Evaluating indoor environmental quality of onsite construction workers housing in Pune, India through performance-based simulation

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Abstract

Construction workers are the city's most essential service providers, but their contribution to the urban economy is frequently overlooked. Most construction workers are migrants, and the primary reason for their migration is to find suitable job opportunities and an improved living standard. Whether the growth of the infrastructure sector raises the standard of life of migrant workers is a matter of concern since these migrant workers frequently relocate every few years to other places living in temporary constructions near or on the job site provided by the owner or a contractor. This research examines the indoor environmental quality of onsite housing for construction workers. It presents a part of the ongoing research assessing the parameters that impact the onsite housing system for construction workers in terms of building materials, services provided, and indoor environmental comfort. Simulation studies were carried out to analyse the annual performance. In addition, the performance of various materials was evaluated along with daylight and ventilation analysis throughout the year. The research's main findings are that onsite workers living in a modular prefabricated system can achieve indoor environmental comfort by using a wall panelling system made of paper honeycomb sandwiched between powder-coated G.I. sheets can provide thermal comfort with additional aluminium bubble wrap insulation for the roof. Eco coolers, a passive cooling system, are also used to improve the ventilation inside the unit. This system provides thermal insulation while also being affordable and scalable for the temporary housing category.

Key Innovations

- Modular System for onsite construction housing
- Practical implications
- Wall Panelling System for Thermal Insulation and Better indoor Quality
- Use of eco cooler for indoor comfort

Research Implications

This research has contributed to creating an onsite housing system for construction employees that is comfortable to stay in. The onsite live scale prototype building and testing for indoor environmental parameters and user feedback will help create a statement of assurance of the workability of the structure and the intangible benefit to the users. The findings are relevant to developing countries where construction workers are important development stakeholders. Along with construction workers, it will assist builders and developers in providing housing for workers that meets the necessary health and safety criteria.

Introduction

A Construction worker who is the most integral part of the construction sector is most vulnerable and often gets neglected. We have seen significant development in the architectural world, from tiny shacks to high-rise buildings; however, the living conditions of onsite construction workers (migrant workers) have not seen the necessary change and evolution. (Shamindra Nath Roy, 2017). In addition to minimum wages, overtime pay, and weekly offs, migrant construction workers should be provided with comfortable housing and other social security benefits such as creches for their children and proper sanitation facilities under labour laws. (The building and other construction workers act, 1996) As a result, it is the developers' responsibility to ensure that the working conditions for their construction workers meet some basic standards. Since the worker's stay is temporary and construction site locations repeatedly change, developers end up providing these workers with temporary shelters. Such shelters are without basic facilities and, in turn, jeopardize their comfort as construction companies do not directly profit financially from the construction of permanent housing for workers. (Srivastav Ravi, 2016) Human's psychological and physiological well-being is impacted by indoor comfort. The indoor comfort favours well-being, productivity, and health, which is why it should be included in the housing for everyone. (Khan, 2017) Developers should offer this personnel adequate, thermally pleasant housing for onsite construction workers as they are the backbone of this industry. (Shamindra Nath Roy, 2017).

An approach was developed that combines interviews, case studies, observations, and content analysis. In addition, a customer satisfaction survey was also carried out. Gaining a thorough grasp of the housing options and user comfort for worksite workers is the main objective of data collecting through a survey. It was done through interviews with developers and construction employees. The existing literature has provided an understanding of indoor air quality issues and how simulation can be utilized to analyse the current situation and assist in designing an environmentally friendly residential unit for onsite construction workers. The importance of indoor environmental quality cannot be overstated because it affects people's health in the short and long term. Thermal comfort, ventilation, humidity, and daylight contribute to the definition of indoor environmental quality. (Rajat Gupta, 2018). As per National Building Code (NBC), a person's thermal comfort lies between Thermal Sensation Index values of 25°C and 30°C. It is tolerable between 30°C and 34°C (TSI), above which it gets too hot for the occupant. Hot and humid climates in the country require air movement or wind for a person to feel comfortable indoors. NBC has defined the appropriate wind speed for respective dry bulb temperature and relative humidity. The material of which a building (especially envelope) is constructed determines the relationship between the outdoor temperature, solar radiation, and indoor temperature in a non-air-conditioned building. Three properties of the building envelope that governs the temperature are: Heat Conductance or resistance to heat flow across the envelope, building mass temperature changes due to energy absorption or release and The absorption of solar radiation that strikes the envelope. (Gireendra Kumar, 2016). Ventilation is another crucial aspect of creating a comfortable indoor environment. A highly cost-effective method of improving indoor ventilation is the eco cooler. Mr. Ashis Paul of Bangladesh devised this straightforward assembly. Discarded PET bottles are split in half, fixed on a plywood panel, and then mounted on a window frame. By enabling improved ventilation, this ventilation technique improves not only indoor air quality but also lowers the interior air temperature. (Purkayastha, 2016).

Figure 1-Eco Cooler

The severe temperatures and lack of ventilation inside the existing house, according to the literature assessment and the data collected on the site, made the users uneasy. Therefore, a prototype unit for housing construction employees onsite to improvise environmental comfort factors was designed. The ideation process for the recommended design is completed. To evaluate the suggested prototype's thermal comfort solution, Design Builder, an energy simulation tool, and CFD analysis were utilized to simulate comfort in the proposed prototype. Thermal comfort was assessed by comparing the proposed prototype and the existing housing unit.

Design Approach

The challenges and pitfalls of the existing workers' housing were examined based on the onsite survey and documentation. Analysis indicated that large metal pipes were used as structural elements; corrugated metal sheets were used for the walls and roofing, which were often in poor condition due to multiple reuses; and poorly done flooring in these units. With the housing having used corrugated metal sheets, these houses were extremely uncomfortable to live in, especially during summers due to the roof heating up and raising the temperature of the indoor spaces up to 40 to 42oC. The extremely high temperatures were also observed due to their being. So, what is the rationale that shapes the nature of labor accommodation?

The literature review results show that those who work in the construction industry are the most frequently disregarded. There is a pressing need to look into their fundamental requirements, such as shelter, sanitization, etc. Case studies also show that we need a new strategy to deal with problems with onsite construction workers and their housing needs. The emphasis should be on giving the proposed case's envelope design to create a comfortable living place. For the construction of wall paneling, a paper honeycomb board was sandwiched between powder-coated GI sheets for the walls and insulated GI sheets for the roof.

Following approaches were used to test the suggested envelope system.

1. Energy Simulation for BAU (Business as Usual) case and design case.

2. Comparison of the BAU (Business as Usual) case with the design case by employing onsite data loggers to record temperature and humidity readings.

Energy Simulation

The operating energy consumption and the indoor thermal comfort level were simulated using Design Builder. Two scenarios were created and put to the test. The first is referred to as the base case and the second as the design case. The base case for this research is the current scenario for worker housing, and the design case is the suggested solution for onsite housing. Following are the two cases considered for simulation

Business as Usual Case: GI sheet for walls and roof with single ventilator.

Design Case: Paper honeycomb board sandwiched with powdered coated GI Sheets for walls, Insulated GI sheet roofing.

Temperature and humidity measurements were taken for both the Base case and the Design case based on the input data and specifications of the building materials used, as well as the building design plan and orientation. The results of the Design-Builder simulation clearly show a reduction in EPI. The EPI for the Base Case is 31 kWh/m2, while the EPI for the Design Case is 19 kWh/m2. The Design case also reduces temperature, electricity, and discomfort hours. Based on the simulation results, energy optimization for indoor comfort was performed. Design optimization was done to reduce the heat gain. To choose the optimal wall and roof assemblies for a prototype, various wall and roof assemblies were analysed for U value, life expectancy, cost, thermal comfort, etc. Passive cooling methods like eco coolers were also taken into consideration, along with the proper sizing of openings and ventilators with shading devices.

It can be observed through the graphs that the heat gain through the wall has been reduced by 36%, and heat gain through the roof has been reduced by almost 80% in the design case as compared to the BAU case.

Figure 2-Base Case

Figure 3-Design Case

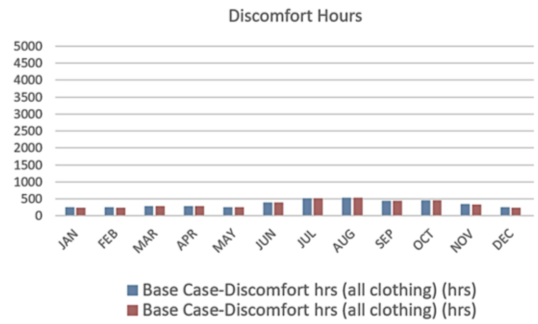

Figure 4- comparative Graph for discomfort hours

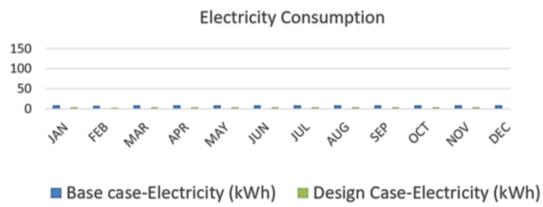

Figure 5-Comparitive Graph for Electricity

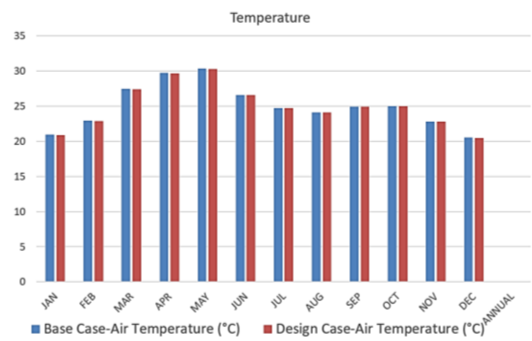

Figure 6-Comparative graph for temperature

Daylight

The need for artificial lighting will be less frequent if there is enough daylight in the rooms of the house that are used regularly. Being in a tropical climate zone, we have a lot of daylight all year long, and utilising it well would ensure energy efficiency in our daily activities.

WWR was established and computer-simulated utilising NBC for the design case.

The wall-to-window ratio (WWR) for the BAU case is no window to 1.77%, whereas the design case WWR is close to 6%. This helps in admitting sufficient daylight inside the space. As the space will be occupied chiefly during night-time, 100-300 lux is desired during daytime. Polycarbonate sheets are used for windows with the benefits of transparent/ translucent daylighting with enhanced safety & security. It has approximately 100 times the impact strength of glass and is durable. In addition, they are lightweight & have good thermal insulation. After the base case for daylight simulation, a polycarbonate sheet was used for the windowpanes in the design case. Polycarbonate sheets are preferred for windows because they provide transparent or translucent daylighting and increase safety and security. It is resilient and has an impact strength of roughly 100 times that of glass. In addition, they offer solid thermal insulation and are lightweight.

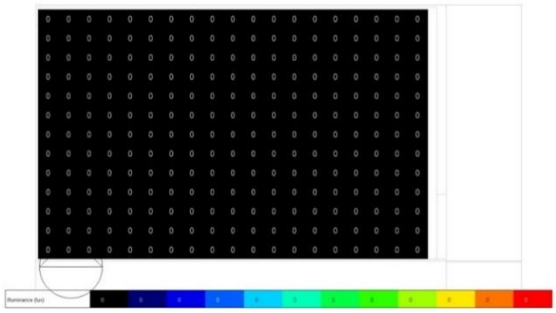

Figure 7- BAU case for Daylight

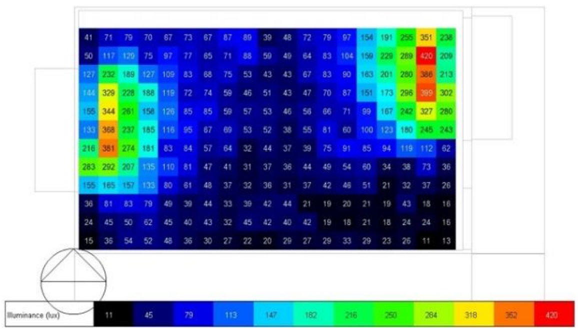

Figure 8-Design Case for Daylight

Ventilation and Thermal comfort

CFDs analysis was performed considering the base case and the design case. Proper sizing of openings and ventilators with shading devices, and Eco cooler-passive cooling strategy was also considered in design case for this analysis.

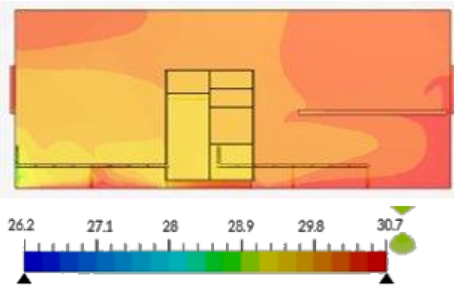

Figure 9-BAU Case-Ventilation and Thermal comfort

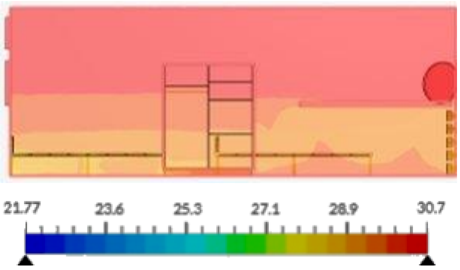

Figure 10- Design Case-Ventilation and Thermal comfort

The traditional design is not suitable for a healthy lifestyle. It leads to high temperatures in summer. Providing windows, ventilators, and eco-coolers in the design case has made the space better ventilated and improved indoor comfort. Implementing the eco-coolers ensures a drop in indoor temperatures by 2 to 3 ° C than the outdoors without using any energy.

Even in maximum humidity, the PMV stays constant throughout the year. The above results suggest that a better comfort level is achieved than the base case (the outdoor PMV is +3, indicating too hot)

Predicated Mean Vote (PMV)

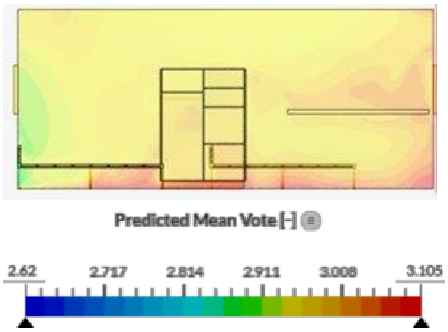

Figure 11-Base Case-PMV

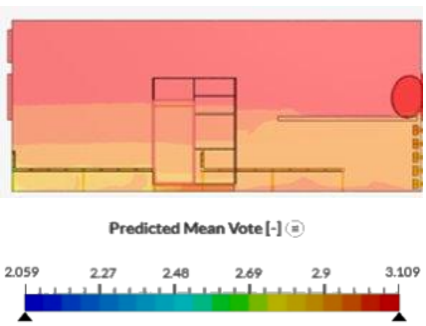

Figure 12-Design Case-PMV

Air flow analysis

Due to eco coolers and ventilators placed in the direction of wind flow, it can be observed that the design case has better indoor comforts, and proper cross ventilation is achieved. The analysis is done considering the conditions in May. The data for analysis is taken from IMD climate data and the adaptive thermal comfort booklet

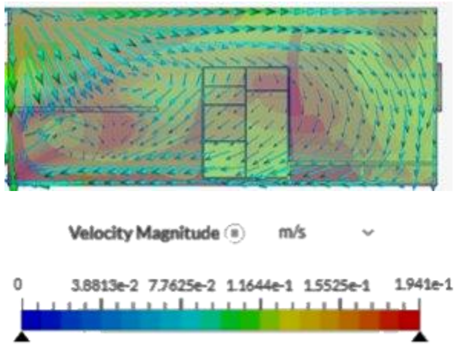

Figure 13-BAU Case-Air flow analysis

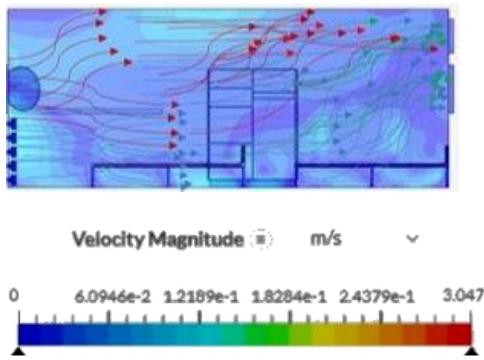

Figure 14- Design Case-Air flow analysis

Conclusion

Migrant construction workers are primary stakeholders in the construction industry, but they are often neglected concerning providing good quality of life. Through the research, it has been shown that these on-site workers spend the day working outside and most of the evenings indoors. Therefore, their comfort indoors is crucial at night-time. Through the modelling procedure for the current scenario, it is evident that the temporary employees' housing unit does not have good indoor environmental quality due to Heat gain through the envelope and a lack of ventilation. The proposed scenario, which involved evaluating the thermal performance of wall panelling, was simulated using the design builder tool. The u value of the envelope was decreased by increasing its thickness and adding insulation to the roof, resulting in less heat gain and, eventually, lower temperatures. Additionally, the CFD study aided in understanding how well eco coolers ventilate and lower temperatures. Through CFD research, the provision and effectiveness of the appropriately sized apertures were also confirmed. Working on wall panelling thickness to improve thermal mass and further limit heat gain is crucial to moving this research forward. Examining materials for panelling and roofing may also be a potential research topic. Other uses of Eco coolers should be investigated to improve ventilation and lower indoor temperatures. Since the research was only done for a short time in Pune, it should be repeated using simulation as a tool for a year to check the viability of the suggested system. This should be followed by data logging in various climate zones. Then, the proposed housing unit can undergo a thorough life cycle analysis as an inexpensive and scalable alternative for builders and owners.

Acknowledgement

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