The Effects of Passive Design and Renewable Energy in Producing Low Energy Efficiency Architecture and Special Identity – (Case Study Libyan Desert Zone – Ghadames)

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Abstract:
The use of passive design is not a new innovation. It is as old as the technique of building and art of architecture. Prior to the modern era, architects and builders had little else other than local materials and natural resources. They designed their buildings carefully so as to maximize the thermal properties of materials and the availability of local resources.

Contemporary architecture reveals its similarity in almost every part of the world without any consideration to regional characteristics, in comparison to vernacular architecture which is almost always climatically appropriate, where architects and builders traditionally had to design with respect to nature and local climate.

This paper attempts to evaluate the housing settlements in Ghadames where the vernacular, urban and architectural patterns provide useful hints for designing more sustainable environments. In this context, the compact city, covered streets and covered courtyard, provide the elements most important to climatic comfort efficacy in a hot arid climatic region. The importance of using renewable energy and local materials are also explored as design tools towards more sustainable development solutions.

Keywords:
Architecture, Climate, Ghadames, Passive design, Vernacular architecture, Renewable energy

1. Introduction

At this present time there is universal concern about our environment. We are living during a unique time in human history, when man has achieved the ability to almost completely control his environment. However, at this impatient point in his development, the relationship between man and environment has become difficult and contentious.

Passive design, in essence taking maximum advantage of nature and the climate in particular to design the built environment, may seem to be the latest trend in building design, but it is an idea that has been with us for a long time. Our early ancestors lived in sympathy with nature and lived in the moment. Nowadays people try to live in the next coming centuries before they even know what will happen in the coming second. Hassan Fathy (1986) confirmed that man has for along time reacted to his environment, using his materials to develop techniques and technologies, in the past he lived attuned to the environment.

EREC (2000) confirmed that ancient civilizations used passive solar design. The new aspects are building materials, construction methods, and software that can improve building design and incorporate passive solar principles into modern residential structures.

As a consequence of our greediness and ignorance of the environment and material resources, and our extensive use of mechanical systems to create comfortable indoor environment which caused a wide range of health, the environmental problems will increase. To limit and reverse these adverse effects, passive design became one of the most needs in saving our built environment, therefore the environmental impact of the buildings should be considered including effects on the global and local environment.

Contemporary Libyan architecture has rarely recognized the local climate or renewable energy. Issues related to these subjects are neglected or rarely studied where as Libyan local architecture, such as that at Ghadames, includes traditional solutions that have been tested over centuries, providing passive design that leads to reducing building's energy consumption as well as creating an architecture related to the local environment. Yet, as this architecture provides a motivating and valid lesson; it also illustrates and present riches of knowledge about how humans remain in touch with nature and how they adjust to the local natural environment and climate.

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2. Sustainable architectural design

Sustainability in general deals with the relationships between human and natural systems and considers the long term. Sustainable architecture can be defined as a planned effort at designing a built environment that is energy and ecologically considerate both internally and externally. According to Brundtland (1987:8) Sustainable development is the "*development that meets the needs of the present without compromising the needs of future generations to meet their own needs*". Sherlock shares Brundtland's definition: "*Sustainability means living now in such a way that we do not threaten future life*" (Sherlock, 1991: 293).

Roaf *et al.*, (2005) defined the eco-house as a house that is closely connected to the site, society, climate, region and planet. Roaf asks the question of why we do not make all building more ecologically connected in this way, and recognises that appropriate more sustainable alternatives are still not acceptable to society as a whole, even when modern buildings are contributing to the trends undermining the planetary systems. Oliver (2003:130) defined the relation between building and climate as "*Buildings do not control climate, which, apart from the wind or sun shadow that they cast, remains largely unaffected. But from within the dwelling can modify the internal climate, even though it is affected by the external conditions. The materials that are used, the forms they take, the volumes they enclose, and the services that are installed may all contribute to the 'micro-climate' that the house generates. This is not always precisely what the occupants require in temperature, ventilation or relative humidity."*

2.1. The principles of the sustainable architecture

There were many studies conducted on sustainable architecture such as (Sherlock, 1991, McDonough, 2000, Cofaigh et al., 1996, John et al., 2005, Roaf et al., 2005).The main principles of the sustainable architecture as following;

- **Respect of the user's socio-cultural values**. Rapaport (1969) clarified that the variety in architectural form can be seen as a result of a host of social, cultural, economic, physical, and technological variables

- **Adapting the climatic conditions.** Sustainable buildings should have the ability to benefit from local climatic conditions and adapt to the daily and seasonal climatic changes
- **Energy conservation.** Buildings consume energy not only in their operation, for heating, lighting and cooling, but also in their construction. Construction often requires large amounts of energy for processes ranging from moving earth to welding. Also the materials used in architecture must be produced, processed, and transported to the building site.
- **The use of local material**. Using the provided local material will significantly contribute in respecting and enhancing the environmental issues.
- **Respect the location (site conditions).** It is essential to consider that the building design and construction will not have a major effect on the site topography and the surrounding architectural style.
- **Water Efficiency.** As water consumption is a serious ecological concern nowadays, it is imperative to consider regulating its use and reuse inside and outside buildings.
- **The use of natural light and ventilation**. Building and window design that utilizes natural light and ventilation will lead to conserving electrical lighting energy, shaving peak electric loads, and reducing cooling and heating energy consumption.
- **The studied use of colors.** Colors have physiological and psychological impacts on the human body and in addition to its esthetic values, it plays a significant role in reducing and reflecting the solar radiation on the external walls.

- **Treatments for ecological problems such as noise pollution**. Noise is like light in its effect on psychological human health, accordingly buildings should be protected from noise sources.

3. Passive design

Passive design in essence is taking the maximum advantage of nature, and the climate in particular, to design the built environment, without using mechanical heating or cooling.

Passive design is a process to develop ideas and strategies “for the design of whole buildings that have minimal reliance on mechanical plant”, it works with the building envelope which filters the climate and tempers the internal environment (Dowdle, 2003:3).

Reardon (2005) confirmed that Passive design is design that does not require mechanical heating or cooling, dwellings that are passively designed take advantage of natural energy flows to sustain thermal comfort.

According to the U.S. Department of Energy (2004) passive solar design or climatic design is designing the components of the building, windows, walls, and floors to collect, store, and distribute solar energy in the form of heat in the winter and reject solar heat in the summer. Gedik (2004) stated that climatic design can be learned and inspired by observation of the old traditional buildings. Architects should pay maximum attention to design buildings adapted to local climatic conditions in order to provide residence comfort while using minimum artificial energy.

For most, passive climate control is a design principle where it is important for the engineer to be aware of how the building is used. At the same time it is important for the user to be aware of any activities that could possibly have an unintended and inappropriate effect on the indoor climate (René *et al.* 2001).

3.1. Principles of passive design:

The principles of passive design in homes:

- Provide acceptable levels of comfort.
- To be as low energy as possible to (Reduces heating and cooling bills).
- As self sufficient in renewable energy as possible
- To have as little impact on the environment as possible by reducing greenhouse gas emissions

3.2. Basic Passive Solar Design Techniques:

NREL (2001) explained 'the difference between a passive solar home and a conventional home is design'. And the key is to take the advantage of the local climate when designing a passive solar home.

According to U.S. Department of Energy (2004) there are three basic types of passive solar design; direct gain, indirect gain, and isolated gain, and every passive solar building includes five different elements as shown in figure (1):
The Collector: collect the sunrise throw windows which should face the south .
Absorber: It is the storage element which could be wall, floor, or partition. Sunlight hits the surface and is absorbed as heat.
Thermal mass: It is the materials that store the heat produced by sunlight. It is the material below or behind the absorber (exposed surface).
Distribution: It is the method by which solar heat circulates from the collection and storage points to different areas of the house.
Control: it is the elements which could control under or over heating during summer time such as using roof overhangs to provide shaded areas during summer months.

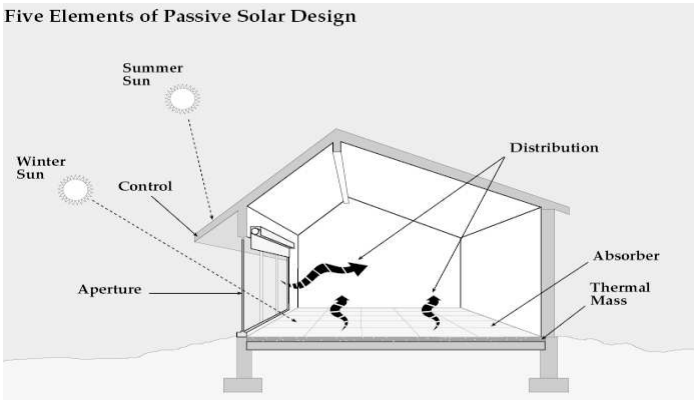


Fig. 1. Five passive solar design elements
Source:http://www.eere.energy.gov/consumer/your_home/designing_remodeling/index.cfm/mytopic

These elements are very important in places which need heating more than cooling, but in the desert regions, which need cooling more than heating, the fifth principle (control) should be the main principle to avoid the overheating.

4. Renewable energy

Renewable energy is introduced as clean, environmentally safe resource when compared with conventional energy resources. While being one of the most oil exporting countries, Libya recognizes the existence and potential for renewable energy resources.

Nasr (2006) illustrates the clean energy resources; Fuel Cells; Geothermal Energy; Micro- and Small Hydro Energy; Large Hydro; Photovoltaic Energy; Solar Energy; Tidal Energy; Wave Energy and Wind Energy. He expects Renewable energy technologies to grow and have the possibility to provide future energy supplies in buildings such as: passive and active heating and cooling systems, photovoltaic and wind power. Khiat and Stambouli (2006)

defined renewable energy projects as tools for the management of reserves and sustainable development of desert communities. They classified the motivations to be taken into account into four points as following: Environment protection, Energy dependence, Rural and agricultural development and Renewable energies availability.

Nowadays most countries are used a combination of fossil fuels, nuclear fuels and renewable energy, whereas, before the industrial revolution, human societies were largely dependent on renewable energy sources such as solar energy which was used to heat, cool and light homes and also wind, water and wood were another source of energy (QSEIDG, 2004). Suharta (2006) clarified that energy can contribute to the three sustainable development pillars: economic, social and environment. However, since one solution does not fit all, the local context (political, social, technical and economic) should be taken into account for all energy involvements.

5. Ghadames- Introduction and Location

As shown in map (1), Ghadames is a town located in a Saharan oasis at the point where the borders of three Arab countries meet: Algeria, Tunisia and Libya. It is located about 620 km southwest of Tripoli in the desert region, its geographical co-ordinates are: 30°08’ latitude north and 9°30’ longitude east. (Chojnacki, 2003).

Ghadames is recognized for its beautiful and creative architecture, designed to fight the harsh desert climate. The present old town is probably 800 years old; it is often called "the jewel of Sahara", and was in 1999 added to the UNESCO World Heritage List, as one of five places in Libya (Kjeilen, 1996).

Map. 1 the location of Ghadames
Source : www.worldsurface.com/images/maps/libya

5.1. The Climate

The climate in the Libyan Desert and semi-desert region generally, is dry and hot in summer. In winter, it is mostly very arid since there is rarely rain. By reviewing the literature, the authors notice that there is no accurate data, the average humidity is 20% to 59%. The minimum average temperature in January is 2.1C° and the maximum average in August is 40.2C°. The winds in this region are southerly and in summer and spring, they are hot and dusty while in winter and autumn, the area experiences northerly winds.

Ahmed (1985) confirmed that and illustrated the most monthly and hourly periods of climate as shown in Fig. (2). Also Chojnacki (2003) has noted that temperatures of over 50.0°C have been recorded. Ghadames rises about 340 to 370 m above sea level. Relative humidity of the air ranges from 72% in winter to 17% in summer. The average monthly climate indicators in Ghadames based on 8 years of historical weather readings cited by climate-zone.com are shown in table (1). As can be seen in the (Figure 2 and Table 1), the maximum average temperature during (1985 to 2007) has been increased from two to three degree in most months.

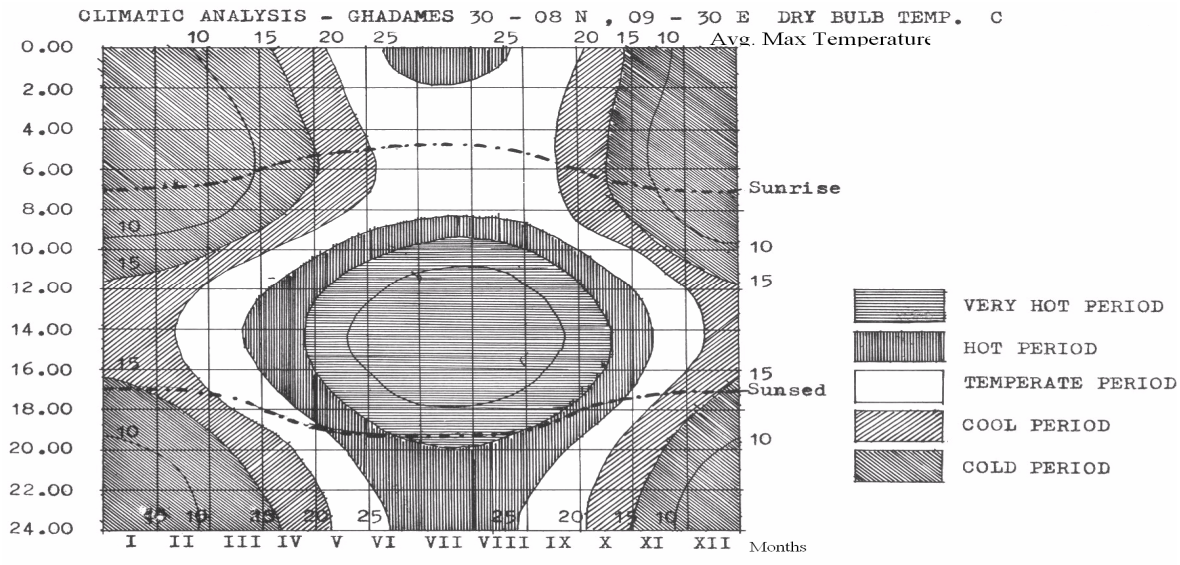


Fig. 2. Shows the hourly climatic analysis during a year (Source author cited from Ahmed 2003)

Table 1: displays the average monthly climate indicators in Ghadames
http://www.climate-zone.com/climate/libya/fahrenheit/ghadames.htm

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temperature	*11*	*13*	*18*	*22*	*28*	*32*	*33*	*33*	*31*	*23*	*17*	12
Avg. Max Temperature	*17*	*20*	*25*	*28*	*35*	*39*	*41*	*40*	*37*	*30*	*24*	18
Avg. Min Temperature	*5*	*7*	*11*	*15*	*21*	*23*	*25*	*26*	*24*	*17*	*11*	6
Avg. Rain Days	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	0
Avg. Snow Days	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	0

5.2. The Characteristics of the City Form

The architecture of the old city in Ghadames (map, 2) is well adapted to desert life. It includes an almost unique system of covered streets with formally arranged squares, to bring together the compact form and reduced exposure to the sun and the proved complete privacy of family life and suitable conditions for social (Chojnacki, 2003, Azzouz, 2000).

In order to create a comfortable internal microclimate, traditional architecture in Ghadames, responds to the harsh desert climate through: protection, modification & adaptation. Protection from extreme solar radiation, high temperatures and dusty wind, then modifying and adapting to these harsh conditions, through sensitive and conscious solutions, construction technologies and well-studied planning and design by using suitable building materials of certain thermal properties that corresponded to the ambient environment (Al-Zubaidi, 2002).

El-Fortea (1989) described the building composition as firmly grouped together and constructed vertically rather than spreading out horizontally. He explained that a tight cluster of houses creates its own cooling system by keeping the streets free from direct sunlight and maintaining the temperature at relatively modest levels, even on the hottest summer days. The small windows located in the narrow gaps between houses help to draw in cool air from the openings and the house entrance which, in turn, cause a movement of cool air in the streets, providing in this way, an almost ideal ventilation system.

The main principles of shaping the old part of the town and the nature of the traditional housing construction are;

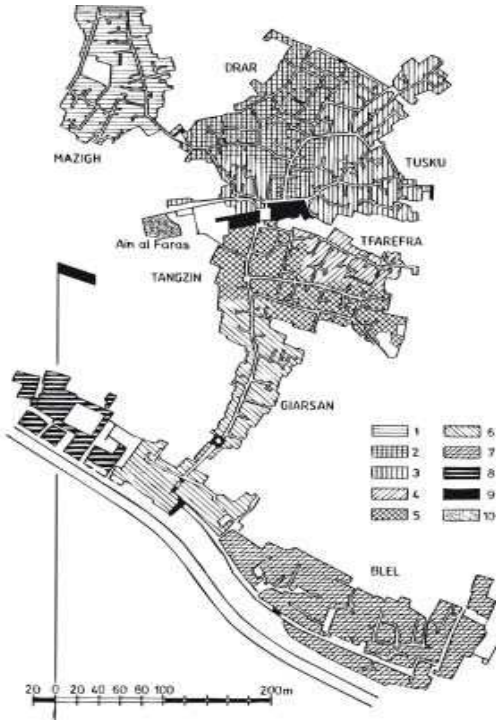
- Compact urban fabric fig(3):
- Covered streets fig (4):
- Narrow passageways :
- Exclusively design houses:
- Building materials and construction.

These principles help to minimize the thermal load on the building envelope and provide comfortable conditions even in the summer time. The streets are also built in a way which makes it possible to maintain a favorable microclimate, functioning together with the buildings as a single, compact structure to keep the temperature and the humidity of air at a satisfactory level fig (5). In addition to reduced exposure to the sun, it provides full privacy of family life and suitable conditions for social life.

The normal streets are used by men fig (6), whereas the roofs are used by women for general circulation. According to that the height of roofs to the entire city remains the same and reaches 10m. According to Al-Zubaidi, (2002) the design of the streets was adapted as one of the most important planning solutions in desert cities because the streets, ventilated and lighted from frequently small openings each 15 m which makes different pressure zones, the air movement from high-pressure zones to low pressure zones, where the hot air is replaced with cooler and humid air in the shaded passageways.

Fig. 3. An over view of Ghadames old city

Fig. 5. Top view perspective for the city of Ghadame



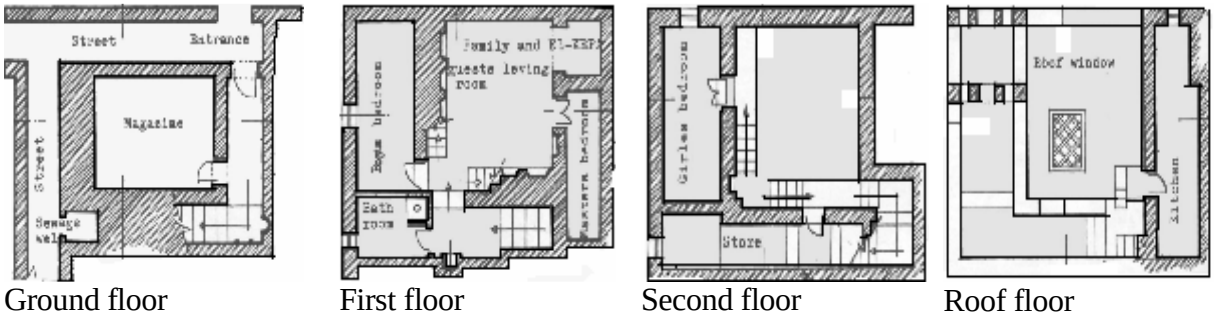
Map .2. Ghadames - plan of the old town
Source (Chojnacki, 2003)

Fig. 4. covered streets Fig. 6. meeting spaces
Figures (3,4,5,6) source (Almansuri, 2000)

5.3. Type of traditional housing

Houses are attached by two or three sides. They comprise of a number of spaces extending on three levels. Men used the first floor and women lived on the top where they could meet each other or call across the roofs in complete privacy from the men, also they could use the roads located at ground level when they needed to. Figure (7) illustrates the design concept of one of the old city houses which includes four levels. The ground level consists of the man entrance, lobby, storage area (which receives ventilation from the entrance door), a small space for sewerage located under the toilet (open only from outside towards the green areas) and stairs leading to the toilet which is located between the first and second floor. The first floor includes the main central hall known as the '*Sadr el-beit*' used as a living and guest area and leads to other bed rooms and storage areas in different levels. This hall is often characterised by an artistic masterwork with brass pots, plaited fabrics, and mirrors to reflect the light Fig.(8). The hall is more than 4m high Fig. (10) and includes a sky-opening centered in the ceiling with a maximum area of 1m square for supplying light and ventilation Fig. (9). The open roof/terrace is used to prepare meals and also to sleep during summer nights.

The upper level of the house mostly forms an open terrace; it includes high walls to provide privacy and help in circulating the air, this area is kept for women's use for two reasons. Firstly, because all dwellings' roofs are connected, women can move freely from one house to another through these connections Fig (5), and secondly, the kitchen is located on the upper floor (Daza, 1982).



Ground floor First floor Second floor Roof floor
Fig. 7. Plans of a typical house in Ghadames- Libya (Source author cited from Ahmed 2003)

Fig. 8. Shows the interior space

Fig. 9. Shows the roof opening

Figures (8,9,10), source (Almansuri, 2000)

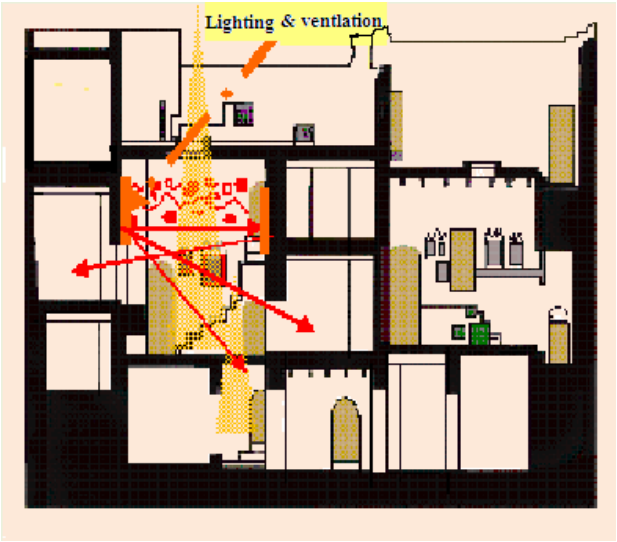


Fig. 10. Longitudinal section in Ghadames's houses shows the different levels and the concept of lighting and ventilation.

5.4. Building materials and Construction system

The primary elements in the construction of the dwellings are the local available materials.

Building elements of walls and roofs had sufficient thermal resistance. They consist of heavy, thick walls of mud, stone and hay that were composited, shaped in blocks and seasoned for over a period of a year (Azzouz, 2000). According to Daza (1982) the main material for walls was 'sun dried brick' which was made out of earthy clay mixed with water, formed in a rectangular wooden frame and then dried in the sun. Corresponding to wall thickness, the size of the bricks is measuring (0,60x 0,40) m in the ground floor, (0.50x 0,40) m at first floor and (0,40x 0,40) m at top floor (Al-Zubaidi, 2002).

Walls, arches and vaults were built using the clay as a mortar to connect the courses of bricks together. Stone was used as a foundation and some times used in the parapet wall fig. (11). They used the palm trees as the beams for roofing fig. (12). and to make doors and shelves fig. (13). Branches of the palm tree were used as a flooring surface which was then covered with palm tree leaves; they also were used as a base for roofing substances, such as clay mixed with sand and small pieces of stone, a surface was then plastered and finished with limestone white wash fig. (14).

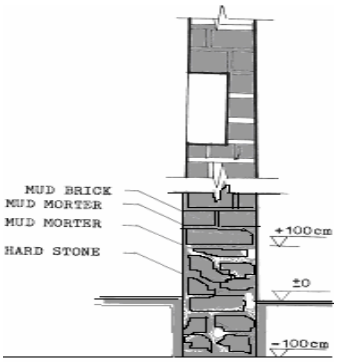


Fig. 11. The wall and foundation Source (Ahmed, 1985)

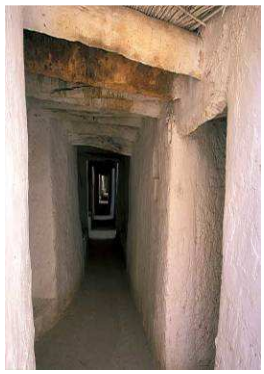
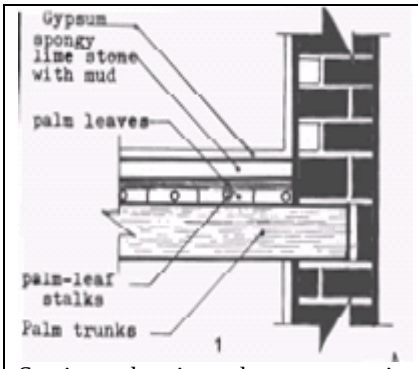


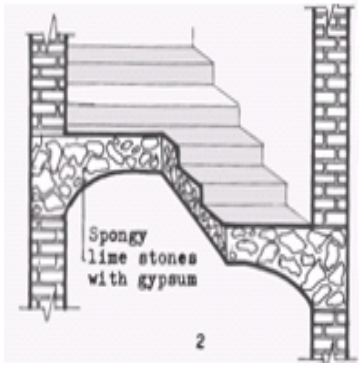
Fig. 12. The roof materials

Fig. 13. Door materials

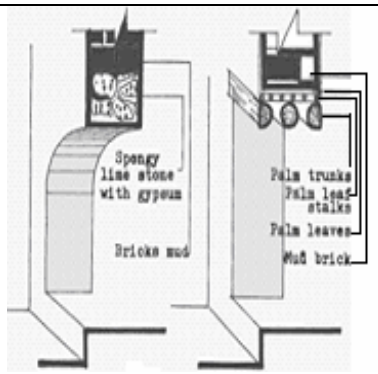
Figures (12, 13) source (Almansuri, 2000)



Section showing the construction building and how it was constructed



Isomtrical section showing the Staircases construction



Isometrical section showing the two methods of the lintels construction.

Fig. 14. Shows the building materials and method of construction source author based on (Ahmed, 1985)

5.5. Thermal Performance of traditional Building

To achieve optimum comfort and energy savings, the building envelope should integrate design of building form and materials as a total system and the way they will operate towards the heat transference through it and modify the internal climate of the building in reaction to the external climate. In Ghadames, the effects of the variation in outside temperatures and extreme solar radiation are the most clear climate conditions that affect on the interior of a building (Al-Zubaidi, 2002). Ahmed (1985) found that the thermal comforts inside the old houses in summer and winter times as shown in fig (15) were always temperate.

An article about an investigation into thermal comfort in the summer season of Ghadames, Libya by Ealiwa et al. found the results of the survey that the occupants have an overall impression of higher standards of thermal comfort in old buildings than in new buildings (Ealiwa, 2001).

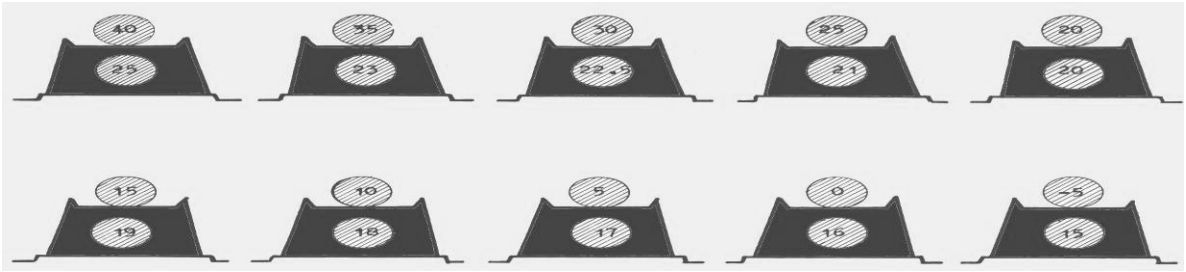


Fig. 15. The difference in temperature inside and outside Gadames old houses (Source:Ahmed, 1985)

6. Results

This paper concludes that the architecture of the old city of Ghadames is well adapted to desert life as shown in fig. (16). and succeeding to provide a sustainable environment according to its characteristics which will illustrate as follows;

- Achieving comfortable living space in a cruel climatic region.
- Producing strong social bonds and representing a clear expression of the socio-cultural requirements.

- Providing protection from the heat and sun for those out in the street and improving the circulation of air in houses by covered and winding some streets which led the wind moving fast.
- Using Local materials.
- The design of the house reflects the expected modesty between males and females through their complete separation.
- The layout provides visual privacy from outside and allowing members of the household to be in contact with outside through the roofs.

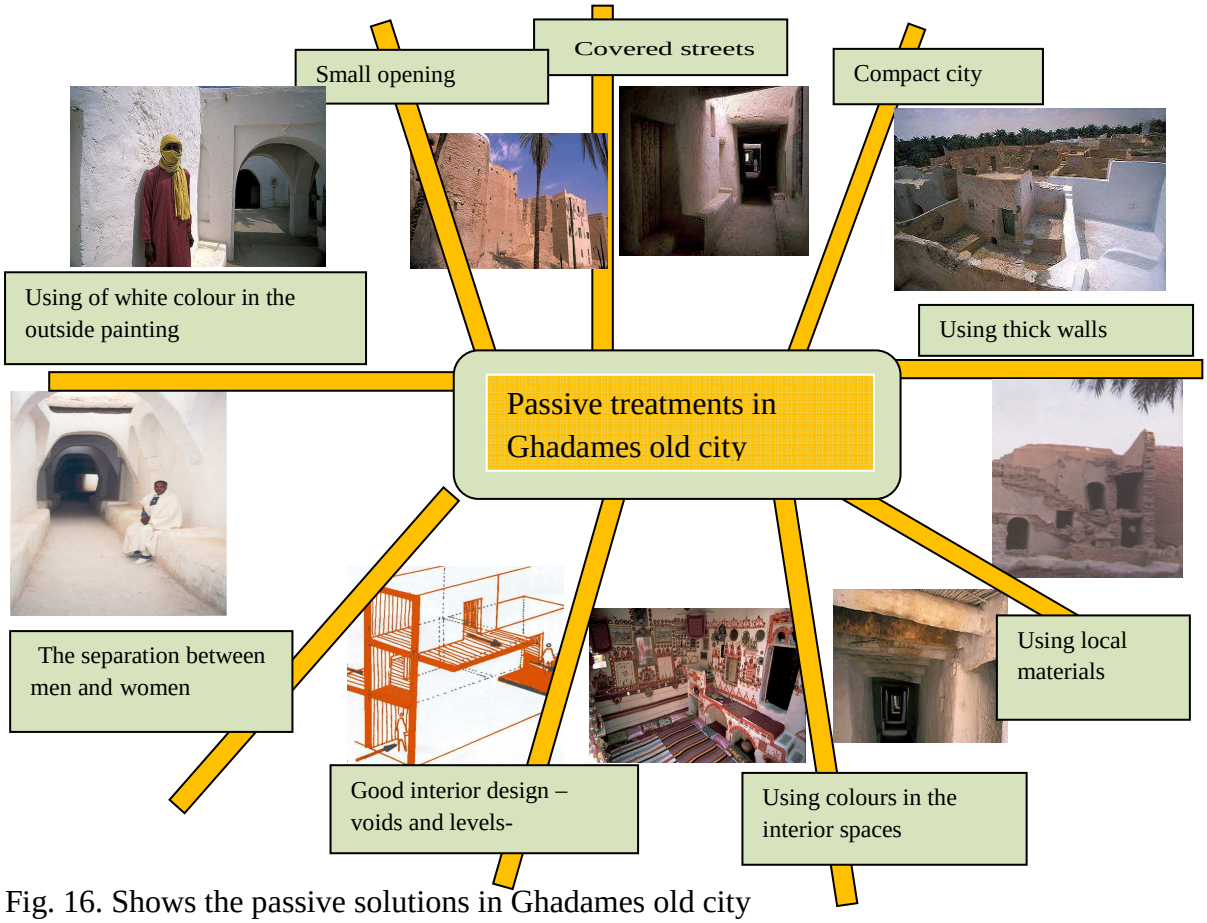
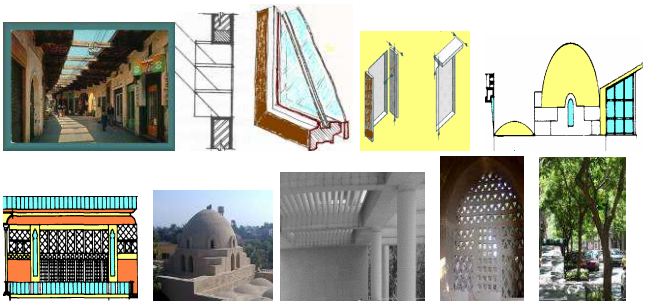
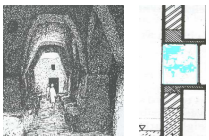
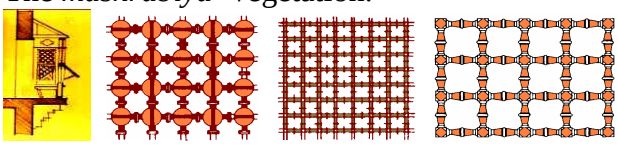
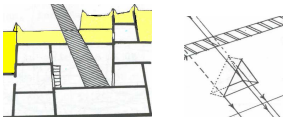
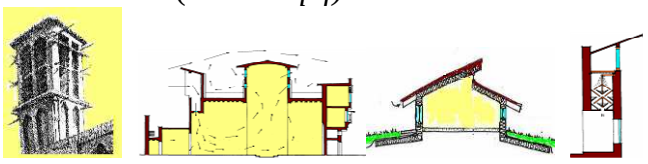
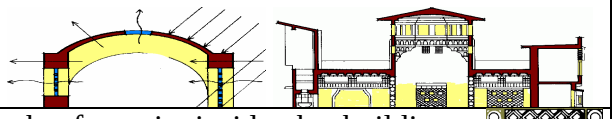
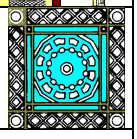


Fig. 16. Shows the passive solutions in Ghadames old city

7. Discussion

As it has been stated in section (6) the results shows that how people before many centuries could adapt their buildings to a harsh climate, However, according to the changes in life style, improvement in building materials and development of building technology, these solutions (as it is) can not meet the nowadays human needs, but lessons still can be learned from vernacular architecture and these solutions can be improved to meet today's needs as shown in Table 2.

Table 2: Design strategies in hot arid regions

The problems	Traditional solutions	Proposed solutions
protection from the heat and sun-	Compact city – covered streets- small openings- bright colours- Thick walls- Local materials 	Shading devices and vegetation to shade streets- The proportion between buildings heights and streets width- bright colours double glazing small openings- Sun-breaker- Arching the roofs - Shading the roofs- Improving the local materials and using thermal insulation- 
protection from dust	Compact city – wood shutter . 	wood shutter on small openings -ventilation blind The *mashrabiya*- vegetation. 
ventilation	Roof opening- the staircase-small opening in the covered streets 	Improve the roof opening -The position of the small openings- The staircase – *Windcatches* (The *malqaf)* 
Lighting	Roof opening- small opening – the staircase – using mirrors and metal – bright colours	Improve the roof opening -The position of the small openings – bright colours- using mirrors and metal 
Humidity		Use the fountain inside the buildings and in the open spaces. 

8. Conclusion

Because sustainable development and approaches intended at reducing environmental impacts and increasing environmental performance are become a very important issue, organizations should look forward to them.

Since the early times, while designing or constructing the buildings from the very different areas of the world, man has used the ideas from nature and has interpreted the objects and structures in nature through their cultures. The signs of the nature can be seen from Ghadames old city. One of the main conclusions of this study is that some concepts and methods that have been used for conception planning and environmental control can be learned and re uses it in future environmental planning.

The paper explains that Ghadames traditional houses can provide a desirable microclimate the whole year round without special air conditioning devices. It has confirmed to be most successful and appropriate in these conditions, by providing its own ventilation and insulation system through the structure of the buildings which is compact and integrated into the hole context in which it is hardly to make a distinction the individual houses.

This paper shows to what expand the local architecture in Ghadames respected the nature, and gives the best examples of the most environmental architecture related to time and place. It has managed to adapt to the climate with considerable success and lessons should be drawn from it in forming recommendations for future.

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