



Thermal Comfort Evaluations of Monumental Anatolian Seljuk Mosques in Konya in the Temperate-Dry Climate Region

Neriman Gül ÇELEBİ ^{1*} , Ümit ARPACIOĞLU ² 

ORCID 1: 0000-0003-0478-0449

ORCID 2: 0000-0001-8858-7499

¹ Mimar Sinan Fine Arts University, Graduate School, Department of Architecture, 34427, İstanbul, Türkiye.

² Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Architecture, 34427, İstanbul, Türkiye.

* e-mail: ngcelebi@gmail.com

Abstract

Monumental mosques are valuable elements of cultural and architectural heritage. Documentation of the features of these structures is important. It is important to document the architectural design properties of these buildings. Mosques are characterized by unique and intermittent working hours. This affects the climate-related design properties of mosques. Providing comfort conditions in interior spaces with energy-efficient methods is an important issue. This study handles the monumental mosques built during the Anatolian Seljuk Period in Konya, a city located in the temperate-dry climate region. It aims to document and create an inventory of monumental religious buildings and investigate them in terms of thermal comfort parameters. In the study prepared within the scope of the Scientific Research Project (BAP), the Tahir and Zühre Mosque built during the Anatolian Seljuk Period is handled. The religious building that is determined the architectural design properties is modeled using the DesignBuilder simulation software and analyzed in terms of thermal comfort. The findings show that monumental religious buildings have great importance in terms of thermal comfort in line with their architectural design features. Studies in this field are limited and this study is pioneering in this respect.

Keywords: Monumental mosques, Anatolian Seljuk period, thermal comfort.

İlımlı-Kuru İklim Bölgesinde Konya'da Yer Alan Anıtsal Anadolu Selçuklu Camilerinin Termal Konfor Değerlendirmeleri

Öz

Anıtsal dini yapılar kültürel ve mimari mirasının değerli öğeleridir. Bu yapıların mimari tasarım özelliklerinin belgelenmesi önem taşımaktadır. Camiler benzersiz ve aralıklı çalışma saatleriyle karakterize edilmektedir. Bu durum, camilerin iklime bağlı tasarım özelliklerini etkilemektedir. İç mekanda konfor koşullarının enerji verimli bir şekilde sağlanması önemli bir konu olarak karşımıza çıkmaktadır. Bu çalışmada, ılımlı-kuru iklim bölgesinde yer alan Konya'da Anadolu Selçuklu Döneminde inşa edilen anıtsal camiler ele alınmaktadır. Anıtsal dini yapıların envanterinin oluşturularak belgelenmesi ve bu yapıların termal konfor parametreleri açısından araştırılması hedeflenmektedir. Bilimsel araştırma projesi kapsamında (BAP) hazırlanan çalışmada, Anadolu Selçuklu Döneminde inşa edilen Tahir ile Zühre Camii ele alınmaktadır. Mimari tasarım özellikleri belirlenen dini yapı DesignBuilder simülasyon programı aracılığıyla modellenerek, termal konfor açısından analiz edilmektedir. Elde edilen bulgular anıtsal dini yapıların mimari tasarım özellikleri doğrultusunda termal konfor açısından büyük bir değere sahip olduğunu göstermektedir. Bu alanda yapılan çalışmalar sınırlıdır ve bu açıdan bu çalışma öncü niteliktedir.

Anahtar kelimeler: Anıtsal camiler, Anadolu Selçuklu dönemi, termal konfor.

Citation: Çelebi, N. G. & Arpacioğlu, Ü. (2024). Thermal comfort evaluations of monumental Anatolian Seljuk Mosques in Konya in the temperate-dry climate region. *Journal of Protected Areas Research*, 3 (2), 171-177.

DOI: <https://doi.org/10.5281/zenodo.14544478>

1. Introduction

Konya is one of the important cities that has hosted many civilizations throughout its history. The city, which has the capital status of the Anatolian Seljuk Civilization, has preserved its importance for many years. At the same time, it is one of the important state centers of the Ottoman Empire. The city, which has valuable elements of cultural and architectural heritage, has been one of the most important main centers of Turkish-Islamic culture and art and architectural center in Anatolia throughout its history (Baykara, 2002). Religious buildings such as mosques belonging to the Anatolian Seljuk and Ottoman periods provide the formation of the city morphology and are the religious buildings of great importance in this respect. This architectural heritage needs to be protected and documented.

Mosques, which are valuable elements of cultural heritage, represent the central area where people bring together for their daily and weekly prayers. They are also considered social, educational, and cultural spaces for Muslims' activities. Mosques are characterized by having a unique intermittent working plan, compared to other building types. They are used simultaneously in a certain region and time zone. Mosques include a large prayer hall that is used intermittently during congregational prayers, five times a day and the mosques' occupancy rates vary in Friday noon prayers and daily times (Azmi & Kandar, 2019). In this situation, the periods when heating and cooling of the building are required affect the energy demand depending on the climate zones (Al-Homoud et al., 2005).

Religious buildings designed with a sense of sacred worship represent a space with unique functions and operations. In this respect, thermal comfort and operation in mosques are of great importance, and mosques should be carefully evaluated in the scope of thermal comfort and energy requirements. The climate-related design properties of mosques affect the interior comfort conditions and the thermal performance of the building (Abdou et al., 2005). Therefore, the thermal comfort of the mosque building largely depends on the overall thermal performance of the building components such as walls, roofs, and windows working together as a system (Al-Homoud et al., 2009). The heating and cooling load of the mosque is important, especially in terms of energy efficiency, because a mosque with poor thermal performance consumes more energy to provide comfort conditions.

Al-ajmi studied thermal comfort in air-conditioned mosques located in the hot-dry climate zone of Kuwait and six mosques were investigated in terms of thermal conditions. On-site measurements included indoor air temperature, operative temperature, relative humidity, and air velocity. In addition, a survey was conducted with worshippers to investigate the factors affecting thermal comfort conditions. The study stated that mosque buildings in Kuwait should be designed to maintain an indoor temperature of 26.1 °C to achieve significant energy savings (Al-ajmi, 2010). In Ahriz et al. study, it is determined the mosque building components that can control and determine thermal comfort conditions as the orientation of the building, the area surrounding the building, the size and geometric shape of the building, architectural form, covered galleries, roof shape, prayer halls, the prayer hall's height, building materials, openings, and surface colors (Ahriz et al., 2021).

In this study, the Tahir and Zühre Mosque built in Konya during the Anatolian Seljuk period is handled, and the architectural design properties of the mosque are documented and the mosque is analyzed in terms of thermal comfort in line with the simulation results. It aims to create an inventory of the monumental mosque, which is a valuable element of architectural heritage, to explain the plan, section, and facade typologies, to reveal the construction technique and material properties, and to evaluate the buildings in terms of thermal comfort. There is not enough research in the literature on the basic design properties of mosques and their thermal comfort and energy performance. In this respect, this study is pioneering for future studies on cities and buildings with historical and architectural value. At the same time, the relationship between the design criteria and construction techniques of monumental mosques and thermal comfort parameters is aimed to inspire and guide designers in providing thermal comfort conditions with energy-efficient methods for designing religious buildings with a sense of sacred worship.

2. Material and Method

This study is prepared for the Scientific Research Project (BAP) scope. Among the monumental religious buildings investigated within the scope of this project, the Tahir and Zühre (13th century) Mosque built in Konya during the Anatolian Seljuk Period is handled in this study. First of all, information about the Konya city and mosques belonging to the Anatolian Seljuk Civilization are collected in the light of the literature. The mosque is visualized with the drone and its properties are documented with photographs. The drawings of the mosque in the electronic environment are taken from the Konya Regional Directorate of Foundations and the drawings are colored and the current situation based on on-site determinations and its relationship with its immediate surroundings are processed on the drawings. In line with the literature review, visuals, on-site determinations and drawings, plan section, facade, and top cover elements are explained, as well as construction techniques and material properties. The mosque's architectural design properties are documented and the mosque is modeled in the Design-BUILDER simulation software. Design Builder is an EnergyPlus-based software developed to measure and analyze the buildings' performance such as energy, comfort, carbon, and lighting (Zhang, 2014). In the DesignBuilder simulation program, models specific to mosque buildings with characteristic properties are developed, taking into account the worshippers, occupancy rate, and usage times. According to the simulation results, the mosque is analyzed in the scope of thermal comfort parameters. At the same time, the relationship between the temperate-dry climatic region and thermal comfort. The evaluations are explained according to the findings.

3. Findings and Discussion

In this section, first of all, Tahir and Zühre Mosque's architectural design properties are explained. This mosque is also analyzed in terms of thermal comfort.

3.1. Tahir and Zühre Mosque's Architectural Design Properties

Tahir and Zühre Mosque was built in Konya in the 13th century Anatolian Seljuk Period. The mosque was built in masonry technique. Tahir and Zühre Mosque's form is square and the building has three spaces in terms of plan organization. The mosque's top cover property is a dome. The religious building order is detached. The Mosque's height (h) is 9.24 m and the total area is 80.78 m². In Figure 1 Tahir and Zühre Mosque's top view and plan are shown.

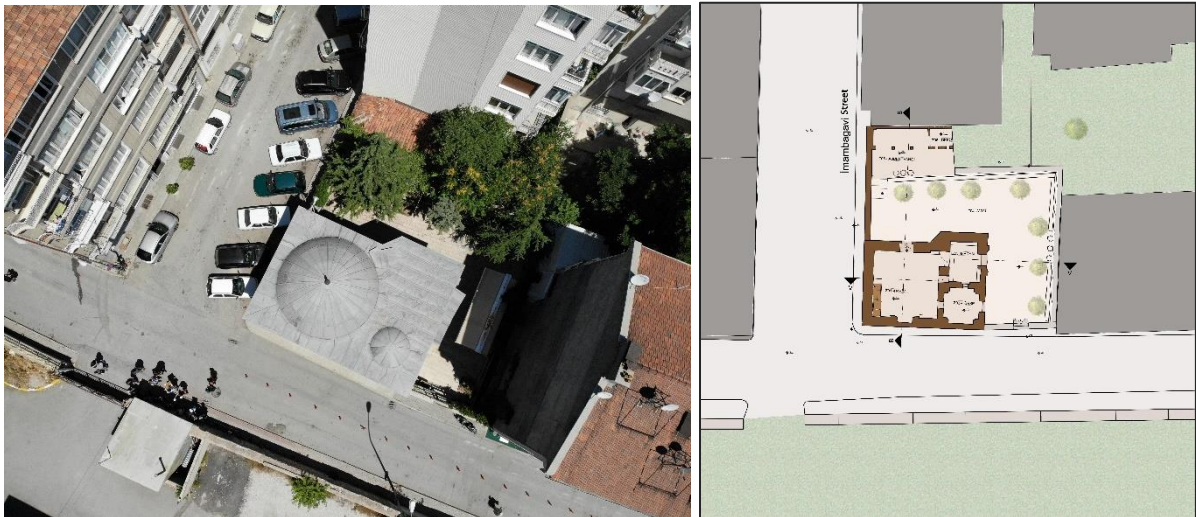


Figure 1. Tahir and Zühre Mosque top view and plan (Photograph and image by the authors, 2019)

Regarding construction techniques and material properties, stone and brick were used together in the Tahir and Zühre Mosque's walls, the mosque's wall thickness is 95 cm, and the bond technique is masonry. In terms of openings, window ratios are mixed. Square windows and 1/2 ratio windows were used together. There are three windows on the north facade, one on the west facade, and two on the east facade. There is no opening on the south facade. The Mosque has a dome and the mosque's top cover technique is masonry. The dome's material is brick, the dome's diameter is 560 cm, and the

dome's thickness is 60 cm. There are no openings on the top cover. The mosque's flooring material is wood flooring. The mosque has no minaret. In Figure 2 Tahir and Zühre Mosque's A-A Section is shown and in Figure 3 Tahir and Zühre Mosque's east elevation is shown.



Figure 2. Tahir and Zühre Mosque's A-A section (Authors, 2019)

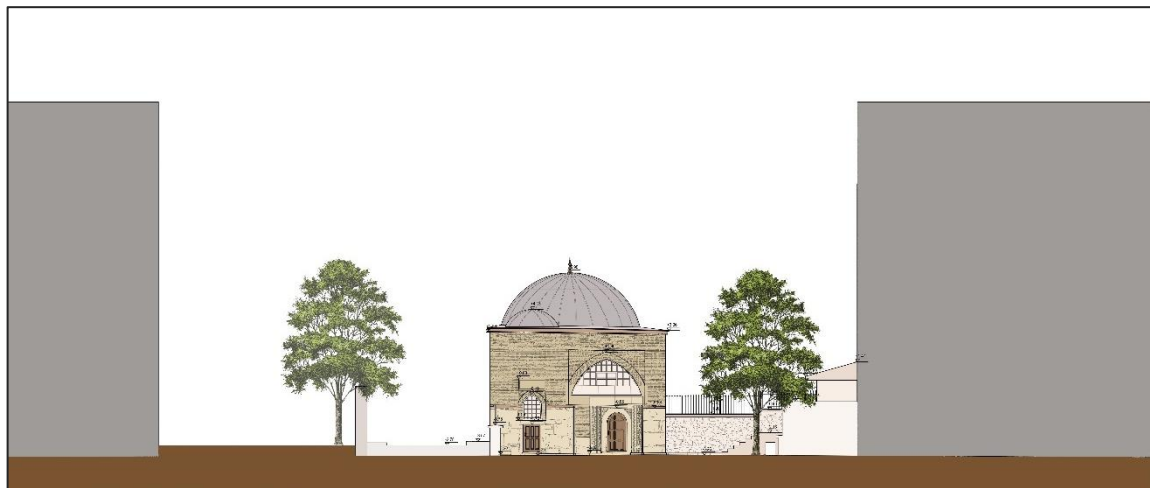


Figure 3. Tahir and Zühre Mosque's east elevation (Authors, 2019)

3.2. Tahir and Zühre Mosque's Thermal Comfort Evaluations

Thermal comfort is provided by controlling environmental conditions such as temperature, humidity, air movement, etc. while balancing the heat gains and losses of the human body. It must understand the heat dissipation mechanisms of the human body and the environmental conditions together to create thermal comfort (Lechner, 2015). Seasonal characteristics and activities performed indoors are important factors affecting thermal comfort. These factors require the increase or decrease of the heat value of the space. Thermal comfort parameters can be classified as user-related and environmental. Environmental parameters include air temperature, mean radiant temperature, relative humidity, and air movement. User-related parameters include users' physical activity status and clothing. It is important to feel comfortable while praying in a mosque. Various models have been developed to relate the feeling of comfort of the person to the relevant environmental factors. ASHRAE is a very important evaluation model for evaluating thermal comfort conditions (Al-Homoud et al., 2009).

The comfort zone should be the goal of the thermal design of a building. To provide thermal control with passive methods, passive design parameters can be handled as the building's location, building orientation and space design, the distance between other buildings, building form, building envelope optical and thermophysical properties, solar control, and natural ventilation layout (Lechner, 2015). Konya is located in the temperate-dry climate zone of Türkiye, where the heating period is important. The building form is a compact, almost square form that will be closed to the wind when heating is desired. Building walls should have an insulation rate that will provide comfort conditions in the

interior. The openings in the facade should be large enough to provide the necessary heat control. It can be said that these passive design parameters are also valid for mosque buildings. However, mosques have characteristic design elements that direct their basic design such as qibla, qibla wall, mihrab, and minbar. The mosque buildings' orientation with a characteristic design approach is the direction of the qibla. The Konya mosques' (their qibla) orientation is in the south direction. The Tahir and Zühre Mosque's building form is square. The square building is the compact form desired in the temperate-dry climate zone. The settlement texture, buildings' locations according to each other, the distance between buildings, and the buildings' heights affect passively benefiting from or being protected from the sun and wind environmental factors. In this respect, the mosque's building order is one of the parameters that directly affect the thermal comfort of a building. The Tahir and Zühre Mosque have a detached order property and this affects the thermal comfort of the mosque. In Figure 4 Tahir and Zühre Mosque's thermal comfort graphic is shown.

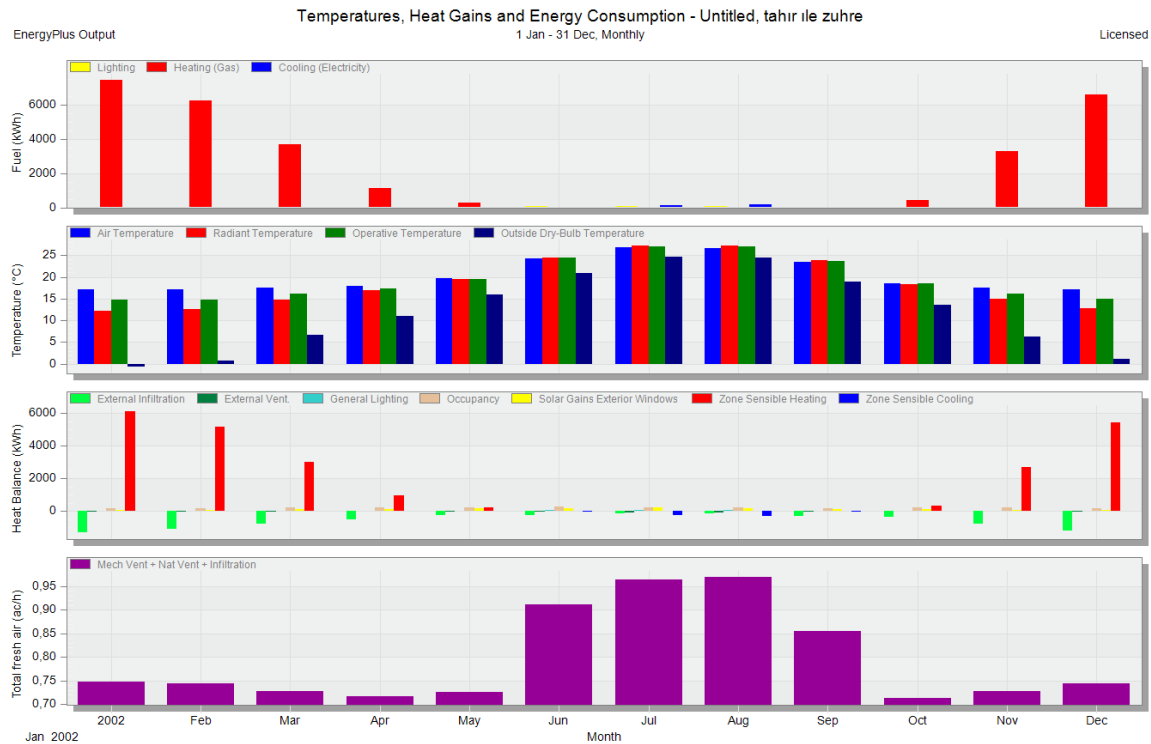


Figure 4. Thermal comfort graphic of Tahir and Zühre Mosque (Authors, 2019)

In line with the temperature graphs, it is seen that the outdoor air temperature, radiant temperature, and indoor air temperature values for Tahir and Zühre Mosque are close to each other. The main reason for this situation can be stated as a phase shift. The building wall's thermophysical properties and the wall thickness are factors that affect phase shift. Phase shift is a property that supports thermal comfort, and the wall thickness and material properties of the Tahir and Zühre Mosque provide this situation. Building envelope optical and thermophysical properties affect the amount of heat transfer through the building envelope's opaque and transparent components, indoor air temperature, and building energy demand. Tahir and Zühre Mosque's wall materials are stone and brick, and the wall thickness is 95 cm. The mosque's dome material is also brick. Stone and brick building materials contribute to the structure in terms of thermal performance. The thermal conductivity properties of the building envelope opaque and transparent components are important parameters that can affect the energy demand and thermal comfort of the buildings and the building envelope thermal conductivity varies depending on the building materials and wall thickness properties. The period when the Tahir and Zühre Mosque (13th Century) was built, the type of stone and brick materials used, the wall thickness of the mosque, and the glass types used in the openings should be handled as factors that affect the thermal conductivity of the wall.

According to the heat balance results, heat transfer in mosques consists especially in cold periods when heating is required. It can be said that this situation is caused by the openings in the building envelope.

Window elements, old joinery due to construction dates and window-wall compositions can cause heat transfer between the interior and exterior. Windows or openings are important for solar radiation gain. The openings in the south direction provide direct solar radiation gain, but multi-directional openings, especially in the north direction, cause heat losses. The size of the windows, the thermal conductivity properties of the windows, and whether they are single or double-glazed are factors that affect heat gain and loss. The total fresh air rate in the interior of Tahir and Zühre Mosque varies by month, and it is seen that these rates are higher between June and September compared to other months. Natural ventilation is one of the most important factors affecting indoor air circulation. Factors such as the size and location of openings directly affect natural ventilation. In this context, the directional openings of the Tahir and Zühre Mosque are one of the important factors affecting thermal comfort.

As a result, mosques' design properties such as building layout and order, building materials, wall thicknesses, directional openings, top cover properties, and thermal conductivity are the properties that can affect the thermal comfort of mosques. At the same time, for mosque buildings, building volume is a parameter that should be evaluated in terms of thermal comfort. In line with the monumental Tahir and Zühre Mosque and the mosques examined within the scope of the project, it should be stated that the architectural design properties of the monumental and historical mosque buildings contribute significantly to thermal comfort.

4. Conclusion and Suggestions

In this study, the monumental Tahir and Zühre Mosque built during the Anatolian Seljuk Period in the Konya, one of the most important main centers of Turkish-Islamic culture and art, is investigated in terms of thermal comfort parameters. The plan, section, and facade properties of the historical mosque have been documented and the thermal comfort of the mosque is analyzed. Konya monumental mosques from the Seljuk Period provide the formation of the urban morphology of our civilization and create a unique typology with their plan, section, and facade properties. In this context, it is important to document the architectural properties of these religious buildings, determine their place in the historical process and their current status, and also analyze them in terms of thermal comfort.

Stating that the mosques built during the Seljuk and Ottoman periods were analyzed, it can be said that mosques, which are valuable elements of the monumental architectural heritage, are valuable in terms of thermal comfort parameters in line with their traditional design properties and construction techniques. Especially in terms of building materials, traditional materials usage with thermal mass suitable for climatic conditions is a sustainable approach that affects the thermal comfort of a building positively. As a result, it can be said that positive results are achieved in terms of thermal performance. Studies in the field of monumental mosques and thermal comfort are insufficient. In this respect, it is expected that this study will create a potential research area for future research. Documenting and analyzing cultural and historical heritage in terms of thermal comfort is pioneering and will light on future studies.

Acknowledgments and Information Note

This study is reproduced from the Mimar Sinan Fine Arts University Scientific Research Project (BAP) titled "Research of the Monumental Architectural Heritage in terms of Comfort Parameters and Energy Efficiency, Seljuk-Ottoman Period" coordinated by Assoc. Prof. Dr. Ümit ARPACIOĞLU.

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

All authors contributed equally to the article. There is no conflict of interest.

References

- Abdou, A., Al-Homoud, M. & Budaiwi, I. (2005). Mosque energy performance, Part I: Energy audit and use trends based on the analysis of utility billing data. *Journal of King Abdulaziz University-Engineering Sciences*, 16(1), 155–173. DOI: <https://doi.org/10.4197/ENG.16-1.10>.
- Ahriz, A., Mesloub, A., Elkhayat, K., Alghaseb, M. A., Abdelhafez, M. H. & Ghosh, A. (2021). Development of a mosque design for a hot, dry climate based on a holistic bioclimatic Vision. *Sustainability* 2021, Vol. 13, Page 6254, 13(11), 6254. DOI: <https://doi.org/10.3390/SU13116254>.
- Al-ajmi, F. F. (2010). Thermal comfort in air-conditioned mosques in the dry desert climate. *Building and Environment*, 45(11), 2407–2413. DOI: <https://doi.org/10.1016/J.BUILDENV.2010.05.003>.
- Al-Homoud, M., Abdou, A. & Budaiwi, I. (2005). Mosque energy performance, Part II: Monitoring of energy end use in a hot-humid climate. *Journal of King Abdulaziz University-Engineering Sciences*, 16(1), 175–191. DOI: <https://doi.org/10.4197/ENG.16-1.11>.
- Al-Homoud, M. S., Abdou, A. A. & Budaiwi, I. M. (2009). Assessment of monitored energy use and thermal comfort conditions in mosques in hot-humid climates. *Energy and Buildings*, 41(6), 607–614. DOI: <https://doi.org/10.1016/J.ENBUILD.2008.12.005>.
- Azmi, N. A. & Kandar, M. Z. (2019). Factors contributing in the design of environmentally sustainable mosques. *Undefined*, 23, 27–37. DOI: <https://doi.org/10.1016/J.JOBE.2019.01.024>.
- Baykara, T. (2002). Konya. Türkiye Diyanet Vakfı İslâm Ansiklopedisi, 26, p. 182-187.
- Lechner, N. (2015). *Heating, Cooling, Lighting: Sustainable Methods for Architects (fourth edition)*. John Wiley and Sons.
- Zhang, L. (2014). Simulation analysis of built environment based on design builder software. *Applied Mechanics and Materials*, 580–583, 3134–3137. DOI: <https://doi.org/10.4028/WWW.SCIENTIFIC.NET/AMM.580-583.3134>

