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The Impact of Roofing Systems on the Environmental Performance of Buildings in Basra, Iraq

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ABSTRACT

The environment of Basra city is characterized by being hot and humid in summer and moderate in winter. This causes the upper floors of dwellings and outdoor spaces to become excessively hot and unusable. Moreover, sometimes, they are the primary source of heat transfer into the dwelling. Therefore, users sometimes use coverings for some spaces to obtain a usable space. Thus, the research formulates its problem as the need to study the role of space coverage in the architectural and environmental revitalization of spaces. Several studies have highlighted the importance of roofs concerning their shape, materials, and role in buildings. This study aims to assess the impact of roofing systems on the environmental performance of residential buildings in Basra. This study employs two approaches: a questionnaire survey conducted on a randomly selected community sample and an environmental simulation model analyzing the effects of roof modifications on building performance. The study shows that roofing systems can reduce indoor temperatures by 1.2 to 2°C, thereby improving thermal comfort in Basra's hot climate.

1. INTRODUCTION

This research examines an architectural phenomenon observed in most Iraqi cities, which involves adding an iron or concrete roof above the final roof of buildings. Due to its architectural impact, this research will define roofs, categorize their types and forms, and review key previous studies that examined this topic to establish the research problem, objectives, and methodology. It will also examine the types and forms of this roofing coverage in the local context through explanation and analysis, leading to research-specific conclusions and recommendations.

This research is based on the emergence of a new roofing style in buildings and local facilities, which is mostly informal but sometimes officially recognized. This phenomenon has influenced building design at various levels, including facades, three-dimensional design, building plans, thermal loads, and the aesthetic and cognitive perception of structures. Additionally, it has created new architectural spaces on rooftops that were previously unused. The study highlights the significance of this roofing approach, shedding light on both its advantages and disadvantages, which impact both the building's functionality and its perception.

Many studies have addressed the study of roofs as one of the necessary elements in buildings, study [1] presented roofing in buildings and its development during the Islamic eras in Mosul in terms of defining roofs and showing the most prominent factors affecting them. The study [2] addressed green roofs in school buildings in Egypt as one of the solutions to improve architectural buildings, as the research concluded the necessity of using sustainability principles in school design. The study [3] focused on the cold ceiling and its effect on the treatment desired in buildings to reduce the thermal load and thus reduce the use of electrical energy in Iraq. The study [4] focused on using metal structures and knowledge of their most prominent characteristics, advantages, and disadvantages in multi-story buildings in Damascus. The study [5] addressed the concrete roof in residential houses and the extent of the impact of inclination angles on heat transfer. The study [6] addressed the geometric shape of the roof and the extent to which this shape achieves the structural purpose for which it was designed. The study (Muhammad) also presented the role of green roofs in attaining thermal balance and comfort by creating roof gardens on top of housing or hotel buildings. Green roofs are considered more expensive to implement than ordinary roofs, but the benefits reflected from them balance the high cost due to their importance in preventing high heat from entering the building and thus reducing the cost of using cooling methods [7]. The study by Bano and Tahseen [8] also identified the most critical factors that control the efficiency of coverage systems in diverse climates: climatic suitability, availability of materials and their local compatibility, long-term maintenance requirements and durability of roofing systems under various environmental pressures. Local cultural preferences, architectural styles, and regulatory frameworks also significantly affect the acceptance and adoption of roofing systems. Recognizing and addressing these constraints will facilitate more informed decision-making processes for stakeholders and participants in sustainable building practices [8].

We note that some studies have focused on traditional imitation systems that were prevalent in ancient times, explaining their most prominent features and advantages. For example, certain studies have explored the use of reductions, or what are known as techniques, to advance from the load to the ceiling [2, 3, 7]. Other studies have discussed the geometric design of bishops' vestments, constructivism, and the amount of physical clothing used for bishops [4, 5].

It is evident from the previous studies that roofs in cities were addressed, with some focusing on climatic factors and how to achieve thermal comfort through specific methods and materials. In contrast, others focused on using sustainable technologies to gain various benefits from roofs. Some concentrate on the construction techniques used in roofs and the different materials used in them. By critiquing the previous studies, it becomes clear that the need for specialized architectural roof survey coverage and the extent of the impact of this treatment on buildings in Iraq represent a knowledge gap.

-Research Problem: While previous studies have evaluated roofing materials in various climates, there is a lack of focus on Basra's unique climatic conditions.

-Research Objective: This research aims to assess the impact of roofing systems on the environmental performance of residential buildings in Basra

-Research Methodology: This study defines and categorizes roofs based on their most prominent types and classifications. It also examines widely adopted roofing types in the local context using visual documentation and analysis. The research further evaluates the advantages and disadvantages of roof coverage techniques to derive general conclusions and recommendations.

2. THEORETICAL FRAMEWORK

2.1 Definition of the roof

The roof is the uppermost part of the building that protects from environmental conditions. It is also an essential structural element in buildings that can use multiple materials and various forms to perform its primary function of protection [9]. Ceilings are also used as part of the visual composition of the interior space by covering them with color, painting, or architectural ornaments. The development of roofing construction has been influenced by factors summarized under three items: construction materials, construction techniques, and the facility's function [10].

Roofs play a fundamental role in energy efficiency because roofs absorb a large amount of solar radiation in hot weather and lose a large amount of heat through roofs in cold weather. Several roofing methods include concrete roofs, cold roofs, insulated roofs, roof gardens, photovoltaic panels, solar roofs, double-skin roofs, pond roofs, and wind catchers. The shape of the building, location, materials, and design elements play essential roles in the energy performance inside the building. Therefore, the role of architects is to integrate them to produce a sustainable building and provide energy use. The roof plays a fundamental role in building sustainability, as it absorbs thermal energy significantly in hot climates [11].

The building envelope determines the quality of internal conditions regardless of transient external conditions. Being directly interacting with external environmental conditions, the building envelope is defined as an interface for energy losses or gains. To reduce energy use in buildings, the energy requirements of the building system must be reduced. Energy efficiency must also be increased, and in this context, energy-saving modification of the building envelope can be implemented by improving the thermal physical properties of the envelope, such as using a specific type of glass for windows, using a cooling water collection system for recycling, and using a well-insulated and sealed building envelope with appropriately selected materials to reduce heating and cooling loads [12].

2.2 Types of roofs

2.2.1 Types of roofs in terms of shape

Roofs can be classified into several types based on various characteristics. The types of roofs and their role in achieving environmental, economic, and design benefits differ. There are gabled roofs, green roofs, and flat roofs, each of which has a role in controlling the thermal efficiency of the building. The green roof supports single-story buildings by reducing heat by 4.5% compared to the gabled roof and flat roof, which supports two-story buildings to increase its efficiency towards that percentage [13].

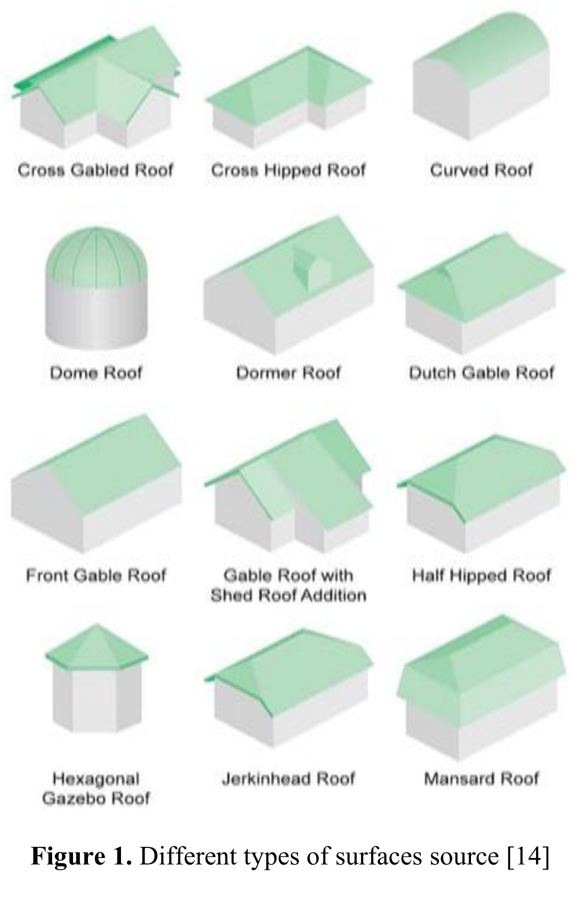


Figure 1. Different types of surfaces source [14]

The difference in the shape of the roofs directly affects the architectural form and the amount of heat gain of the roofs in particular and the buildings in general, as the research depends on the method of covering the horizontal roofs, as it is one of the most common methods in Iraq, Basra. The shapes of roofs vary, as shown in Figure 1. This diversity is determined by various factors, including climatic conditions, economic considerations, aesthetic characteristics, the type of building material, the preferences of the designer or owner, and other factors. These factors are represented by three main determinants: 1. The building plan that the roof must cover, whether it is square, rectangular, or square; 2. The building materials used for the roof, due to differences in their general properties, especially physical ones; 3. The space, as spaces differ in terms of spans, including oversized, small, and medium spaces [14]. As for Iraq, the most widespread type is the horizontal roof, which is considered one of the characteristics of hot, dry climate regions.

2.2.2 Roofing according to construction materials

The old traditional houses in Basra city are characterized by their roofs made of "Uqada" (a traditional roofing technique) using bricks and steel I-beams. The roof is finished with clay material (soil mixed with straw) or flat bricks. The roof in this type of roofing is level, and a secondary ceiling is made of wood from the inside to serve as thermal insulation and an aesthetic form for interior ceilings [15].

Tile and stone roofs enjoyed a high degree of formative potential, although they were limited to shapes resulting from the arch. This was achieved by manipulating the size, number, and shape of domes, vaults, and arches (semicircular, double-centered, triple-centered, quadruple-centered) and their formative compositions that comprise a group of domes for coverage. Metal roofs provided shapes with various forms and methods of assembling them. As for concrete, it is the wealthiest material through its formative ability due to its unique nature and as a flexible moldable paste, which makes it, with continuous technological development, play a role in the concrete industry with designs whose shapes cannot be limited [16].

Basra's heritage houses and roofing methods.
Iron roof covered with mud and straw for protection (Power house building in Basra).

Roofing methods adopted in heritage houses in Basra.
Roofing the floors with knots and the ceilings with timber.

Figure 2. The models of roofs in the city of Basra using different materials
Source: Researchers.

It is used in various building patterns, such as mosques and dwellings, due to its rigidity in distributing weight evenly on the walls and tightening and stabilizing the building. The method of building domes developed considerably when humans began using tiles and stone, as these two materials are more solid, more substantial, and more durable than mud and clay. Therefore, it became possible to build more giant and more complex domes with them [17], some of the traditional roofing methods that were prevalent in the city of Basra, which later evolved into more advanced methods such as reinforced concrete, gabled iron roofs, and other types of roofs, including roof coverings, which the research will discuss in detail as shown in Figure 2.

2.3 Some materials used in roofing

Various materials are used for roof covering, and each material has characteristics and features that suit the consumer in terms of durability, suitability for local weather conditions, aesthetics, building condition factors, and many other factors. The most important materials used in roof covering include: asphalt tiles; clay tiles; glass tiles; rubber tiles; asphalt shingles; wooden shingles; asbestos shingles; stone slabs; metal sheets (such as stainless steel, copper, lead, or zinc); and on-site prepared coverings.

For example, in Iraq, metal sheets have been used for roof covering in recent times for several reasons, including economic and other factors [18]. These are illustrated in Figure 3.

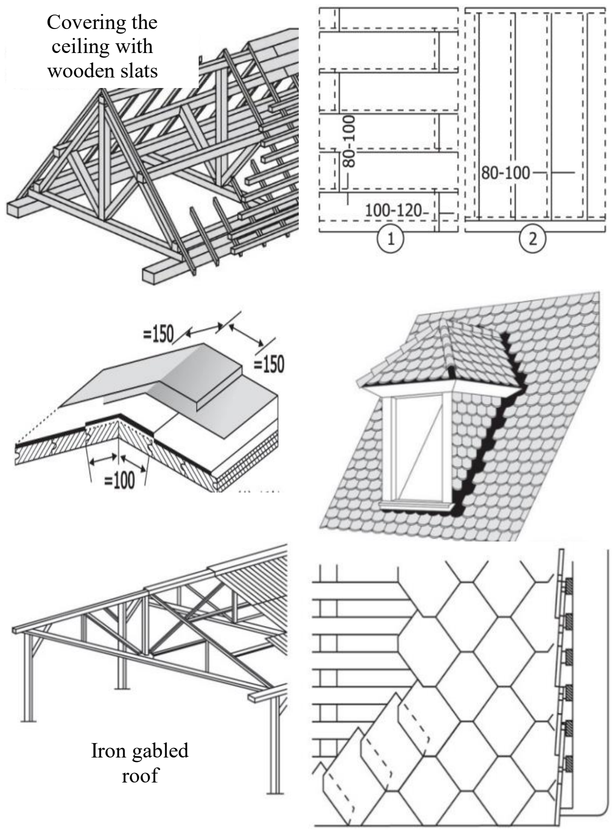


Figure 3. Different types of materials used in roofing
Source: Study [18].

This section provides an overview of the various materials used in roofing, highlighting that each material has characteristics that make it suitable for different contexts. The text emphasizes that the choice of roofing material depends on factors such as durability, local weather conditions, aesthetics, and building requirements. It also notes that metal sheets have become popular in Iraq recently, likely due to economic and other factors.

2.4 History of roofing in Iraq

Various studies show that most materials used in roofing buildings in Iraq are found in nature. Most studies and research indicate that most artefacts discovered in Mesopotamia contained foundations and some parts of walls because the roof was often built from lightweight and perishable materials.

The ancient craftsman knew roofing using reeds and papyrus, as in the Tell Hassuna site, where tiny houses were found with their roofs made of bundles tied together in a gabled form to raise the mat roof, and these roofs were covered with clay, which represents the development of vaulted roofing. Tree trunks were also used, and domes were used in roofing [1]. Other studies refer to types of roofs as:

- Flat (horizontal) roofs: This is the prevailing roofing system throughout Iraq, which was created from wooden beams with mats placed on top and a layer of clay.
- Sloped roofs: Similar to the current gable roof, whether sloping in one direction or two, to avoid weather conditions.
- Vaulted and domed roofs: Most archaeologists believed that circular houses were roofed with domes or in a conical shape due to the difficulty of roofing them with a horizontal roof [19].

These traditional methods with local materials continued for long periods in roofing most buildings in Iraq. Then, roofing was developed by introducing reinforcing steel, known locally as "Shilman", used with brick material and gypsum mortar to form vaulted ceilings in houses or buildings. Concurrent with this type of roofing, gabled roofs made of iron sheets appeared as a means of roofing, especially for large spans [14].

Using a regular slab after painting its white roof saves 35% of what the roof consumes with the presence of a regular slab. This method requires painting the roof at the beginning of each summer so that the white color fades at the beginning of winter, which is a good gain. Covering the regular slab with plastic tiles reduces 28% while using slabs with 8 mm thermal insulation with a fiberglass camouflage network is considered the lightest slab and achieves energy savings of 27% [20].

These roofing patterns became common in the 1930s and are still used despite their decline. The use of reinforced concrete became common in implementing roofs for various buildings. With the use of these materials, finishing methods or materials for roofs have also been developed, such as stucco and tiles of different types, as well as many other materials. Recently, using materials to cover roofs instead of finishing the roof itself has been observed, as shown in Figure 4. This treatment was added to urban buildings, primarily residential houses, and affected the visual perception of these buildings.

This section provides a historical overview of roofing techniques in Iraq from ancient times to the present day. It highlights the evolution of materials and methods, from natural materials like reeds and clay to modern techniques involving reinforced concrete and various finishing materials.

The text also notes recent trends in roof covering that have impacted the visual perception of buildings, especially residential houses.

This roofing style led to the emergence of an architectural space that the building owner could use as a service floor and a recreational area after designing it to suit these functions. It can be used as gardens, children's play areas, or family gathering spaces, according to the building owner's needs, as shown in Figures 5 and 6.

Figure 4. Some real-life models showing the effect of roof covering on the facade in completed and incomplete buildings

Source: Researchers.

Figure 5. The American Embassy in Baghdad in the 1950s and the use of covering the roof with concrete, designed by José Luis Sert

Figure 6. A model of roof design in Iraq (Basra) and the transformation of roofs into positive spaces

Source: Researchers.

3. RESEARCH METHODOLOGY

A questionnaire was prepared in one step, involving a random sample of 51 residents of dwellings with various roof treatments, to determine the significance of roofs based on several factors (Table 1). Their participation was sought in selecting the most efficient roof based on their experiences and expertise as users (Table 2). The second step involved preparing an environmental simulation model to study the positive ecological changes provided by roofing, as follows.

Table 1. Vocabulary used in measurement

Symbol	Secondary Vocabulary			Main Vocabulary	
A1	plans		2D level	Aesthetic impact at the building level and mass formation	The effect of roof covering on the building
A2	facades				
A3	coverage		3D formation		
A4	Increased loads on walls without floors		Walls and floors	Structural impact	
A5	speed of completion		Roofs		
A6	very high percentage low maintenance costs spent on coverage		the effect of coverage on the economic aspect in term	Economic impact on the building	
A7	thermal insulation		Impact aspects on the surface	Environmental impact on the building	
A8	acoustic insulation				
A9	shading				
A10	creating a sustainable space		Using the roofs	Utilitarian and design aspect	
A11	most community members to adopt such coverage in their homes			Social aspect	
A12	durability	Comparison properties	tile roofs		
A13	aesthetic dimensions		metal roofs		
A14	desirable		wooden roofs		

Source: The researcher.

Table 2. Temperature, heat gains and total cooling parameters

Are you having trouble with your ceiling or second floor getting too hot in the summer?	Yes		No		
Does your house have any shading features, such as awnings or a roof covering?	Yes		No		
<u>The aesthetic influence on the building's form and overall mass</u>	1	2	3	4	5
Two-dimensional level – plans -which could refer to the exterior materials or design elements affect the aesthetic appeal of the plan?					
Two-dimensional level – facades- referring to (exterior materials or design elements) affect the aesthetic appeal of the façade					
The level of three-dimensional massing - How does it affect the overall massing?					
<u>Structural aspect</u>			1	2	3
Wall and floor levels - Do you expect an increase in loads at the wall level without the floors?					
Wall and floor levels - Is there an expected increase in roof loads?					
Permanence - Is this addition permanent or temporary?					
<u>The economic impact on the building</u>	1	2	3	4	5
Were the economic factors the primary motivation for adopting this type of coverage?					
<u>Environmental impact on the building</u>	1	2	3	4	5
Is the reason for using this cover to influence environmental insulation and create confusion?					
<u>Utilitarian and design aspects</u>	1	2	3	4	5
Is the reason for using this cover to influence environmental insulation and create confusion?					
<u>Types of ceilings</u>			1	2	3
- Which of the ceilings is the most durable over time?					
- Which type of ceiling is considered the most aesthetically pleasing for both exteriors and interiors?					
- Which type of ceiling is the most preferred for use in Basra's environment					

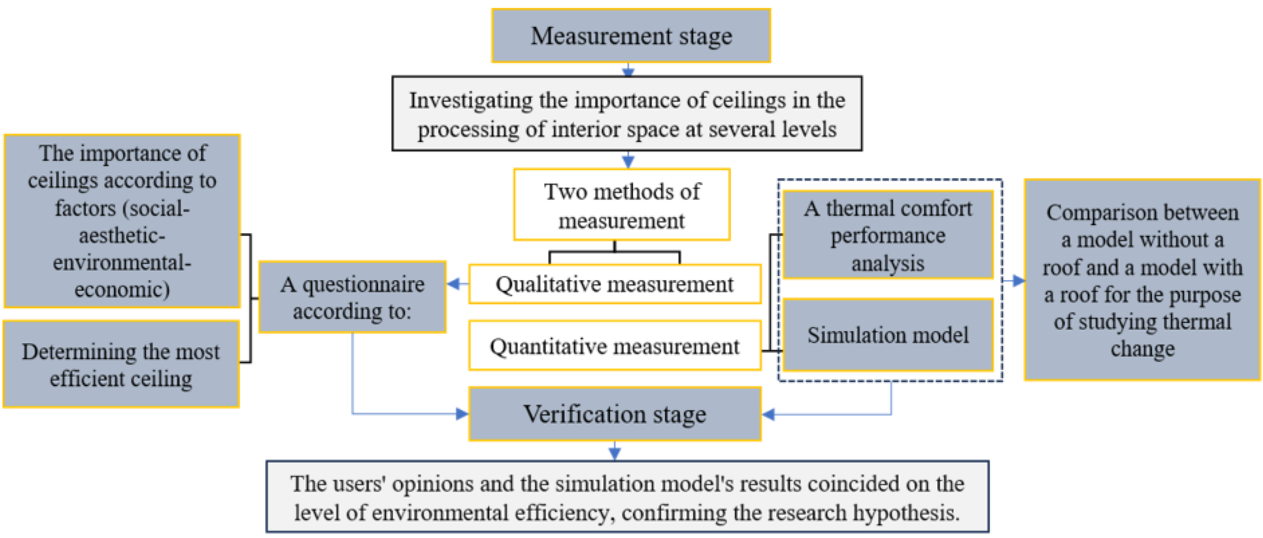


Figure 7. The usual methodological steps in measurement
Source: Researchers.

A thermal comfort performance analysis was conducted using the Design Builder program, a commonly used tool for evaluating energy efficiency and thermal comfort for building users. It uses Energy Plus to build energy simulation. Design Builder is considered a complete building simulation engine developed by the U.S. Department of Energy. By integrating heat and mass balance calculations, Energy Plus has been shown to accurately predict temperatures in naturally ventilated spaces [21, 22].

The building form, interior layout, and opening dimensions were maintained according to the dwelling dimensions in the case study. Weather data for Basra Governorate was unavailable in Energy Plus weather format for use in Design Builder. Therefore, weather data for Basra International Airport, Iraq, located nearby, was taken as a reference, as shown in Figure 7.

The interior spaces in the dwelling in the case study were classified. The design was simplified for representation in Design Builder by combining thermally similar areas to reduce the number of zones. However, these simplified zones will not be included in the thermal performance analysis. The reference simulation model consists of several rooms within a central thermal zone for thermal performance analysis. It is on the first floor (below the roof) to calculate the direct effect of roof shading on the spaces underneath.

Design Builder templates and databases for typical general data were loaded for the entire model or each zone. The HVAC template was selected as natural ventilation without heating or cooling systems. The natural ventilation operation schedule was set to the residential function schedule, rather than a '24/7' schedule. For the reference model, other internal loads, such as general lighting, were not activated, while equipment and computers were turned off. Similarly, a specific template was chosen for each zone from the activity templates available for residential spaces in Design Builder. Each zone's occupancy density and metabolic activity were based on the specified activity template, as shown in Table 3.

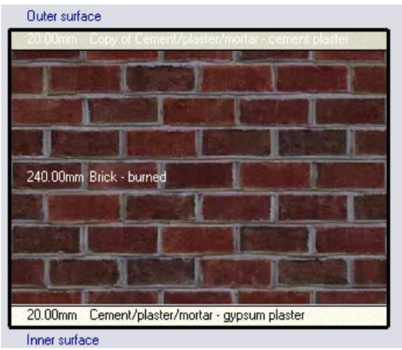
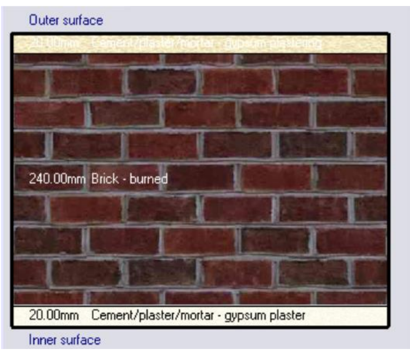
Table 3. Characteristics of each region and use of Design Builder templates in the reference simulation of the source model (Researchers)

	Day Areas	
	Living	The hall
Activity model	Living hall	Living hall
Occupancy density (persons/m^2)	[0188]	[0188]
Metabolic activity	Eating + drinking	Eating + drinking

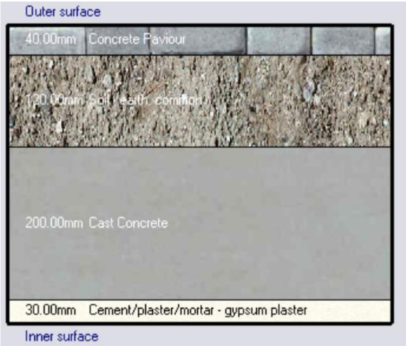
Most building materials used in the reference simulation model were as specified in the case study building. However, it was assumed that all building systems were non-insulated, to replicate the building systems of the case study building. The specifications of the building materials used in the reference simulation model are shown in Table 3. Regarding their design as components, the building system was selected with load-bearing brick walls and concrete floors.

Referring to Table 4, the model shows limited use of insulation layers, which depends on the R-value of the low-cost main materials that are mostly available.

Table 4. The details of the building materials and finishing layers that were adopted in the source model (Researchers)

Section		Details and Thickness	Building Materials
External Walls	 	1. Exterior cement plastering (20) mm 2. Brick wall (burned clay) (240) mm 3. Juss Plastering (20) mm 4. Gypsum Plastering (2) mm **Total Thickness: 284mm**	**Inner surface** Convective heat transfer coefficient (W/m2-K) 2.152 Radiative heat transfer coefficient (W/m2-K) 5.540 Surface resistance (m2-K/W) 0.130 **Outer surface** Convective heat transfer coefficient (W/m2-K) 19.870 Radiative heat transfer coefficient (W/m2-K) 5.130 Surface resistance (m2-K/W) 0.040 **No Bridging** U-Value surface to surface (W/m2-K) 2.862 R-Value (m2-K/W) 0.519 U-Value (W/m2-K) 1.925 **With Bridging (BS EN ISO 6946)** Thickness (m) 0.2800 Upper resistance limit (m2-K/W) 0.519 Lower resistance limit (m2-K/W) 0.519 U-Value surface to surface (W/m2-K) 2.862 R-Value (m2-K/W) 0.519 **U-Value (W/m2-K) 1.925**
Internal Partitions	 	1. Gypsum Plastering (2) mm 2. Juss Plastering (20) mm 3. Brick wall (burned clay) (240) mm 4. Juss Plastering (20) mm 5. Gypsum Plastering (2) mm **Total Thickness: 284mm**	**Inner surface** Convective heat transfer coefficient (W/m2-K) 2.152 Radiative heat transfer coefficient (W/m2-K) 5.540 Surface resistance (m2-K/W) 0.130 **Outer surface** Convective heat transfer coefficient (W/m2-K) 19.870 Radiative heat transfer coefficient (W/m2-K) 5.130 Surface resistance (m2-K/W) 0.040 **No Bridging** U-Value surface to surface (W/m2-K) 2.885 R-Value (m2-K/W) 0.517 U-Value (W/m2-K) 1.936 **With Bridging (BS EN ISO 6946)** Thickness (m) 0.2800 Upper resistance limit (m2-K/W) 0.517 Lower resistance limit (m2-K/W) 0.517 U-Value surface to surface (W/m2-K) 2.885 R-Value (m2-K/W) 0.517 **U-Value (W/m2-K) 1.936**

Roof



1. Concrete tiles (40) mm
2. Sand (120) mm
3. Asphalt Mastic Roofing (nts)
4. Cast Concrete (200) mm
5. Juss Plastering (30) mm
6. Gypsum Plastering (2) mm

Total Thickness: 392mm

Inner surface	
Convective heat transfer coefficient (W/m2-K)	4.460
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.100
Outer surface	
Convective heat transfer coefficient (W/m2-K)	0.342
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.170
No Bridging	
U-Value surface to surface (W/m2-K)	2.694
R-Value (m2-K/W)	0.641
U-Value (W/m2-K)	1.559
With Bridging (BS EN ISO 6946)	
Thickness (m)	0.3900
Upper resistance limit (m2-K/W)	0.641
Lower resistance limit (m2-K/W)	0.641
U-Value surface to surface (W/m2-K)	2.694
R-Value (m2-K/W)	0.641
U-Value (W/m2-K)	**1.559**

Internal Floors

1. Terrazzo tiles (22) mm
2. Cement mortar (70) mm
3. Cast Concrete (200) mm
4. Juss Plastering (30) mm
5. Gypsum Plastering (2) mm

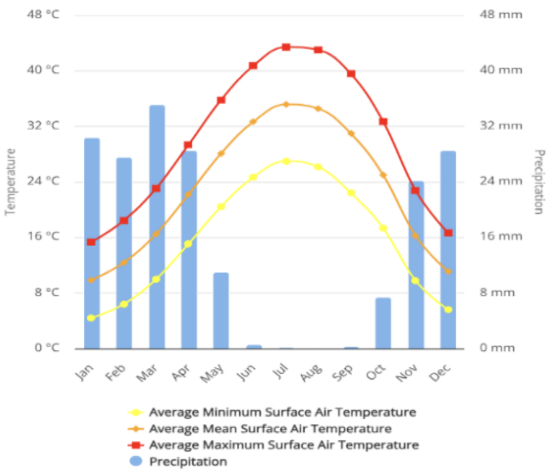
Total Thickness: 324mm

Inner surface	
Convective heat transfer coefficient (W/m2-K)	4.460
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.100
Outer surface	
Convective heat transfer coefficient (W/m2-K)	0.342
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.170
No Bridging	
U-Value surface to surface (W/m2-K)	3.369
R-Value (m2-K/W)	0.567
U-Value (W/m2-K)	1.764
With Bridging (BS EN ISO 6946)	
Thickness (m)	0.3220
Upper resistance limit (m2-K/W)	0.567
Lower resistance limit (m2-K/W)	0.567
U-Value surface to surface (W/m2-K)	3.369
R-Value (m2-K/W)	0.567
U-Value (W/m2-K)	**1.764**

Climate Basra: Monthly Averages

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Nov	Oct	Dec	Year
Record high °C (°F)	26.0 (78.8)	34.0 (93.2)	40.0 (104.0)	43.0 (109.4)	48.0 (118.4)	51.0 (123.8)	54.0 (129.2)	52.0 (125.6)	50.0 (122.0)	46.0 (114.8)	37.0 (98.6)	28.0 (82.4)	54.0 (129.2)
Average high °C (°F)	19.21 (66.58)	21.68 (71.02)	27.42 (81.36)	33.6 (92.48)	40.33 (104.59)	45.29 (113.52)	47.69 (117.84)	47.37 (117.27)	44.01 (111.22)	36.82 (98.28)	26.46 (79.63)	20.53 (68.95)	34.2 (93.56)
Daily mean °C (°F)	15.82 (60.48)	17.96 (64.33)	23.41 (74.14)	29.65 (85.37)	36.63 (97.93)	41.24 (106.23)	43.27 (109.89)	42.72 (108.9)	39.05 (102.29)	32.28 (90.1)	23.01 (73.42)	17.24 (63.03)	30.19 (86.34)
Average low °C (°F)	11.43 (52.57)	12.97 (55.35)	17.55 (63.59)	23.22 (73.8)	29.87 (85.77)	33.27 (91.89)	34.84 (94.71)	34.33 (93.79)	30.82 (87.48)	25.3 (77.54)	18.22 (64.8)	13.05 (55.49)	23.74 (74.73)
Record low °C (°F)	2.0 (35.6)	2.0 (35.6)	8.0 (46.4)	12.0 (53.6)	22.0 (71.6)	28.0 (82.4)	30.0 (86.0)	29.0 (84.2)	23.0 (73.4)	16.0 (60.8)	8.0 (46.4)	6.0 (42.8)	2.0 (35.6)
Average precipitation mm (inches)	18.99 (0.75)	18.92 (0.74)	22.55 (0.89)	15.78 (0.62)	15.61 (0.61)	0.12 (0.0)	0.0 (0)	0.01 (0.0)	0.0 (0)	9.27 (0.36)	44.92 (1.77)	24.09 (0.95)	14.19 (0.56)
Average precipitation days (≥ 1.0 mm)	2.27	3.55	4.09	4.64	2.27	0.0	0.0	0.0	0.0	1.73	4.36	3.09	2.17
Average relative humidity (%)	43.23	37.87	29.04	22.62	15.96	9.57	10.04	10.88	12.45	21.58	36.66	41.82	24.31
Mean monthly sunshine hours	8.22	8.4	10.53	12.8	13.64	14.07	13.79	13.13	12.02	11.21	8.37	8.3	11.21

Monthly Climatology of Average Minimum Surface Air Temperature, Average Mean Surface Air Temperature, Average Maximum Surface Air Temperature & Precipitation 1991-2020; Iraq



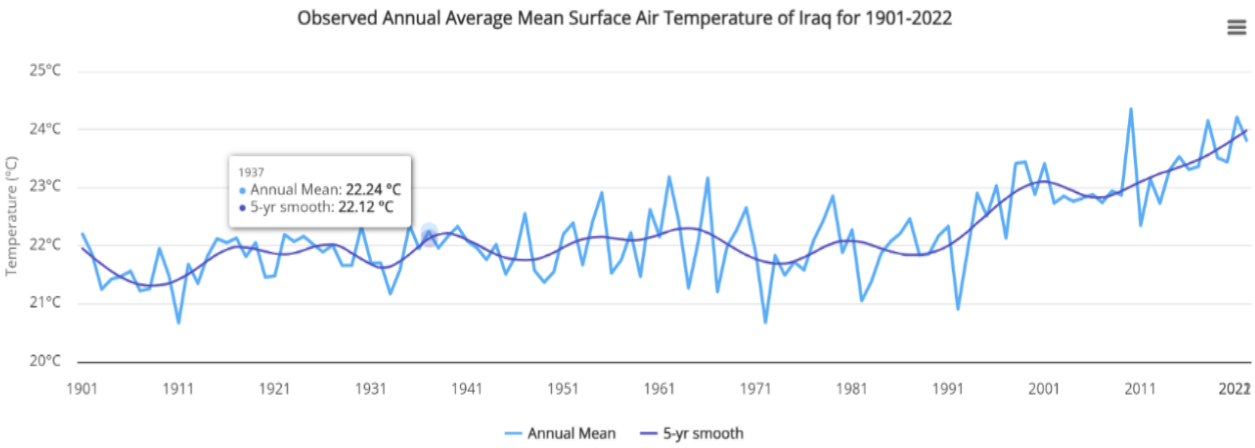
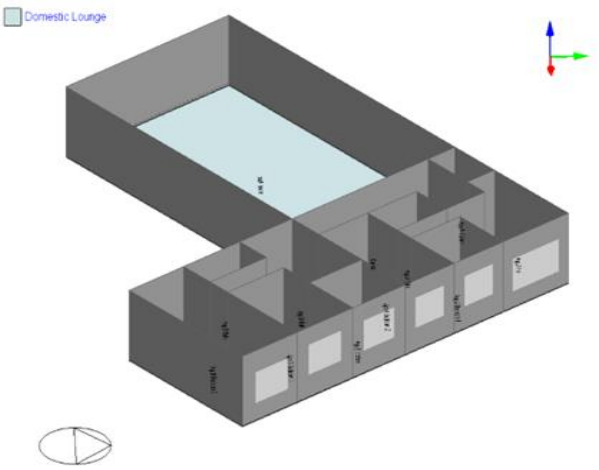
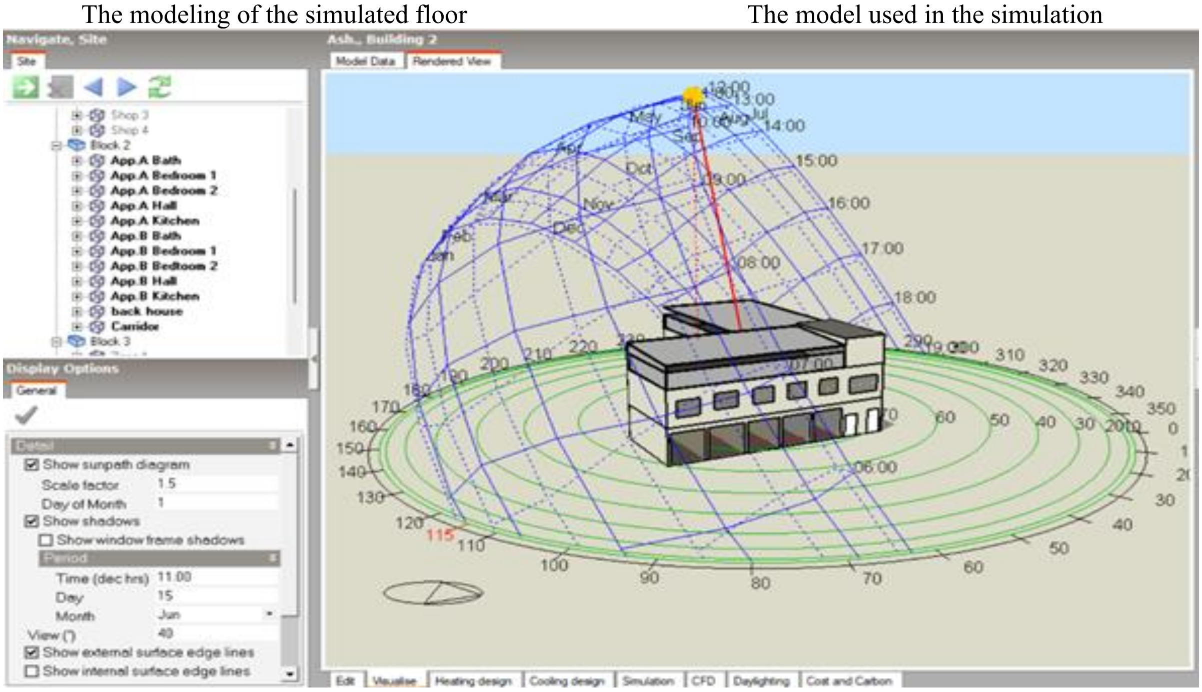


Figure 8. The temperature ranges in Iraq
Source: Study [23].



The modeling of the simulated floor

The model used in the simulation



The building modeling with Design Builder

Figure 9. The steps of building the simulation model
Source: Researchers.

Specifications of Openings in the Reference Simulation Model: The dimensions of windows and doors in the reference simulation model were according to the schedule of openings in the dwelling in the case study. The glazing for all windows and doors consisted of 6mm single-glazed clear glass, with a U-value of 5.8 W/m²K, a Solar Heat Gain Coefficient (SHGC) of 0.86, and a Visible Light Transmittance (VLT) of 0.88. The frame construction was made of iron. The operation schedule for all windows was assumed to be 24/7. Glass doors were designed with the same dimensions as the windows. However, the operation schedule for all doors was assumed to be closed 24/7, as shown in Figures 8 and 9.

Thermal Comfort Assessment Criteria: According to various bioclimatic charts used to determine comfort levels, the commonly used values for defining thermal comfort include an average radiant temperature and air temperature between 18°C and 26°C. Heat was evaluated only during daytime hours (to study the effect of sun and shading) for each zone. Daytime occupancy was classified in (living and kitchen) areas.

- Daytime use zone: 07:00 AM - 7:00 PM
- Total annual hours: 12 hours per day × 365 days = 4380 hours

4. RESULTS AND DISCUSSION

4.1 Survey results

- Results of the variable (Aesthetic impact at the building level and mass formation): Variable A1 achieved a weak percentage in terms of the aesthetic relationship between coverage and 2D plans, while variable A2 achieved a high percentage in terms of the relationship between coverage and facades at the 2D level. Variable A3 achieved a high percentage regarding the aesthetic relationship between coverage and 3D formation.
- Results of the variable (Structural aspect impact): Variable A4 achieved a high percentage in terms of the role of coverage in reducing loads at the level of floors and walls, while variable A5 achieved a weak percentage in terms of the role of coverage in reducing loads applied to the permanent surface.
- Results of the variable (Economic impact on the building): Variable A6 achieved a very high percentage in terms of the effect of coverage on the economic aspect in terms of speed of completion, low maintenance, and costs spent on coverage materials.
- Results of the variable (Environmental impact on the building): Variables A7, A8, A9 achieved a very high percentage in terms of the strength of the environmental variable with all its effects in terms of thermal and acoustic insulation and shading.
- Results of the variable (Utilitarian and design aspect): Variable A10 achieved a very high percentage in terms of the importance of a utilitarian design for coverage and its role in creating a sustainable space that can be considered another social space within the dwelling.
- Results of the variable (Social aspect): Variable A11 achieved a high percentage in terms of the desire of most community members to adopt such coverage in their homes due to its social environmental importance.
- Results of the variable (Types of roofs): Variable (A12) achieved a high percentage in terms of the durability achieved by both tile roofs and metal roofs compared to wooden roofs, which may not be suitable for the climate of Basra city due to humidity and need continuous maintenance. Variable (A13) achieved a high percentage in wooden roofs regarding aesthetic dimensions compared to both tile and metal. Variable (A14) achieved a high percentage in wooden roofs due to its aesthetics, followed by tile roofs, while metal roofs achieved a weak percentage, as shown in Figure 10.

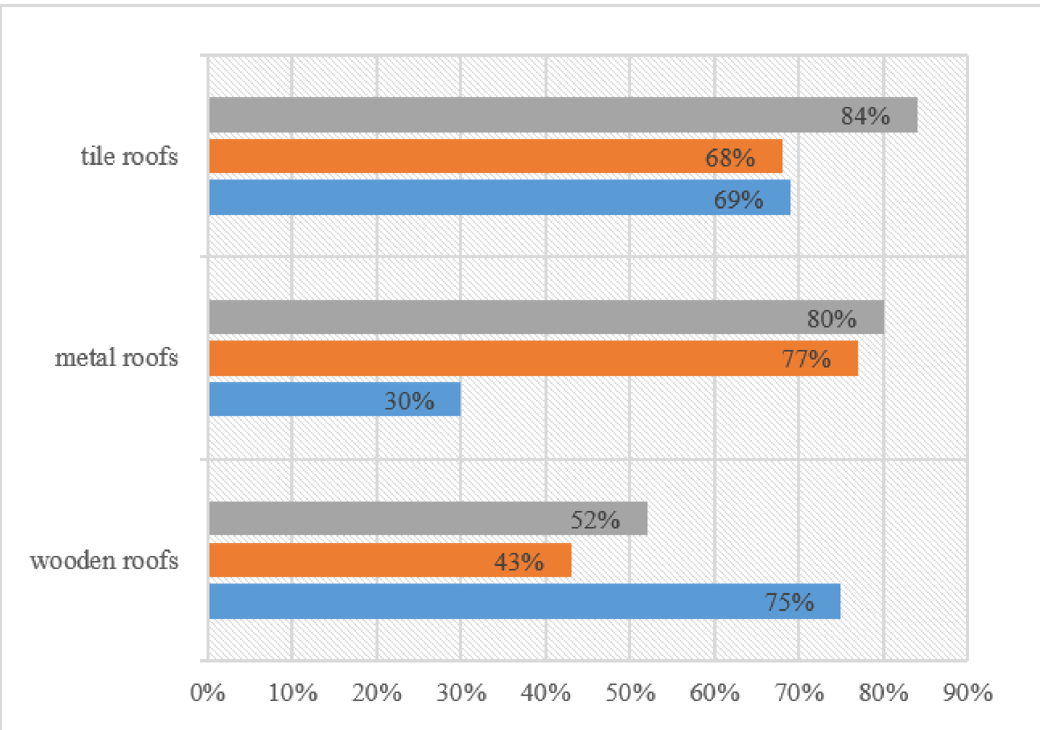


Figure 10. The percentages reached through the questionnaire
Source: Researchers.

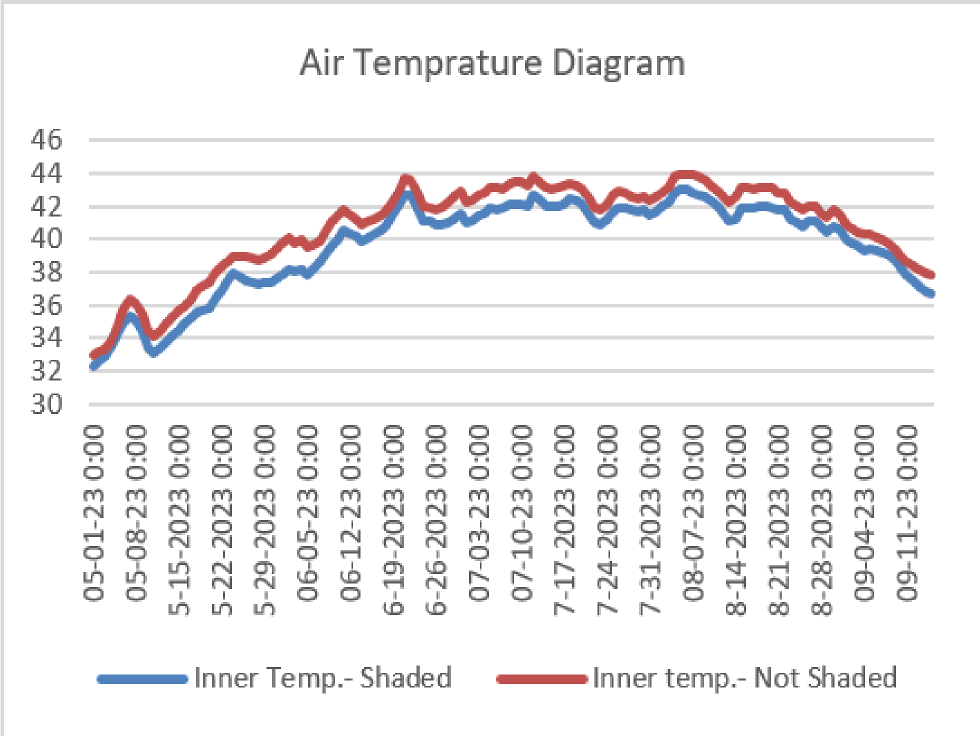


Figure 11. The internal temperature of the building with and without roofing
Source: Researchers

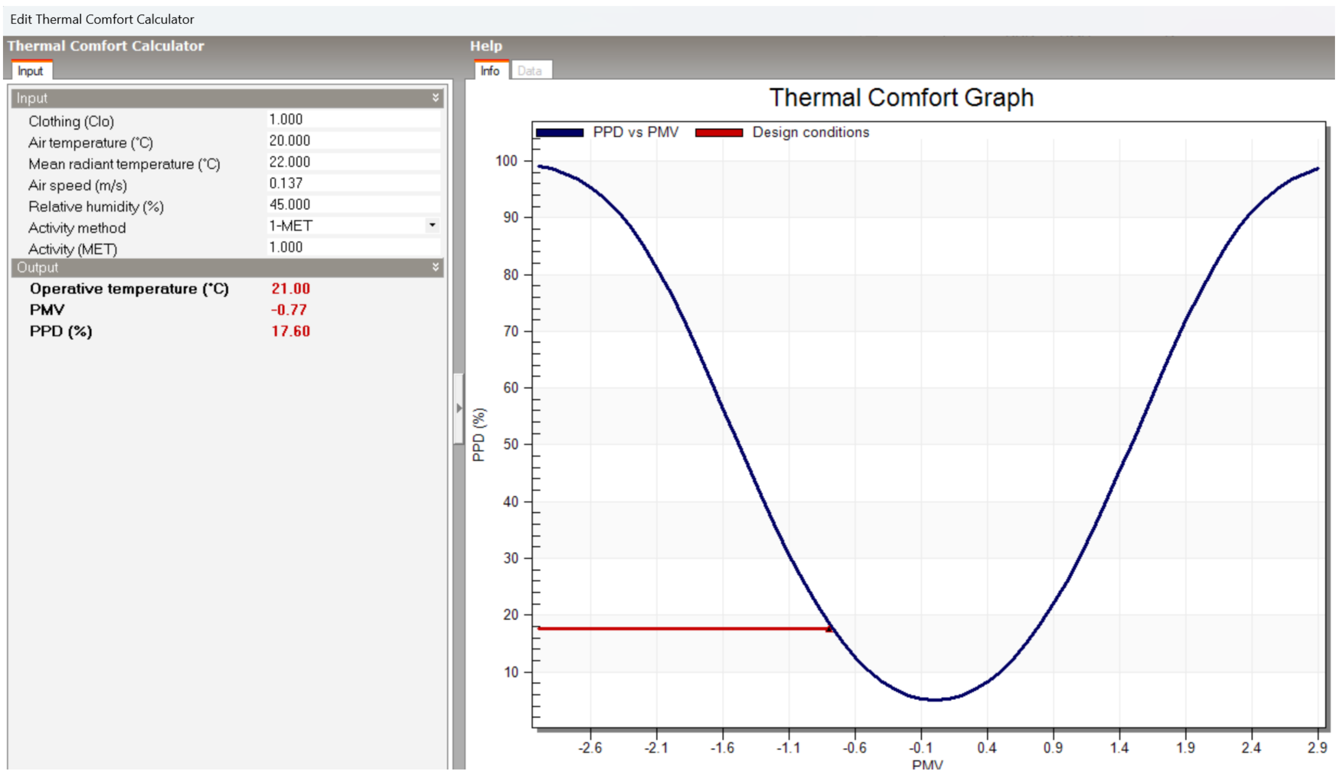


Figure 12. The simulation shows not cofortable parameters
Source: Researchers.

4.2 Results of the simulation model

After simulating the reference simulation model, indoor temperatures were calculated in two cases (the first without roofing and the other using roofing in the model). The data was exported using a CSV file created by Energy Plus. The results were reviewed within the "Design Builder" interface developed by Energy Plus. After implementing each design strategy, a simulation process was performed. Figure 11 below shows that the dry indoor temperature inside the building with the presence of roofing (Shaded) is lower than the case without roofing (Not shaded). As for the degree of temperature difference, the shaded roof open from the sides contributed to reducing the indoor temperature by an average of (1.2-2) degrees, even though the roof in the model is not typically insulated. Both cases (with roofing or not) are not comfortable thermally (Figure 12), however, the reducing the indoor temperature achieved energy saving in total cooling more than (2400) kW per hour during runtime (Figures 13 and 14).

Temperature and Heat Gains - Block 2

EnergyPlus Output   1 May - 15 Sep (Zone conditions reported for user defined periods only), Run period   Licensed

	Year
Air Temperature (°C)	33.96
Radiant Temperature (°C)	33.91
Operative Temperature (°C)	33.93
Outside Dry-Bulb Temperature (°C)	36.26
Glazing (kWh)	469.44
Walls (kWh)	4230.31
Ceilings (int) (kWh)	-1.09
Floors (int) (kWh)	-19.14
Partitions (int) (kWh)	-36.39
Roofs (kWh)	4413.68
General Lighting (kWh)	935.68
Occupancy (kWh)	82.70
olar Gains Exterior Windows (kWh)	4437.04
Zone Sensible Heating (kWh)	33.85
Zone Sensible Cooling (kWh)	-13478.08
Sensible Cooling (kWh)	-13909.19
Total Cooling (kWh)	-13938.50

Figure 13. Not shaded case

Temperature and Heat Gains - Block 2

EnergyPlus Output   1 May - 15 Sep (Zone conditions reported for user defined periods only), Run period   Licensed

	Year
Air Temperature (°C)	34.01
Radiant Temperature (°C)	33.95
Operative Temperature (°C)	33.98
Outside Dry-Bulb Temperature (°C)	36.26
Glazing (kWh)	480.55
Walls (kWh)	4090.93
Ceilings (int) (kWh)	-1.00
Floors (int) (kWh)	-17.83
Partitions (int) (kWh)	-33.58
Roofs (kWh)	2243.22
General Lighting (kWh)	935.68
Occupancy (kWh)	75.19
olar Gains Exterior Windows (kWh)	4433.11
Zone Sensible Heating (kWh)	34.31
Zone Sensible Cooling (kWh)	-11087.99
Sensible Cooling (kWh)	-11492.64
Total Cooling (kWh)	-11523.12

Figure 14. Shaded case

5. CONCLUSIONS

The coverage has several aspects and effects that can be clarified as follows.

First: Aesthetic aspect: The coverage affected the architectural facade of the dwelling, leading to an undesigned formal and visual distortion, resulting from the fact that those working in the field of coverage are artisans, in addition to the fact that the coverage was not taken into consideration from the beginning of the design, as it is an addition forced onto the dwelling.

- There is no high impact of coverage in terms of aesthetic aspects on 2D plans, but its relationship and effects can be determined on the 3D mass on the one hand and at the level of facades on the other. Therefore, the shape and type of material adopted and the method of its arrangement in roofing should be carefully chosen to reflect the high aesthetic aspects of the building.

Second: Structural aspects: Coverage on walls and floors reduce the dead load. In contrast, its effect is weak in reducing loads on the permanent ceiling as they are temporary and local materials. Therefore, it is necessary to increase the efficiency of coverage by choosing light and insulating materials.

Third: Economic aspect: Most homeowners use this method to reduce costs by covering roofs with local materials such as (“shtaiker” and “Farshi” Bricks) in addition to the speed of completion and low maintenance.

Fourth: Environmental aspect: The coverage formed an insulator for the surfaces on which it is built, thus dispensing with the usual insulation of ceilings (local), as it works to prevent rain, dust, and heat from falling directly on the roof, which helped reduce the thermal load of roofs. It also helped provide shaded areas between roof curves.

Fifth: Utilitarian aspect: Roof coverage provided an opportunity for the emergence of some green areas on roofs as compensation for ground gardens that are gradually shrinking in Iraqi houses due to several factors.

- Roofs were used as gathering and entertainment areas for the family, as the roof moved from a neglected space to a positive space that is important to the residents. It can also be used for security aspects and increased protection for the building.

Sixth: Social and legal aspect: Covering the roofs of the second floor led to the addition of another floor to residential houses, providing a new social space that is more environmentally suitable for family members, but this led to an increase in the height of the residential unit.

Seventh: Design-wise: The research distinguished between two types of surfaces, one designed before implementation, which is permanently above the roofs and acceptable to the recipient, and the other type designed by artisans, which is primarily temporary and often causes visual distortion to the facades.

Eighth: Wooden roofs are considered roofs that reflect aesthetic dimensions in providing spaces for comfort and sitting, reflecting the dimensions of nature within the space, but their durability is low due to the environmental conditions of Basra city despite the increased demand for establishing such spaces. While the tile roof is considered a medium option in terms of durability and aesthetic dimensions, this cannot be seen in metal roofs.

6. RECOMMENDATIONS

The research recommends following this pattern of roof coverage due to its numerous benefits and advantages, and designing it to be compatible with building facades and construction elements. It also recommends the necessity of enacting a law that clarifies the possibility of adding roof coverage and its determinants.

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