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On The Intrinsic Flexibility of the Double Skin Façade: A Comparative Thermal Comfort Investigation in Tropical and Temperate Climates

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Abstract

Double Skin Façades (DSFs) are applied in both new and existing buildings, and most of such applications are found in temperate climates. Although research in this area is growing steadily, comparative analyses of DSF applications in different climates are still few and far between. This paper addresses such a gap by means of a comparative thermal comfort analysis of a DSF building model in both tropical and temperate climates. London and Rio de Janeiro have been selected as two representative cities, and three building orientations in each city have been considered; S, SW, and SE, for London in northern hemisphere and N, NW, and NE for Rio in southern hemisphere. Dynamic building energy modelling has been used to determine and assess indoor environmental conditions. While IES VE as the main software tool was utilised, the accuracy and reliability of the results were also cross-checked against a computational fluid dynamic (CFD) software package. Thermal comfort has been assessed through the adaptive comfort approach and results have been analysed and presented in form of comfortable indoor conditions during occupied hours. Results of this study show that the intrinsic flexibility of the DSF can offer indoor comfort for more than half of a year in both climates without any need for mechanical heating/cooling, which contributes significantly to reducing energy demands and cutting CO_2 emissions. Additionally, the study shows that the wind force plays a dominant role in driving airstreams in and through the DSF, which highly impacts the overall thermal performance of the buildings. Findings from this research can be useful to academics and practitioners alike, to inform better DSF design and to shed light onto further avenues for DSF research.

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Keywords: Double-skin Façade; Natural ventilation; Thermal comfort; Free-running building; Low-carbon building.

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1. Introduction

Around half of the energy consumption, greenhouse gas (GHG) emissions and depletion of natural resources worldwide are believed to be down to construction sector [1]. Without a resolute and concerted effort, carbon dioxide (CO_2) emissions related to worldwide energy consumption will double by 2050 [2]. Although much can be done by maximising the share of sustainable and renewable sources, the role of reduction in energy demand cannot be overlooked [3]. It is of paramount importance for the construction sector, to reduce its energy demand while also 'greening' its energy supply through maximising the use of renewable energy and passive strategies. In fact, the need of realising more efficient buildings is holistically called upon for by all future agendas. Given this context and the flexibility that Double Skin Façades (DSFs) can offer in design, they can provide significant benefits in reducing both heating and cooling loads of the buildings to which they are applied [4]. A DSF consists of an internal layer and an additional, usually glazed, external skin, separated by an air cavity that may either act as a thermal buffer zone, as a ventilation channel or, more often, as a combination of the two. Additionally, the cavity often incorporates shading devices, such as blinds, to protect the internal rooms from overheating caused by solar gain [5].

Existing literatures on DSF cover a broad range of different aspects, such as shading elements in the cavity [6-9], airflow analysis and prediction [10-13], fire and smoke spreading issues [14-17], operational and embodied energy [18, 19] and natural ventilation [5, 20-22]. Natural ventilation is of paramount importance for the operational behaviour of the façade and, in this respect, the surrounding climate plays a crucial role in determining the DSF's effectiveness [23-25]. Recent reviews [26] have shown that our understanding of natural ventilation aspects of DSFs is yet to be fully substantiated, and that the cavity is often considered as an 'isolated' structure and treated as a local thermal feature without taking into account its influence on and exchanges with the spaces.

Furthermore, research on DSF is generally focused on single climatic zones [e.g. 27], if not a single season within a single climate [e.g. 23]. Although one might argue that the depth of such an investigation often requires a narrow approach, there is no doubt that the sacrifice of a broader assessment aimed at understanding the potential flexibility of DSF technologies, as a result, is inevitable. Few comparative assessments do exist, but they have either taken an oversimplified approach to building models [28] or have taken such a specialised approach to specific types of DSF that do not represent current practice with the Architecture, Engineering and Construction (AEC) sector (for instance façade equipped with phase change materials (PCM) in the air chamber [29]).

This research aims to fill such a gap in knowledge by means of a comparative thermal comfort analysis of a DSF building model in both tropical and temperate climates. London and Rio de Janeiro have been selected as two representative cities, and three building orientations in each city have been considered; S, SW, and SE, for London in northern hemisphere and N, NW, and NE for Rio in southern hemisphere. The focus is on achieving thermal comfort merely by passive operational strategies (passive heating/cooling) of a DSF. A methodology based on dynamic building energy modelling has been used to determine and assess indoor environmental conditions, and it is presented in the following section.

2. Methodology

Due to the free-running nature of such naturally ventilated buildings the adaptive thermal comfort approach is used for which air temperatures and air velocities are combined together to determine whether or not indoor conditions fall within or outside a comfort range [30, 31]. In this respect, Building Energy and Environmental Modelling (BEEM) software tools are arguably the most effective ways to achieve detailed analyses of buildings, such as those presented in this paper. Furthermore, they represent the only possible approach where the aim is to assess different orientations of a building, with different configurations, in different climates—which is the case of this research. The main software tool used is IES VE, a building thermal simulation calculation engine that can model natural ventilation systems using the airflow network approach. Additionally, a model calibration through a comparison against FLOVENT, a computational fluid dynamics (CFD) software package, is also carried out to assess the accuracy and reliability of the results.