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Thermal performance of slum rehabilitation projects in Pune

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Abstract - Slums are a common style of housing in many developing metropolitan areas, ranging from Nairobi's Kibera to Mumbai's Dharavi. These slums are overcrowded, unsafe, unhealthy and lack access to basic services. An estimated 1 billion people will be living in these informal settlements by the year 2030 while 35.2% of the urban population in India currently resides in slums (habitatforhumanity, n.d.). In order to address this issue, the Maharashtra government established the Slum Rehabilitation Authority (SRA) in December 1995 to facilitate slum redevelopment throughout Mumbai. The SRA has established a total of 1481 projects in the urban contexts of Pune & Mumbai. This research aims to compare the thermal performance of an urban slum redevelopment project in Pune, India and also study the design optimization of slum redevelopment. This includes a data collection and experimental simulation approach to understand the thermal comfort in Slum rehabilitation Projects in Pune. The results of the research will help in indicating the performance and design of SRA projects and form a comparative analysis of horizontal slums to vertical 'slums'.

Keywords – slum redevelopment, Slum Rehabilitation Authority, thermal performance, energy modelling, slums, thermal comfort

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INTRODUCTION

Due to urbanization, the cities went under unforeseen transformation with rapid migration of the working class. This created a vast demand for housing in a region with a lack of land and resources to accommodate these demands. Slums form and grow in different parts of the world for many different reasons. Causes include rapid rural-to-urban migration, economic stagnation and depression, high unemployment, poverty, informal economy, forced or manipulated ghettoization, poor planning, politics, natural disasters, and social conflicts (Machine, 2007). They are overcrowded, unhealthy, unsafe, unhygienic and lack basic services like water supply, toilets and electricity. There are a total of 564 slums in Pune, out of which 353 are notified by the Government. A majority of these slums lie on private lands which increases their sense of insecurity. The SRA (Slum Rehabilitation Authority) has the authority to develop programmes for the rehabilitation of slum regions. These projects are offered up to the bidding builders for construction by the Municipal Corporations of the respective cities. According to the Slum Rehabilitation Authority (SRA), there are 12.50 lakh slums in Mumbai, with 62 lakh people living in them. If the present rate of rehabilitation continues, with an average of 8,963 households receiving houses each year, it will take at least a century to rehabilitate all existing slum inhabitants (Correspondet, 2020). Maharashtra government has recently increased carpet area for SRA to 322 sqft from 269 sqft, granting a little more breathing space for the overly compact high-rise buildings. This research aims to look into an aspect less discussed while construction of these projects, i.e., the thermal comfort and performance of the Slum Rehabilitation Projects. It can also lead us to understand if the quality of the thermal comfort in residences is the reason for the so called 'rebound effect' in Slum Rehabilitation Projects.

A comfortable environment is essential for the mental and physical growth of an individual. There are six factors affecting thermal comfort are air temperature, radiant temperature, air velocity, humidity, clothing insulation and metabolic heat. This paper focuses on environmental factors that affect thermal factor, that is, air temperature, radiant temperature, air velocity and humidity (www.hse.gov.uk, 2016).

To determine the thermal comfort of the residences, a twelve-story high SRA project was observed under

these parameters. The project, which included 192 flats, was completed in 2019. This case study is an example of in-situ redevelopment, with more than half of the slum-dwelling ('baasti') cleared for this project and the remaining area given to the builder for commercial use.

METHODOLOGY AND METHODS

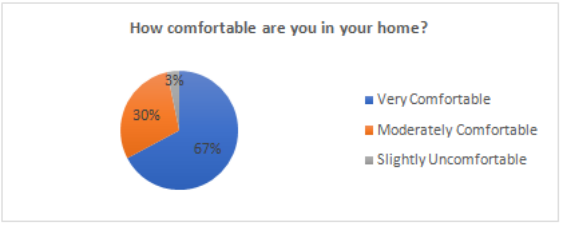
The study used a combination of qualitative and quantitative research methods. A questionnaire survey was conducted for the residents of an SRA project to understand the quality of thermal comfort they experience in their residences. The questions ranged from the duration of sunlight to the comfort of the residents during the various seasons. The research also includes a context analysis to analyse the documented information from text, images, videos, etc. Simulation software used for radiation analysis was a rhino plug-in called ladybug. Simulation software used for daylight analysis was a rhino plug-in called honeybee.

RESULTS AND FINDINGS

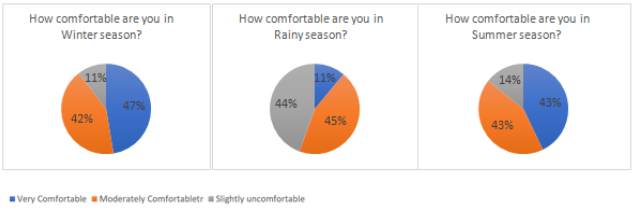
A twelve-story SRA project was studied under these parameters to determine the thermal comfort of the residence. Each floor plate contains 16 flats with a carpet area of approximately 26 sqm (280 sq. ft), and essential services such as a fire exit staircase and a lift, as well as a central breakout space opposite the service core. The building is a linear, densely built high-rise structure with compact apartments. These are some typical features in an SRA project and seem to be in common with others. In total, there are 192 flats in the building. The building is northwest – southeast oriented, and the flats are distributed along a long linear passage aligning southwest to northeast. The orientation of the building greatly affects the airflow and cross ventilation while simultaneously determining which apartments get harsher sunlight throughout the day. It is essential to note that the outcomes of the research may vary when many or all SRA projects in Pune are taken into consideration.

Figure 1: Location of SRA project

The research was established on a combination of qualitative and quantitative research methods. A survey was conducted to deduce the qualitative aspects of Slum Rehabilitation Authority projects with careful consideration of the resident's perception of thermal comfort in their homes. The following data reflects on how comfortable the residents feel in their apartments.



The majority of the residents felt comfortable in their houses agreeing with the statement that is it much better than their previous accommodations. Almost all residents found their homes to be spacious enougheven when the number of residing occupants varied from 4 to 7 occupants. As thermal comfort parameterschange in different seasons, it is essential to keep in mind the change in temperature and humidity of these seasons.



It is noticed that due to seasonal change, the comfort level of the residents' also changes. While many feel sufficiently comfortable in Winter and Summer seasons, during Rainy season 44% resident feel slightly uncomfortable. The reason for this discomfort is either due to high humidity or due to water seepage causing slight flooding in the apartments. While many felt comfortable in Winter seasons, a few noted that the strong winds (cross ventilation) do result in some discomfort.As a generalized finding, one can conclude that throughout the year, the residents feel moderately comfortable in their homes.

When questioned if they were likely to move back to slums, all of the interviewed residents agreed that they do not wish to or are highly unlikely to move back into slum housing. They found their new accommodations to be spacious and comfortable enough to reside pleasantly for the coming days.

Observational analysis along with quantitative analysis slightly disagree with the resident's experience of these spaces. Due to the northwest-southeast orientation of the building, the hours of sunlight received are wholly dependent on the location of the apartment. Thus, the apartments facing northwest received harsh sunlight in the afternoon leading to many residents having their curtains drawn to prevent glare. The use of ceiling fans was constant in every household due to the

summer heat but many residents agreed that it is not significantly hotter than usual. Fenestration is provided in the living room, the bedroom, and the kitchen although the opening in the kitchen is facing a duct. Thus, the working area of the kitchen remains in dark even during the day, especially in the lower flats. Cross ventilation only occurs if the main door is open causing the residents to rely on the ceiling fan to increase thermal comfort. Another observation made was that even with essential community space provided, residents were hesitant to use these spaces for recreational purposes. Almost all residents felt that the living room in their apartments was the most comfortable space to occupy during the day. Many residents preferred to take their afternoon naps in the hall rather than in the bedroom.

Concluding with the qualitative analysis of thermal comfort in the SRA project, it is found that the residents are far more comfortable in their new accommodations rather than in their previous accommodations of slum housing. Even though their comfort satisfaction may vary, on average the residents are moderately comfortable in all aspects.

The data collected through the surveys remain subjective as it entirely depends on user experience and a comparative mindset of the residents, considering their previous accommodation was a cramped slum. When a simulation-based approach is taken into consideration, the result varies widely depending on the location, orientation, and altitude of each flat. Considering the case of two flats of equal dimensions but oriented in opposite directions, a daylight analysis simulation is run to determine the number of direct sun hours in each flat.

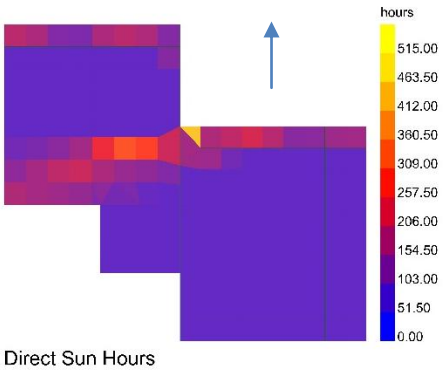


Figure 2: Daylight Analysis of flat facing north-west

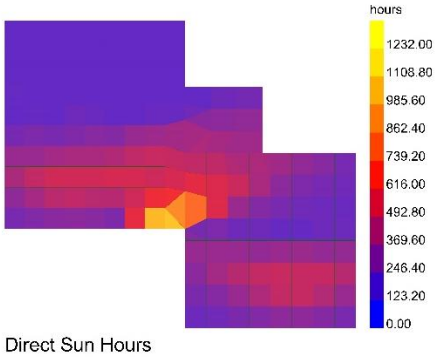


Figure 3: Daylight Analysis of flat facing south-east

It is found that the flats facing southeast receive more hours of sunlight than those facing northwest. The peak point of sun hours received in a southeast-facing flat is 1232 hours while that of a northwest-facing flat is merely 515 hours. This huge difference results in the sun hours of the two flats, changes the thermal comfort drastically as one flat is exposed to more thermal radiation. This eventually leads to an increase in the usage of mechanical ventilation devices like table fans and ceiling fans, thereby also increasing the cost of running the household as electricity consumption increases. There is low illuminance in the kitchen, as the source of light is a window facing a service duct. This results in no direct sunlight in the kitchen on lower floors especially. Artificial lighting devices must be used throughout the day to work in the kitchen. The bedroom receives harsh sunlight as there is no buffer. This could be the reason why the residents feel more comfortable using the living room rather than the bedroom.

In radiation analysis, the three parameters considered are the location, orientation, and altitude of each flat. The plans below showcase the entire floor plate with radiation mesh indicating the radiation of the floors of the flats in consideration for the simulation.

Figure 4: Radiation Analysis of flat located on the first floor

Figure 5: Radiation Analysis of flat located on the sixth floor

Figure 6: Radiation Analysis of flat located on the twelfth floor

Through visual comparative analysis, it can be deduced that the altitude of the flats doesn't affect the floor radiation significantly. However, the amount of floor radiation occurring is solely dependent on the location and orientation of the flats. Those facing the southeast receive the harsher sun leading to an increase in thermal radiation. The floor of the corner flats gains a rather substantial amount of radiation than that of the flats located in the middle region as two sides of the corner flats are exposed to the sun. Proper allocation of fenestrations is essential for the thermal comfort of the flat. This discomfort is combated by the cross ventilation that occurs in the corner flats.

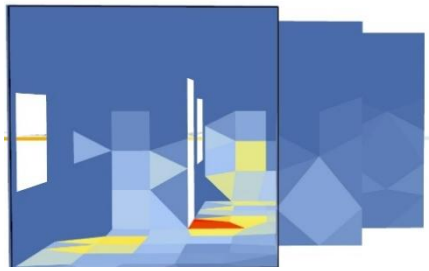


Figure 7: Radiation Analysis of flat located in the middle facing northwest

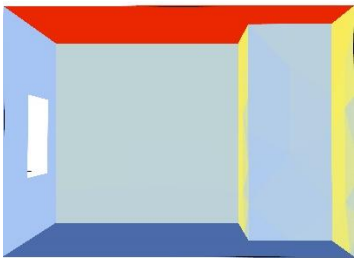


Figure 8: Radiation Analysis of flat located in corner facing northwest

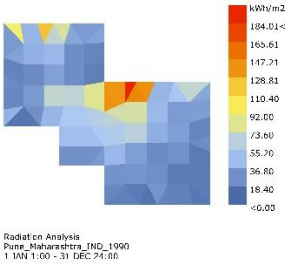
A sectional view of radiation analysis of the corner flat and the flat located in the centre of the floor plate indicated that the position of the flat on the floor plate significantly changes the thermal performance of the flats. The middle flats might feel stuffy due to the lack of cross-ventilation, they remain relatively cooler than the corner flats. In summer heat when the cross-ventilation only brings in warm winds ('Loo'), it is beneficial to have a cooler flat rather than a windier flat.

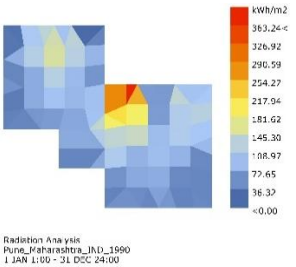
From an observational perspective, the area on the 12th floor appeared to be hotter than the area on the 1st floor as the 12th floor receives direct sunlight without a decrease in fenestration sizes. The modular design of the apartments with fixed fenestration sizes especially in a high-rise building led to discomfort for its residents and reduces the thermal comfort in the flat.

CONCLUSION

Slum Rehabilitation Projects seem to be on the rise in India as well as in other developing countries as many cities pledge to create slum-free metropolia. While this is a noble idea, it cannot be paid at the expense of the re-habitant's discomfort. SRA projects are a complicated affair as there are many parameters involved and the comfort of the residents is often forgotten. We need slum rehabilitation projects but we also need them to be designed without modularity so that they can provide an environment for mental and physical growth.

The modular design of the flats reduces the overall thermal comfort in the building. It doesn't take into consideration different variables like orientation, altitude, and location. Conclusively, the thermal comfort of the building can vary remarkably for the residents.While experimenting for the best flat orientation, it was discovered that those facing north receive the least amount of radiation while those facing west receive the most. As a result, as compared to central flats, apartments positioned at corners, particularly the southern west corner, absorb a huge range of radiation. For the least amount of radiation measured kWh per m2, the best direction for the flats is north-east. The figures below depict the radiation analysis in relation to various orientations.





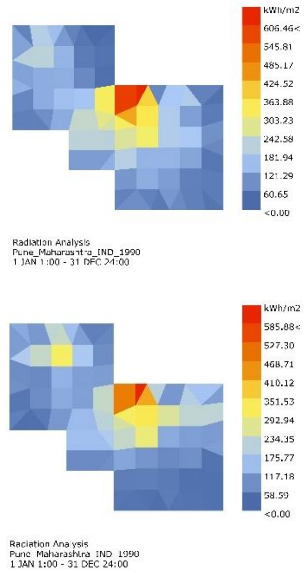


Figure 9: North Orientation, East Orientation, West Orientation, South Orientation

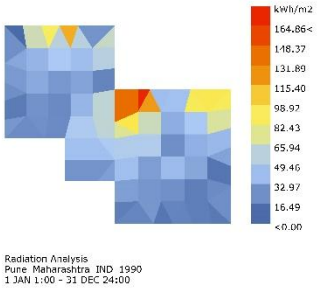


Figure 10: North-East Orientation 30◦ east

A major finding of the research concludes that the residents of SRA projects in Pune are comfortable with their residences. A comparative study can be conducted to analyse how other cities in Maharashtra fare in this parameter. A comparative analysis of all the projects in Pune might be difficult as each project has its own design parameters. The results of the study can lead to formulating an ideal module for effective thermal performance with the help of energy modelling. This study can help formulate suggestions for future SRA projects.

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