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RESEARCH ARTICLE

Using passive cooling strategies to improve thermal performance and reduce energy consumption of residential buildings in U.A.E. buildings

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Abstract
Passive design responds to local climate and site conditions in order to maximise the comfort and health of building users while minimising energy use. The key to designing a passive building is to take best advantage of the local climate. Passive cooling refers to any technologies or design features adopted to reduce the temperature of buildings without the need for power consumption. Consequently, the aim of this study is to test the usefulness of applying selected passive cooling strategies to improve thermal performance and to reduce energy consumption of residential buildings in hot arid climate settings, namely Dubai, United Arab Emirates. One case building was selected and eight passive cooling strategies were applied. Energy simulation software – namely IES – was used to assess the performance of the building. Solar shading performance was also assessed using Sun Cast Analysis, as a part of the IES software. Energy reduction was achieved due to both the harnessing of natural ventilation and the minimising of heat gain in line with applying good shading devices alongside the use of double glazing. Additionally, green roofing proved its potential by acting as an effective roof insulation. The study revealed several significant findings including that the total annual energy consumption of a residential building in Dubai may be reduced by up to 23.6% when a building uses passive cooling strategies.

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1. Introduction

1.1. Background

Passive cooling uses free, renewable sources of energy such as the sun and wind to provide cooling, ventilation and lighting needs for a household. This additionally removes the need to use mechanical cooling. Applying passive cooling means reducing differenecs between outdoor and indoor temperatures, improving indoor air quality and making the building both a better and more comfortable environment to live or work in. It can also reduce levels of energy use and environmental impacts such as greenhouse gas emissions. Interest in passive design for either heating or cooling has grown recently – particularly in the last decade – as a part of a movement towards sustainable architecture. Well-designed envelopes maximise cooling movement of air and exclude the sun in the summer season. There are many types of passive cooling strategies that can be recommended for use in a hot arid climate such as the United Arab Eirates (UAE). Design strategies that minimise the need for mechanical cooling systems include proper window placement and daylight design, the selection of suitable glazing for windows or skylights, proper sized shading of glass when heat gains are being avoided, the use of light or reflective-coloured materials for the building envelope and roof, careful siting and wise orientation decisions alongside appropriate landscaping design (Santamouris and Asimakopoulos, 1996).

1.2. Statement of the problem

Despite the massive potential for energy savings in buildings of UAE, the country has been identified as one of the highest carbon emitters per capita (WWF, 2012). Several factors have contributed to the existence of an inefficient building stuck in the country, including a construction boom; a lack of stringent green building practices and codes; artificially cheap prices of electricity and limited awareness with green building practices when compared with most of the advanced countries (Ghazal-Aswad et al., 2012).

1.3. Aim of the paper

The aim of this paper is to test the usefulness of applying selected passive cooling strategies to improve thermal performance and to reduce energy consumption of residential buildings in hot arid climate settings, namely, Dubai, United Arab Emirates. For the purpose of this investigation, a real case building was selected and eight passive cooling strategies were considered.

1.4. Research methodology

This study adopts 'simulation study' as the main investigatory method. Energy simulation software – namely IES (Integral Environmental Solution) – was used to assess the performance of the building. Solar shading performance was also assessed using Sun Cast Analysis, as a part of the IES software. Validation processes were attempted to calibrate the results including monitoring the temperature indoors and outdoors on different days of the year. Two simulation programs were also used for validation purposes – namely DesignBuilder and the IES. Against actual measuring on site, they recorded the highest temperatures in °C. The experimental process began in January 2011 and continued until December 2012 with averages being taken once each month during that period. Figure 1 shows that the difference between the three recorded temperatures came to less than 4.5%. Calibration took into account that air-conditioning was used during the summer, autumn and spring (with a set point of 22 °C), but was switched off during the winter – comprising November, December and January (Figure 2).

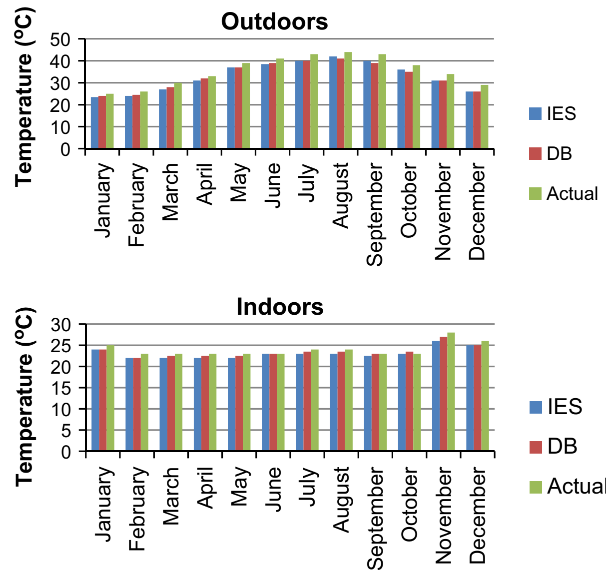

Figure 1 Calibration between the two software packages with the actual measurement on-site outdoors and indoors.

According to Rahman et al. (2008), if the difference recorded between measured and simulated readings is less than 5% then the modelling procedure can be described as valid. Thus, whilst the computed outdoor temperatures have validated the measurement experiment, the calibration of the indoor temperatures indicates a reasonable modelling accuracy when using the IES software. The next stage was to consider eight cooling strategies in order to assess the collective effect of applying all these strategies on shading, thermal performance and energy levels for the whole house. Thermal analysis was also conducted for the living room in particular. This zone was selected for this analysis because it occupies a large area with a reasonable glazed area, not to mention the fact that this is the zone that occupants spent most of their time in. The strategies considered for this study include evaporative cooling, improved shading and glazing arrangements, enhancing insulation, natural ventilation, radiant cooling and the application of light coloured coatings with high reflection in addition to green roofing. Whilst natural ventilation removes unwanted heat from the house, the remaining strategies were aimed to slow heat transfer into the villa, either by heat conduction or heat convection or thermal radiation that primarily comes from the sun.

1.5. Summary of findings and contributions

Energy reduction was achieved due to both the harnessing of natural ventilation and the minimising of heat gain in line