BUILDING WITH REEDS: Revitalizing a building tradition for low carbon building practice

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ABSTRACT

Since ancient times, reeds have been used as a low-tech building material in several construction purposes. Reed is a natural building materials that possess many useful benefits in contemporary building practices. Reeds grow around lakes, swamps and other water canals and have no environmental impact if dismantled after construction as they are biodegradable. Reeds are also easy to cut and handle making for a flexible material easily used in construction. Similar to several other building traditions, reed construction is disappearing in many parts of the world, especially now that there are no serious preservation or documentation attempts. In Egypt, this ancient and traditional building craft has been common for millennia, and was the predominant building technique in certain regions until recently. As previously the dwellings and the communal prayer areas of several fishing villages in Egypt were entirely built using reeds, there is still great potential for reintroducing reed building techniques to respond to different environmental and economical conditions in specific regions. This research paper demonstrates how we can revitalize this craft through learning how to use reeds as a low carbon contemporary building practice.

KEYWORDS
Reeds, building know-how, low carbon construction, vernacular for tomorrow

1 Introduction and study background

Throughout history, human beings have striven to erect shelters that fulfil their basic needs and provide a comfortable indoor environment (Piesik, 2012). Reeds are one of the oldest and most global primary building materials for human shelters, especially in rural areas in temperate, tropical, Mediterranean and subtropical climatic zones (Narayanamurty & Wiener 1972). They are available near wetlands, along rivers, ditches, and ponds and can be found on sand dunes and on the periphery of agriculture fields. Although there are many species of reeds *Arundo donax* is the most common. It is believed to native to eastern Asia, but has been cultivated throughout the Middle East, North Africa and Southern Europe for thousands of years (Bateman et al., 1990). Research states that dwellers who live in dwellings from reeds and bamboo are more than dwellers who live in buildings with other materials (UNEP, 2009). Aside from being used as a building material for walls, floors and ceilings, reeds are also used as wind breakers, barriers, fences, and supports for plants (Lim, 2009). . Reeds can also be used to make baskets, music instruments, paper, and bio-fuel (Singh, B.P. (red.), 2013). They are also used internationally as an erosion-control agent in drainage canals (Abissy & Mandi, 1999).

Fig. (1) A map showing the regions where reeds exist.

Building with reeds is considered an old building tradition that is now fading in many countries and the vernacular knowledge is rapidly being lost. In some countries it has become an invasive pest species covering big portions of lands, killing local vegetation, (Barreca, 2012) and sometimes causing massive fires in hot dry seasons. In the Mediterranean regions there are attempts to eradicate reeds, especially in the southern part of Spain (Barreca, 2012). Several international research centers and organizations are trying to find feasible solutions to control reed growth in parts of the world and eradicate it in other parts.

Similarly, several initiatives have begun to revitalize this building tradition and use reeds as a flexible and sustainable construction material in contemporary modern designs (Lim, 2009). The use of reed in construction has shown to provide stable structures resistant to several climate conditions (Lim, 2009).

There are calls for learning from past building solutions and techniques, especially if they still exist in certain rural contexts.

This paper is not a study of the re-use of a traditional material and building techniques or the re-proposal of the archetypes of vernacular buildings. Rather, it intends to revive meanings and values for possible innovative contemporary uses whilst preserving a threatened vernacular building tradition. Reeds have potential as a natural low carbon material in terms of performance efficiency and carbon footprint. Modern uses for traditional vernacular techniques are recognized as an excellent solution to building problems, especially in developing countries (Woolley, 2006).

1.1 Reed as a building material

Unique properties of reeds have been noted for a long time in all regions of the world. Reed construction is popular for several reasons; it is cheap, abundant, and offers a low-tech building technique requiring only simple tools. Additionally, it is easy to maintain or repair, stays well-ventilated, and has high thermal insulation properties. Therefore, reed construction is best suited to hot and humid climates. It has high resistance to seismic acts as well. Moreover, like many other natural materials, reed consumes a minimum amount of energy in its life cycle –from raw material until finished product – and it has low disposal cost at the end of the building's life (Almusaed & Almssad, 2015). However, reeds have drawbacks if they are not well treated before use or if they are cut in the wrong season. These drawbacks include: deterioration by rot, fungi, insects and most importantly, weak fire resistance (Elizabeth & Adams (red.), 2005).

Reed is mature at 1-2 years old when it is flexible and versatile. Reeds reach an average of 6-8 meters high, and in some parts of the world (especially the tropics) can reach up to 10 meters high. The stem has an average external diameter of 1-5 centimeters and a thickness of 0.2- 0.6 centimeters (Spatz et al., 1997).

Table (1) Physical and mechanical properties for 4 cm reeds based on Esteves et al., 2003 , Soliman, 2009.

Properties	Values
Density	2,295.00 N m-3
Tensile strength	32.17×104 N m-2
Bending strength	130.00×104 N m-2
Compressive strength	66.50×104 N m-2
Bearing strength	26.68×104 N m-2
Thermal conductance *K* value	0.063 W m-1 K-1

1.2 Reeds in Egypt

Reeds in Egypt are locally available and abundant to the north of the Nile Delta, which is characterized by a series of salty lagoons and lakes (e.g.: Maryut, Idku, Burullus, and Manzala) created by centuries of irregular Nile floods and the rise and fall of the Mediterranean Sea (Zahran & Willis, 2009).

Fig (2) Satellite image showing the location of Lakes Manzalla, Burullus and Edku.

The Northern Lakes have undergone drastic alterations since the 1980s. Pollution and lake drainage have reduced reeds' productivity. Now the Lakes and their surrounding habitats face great threats. In addition to agricultural filling and construction projects, sewage water pollutants from cities and industrial areas are mixing in with the agricultural sewage water and changing the water quality and affecting the sensitive ecosystem in the region.

Fig (3) Manzala lake region, a vaniching ecosystem.

The Northern Lakes area is characterized by weak soil conditions and limited natural building materials within a damp and relatively wet environment. Thus, they provide an interesting case study for examining how inhabitants adapted to these conditions. Surveying and researching the surviving dwellings with particular building materials and techniques in response to the environment of the region and the changing needs of the inhabitants were of concern. The intention is to understand and examine the suitability of reed as a building material in contemporary dwellings. Most of the vernacular reed shelters in Egypt have no interior toilets, indoor water supply, or cooking facilities, leading to abandon of villages and increased speed of deterioration.

Reed beds cover vast areas of The Northern Lakes of Egypt, making them cheap and available materials that are easily prepared for building purposes. In addition to their availability, reeds are also characterized by their plasticity and ability to bend, forming different shapes while maintaining strong tension. However, other natural characteristics prove to be restrictions. For example, reeds' weak compression forces resulted in the building of only single story structures, while high flammability makes it necessary to provide proper buffer zones between buildings (Almusaed & Almssad, 2015).

Fig (4) Reed, an abundant material that is still used in mats production in Egypt.

2 Methodology

We used analytical, descriptive, and investigative approaches as well as an experimental urban living laboratory test. Primarily qualitative site survey tools were employed. We started by documenting a range of existing building typologies using reeds. The aim of this analytical investigative phase was to locate existing buildings and their current situation in different regions of Egypt where reeds are used as a main building material. The site survey revealed main reasons why the tradition of building with reeds is threatened. We used semi-structured interviews with senior craftsmen through local planned meetings. The senior craftsmen had experience and vernacular knowledge passed onto them orally. Our study also investigated available books and archives on the history of reed in Egypt in addition to its physical properties. The analytical investigative phase helped to layout the main issues threatening vernacular reed buildings and helped to draw future potential scenarios in order to support preserve this craft and its contemporary and future value.

Our investigation was followed by an experimental phase. In this phase we organized a pilot training to revitalize building with reeds through the practical implementation of small prototypes. Based on the knowledge collected from site surveys, we organized this workshop as a pilot to start teaching different techniques of reed building to young practitioners. Twenty-nine participants joined the workshop, the majority of whom were architects and planners. We tested different approaches to using reed both inside and outside buildings. The physical outcome of the workshop was a shed structure. The ultimate goal of the workshop was to provide recommendations for monitoring similar prototypes to measure their thermal characteristics, efficiency, life span, durability, safety, life cycle cost, and carbon footprint. Since traditional materials possess high potential as low carbon footprint building materials, the intention was to help develop methods for integrating reed use in contemporary design.

3 Building typology and architecture forms of reed settlements

The built form of the architecture in the Northern Lakes region of Egypt has changed dramatically in recent years. Old settlements have disappeared as the topography and socio-economic status of inhabitants has changed. Changes in the old settlements can be attributed to continuous and rapid land use changes surrounding the lakes, where private agricultural properties and fisheries are emerging in the old lake beds. The very rare extant examples of reed architecture belong to destitute fishermen, thus, reed structures are a clear indication of the poverty of its inhabitants, as they cannot even afford building with modern industrial materials like fired bricks.

Traditionally, the built environment of the Northern Lakes region was characterized by unique features. While in almost all of the traditional villages and rural settlements the buildings were collected to form one dense cluster preserving the rest of the land for agriculture, in the Lakes area, the reed buildings were dispersed among the islands, waterfronts, canals, and fields. Such scatterings of dwellings were the result of a number of natural and socio-economic conditions. Originally, the inhabitants of the area were Bedouin tribes who stuck to their tribal traditions and tended to live separately without creating a fixed settlement. In such communities, marking out a large territory and building a house or a hut was enough to claim ownership. Fishing and working in fisheries were the main activities, requiring direct contact with the waterfront. The site topography, humidity, and weak soil characteristics also hindered the creation of dense settlements.

Most of the structures built in the Northern Lakes area were dwellings, yet a few small mosques and coffee shops also still exist. Reed structures can be divided into two types:

1- A free standing structure
2- A group of units enclosed by a high fence

Both types include a simple rectangular reed structure as the building unit, which was either used for one specific function (as a bedroom, living room, reception space for guests) or was divided by partitions to include a latrine and a small kitchen. The grouping of several units creates an irregular open space, which is enclosed by a high reed fence pierced by a number of gates. This created a small settlement for an extended family, which would share some utilities (reception space for guests, shelter for poultry, etc.) placed near the main entrance of the settlement.

The units had clear shapes and did not have projections that would make the roofing process difficult. The two main shapes were:

1. ‘*Al Koshek’*(the kiosk): a rectangular plan with perpendicular vertical walls and a slightly gabled roof

2. '*Al Aesh'*(the nest): a circular plan with cylindrical walls and a conical roof

In addition to the main structures, storage structures were also built, which had irregular shapes and low flat roofs.

Fig (5) To the left an interior shot for the Al Aesh structure and to the right for Al Koshrk one.

3.1 Building Techniques

Reed structures were among the earliest simple Ancient Egyptian dwellings. The earliest were huts which consisted of a semicircle of bundled reeds forming a point at the top or bent over to form a conical or hoop roof. These primitive structures were illustrated in ancient Egyptian drawings. Despite their ancient origin, the reed structures in the Northern Lake Region found today do not resemble the Ancient Egyptian drawings nor do they resemble descriptions of the ancient huts. Rather, they seem more similar to the dwellings of the marsh Arabs in Iraq. There, stranded between small reed islands in the lower Tigris and Euphrates delta, residents built exclusively with reeds both for normal sized dwellings and for massive reception halls called '*mudhif*.

A reed hut can stand for 20 years as long as good materials are used to build it and proper maintenance is regularly undertaken. Constructing with reeds depends on the skills acquired in a number of crafts, such as fishing, net making and straw mat making. The same techniques of these crafts are applied to join the walls, posts, and roof. The process begins by preparing and flattening a piece of land and marking the proportions of the hut. It usually ranges from 3.5-4 meters in length and 2.5-3 meters in width. The hut does not require a foundation, but its perimeter is dug (at a depth of 20 cm) to insert the reeds. Initially, a reed bundle is inserted into each corner of the perimeter in order to form a column. A fifth reed is then inserted to support the door. The other vertical bundles are also inserted 15-20 cm apart from each other. Then, groups of reed bundles are laid diagonally in two directions (with an inclination angle of 60 degrees) to create the shape of a net. After inserting the reed bundles, they are tied using nylon threads (the same material used in fishing nets).

The structural system applied in building the walls consists of reed bundles (10 cm in diameter) used as lateral beams placed in three locations. The first is 0.75 meters above ground level, and the second is used above the window sill at a height of 1.50 meters, while the third is at the end of the wall (almost 2 meters high). These lateral beams are used in both the interior and the exterior of the wall to ensure the stability of the hut. The interior of the unit is covered in individual reeds to ensure the closure of any small gaps. The gabled roof is constructed by placing one main wooden beam above the wooden poles and the corner reed bundles. Then, secondary, simple wooden beams create the main roof structure, which is covered by reed bundles in the same method applied in covering the walls. For water proofing, a layer of plastic sheeting is laid and kept in place by another layer of uniform reeds. This layer of plastic sheets is a new addition to the construction method as of the 1980s, before which straw mats were used.

Door and window frames are tied in compact bundles before applying mortar coats. The mortar is a mixture of mud and rice straw and is applied in intervals (in order to provide time for the mud to dry) on both the interior and exterior of the walls. The roof is never covered by mortar so that it does not stick to the reeds or fall when it rains. The huts require annual maintenance, especially after the winter rains; however, this method of construction enables the owner to replace any wall without demolishing the whole structure.

The aforementioned construction method is known locally as “Alsheibika” (the small net).
There are two other building methods: the “Sheibika” method for Aesh construction and the “Al Saddad” method, with which the hut covered in gypsum. The “Al Aesh” method utilizes a circular plan, usually about 2.5 meters in diameter. It is defined by a wooden pole inserted in the center. The ground is prepared and the circumference of the circle is drawn with lime, then a depth of 20 cm is dug out. The same method of using vertical and diagonal reed bundles is applied, and the lateral beams are also used to strengthen the whole structure. The conical roof is constructed through the same method, and reed bundles are added at different intervals (to preserve the conical shape) as ring beams around the roof. Although the conical shape is the most appropriate roof shape, the “Aesh” method is the least popular due to the constrictions of its small circular space, which can only be used as a bedroom with a built-in bed (Helal, 1989).

The “Al Saddad” method, which incorporates gypsum, is used to construct rectangular huts. The hut is composed of 5cm by 5cm wide joists and separate wooden panels, which are almost 75 cm wide. The hut is built by nailing the panels together and then the gabled roof structure is placed above. The panels are blocked by reed mats (which are used all over Egypt to cover floors) and are made using a loom and fibers. Thin tin plaques are usually used to fix the mats into the wooden panels. The walls are covered in gypsum mortar and the hut is smoothly plastered on both sides. The roof panels are also blocked by reed mats and fixed by nails and thin tin plaques. As in the two other construction methods, a layer of plastic sheeting is added and fixed by another layer of reeds and never covered by any kind of mortar. This method requires more attention to the hut's maintenance as gypsum lumps are heavier and tend to fall more easily than the light mud mortar.

3.2 External Characteristics

Openings

Openings make up almost 0.1% of area of the wall. There are usually one or two holes to improve the lighting and ventilation but do not serve any aesthetic function. This limitation is simply due to the fact that any opening will weaken the structure of the reed wall or "*Sheibeka*". The need for privacy in the poorly sound insulated structures means that the sleeping units are left without openings apart from the door and one or two tiny, high ventilation holes. However, other less private living spaces, such as for spaces for cooking and dining, had larger square windows.

Fig (6) Showing the small openings, the structure of the reeds and the different textures and finishes applied.

Color and Texture

The color used for plastering the walls is the natural color of the clay mortar. Sometimes other oxides are added to the lime mortar such as yellow, white, light blue, or green, a cheerful palette related to the surrounding environment. In most cases, bright colors are used to differentiate the building from its lush green surroundings. The mortar coats help in noise insulation, thermal insulation to a certain extent, and also serve to strengthen the whole structure. The texture is generally coarse due to the addition of rice straw in the mud mortar, which helps prevent cracking. However, some people soften the final mortar coats to better resist rain and give a cleaner look to the hut.

Fig (7) The dwellers added cement coats, especially at the base to create a plinth. Whitewashes are still applied to brighten the muddy surroundings.

Fig (8) A crudely applied mud mortar (the mud of the lake is black, and making the hut appear dull grey when dry) –the dweller admitted that the quality of the hut and the plastering are not as good as they used to be since most of the few remaining huts are used as rest houses or shelters for fishermen.

4 Threats facing reeds vernacular architecture in Egypt

Reed structures and construction methods in the Northern Lakes region have almost disappeared entirely. According to the fishermen and residents in the area that were interviewed, this building style has been abandoned for several reasons:

- Draining vast areas of the lake encouraged many people to settle on these newly reclaimed plots by building more permanent structures in an attempt to occupy or own the land.
- The whole ecosystem of the area has changed, affecting the socio-economic situation, and accordingly, cultivating and smuggling has replaced fishing as a means for livelihood. This shift in jobs has meant abandoning the old building systems that were tailored to fishermen.
- As in most rural communities in Egypt and elsewhere, locals are embarrassed of the traditional huts and feel inferior in comparison to their neighbours who can afford building using fired bricks. Residents would like to state their financial success by having a more "modern dwelling". Nevertheless, newly built fired brick dwellings cannot stand the dampness of the soil and the high humidity of the region, and most of the lower parts of such dwellings are rapidly eroding as a result. Moreover, as stated by residents, applying the cement mortar plaster 'to give the dwelling a modern look like the city' dwellings' increased indoor temperatures, especially during hot humid summers.

Fig (9) An example of an eroding reinforced concrete skeleton dwelling on the lake shores, which proves that building with concrete is not a sustainable nor climatic responsive approach.

- The large amount of pollution in the lake led to an increase in the number of rats, rodents, and insects. These pests attacked young children and propagated diseases throughout the area. The lack of proper sanitary conditions, one of the major disadvantages of the reed structures, increased the spread of such diseases and encouraged people to abandon their huts for more hygienic dwellings.

Fig (10) Examples of the dilapidated and poorly maintained remaining structures.

5 Reeds as an environmentally friendly material for future building practices

The majority of the energy used in the building sector and the largest percentage of carbon is emitted during the production of building materials and during the construction and demolition of buildings. Barreca notes that the proper utilization of natural materials could help reduce energy consumption during the construction and occupation of buildings. He explains that the utilization of local materials, like reeds, in rural buildings minimizes transportation energy costs and emissions in addition to lowering the building’s overall environmental impact (Barreca, 2012). Reeds are a climatically responsive material and possess several qualities that are positive for the environment, such as a low thermal conductivity coefficient. In terms of reeds’ long-term environmental impact, reeds are biodegradable, decomposing back into the ecosystem after building demolition. They can also be used as biofuel or even as food for animals.

Improving material properties and construction techniques is now possible and offers a practical step towards revitalizing reed craftsmanship and reed construction implementation. Incorporating modern toilet facilities, kitchens proper drainage will also help improve the quality of life inside reed shelters (especially for rural dwellers). One major encouraging step in supporting this notion of re-using reeds as a building material is to create a national code for alternative and low-tech construction techniques. Another explanation for the lack of interest in using reeds is that the traditional construction methods have failed. For example, historically, reed structures have provided insufficient insulation against humidity and noise. A few experimental reed structures such as a prayer hall, a class with a curved roof, a chalet with a conical roof, and a pre-fabricated unit for emergencies have been constructed in Egypt. The prayer hall was 11 meters wide and its dome-shaped roof was supported by beams in three directions. The tapering cylindrical columns, made by the *shebeka* method previously explained reached a height of seven meters. These experimental structures did not only test wider spans and different roof shapes, but tried to tackle the problem of sound insulation through the incorporation of a mixture of gypsum and straw fibers used to fill the gaps between the reed bundles thus enhancing the sound insulation. Nevertheless, more contemporary projects are needed to showcases reed building techniques and regain trust in the natural material.

5.1 The living lab test and the experimental workshop

The second phase of this study included organizing a practical workshop to train young practitioners on how to build with reeds. Twenty-nine participants joined the workshop and were provided the opportunity to learn how to use reeds in different light construction processes. They were provided background information on the material properties of reeds. They were then taught how to treat reeds starting with pealing, splitting, cutting, and node and tie preparation. They learned how to use reeds to build do it yourself structures for indoor and outdoor purposes. They also had the chance to learn roof, fence window, and door making techniques. Two craftsmen were invited to the workshop to share their knowledge and expertise with the participants.

Fig (11) Testing different applications for using reeds in walls and roof construction. Photos Credits; Insaf Ben Othman

The participants were able to test some building methods on site and assess the strength of reed construction practices. Some participants were doubtful that reeds could bear heavy loads whilst remaining flexible enough to be shaped. We had sensors on site to measure the U-value and the thermal conductivity of the walls and fences that were constructed. We also made a few simple calculations for the CO_2 reduction potential for reeds. As plants, reeds absorb carbon from the atmosphere as they grow. If reeds are available on site, no transportation is needed. Reeds do not need heavy machinery to treat. Only simple splitting, cutting, and pealing hand tools are required. During construction, only ropes are needed. After reed structures are demolished, reeds biodegrade and become reincorporated in the soil. For all of these reasons, reeds can be considered a low carbon building material.

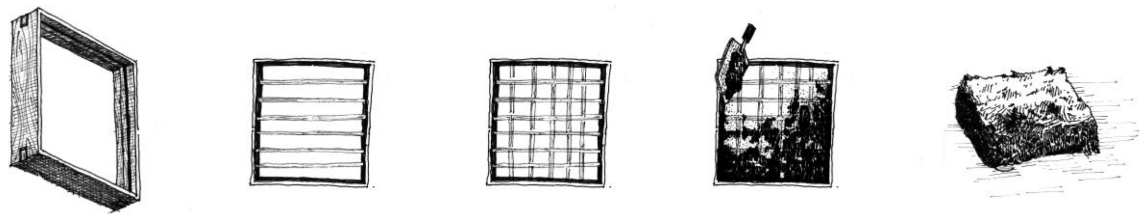

Figure (12) Sketch showing the steps needed to construct a clay brick using reeds as reinforcement elements. Courtesy: Ibrahim I.I Al Najar

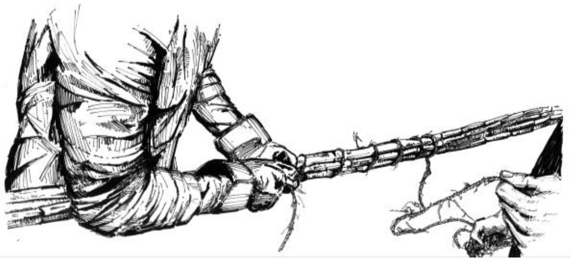

Figure (13) Sketch showing how to make nodes and ties. Courtesy: Ibrahim I.I Al Najar

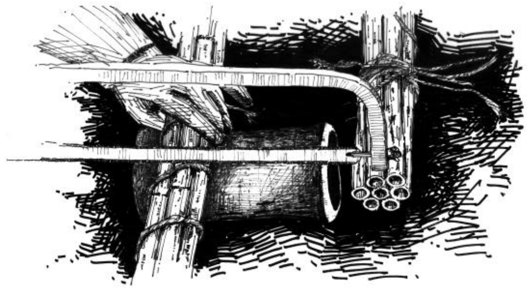

Figure (14) Cutting the reeds with saws based on the length needed. Courtesy: Ibrahim I.I Al Najar

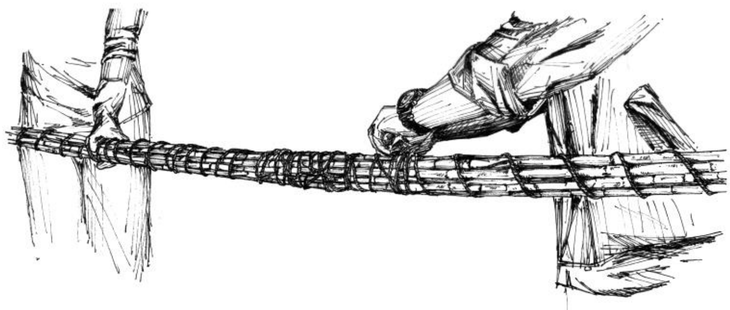

Figure (15) Connecting two reed columns together. Courtesy: Ibrahim I.I Al Najar

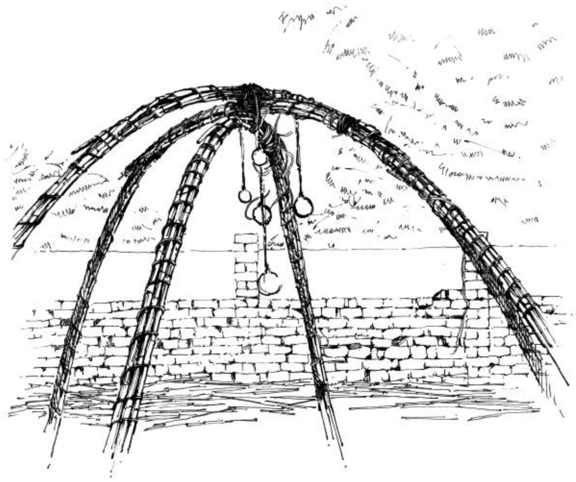

Figure (16) A sketch for one of the outdoor elements built with reeds during the workshop. Courtesy: Ibrahim I.I Al Najar

Figure (17) One of the outcomes of the workshop, an outdoor shed structure. Photo credit: Lobna Mitkees

6 Conclusion

The study results show a documentation process for existing reed structures in Egypt. We explored the potentials and future challenges facing reed building practices. We have discussed how using reeds as a construction material can be a promising practice for the construction of carbon neutral shelters, and if applied, we can make use of reed as a building material that is more economical and has low to no environmental impacts. During the training we had several discussions on the possibility of re-developing and re-introducing reeds into the architecture market. We can conclude from the discussion that there is still no trust in the durability of reed and the stability of reed structures. Another challenge mentioned by the participants is that there are no standards or best practice manuals for reeds and no documentation on when to cut and how to treat reeds. Building with reeds can offer a lot of job opportunities, especially for minority groups. It also offers a cheap and low-tech method of building that can be used in permanent or temporary shelter construction as well as in the fields of landscaping and furniture-making. Reeds are not only environmental friendly materials but are cheap, abundant and could be easily used in building. Working on preserving this craft through developing its properties and uses would serve in not only helping to preserve a dying tradition, but would also introduce a potentially ecofriendly building material into the architecture market.

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