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Article *in* Case Studies in Construction Materials · November 2019

DOI: 10.1016/j.cscm.2019.e00311

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Case study

Comparative study of traditional and modern building techniques in Siwa Oasis, Egypt
Case study: Affordable residential building using appropriate building technique

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ARTICLE INFO

Article history:
Received 13 July 2019
Received in revised form 10 November 2019
Accepted 13 November 2019

Keywords:
Siwa Oasis
Unique architectural character
Eco-friendly
Traditional building technique
Karshif particles
Affordable house

ABSTRACT

Egyptian Oases are still the most varied in the world, each one has a special character. Siwa Oasis is a place of magic and quietness with a unique ecology. This research tends to show the problems associated with the traditional construction technique in Siwa oasis due to the weakness of the available building materials such as Karshif particles and silt mortar which do not have an appropriate strength and rain resistance. On the other hand the modern building technique which is used in the building nowadays is not only unsuitable with the oasis unique architectural character but also has a negative impact on environment and cultural heritage. This research paper discusses the environmental impact of construction and the preservation of vernacular techniques of construction as the heritage of Siwa oasis. So, it presents a proposed construction technique using a durable structure system with enhanced local materials to be able to survive a long period of time and conserve the unique character of Siwa Oasis. In addition, the proposed architectural design of affordable residential building is compared with the traditional and modern building techniques through their strength, thermal insulation and cost. The comparison outcome shows the advantages of the proposed architectural design and its reinforced concrete structural system which using Karshif particles as exterior walls to be an eco-friendly enclosure with the surrounding environment and create a pleasant indoor environmental quality for inhabitants.

1. Introduction

Egypt has many oases in the Western Desert such as Bahareya, Siwa, Kharga, Dakhla, Farafrah, Baris oasis. The word "Oasis" was originally an Egyptian word which derived from Coptic outage [10]. The architecture and construction of the oasis were developed by the occupants of the oasis using local raw materials, although their buildings fulfilled all their needs but they had their own problems which they couldn't overcome. Residential building design has reflected the evolution and development of different building techniques and materials to overcome climate problems through different historic periods. Nowadays with the huge growth of population and high consumption of raw materials and energy resources, an environmental architecture is the significant tool to mitigate the negative impact of the recent construction sector and its basic goal is to construct an attractive, comfortable and affordable shelter that does not have negative impacts on the surrounding environment [7]. Environmental architecture aims at:

- Creating a comfortable internal atmosphere.
- Minimizing the use of non-renewable energy by depending on the renewable energy resources

https://doi.org/10.1016/j.cscm.2019.e00311

- Designing buildings taking into account obsolescence and modularity / adaptability; use bioclimatic design.
- Designing the residential buildings to be future proof, with access channels all around the structure to easily upgrade and add contemporary technology.
- Reusing the local agricultural and demolition waste in the construction methods in order to enhance the economy and protect the environment at the same time.

1.1. Eco-lodge development process

The development's design process is intended to be a logical treatment and rigorous reasoning for solving environmental problems [2]. The Eco-lodge design process involves extensive research as a predesign phase [8]. The purpose is to incorporate knowledge generated from research into design. The design process encompasses two major phases, each of which is a multi-step process.

The two phases are: the Research Phase and the Design Phase. The research phase includes the evaluation of the surrounding landscape, developing the architectural program and defining design imperatives. Although every eco-lodge design process would have a specific set of imperatives, a generic design decision making checklist can be envisioned:

- Use the simplest technology appropriate to the functional needs.
- Provide minimal environmental disruption.
- Optimize use and flexibility of spaces
- Minimize impacts on natural and cultural resources.
- Provide equal access to the full spectrum of people [5].

The difference between the development process of conventional architecture and the ecological architecture which is defined Eco-tecture is shown in Table 1.

2. Siwa Oasis

Siwa Oasis Egypt lies on the edge of the Great Sand Sea only 300 km south west of the Mediterranean and Marsa Matrouh [14]. It has a magical natural beauty and distinguishable architectural style. Siwa oasis faces different challenges like cities in Egypt. These challenges are the invasion of concrete blocks destroying the natural environment of the oasis, changes in economic activities, and negative impact of human behavior on the surrounding environment.

2.1. Siwa Oasis location

Siwa oasis is located at the farthest western edge of the western desert as shown in Fig. 1, and forms a sort of closed basin. It is located about 65 km east the Libyan border and 300 km south west of Matruh city. The oasis is 82 km long and has a width which varies from 2 to 20 km.

2.2. Key guidelines for future development initiatives in Siwa

Proposed below are a number of key guidelines and a critical review of current literature for future development initiatives in Siwa, covering the areas of cultural heritage preservation, socioeconomic development, infrastructure development, and biodiversity conservation.

- Cultural Heritage Preservation Protection and Revival of Traditional Handicrafts: Traditional arts and crafts reflect the artistry and creativity of Siwan women. To avoid the extinction of these traditions, projects should be designed that targets household-based enterprises.

Table 1
Comparative analysis between the development processes of conventional architecture and Eco-tecture [9].

Terms of Comparison	The development Process of Conventional Architecture	The development Process of Eco-tecture
Goal	Greed driven to make a large profit	Community driven to meet community needs and social aspirations
Means	Land speculation - Community exploitation	Land nurturing - Community empowerment
Financial Resources	Borrowing from anywhere mostly banks - Profits Exported	Ethical investment - Profits benefit the community
Materials and Human Resources	Anything goes/Convenient - Market driven - Capital intensive - Nature and people are treated as the fuel of economic activity	Carefully selected - Environmentally responsible - Labor intensive - The economy is in the service of community and ecology

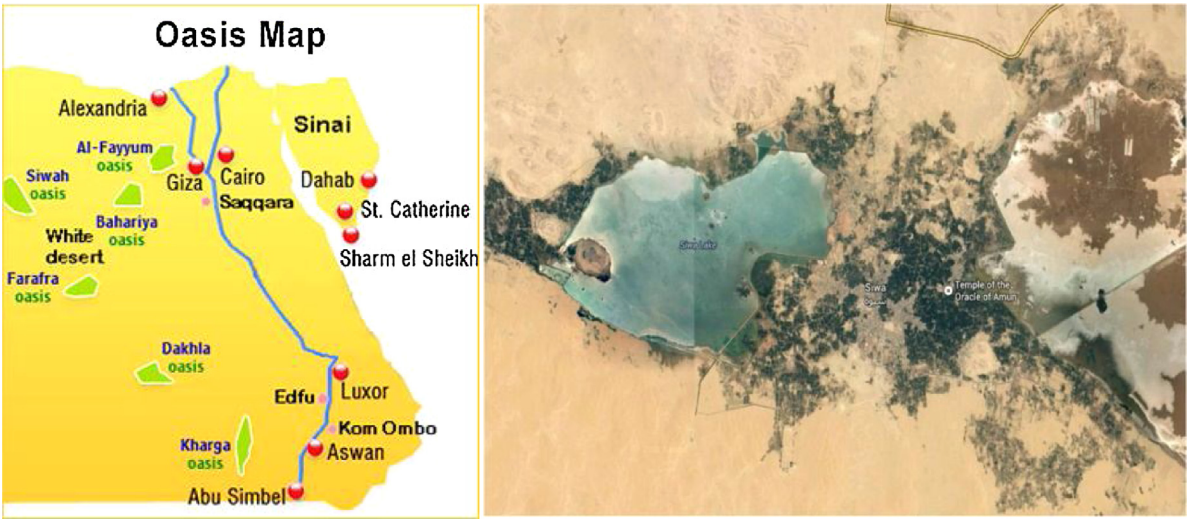

Fig. 1. Egypt Oases and Siwa Oasis https://www.traveldiscounters.ca [4,15].

- Socio-economic Development There seem to be many opportunities for the development of the existing small enterprises that feed the needs of the growing urban population:
- Expansion in Agricultural and Industrial Activity
- Development of Tourism
- Establishment of Education and Research Institutions
- Conservation and Management of Water and Wastewater
- Development of Solid Waste Management System
- Conservation of Biodiversity by Establishment of Desert Park
- Rehabilitation and Preservation of Traditional Architecture patrimony

2.3. Siwa traditional construction systems and materials

The traditional bearing walls construction system in ancient Shali village in Siwa oasis was economical because the buildings were built using the local materials which were extracted from the surrounding environment. Walls were built by Karshif particles which are bonded with Siwan silt mortar. Ceilings were made of palm wood and olive leaves to strengthen the roof against the rain. The openings for windows and doors were rectangular shape and they were made from palm trees wood (site investigations). The building' façades were plastered using a special kind of green silt found in Siwa, in order to make the building an eco-friendly. In addition, the final walls texture is rough to break sun rays in order to provide shade on the facades as long as possible to decrease the amount of absorbed heat.

Karshif is a stone naturally formed at the shores of the salt lakes. It particles consist mainly of salt bonded with clay and fine sand. The stone have irregular shapes with different sizes, typically varied from 50 to 200 mm as shown in Figs. 2 and 3.

Fig. 2. Traditional Building Technique (taken by the researcher).

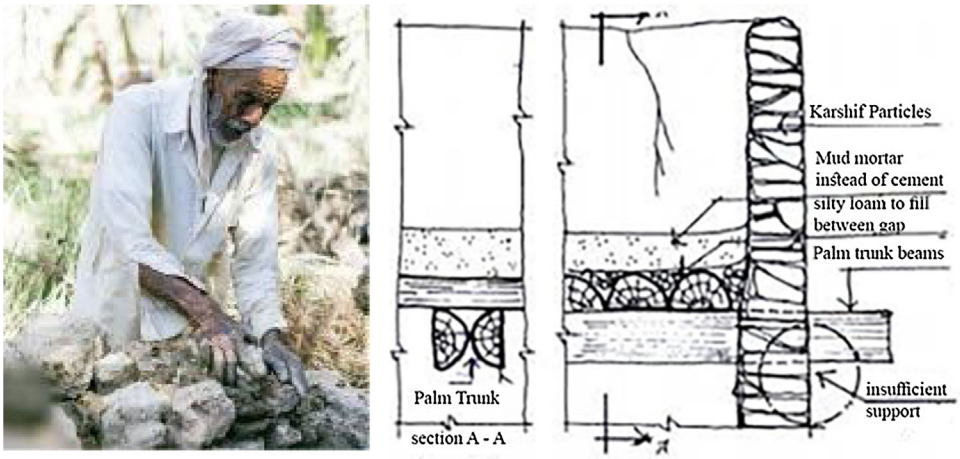

Fig. 3. Karshif Particles and palm trees building technique [6,12].

The typical color of it is white grey [6]. Palm trunks are used as beams and ceiling and mud mortar (Tlakha) which is karshif fine particles used as a covered flooring above the palm trunks and silty loam used to fill the gabs between these trunks as shown in Fig. 3 [16].

2.4. Siwa modern construction system and materials

The new public buildings were built as skeleton construction system by the Egyptian authorities such as houses, schools, religious, hospital and governmental buildings. These buildings were contrasted using completely different architectural style. They were built using reinforced concrete and red brick or cement brick. Walls are made of brick, columns and roofs are made of reinforced concrete and floors finishing was made of ceramics. These construction system and materials look odd compared with the surrounding environment and ancient oasis buildings as shown in Fig. 4. The difference between the two architectural styles is clear; the old Shali for example is a unique and distinguishing style, while the new technique destroys the style of the oasis completely. The problem was that the new building materials do not provide thermal comfort for the inhabitants and they have a negative impact of environment [10].

The traditional building technique in the Siwa oasis is more environmental, social and economic than the modern technique but it has disadvantage of its stability and durability due to the weak strength and rain resistance (Site investigations by the researcher). So, we have to create a different technique which conserving the oasis unique architectural character and at the same time it makes buildings durable throughout their life cycle.

Fig. 4. Modern Building Technique (taken by the researchers).

Fig. 5. Case study selected site at Elsadat St., google map.

3. Case study: Siwan affordable house

This research section presents a comparative study of architectural design alternatives of an affordable house in Siwa Oasis which is depending on the available local materials and appropriate construction system.

The selected site as shown in Fig. 5 is in el-Sadat St. at the downtown in Siwa oasis. The majority of the site land use is residential, commercial and services buildings.

3.1. Proposed affordable residential architectural design

Fig. 6 illustrates the ground and first floors of the proposed residential units which are consists on: four affordable apartments (85 m^2) each one consists on: living, dining, two bedrooms, bathroom, kitchen and terrace. This residential unit is a prototype of affordable housing group which will repeated to create an affordable compound in Siwa Oasis. An ecological residentail building design respects the surroung environment by applying the ecological features such as eco-materials, renewable energy, water and waste management [1].

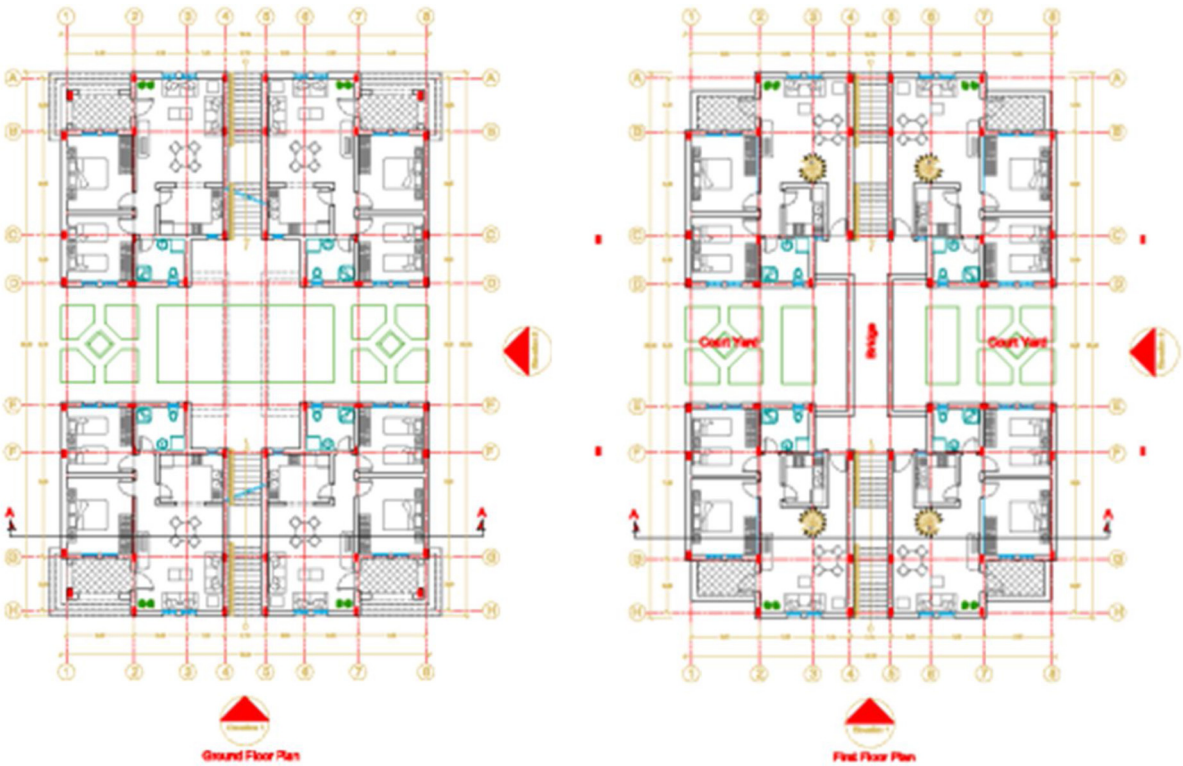

Fig. 6. Proposed Architectural Design of Affordable Residential Units (Designed by the researcher).

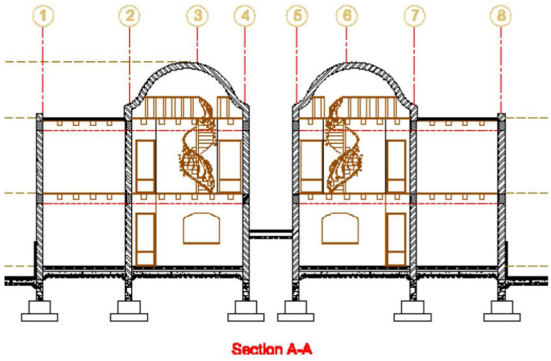

Fig. 7. Proposed Architectural Affordable Residential Unit Section (designed by the researcher).

The proposed architectural design respects the surrounding environment in Siwa oasis. Building Exterior are finished by the local stone as an exterior skirting around the lower level of building to save the building from the collected water from rain. The main facades are finished with the rammed earth plastering "enhanced Siwan mortar". Vaults are used at the top of building to improve the inner air quality by increasing the inner space to help the warm air to go to the upper level and the cold air remains at the lower level. In addition the vault creates an additional space at the higher level of house for children and storage. The building interior is finished also with the enhanced Siwa mortar and wooden beams, doors, windows and cladding which adding a good appeal inside the residential building. From economical vision, the proposed design tries to reduce the construction cost by selecting the available raw materials and the appropriate structure system. The main design concept is how to collect a big number of houses in a small area and the all architectural design principals are valid (Figs. 7 and 8).

3.2. Proposed construction techniques and different materials

3.2.1. Traditional building technique

Structure system: Bearing Walls - Foundations: Karshif particles and stone
Walls: Karshif particles - Ceiling: Palm trees (beams and ceiling)
Floors: Natural Stone - Finishing Exterior: Slit and Siwan mortar (as shown in Fig. 9)
These local materials are found at the surrounding environment which are ecofriendly materials but the building is not durable due to its weak strength and rain resistance.

3.2.2. Modern building technique

Structure system: skeleton reinforced concrete (as shown in Fig. 10)
Foundations and columns: reinforced concrete
Walls: cement or red brick
Ceiling: reinforced concrete beams and roofs
Floors: Ceramic, porcelain, marble and wooden floors
Finishing Exterior: Cement plaster and painting
These materials are brought from outside oases which are expensive and have negative impact on environment but the building is durable due to its strength and rain resistance.

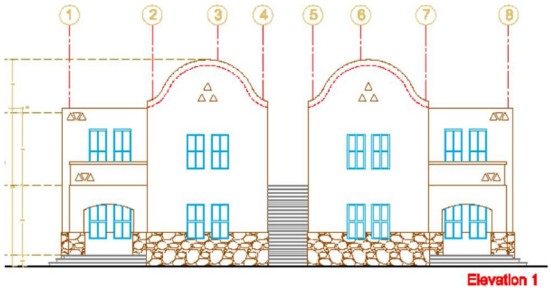

Fig. 8. Proposed Architectural Elevation Design (designed by the researcher).

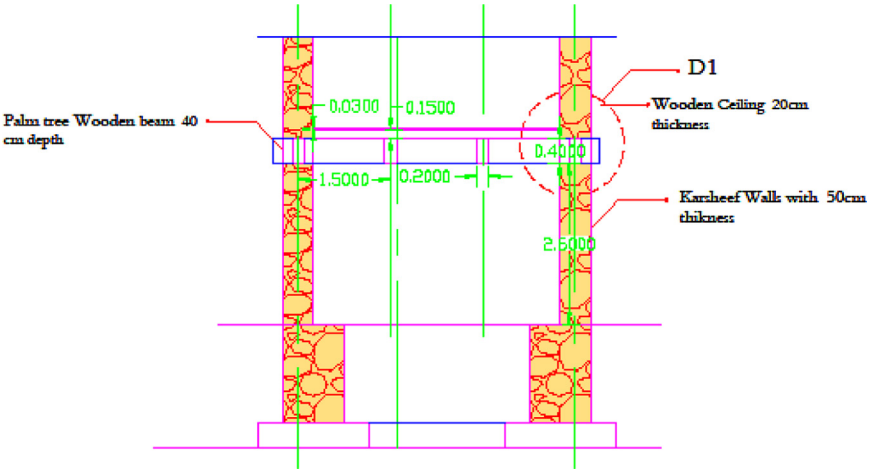

Fig. 9. Existing Building Technique (drawn by the researcher).

3.2.3. Proposed structural system and materials

First of all, the local building materials in Siwa oasis should be enhanced to be able to stand against the rain and other environmental issues.

3.2.3.1. Karshif particles. Karshif particles are cut into smaller particles of length between 30 to 50 cm, width of 15 to 25 cm and thickness of 10 to 15 cm. Siwan mortar is prepared to be used in bonding Karshif particles as shown in Fig. 3. It is made of two types of silt "Silt L" and "Silt M" [10]. Chemical analysis of karshif are listed in Table 2.

3.2.3.2. Silts. The two traditional types that are used as a construction materials in Siwa oasis. The first one is that brought from the surrounding mountains referred as Silt M. While the second one is that brought from the surrounding lakes referred as Silt L. The chemical composition of a mixture of silt M and silt L following the ratio 1:4 respectively, is simply calculated and also included in the Table 2 [10].

3.2.3.3. Siwan mortar. The traditional mortar which contains 80 % silt M and 20 % silt L in building technique should be enhanced to be durable by adding other material such as calcium oxide (CaO) and ash or rice husk [13]. These additives are added to the mortar to be more durable because the traditional mortar components are basically made from silt which is very weak and not able to resist any source of water so the CaO and ash are added to increase its strength. Many researches have introduced an enhanced mortar mixture in Siwa oasis. For instance, the combined effect of calcium oxide and ash on the strength of the Siwan mortar may lead to very promising results. A compressive strength on the order of 57.2 kg/cm^2 at the age of 56 days was achieved [13]. Moreover, when molasses was incorporated to that mixture the water content reduces from 20 % to 15 % and mortar strength could attain higher levels 64.8 kg/cm^2 at the age of 28 days and recently this strength reaches to 80 kg/cm^2 which is considered very promising [10].

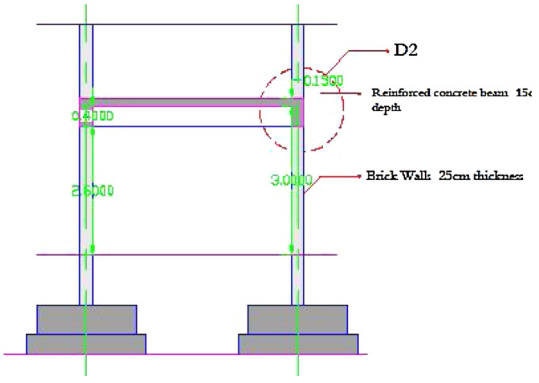

Fig. 10. Modern Building Technique (drawn by the researcher).

Table 2
Chemical Composition of Karshif particles (Husein, N., 2005 [10]) all percentage are by weight.

Contents	Total Silica SiO_2	Calcium Oxide CaO	Aluminum Oxide Al_2O_3	Ferric Oxide Fe_2O_3
Karshif particles (Percentage)	11.308	6.06	1.2	0.32
Silt L	74.91	1.96	3.8	2.00
Silt M	69.03	11.4	1.5	0.44
Mixture Silt L & m	73.7	3.8	3.3	1.70

Structure System: skeleton reinforced concrete (foundations and columns only)
Foundations and Columns: reinforced concrete
Walls: Enhanced Karshif particles which cover all the building facades including the columns.
Ceiling: palm trees wood beams and roofs
Floors: wooden and natural stone floors
Finishing Exterior: enhanced silt and siwan mortar (rammed earth plastering)
These materials are mixed between the local and transported from outside oases. The majority of these materials are found in Siwa oasis such as Karshif, silt, palm wood and natural stone which are ecofriendly and at the same time building is durable due to its strength and rain resistance as shown in Fig. 11 and architectural detail in Fig. 12.

4. Comparison between traditional, modern and proposed building techniques

4.1. Strength

Fig. 13 shows the strength diagram of the three materials karshif, reinforced concrete and brick bearing walls. The reinforced concrete has the highest strength and it is recommended to be the main structure system of the proposed building technique.

4.2. Cost

Fig. 14 shows the cost diagram of karshif, reinforced concrete and brick bearing walls. The reinforced concrete is the highest but it has a highest strength. The proposed technique (pro.) is the economical alternative.

4.3. Thermal insulation

Fig. 15 shows the thermal insulation of the karshif, reinforced concrete and brick bearing walls. The karshif is the highest thermal insulation so, it is recommended to be the enclosure material of the proposed building technique.

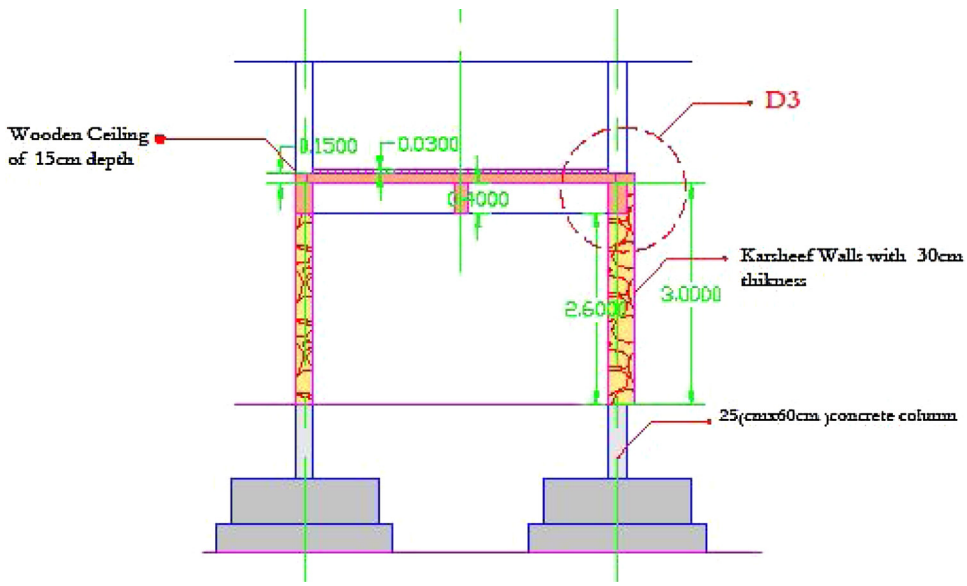

Fig. 11. Proposed Building Technique (designed by the researcher).

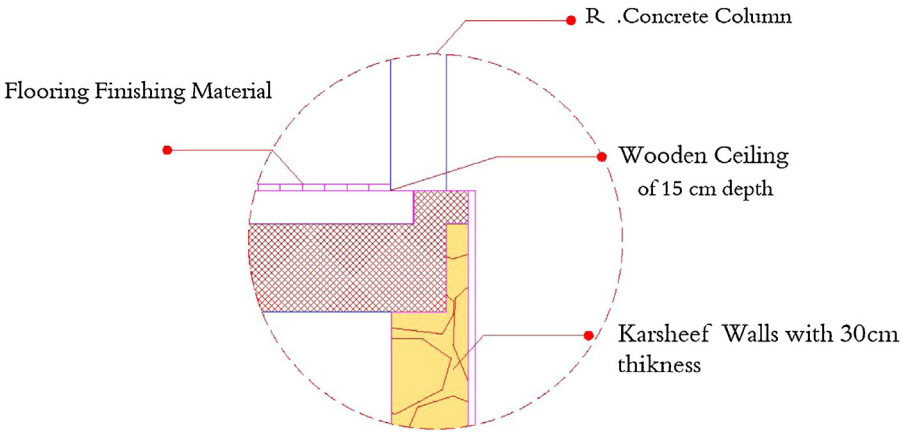

Fig. 12. Proposed Structural System and Finishing Materials (designed by the researcher).

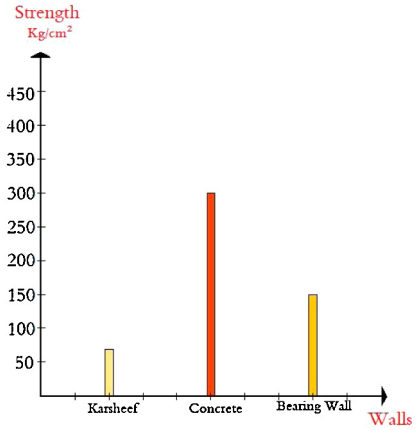

Fig. 13. Strength Diagram (made by the researcher).

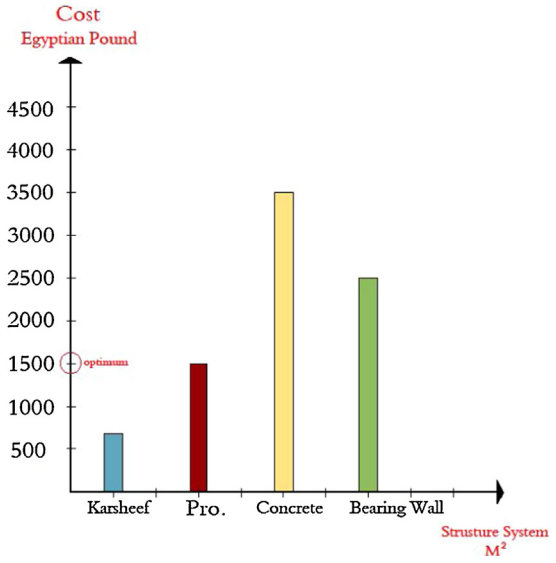

Fig. 14. Cost Diagram.

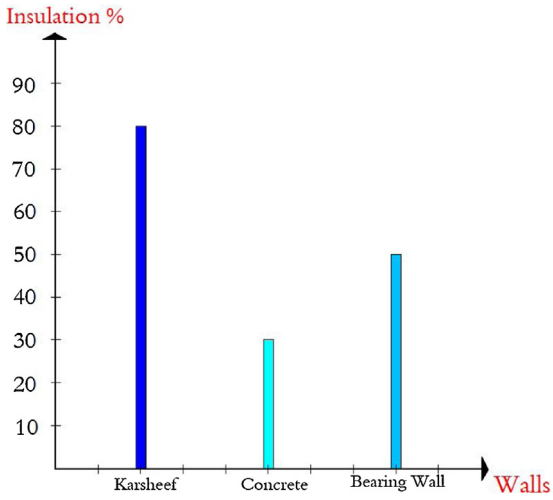

Fig. 15. Thermal Insulation Diagram (made by the researcher).

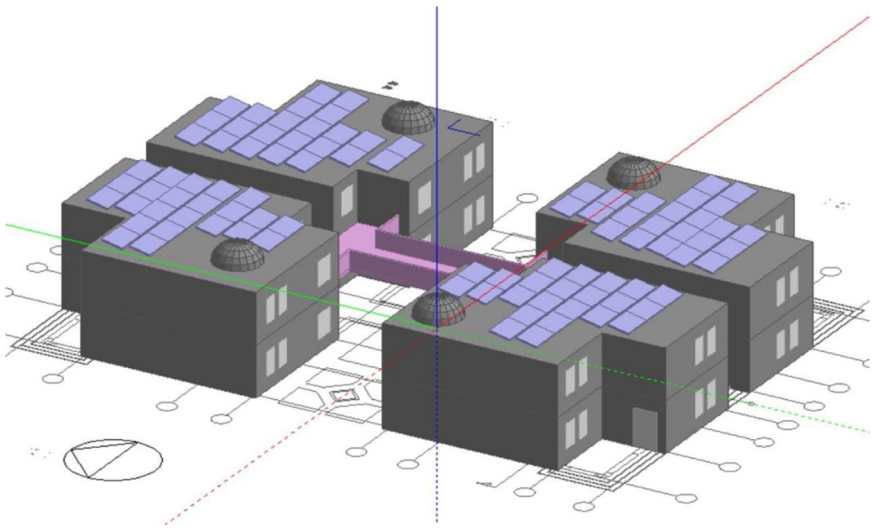

Fig. 16. Proposed Eco-house simulation building by design builder model.

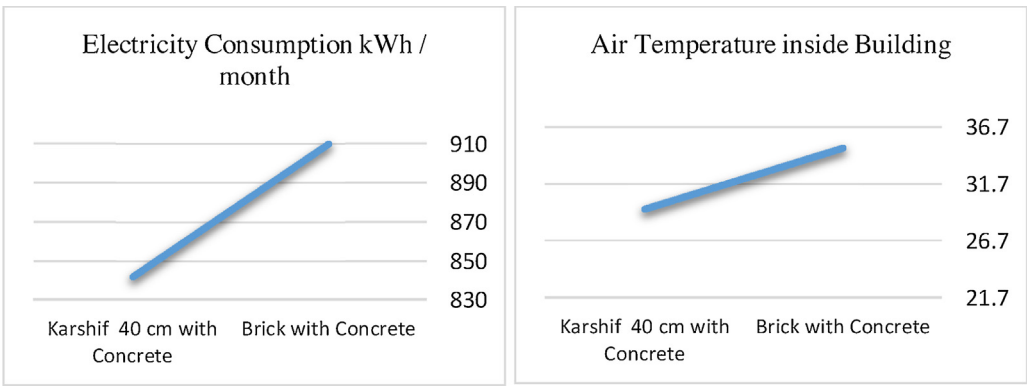

Fig. 17. Electricity consumption and inside temperature of the two alternatives (Design builder results).

Table 3
The results of design builder program when assessing the electricity consumption and inside temperature of the two structural system alternatives.

Structural System	electricity consumption kWh/month	Inside Temperature °C
Proposed Structure Technique	910.21	34.88
Modern Structure Technique	842.21	29.51

4.4. Building simulation with design builder

Fig. 16 shows the building simulation using Design Builder program to evaluate all the ecological features which are used in the proposed affordable house. In addition to the proposed structural system and building technique the photovoltaic panels are used to generate the electricity for the house energy requirements. Electricity consumption and inside temperature in the affordable house is measured by the design builder program as parameters and the results are shown in Fig. 17.

The charts in Fig. 17 show that the electricity consumption and inside temperature of the proposed structure technique is lower than the modern structure as shown in Table 3.

4.5. Overall comparison of the three alternatives

Table 4 shows the overall comparison of the three alternatives which are discussed above.

Table 4
Comparison between the Traditional, Modern, and Proposed Building Techniques.

	Item	Modern Building Technique Reinforced Concrete R.C.	Siwa Traditional Technique Karshif Particles and Silt	Proposed Building Technique R.C. and Enhanced Karshif Particles
1	Building Materials	Brought from the outside of the oasis	Are surrounding materials found all over oasis	Brought only the materials of skeleton and the rest are surrounding materials
2	Building Settlement	No settlement occurs as the foundation is R.C.	Settlement takes place as foundations are made from silt and Karshif particles	No settlement occurs as the foundation is R.C.
3	Building Strength	High strength, rain resistance	Weak strength, white ants attack the palm trees wood and can't stand against rain	High strength, rain resistance
4	External walls finishing	Surface texture is smooth and colored	Surface texture is rough, silt is used to cover the exterior walls	Surface texture is rough, silt is used to cover the exterior walls
5	Interior Finishing	Walls and ceiling are painted with oil or water based paints and the floors are ceramic or wooden floors	Walls are covered with silt which has an olive color, floors are made from stones which cut from near mountains	All materials may be used
6	Openings	Made from palm trees and olive trees wood	Made from palm trees and olive trees wood	Made from palm trees and olive trees wood
7	Heat Transmission	Heat is transmitted easily through reinforced concrete walls and roofs during day time which creates an internal unpleasant atmosphere	Karshif and silt walls reduce heat transmission. Heat is absorbed then it is radiated by night time creating a pleasant internal atmosphere	Karshif and silt walls reduce heat transmission. Heat is absorbed then it is radiated by night time creating a pleasant internal atmosphere
8	Inside Temperature	High	Low	Low
9	Air Condition	It is a must during summer time.	It is not needed at all seasons	It is not needed at all seasons
10	Architectural Style	The appearance of a new architectural style is completely different from the Siwa unique style	The appearance is unique and eco-friendly	The appearance is unique and eco-friendly
11	Energy Consumption	High	Low	Low
12	Environmental Impact	Damage Environment	Eco-friendly	Eco-friendly
13	Cultural Heritage	Not conserved	Conserved	Conserved
14	Labor	Builders are brought from the outside of the oasis because the Siwa people are not familiar with the new construction techniques	The inhabitants of Siwa oasis are familiar with the traditional construction technique	Siwan People will be trained to be familiar with the proposed technique
15	Economy	Builders require high wages Transportation of building materials is high cost	Builders are the owners of the buildings Materials are taken from the surrounding environment	Builders are the owners of buildings The main Materials are taken from the surrounding environment
16	Maintenance	Easy to maintain	Difficult to maintain	Easy to maintain

Made by the researcher.

4.6. Main results

- The proposed building technique is depending on the reinforced structure system to carry the building load and the enhanced karshif particles with its enhanced mortar cover all the building including the structure system. All the local building and finishing materials are used in this proposed technique.
- The proposed structural system and enhanced local materials is the promising solution in order to keep the unique architectural character of Siwa oasis and produce an ecological and economical buildings.
- The proposed affordable house depends on solar energy to fulfill its electricity demand.
- The electricity consumption and inside temperature of the proposed structure are lower than the conventional system.

5. Conclusions

- The traditional construction technique in Siwa oasis resulted into unique distinguishable architectural style of shelters but at the same time these shelters are not save due to the weakness of the natural building materials used.
- Past experience indicates the occurrence of many defects, collapses, and other problems that were observed in Siwan buildings and villages during the past decades.
- The available building materials in Siwa oasis are Karshif particles, silt, palm and olive trees and stone. These materials are eco-friendly and suitable for construction at oasis but their properties should be enhanced to be able to stand against rain and other environmental factors.
- The proposed architectural design for the affordable residential buildings in the selected site at Siwa oasis considers the surrounding environment and indoor air quality for the inhabitants.
- The proposed building technique used reinforced concrete as a main skeleton and Karshif particles are used as enclosure material with enhanced mixture of silt L & M as a mortaer.
- A compressive strength of the proposed mixture of mortar 57.2 kg/cm^2 at the age of 56 days was achieved. Moreover, when molasses was incorporated to that mixture the water content reduces from 20 % to 15 % and mortar strength could attain higher levels 64.8 kg/cm^2 at the age of 28 days and recently this strength reaches to 80 kg/cm^2 which is considered very promising.
- Design builder program is used to evaluate the alternatives throughout electricity consumption and inside temperature as simulation parameters.
- The three alternative proposals are compared through their strength, availability, cost, architectural character, environmental and social aspects.
- The comparison results are:
- The traditional building technique is eco-friendly but it is not durable
- The modern building technique is durable but it is not eco-friendly
- The proposed building technique is durable, eco-friendly and economical.

6. Future researches

- This study should be expanded in order to create comprehensive project in Siwa oasis which considers the other sustainable development such as renewable energy usage, water and waste management. Cultural heritage should be discussed at Siwa oasis in the future research in order to conserve this heritage of the all activities in the oasis.

Declaration of Competing Interest

Author confirm that there is no conflict of interest.

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