

## **Architectural Mud Brick Prototypes As Efficient and Sustainable Shelters for the Low-Income Group in Jordan**

*Abu-Hammad, N.O.*

Department of Civil Engineering, Faculty of Engineering Technology, Al-Balqa' Applied University, Jordan,  
P.O Box: 620220, Amman (11162), Jordan, E-mail: abuhammad@bau.edu.jo

### **ABSTRACT**

In Jordan, a wide spectrum of the population is classified as low, to middle-income groups, and therefore most of them cannot own proper housing, taking into consideration health, environment and cost factors. The current study examines the possibility of exploring the potential of using the locally available materials, particularly in the poor and remote areas, to construct housing systems at low cost, but with acceptable standard. Several housing units (prototypes) have been proposed to accommodate the variable demands and needs of the end-user taking the limited financial resources into account. The study concludes the suitability of using the adobe techniques in constructing such housing models at low cost and without harming the surrounding environments.

**KEYWORDS:** Dwelling, Mud, Prototype, Adobe, Architecture, Low-cost housing, Jordan.

### **INTRODUCTION**

Everyone has the right to have a standard of living, financially affordable and adequate for well-being, particularly in the developing countries. In the light of the current global economical crisis, governments and international agencies are striving to provide millions of living habitats with suitable dwelling facilities. Affordable housing is a term used to describe dwelling units the total housing costs of which are deemed "affordable" to a group of people within a specific income range (Rinku and Vidya, 2009). Mud houses are well known since ancient times regardless of the climate conditions. Going back to earth does not imply in any means that man is going backward with the human civilization, but as a matter of fact it could replace the concrete and steel houses as an opportunity to save the

planet. It is widely known that buildings are the most single damaging polluters on the planet, consuming over a half of all the energy used in developed countries and producing over a half of all climate-change gases (Roaf et al., 2001). The shift towards green design began in the 1970s and was a pragmatic response to higher living costs. Eco-houses around the world are not ordinary houses, as the majorities are built by architects for themselves and often by themselves, not for clients. They express, in their varied forms, the local climates, resources, cultures and tastes of their designers, as well as the design ethos of the times in which they were built (Roaf et al., 2001).

In many parts of the world, mud houses as an alternative shelter have become a very acceptable idea for several habitants living under difficult financial conditions (Meijer et al., 2001). For instance, in Argentina, India and Vietnam, several international agencies and NGOs have deployed eco-houses (Meijer et al., 2001). Jordan which is located in the Middle East

with more than six million inhabitants did suffer the consequences of the latest global economical crisis. The issue of having affordable accommodation becomes more serious, particularly after the recent global financial crisis. Starting from this vital point, His Majesty King Abdullah the Second launched a huge national project aiming at providing every Jordanian who belongs to the low- to middle- income groups a suitable house in terms of cost and comfort, taking the various environmental issues into consideration. The current article explores the potential of spreading the concept of dwellings in Jordan, particularly in the remote and arid southern and eastern regions of the country. The arid areas represent a rich source of mud which is the main raw material in the construction of dwellings. Moreover, such areas are considered below the poverty line established by the Government of Jordan (DOS, 2007). Such houses, although made of mud, should comply with the international accepted standards in terms of safety and sanitary. The energy efficiency is one important component of such shelters. Architectural charisma and well organized dwelling complexes are other important components of this system. For this purpose, mud bricks have been prepared from local materials, processed and tested for the suitability of construction.

#### **MATERIAL PROPERTIES AND SPECIMEN PREPARATION**

In order to achieve the most suitable raw material for construction of mud houses, a semi-arid area has been selected located 45 km south of Amman, known as Arenbah. The area is classified as a semi-arid rural area which is rich in terra-rosa soil cover with no or very limited vegetation cover. For the purpose of producing mud bricks, wooden moulds with 15x10x30 cm dimensions have been prepared. Representative soil sample was collected from the study area and mixed thoroughly with water and hay in order to achieve a homogeneous mixture (Fig 1). Hay is used to strengthen the produced mud bricks and prevent possible fractures

and cracks. The mix was covered with a thin layer of hay in an open area for 48 hours to achieve the optimum level of saturation required for further processing. The mixed soil was re-blended and several brick samples using the wooden moulds were prepared. The prepared bricks were exposed to direct sun for 14 days. Two types of bricks are supposed to be produced; the sun-dried bricks and the burnt bricks. Each brick type has been treated and processed for different construction purposes. The sun-dried bricks are intended to be used in constructing the interior walls, whereas the burnt bricks are made to construct the support walls and external structural elements. Based on visual examination, only bricks with no cracks and/or deformations have been selected for further processing using the burning techniques. However, bricks with insignificant cracks and deformations were used for the construction of other minor components. Extremely deformed and cracked bricks have been excluded from any further processing. Using heavy fuel residuals as a burning medium supported with woods in order to achieve burning continuity, the bricks were fired for 12 hours in an oven made out of the sun-dried bricks at about 450°C. The sun-dried bricks' kiln was designed with raw stacks and passages as stated in any standard operating procedure. The burnt bricks gained atmospheric temperature naturally.

#### **TESTING**

Taking the minimum amount of expected rain fall in the arid region into account and in order to check the durability of the produced samples, the burn samples have been showered with water for 20 minutes and left to dry in natural atmospheric conditions. The showering continued for several times on a span of ten days. The selected samples did not show any deterioration, despite the fact that no plastering has been used for more protection. Four samples from each type (sun-dried bricks and burnt bricks) have been selected to conduct the compression test. The results indicated that the sun-dried samples are durable and have a good compression



**Figure 1: Mud mixing operation**

strength, ranging from 28 to 34 kg/cm<sup>2</sup> with an average of 33 kg/cm<sup>2</sup>. The burnt samples indicated a compression strength ranging from 45 to 55 kg/cm<sup>2</sup> with an average of 49 kg/cm<sup>2</sup>. It is worth mentioning that the achieved compression results of the sun-dried samples are almost similar to those of the non-bearing concrete bricks which are determined not to be less than 35 kg/cm<sup>2</sup> according to the Jordanian Standards (JS 84: 1992). The achieved compression strength indicates that the sun-dried bricks and the burnt bricks could substitute the non-bearing and bearing concrete bricks, respectively. Based on a previous investigation (Assem, 1992), the adobe bricks in comparison with hollow concrete bricks showed a higher energy efficiency (Fig. 2). Fathy (1988) proved that mud bricks' houses indicated an efficient heat transfer in comparison with concrete houses, as the former maintained the interior temperature within 2°C variation over 24 hours ranging from 21 to 23°C, whereas the latter indicated 9°C variation. This is due to the fact that concrete has a higher heat conductivity (0.9) in

comparison with mud (0.3).

## DISCUSSION

Four prototypes have been designed for the purpose of utilizing the produced adobe bricks and to make the best use of the available spaces to reduce the construction cost on one hand and accommodate the family members on the other. The proposed prototypes are classified on the basis of plot size, courtyard location and total number of the family members. Groups A, B, C and D with sub-prototypes are shown in Figure (3).

Figure (3) shows the recommended plot sizes and the total constructed areas in each design. The plot size in prototype (A) is from 90 to 125 m<sup>2</sup>; in prototype (B) from 125 to 143 m<sup>2</sup>; in prototype (C) 172 m<sup>2</sup> and in prototype (D) from 168 to 195 m<sup>2</sup>, whereas the expected number of family members is ranging from 3 to 12 persons, differing from one prototype to another. However, the built-up spaces of the proposed prototypes range from 62 m<sup>2</sup> to 173 m<sup>2</sup>.

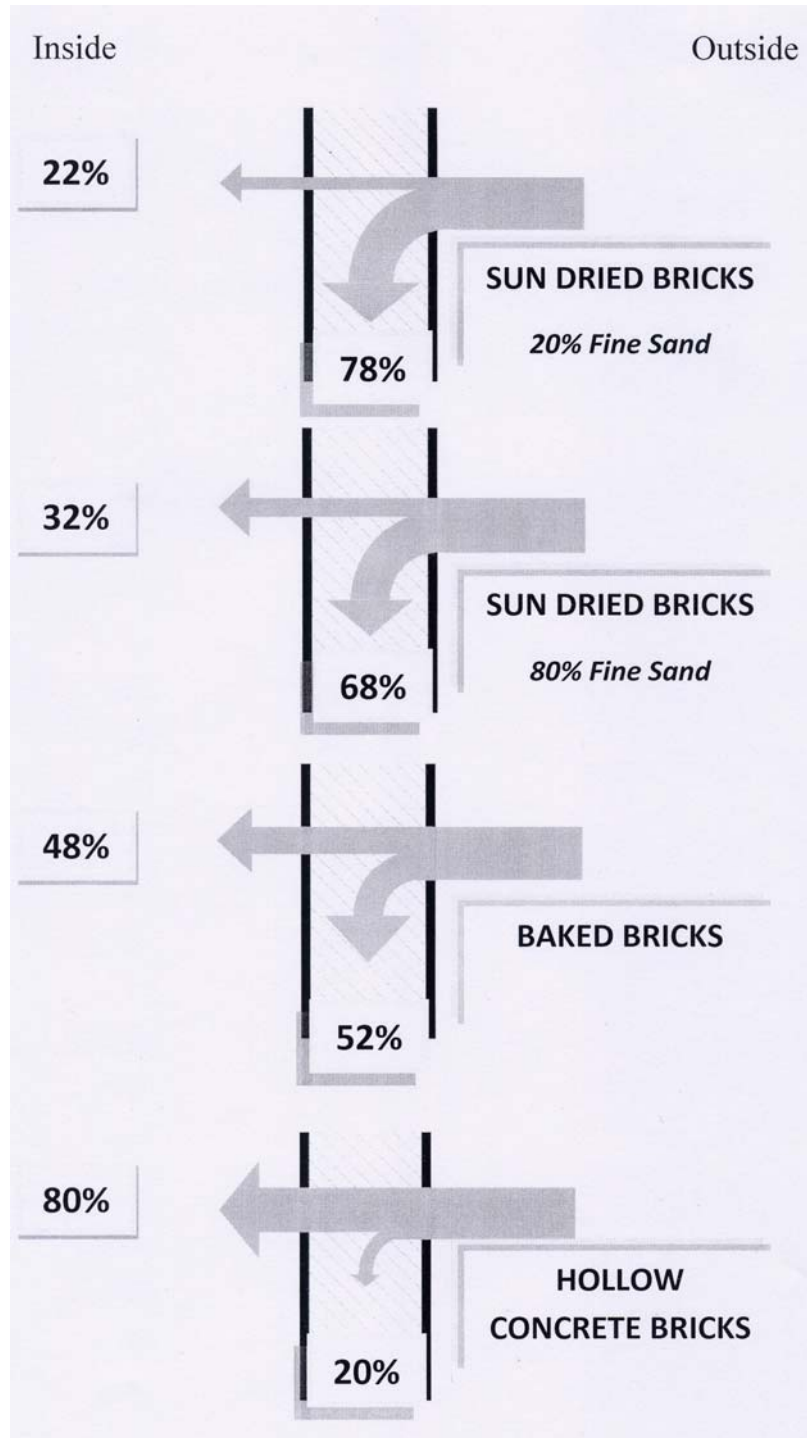


Figure 2: Comparison of heat conductivity among various types of bricks (after Assem, 1992)

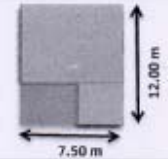
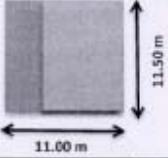
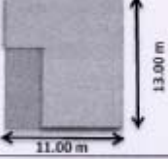
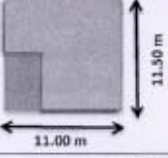
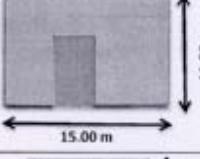
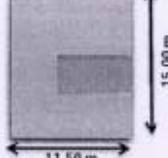
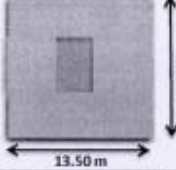
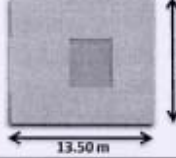
Prototype	Footprint of built-up area	Plot size m <sup>2</sup>	Built-up area m <sup>2</sup>
A1		90	62
A2		125	86
B1		143	117
B2		125	100
C1		172	132
C2		172	142
D1		195	173
D2		168	151

Figure 3: Proposed prototypes A, B, C and D classified on the basis of the plot size and courtyard location

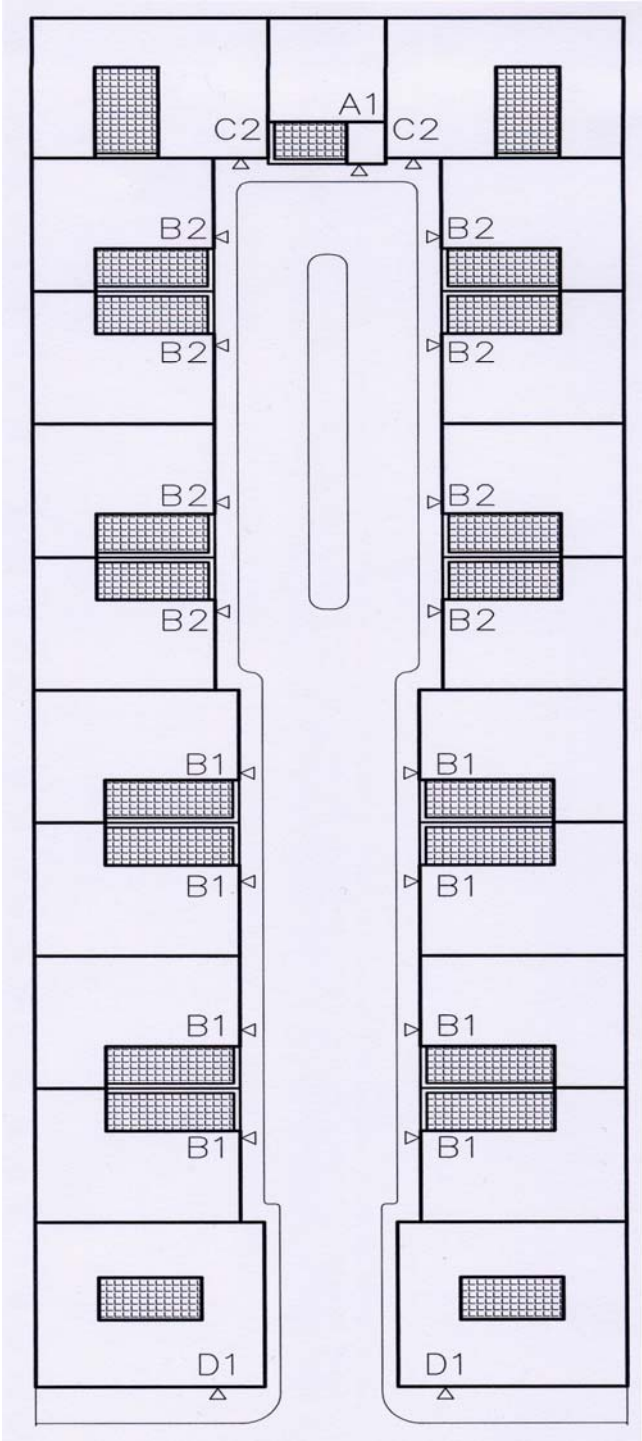


Figure 4: Resultant neighborhoods of different dwellings units

The basic classification of the proposed prototypes is based on the side attachments. Fully attached from one, two, three and four sides are the distinguishing features of prototypes A, B, C and D, respectively. The proposed prototypes are courtyard houses and maintain high privacy, particularly in the rural areas, therefore the windows are located in the inner courtyard, whereas the windows located on the front elevation are designed at a higher level.

The proposed designs provide a usable external living space in the form of courtyards and also result in a more efficient land use scheme; i.e., a larger percentage ratio of built-up area to land area. The use of set backs should be avoided when land availability is scarce, as they result in unusable strips of land around the units and, therefore, in an inefficient land use. The resultant neighborhoods between the different dwelling units developed from the above-mentioned prototypes are illustrated in Figure (4).

### CONCLUSIONS AND REMARKS

The current study indicates the economical

efficiency of using adobe bricks to construct a housing system deploying any of the four proposed prototypes, particularly in rural areas suffering from poverty. This conclusion is based on the following facts:

- Availability and suitability of raw material at low or no cost.
- Production of adobe bricks could be carried out by the end-user with some or without any help from the experts in the field of bricks' production.
- Sun-dried and burnt adobe bricks show an acceptable range of strength.
- More efficient land use, utilizing a larger percentage ratio of built-up area to land area.
- Acceptable energy efficiency upon using adobe bricks (Assem, 1992).
- The proposed prototypes maintain privacy and keep the traditional heritage.
- All the raw materials involved in the processing are considered environment friendly.

Therefore, it is highly recommended to disseminate the concept of adobe housing usage in Jordan in order to serve the wide spectrum of low-income and middle-income groups.

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