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Evaluating building material based thermal comfort of a typical low-cost modular house in India☆

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Abstract

'Housing for All by 2022' is an ambitious initiative by the Government of India, to provide affordable and quality housing to the people of economically weaker sections (EWS) and the low-income group (LIG). Modular housing has become the de-facto in this context of low-cost and affordable housing. In this study, we evaluate the thermal comfort of a commercially available modular house with respect to different low-cost building wall materials and window glass panes. Dynamic energy simulations were carried out for Mumbai to analyse the thermal-comfort performance of such houses throughout the year. Results have shown that none of the low-cost building materials were competent enough to meet the ASHRAE-55 standards. However, a combination of glass fibre reinforced gypsum board and a blue tinted glass of a 6mm thickness, performed better in thermal comfort in comparison to other materials. This study showed the need for development of efficient low cost building materials in order to address the long-term sustainability of the low cost housing project.

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Keywords: Building materials; Mean radiant temperature; Operative temperature; Thermal comfort; Low-cost housing; Sustainability

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1. Introduction

The Ministry of Housing and Urban Poverty Alleviation (MHUPA), the Government of India (GoI) in their annual report for the FY- 2014-15, estimated that India suffers from housing shortages by 18.54 million units [1]. 96% of the housing shortage is in economically weaker sections (EWS) and the low-income group (LIG), who also suffers from lack of basic amenities like sanitation services, potable drinking water, electricity and effective solid waste disposal services [1], [2]. Attempts to mitigate this problem pertaining to the quality of life (QoL), the Ministry announced the National Urban Housing and Habitat Policy, 2007, which focusses on 'affordable housing for all with special emphasis on economically weaker sections of society such as SC, STs, OBCs, Minorities, women-headed households' [1].

In this purview, private corporations have flocked in to cater to this ambitious aim of the MHUPA, by providing modular low-cost houses, with an average floor area of 600 square meters [3]. However, the long-term sustainability of such modular houses is still unidentified, as different strata of the society has varied lifestyles with cultural and social needs. Moreover, current literature lacks building performance analysis in terms of thermal comfort of such modular houses, which can provide valuable insights pertaining to their long-term sustainability, and prepare designers, engineers and investors towards more sustainable low-cost housing design.

In India, where only 7% of the residential houses uses ACs during the summer months [4], [5], hence maintaining optimal thermal comfort levels becomes a critical sustainability clause, especially for EWS and LIG houses. Thermal comfort is defined as "that condition of mind which expresses satisfaction with the thermal environment" [6]. ASHRAE-55 standards suggest 26ºC as the desirable indoor temperature for prolonged thermal comfort [7]. Indian codes specify uniform comfort temperatures between 23 and 26ºC for all types of buildings as the required thermal comfort range [8]. The thermal temperature that our body experience in an indoor space is known as operative temperature (t_o). It is a combined effect of mean radiant temperature (t_r) and the air temperature (t_{db}). Mean radiant temperature (t_r), is defined as 'the uniform surface temperature of an imaginary black enclosure in which an occupant would exchange the same amount of radiant heat as in the actual non-uniform space' [9].

Here, we investigated the thermal comfort performance of a commercially available low-cost house with respect to different low-cost building material, with mean radiant temperature (t_r) and operative temperature (t_o) as the performance indicators.

Nomenclature

$F_{s \to i}$	angle factor between the ith internal surface of the envelope and the subject
T_i	the absolute surface temperature of the surrounding surfaces
C_{dn}	day–night coefficient (equal to 1 in the daytime period and equal to 0 in the night period)
C_s	shading coefficient (equal to 1 when the subject is directly hit by the solar beam and equal to 0 in the other cases)
ε_s	emissivity of the human body
σ	the Stefan–Boltzmann constant (=5.67 X 10^{-8} Wm^{-2} K^{-4})
α_{irr}	the absorption coefficient
$I_{d_i,j}$	the diffused coefficient entering the room
$f_p I_b$	the projected human area factor in all the six directions
t_r	mean radiant temperature
t_o	operative temperature
t_{db}	outdoor temperature (dry-bulb temperature)

Fig 1. A typical commercially available low-cost modular house in India and its CAD model. [1]