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Comparison of temperature and humidity among traditional underground and modern house in Gharyan, Libya

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A B S T R A C T

Modern buildings are associated with a lot of shortcomings, such as consumption of an excessive amount of non-renewable energy and resources, environmental pollution and depletion of natural landscapes, etc. Vernacular buildings can be argued to help in reducing environmental problems for local society. Libya, as a developing Arab country, has also faced several urbanization problems in recent years. However, the country has a remarkable span of vernacular architecture patterns. Vernacular architecture that the country owns may be a solution to combat such challenges. There are three types of traditional vernacular dwellings in three regions of the country as underground housing (the mountain region), compact dwelling (the desert), and the courtyard house (coastal region). Thus the aim of this study is to make a comparison between underground and modern housing in Gharyan, Libya, with regards to thermal performance and humidity. Thermal performance in both underground and above ground houses was measured with an instrument called a hygrometer. The result from the thermal measurement that was done in one month of the winter season (21/01/2019-18/02/2019) demonstrates that the underground house has an indoor mean temperature and humidity of 16.12°C and % 62.07 RH while the other house type has an indoor temperature and humidity of 12.70°C and % 70.13 RH. The underground house seems to have a relatively reasonable and stable indoor temperature compared to the modern house indoor. In addition, the underground house seems to be relatively less humid compared to the modern house for indoor environment in particular.

1. Introduction

It can be suggested that human societies as a whole must begin to change their philosophy and policies for the survival of the earth. Thus sustainable urbanism has emerged within the last decades as a significant concept (Oktay, 2012; Sharifi, 2016). Issues ranging from the preservation of flora and fauna to the ecological planning and design of cities have gained urgent significance. At this point, it can be argued that vernacular architecture has become a critical subject having great importance within the environmentalism debate. Hence issues such as energy consumption and efficiency in buildings have become a significant topic within the sustainable urban planning and design discourse (Allouhi et al., 2015).

Such that modern dwellings are associated with consumption of an excessive amount of non-renewable energy and resources, pollution and depletion of natural landscapes and topography, etc. Thus, adopting the dynamics of vernacular architecture to modern architecture can be a tool for combating the existing problems in urban environments. Hence the buildings that are constructed using locally available materials display a greater focus on the existing environment and also consider the constraints imposed by the climate (Singh et al., 2009). Libya is a country that has a remarkable span of vernacular architecture patterns. However, in the last decades, contemporary architectural planning and design trends have deficiencies in adopting the advantages of vernacular philosophy. Such that there has been a development of infrastructure and public facilities such as hospitals, schools, hotels, and others. In particular, the housing sector is one of the most important

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sectors for Libyans. The modern buildings were designed by foreign architects from western countries such as England, Korea, Turkey, and recently Indian and Chinese architectural firms with limited participation of Libyan architects involved. These foreign architects were given a large number of building construction contracts; however, they failed to take into consideration the climatic and social factors. As such, these factors should be considered among the most significant features for the design of houses in Libya. The vast majority of public housing in cities was constructed with similar design without considering the climatic conditions. However, for the accomplishment of sustainable planning and design efforts, the features of vernacular architecture must be implemented in practice also in Libya.

The underground dwellings that were once highly prevalent for Libya have been the oldest form of shelter known to humans tracing back to ancient eras. These underground dwellings methods are utilized in various parts of the world today through new technological approaches. Underground dwellings are designed and implemented for the conservation of the natural environment as well as protection from pollution and usage of non-renewable energy resources as much as possible. This type of building is consistent in providing comfortable, moderate temperature to its inhabitants in different weather conditions.

Within this framework, this study aimed at comparing earth-sheltered housing (underground housing) and modern housing (above-ground housing) in relation to thermal performance and humidity in Gharyan, Libya. Therefore, after providing a review of the relevant literature, the study then explains the case. Next, the methodology is presented, and the findings are displayed and discussed. Finally, a conclusion is interpreted, and recommendations are made.

2. Architecture in Libya

2.1. Vernacular architecture

Vernacular architecture had originated when humanity began to make use of the natural resources around him for dwellings. Ever since vernacular architecture has proven to consume lower energy and to be sustainable. In other words, vernacular houses provide a comfortable climate for their inhabitants over the years. It is closely and traditionally linked to energy efficiency due to its adaptation to climate and location (Pozas and González, 2016). In the present time of rapidly increasing technological development and urbanization, there is still much to be learned from the conventional knowledge of vernacular construction approaches. Thus there is the necessity of sustaining the future of these traditional buildings and historic sites through the recovery of bioclimatic strategies and the indoor comfort inherent in vernacular architecture construction (Bionaz, 2015).

Since the early times, mankind has lived in underground spaces as a unique type of vernacular architecture. Individuals, as well as other living creatures, have often utilized earth for protection against climatic conditions or predators. Since the usage of caves as shelter, humanity had tried to achieve the needs of their tribes via the usage of the earth in their construction ideologies. The cave was also used as a place for living or as building material (Albasha, 2010). The utilization of the underground housing system has protected humankind for a significant period of time and, at the same time, protected and improved the environment.

Accomplished from the ancestors who had discovered simple building techniques, the traditional housing in Libya represents the wealth of vernacular architecture. Such that via the knowledge and experience positively acquired through daily life, vernacular buildings built with local material provide thermal comfort throughout both summer and winter season. There are three types of traditional vernacular dwellings in Libya that are distributed in three regions of the country as underground housing (the mountain region), compact dwelling (the desert), and the courtyard house (coastal region) (Gabril, 2014).

2.1.1. Vernacular houses in the mountain region

The Mountain of Jabal in the Nafusah region in Libya is famous for its underground dwellings, especially in Gharyan city. These houses have a lot of characteristics. As such, they are very simple in design and inexpensive to build. They achieve less energy consumption compared to aboveground dwellings with the help of passive cooling and heating techniques (Gabril, 2014; Milanović et al., 2018). The underground houses also contributed largely to the green building construction. For this reason, more knowledge on how to conserve energy and the environment resulted in the continuous and rapid increase of the construction of underground houses (Boyer and Grondzik, 1987) (Fig. 2). Fig. 1 shows two of the underground dwellings; one consists of 3 rooms, and the other 8 rooms (photo by author).

Inhabitants of Gharyan in Libya excavated the soil to build underground houses by hand using simple and locally made tools such as shovels and picks. The underground dwellings consist of between 3 to 8 rooms of almost similar sizes, there are three small kitchens of trapezoidal shape with various spaces, and approximately 2.00m high. Between every two rooms is a kitchen shared by the two families with open doors, in order to provide ventilation when cooking. The rooms were warm during the winter and cold in the summer.

Traditionally in the past, each room in an underground dwelling was inhabited by one family opening on a courtyard. This approximately 10x10m courtyard with a depth of 7 to 10m allows the flow of air and entrance of sunlight rays to the rooms during the day. The primary reason for this sort of construction was to provide shelter from difficult conditions such as harsh climates and predators. There are two types of underground houses as Aboskefa and Al-feseal (Shahran et al., 2017).

Fig. 1: Two of the underground dwellings, one consists of 3 rooms, and the other 8 rooms

Aboskefa (First type): This kind of dwellings (Aboskefa) is completely underground, excluding the main entrance door. It consists of a square-shaped courtyard surrounded by rooms. The courtyard is surrounded by an iron fence or a small external wall to prevent people and animals from falling (Daze, 1982) (Fig. 2).

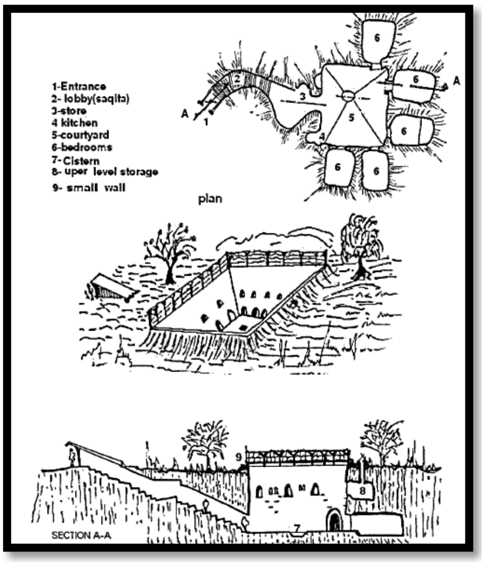


Fig. 2: The first type of underground house (Aboskefa) (El-Dweb, 1995)

Al-Feseal (Second type): This kind is located in the foothills of the mountains on a steep slope. This dwelling has an elevation above ground, and its rooms are on the level of the ground. And it consists of a rectangular-shaped courtyard surrounded by rooms built on three sides, and the fourth side is built of stone. The light and air enter the rooms directly from the exterior. This type may have a terrace in front that acts as a courtyard (Fig. 3).

2.1.2. Vernacular houses in the desert region (Old city of Ghadames)

Ghadames is a Libyan Desert city, located at 630 km southwest of Tripoli with a desert climate. There are high-temperature variations between day and night in the summer, with average temperatures in summer reaching up to 40ºC. UNESCO declared in 1987 that the old city of Ghadames is a World Heritage site (Gabril, 2014).

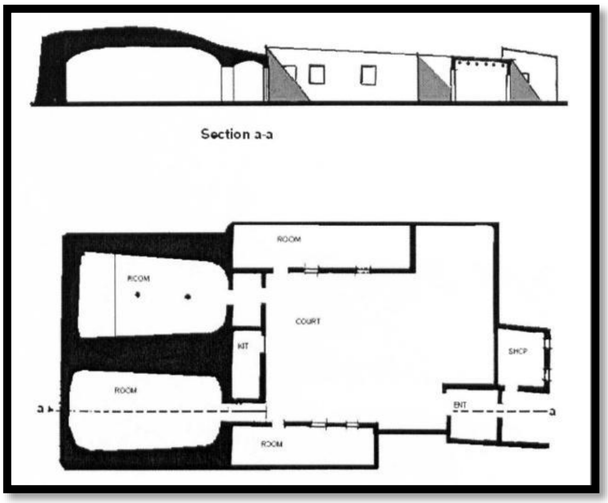
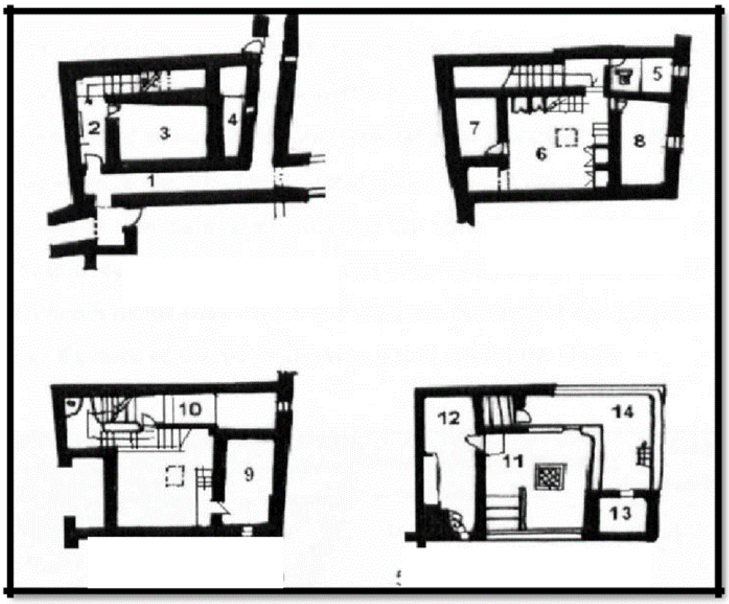


Fig. 3: The second type of underground house (Alfasel) (DA, 1964)

The dwelling of Ghadames is considered as one of the most important architectural components of the ancient city of Ghadames, with its unique and exquisite architecture and its white walls from the abundance of inscriptions and decoration that give the place aesthetic visual. The construction of Ghadames dwellings appropriately takes into consideration all geometric shapes, measurements, calculations, and local building materials in order to obtain thermal comfort inside the dwellings. These houses are relatively cool throughout the day and warm during the night. The dwellings were built by domestic people who used locally available material such as clay, soil, lime, and gypsum; these construction materials are largely in harmony with the surrounding environment.

The traditional house in Ghadames: The ground floor consists of a covered passageway where the entrance is opening directly inside the house. It is usually painted white, and usually, there is a number of mirrors to reflect light and keep on bright space. On the ground floor, there is a space used as storage for agricultural tools or commercial goods. A staircase leads to the next (first) floor. The first floor consists of a space referred to as Sadr el-beit serving as a living room and a reception at the same time. It is located in the middle of this floor. With lighting and ventilation coming from a small-unglazed window (75x75cm) in the ceiling, lighting is distributed by mirrors into all parts of the house (Amer, 2007). The second floor or rooftop consists of a kitchen and terrace for the storage of fuel. The kitchen is located at this top or roof floor in order to discharge the extra heat and smoke caused by cooking (Fig. 4).



House plan key
1-Street
2- Entrance corridor
3-Store
4- Latrine pit
5- Latrine
6- Sadr el-beit
7- Girls room
8- Main bedroom
9- Boys room
10- Store room
11- Roof terrace
12- Kitchen
13- Children sleeping room
14- Steps

Fig. 4: The dwelling as a traditional house in Ghadames (Chojnacki, 2003)

2.1.3. Vernacular houses in the coastal region (The courtyard house)

The courtyard dwellings are known in most of the Arabic cities, as well as in Libya. They are widespread, especially in the coastal cities such as Tripoli, Maserati, and Khoums built with locally available construction materials. The courtyard houses are usually constructed in rows in the cities and have only the front face opening on the narrow streets, while the other sides are connected to adjacent dwellings. The average area of these houses is 300 square meters, and the courtyard ranges in the area from 70 to 100 square meters. The courtyard may contain a planted tree and a water fountain in the middle (Amer, 2007) (Fig. 5).

Fig. 5: Fountain and the tree in the center of the courtyard house (Shahran, 2018)

2.2. Modern housing in Libya

Libya has experienced a lot of development in all sectors after the discovery and production of oil, starting from the 1970s. Starting from these years, the patterns of modern architecture have gained momentum within the construction sector of the country. Such that there are many modern housing projects in Libya, ranging between one to 13-stories with different designs, different built-in periods (Amer, 2007). Also, there were individuals who obtained real estate loans, and they built private housing.

In addition, thousands of housing have been built by the government of Libya. In brief, there are many patterns of modern housing in Libya, some of them have been built by the government in different periods during the past decades, and the others were built by citizens individually. It can be argued that for modern housing, there is a variety of design and construction systems used both traditionally and prefabricated. Types of modern housing in Libya can be classified as a private traditional popular house, public housing, villa, and apartment (Gabril, 2014; Tošković, 2006).

2.3. Libya as the case

Libya is located in the north of Africa and covers 1,759,540 million km^2. It lies between latitudes 19N and 33N and between longitudes 9E and 26E. The country is bounded by the Mediterranean Sea to the north. Egypt lies to the east, Sudan to the southeast, Chad, and Niger to the south, Algeria to the west, and Tunisia to the northwest (Amer, 2007). Libya is considered one of the largest cities in Africa by landmass. However, only 6% of the land is considered usable. It means that 94% of the landmass or total area is covered with sand (desert). After the discovery of oil, a majority (three-quarters) of the population moved to live in urban areas because the urban areas achieve better job opportunities and better social amenities; in addition, major agricultural cultivation of land is observed. Cultivation of land for agricultural use is observed in less than 2% of the country's total area (Kezeiri, 1983; Aburroush, 1996) (Fig. 7). Gharyan is a city located in northwest Libya. Gharyan is the largest city in the Mount Nafusa region. Gharyan region extends across the top of the plateau at the end of the Jebel Nafusa. It is located about 85 km south of the capital Tripoli, and just before Yefren, the latitude of the Gharyan is 32°11' N, and the longitude is 13°00' E. With GPS coordinates of 32°10'18.462' N and 13°1'6.2832' 'E. The height of Gharyan is about 700 meters from sea level (Fig. 6).

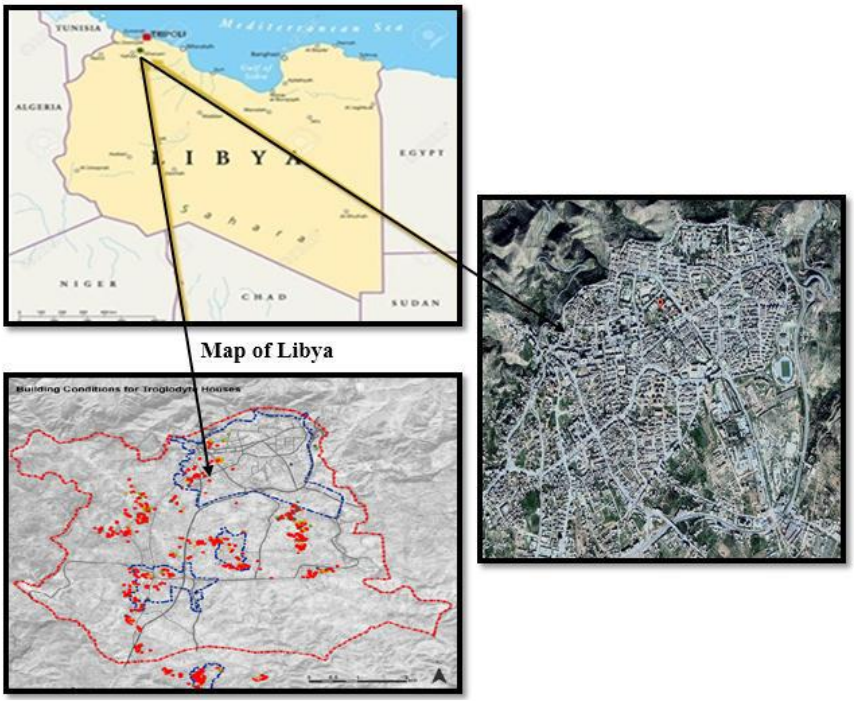


Fig. 6: The administrative boundaries of the city of Gharyan (NCB, 2009)

The Climate in Gharyan: The city is generally cool. In winter, the temperatures sometimes fall below freezing, and snowfalls occasionally. The coldest month is December. The highlands of Jebel Nafusa and Jebel Akhdar areas have the best summer climate because the relative humidity is much lower than that in the coastal zone. In addition, in summer, the main temperatures of this zone are lower than those in other regions. The hottest month is July, when the max temperature is about 32^{0}C. Usually, the second week of the month is the hottest. Gharyan has a Mediterranean climate, but the mountains are the cold region (Gabril, 2014). The mean relative humidity of the air is 61% RH in winter, the maximum reading for relative humidity could rise up to 80%, and in summer, the mean monthly relative humidity is nearly 28% RH, and the annual average is nearly 41%.

3. Materials and methods

3.1. Research design

For the measurement of temperature and relative humidity, two digital instruments called hygrometer (Beurer HM 16) were used. One of them was used in the underground house, and the other one was used in the modern house. The underground dwelling and modern house are located close to each other with a distance of not more than 100 meters. The vernacular house was empty, and the modern house had occupants during the measurement. The locations of them are displayed below. As seen in the related figures, the houses are neighbors to each other almost at the same location (Fig. 7 and 8).

Fig. 7: The location of the underground house that is used in the field study

Fig. 8: The location of the modern house that is used in the field study

3.2. Research context

The underground house used for the field study: It is located in an area called Abo Gelan in Algwassem, approximately 18km north of the center of Gharyan. It was built in the 1660s. The owner of the house is Belhaj Family. It has a total area of 375m^2, including the courtyard. The underground house was built with the open courtyard design system as a square, with opened 8 rooms created on the sides of the central courtyard as well as three kitchens. There is also a room on the top wall of the courtyard for storage. Guest rooms are usually on the ground level.

Room length between 4m to 9.00m, width is from 3.5 to 7m. The height ceiling in rooms is 2.25 to 2.60m. The courtyard area is 9.30x9.30m, and the depth is 7.60m from the natural earth level. The main entrance was built on the northwestern side. It is a long channel (corridor) with a length of approximately 15m and has a curved ceiling with a width of 1.2m and height is up to almost 2.00m. In the courtyard of the house, there is a hole with a depth of 1.5m and a diameter of 1m for discharging stormwater. The rubble stones were used to prevent soil collapse at the top of the courtyard (Fig. 9 and 10).

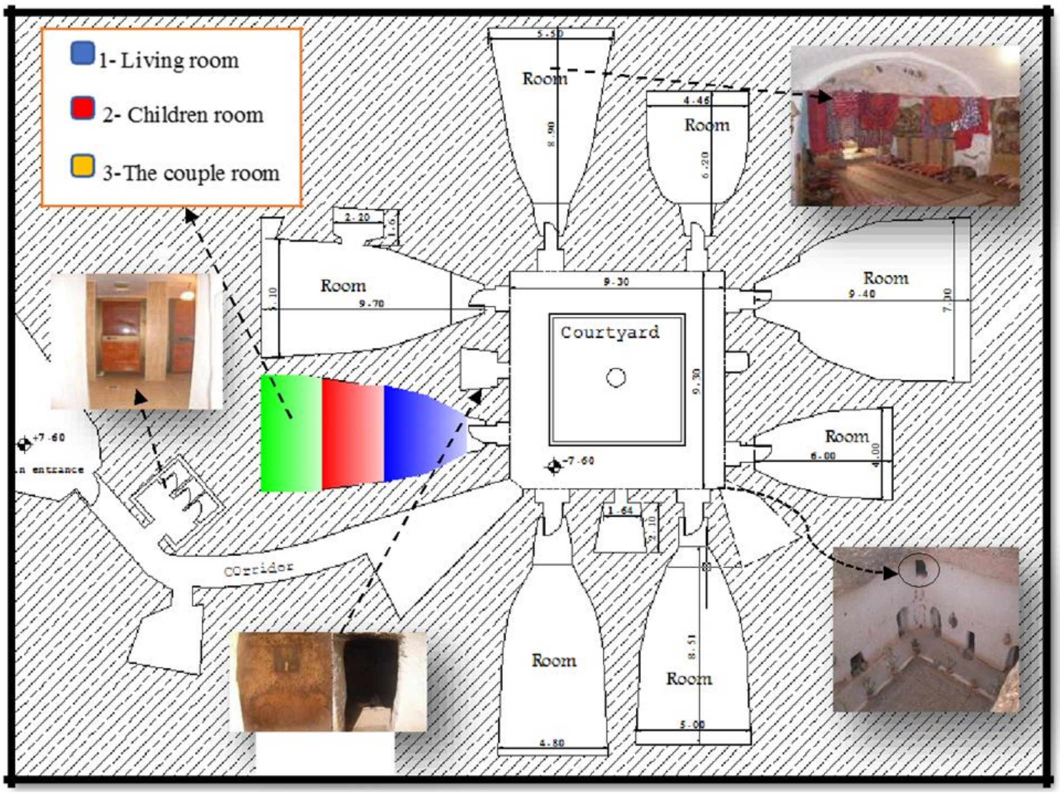


Fig. 9: The underground house has 8 bedrooms on the four sides of the courtyard and 3 kitchens

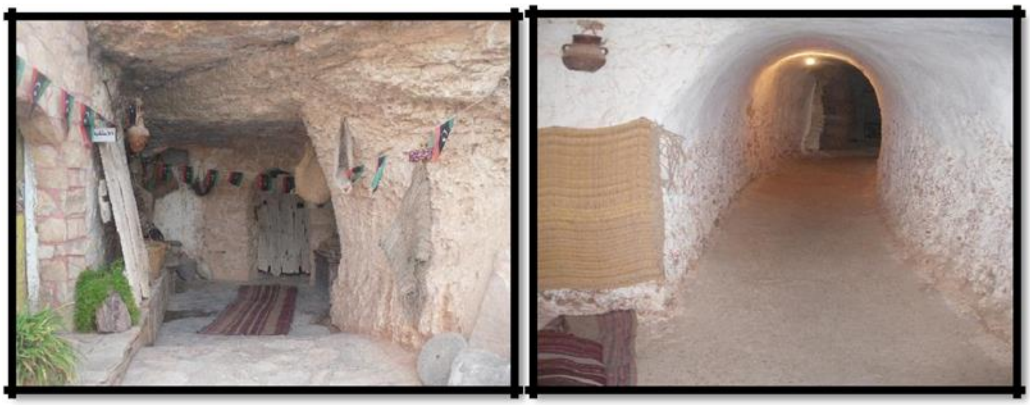


Fig. 10: The main entrance and corridor of the underground house

The modern house used for the field study: It is located in an area called Abo Gelan in Algwassem, approximately 18km north of the center of Gharyan. It was built in 1994. The owner is Belhaj Family. The total area of the house is 247m^2, and it has a structural system. The house's structural designed system consists of 2 bedrooms, a men's salon, living room, kitchen, bathroom, a stair inside the house, and a surrounded fence from all sides of the house with a measurement of about 2m high.

The main entrance was built on the northeastern side. Dimensions of bedrooms were 5x5m and 4x4m. Dimensions of men salon and kitchen were 5x5m. The dimensions of the living room were 6.35x6.25m. The dimensions of the bathroom were 3.5x2m, and the height of the ceiling was 3m (Figs. 11 and 12).

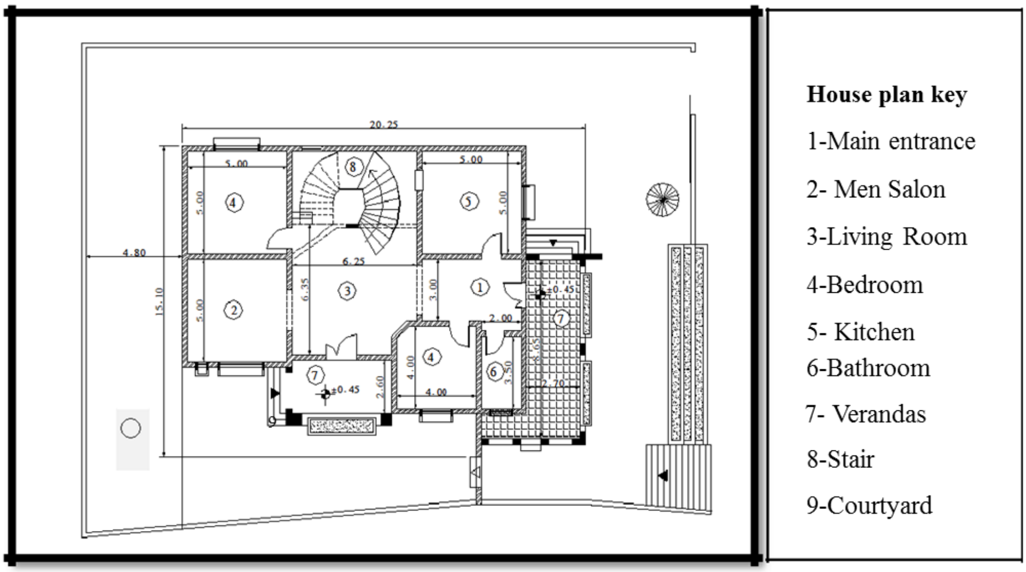


Fig. 11: Plan of the modern house in Gharyan

Fig. 12: Different facades of the modern house

The house was designed without an internal courtyard in contrast to an underground house, and windows opened outward on the garden surrounded by open spaces. The verandas are located at the eastern and southern facade of the house. Regarding construction material, it can be argued that walls were built of limestone and columns from reinforced concrete. The floors were covered with tiled, marble, and wood. The ceiling was constructed from reinforced concrete. The doors were made of wood with dimensions of about 1x2.2m. The windows were made from PVC with different dimensions with steel fence or mesh for security.

This house had separate foundations with dimensions of about 1x1m and a height of 50cm. Walls were built from limestone with a thickness of

25cm. Columns with dimensions of 25x25cm were constructed by reinforced concrete. Beams with a width of 25cm and a depth of 40cm and the ceiling with a thickness of 15cm were constructed with reinforced concrete. The gypsum is used for decorating indoors of the house, whilst pharaonic stone is used for decorating the external walls to cover the verandas facade located in the main entrance.

3.3. Research measures

The fieldwork, total measurement of temperature, and humidity were carried out within the period between January (21/1/2019) to February (18/2/2019). Every day within this period, the measurement was carried out four times per day at 7.00 am, 1.00 pm, 7.00 pm, and 1.00 am to record average temperature, and humidity for both underground and modern (above) houses manually. For each measurement of both houses, the recording was made once indoor and once outdoor. For the underground house, the recording was made inside the house and in the courtyard. And for the modern house, the recording was made inside the house and outside the house on the veranda.

4. Results

Table 1 and Fig. 13 display the mean temperature recorded both in an underground and modern house. The mean indoor temperature measured for underground houses is 16.12°C while the same measurement for a modern house is 12.7°C. All these measurements were observed in winter during a month period. The outdoor (courtyard) mean temperature of the underground house was recorded to be 9.78°C, while the mean temperature outside the modern house was recorded to be 9.23°C (Table 1 and Fig. 13).

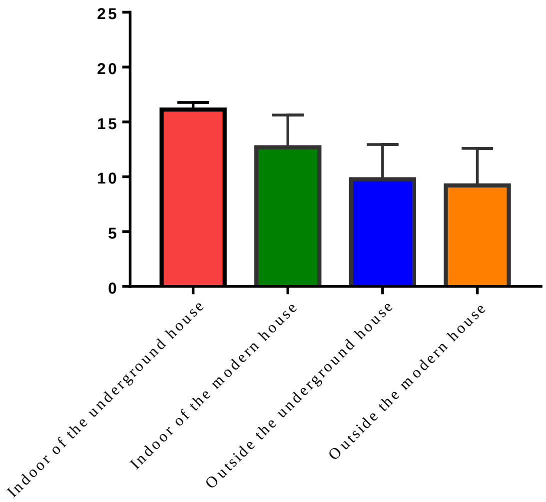


Fig. 13: Average temperature from 20/01/2019 to 18/02/2019

Table 1: Average temperature from 20/01/2019 to 18/02/2019

Date	Average indoor temp. of the underground house	Average indoor temp. of the modern house	Average temp. in the courtyard	Average temp. outside the modern house
20/01/2019	17,53	14,95	14,93	13,60
21/01/2019	16,93	16,70	13,83	14,08
22/01/2019	14,70	17,38	12,75	12,68
23/01/2019	15,80	11,60	8,40	8,20
24/01/2019	16,00	12,45	10,13	9,55
25/01/2019	16,23	11,15	7,23	5,45
26/01/2019	14,13	9,68	6,53	6,18
27/01/2019	16,53	11,60	11,70	7,75
28/01/2019	15,60	14,05	11,90	12,18
29/01/2019	15,70	13,30	11,33	7,85
30/01/2019	15,85	13,53	10,90	7,15
31/01/2019	16,05	14,83	13,00	11,25
1/02/2019	17,10	17,30	15,23	15,75
2/02/2019	16,28	20,38	17,75	18,98
3/02/2019	15,93	16,70	9,75	10,28
4/02/2019	15,40	12,48	4,28	5,90
5/02/2019	16,45	9,15	6,55	5,63
6/02/2019	16,55	9,33	7,55	7,30
7/02/2019	16,03	9,05	8,40	7,25
8/02/2019	16,18	11,85	7,75	7,55
9/02/2019	15,93	12,03	8,65	7,03
10/02/2019	16,03	13,83	11,83	11,05
11/02/2019	15,85	14,65	9,20	11,65
12/02/2019	16,80	12,55	7,20	7,25
13/02/2019	16,60	9,13	5,33	5,33
14/02/2019	16,30	9,50	7,10	6,35
15/02/2019	16,48	10,73	7,53	7,70
16/02/2019	16,55	9,28	6,85	6,15
17/02/2019	15,93	10,48	10,20	10,28
18/02/2019	16,33	11,28	9,58	9,48
Mean	16,13	12,70	9,78	9,23
Std. Deviation	0,66	2,93	3,17	3,36

In addition, Table 2 ad Fig. 14 illustrate the mean relative humidity recorded both for underground and modern houses. The indoor relative humidity recorded in the underground house was 62.07% RH, while in the modern house record was up to 70.13% RH in the same period. The average humidity measures outdoors for both underground and modern houses are 66,52% RH and 66,28% RH, respectively (Table 2 and Fig. 14).

Further, mean values for both temperature and humidity are measured according to the timing of the study. Hence the measurement was made four times a day for each of the two houses at 7 am, 1 pm, 7 pm, and 1 am (Table 3 and Table 4).

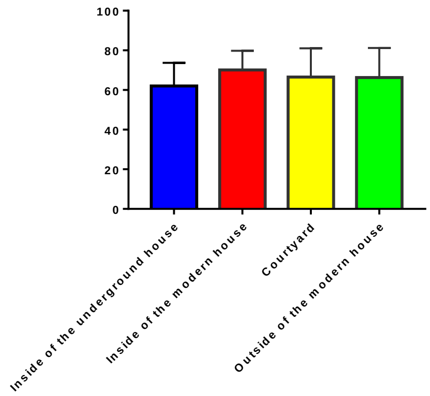


Fig. 14: Average relative humidity from 20/01/2019 to 18/02/2019

Table 2: Average relative humidity from 20/01/2019 to 18/02/2019

Date	Average humidity inside the underground house	Average humidity inside modern house	Average humidity in the courtyard	Average humidity outside the modern house
20/01/2019	41,25	62,25	43,25	49,25
21/01/2019	53,25	52,25	44,25	40,75
22/01/2019	54,75	60,25	58,25	66,25
23/01/2019	61,75	72,75	64,25	77
24/01/2019	53	68,5	60,5	64,75
25/01/2019	52,75	66	61,75	65,5
26/01/2019	48,5	70,75	57,25	62
27/01/2019	60,25	71,5	57,25	63,25
28/01/2019	48	66,25	49,5	53,5
29/01/2019	53,5	61,25	50,75	63,75
30/01/2019	55,5	65	60	59,25
31/01/2019	73	67	64,75	60
1/02/2019	57	57	52,75	45,5
2/02/2019	41	44,75	41,25	39
3/02/2019	44,25	60	60,25	38
4/02/2019	60,75	69,25	82,5	71,75
5/02/2019	76,75	75,75	96	96,5
6/02/2019	76,25	85,75	94,5	89
7/02/2019	66,5	87	73,25	88,25
8/02/2019	64	77,25	80,75	77,25
9/02/2019	61,25	80,5	82,25	77
10/02/2019	65,75	74,75	67	69,5
11/02/2019	65,75	69,5	63,25	52
12/02/2019	71,5	74,5	76,75	79
13/02/2019	76,75	75,75	87	84,5
14/02/2019	75,25	81	81,5	77,5
15/02/2019	77,25	80	78	71,75
16/02/2019	78,5	79	74,25	74,25
17/02/2019	77,25	77,25	66,75	66,75
18/02/2019	71	71	65,75	65,75
Mean	62,07	70,13	66,52	66,28
Std. Deviation	11,60	9,64	14,56	14,89

Table 3: Mean temperatures of both house types according to the research timing (^{0}C)

	Temperature (C)							
	7am		1pm		7pm		1am	
	Inside	Courtyard	Inside	Courtyard	Inside	Courtyard	Inside	Courtyard
Underground House	15,91	8,82	16,31	11,86	16,10	10,19	16,17	8,23
Modern House	12,04	7,74	13,25	11,80	13,09	8,88	12,40	8,49

Table 4: Mean humidity of both house types according to the research timing (% RH)

	Humidity (%)							
	7am		1pm		7pm		1am	
	Inside	Courtyard	Inside	Courtyard	Inside	Courtyard	Inside	Courtyard
Underground House	61,27	68,10	61,83	61,57	63,10	66,63	62,10	69,77
Modern House	70,37	70,40	67,50	60,13	69,27	67,87	73,37	66,73

4.1. Evaluation of the results

Result demonstrates that the underground house has an indoor mean temperature and humidity of 16.12°C and % 62.07 RH while the other house type has an indoor temperature and humidity of 12.70°C and % 70.13 RH. According to these findings, there is a remarkable temperature difference among the indoors of the house types; the underground house is measured to be almost 3,5°C warmer. With the consideration of the season to be winter (21/01/2019-18/02/2019), it can be argued that the underground house seems to have a relatively more reasonable indoor temperature compared to the modern house indoor. In addition, if we evaluate the standard deviation values, it can further be argued that underground house indoor achieves lower temperature variability providing a more stable and constant temperature. For the outdoor measurement of temperature, there is almost no difference between the houses. In addition, the underground house seems to be relatively less humid compared to the modern house for the indoor environment in particular, such that the difference is almost 8 RH.

The temperature difference among the indoors of the two house types can be argued to be related to the construction materials and simple and local construction techniques of the underground house, providing thermal comfort and stable temperatures inside the house. As a strength of the study, there are related studies displaying data proven in our study. For instance, Elwefati (2007) pointed out that the indoor temperature of the underground house in Gharyan was within the range for human comfort both within summer and winter. In addition, Krarti (1997) found that a Tunisian underground house was cooler in the summer and warmer in the winter according to the modern house. Shahran et al. (2017) also achieved data indicating that the troglodyte dwellings (underground houses) provide a more comfortable environment in the Gharyan region throughout the year.

It is also important to note as a limitation of the research that our study measurements were observed for only a one-month period in the winter season. Future studies may involve measurements in different periods, also including the summer season.

5. Conclusion and discussion

In the last decades, the significance of environmentally responsive architecture has been acknowledged as we are facing more and more challenges caused by global warming and climate change, which is a phenomenon that mostly occurred as a result of neglecting the principles of ecological planning and design (Allouhi et al., 2015; Beyaz and Asilsoy, 2019). At this point, it can be argued that vernacular architecture has the potential to guide sustainable architecture as it achieves both climate and culture responsive design. In other words, most of the elements and architectural features that are now the basis of sustainable design are derived from the composite aspects of vernacular architecture and its characters (Cardinale et al., 2013).

Libya is a country that contains disparate types of vernacular architecture, and these traditional architectural features need to be conserved and sustained from past to future. Within this framework, this study had a focus on Gharyan, Libya, for making a comparison between underground houses with modern style housing about temperature and humidity.

It can further be said that underground houses have several advantages over modern houses, such as the usage of local environmentally friendly construction materials and simple construction techniques to provide thermal comfort and stable temperatures inside the house both in winter and summer. This means that underground houses have passive cooling and heating, where it meets the needs of people.

However, there are a few disadvantages associated with underground houses, such as inefficient natural light and sewage systems. These challenges have to be taken into account while adopting the traditional architecture knowledge to the planning and design of contemporary architecture. However, such problems can be solved easily by the use of modern technology. Hence, no matter what such challenges are, inspiration coming from vernacular patterns will give us the chance to create more sustainability-oriented environments.

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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