहमत हैं, तो आपको स्वास्थ्य स्थिति और आपके सामाजिक-आर्थिक स्थिति के साथ-साथ घर में भौतिक मापदंडों को मापने के लिए एक छोटी प्रश्नावली भरने के लिए कहा जाएगा।

जोखिम और असुविधाएं: कुछ प्रश्न आपके लिए असुविधाजनक हो सकते हैं। आपको असुविधा के इस अर्थ से बचाने के लिए, आपको उस किसी भी सवाल का जवाब देने की आवश्यकता नहीं है जिसे आप नहीं देना चाहते। अध्ययन आपकी जानकारी की पूर्ण गोपनीयता सुनिश्चित करेगा।

लाभ: यद्यपि आप इस अध्ययन से तत्काल लाभ प्राप्त नहीं करेंगे, तो आप और मानवतावादी क्षेत्र से अन्य लोग भविष्य में इससे लाभान्वित हो सकते हैं

प्रक्रियाओं की अवधि: प्रश्नावली को भरने में 15-20 मिनट लग सकते हैं।

नुकसान भरपाई: अध्ययन में आपकी भागीदारी के लिए कोई मौद्रिक मुआवजा नहीं होगा।

गोपनीयता: यह सुनिश्चित करने के लिए कि इस अध्ययन में आपके द्वारा दी जाने वाली जानकारी के बारे में कोई भी नहीं जान पाए, आपका नाम किसी दस्तावेज़ या परियोजना से संबंधित अन्य सामग्रियों पर दिखाई नहीं देगा। प्रत्येक प्रश्नावली को एक कोड दिया जाएगा। भरे हुए फ़ॉर्म को ताला और चाबी के तहत एक सुरक्षित स्थान पर रखा जाएगा और मुंबई में हमारे द्वारा नियुक्त केवल अधिकृत व्यक्तियों को सुलभ किया जाएगा। साक्षात्कारकर्ता की पहचान हमेशा गोपनीय रहेगी। आपका नाम सभी रिकॉर्ड से हटा दिया जाएगा।

इनकार करने या वापस लेने का अधिकार :इस अध्ययन में आपकी भागीदारी स्वैच्छिक है; आप दंड के बिना भाग लेने के लिए अस्वीकार कर सकते हैं |यदि आप भाग लेने का निर्णय लेते हैं, तो आप किसी भी समय अध्ययन से वापस ले सकते हैं।

यदि आपके अनुसंधान के बारे में प्रश्न हैं: परियोजना कर्मचारी आपके द्वारा वर्णित प्रक्रियाओं से संबंधित किसी भी प्रश्न का उत्तर देने के लिए तैयार है। यदि आपके अनुसंधान के बारे में कोई प्रश्न हैं, तो आप डीएफवाई (पते) से संपर्क कर सकते हैं

प्रतिभागियों की सहमति: मैंने इस पूरी सहमति फॉर्म को पढ़ा और समझ लिया है और मेरे जो प्रश्न हैं उनके मुझे संरोषजनक उत्तर मिले हैं हैं। मैं अध्ययन में भाग लेने और सवालों के जवाब देने के लिए सहमत हूं। मैं अध्ययन में मेरी भागीदारी के उद्देश्य, प्रकृति और लंबाई को समझता हूं। मैं समझता हूं कि मैं परियोजना की शुरुआत में या किसी भी समय दंड के बिना परियोजना के दौरान भाग लेने के लिए मना कर सकता हूँ।

_____ _____

उत्तरदायी के हस्ताक्षर **दिनांक**