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A Wholistic Housing Solution for Onsite Construction Workers

Sayali Andhare
Dr. B. N. College of Architecture, Pune, India

Namrata Dhamankar
Dr. B. N. College of Architecture, Pune, India
(Corresponding Author: namrata.dhamankar@bnca.ac.in)

Highlights

- Modular System for onsite construction housing, designed as DIY kit.
- Wall paneling system designed for thermal insulation.
- Use of eco cooler
- Design and prototyping focusing on affordability, scalability, and adaptability.

Abstract

Construction workers are among our cities' most important 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 good job opportunities along with an improved standard of living. The big question is whether this migration and growth of the infrastructure industry benefits the migrant workers' standard of living. The primary goal of the research has been to design and test a prototype housing system for onsite construction workers for indoor environmental quality. It presents a part of the ongoing research examining the parameters that influence the onsite housing system for construction workers in terms of building materials, services provided, and indoor environmental comfort. Simulation studies were carried out using Design Builder software to assess the annual performance, operational energy use, and indoor thermal comfort condition of the Business-as-usual case and the proposed design case. The EPI for the Business-as-Usual Case is 31 kWh/m^2, while the EPI for the Design Case is 19 kWh/m^2. To put the idea to the test, an actual prototype of a construction worker housing system was created and tested for thermal performance and user experience, along with onsite installation and long-term viability. The primary findings of the study are that onsite workers living in modular prefabricated housing can achieve indoor environmental comfort by using a wall paneling system made of paper honeycomb board sandwiched between powder-coated G.I. sheet can provide thermal comfort with additional aluminum bubble wrap insulation for the roof. Lower U values for the wall assembly and the use of Eco coolers, a passive cooling system, have increased thermal comfort and ventilation, respectively. The research also evaluated the affordability, scalability, and adaptability of the suggested prototype for a holistic housing system. The current study's objective is to assess how well the created unit performs in Pune or another city with a comparable climate.

Keywords: Onsite Construction Workers Housing, Thermal Comfort, Modular Construction, Eco Coolers, Data Loggers

Introduction

The construction sector is one of the biggest employment generators in India. The infrastructure projects that lead to the growth and development of cities generate employment for migrant workers who come from all parts of the country to earn money and grow. But the major question is, are these migrant workers getting any share of this growth? A Construction worker who is the most integral part of the construction sector, is most vulnerable and often gets neglected. We have seen great development in the architectural world, from small shacks to high-rise buildings, but the living conditions of these workers have not changed much [1].

In addition to minimum wages, overtime pay, and weekly off, migrant construction workers should be provided with comfortable housing and other social security benefits under labour laws [2]. As a result, it is the developers' responsibility to ensure that the working conditions for their construction workers meet some basic standards. To understand the developer's perspective and the challenges they face with migrant construction workers, we must first understand that these construction workers are typically migrants who stay onsite for anywhere between 3 months to 3 years. Because construction site locations change repeatedly, developers end up providing these workers with temporary shelters, as

building a permanent residence for construction workers does not provide builders with any direct financial benefits, as a result jeopardizing their comfort [3].

Indoor thermal comfort affects humans psychologically and physiologically. It positively impacts health and productivity and improves the sense of well-being [4]. Thermal comfort is defined as "that mental state expressing satisfaction with the thermal environment." The ASHRAE-55 standards recommend an indoor temperature of 26℃ for long-term thermal comfort. For all types of buildings, Indian codes require uniform comfort temperatures ranging from 23 to 26℃ [5].

For these reasons, thermal comfort for all should become an important goal for all developing countries. Under the 2030 Agendas for Sustainable Development that proposed 17 Sustainable Development Goals, Goal 11 says to make cities and human settlements inclusive, safe, resilient, and sustainable, while target 11.1 of the Sustainable Development Goals aims to "ensure access for all to adequate, safe, and affordable housing by 2030."Developers should consider SDG goals and plan for inclusive development. They should provide these migrant onsite workers with adequate housing that is modular, adaptable, and thermally comfortable so that workers are happy and productive as a result of the comfort they have in their homes [1].

Method

The research was conducted in three stages, starting with a literature review, which was conducted by reading various papers and articles related to the research topic to gain an overview of current research, establish understanding and relevance of research, and identify gaps in current research. The literature review also helped to select a method to be followed for the study.

The next step was to establish a methodology, which is a combination of interviews, case studies, observations, and content analysis. As a result, quantitative data about the selected parameters was gathered via onsite measurements and physical building assessments, and qualitative data was obtained via an occupant satisfaction survey to gather first-hand information about users' experiences of living in labour housing. Leading developers in Pune were identified for research purposes. The primary goal of data collection is to gain a comprehensive understanding of onsite workers' housing and user comfort, for which an interview-based survey of construction workers and developers was conducted. The sample selection was purposive due to permissions to access construction sites.

A survey of 5 officials from the developers' side and 33 construction workers from various backgrounds was randomly conducted. Onsite workers (Male/Female) were the primary respondents. With the help of a pre-tested structured questionnaire, data was collected focusing on user comfort, details of construction techniques, materials, their thermo-physical properties, and various schedules based on the occupant's behaviour and occupancy. The data collection included specific information about comfort in the summer and winter. Other parameters include providing water for drinking and other uses by constructing or organizing necessary water-related infrastructure, sanitation infrastructure, sewage disposal, drainage, solid waste management, provision of electricity, and facilities like creche, health services, and recreation areas.

Further mapping exercise was carried out where photographic documentation and physical measurements were taken to capture the current situation. For checking indoor environmental comfort, Spot measurements of specified parameters of comfort, mainly temperature, humidity, air movement, and air quality, were taken using Five in one meter and a CO_2 data logger.

Figure 1: Interior and exterior spaces at labour camp (Business-as-usual case)

Findings from Developers Survey and Construction Workers Survey

Construction workers occupy housing on construction sites anywhere between 3 months to 6 years. Feedback says indoor temperature in summer is typically unacceptable, there is no ventilation, and lighting conditions are very poor. All the workers use mechanical ventilation, mostly ceiling fans, as an adaptive strategy to reduce temperatures. Following is the set of questions asked to the onsite construction workers as part of the survey:

What is the typical size of one usnit?

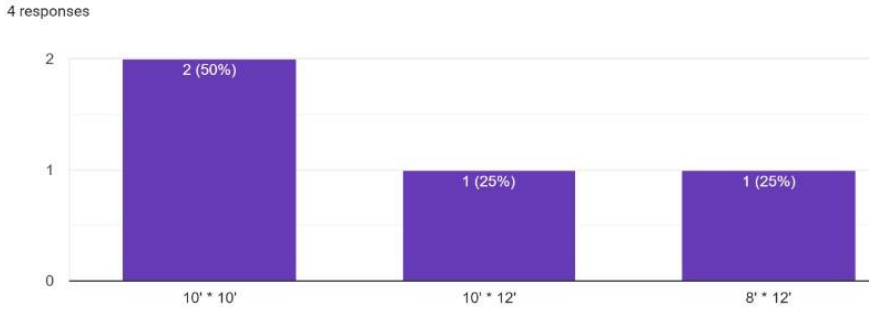

Figure 2: Graph Showing the typical size of labour unit

What materials are used for the construction of housing units for onsite workers?

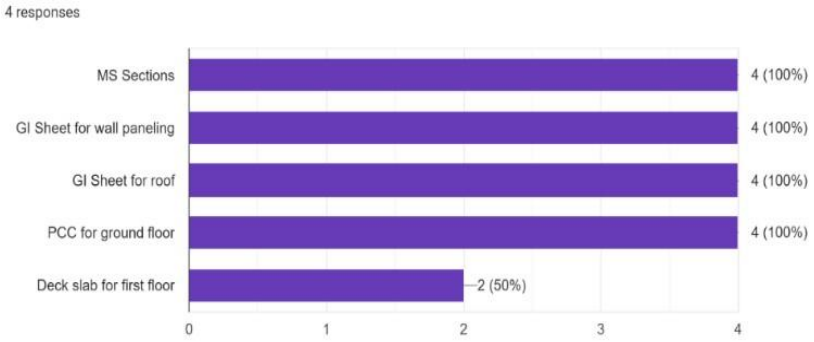

Figure 3: Graph showing materials used for construction

Can these materials be reused again?

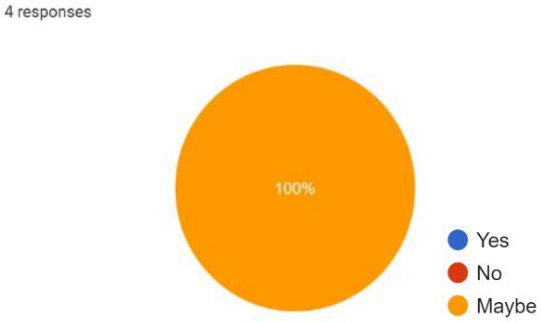

Figure 4: Graph showing the reusability of materials

What is the duration of the construction period for a particular project?

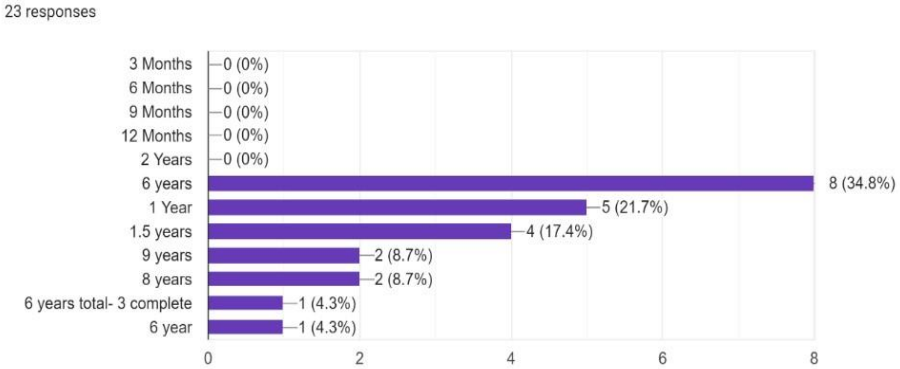

Figure 5: Graph showing the duration of construction

What is the typical duration of occupancy of a construction worker on site?

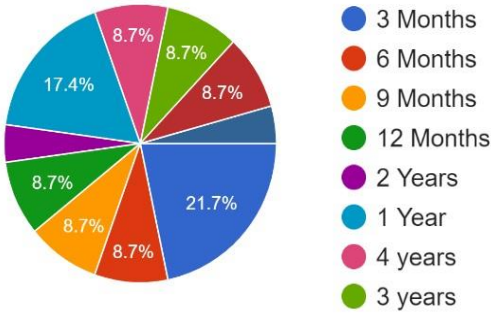

Figure 6: Graph showing occupancy of construction workers on site

Daylight in the house

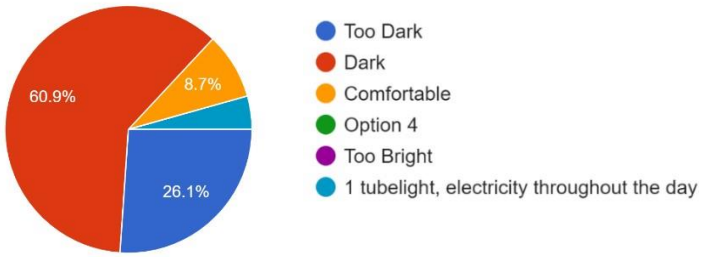

Figure 7: Graph showing daylight hours in the workers' housing unit

Indoor temperature in summer

Figure 8: Graph showing indoor temperature

Air Movement /Ventilation

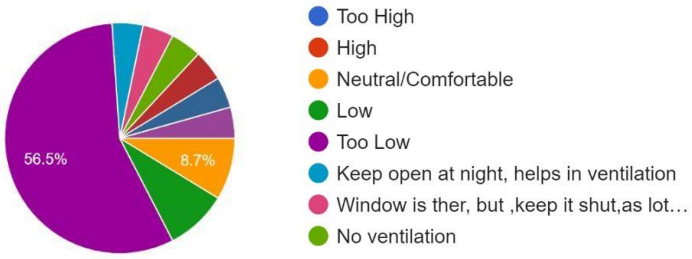

Figure 9: Graph showing the ventilation rate

What is the adaptive strategy in summer?

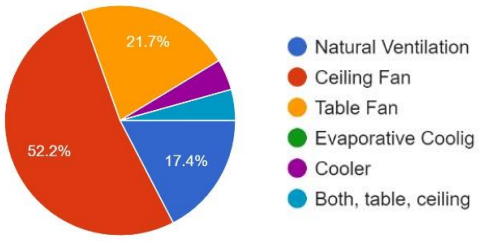

Figure 10: Graph showing adaptive strategy for summer

Based on the literature review and data gathered from the site, the users were not comfortable inside the existing housing due to harsh temperatures and no ventilation. It was decided to build a prototype unit for onsite construction workers' housing to improve environmental comfort parameters. The proposed design's ideation was completed. Design Builder, an energy simulation tool, was used to simulate comfort in the proposed prototype, which was later built to evaluate the thermal comfort solution provided. A comparative analysis of current housing and the proposed prototype was carried out to evaluate thermal comfort. Data loggers were installed in one of the units from the current worker housing unit and proposed built prototype. The data was recorded for 15 days, from the 29th of April to the 15th of May 2022.

A design approach was developed in the last stage based on the literature review and data gathered from the site. The users were not comfortable inside the existing housing due to harsh temperatures and no ventilation. It was decided to build a prototype unit for onsite construction workers' housing to improve environmental comfort parameters.

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Design development of proposed prototype:

Two cases were considered for design development: business-as-usual case and the design case. The business-as-usual case is the existing housing units. These units have metal pipes as structural elements, corrugated metal sheets for the wall and roof paneling, often in poor condition due to multiple reuses, and no or poorly done flooring. The units were hot to live in during the summer. There are no windows and only one door, resulting in insufficient natural light and ventilation. Environmental comfort is rarely considered in this case. The findings from the survey of construction workers say that indoor temperature in summer is typically unacceptable; there is no ventilation, and lighting conditions are very poor. All the workers use mechanical ventilation, mostly ceiling or table fans, as an adaptive strategy to reduce temperatures. The literature review also states that construction workers are the most neglected people in the construction industry, and there is a strong need to redefine labour accommodation. A new design approach to address these issues concerning onsite construction workers' housing requirements was developed through a design case that focuses on providing a comfortable abode to this working class. To achieve this aim, the design intent was defined, focusing on achieving comfort for the user by selecting an appropriate building system and materials constructability of the module. Manufacturing and assembly were also considered in the design case.

To incorporate thermal comfort concepts into affordable housing, POE performance indicators like Design quality, building layout, Interior and exterior appearance, Access to campus facilities, quality of the indoor environment (IEQ), Improved indoor air quality- The quality of air within a facility or the built environment, Acoustic comfort, Visual comfort, Security and fire protection, quality of building support services were identified [6].

Wall and roof assemblies were selected for research as they provide a unique opportunity for energy conservation as these surfaces receive most of the solar radiation. Criteria for selection materials in the proposed case were durability, low cost, local, and healthy comfort creating. At the same time, the parameters defined for the system were sturdy, reusable, transportable, modular, lightweight, additive, fireproof, and waterproof. A series of experiments were carried out to finalize the material and system for the proposed prototype. For wall paneling, various assemblies of material were explored. These assemblies were analyzed for durability, cost, maintenance, strength, moisture resistance, fire resistance, and, most importantly, the thermal comfort they provide. Based on the comparative analysis of assemblies, in the proposed prototype, a paper honeycomb board for the wall paneling is used because it is a good thermal insulator due to the presence of air cavities. It is an indefinitely recyclable material made from wastepaper, which is why it is not naturally waterproof. That's why it is sandwiched between a powder-coated G.I. Panel, which also helps to prevent fire. It is light, strong, and stiff, which helps in building modular systems.

The proposed prototype's walling assembly is 35 mm thick and is fixed within a 50 mm M.S. section. It does not need to be plastered. The components in this assembly can be recycled and have a good market presence. The value of this assembly was checked using the Testo 635 U-value promo set, which essentially measures a material's thermal insulation properties. For the roof, along with G. I. Sheet, an Aluminum bubble wrap sheet is used to control the heat gain from the roof.

(1) (2) (3) (4)

Figure 11:(1) M.S. pipe for the frame, (2) Honeycomb board wall panelling, (3) cement sheet for the floor, and (4) G.I. Sheet with aluminium bubble wrap for insulation

In the business-as-usual case, it is clear from the survey and onsite observations that there is no provision for a window. 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, which is used in the proposed design case [7].

Figure 12: Eco Cooler

Modular construction is a relatively new concept in India. This concept requires awareness and education among builders and developers in order for its application to be maximized [8]. To make the proposed solution practical, scalable, affordable, and adaptable, it must be simple and quick to build, and that is why modular construction is one of the key approaches used in the proposed prototype.

The prototype has been designed as a DIY kit that can be easily assembled or dismantled on site. The construction of the proposed unit was done in 3 stages: manufacturing, packaging, and transportation. The process of onsite installation is explained in Figures 12, 14, and 15.

Figure 13: Bucket Foundation

Figure 14: Installation Process

Figure 15: Prototype

Conclusion

Despite being the key stakeholders in the construction industry, migrant workers are sometimes disregarded when it comes to ensuring a decent quality of life. According to the research and survey, these onsite construction workers work largely

indoors in the evenings and outdoors throughout the day. As a result, it is critical that the workers should feel comfortable inside the dwelling unit at night. The energy simulation technique, as well as survey data, demonstrate that in the current scenario (business-as-usual case) of a temporary dwelling unit, indoor environmental quality is poor due to heat build-up via the envelope and a lack of ventilation. U value of the structure was reduced by increasing the thickness of the envelope using prefabricated paper honeycomb board sandwiched panels and adding aluminium bubble wrap insulation to the roof, resulting in less heat gain and lower temperatures, resulting in better indoor comfort. The addition of an entrance and the usage of eco-coolers aid in ventilating and lowering the temperature of the planned unit. Moving this research forward will necessitate a focus on wall panelling thickness to increase thermal mass and limit heat gain even further.

This research has helped the development of a modular onsite housing system for onsite construction workers that is comfortable to live in. The onsite live-scale prototype building and testing for indoor environmental parameters, as well as user feedback, helped to create a statement of assurance of the workability of the structure and indoor thermal comfort for the users. The research conclusions will be significant to emerging countries where construction workers are important development stakeholders.

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