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Evaluation of urban residential thermal comfort in relation to indoor and outdoor air temperatures in Ibadan, Nigeria

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ABSTRACT

A thermal comfort survey was conducted in Ibadan metropolis, Nigeria. Ten percent (12) of the 119 neighbourhoods identified from the metropolitan map were selected by stratified random sampling comprising 2 low, 3 medium and 7 high residential densities. Systematic random sampling was used to select a total of 528 houses within these neighbourhoods for the survey. Indoor and outdoor measurements of air temperature and other relevant climatic elements were carried out in representative buildings within the neighbourhoods. For each selected building, an adult resident filled a questionnaire indicating the indoor thermal response at different periods of the day using the ASHRAE thermal comfort scale. Significant variations of air temperature and thermal response manifested across the residential densities and neighbourhoods. The air temperature variation across the neighbourhoods was found to be influenced by the different neighbourhood characteristics. Maximum values of measured outdoor and indoor temperatures ranged from 34.1 °C to 36.9 °C and from 32.5 °C to 35 °C respectively. The reduction in maximum temperatures from outdoor to indoor was in the range of 1.6–1.9 °C. The variation of temperature across residential densities was found to affect indoor thermal comfort. It was inferred that the urban microclimate had impact on the indoor comfort of residents. Mean comfort vote was related to indoor and outdoor temperature by linear equations.

1. Introduction

High amounts of solar radiation for extensive periods generate remarkable amounts of heat in the tropical environment. The heat intensity is felt within buildings by the residents as described by the high indoor air temperature values. The substantial levels of activity and congestion due to high population density as well as industrial processes in the tropical city environment also contribute to the buildup of heat. All these add up to the discomfort experienced in the tropical built environment. Urban transition is currently at its peak in the tropical regions leading to congestion and thermal discomfort [1]. It has been stated that the urban air temperature is gradually rising in all cities in the world, caused by drastic reduction in the green area in cities [2]. For Ibadan metropolis in Nigeria, the study area specifically, it was found that mean maximum temperature has been on the increase from 30 °C in 1979 to 33.5 °C in 2009 [3]. The level of indoor thermal comfort obtainable in such high temperature conditions is of concern, especially with the treat of climate change.

Indoor and outdoor air temperatures remain the dominant climatic factors affecting thermal comfort in the tropics. The afternoon period in the tropics is noted for discomfort due to the impact of intense solar radiation leading to high air temperatures during the period. This consistent impact of high insolation affects buildings and dictates levels of indoor comfort to a high degree. It has been established that buildings must provide a functionally acceptable thermal environment. The residential building in particular, as the home environment, should present a comfortable atmosphere suitable for its purpose of being a place of rest. The variation of temperatures across residential densities in urban areas and the effect on indoor thermal comfort will be taken as a pointer to the impact of the urban microclimate on the built environment in cities.

A thermal comfort field survey was carried out in Ibadan metropolis with a view to relating the indoor comfort of residents to the outdoor and indoor air temperatures across the different residential neighbourhoods. According to Humphreys, field studies of thermal comfort are with two purposes: (1) to find a way of describing the thermal environment which correlates well with human response, thus enabling reliable predictions to be made, and (2) to define the range of conditions found to be pleasant or

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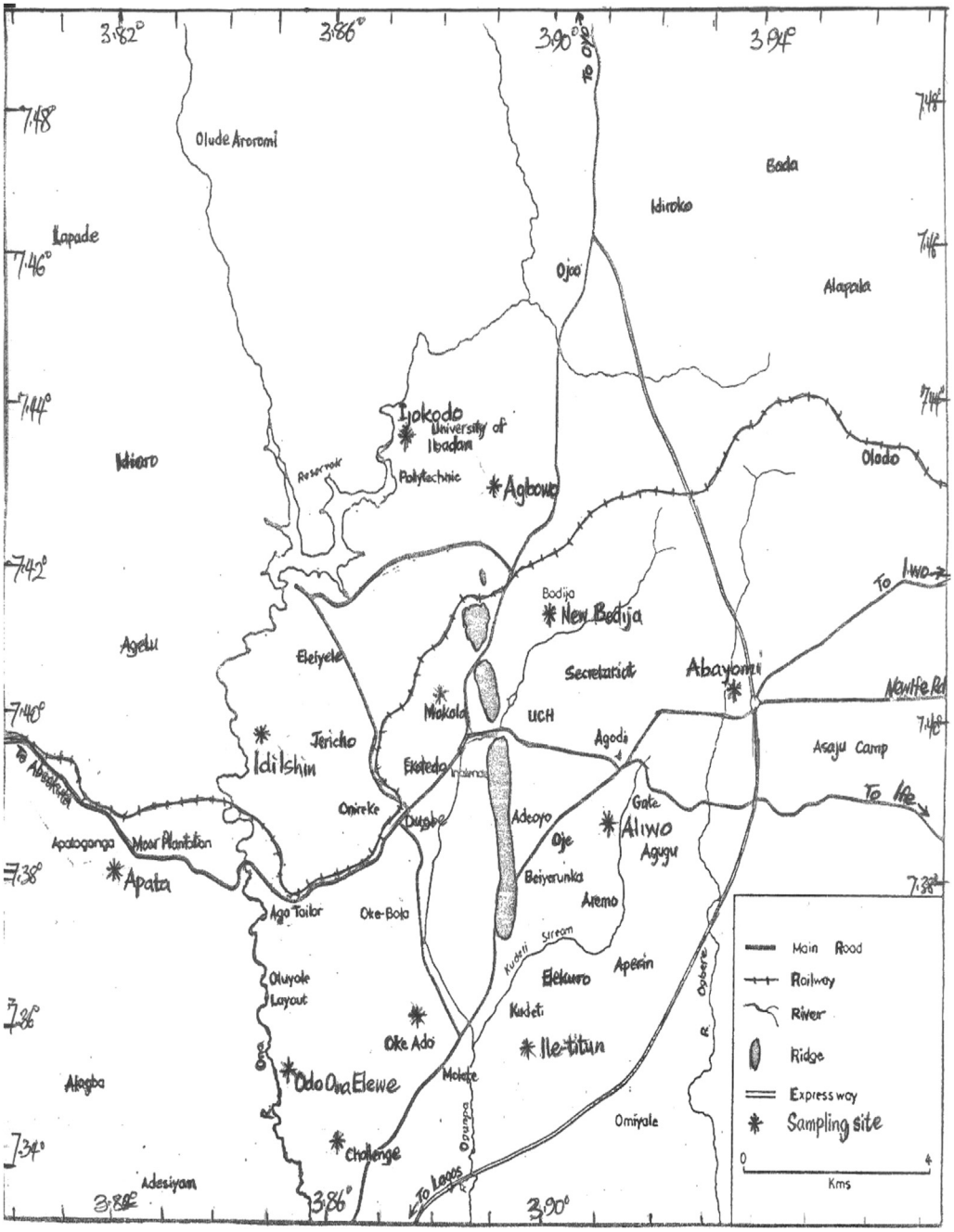

Fig. 1. The site of Ibadan. Source: Adapted from Ref. [32].

tolerable by the population concerned [4]. This contextual study was aimed at examining residents' thermal response in relation to the dominant climatic factors of indoor and outdoor air temperatures in the tropical environment.

2. Literature review

The architecture of residential buildings should collaborate with nature to enable harmony with their surroundings. The concept of human shelter is the provision of building spaces to offer protection from uncomfortable climatic conditions and facilitate various human activities. Buildings actually modify climate and influence human behaviour and culture [5]. A building can be climate-responsive. Beng observed that climate as a prime factor in built form, is the mainspring for all the sensual qualities that add up to a vital tropical architecture [6]. The building envelope is a designed selective filter: excluding unwanted influences like excessive radiation, but admitting the desirable and useful elements like appropriate day-lighting. It should be the designer's aim to ensure the required indoor conditions with little or no use of energy, other than from ambient or renewable sources [7]. The thermal behaviour of a building, which is a product of the interaction between architecture and climate, has great effect on the energy use and sustainability of the building. Attainment of thermal comfort within residential living spaces will also induce user satisfaction. There is need to design low energy buildings without reducing the internal environmental quality. Energy efficiency has proved to be a cost-effective strategy for building economies without necessarily