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The Effect of Thermal Insulation for Heritage Mosques Roofs on Indoor Thermal Comfort Temperature: Case study in Taif city, Saudi Arabia

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Abstract:

The main aim of this paper is to investigate the impact of roof insulation on internal temperature for heritage mosques in Taif in Saudi Arabia. This study examines the different scenarios of roof insulation to determine the best scenarios in both selected cases (Alkaua Mosque (ALM) and Abdullah bin Abbas Mosque (ABM)). These buildings were chosen as case studies because of the civilization and historical values they carry for the Kingdom of Saudi Arabia, their connection to the era of prophethood, and the revival of its architecture in the last century. The evaluation of the thermal performance for both cases used EDSL TAS simulation. The roof scenarios were simulated using EDSL TAS. The main finding was that the SI2 followed by SI3 scenarios had the best results. These results were taken during the summertime periods at 213 and 247 days. This shows to what extent the U value of the insulation layers can have a good impact. The roof insulation has the advantage of taking into account the character and style of the heritage buildings and does not affect the exterior appearance, or the building's value. These scenarios can have a clear impact on thermal comfort in terms of decreasing the internal temperature compared to the base case and external temperature. This study opens many horizons for future studies by applying different environmental strategies such as isolating windows with different materials and technical solutions that help improve the thermal performance of the building, or through treatments for walls from the inside in a way that preserves the identity of the building (261).

Keywords: Heritage mosques,ٍ software simulation, insulation roof scenarios, thermal comfort and Western Saudi Arabia.

I. INTRODUCTION

Historical mosques are of religious and touristic importance to many countries worldwide.

Saudi Arabia has a large number of historical mosques, some of which have been restored and some of which are still waiting for the concerned authorities to pay attention or take the initiative. They have importance for tourism, especially religious tourism, and these mosques are considered from the point of view of their religious heritage. It is well known that world heritage buildings have undergone many changes during the past decades. However, there are many strategies that have been introduced to preserve them, such as restoration work and environmental treatments that have helped keep these buildings cohesive as well as preparing them for the end user.

The "Reconstruction of Historic Mosques" programme, which was adopted by the Saudi Commission for Tourism and National Heritage in partnership with the Ministry of Islamic Affairs and the Heritage Charitable Foundation, is the most important programme and has been recently launched and adopted. The programme was able to enumerate more than 1140 historical mosques, to restore and rehabilitate 80 historical mosques in the regions of the Kingdom, and to identify a list of priority target mosques in the regions of the Kingdom, numbering 130 historical mosques, in addition to implementing the architectural and historical documentation project (Atlas of Historical Mosques. No. 1) It includes 50 historical mosques, and the establishment of the Historical Mosques Fund in the Authority to receive donations.

The restoration of the urban heritage in the Kingdom of Saudi Arabia has received great attention from the government and the local community. The importance of caring for historical mosques, enhancing their social and cultural role, and achieving the main goal of their rehabilitation programmes, is to enhance the balance between their reconstruction and the content of their religious and educational mission. One of the cities which is rich in heritage and historical buildings is Taif city.

Taif city has numerous heritage types, such as palaces, bridges, mosques and homes. One of the mosques is BaAntar mosque, which was established and refurbished after 1045H. Alkubzah mosque is located in an orchard in Taif and its minaret style is similar to Yemen and Egypt. It was built in the seventh century and is being renewed at the present time. One of the most famous mosques is the Sidra mosque, which is attributed to the Prophet Muhammad era. This mosque is distinguished by its architectural features. Abdullah bin Abbas mosque was built by him during his visit to Taif. The current building was built in the late Ottoman era. This mosque is located in the position of the Prophet Muhammad [1,2].

One of the buildings that has been restored with some modern treatments which have been introduced, such as suspended ceiling and modern lighting, is Al-Kawa mosque [3]. However, one of the problems observed is the indoor quality of the thermal performance. Consequently, some buildings had lacked specifications that may affect the comfort and thermal performance of the building [4]. An environmental building can have a positive impact in terms of improving the internal temperature, as well as decreasing the internal temperature.

Construction of the wall and roof can have a good impact on the thermal performance [5].

In this research, the researcher will study the thermal comfort of heritage mosques. This study will look at both stages: the current condition and the improved situation. The two mosques are located in Taif, in the Kingdom of Saudi Arabia. The evaluation of the thermal comfort of the two mosques will be done by simulating the base case before the alternative situations.

II. PURPOSE OF THE STUDY

Energy consumption is one of the issues that the supervisory authorities who operate mosques are concerned about. On the one hand, this is in terms of the cost of electricity consumption, while on the other hand, mosque components and their internal electrical equipment are not in harmony with climate change issues. The idea is that buildings should become more efficient through the application of an environmental strategy, such as thermal insulation, natural lighting, ventilation and others. In this study, the researcher will present the relationship between different scenarios of roof insulation and building, and their impact on reducing the internal temperature, which of course will be reflected in energy consumption.

III. BUILDING INSULATION

One of the building components that can be insulated is the roof. One of the features that can distinguish the roof construction is the thermal insulation layers [6]. The efficiency of the insulation can be affected by different factors such as insulation material and its thickness, and the surrounding circumstances such as increased water content [7].

Moreover, Hansen and Wittchen [8] referred to the energy saving of the building being achieved through several measures as well as façade insulation, such as roof insulation and window openings. Another author indicated that insulation in the historical building can lead to improving the thermal performance and internal temperature without a negative impact on heritage style or building features [9]. This view is also supported by Sakiyama et al. [10], who stated the insulation can have a positive impact on building performance in terms of saving energy and thermal comfort. Using roof and wall insulation in mosques can help to reduce cooling energy, which is economically viable as a measurement [11]. Construction material can also be an insulation material, such as coral stone, which is used in traditional buildings in Jeddah, and this kind of integration has to be considered during its implementation to heritage buildings [12,13]. There are various types of roof forms: pitched, flat and thatched [14]. In this research, both cases have flat roofs. In addition to that, it is said that roof insulation in historical buildings is classified as less invasive and more cost-effective [15]. Some government standards refer to thermal insulation as a passive design strategy, such as Malaysian Standard [16]. The insulation of heritage mosques can be extended to each component of historical buildings, such as insulation coating for building materials that can be used during historical mosque maintenance [17]. All these measurements can have a clear impact on thermal performance. For this reason, this study concentrates on roof insulation to assess its impact on thermal comfort for heritage mosques. The following section will introduce the methodology before assessing the result of the case studies.

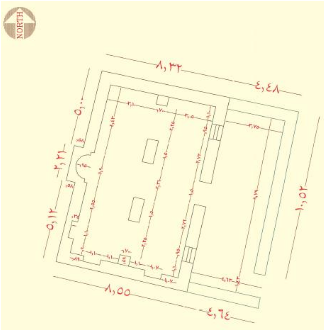
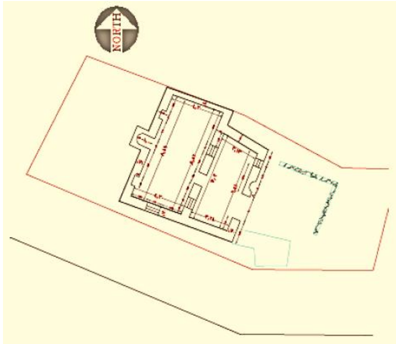
IV. METHODOLGY

IV.I Selection of the case studies

Two case studies (Abdullah bin Abbas Mosque (ABM) and Alkaua Mosque (ALM)) were selected in Taif city. The comparison between the two cases is introduced in Table 1.

Table 1: Information for two case studies

Criteria	Abdullah bin Abbas Mosque (ABM)	Alkaua Mosque (ALM)
View		
Historical value	It is noteworthy that this mosque was built by Abdullah bin Abbas when he visited Taif and its current construction was in the Ottoman era.	This mosque is located in the position of the Prophet Muhammad. It is located in the Muthnnah.

Orientation	West north	North west
Ground floor		
Carrying capacity	147 users	109 users
Building materials	Stone, wood and mud	Stone, wood and mud

IV.II Building design descriptions

IV.II .I ALM

This mosque is located in Almathanah in Taif city. The building façade is oriented to north west. This mosque has one window and the main door. Its ventilation and lighting are natural. The area of this mosque is 86m^2. The window of the building is located on the south wall. Its design is described thus: its area is 8 * 7 meters, its height is 3 meters, and its back has a covered courtyard, the length of which is 7 meters and the width of which is 4 meters. Its height is 1 meter [1,2]. The carrying capacity of this mosque is 109 users.

IV.II . II ABM

This mosque is located in Almathnah in Taif city. The building façade is oriented to west north. This mosque has two windows and the main door. Its ventilation and lighting are natural. The area of this mosque is 162.53m^2. The windows of the building are located on the east wall. Its design is described as square in shape, with a rectangular courtyard at the back with two rectangular windows. The mosque is divided into two parts with three arched openings, and the Mihrab is located in the western part opposite the door, and is hollow in shape and crowned with a lobed arch [1,2]. The carrying capacity for this mosque is 147 users.

IV.III Simulation of the current scenario and improved scenarios

IV.III.I Simulation tool

TAS EDSL simulation software was used in this study. This tool is capable of assessing the thermal performance of buildings. This software has been used in several studies and gives positive results [18].

IV.III.II Building materials for ALM and ABM

Building construction materials for both cases are introduced in Table 2, as are the proposed scenarios for roof insulation (SI1, SI2) and combined scenarios for both cases. These scenarios were considered for simulation by the use of EDSL TAS.

V. RESULTS AND DISCUSSION

The current roof for both cases is constructed from a concrete layer and wood. The results of comparison between Alkaua Mosque and Abdullah bin Abbas Mosque for simulation of their internal temperature are illustrated in Figures 1 to 4, as well as in Table 3. These results are for the base cases (current status and improved scenarios (SI1, SI2 and SI3)) for green roof insulation during the summer period in 213 and 247 days. Figures 1 to 4 show the roof insulation scenarios: Green roof with clay (SI2), followed by combined insulation (SI3) have the highest impact on internal temperature for both cases and demonstrate the best results. Tables 2 and 3 include the details for both scenarios in terms of roof materials and temperature details. The result of SI1 scenario is that at 213 days it had a good impact and a small difference at 247 days compared to the current status. Green roof with clay (SI2) shows the best results at reducing the internal temperature compared to the current status and the external temperature.

Table 2: Building materials for two case studies

	Layer	Width (mm)	U value (W/m².°C)
External wall for ALM and ABM current case	Rock	700	2.431
External wall for ALM and ABM proposed case	Rock and clay	730	2.21
Ground	Sand dry - Crushed aggregate - Concrete	1250	0.286
Roof current scenario (CS) for both cases	Concrete - Wood	200	3.876
Roof insulation scenario (SI1) for both cases	Concrete - Insulation - Asphalt	230	0.979
Roof insulation scenario (SI2) for both cases	Concrete - Waterproof membrane - Polyethylene fabric filter - Soil - Plant	350	0.187
Roof insulation scenario (SI3) for both cases	Concrete - Asphalt - Waterproof membrane - Polyethylene - Fabric filter - Soil - Plant	450	0.776
Door and windows for ALM and ABM, current and proposed	Wood	30	2.602

Table 3: Simulation for two case studies

ALM					
Hour	**External temperature (°C)-213-(°C)-247**	**Current**	**Clay on insulated roof (asphalt layer)**	**Green roof with clay**	**Combined**
213, 15	35.6	33.8	33.31	32.74	32.84
247, 15	37.8	35.52	35.43	33.99	34.12
ABM					
Hour	**External temperature (°C)-213-(°C)-247**	**Current**	**Clay on insulated roof (asphalt layer)**	**Green roof with clay on roofs**	**Combined**
213, 15	35.6	34.05	33.49	32.97	33.15
247, 15	37.8	35.67	35.21	34.35	34.39

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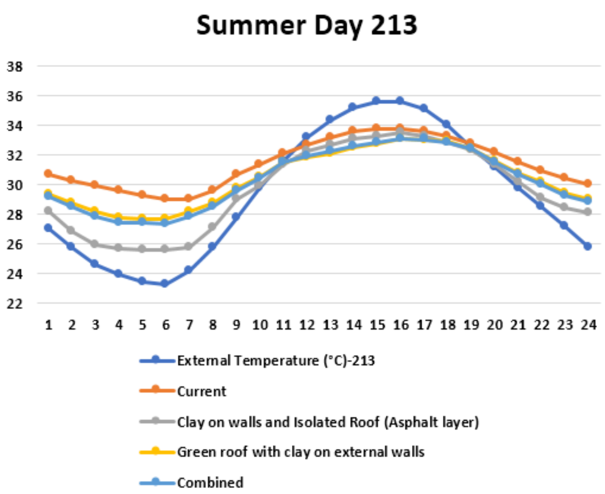

Figure 1: ALM result for 213

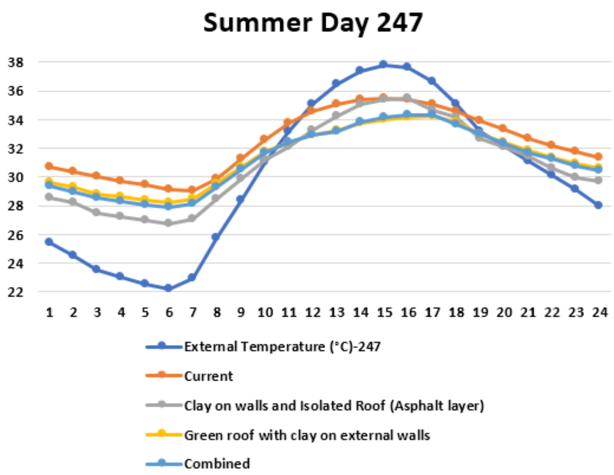

Figure 2: ALM result for 247

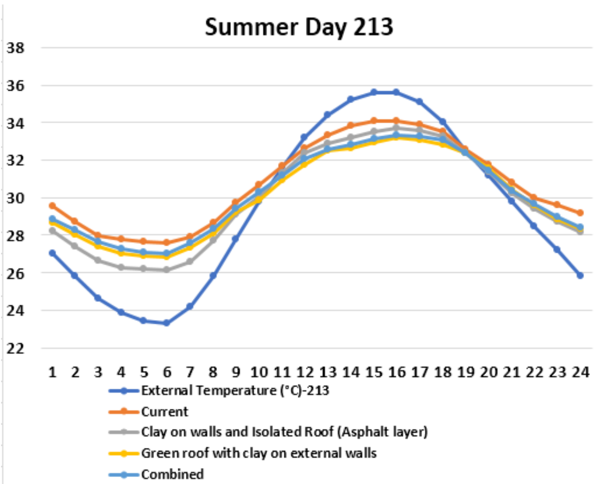

Figure 3: ABM result for 213

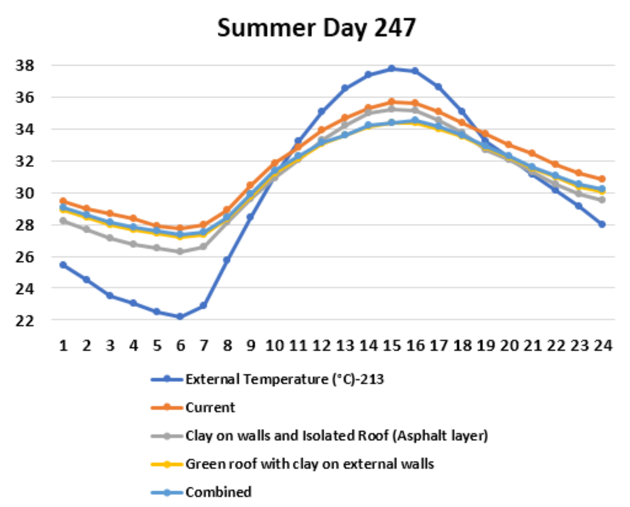

Figure 4: ABM result for 247

VI. CONCLUSION

In this study, the main focus was on thermal comfort through three scenarios, to assess the impact of the insulation material on the internal temperature in heritage mosques in Taif. The main purposes for selection of these scenarios are saving energy and considering the heritage style. The simulations were applied for both cases for 24 hours and during the summertime using EDSL TAS software. The result of the simulation indicated that SI2 and SI3 had the best impact and the highest performance in terms of internal temperature (thermal comfort). Briefly, the large number of layers of insulation does not mean that the temperature is affected and the thermal comfort of the building is improved. However, the types and characteristics of insulation layers can have a major impact. The results of this study will be a basis for the resumption of future studies and applications.

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