Determining Heat Losses and Heat Gains Through The Building Envelope of The Mosques

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Determining Heat Losses and Heat Gains Through The Building Envelope of The Mosques

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ABSTRACT. Mosques are religious structures used at different times of the day and vary in intensity depending on the days. For this reason, when compared to a typical residential or office-type building, it needs to be evaluated differently in terms of energy consumption and building envelope. In this context, it is aimed to determine the effect of heat energy losses on the building envelope of the two mosques having different heating, cooling and ventilation systems and different building envelope properties. The sampling mosques are located in the province of Istanbul with a temperate humid climate type. The mosques were built in 2012 with modern materials and construction techniques. While Hz. Ali Mosque is being built with classical style Ottoman Mosque architecture, Marmara Theology Mosque is designed inspired by the swallow ceiling technique which is characteristic of Seljuk architecture. Heating, cooling and ventilation are done by air conditioning system in Marmara Theology Mosque's. In Hz. Ali Mosque, windows provide natural ventilation and the interior is heated with floor heating system and split air conditioner. The facade design of mosques is different. To determine the heat loss and gain from the building shell, the temperature of building envelope was observed with the Fluke Ti27 thermal imager. When the images were taken, Indoor temperature and thermal comfort were measured with TESTO 480 Anemometer Thermal Comfort Measuring Device in The Mosques. The findings are evaluated and the effect of heat energy loss-gain on the building envelope is investigated and suggestions are presented.

1 Introduction

The industrial revolution in 18th century and developments in the industrialization as well as the increase in living standards around the world, increase the need for energy resources. According to the research, primary energy consumption between 2010-2040 around the world will approximately increase 56% [1,2]. The decrease in energy resources and increase in the population in 21th century, conservation and sustainability of the energy has become mandatory. Major part of the energy consumption is allocated to maintain comfort in housing or public areas. Effective energy usage and preservation in the buildings depends on effective energy design.

In this study, the effect of building envelope on indoor temperature and thermal comfort is investigated for two mosques with different heating, cooling, and ventilations systems in December 2016 in İstanbul which is located in the temperate humid climate region of Turkey. To determine the thermal losses and gains in the building envelope, Fluke Ti 27 Thermal Cameras are used to take image samples from the building façade. To determine the indoor temperature and thermal comfort, measurements are made with Testo 480 Anemometer Thermal Conform Measurement Device.

2 Thermal Comfort in Buildings According to Fanger Method (PMV-PPD)

P.O. Fanger has developed a model with 1300 people to determine the constant ambient conditions in climatized buildings in temperate humid climate regions when he was in college in 1960. Fanger combines psychological perception and statistical data and created a scale that predicts thermal precision of individuals [7]. Fanger generated PMV (Predicted Mean Vote) scale that covers the individual satisfaction states according to indoor temperature, air velocity, mean radiation temperature, relative humidity, individual activity level, and clothing insulation values. Since developed PMV-PPD scale is applied with participation of limited individuals in certain indoor conditions, seven thermal sense were created for ASHRAE standards and the scale enables to be used in different climate regions, and various building types. ASHRAE-7 thermal sense scale is used to determine the individual sensitivity of the people who are in the environment [8].

PPD (Predictive Percentage Dissatisfaction) value is the percentage value that states the thermal dissatisfaction of the people in the environment by using the PMV value. Comfort range should be identified on PMV-PPD scale to determine the thermal comfort in different building and climate types. The comfort zone for the PMV-PPD scale is -0,5<PMV<+0,5 and PPD <10% according to numerical calculation for the environment [5]. To have healthier results from PMV-PPD scale created in the laboratory environment in real life application, the thermal sense range perceived by the users of the environment should have a comfort zone of slightly cool (-1) and slightly warm (+1) in the ASHRAE-7 thermal sense scale [5].

The study has evaluated measurement results according to PMV-PPD thermal comfort scale to determine the appropriate thermal comfort conditions. PMV-PPD is divided into 3 categories in terms of sensitivity. Category A is -0,2<PMV<+0,2 and PPD<6%, category B is -0,5<PMV<+0,5 and PPD<10%, category C is -0,7<PMV<+0,7, and PPD<15%. As the number of individuals and age range in the mosque are variable, the measurement results are evaluated for category B. Comfort zone is accepted as -0,5<PMV<+0,5 and PPD<10% as determined by ASHRAE-55 and ISO 7730 standards [5,6].

3 Energy Conservation and Building Envelope Effect in Mosques

As the technological developments are enhancing day by day, HVAC systems for the buildings are developed. To create a uniform thermal comfort in the buildings, thermal performance of structure envelop is important for conservation of energy. In addition to quality of heating, cooling, and ventilation systems in the buildings, heat transfer resistance of materials used in building envelope are also effecting the amount of energy consumption.

Mosques are important public areas in the Islamic countries. The one third of the consumed energy in Turkey is caused by the non-domestic public buildings [3]. Mosques are prayer structures for Muslims that are used in different periods of day, that has different usage density. TÜİK 2013 data shows that there are 85,412.00 mosques in Turkey with various size [4]. Since the mosques provide services to wide range of users in different time periods, thermal comfort and thermal energy conservation can be challenging. Religious buildings have an important place in many countries. Although mosques have similar architectural properties in Islamic countries as well as other countries, design and material can be different.

3.1 The Relationship Between Thermal Energy and Thermal Comfort in Building Envelope of the Sample Mosques

Sample mosques are in İstanbul municipality which is in the temperate humid climate region of Turkey. The thermal camera images from Marmara Theology Mosque and Ali Mosque in Figure 1 demonstrates the thermal comfort measurements which were made in winter, on December, at 12.30-13.30. The air temperature is 4-6 °C, relative humidity is 50-75%, and outer air speed is 1.5-4m/s on the measurement days.

Figure 1. Marmara Theology Mosque and Ali Mosque

Marmara Theology Mosque is defined as a single domed mosque with the combination of modern design and Ottoman architecture. Heating, cooling, and ventilation systems are resolved with mechanical systems. Although the building envelope has glass surfaces, the window system is not suitable for natural ventilation. As seen on Figure 2, two entrance doors of Marmara Theology Mosque are directed to north and west. The mosque is situated on southeast-northwest axis. There are no high-rise buildings to prevent direct sunlight. The heating system inside the mosque is provided with PVC cables inside the carbon film under the carpet which is operated by electric energy and by mechanical cooling system forced by pipelines located on the upper edges of the glass surfaces inside the building envelope. The grid located on the front section of the glass surfaces are absorbing the indoor polluted air.

Ali Mosque is built according to Ottoman mosque style in 2013. The mosque is heated by split air-conditioners on the walls and PVC cables inside the carbon film under the carpet. As shown on Figure 2 the ground floor plan of Ali Mosque consists of two section. There are two sections; entrance and main section. The entrance in the building is functioning to provide a prayer area for the last individuals and as a wind shield. The windows on the building envelope are helping the natural ventilation. The blue coloured areas on Fig. 2 are glass surfaces.

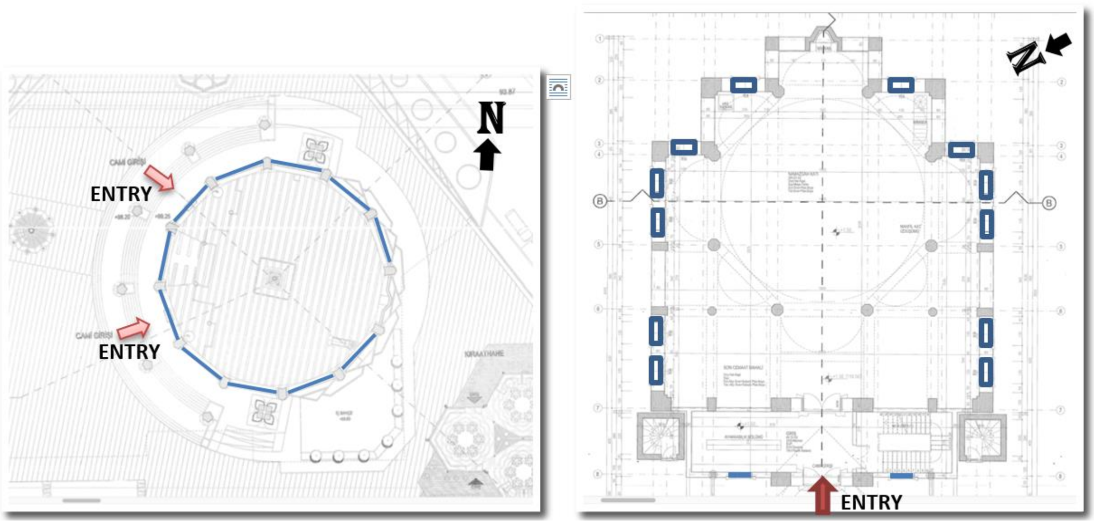


Figure 2 Ground Floor Plan of Marmara Theology Mosque and Ali Mosque

The roof of Marmara Theology Mosque is formed by covering the steel construction with wood and fibro-concrete. In the building envelop sections shown in Figure 3, the steel carriers are bundled with rock wool of 4 cm thickness. The details of the roof are galvanized sheets and polyurethane spray waterproofing on glass. On the glass surfaces, there are 4 pieces of glass plate with 6 mm depth. There is a 20 mm gap between the dual glass surfaces. There are ornaments made of fibro-concrete to function as a sun reflector on the surface of the glass facing the outer centre.

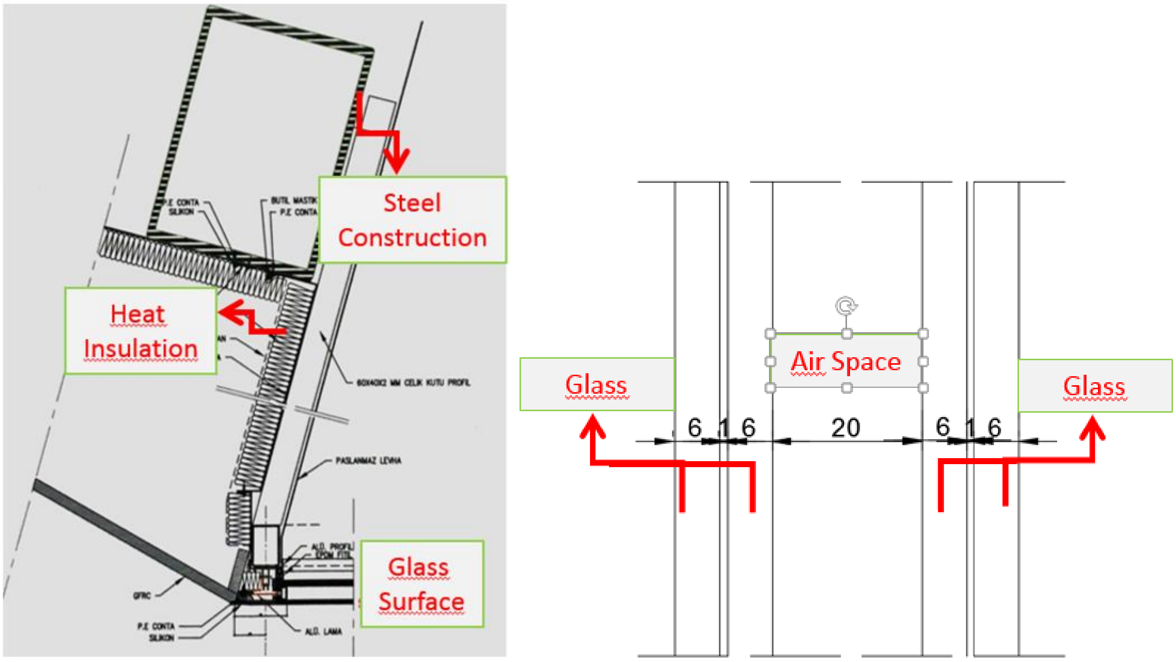


Figure 3 Dome and Glass Surface Cross-Sectional Details of Marmara Theology Mosque

3.2 Heat Loss-Gain and Thermal Comfort Analyses on Building Envelope of Marmara Theology Mosque

The thermal images obtained to determine the heat losses and gains on the building envelope of Marmara Theology Mosque, it is evident that large glass surfaces are causing heat losses. The temperature value of the air conditioning system that blows hot air from the glass surfaces is shown on Fig. 4. It has been found that the temperature values decrease as approached from the heaters to the central areas of the glass surfaces. Thermal camera images taken under closed sky conditions show that there are not significant temperature differences depending on the directions.

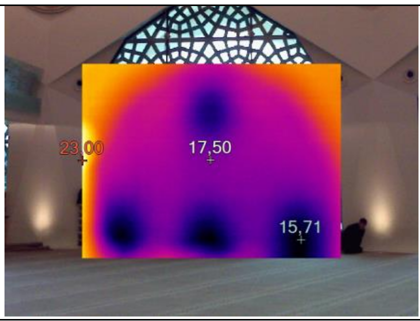
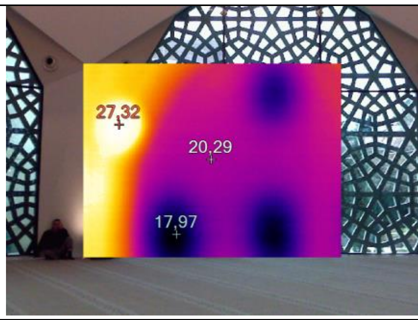
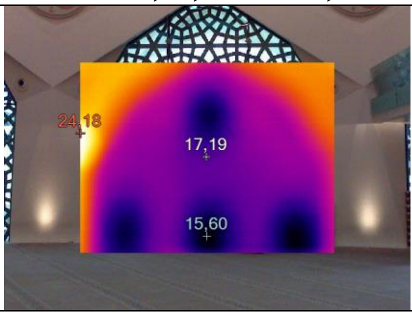
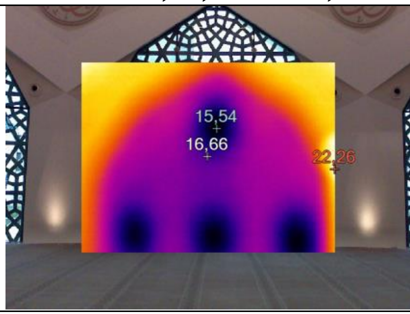
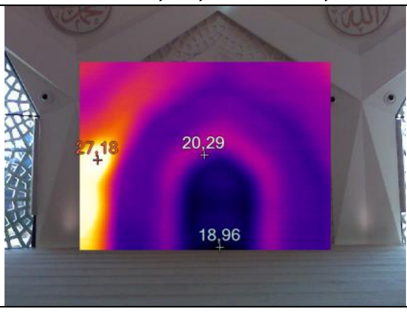
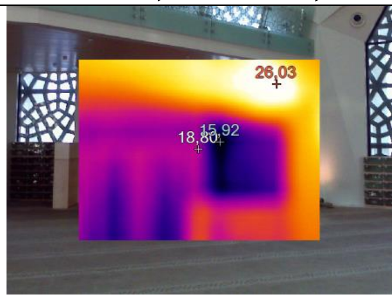
East Side		
	PMV -0,34, PPD % 7,42	PMV +0,01, PPD %5,34
West Side		
	PMV +0,08, PPD %5,26	PMV +0,03 PPD %5,18
SouthEast Side and NorthWest Side		
	PMV +0,06, PPD %5,25	PMV -0,26 PPD %6,4

Figure 4 Thermal Camera Images and Thermal Comfort Measurement Values of Marmara Theology Mosque

According to ISO 7730 and ASHRAE 55-2013 standards, PMV-PPD measurement values, which are made according to directions in the Marmara Theological Mosque, are among the thermal comfort values [5,6]. It is found in the thermal camera images that the U-value is very low on the surface of the building, whereas the glass areas are the weakest regions on the building envelope despite the use of heat-strengthened glass. Different temperature values are determined in glass surfaces which are in the different parts of the building envelope. The fact that the temperatures at the entrance of the mosque are higher than the glass surfaces indicates that the double entry system has been successfully applied in the doors, and that the wind protection is important. The Marmara Theology Mosque, where the climate system and the floor heating system are applied, is comfortable in terms of thermal comfort values.

3.3 Heat Loss-Gain and Thermal Comfort Analyses on Building Envelope of Ali Mosque

In Ali Mosque, thermal camera images obtained under closed sky conditions and measured thermal comfort values are found to be uncomfortable in terms of thermal comfort in winter season conditions of indoor environment. In the mosque, open flooring type split air conditioners are positioned in front of the walls for heating purposes. There are no heating devices in front of the window that has the maximum amount of heat loss.

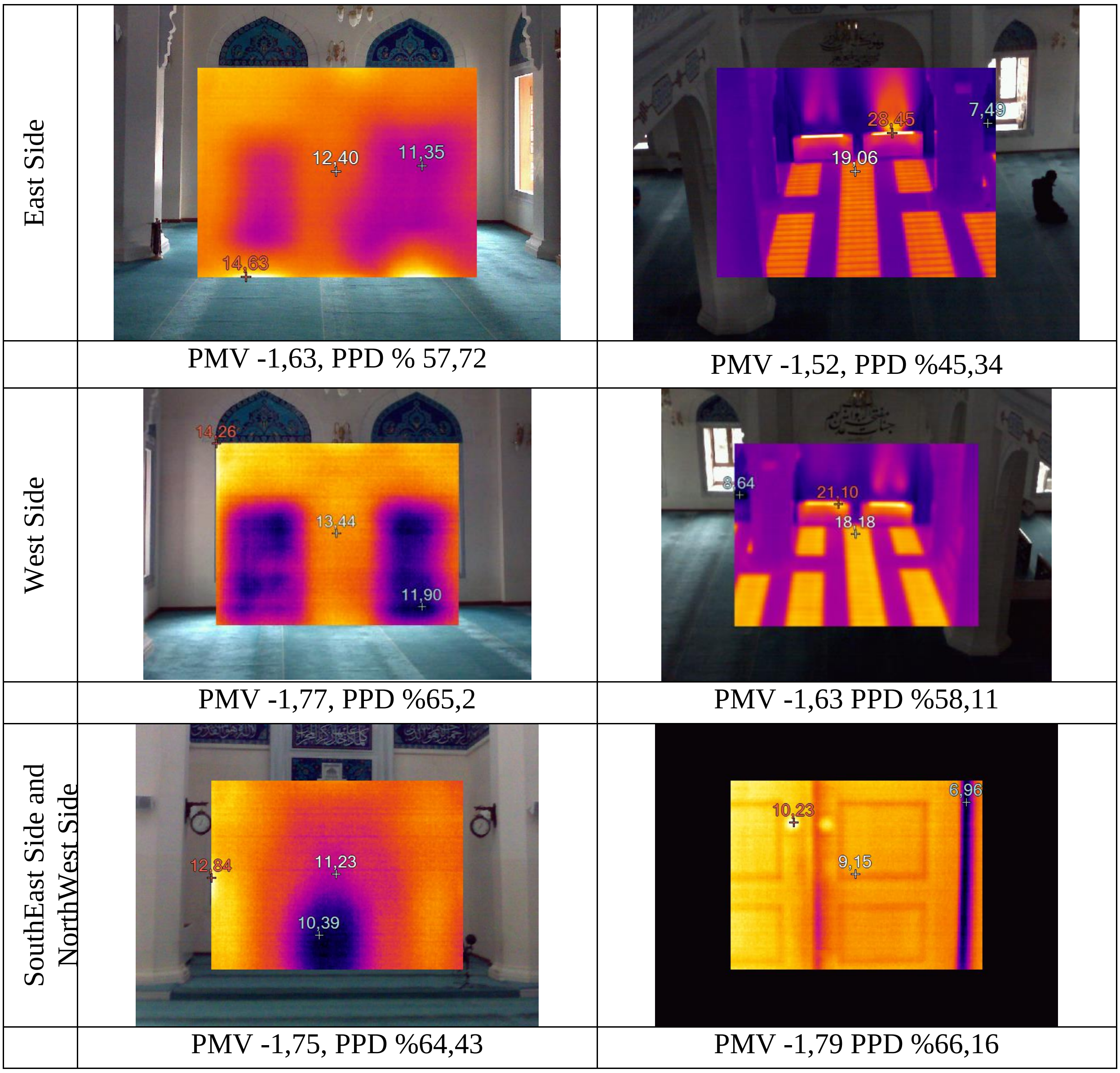


Figure 5 Thermal Camera Images and Thermal Comfort Measurement Values of Ali Mosque

21 ° C (28.45 ° C -7.49 ° C) temperature differences are detected between the surface of the glass and the glass front in the images where the glass surfaces are detected as the coldest area.(Figure 5) It is observed that although the heating system and the split air conditioner are operated together, the ambient temperature is outside the comfort range in terms of thermal comfort values according to ISO 7730 and ASHRAE 55-2013 standards. It has been determined that the temperature values are low in the southeast region of the mosque, although there is no window or any openness that may cause any heat loss. The reason for this is that only the floor heating system is considered as the heater in that area and the indoor heaters are insufficient.

4 Results

The study is presented to investigate the heat loss-gains of building envelop properties and the effects of current air conditioning systems on thermal comfort in mosques. The heat loss based on glass type and materials on the building envelope in the mosques are analysed. The thermal comfort values of the sample Marmara Theology Mosque are between ISO 7730 and

ASHRAE 55-2013 standards values although the glass surfaces cover a larger area. Although building surface of Ali Mosque is covered by lower glass surface amounts, the mosque is outside the comfort region of the standards.

The outcomes for energy conservation according to thermal camera images and thermal comfort measurements on current samples are indicated below.

- Regardless of the fact that glass surfaces cover a large area on the building envelope of the mosque design, when appropriate thermal transmission coefficients are provided, the heat loss values are minimized.

- If appropriate thermal transmission coefficient isn’t achieved event though the glass surfaces on the building envelope cover a smaller area, these areas are determined as weak areas where heat losses occur. The glass surfaces on the building envelope should be strengthened in terms of heat transmission coefficients.

- As the indoors heating systems are dispositioned, the desired efficiency is not obtained although the systems are operated for sufficient time and at sufficient temperature.

- Failure to form necessary heaters in front of glass surfaces causes radiation asymmetry in terms of thermal comfort

- The creation of a windbreaker or zoning at the entrance of the mosque with a dual door system creates a positive design parameter in terms of reducing heat losses.

- When the indoor temperature values in the mosques fail to reach the required temperatures and when the heating systems are activated from the floor, they cause radiative asymmetry for the users in terms of thermal comfort.

- As the mosques have variable usage period and user number, fast performance heaters are recommended in addition to floor heating systems under the carpets.

In this study, heat losses and gains on the building envelope of two mosques with different heating, cooling and ventilation systems were examined considering climate data and thermal comfort measurements were made according to the direction of building envelope. This study aims to transfer knowledge through sampling for users and designers in design, usage, and maintenance of the mosques.

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