SUSTAINABLE HOUSING UTILIZING INDIGENOUS MATERIALS IN THE MARSHES

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ABSTRACT

Low cost housing is always thought to be an affordable non-sustainable housing for rural areas and is not part of urban planning. It would be a challenge to develop and plan a complete, sustainable, and affordable housing scheme for rural areas which utilises local indigenous materials. This needs the introduction of carefully-targeted interventions to improve the lives of people in the marshes through affordable and durable building stock, drinking water, health care, and employment opportunities. In some areas of these marshes there is a tendency for a modern lifestyle similar to that of an urban population. Such areas are losing individuality and a real need for preservation is deemed necessary. The environmental and socio-economic factors could create a rural settlement fabric pattern that would be unique in the world. This paper will present the planning and implementation of a housing complex in the marshlands of Iraq. The paper will also touch on a full-scale trial embankment constructed in an experimental station in the marshes that utilized bundles of reeds as reinforcement.

Keywords: Sustainable Housing, Developing Country, Indigenous Material of Construction

1. INTRODUCTION

The marshes in Iraq cover an area of 4000km^2 during drought time and 15000km^2 during flood time. The altitude varies between 1m below mean sea level to 4m above mean sea level. The area is strongly characterized by marshes and marshland (Maxwell, 1998). The soil in the marshes was formed during the Pleistocene time. It is fully covered by recent quaternary river alluviums. Marshland soil is characterized by continuous water presence, near or above the land surface which creates particular conditions for lacustrine life. The water level in the marshes varies from 50cm to 400cm which may increase somewhat during exceptional flood. The climate in the area is of a sub-tropical type, hot and dry in summer; cool with little rainfall in winter. Dominant winds are northwesterly. The mean air temperature ranges from about 12°C in January to about 37°C in July, and the mean relative humidity in the same period ranges from 78% to 49%.

The main types of plants are palm trees, cane (Phragmites karka Trin.) and papyrus (Typha latifolia) which grow on the edge of marshes between 0.5 and 2.5 m of water level. These plants have been used as building materials since the past and the techniques of material processing and building have been gradually improving till the present day. Reed houses are the most peculiar features of the marshes. Such houses are built on small artificial islands made out of layers of papyrus and mud. The utilization of reeds and mud houses of all forms has reached an excellent level by traditional standard as reeds are natural (need no treatment) and almost manually transformed without any external tool (Salim, 1970).

This technique confirms the variety and richness of inventions by local builders who made the best possible use of simple and locally available building materials. They also satisfactorily meet the needs arised from various regional and environmental conditions. This environment is characterized by a close relationship with nature ever since the earliest forms of civilization. The rural population has maintained the local characteristics of their homeland settlement and it becomes a rational and emotional necessity (Samarai and Azawi, 1997).

The adoption of imported sophisticated building technology contributes to high energy consumption, expensive maintenance and counteracts the move for the use of lower-cost housing technologies to raise the living standards of the low income population in developing countries. Local authorities and standards do not encourage the use of indigenous materials. What is indigenous is often considered outdated and inferior, and more turn toward the use of concrete blocks which are not friendly to the environment and require high energy in their production. Among the challenges in the new century is the conservation of the environment. This requires the use of renewable and ecological materials of low energy and low cost like vegetable plants and their fibers.

The marshes entered a new phase of development which was initially limited to giving people their full rights and providing them with basic needs of life. The engineers were faced with huge task of providing the marshmen with their basic human needs. Therefore, great schemes for providing the area with a network of hospitals, schools, water supplies and electricity were launched. This infrastructure had had a great influence on the area and, to be even more productive, the provided services were reinforced with great schemes that would advance the economic life of the people.

To put all these factors in context, studies on planning all services and design of the future villages were undertaken. This led to the start of our first experiment in Seydia, where a system of housing units based on traditional forms, materials and construction was devised. Through the use of modular co-ordination of units and components, a great flexibility was achieved. The basic building materials were cane and papyrus. These materials were exposed to the outside and the interior was lined with fireproof interior finishes such as plaster, fiberglass, and eternite. In some cases the cane was also left exposed to the inside of the building.

Regarding reeds and papyri, research was carried out to find if it was possible to make reeds insect-proof, rot-proof and fire-proof with a single-step process. There was also a need to further examine the feasibility of the reed fibers for making the building panels and to examine the reed-panels structural performance after improving the reeds life span.

For the earth materials, research was conducted to stabilize the soil with additives and then compressing the blocks with a compaction pressure of about 10 MN/m^2. The blocks were initially pressed using a manually-operated hydraulic machine so that the blocks became dense, more durable, strong in green state, and have better strength and appearance (Samarai and Laquerbe, 1987).

Overall the situation of the infrastructures was rather bad. There was lack of portable water supply except at a few places. Effluent disposal and lavatories was one of the key environmental problems in marshes and water areas and certainly the most difficult to solve. Accessibility was always a more difficult problem and more costly in marshes than on dry land.

This paper presents the planning and implementation of a major low-cost housing project for areas of special alluvial nature. It was essential to take into account the very specific natural, historical, social and economic characteristics of the wider study area. So, the tendency of the people to leave the marshes for urban regions could be forestalled. The environmental and socio-economic factors could create a rural settlement fabric pattern that would be unique in the world. This project is the first of its kind in the region.

2. PROJECT SIGNIFICANCE

The people in some areas of the marshes in Iraq have a growing tendency to seek a modern lifestyle similar to that of an urban population. As a result, they tend to leave the marshes for urban regions. Such areas are losing individuality, and therefore a real need for preservation in these areas is deemed necessary. The population is of enough size and density to start a complete and distinct settlement. The water surface and supplies are enough to maintain the local landscape and economic conditions and to keep the local characteristics. There is a good and viable economical proposition to start agro-industrial projects in this area. The distinct geographical and environmental conditions have created some remarkable sites, interesting land and water sequence and aura which could create a natural park.

There is also a lack of acceptable standard of living and a lack of durable building materials. Constructions are not fire-proof, and particularly the reed structures. If electricity is installed, the risk of fire will substantially increase. Reeds are susceptible to deterioration by insects and rot fungi. As such, if the reeds are not improved to increase their life span, the reed construction will need frequent replacement. This puts extra burden on the inhabitants and reduces their standard of living. Flooding is one of the most serious problems in the marshes. Mud houses are not suitable in these areas (Samarai, 2005). The reed structures offer shelters for all species of insect which also create additional problem.

Not only the target of the project is to improve the level of services for the dwelling units, but also for all the social and public services including technical infrastructures and utilities. The research is to consider all possibilities of utilizing local building materials (reeds and earth) in a rational and feasible way and adapting to the local conditions of the region. The environmental and socio-economic factors could create a rural settlement fabric pattern that would be unique in the world (see Figure 1 below).

Figure 1. Typical village in the marshes.

3. RESEARCH METHODOLOGY

The project was related to analysis and diagnosis, with two basic lines of research:

1. A thorough analysis of previous experience and studies to check the previous data and to integrate and synthesize the relevant planning and implementation experience in the study region and abroad;
2. Synthesis and elaboration of diagnoses, aimed at comparison of various factors, proposals and techniques, as an input to the implementation of the project.

A methodological outline contained in this study recapitulates the overall context of the project and the retained methodology for the future work. Taking into account the very specific natural, historical, social, and economic characteristics of the marshes, the target of the project is to increase direct involvement of local population in the existing housing stock and the level of services. They include social and public services; and technical infrastructures and utilities for quality living in the marshes.

The research aimed to consider all the possibilities of utilizing local building materials –reeds, papyrus and earth in building construction in the marshes. The research also aimed to improve the usage and life span of local materials to improve housing conditions through utilization of local manpower, and techniques of manufacturing that minimize the need for sophisticated maintenance, such that continuity in using these kinds of materials with local expertise can be maintained. There is also a need to further examine the feasibility of utilizing the reeds for making building panels and to examine if structural elements can be made with reeds after improving their life span.

To put all these factors in context, studies on planning all services and design of the future villages were undertaken. This led to the start of our first experiment in Seydia, where a system of housing units based on traditional forms, materials and construction was devised. Through the use of modular co-ordination of units and components, a great flexibility was achieved. The basic building materials were cane and papyrus. These materials were exposed to the outside and the interior was lined with fireproof interior finishes such as plaster, fiberglass, and eternite. In some cases the cane was also left exposed to the inside of the building.

Foundations suffered from different problems that include settlement of embankments, waving of surface, and sometimes failure of embankment. To evaluate and assess these problems in order to avoid them in future development in the marshes, a full scale trial embankment was constructed in Madaina experiment station. The fully instrumented embankment was 90m long, 6m high with side slopes 2.5:1. The width of crest was 12m. Two sections were constructed. Section A was reinforced with bundles of reeds (called *berdi*) and Section B was without reinforcement. The bundles of berdi were placed on the marsh across the bottom of the embankment aligned perpendicular to the centerline of the embankment. The two sections were fully instrumental to monitor settlement, pore pressure and lateral deformation of the embankment and the foundation soil underneath.

4. MATERIALS AND BUILDING TECHNOLOGY

4.1 Foundation System

Traditionally, dwellings in the marsh environment are erected on islands ranging from 150-200m². This surface area of the island is sufficient to accommodate the house and its related service facilities such as storage and cattle barn. Provision is also kept for future expansion and for boat landing space.

Since the site bed is about 30m thick and made of fine soil, it is evident that conventional foundations build over such thick layer of unconsolidated saturated soil would settle excessively with large differential settlement. It would not be feasible to use pile foundations which would certainly have a prohibitive cost in this area.

Locally, a reed island is typically faced along its periphery with a protection made of planted and plaited reeds. This fence also provides protection against mechanical erosion due to water rippling. Inside this fencing, mud and cane are added to increase the ground level thereby sheltering the island's surface from flooding, and decreasing its moisture content. The resulting platform is consolidated by means of rough manual compacting. This technique allows for construction of a light reed structure. However, due to poor subsoil conditions, the underlying layers are liable to deform and sink and constant maintenance of the island is necessary (Mohamadi and Samarai, 2004).

A trial embankment was constructed in a typical marsh area at Medina where piezometers, inclometers and settlement gauges were installed at different places along the cross-sections and at different depths to monitor settlement with the passage of time. Two sections were constructed: Section a was reinforced with bundles of reeds *(berdi)* and Section B was without reinforcement. The bundles of berdi were placed on the marsh across the bottom of the embankment aligned perpendicular to the centerline of the embankment.

4.2 The *Mudief*

The traditional craft of making reed houses follows a technique that is thousands years old and is best illustrated in making a '*mudief*' (guesthouse). The typical mudief is built from a cane skeleton which consists of long and thick bundles for making continuous columns and beams and thin bundles for purling. The skeleton is covered with cane mats. The lower part of the mudief is left open with cane grills to allow the air to pass through during the summer and is closed during the winter with reeds.

To make a mudief, a small group of workers dig holes opposite to each other. The holes are 75cm deep in the ground and about 2m apart in two parallel lines. The cane bundles are firmly placed into these holes. The height of each bundle is 3-5m and is kept leaning to the outside and is tied at the top forming arches. The workers stand on the formwork of a temporary column made of cane. One of the workers brings the top of the cane bundle while the other brings the other opposite top and they tie the two tops together. All structural reed bundles are tied with cane strips. However, these cane strips are liable to breakage and become loose after some time. We suggest tying all these parts with galvanized steel wire.

The purling is made out of cane bundles that are spaced closely throughout the building and are placed horizontally to tie the columns. At this stage, the building is ready to be covered with golden-colored cane mats and with time, the cane mats will become discolored and change to earthen color. Some parts such as the front, the back, and the side grills are pre-fabricated on site and cut to size after attachment to the structure.

In the Seydia experiment station, a complete model of the mudief was constructed using the same procedures and materials as in the marshland (Figure 2 below). The construction was carried out by local people from the same region. The aim was to check the possibility to mechanize parts of the erection and to enhance the materials durability by additives to protect it against fungi attack, fire and rot.

4.3 Reeds and papyri

Research was performed to improve the properties and durabilty of the reeds and papyri as structural building panels. A semi-industrial production of two species of reeds growing in the marshes were used for roofing, walls, and doors of new dwelling units. These species were *Phragmita Communis* reed and *Typha Angustifolia* papyrus. Among the glues tested are urea-formol glue (65% dry extract), melamine-urea-formol glue (65% dry extracted), isocyanate glues, and powdered asphalt as urea-formol glue complement. All panels were hot-pressed at 190°C and the pressure was regulated according to the panel thickness and density.

In the Seydia experiment, a thin cement mortar was used to fill all irregularities on the surfaces of cane mats and then adhesive was spread evenly on the whole wall surface. Ordinary wall adhesive was used and then, the fiberglass wall finish was applied. This finish can be applied to surfaces such as gypsum panels or plastered surfaces.

(a)

(b)

Figure 2: The mudief (a) during and (b) after construction.

5. EXPERIMENTAL WORK AND SUGGESTED IMPROVEMENTS

5.1 The Island

The conventional method of constructing an island was to use alternate mud and cane layers. The cane reinforcement helped reduce the lateral spread of the island and contributed to the island's initial stabilization. However, this vegetal matter would entail some island subsidence due to rotting but by the time the rotting had happened, most of the settlement would have occurred. It was very important to construct the island sufficiently higher than the designed level to allow for anticipated settlement of the fill. This additional fill would also provide some surcharge, i.e., a temporary load equal or in excess of that of the reed structure (maximum load of reed structure 250 kg/m^2), which would accelerate the rate of primary consolidation of the underlying layers. This helped to eliminate most of the post-construction primary consolidation and part of the secondary consolidation.

As mentioned earlier, a trial embankment was constructed in a typical marsh area at Medina and instrumented with piezometers, inclometers and settlement gauges at different locations and depths along the cross-section to monitor settlement with the time. The instrumented embankment was 90m long, 6m high with side slopes 2.5:1. The width of crest was 12m. Two sections were constructed; Section A was reinforced with bundles of reeds (*berdi*) and Section B was not reinforced. The bundles of *berdi* were placed on the marsh across the bottom of the embankment and aligned perpendicular to the centerline of the embankment. The two sections were instrumented to monitor settlement, pore pressure and lateral deformation of the embankment and the foundation soil underneath.

5.2 The *Mudief*

Using traditional methods, the foundation of the cane bundles are placed in the hole dug in the ground. Shortly after placement, the cane decays. The decayed portion is cut off and the supporting cane post along with the carried superstructure is lowered accordingly. This process continues as needed. The improvement of the foundation is aimed to extend the life span of the cane post buried in the ground. The following improvements are suggested:

1. Treatment of reeds with suitable chemicals to render them more rigid and particularly to extend their service life.

2. Applying protective coating by dipping in hot asphalt, and preferably spraying with a simple hand pump the sides and bottom of the hole with cut back bitumen (asphalt and kerosene oil) to seal the capillary pores in the soil and provide extra protection against water.

The two basic constraints for the roof are water proofing and durability of connections of various architectural and structural members. For waterproofing, polyethylene sheet should be installed between the top mat and the reed structure. This will not pose a ventilation problem in summer as the Mudief is left open with cane grillx to allow for air passage during the summer and closed during winter with reeds. For better and durable connections, the various members can be tied together firmly using soft galvanised iron wire or cords instead of cane strips.

5.3 Housing Units

In the experiment conducted at Medina, the existing technique of building was modified using a lightweight timber or steel framework instead of a cane skeleton. The structural and non-bearing elements can be removed or added without affecting the whole structure of the building unit. The structure is adapted for seasonal changes through the use of reed panels that fit into the cane grills. The panel covers the grill in winter and can be easily removed in summer. A framework of PVC tubes can also be assembled for sanitary and plumbing utilities. The principle is the same as for the metallic framework but with plastic tubes instead. The erection of the above durable framework can be fast and assembled by local non-skilled and non-trained builders directed by a craftsman. The reed mats, manufactured by the inhabitants, can then be placed on the completed framework.

The floor of the building unit can be improved to limit moisture penetration and to stabilize the body of the island. This may be achieved in either of the following manners:

1. Use a water barrier (polyethylene sheet) and about 10cm of granular material (sub grade) with stabilized soil or other suitable topping.
2. Use two layers of crossed reeds covered with a bitumen coating and soil.

For the industrial prefabricated reed board, a small production plant was built in the experiment station where those panels were manufactured and different binding materials and reinforcing frames were tested (see Figure 3 below).

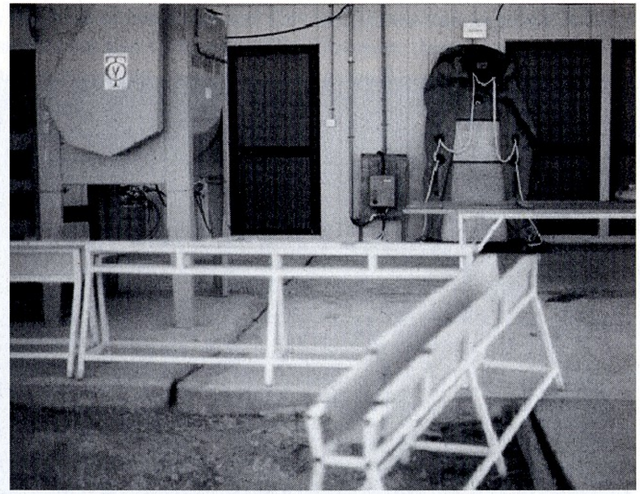

Figure 3: Production unit.

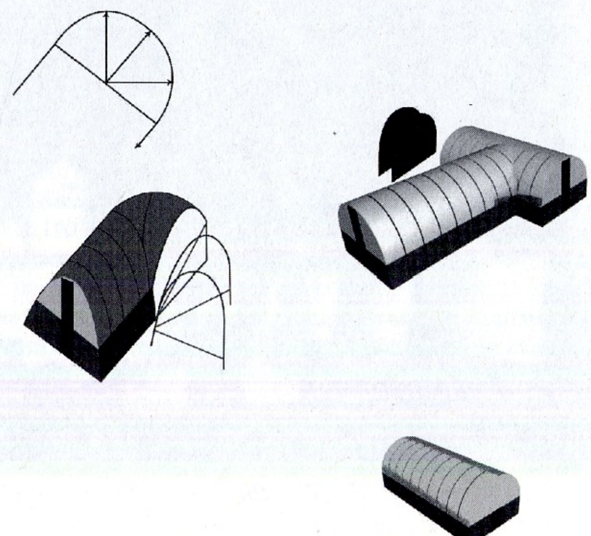

Figure 4: Erection of flexible elements.

5.4 Modular Co-ordination of Housing Units

The units in the Seydia experiment were uniform in size and they were 6.4m long and 3.2m wide. Each unit consisted of reed panels fixed to either metal or timber frame at 1.6m on center. A combination of any of the following units can be adopted such as guest and bed room, two bed rooms, farm store closed or open, guest room, kitchen and store, service unit for kitchen, toilet and bathroom.

The adopted system in the Medina experiment was an open system. Modular co-ordination was related to building elements and not to building units as in Seydia. The shapes had flexible arrangements in many directions as shown in Figure 4. Elements can be added or taken away in modules of 1.5m without affecting the unit.

6. RESULTS AND ACHIEVEMENTS

6.1 Boards, Panels and Housing Units

Physical and mechanical tests of the produced reed conglomerate panels showed the possibility and feasibility of making boards from reeds and papyri. Typical constituents of some of these panels are listed below:

1. Chip board (density = 0.550 kg/cm^3) composed of 80% *Typha Angustifolia* papyrus and 20% *Phragmita Communis* reeds. The components are cemented together by using urea-formol glue. Additional use of 10% asphalt is recommended for external uses. The panels are pressed for 10 minutes under a pressure of 18 bars.
2. Chipboard with pure *Phragmita Communis* reeds. The components are cemented together by using 15% urea-formol glue and 0.7% wax. The panels are pressed for 10 minutes under a pressure of 18 bars.

A variety of glues were used for the manufacturing of many types reed panels. There were tangible variations in the physical properties of the panels which could be attributed to variations in the properties of reeds and papyrus used in the study (Samarai, 1998). This necessitates a more extensive study to be carried out on the panels and glues.

The improvements and protections applied to roofs, floors and frames proved to be very efficient and effective. After a year of monitoring, no deterioration or rotting was observed. On the other hand, the non-treated elements showed defective signs after six months. The erection of the durable framework was rapid even with the unskilful and the untrained builders directed by a craftsman—all residents of the experimental village. It was also observed that boards can be industrially prefabricated with glue and cement for partition walls using reed as raw material, with or without adding soft wood. Using these prefabricated reed panels in superstructures outside the marsh area is also possible. A small production unit was built in the marshes where those panels were manufactured and different binding materials and reinforcing frames were tested.

6.2 The Island and Foundations

Based on the observations of the two trial embankments of the island, the reed reinforcement was shown to be effective in reducing lateral movement and the settlement was uniform throughout the cross-section. Large percentage of excess pore pressure in the embankement was also observed in the first few months after construction. However, excess pore pressure was not completely dissipated even after a one-year period.

The settlement of the unreinforced section (Section B) was almost twice the settlement of the reinforced section (Section A) for embankment height up to about 3.4m. When the embankment height exceeded 3.4m, the settlement in Section A increased at a faster rate than that of Section B. This behavior indicated that using bundles of reed as reinforcement at the bottom of the embankment in Section A was effective in restricting lateral displacement at the interface between the fill and the natural ground, thus reducing the maximum settlement. At the end of the construction, the settlement of the reinforced Section A was still smaller than the unreinforced Section B by about 17%. The difference in settlement between Sections A and B was maintained throughout the process. The final settlement of Sections A and B at the end of consolidation stage was 460mm and 540mm respectively. This difference was attributed to the use of reed reinforcement in section A which had reduced the settlement all along the processes. The maximum measured lateral displacements at plates near the toe of the embankment were 28mm and 61mm for Sections A and B respectively. This result showed the effectiveness of the reinforcement provided by the bundles of reed.

It was also important to allow the island to settle for a few months, as during this period the level of the island would be substantially reduced unevenly. The large depressions due to settlement should be filled with excavated earth from the bottom of the marsh. Cutting from the higher portions of the island to fill the lower parts should be avoided. Once the leveling operation was completed, the island could be landscaped for effective drainage and stability. After this operation, the created island could be left for some more time to allow for additional settling. The above procedures would help the island stabilization and were expected to significantly minimize the need for periodical maintenance.

6.3 Modular Co-ordination of Housing Units

To test the actual behavior and durability of the suggested improved housing units, local families were moved to the experimental stations to occupy the units for over a year. The feedback provided by the families occupying the units was used to assess the functionality of the services, the flexibility of the units and the durability and behavior of the treated elements and frames. The proposed technique for open system housing in the marshes using panel modules of 1.5m was well received and utilized by the inhabitants. Modular co-ordination was related to building elements and not to building units. The shapes had flexible arrangements in many directions as shown in Figure 4. Elements could be added or taken away in modules of 1.5m without affecting the unit.

7. CONCLUSION

The main task in building low cost houses is to find a simple structural frame which makes the house more durable. Wall and roof panels could be produced using pre-treated vegetable plants and their fibers to improve their fire, insect, and moisture resistance. The effectiveness of reeds as reinforcing elements to artificial embankment was examined by constructing two sections of trail embankment; one reinforced with bundles of reeds (Section A) and the other was not reinforced (Section B). During construction stage of the trial embankment, the settlement increased linearly with the increase of embankment height in both the reinforced and the unreinforced sections. The settlement of unreinforced section was almost twice than that of the reinforced one. This shows the effectiveness of the bundles of reeds as reinforcement at the base of the embankment. It restricted the lateral deformation of the embankment and foundation soil, thus reducing the settlement. The final settlement of the reinforced section was 17% less than that of the unreinforced section. The proposed technique for housing in the marshes using panel modules of 1.5m (could also be of other sizes) was well received and utilized by the inhabitants. The study revealed that the use of reed as raw material, with or without adding soft wood, can be successfully employed to produce prefabricated boards for building low cost houses. However, further research is necessary to solve the problem of services and test the large scale production of the panels.

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9. REFERENCES

Maxwell, G. (1998). *A Reed Shaken by the Wind*, London, Eland Publishers.

Mohamadi, N. and M. Samarai (2004). Analysis of a Trial Embankment in Marsh Areas. *Proceedings of the International Conference on Geotechnical Engineering Soil Exploration, Testing and Foundation Design* organised by University of Sharjah in Sharjah, UAE 3-6 October.

Salim, S. (1970). *Ech-chibayish—An anthropological study of a Marsh village in Iraq*, Baghdad, Al Marifa.

Samarai, M. and A. Azawi (1997). Use of Indigenous Building Materials in Ancient and Islamic Civilizations. *Proceedings of the Conference on Challenges that face the Islamic World in the Next Century* organized by the University of UAE in Al-ain, UAE on 20-22 December.

Samarai, M. and F. Al-Taie (1986). The Development of Clay Building in Iraq. Proceedings of the Symposium on the use of Clay for Housing and Modern Techniques, Arab League, Tunisia 8-10 October.

Samarai, M.A. (1986). Kassir chemical Data and tests on reeds and reed products. *Proceedings of the International Symposium on the Use of Vegetable Plants and their Fibers for Buildings*, organized by NCCL in Baghdad, Iraq on 7-10 October.

Samarai, M.A. and M. Laquerbe (1987). Cold stabilized bricks, SBFProcess. Expert group meeting on energy-efficient building materials for low-cost Housing organized by UNESCO in Amman, Jordan on 14-19 November.