Investigating the intelligence of the low-tech earth architecture of the Sahara: A feasibility study from the western desert of Egypt

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RESEARCH ARTICLE

Investigating the intelligence of the low-tech earth architecture of the Sahara: A feasibility study from the western desert of Egypt

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Traditional building techniques such as earth construction have withstood the test of time. Its effectiveness and intelligence in responding to the socio-cultural and climatic context of many regions across the world have been well demonstrated. This article is concerned with the technical and social factors that led to the decline of this intelligent-architecture approach in the Sahara desert. The article investigates the potential and constraints of reintroducing earth construction architecture in four of the six western desert oases as case studies. These oases form the New Valley Governorate of Egypt: Baharia, Farafra, Al-Dakhla and Al-Kharja. Two field studies were undertaken. The first took place during a research trip that included Cairo, Giza, the four oases and Luxor, while the second was conducted in Al-Dakhla only. The results suggest a strong possibility for reusing earth architecture in the four oases from the environmental point of view. However, a number of limitations were identified – durability, buildability and the attractiveness of the mud architecture to the locals. Validation of the results and addressing those constraints are the focus of future work to assess the thermal performance of vernacular and modern case studies in the oases under investigation.

Keywords: earth architecture; Egypt; mud; oasis; Sahara

INTRODUCTION

Earth construction techniques have been in use in deserts around the world for thousands of years. Mud or clay was traditionally used in different ways as a building material. Earth is layered in formworks forming walls, as in rammed earth buildings, or shaped into rectangular forms of different sizes to produce blocks that are then sun-dried, fired or compressed to form green or unbaked adobe, fired bricks or compressed air blocks, respectively. Using mud as a building material has advantages and disadvantages. On the one hand, mud has weak resistance to water and may shrink after drying causing cracks. On the other hand, it is an environmentally sustainable material. In most cases it is sourced locally. Its production,

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installation and maintenance consume low levels of energy compared with modern construction materials and techniques; hence its low embodied energy. The heavy thermal mass, a common characteristic of earth buildings, compensates for the low heat resistivity of the mud walls by dampening the temperature troughs and peaks, leading to a substantial reduction in energy use. In addition, an earth wall absorbs moisture from the air which creates a humidity balance inside the building. Mud is also an economically sustainable building material. In developing countries, the cost of a medium-sized house built of mud is considerably lower than the same size house built with reinforced concrete and fired bricks. This is an important factor in developing countries where resources are limited and the need for basic shelter is considerable. All this makes it intelligent from the economic and environmental perspective.

Deserts occupy about 25 per cent of the total land area of the Earth (Ezcurra, 2006). Global climate change, overgrazing, drought, and the rapid change of the socio-economic patterns of the pastoralists are all factors leading to desertification around the world. It is possible that the southern Sahara and the Sahel region are suffering more than some other desert regions. The Sahara (a word derived from the Arabic word *as-sahrā'* meaning wilderness) is the world's largest desert with an area of almost 9.1 million square kilometres (Allaby and Garratt, 2006). It is formed of several deserts, distinct in nature and landscape (eastern, central, southern, northern and Atlantic Sahara), covering the whole of northern Africa. It stretches from the Atlantic Ocean in the west to the Red Sea in the east, and from the semi-arid Savanna (the Sahel belt) in the south to the Mediterranean Sea in the north. It fully covers several countries: Mauritania, Morocco, Algeria, Tunisia, Libya and Egypt, and partially covers Sudan, Mali, Niger and Chad. The majority of these countries are members of the Arab League where the Sahara is known as The Great Desert (Arabic: *as-sahrā' al-kubra*). As a result of several factors, the area of the Sahara is expanding annually to the south taking over the Sahel.

The western desert of Egypt (western desert will be used hereinafter to describe the Egyptian western desert) constitutes a substantial part of the eastern desert of the Sahara. It was chosen as a geographical limit of the work presented in this article. A number of communities were visited to explore traditional earth architecture and its techniques in use.

RESEARCH CONTEXT

Egypt occupies the north-east corner of the African continent. It is bounded by the Mediterranean Sea to the north, the Red Sea, Israel and the Gaza Strip to the east, Libya to the west and Sudan to the south. Its total area is just over 1 million square kilometres. Only 4 per cent of the land is inhabited and the rest is hot arid land divided into seven climatic zones. The desert to the west of the Nile Valley is known in Egypt as the western desert (Arabic: *as-sahrā' al-gharbia*). It covers two-thirds of Egypt's total area. It stretches from the Mediterranean Sea in the north to the Sudanese borders in the south (Figures 1 and 2). The western desert is characterized by arid climatic conditions with extremely high temperatures and almost no rain and a high diurnal difference throughout the year that ranges between 15.3°C in September and 17.7°C in April. According to the Egyptian Meteorological Authority (CARMS, 2006), the average maximum temperature in Siwa in the north of the desert ranges between 19.5°C in January and 37.9°C in July, while the average minimum temperature ranges between 5.2°C in January and 21.4°C in July. The temperatures increase towards the south where the maximum temperature in Al-Kharja reaches 45.6°C in July and the average minimum temperature ranges between 5.9°C in January and 23.7°C in July.

Figures 3–5 illustrate the average monthly ambient temperature, mean irradiance of global radiation horizontal and the stereograph diagram of Al-Kharga. Average ambient temperature ranges from 14°C in January to 33.4°C in July. However, mean irradiance of global radiation horizontal ranges from 196 W/m^2 in January to 358 W/m^2 in June. Al-Kharja receives some rainfall

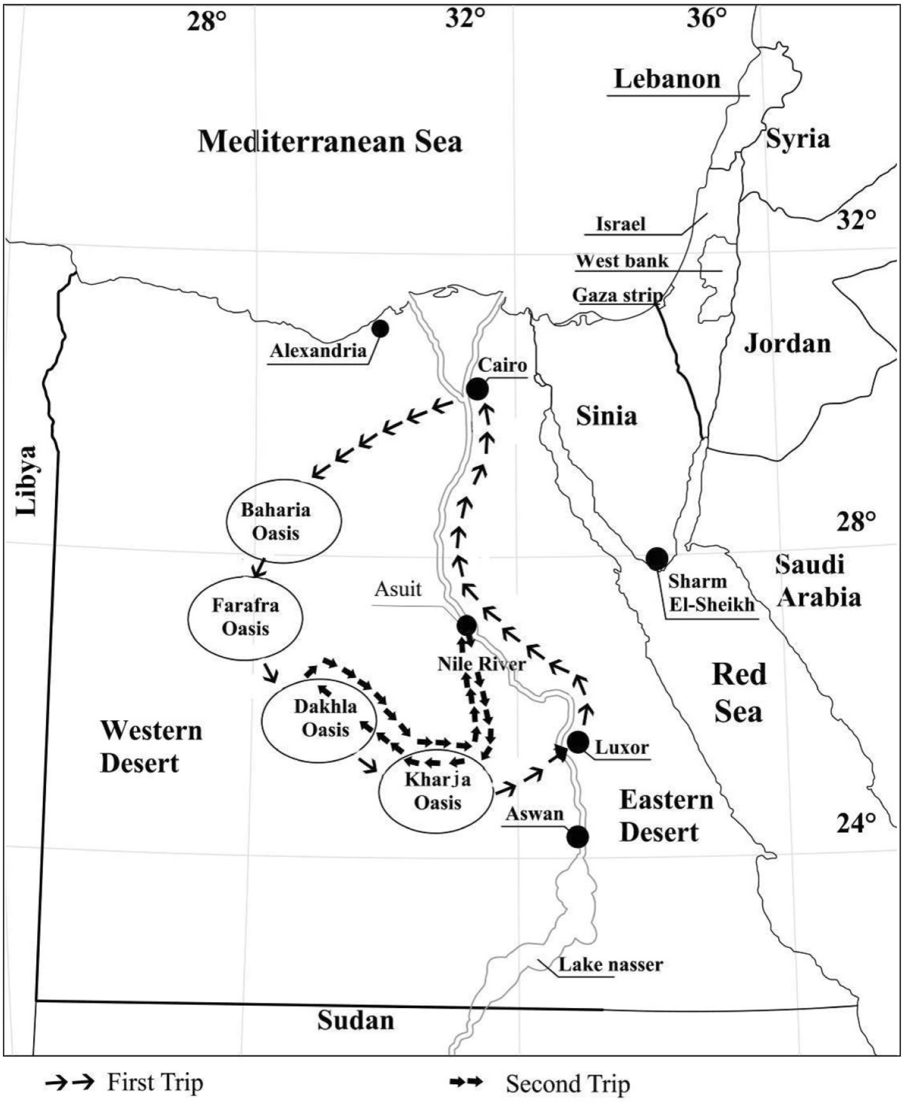

FIGURE 1 The routes of the two trips through the western desert of Egypt

during January and December but it does not exceed 0.2 mm/month. These weather conditions lead to a harsh environment characterized mainly by aridity, high summer daytime temperature, large diurnal temperature range, and high solar radiation. These regions are dominated in all months by the subtropical anticyclone, with its descending air, elevated inversions and clear skies.

EARTH ARCHITECTURE AND ITS CONSTRUCTION TECHNIQUES

Ancient Egyptians used 11 types of stone, as well as sun-dried clay-rich Nile mud, to build their sacred monuments and houses. Mud has continued to be used in Egypt as a building material ever since. Most Egyptians were living in mud houses before 1952 (Encyclopaedia Britannica, 2007).

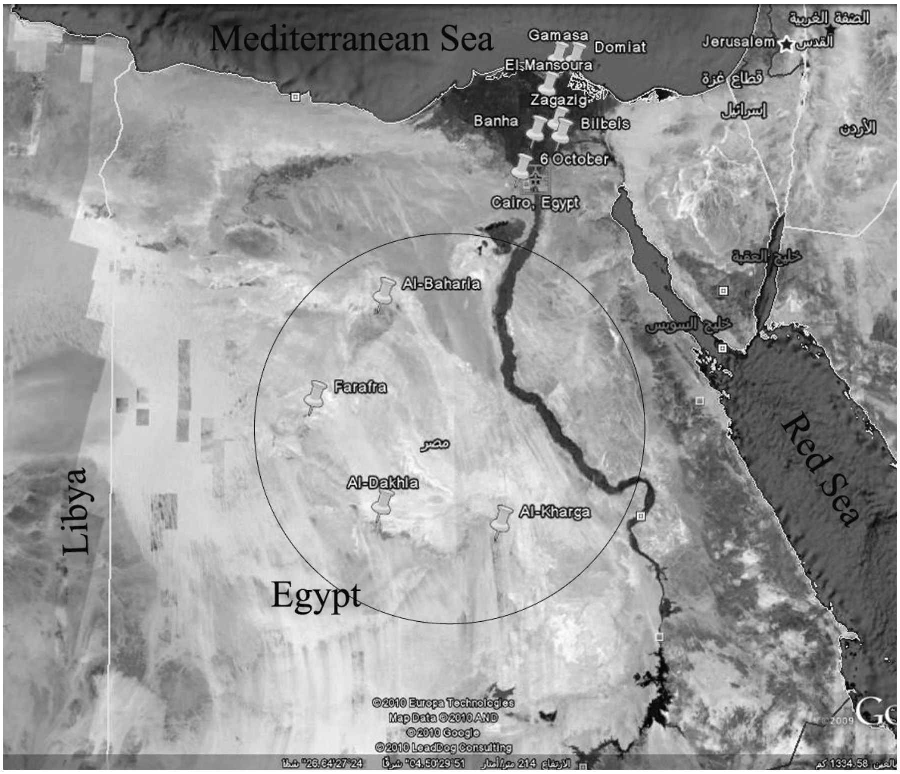

FIGURE 2 The western oasis of Egypt (source: Google Earth)

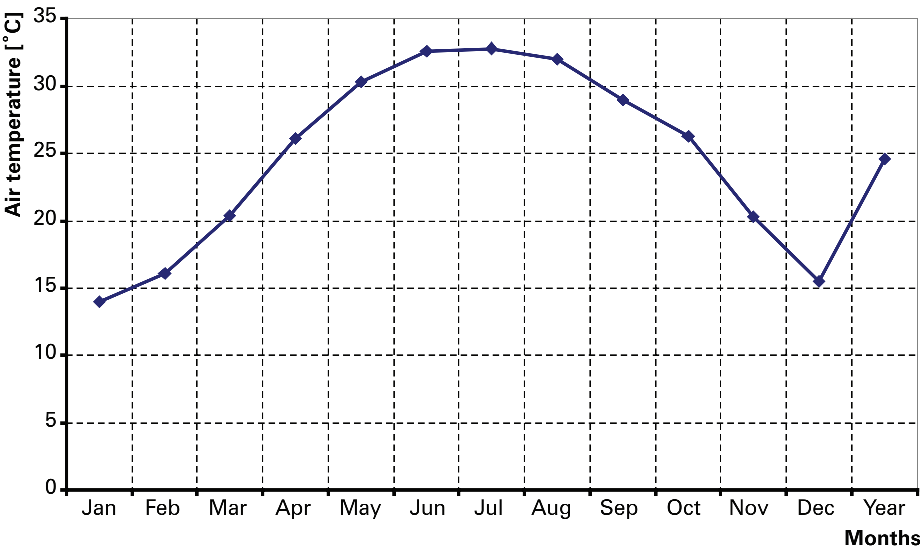

FIGURE 3 Average monthly ambient temperature in Kharga (US Department of Energy, 2006)

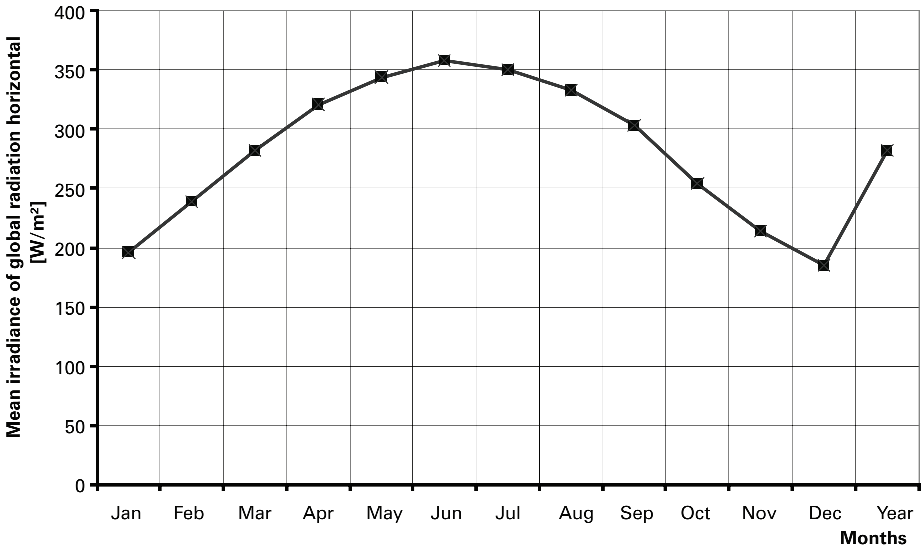

FIGURE 4 Mean irradiance of global radiation horizontal (US Department of Energy, 2006)

While earth construction techniques are being developed in industrialized countries, and other developed countries such as France and Germany, modern building techniques using mainstream materials and technologies such as reinforced concrete and fired bricks have widely replaced earth construction throughout Egypt. The western desert is no exception, with buildings being built using similar techniques to those used in the Nile Valley cities, despite the difference between the two environments.

Medieval mud villages in the western desert are characterized by a compact urban form with narrow, winding, shaded streets as shown in Figure 6. Al-Dakhla, for example, was divided into zones; each encompasses the houses of an extended family sometimes with large open areas for meetings and festivals. The ownership of land and the nature of social relations traditionally dictated the urban development of the villages. Most of the houses were attached on two or three sides with some buildings built around small courtyards. Some houses were built up to four storeys high using silt and timber. Smaller houses used mud bricks (60 x 100 x 200 mm) made of surface soil mixed with fine sand and straw (known locally as *tebn*). Walls were then rendered with silt.

It is believed that several technical, social, economic and political factors had recently played a significant role in causing traditional urban forms and the unique mud architecture of the western desert to diminish. The majority of locals we interviewed expressed fears that this is changing the nature of the social structure of their communities and is changing the way in which the relationships among their community members develop. This article explores the factors that have affected the use of intelligent earth architecture in four of the western desert oases – Baharia, Farafra, Al-Dakhla and Al-Kharja.

The two most prominent architects who had developed traditional earth architecture in Egypt were Hassan Fathy and Ramses Wissa Wassef. Fathy pioneered modern earth architecture in Egypt in the early 1920s. After he died, several architects followed him in adopting the construction technique such as Abdel-Wahed El-Wakil, Ahmed Hamed, Rami El Dahan, Hany El-Menyawy and Gamal Amer.

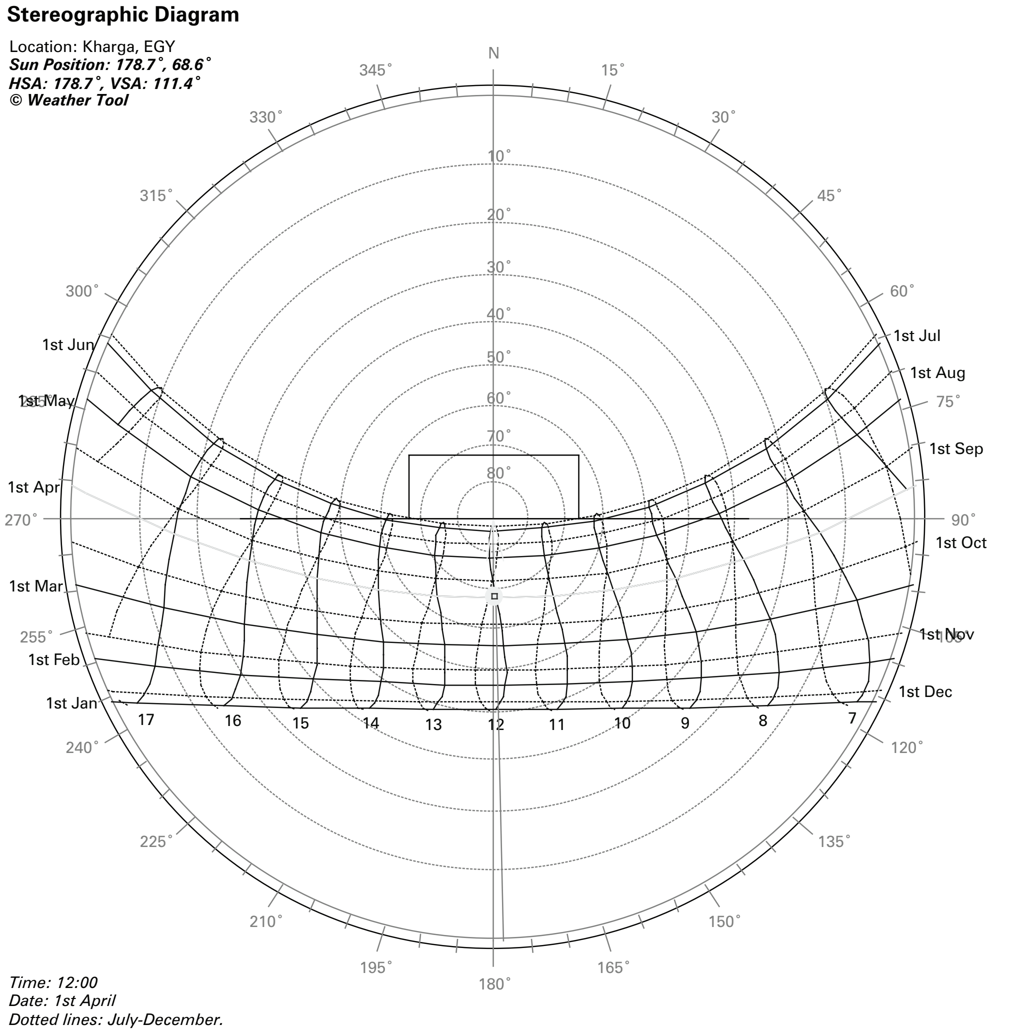

FIGURE 5 Stereograph diagram of Kharga (US Department of Energy, 2006)

RESEARCH PROBLEM AND PREVIOUS WORK

The problem at the heart of the current research presented in this article is that the use of earth architecture, techniques and materials that have the potential to provide a large number of Egyptians with much-needed decent shelters is declining across the country. The western desert is one of the regions where earth architecture was used for hundreds of years. Economically and environmentally unsustainable reinforced concrete construction techniques are widely used instead. In the harsh climate of the desert, the thermal performance of concrete houses is expected to be poor compared with that of the earth buildings. A review of literature revealed that little is known about the potential and constraints of using earth architecture, materials and construction techniques in Egypt including the new valley where the traditional precedents of mud building

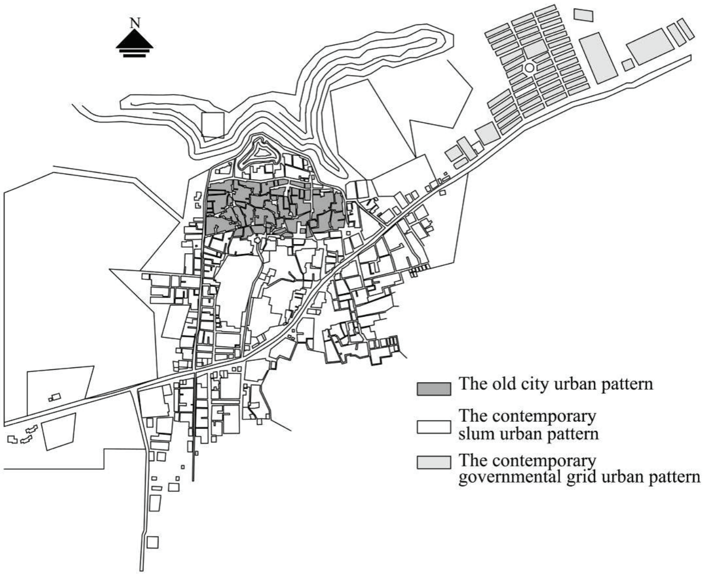

FIGURE 6 Old and new urban pattern in Al-Qasr, Al-Dakhla (Saaid, 2004)

can set a good example for the future development of intelligent earth building technology.

In an attempt to investigate the effect of building material and form on the environmental performance of interiors, Fathy used two case-study buildings of the same volume in Cairo (Fathy, 1986). The first was constructed with 500 mm thick earth walls and covered in mud vaults. The second was constructed with 100 mm prefabricated concrete walls covered with a concrete flat roof. The internal air temperature was logged inside both spaces.

Analysis of the results revealed that the performance of the earth construction house was superior to that of the concrete house. The variation in internal air temperature in the concrete house reached 16°C, whereas temperature variation in the mud house was only 4°C. Further analysis of Fathy's results found that the internal air temperature in the earth construction house fell within the comfort band throughout the whole day, whereas it was outside the comfort band for 66 per cent of the time in the concrete house, as shown in Figure 7. The contrast can be explained by the fact that concrete has a thermal conductivity of 0.9, whereas that of mud brick is 0.34, and the mud-brick wall is five times thicker than the prefabricated panels. Thus, the mud-brick wall has a thermal resistance more than 13 times greater than the prefabricated concrete wall (Fathy, 1986).

Several investigations into the revitalization of traditional building technologies in Egypt in terms of construction methods, materials and architectural character followed Fathy's work. Elnokaly and Elseragy (2006) investigated the revitalization of traditional curved roofs in Aswan city which represents the hot-dry climatic zone. They studied the relationship between the intensity of the absorbed incident solar radiation and the geometrical configuration of the roof. They confirmed that the orientations of a curved roof have a significant effect on the amount of absorbed incident solar radiation; the curved roofs also seemed to be more energy efficient. When comparing absorbed daily average incident solar radiation, a vaulted roof on a north-south

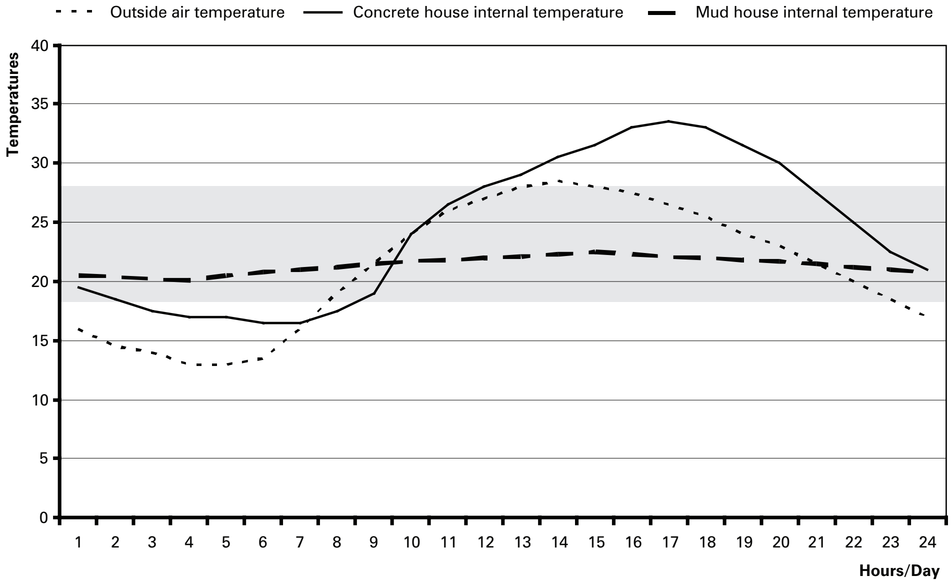

FIGURE 7 The internal air temperature in earth construction and concrete buildings (Fathy, 1986). The grey area is the comfort band of Cairo

orientation receives 33.7 per cent less radiation than a flat roof, and hence the required energy for cooling the space under a vaulted roof is less than that required for cooling the space under a flat roof.

Iscandar (2006) discussed how the character of design derived from traditional Egyptian techniques could support the demands of modern requirements. He presented some neo-vernacular case studies of Michael Graves, Hassan Fathy and Ramses Wissa Wassef. Iscandar suggested that those examples show respect to the site, the natural environment, the climate and were successful in mixing traditional aesthetics with contemporary technology and requirements. Uehuawi (2006) looked into the reintroduction of courtyards into contemporary architecture in Egypt. This work asserted that the new building regulations were one of the most important reasons that negatively affect the possibility of building courtyards. It also confirmed that the provision of movable shading devices in courtyards, taking into consideration vegetation features and aesthetics, could enhance the environmental performance of the courtyards. Other researchers (Nassar, 1988; Mandour et al., 1989; Hamdy and Fikry, 1998; Klemm and Klemm, 2001; Thomas et al., 2006; Emery and Morgenstein, 2007) have looked into earth construction from geochemical, historical or structural points of views. Filippi (2006) analysed the main characteristics of the urban pattern and building typologies of traditional earth architecture in two settlements at the Al-Dakhla oasis – Al-Qasr and Balat. He aimed to understand the local context of those medieval villages and how they adapted to the harsh climatic conditions of the western desert in order to establish appropriate conservation strategies. He confirmed that earth architecture and its construction techniques can intelligently achieve the required adaptation to the harsh climate of the desert with the participation and support of the local communities.

RESEARCH METHODOLOGY

Data were collected from the field during two study trips to the western desert in Egypt conducted during October 2006 and April 2007. The first field trip started at the south-western outskirts of Greater Cairo city, going through Giza and the 6th of October Governorate, and then through the western desert stopping at Baharia, Farafra, Al-Dakhla and Al-Kharja oases. The second field trip started at Sohag, going through Assiut and ending up in Al-Dakhla. Figure 1 shows the routes of the two trips. The team visited the old mud villages of Al-Farafra (*aser el farafra*) and Al-Dakhla (*el-aser*). The visit also included Bader museum in Al-Farafra built using traditional earth construction techniques by the 'natural artist', teacher and mud-building enthusiast Badr Abdel Moghny. The visit also included Desert Lodge hotel, a modern tourist resort to the north-west of Al-Dakhla old village. Several concrete dwellings of different sizes were also visited.

Interviews aimed to explore the potential and constraints of reusing earth architecture, its construction techniques and materials throughout the oases from technical, environmental and social points of view. Eighteen in-depth semi-structured interviews – over the two trips – were conducted with locals from four oases to discuss their opinions and experiences in relation to earth architecture. Each interview during the first visit used a maximum of 15 open-ended questions chosen from a list of 29 questions covering issues grouped into the following eight categories:

- need for privacy;
- sense of neighbourhood;
- visual distinction between private/public;
- private/public thresholds;
- site response;
- social values;
- environmental features;
- transportation.

Interviews conducted during the second trip included open-ended questions covering the same issues as in the first field trip interviews. All the interviewees were chosen randomly from different age groups and social backgrounds including drivers, porters, government employees and a Muslim cleric. All the interviews were videotaped. Transcripts were later translated from Arabic and analysed.

TRADITIONAL EARTH ARCHITECTURE AND ITS TECHNIQUES VERSUS MODERN CONSTRUCTION TECHNOLOGY

Date palm and desert clay are found in abundance across the New Valley oasis from Siwa in the north to Al-Dakhla and Al-Kharja in the south:

> *Besides the fruit … the date palm over the centuries … provided [the people of the desert] with a large number of other products which have been extensively used … in all aspects of daily life [including construction] … Practically all parts of the date palm, except perhaps the roots, are used [in construction] for a purpose best suited to them. (Barreveld, 1993)*

High-quality clay such as Baharia clay, Farafra clay and East-Oainat clay can be acquired without much difficulty (HBUPRC, 2001). One informant said:

> *Everywhere in the desert you can find clay and sand. You can use them to make adobe without even having to use manure or straw [as stabilizers] and use the clay as mortar.*

Traditionally, mud buildings in the western desert are built using sun-dried adobes known locally as unbaked or green bricks (*el-toob el-nay*) and, in some cases, stone is used for the foundations. Timber from several kinds of local trees is traditionally used as horizontal structure elements in the roofs and as wall ties, as well as doors and window frames, sill and lintels.

To produce green bricks, subsoil clay is excavated manually, mixed with water, kneaded and stirred to enhance binding between the elements used. The mixture is then thrown into a wooden form and left to dry in the sun. Different types of additives are usually used to modify the characteristics of the loam being used. Straw (known locally as *kash*) is added to the mixture to increase the binding forces of the mixture, decrease the shrinkage ratio and reduce the appearance of cracks. Minke (2006) suggested that adding straw also enhances the thermal insulation properties of the mud. Minerals and animal manure is used to stabilize loam against water erosion and to enhance the binding forces. In the New Valley, readily available chemical fertilizer (sodium phosphate [Na_3PO_4], sodium nitrate [Na_2NO_3], ammonium nitrate [NH_4NO_3] and potassium nitrate [K_2NO_3]) are used. Walls are then plastered with a paste of mud and straw mixture.

The ceilings and roofs of mud buildings in the oases, as in other parts of rural Egypt, were traditionally supported by timber beams produced from three types of local trees. These are the camphor tree known locally as the *kafoor* tree (*Eucalyptus legatensis*), the casuarina tree known locally as *gazwarin* tree (*Casuarina equisetifolia*) and the date palm known locally as *nakhel* (*Phoenix dactylifera*). In some cases, cupressus trees known locally as *saro* were used, but mainly for windows and door frames.

In the oasis, the most common type of timber used for beams is from date palm trees. The trunk of the palm tree is split into two halves, each is known locally as a *felag* (in the plural, *ef'lag*) which are then put with the longer width perpendicular on the walls, used as shown in Figures 8 and 9. Beams are covered by hand-woven canvas made of date palm leaf midribs or stalks known locally as *greed* (singular, *greda*). The stalks are traditionally tied together using handmade ropes made of shredded date leaflets or sheath fibre from the leaf base known locally as *leaf el-nakhl*. The robes were usually made on site in a process known locally as *fet'el*. But recently, readymade flax, kenaf, cotton or jute ropes have been used instead to speed up the process and save the cost of the worker hired to make the ropes on site. The canvas is then covered with date palm reeds known locally as *za'af* and a layer of sun-dried mud bricks is laid on top to increase the stiffness and water erosion resistance of the roof. The bricks are then covered with a clay paste to enable the roof to be used for sleeping and other activities. Recently, a polyethylene water barrier has been put under the brick layer to further protect the roof from water leakage caused by occasional rain.

FIGURE 8 Using palm trunks and leaves in roofs

Openings in the walls are relatively small and sometimes comprise decorative brick units or are fixed with unglazed timber shutters to protect the interiors from glare and hot winds. In Al-Qasr – a traditional village at Al-Dakhla oasis – the *sunt* timber (*Acacia* spp.), although not found in the western desert anymore, was used to make door lintels that were decorated with verses from the Holy Koran. The majority of the buildings had small triangular or rectangular openings located directly under the ceiling to allow the dissipation of hot stagnant air accumulated inside spaces.

Several elderly informants confirmed that years ago they were able to use different earth materials and construction techniques themselves to build their own homes. Everyone used to have enough building skills to build their own houses and help relatives and neighbours with their houses. The majority confirmed that they used to help each other build their houses and exchanged necessary building materials. As one 73-year-old informant recalled:

> *My neighbours were helping me in building my home and we did not need to bring skilled workers to work for us. We were building ourselves.*

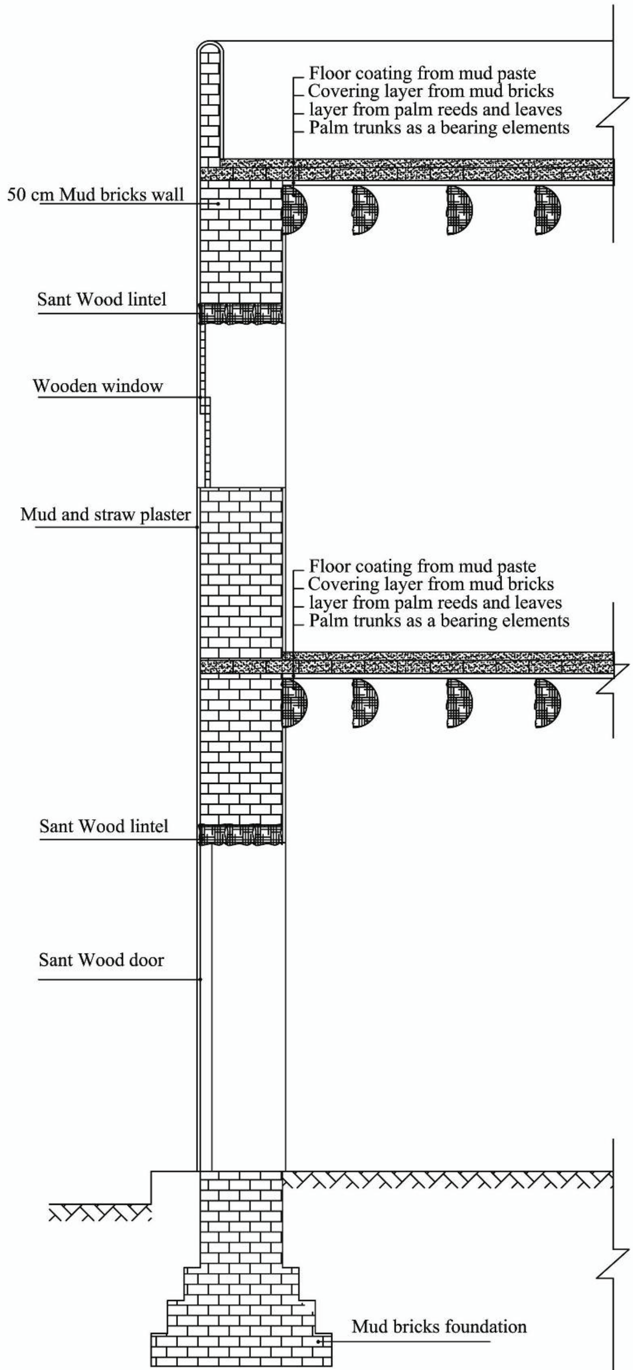

FIGURE 9 Vertical section of a house constructed using earth techniques

However, this knowledge base and communal cooperation has almost completely disappeared from the community and has been replaced by concrete construction houses built by contractors and professional builders. All the building materials used in concrete construction, such as cement, aggregates, reinforcing steel and fired building bricks, are imported from various parts of the country increasing the overall cost of construction and the overall embodied energy of the building.

The fact that the old mud village in Al-Dakhla is crumbling away and in dire need of attention after the government had evacuated its houses – in an attempt to preserve the buildings – does not set a good model to follow. Careful field observation revealed several technical and social reasons that gave mud architecture in the New Valley its bad name and contributed to the decline of this traditional technology.

First, the quality of contemporaneous, locally produced mud bricks is poor. Unnecessarily stronger, fired mud bricks made up of rich topsoil excavated from the Nile Valley and Delta are preferred instead. Despite it being illegal to manufacture red bricks after the government had banned topsoil excavation, red bricks are still produced and transported to the oasis. One of the informants said:

> *The old mud bricks we used to have were far better than the ones we get today as we lost our clever [skilled] workers.*

The second reason is the need to build multistorey houses to accommodate large extended families. Despite several of the traditional mud-brick houses found in old villages being three or four floors high (Figure 10), people do not trust the present earth technologies and skills and choose to use concrete technology instead.

Rain and underground water are always the main enemies of any mud building. Traditionally, mud-brick villages across the western desert in Egypt were built on high ground to avoid underground water erosion and occasional floods. With the increase in population, people needed to expand their villages and started building houses lower down the hill. At the same time, the water table started to rise and this is when problems started to occur. Walls were cracking due to the rising water and maintaining the houses became a difficult, laborious and expensive job. In 1991, Bawiti, a village in Al-Dakhla oasis, was flooded and most of the mud-brick houses and schools were damaged leaving families living on the streets. Consequently, all the families that were able, rebuilt their houses in concrete, for the following reasons:

FIGURE 10 Traditional three-storey mud building

> *When the water reached my house and caused it to collapse, I decided to build my new house in concrete. I had to pay for rebuilding the house anyway, so I decided to pay a bit more and end up with a concrete house, just to be on the safe side.*

> *I want a concrete roof so I can close the door and live inside no matter what is going on outside. But when it comes to*

health [comfort], the mud houses are much better. In a concrete house your children will suffer and no one can sleep in summer.

Since the Aswan High Dam was completed in the late 1960s, the water flowing downstream became silt free and the salinity of the water increased due to long-term storage in Lake Nasser. This, in addition to the excessive use of water in irrigation, had caused water logging causing the water table to rise bringing salt to the surface (Saad, 1993). In New Gourna village, Hassan Fathy had used limestone to build the foundations of mud walls to protect them from the damp. High levels of underground water caused by the Aswan High Dam reacted with the stone (calcium carbonate) causing substantial damage to the building's foundation and walls. Mr Sabra, the owner of one of the three remaining houses in New Gourna who was keen to maintain the house that Hassan Fathy had built for him, informed us that he had found out during the renovation process that the stone used in the construction in the 1940s was of poor quality.

Finally, termites (known locally as the white ants, in Arabic *el'namel al abiad*) damage the untreated timber beams causing roofs to collapse as in the case of an old mosque in Al-Qasr. The locals replaced the damaged timber beams with steel beams, but the mud walls could not endure the weight of the steel beams and cracked. People are claiming that Al-Dakhla was infected with termites when the local government brought sand and spread it over the ground of the old village in an attempt to clean it up for a visit by one of the senior government administrators. There is no way to verify this claim.

Now, two construction systems are spreading widely across the oasis (Figure 11) – bearing walls and reinforced concrete slabs, and concrete frame structures. In the bearing wall system, the walls are constructed using fired mud bricks (known locally as red bricks, measuring 25 x 12 x 60 mm) or limestone blocks (200 x 250 x 400 mm) quarried from the mountains to the west of the Nile Valley, both transported at least 300 miles. In-situ reinforced concrete slab is then poured in a wooden formwork, made of imported pinewood. In a few cases, traditional timber roofs are used instead of concrete roofs. In the reinforced frame system, concrete is used for the structural frame and fired red bricks or white stone blocks are used to construct the external walls and the internal partitions.

FIGURE 11 Concrete and white blocks in Al-Dakhla

In the following two sections, the environmental and socio-cultural drivers for reusing earth architecture and its construction techniques are discussed.

ENVIRONMENTAL DIMENSION

The old mud towns of the oasis are characterized by their narrow, winding streets which are sometimes covered as shown in Figure 12. This means that pedestrians as well as houses are shaded for most of the time. Cold air deposits during the night are trapped in the streets which become reservoirs of cool fresh air that can be used in hotter times of the day to cool the structures and the inhabitants using Venturi action. High, small, clerestory windows opening into the shaded street, known as *rusha* or *taka*, are built at high level, facing larger windows on the opposite side of the space. This creates a pressure difference that induces cross ventilation with a higher speed airflow. North-facing walls were built lower than south-facing walls to increase the shade and trap more

FIGURE 12 Shaded streets in the old cities in western desert (Al-Qasr in Al-Dakhla)

of the prevailing cool wind blowing from the north west. Because the *rusha* is higher than the window, cool dense air falls towards the floor and moves across the occupants cooling them as it passes.

Gado and Osman (Gado and Osman, 2010) studied the natural ventilation drivers in Al-Qasr. They analysed the village's urban pattern along with two different case studies. The analysis revealed intelligent designs that ensure good natural airflow for ventilation purposes and cooling on both the urban and architectural scales. The analysis also highlighted the indigenous awareness that traditional builders have of the physics of air movement. Interviewees who had never lived in a traditional house were completely unfamiliar with these passive design measures. When demonstrated to them, they doubted it could be widely applied in modern houses due to the increasing prices of timber used for window frames, and the bulky modern furniture that minimizes the areas available for windows. More importantly, the increased use of cars has led to wider streets to accommodate motor traffic, thereby losing a whole number of environmental benefits.

Traditional mud-brick houses benefit from the heavy thermal mass of their structures that dampens the extreme outdoor conditions keeping occupants thermally comfortable for most of the year. The analysis of Al-Kharja oasis climate reveals that the use of thermal mass could increase the percentage of time spent within thermal comfort limits on yearly average by 53 per cent (Figure 13). This proves Hassan Fathy's experiment of comparing the effect of mud walls and prefabricated concrete panels on the thermal performance of buildings. From Figure 13, it is clear that comfort levels are higher in the autumn and the spring seasons than in the summer and winter seasons. Average ambient temperature in the autumn and spring seasons is about 22°C which lies within the comfort zone and the average mean irradiance of global radiation horizontal is 250 W/m^2. However, in the winter and summer, the ambient temperature and the mean irradiance of global radiation horizontal are either very high or very low – extreme weather

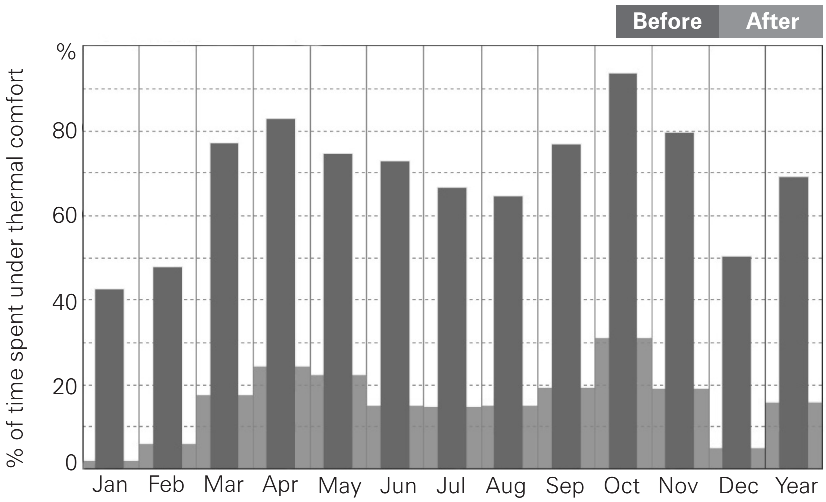

FIGURE 13 The effect of thermal mass under Al-Kharga climatic context. Light grey columns represent the percentage of the time spent inside a building without heavy thermal mass and the dark columns represent the percentage of time spent under comfort conditions inside a building with heavy thermal mass

conditions – which lie far out of the comfort zone. All the informants who moved from a mud house to live in a concrete dwelling confirmed that the thermal performance of their new house was extremely poor compared with the old house:

> *Mud houses are healthier [more comfortable]; the house is cool in summer and warm in winter. The concrete or block houses are hot in summer and extremely cold in winter.*

This was proved by Gado and Osman (2009). They investigated the thermal performance of a modern concrete house in New Al-Minya city within the desert climatic region. The study confirmed the poor thermal performance of the dwelling. The internal temperatures were found to be out of the comfort range during the summer months even when a night purge ventilation strategy was applied.

Apart from using small openings and natural materials, all new mud houses lack any effective traditional passive techniques such as night purge ventilation, cross ventilation, wind catchers, open sleeping areas or courtyards. Despite this, newly built mud houses were reported to be more thermally comfortable than the concrete ones for most of the time without the need to use any mechanical ventilation apart from fans during a few hot summer days. In comparison, the residents of concrete houses use fans during occupation hours throughout the year except during the three winter months. Families that cannot afford to buy or pay to operate fans are forced to sleep outside their houses on most nights. In some cases, it was reported by several informants that families living in modern flats had to move to their parents' mud houses during the summer to escape the unbearable thermal conditions of their newly built flats.

SOCIO-ECONOMIC DIMENSIONS

Following the 1952 revolution, families across the country and particularly from Upper Egypt were encouraged to move to the new villages of the New Valley to help expand Egypt's arable land. People took their social and moral values to the oases making the social structure and patterns of the communities inhabiting the western desert unique indeed. Privacy of the family had remained a major design requirement, with gender segregation becoming relatively less of an issue although there is always the need for a separate guest room, known as *madyafa* or *mesafreen* room, in the case of flats (sometimes called *saloon*). Very rarely a separate private entrance to the house for women is required.

The main sources of income in the oasis are agriculture, tourism and government employment. In a country where the mortgage system is still embryonic with less than a handful of banks offering loans, working in any of these sectors cannot – in the majority of cases – finance the building of a concrete house. However, the cost of earth house construction is substantially less than its concrete counterpart. Concrete technology is expensive due to the high prices of steel and cement that are always rising in an unstable economic market such as Egypt. The prices of reinforcing steel and cement increased by 300 per cent between 2006 and 2008 pushing up the total construction cost by an equal amount.[1] At the time of the field study, the average total cost of a 100 m^2 mud house was in the range of £800–1000 compared with £8000 for the same-sized concrete house.[2]

Strangely, natural raw materials in the oases, which are relatively cheap, are abandoned. High-quality clay can be easily acquired from the desert and palm wood and leaves are readily available. People do not have to buy earth blocks, but instead can produce them on site. The cost of producing 1000 bricks on site is equivalent to just £3.50 (as at May 2010). This includes the cost of clay transportation and the unskilled workers required to mix the clay and form the blocks. For example, a 3000 x 4000 x 500 mm mud wall will require 5000 bricks costing about £17, whereas the same wall area constructed of red bricks will cost just over £147. What increases the total cost of mud houses is perhaps the cost of doors and windows as well as floor tiling that has to be imported from outside the oasis. The maintenance of mud houses is also not expensive and is only required when an accident takes place. On average, maintenance of an average mud house is required every two years and would cost about £100. One informant said:

> *It [a mud house] does not need maintenance, only simple things, and only when an accident occurs, for example when a pipe bursts under a wall or a lot of rain that ruins the roof. But usually nothing needs to be done. If maintenance is required, it is very cheap as we use natural materials from the environment. Everybody has palm trees that they can use for construction.*

Despite all of the above, the majority of the oases inhabitants are keen to use reinforced concrete for social reasons. Although almost everyone we interviewed was aware of the good qualities of earth buildings, the majority believed that mud houses are not suitable any more for their modern needs. Older generations had spent the majority of their lives in mud buildings – some dating back to the 16th century – thus they appreciated the values of earth materials and construction techniques more than the younger generations or the families who had migrated to the New Valley from modern towns or cities. Although the younger generations had witnessed mud buildings on their doorsteps withstanding the test of time surviving hundreds of years, they did not share the same views with their ancestors. When asked about the reasons that led to the decline of earth architecture and its construction technique, the majority of informants reported that concrete houses are better because they are more 'robust', 'modern', 'neat' and 'clean'. However, between the lines, it was clear that social pressures are perhaps playing a more profound role in shaping the inhabitants' views, as discussed in the following section.

The number of individuals working in big cities or in the capital or in one of the oil-rich Arab Gulf countries is increasing. Others are heavily involved in the tourism industry, which is lucrative, and they also manage to secure some savings. Young men and women frequently visit Cairo and other urban cities for work, education or leisure more than ever, where all the buildings are constructed using modern building systems. On returning to the oasis, they find themselves uncomfortable with the context they grew up in and seek modern solutions or should we say ‘modern appearance’. The media had also influenced their views with more houses than ever having access to tens of free satellite television channels with mixed programmes from Western and Arabic countries. ‘This communication revolution in satellite media has greatly influenced (their) … tastes and choices’ (Singerman and Amar, 2006). In a country where 69.4 per cent of adults over 15 years and 57.3 per cent of women are illiterate (UNDP and Institute of National Planning, 2004), television remains an important vehicle for communication, education and entertainment. On the one hand, concrete houses became a sign of modernity and a way of showing off wealth, and on the other hand, mud houses became associated with poverty and peasants. Their inhabitants are assumed to be *bi’a* or *balady*, a derogatory term for those of a lower social level. People are concerned to be criticized and deemed as ‘poor’ and ‘low life’ if they live in a mud house as one of our informants said:

> *I am afraid that people will criticize me. If I build or live in a mud house, everyone will say I am socially retarded.*

In some cases, people built a concrete extension to their traditional mud houses just for receiving and greeting their guests, while continuing to live in the mud built area.

In their desire to gain higher social status, young women refuse to marry men who do not own a concrete house. For them, the concrete house is a means of expressing the financial status of their groom and their social distinction. This pushed all young men seeking marriage to aspire to build a concrete house, increasing the average marriage age of both men and women; this became a social problem in a religious community that does not allow sexual relationships outside marriage. An example is a minibus driver, a 23-year-old man who has to work extended hours every day to be able to finance building a concrete house. He started building on a plot of land provided by the local government that subsidizes land prices in an attempt to support the younger members of society. If he had used alternative technologies, such as earth construction techniques, he could have finished building the house and started his family.

A father of a young man from Al-Kharja justified this attitude by saying:

> *They are just youth [young] and they – especially girls – are constantly watching [aspiring to or envy] what others are doing. They want to have what their fellow friends have got.*

Another informant said:

> *All the girls in the area prefer concrete or brick houses [houses built using fired bricks]. In their culture mud is only for the poor.*

Several interviewees said that ‘mud’ is not widely used in contemporary buildings because the technology was never developed. They believed that mud buildings do not look ‘innovative’ or ‘beautiful’ or can even be fitted with modern amenities such as telephone lines, proper electric fittings or modern bathrooms. The following account is particularly illustrative:

> *Mud buildings look the same since the Romans’ time! They have not been developed since then. People are fed up and want to own modern homes that look nice and can be furnished properly [furnished richly].*

Despite this, everyone confirmed that they are looking forward to seeing new technologies that would make earth buildings look ‘neat’ and ‘modern’ and agreed that this would attract lots of people. One interviewee said:

> *If there is a new style or technique that can produce earth buildings that look stylish and chic, people will definitely accept it.*

The people of the oases – especially those who work in the tourism industry – are aware that preserving the architectural identity of their villages is essential for their economic sustainability. They can foresee how this could encourage tourism which will accordingly boost the economic growth of their businesses. Those who were aware of this prospect showed great enthusiasm and commitment to earth architecture. An example is Mr Abdel Hamead from Al-Dakhla who was brought up in the old village of Al-Qasr. He has developed a resort to the north of Al-Qasr old village completely made of mud. He proudly showed us around his resort, which to a great extent had resolved several technical and design issues in relation to the construction technology of the earth architecture. He had also developed a new mud house for his family down the hill after his family was evacuated from his family house. Mr Abdel Hamead invited several families from Al-Qasr to visit his resort and house in an attempt to encourage them to adopt the same approach. However, when we referred to those two examples in our interviews, almost everyone expressed the same view. Although they could all see how the majority of technical issues they were facing had been resolved neatly in Abdel Hamead's lodge and house, they strongly believed that this did not come cheap and said they could not afford to do the same. At the same time they see that building with *el'belok* (limestone blocks) or *kharasana* (reinforced concrete) is much quicker. They are not willing to make the effort to build or maintain mud houses and would rather prefer to pay more for a builder to do the job for them and to have a maintenance-free house. They all made statements such as:

> *When the white blocks were introduced, our lives were made easy.*

CONCLUSION

The lack of experience of contemporaneous oasis inhabitants and the obvious poor support from the Egyptian Supreme Council of Antiquities led to the deterioration of traditional earth architecture as in the case of Al-Qasr. This, among other factors discussed in the article, had led to the decline of the intelligent traditional earth techniques. It is clear from the discussions with the public that there is a need to initiate a debate within the community in relation to the social potential of earth construction and what is considered to be 'modern'.

Four main conclusions from this work can be drawn as follows:

- The thermal performance of earth buildings is better than other construction types in the Egyptian western desert. This was suggested by the subjective response of inhabitants.
- Technical problems in relation to using earth construction techniques, such as the sensitivity and weak resistance to water, could be easily overcome with affordable and local techniques.
- Earth construction houses are much cheaper than their concrete counterparts.
- Reintroducing earth architecture and its construction techniques could not be achieved without overcoming the social constraints. The public have to learn more about the benefits of earth construction techniques before they can accept earth architecture.

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NOTES

1 It is to be noted that at the time of publication, the British pound had fallen in relation to the Egyptian pound by 23 per cent following the credit crunch.

2 The price of the land is excluded in both cases.

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