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Effects of solar shading on thermal comfort in low-income tropical housing

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Abstract

This paper evaluates the effects of solar shading strategies on thermal comfort in low-income tropical housing in Uganda. Dynamic thermal simulations are conducted and the effects of various shading strategies including curtains, roof and window overhangs, veranda and tress on solar heat gain and thermal comfort are investigated. Adaptive approach for naturally ventilated buildings defined by CEN standard is used to assess the conditions in the case study buildings. According to the results, although shading significantly reduces solar heat gain, it is less effective in meeting thermal comfort requirements in low-income tropical houses. Solar shading is however considerably effective during the hottest periods of the year reducing the risk of extreme overheating by up to 52%. In this respect, a north-south building orientation with the main openings on the north elevation is recommended. Due to excessive solar heat gain, large openings on east- and west-facing walls should be avoided.

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Keywords: Solar Shading; Thermal Comfort; Low-income; Tropical; Housing; Uganda

1. Introduction

Uganda is one of the most economically deprived countries in the world. Around 33% of Uganda's population live in severe multidimensional poverty [1] and over 60% of its urban population living in slums [2,3]. Uganda has a moderate tropical climate [4] although global warming is expected to increase the average air temperature in East African countries by 3-4 °C during the next 70 years [5]. This situation along with inappropriate and defective

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construction methods and materials [6,7] may deteriorate thermal comfort conditions [8] affecting low-income populations the majority of whom live in single-roomed [9] overcrowded homes [10]. Considering the very low access to electricity in Uganda (18.2% [1]), natural ventilation is the major ventilation/cooling method in the majority of buildings. Natural ventilation can provide thermal comfort; however, to provide effective natural ventilation it is important to minimise internal and external heat gains [11].

Solar heat gain is identified as one of the main contributors to overheating in residential buildings. Therefore minimising solar heat gain can improve effectiveness of natural ventilation. Solar heat gain can be controlled by reducing solar transmittance through windows, improving construction details/types to minimise surfaces heat transfer [12], and introducing shading to minimise solar transmission and heat gains through glazed and opaque surfaces [13]. Solar transmittance which is usually measured by g-value and solar heat gain coefficient (SHGC) [14] is highly affected by glass types. Due to possible high costs and limited access to different glazing types for low-income people, changing the glazing may not be an appropriate strategy to control solar heat gain in low-income housing. Solar shading in contrast could be an appropriate strategy which could be considered to improve thermal comfort in low-income housing. Solar shading can be provided by means of internal and external shades. Generally, compared to internal shadings, external shadings are up to 30% more effective in minimising solar heat gain. For south and north facing windows it is generally recommended to use horizontal external shading while for east and west facing windows application of vertical shading is recommended [13]. Although more effective, external shading tend to be more expensive compared to internal shading [15]. This may arguably limit the applicability of external shades in low-income housing.

Fig. 1. Low-income housing.

This study evaluates the effects of solar shading strategies on the risk of overheating and thermal discomfort in low-income tropical houses in Uganda (Fig. 1). The effects of alternative construction methods and materials as well as refurbishment strategies on thermal comfort have been reported in other papers [8,16].

2. Methodology

Dynamic thermal simulations (DTS) were conducted in EnergyPlus to evaluate the effects various shading strategies on solar heat gain and thermal comfort in a typical low-income house in Uganda. The Test Reference Year (TRY) for Kisumu in Kenya was chosen as the closest available weather data to Kampala as there are no available weather data for thermal simulations in Uganda. Kampala and Kisumu are located on the northern shore of Lake Victoria with similar altitudes above the sea level.

Considering over 50% of Ugandan families live in single-roomed homes [9] with an average household size of 3.9 people in urban areas [17], a single-zone 3×3×3m house with 4 occupants was modelled. A south facing window