Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 133 (2017) 290–299

Energy Procedia

www.elsevier.com/locate/procedia

Climamed 2017 – Mediterranean Conference of HVAC; Historical buildings retrofit in the Mediterranean area, 12-13 May 2017, Matera, Italy

Applying underfloor heating system for improvement of thermal comfort in historic mosques: the case study of Salepçioğlu Mosque, Izmir, Turkey

Khaled S. M. Bughrara[a] – Zeynep Durmuş Arsan[b]* – Gülden Gökçen Akkurt[c]

[a] *Energy Engineering Programme, Izmir Institute of Technology, Gülbahçe, Urla, Izmir, 35430, Turkey*
[b]*Department of Architecture, Izmir Institute of Technology Gülbahçe, Urla, Izmir, 35430, Turkey*
[c]*Department of Energy Systems Engineering, Izmir Institute of Technology, Gülbahçe, Urla, Izmir, 35430, Turkey*

Abstract

Mosques differ from other types of buildings by having an intermittent operation schedule. Due to five prayer times per day throughout the year, mosques are fully or partially, yet periodically, occupied. This paper examines the potential of using an underfloor heating system for improvement of indoor thermal comfort in a historic mosque, which is naturally ventilated, heated and cooled, based on adaptive thermal comfort method. The selected Salepçioğlu Mosque, housing valuable wall paintings, was built in 1905 in Kemeraltı, Izmir, Turkey. It requires specific attention with its cultural heritage value. Firstly, indoor microclimate of the Mosque was monitored for one-year period of 2014-15. Then, dynamic simulation modelling tool, DesignBuilder v.4.2 was used to create the physical model of the Mosque. The ASHRAE Guideline 14 indices were utilized to calibrate the model, by comparing simulated and measured indoor air temperature to achieve hourly errors within defined ranges. The results of calibrated baseline model indicate that the Mosque does not satisfy acceptable thermal comfort levels for winter months that provided by the adaptive method. Then, the effect of underfloor heating was examined in the second model by the

Peer-review under responsibility of the scientific committee of the Climamed 2017 – Mediterranean Conference of HVAC; Historical buildings retrofit in the Mediterranean area

Keywords: Historic mosque; low temperature electric radiant heating system; adaptive thermal comfort; dynamic simulation model.

* Corresponding author. Tel.: +90 232 750 7020; fax: +90 232 750 7012.
E-mail address: zeynepdurmus@iyte.edu.tr

Peer-review under responsibility of the scientific committee of the Climamed 2017 – Mediterranean Conference of HVAC; Historical buildings retrofit in the Mediterranean area
10.1016/j.egypro.2017.09.390

1. Introduction

Mosques are the religious buildings functioning as the place of worship for Muslims. By having an intermittent occupancy schedule, they differ from other type of public buildings. The worshippers require feeling calm and comfortable to perform their prayers in tranquility and reverence. Hence, thermal requirements of a mosque should be carefully examined.

Historic mosques are naturally ventilated, heated and cooled. Limited research has been done on thermal comfort conditions of historic mosques. Since most comfort studies are likely conducted in other types of buildings such as dwellings, offices, and classrooms, more studies are needed for mosques, especially the historic ones. Any intervention for the improvement of thermal comfort in a historic building should be done without compromising its cultural heritage value. In line with this, thermal comfort study of historic mosques should be carried out with a special attention to heritage characteristics of buildings.

In most buildings, human thermal comfort is the paramount target. People can live and survive in very hot to cold conditions, that no absolute standard can be determined for their thermal comfort (5). As indicated in its definition, thermal comfort depends on the condition of mind that expresses satisfaction with thermal environment.

Several models have been used and developed in order to understand and determine the acceptable thermal conditions. The most recognized method of thermal comfort is the one presented by Fanger in 1970, which is based on the collection of experimental data and heat balance principles under the steady state condition in a controlled climate chamber. In Fanger model, two variables are necessary to be addressed: environmental variables such as air velocity, air temperature, radiant temperature, and relative humidity, and subjective variables such as activity level and clothing insulation (10), (3). Yet, the Fanger's model for predicting the thermal comfort provides better results in a mechanically ventilated building rather than a naturally ventilated building where indoor conditions directly follow outside environment, and whose occupants have the opportunities for adaptation. The discussions about the bias in PMV prediction differing by context suggest that the use of Fanger's model is no longer applicable for unconditioned buildings (4). Thus another method, i.e. adaptive thermal comfort model, was introduced by De Dear's team, based on the hundreds of field studies where the occupants were able to control their environment by means of clothing, sun shades, fans, operable windows and personal heaters (7). The concept of adaptive thermal comfort has emerged, when ventilating buildings naturally became more concerned because of the rising interest around energy efficiency and indoor air quality (12).

The adaptive model proposes that indoor comfort temperature can be estimated from the outdoor air temperature (13), (6). By plotting them tighter with the monthly or daily outdoor maximum, minimum and mean air temperatures, this can help reaching comfortable buildings. It enables to analyse the possibility of using passive cooling and/or heating design systems in the examined climate. The adaptive method is defined in The ASHRAE Standard 55 (3).

The recent studies mostly concern on permanently or periodically occupied/operated buildings such as houses, schools and offices. Few studies were noted on intermittently occupied/operated buildings such as mosques and churches. Ibrahim et al. (11) examine thermal comfort conditions in the mosque located at Kota Samarahan, Malaysia. They found that thermal comfort is not achieved. The simulation study is conducted by using EnergyPlus dynamic simulation software. The new materials are applied into digital model to enhance the thermal comfort (11). In 2009, Al-Homoud et al. (1) published the study on evaluation of thermal comfort and energy use in several mosques in hot humid climate. They conclude that in most of the studied mosques, specifically the one without insulated, thermal comfort is not accomplished. The addition of thermal insulation material to the mosques leads to improve in thermal comfort to the acceptable level. Beside to insulation material, the air conditioning system with intermittent operation can improve the level of thermal comfort with use of less energy.

The aim of this paper is to understand the indoor environment of historic mosques, and to evaluate and enhance their thermal comfort requirements. Therefore, the specific objective is to analyse the potential of using an