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RICE STRAW IN BUILDING

The Egyptian environmental friendly house as a case study

HEIDI A. SHALABY

Lecturer of Architecture, Faculty of Engineering, Zagazig University – EGYPT

*ABSTRACT:***Email: <heidi.shalaby@yahoo.com>**

ABSTRACT:

Rice is one of the strategic crops in Egypt. In 2013, 1.42 million feddans has been grown with an average production of about 4.3 million tons. It is mainly cultivated in the northern east part of the country especially in Kafr El-Sheikh, Al-Sharkia and Al-Dakahlia governorates. But the processing of that large amount of rice yields approximately 4 million tons of rice straw as an agricultural residue annually. In Egypt, only 20% of the rice straw used for other purposes such as ethanol, paper, fertilizers production and fodders. The remaining part was left on the fields for burning, causing high degrees of environmental pollution known as the Black Cloud, despite the high economic value of these residues if they are recycled and reused. This paper explores the different architectural styles of straw construction worldwide, whether by the rice-cement bricks, straw panels or straw bales. With an aim to reach an economic environmentally adapted system for wide application of straw construction in Egypt. The paper presents an Egyptian environmental example of building a low-cost house which saving about 40% of the direct cost if it built by the traditional cement bricks method, in addition to the indirect cost saving in energy consumption, and thermal insulation.

Key words: *rice straw; environmental; buildings; pollution; building materials; R-brick.*

INTRODUCTION:

Rice straw is a plant stems resulting from the harvest of rice, which are in the form of high-flexible sticks, do not break but grinding. It has been used by farmer to make their house roof because it's high efficiency in rainwater and heat absorption [1]. Straw also is a natural fiber that can last many thousands of years under certain conditions. Intact straw has been found in dry Egyptian tombs and buried in layers of frozen glacial ice [2]. In fact, a piece of straw is simply a tube made of cellulose. Tubes are recognized as one of the strongest structural shapes [3]. However, under typical conditions straw will slowly degrade as do all natural fibers materials like wood, paper, cotton fabric, etc. The rate at which this happens is highly dependent on the conditions under which the straw is stored, primarily moisture content and temperature. With proper attention to moisture control, a straw structure should be able to last as long as any conventional wood framed home [4].

2 The world experiences of building by the rice straw:

The using of rice straw in construction started from a long time ago up to now, with the developing of construction technology and processing rice straw bales against rot and fire, it is possible now to build modern houses by straw bales.

2.1 Using straw in USA:

Building with straw bales has become almost mainstream in some parts of the United States, especially in the southwest [5].

The oldest straw bales barring walls building found in the town of Alliance, Nebraska, USA at the end of 19th century.

Because of the lake of trees and woods using in constructions that time, they had to use the straw bales to build the farmers houses, churches, schools and many other buildings [6].

But now enough straw is currently produced every year in North America to meet most residential building needs [2].

Many localities have specific codes for straw bale construction, and some banks are willing to lend on this technique to reduce the environmental pollution [5] . Fig (1)

Figure 1: The first rice straw building. Nebraska

2.2 Using straw in Europe:

In Europe, the using of rice straw as a building material began 200 years ago, because it was cheap, available and fairly easy to build with [7].

And now they use straw due to several reasons, including[8]:

- The rice straw is a cheap building material especially in rice-producing areas.

- The rising of woods price and limited availability in the future.

- The burning of rice straw in the fields is a major pollutant of the air.

So the laws has been developed to deprive burning the straw in a lot of rural areas in these countries. And it is began to thinking in different alternatives to use the rice straw, especially in the rural construction works as a building material using straw bales and the compressed straw panels [8].

2.3 Using straw in Australia:

In Australia, there was a project of design and build a complete neighborhood by using the straw pales in the south-west of Adelaide (South Australia), named The Christie Walk project. This project was designed to test and demonstrate the processes, plans and principles contained in the 'ecological city' vision of the non-profit environmental education association Urban Ecology Australia (UEA). It is part of the Whitmore Square Eco City Project – a conceptual strategic framework adopted by UEA for mapping the southwest quarter of the city as a future piece of Eco city. The project has been realized during the celebration of Earth Day 2002.

The design brief was based on energy efficiency, the use of renewables and a high overall ecological performance allied to user-participation in the design and development process[9] .

A key aspect of this project is its inner-city location. It is situated in the most mixed-use, least wealthy and most culturally diverse part of the City of Adelaide, which require a design of complex inner-urban contextual demands. A total site area of 2000 sq. m. is being developed for housing with a mixed-use building in the main Sturt Street, and the project done in 3 stages. Non-toxic construction and finishes are used, and all timbers are plantation or recycled. All buildings have solar hot water and photovoltaic panels [9].

Construction of the straw bale buildings provided an excellent and popular workshop and educational environment, and the construction details were designed to achieve particular architectural and environmental design outcomes with a low-cost, rapid and non-polluted construction material. Fig (2, 3)

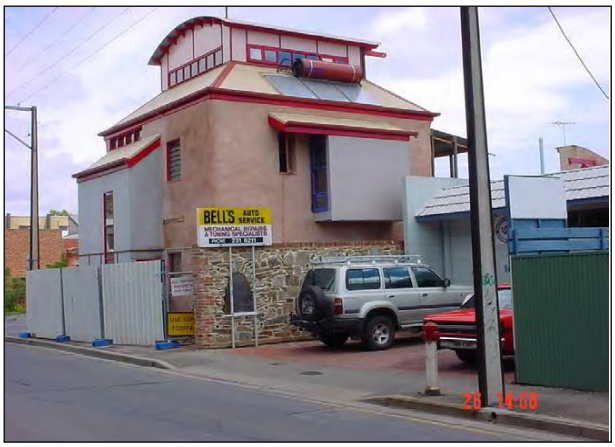

Figure 2: The new rice straw building. Australia

Figure 3: The interior of the rice straw building.

3 Advantages of using rice straw for building:

Rice straw is a renewable resource for building materials which is grown extensively in Egypt every year. It has a great capacity for thermal and sound insulation, up to ten times more than the walls of brick and wood, fire and earthquake resistance, energy efficient, quick and easy in construction and require minimum maintenance [10].

Straw bale construction is owner-builder friendly because the wall raising is easily done and less labour cost than other common wall systems [2]. All these advantages in favour of straw construction cumulate significant cost advantage compared to conventional building techniques with bricks or wood. Furthermore, it provides an opportunity for creativity and architecture harmony with the surrounding environment, along with comfort and beauty conditions inside and outside the building.

New buildings codes for Rice straw construction have been introduced in many countries. The most famous one is California Code. However, In Egypt, a new Rice straw construction code using rice brakes or straw bales, is currently under review.

Despite the fact that rice straw can be used in many industries and can save a lot of money, the reason why it is not being widely used in Egypt is mainly due to lack of people awareness.

Surprisingly, countries such as India and China, who are the worlds' largest cultivators of rice, are not suffering from the problems of rice straw. They are constantly developing new technologies for the utilization of rice straw and have succeeded in using the straw in many aspects especially paper industry [11].

4 How to use rice straw for building:

4.1 Rice straw bales:

Straw bales is a direct way of using rice straw in construction, during the harvest it has been pushed in the form of bales, linked with two or three wires or plastic strips. Fig (4)

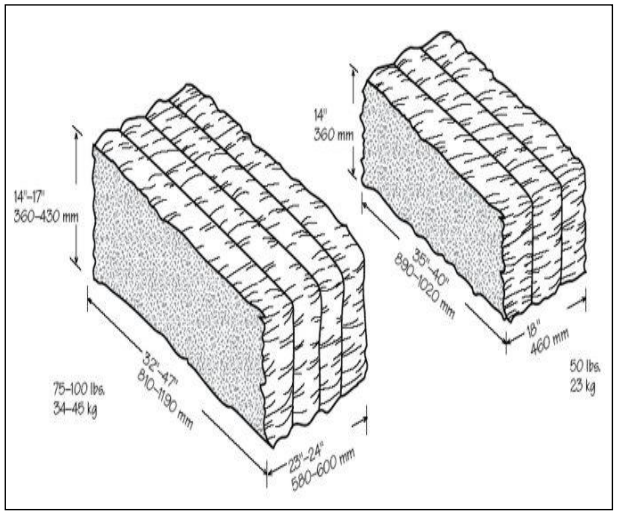

Figure 4: Rice straw bales

There are two primary forms of straw bale construction, load bearing and non-load bearing (post and beam).

4.1.1 Load bearing structures (the Nebraskan style):

the weight of the roof and lateral shear pressures are actually carried by the bales and the plaster which encases them [2]. Fig (5)

Figure 5: Load bearing structure

When using this system in construction, the buildings is characterized by the following [8]:

1. **The buildings must be in a simple form, square or rectangular, and balanced roofs to distribute loads evenly on the load-bearing walls.**
2. **The straw bales must be staggered, to avoid the continuation of its vertical seams.**
3. **The Height of the walls must not be more than 3.6 m, and the length must not be more than 6 m without vertical elements.**
4. **Raise the first row to straw bales more than 15 cm above the natural earth with moisture isolation, as well as the last row under the ceiling, to protect the wall from potential moisture leakage from the top of the wall and keep it dry.**
5. **Use a narrow, balance and small number of windows and doors, to prevent the landing uneven walls.**
6. **The need to use the wood or iron bars in the vertical and horizontal links between the straw bales, to prevent sliding of these elements from each other.**

Fig (6)

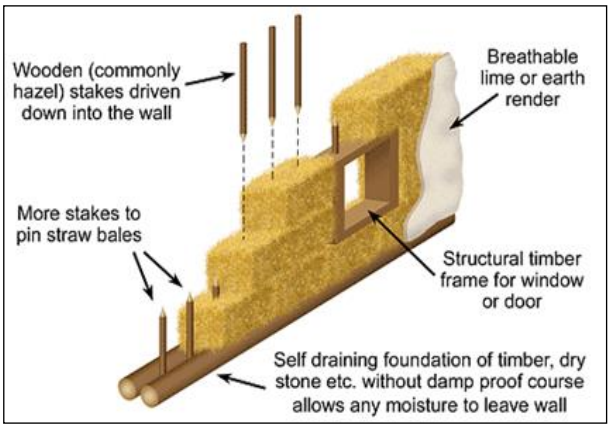

Figure 6: Using the wood pars to prevent bales slid ing.

7. **Use a good insulated water pipes in the straw walls, to prevent any leakage inside the wall.**

4.1.2 Non-load bearing straw bale construction (post and beam method):

a frame is first built out of wood, stone or concrete, and the bales serve as an in-fill insulation [2]. This is the most common form using in the USA. Fig (7)

Figure 7: Non-load bearing structure

When using this system in construction, the buildings is characterized by the following [12]:

1. **Provide the flexibility in the design of the building, the roof can be in irregular shape and does not affect the distribution of loads.**

2. Provide a great freedom in the distribution of the holes on the building without affecting the landing walls rates.

3. The building height can be one and half to two floors.

4. The structural elements can be outside or inside the wall.

5. The roof of the building can be finished before the walls, which serves to protect the straw bales from the rain and humidity.

4.2 The rice straw compact panel:

this is the second alternative to using rice straw in construction, the idea of producing compact panel of rice straw started in Sweden at 1945, then the idea developed and was commercially produced in England in the late twentieth century, then spread in many European countries. When pressed rice straw under high temperature up to 200 degrees Celsius, the rice straw fibers fuse with each other, and when it cooled, it remain as they are. The thickness of the panels ranges between (50 to 100 mm). They are used primarily as an internal walls, although some of these panels can be assembled together to be external walls. These panels are very suitable in the refabricated typical buildings [12]. Fig (8)

Figure 8: A house by the rice straw compact panels.

4.3 Rice Straw- Cement Bricks:

In Egypt, there are a research team at the National Research Center, led by Dr. Gihan L. Garas and Dr.Mostafa E. Allam, makes many experiences to produce the Rice Straw- Cement Bricks. Regardless the lack of researches on mix the rice straw with other structural materials, the team already produced the rice brick (R-brick), and performed different tests like loads, fire resistance and the economic feasibility study to evaluate the rice straw brick.

The produced R-brick has standard brick dimensions 25*12*6 cm, it is a mixture of chopped rice straw, coarse, fine aggregates, cement and water with specific mixing ratios. The density of R-brick was 25% less than regular cement brick, and the production cost was less about 25% of the total direct cost /1000 bricks. This direct saving in costs is added to the environmental profit of recycling rice straw which is traditionally burnt by farmers in open fields, boosting air pollution and serious human health problems. Besides, rice straw material is known for its high insulation properties which could add another indirect saving value by minimizing energy consumption. Fig (9)

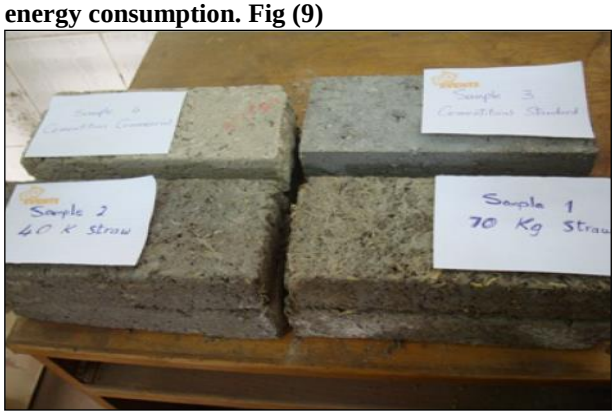

Figure 9: various density of the R-brick

The R-brick also can resist fire up to 400 ° C in load-bearing walls and 800 ° C in the structural building for a full hour, like regular concrete brick. In the end, the proposed R-bricks provides an economical, light weight brick, with competing thermal insulation properties, while maintaining adequate mechanical properties, and good fire resistance [13].

5. A practical model for building using rice straw bales and R-brick (Egyptian experience):

Another experience for this creative research team, is create a residential building of one floor, 100 m2 area, in Sixth of October City as a model. The outside walls has been set up by rice straw bales with dimensions: 100 * 50 * 50 cm, was treated to match the California Code of rice bales bearing-walls building. The house was designed and allocated to provide the thermal comfort required for an occupant resident in an arid desert area. [14]. Fig (10)

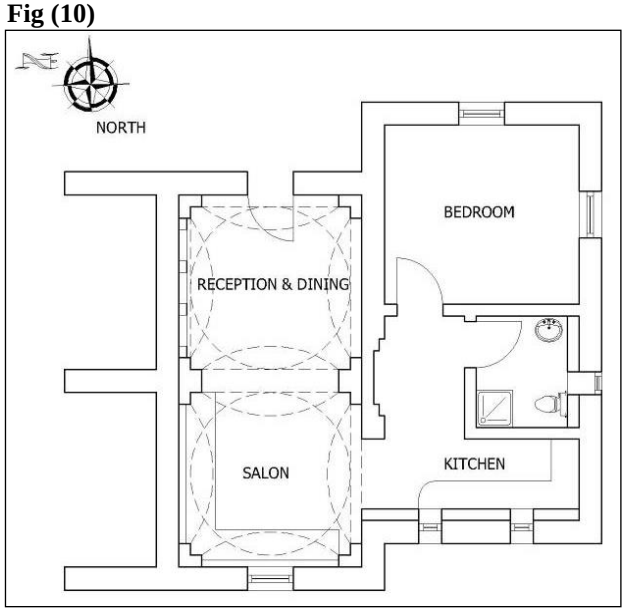

Figure 10: The Egyptian building using rice straw bales and R-brick

The roof system combines domes and vaults, which is belong to the traditional Egyptian architecture elements, therefore it is nearest to Egyptian cultural content than the wooden ceilings used in the West. Besides, the timber does not grow in Egypt, and relatively expensive, while the domes and vaults can be built using local materials. This traditional architectural elements (domes and vaults) characterized by moving the air in the architectural vacuum, good heat insulation, easier low cost construction technique than the traditional reinforced concrete slab, and finally, can cover the wide span without any columns in the middle. Fig (11)

Figure 11: The volt by R-brick and red- brick

At the interior of the straw bale walls, 6 corner made of R-bricks (Figure-4) were designed to support the 2 domes roofing the reception area. A similar technique was adopted to lift the line load resulting from the vaults (Figure-5) used for roofing the kitchen and the bathroom, In this technique the straw bale walls acted as insulators without carrying any vertical loads except its own weight [14]. Fig (12)

Figure 12: The 6 corner made of R-bricks

6. CONCLUSIONS:

This paper provides the importance of reuse the agriculture waste in many ways, especially in building. And presents a successful practical building, environmentally friendly, low-cost, easy construction, good heat insulation and provide a comfortable heat of the human content.

And Find out the following results:

1. The illegal and uncontrolled burning of rice straw causes seriously chronic chest diseases to the great population of Egypt. This is considered one of the main environmental pollutants as it results in the annual phenomena known as "The Black Cloud".

2. Using rice straw in construction is one of the most important ways to solve this annually severe environmental problem in a non-polluting way.

3. There are many types of using rice straw in buildings: straw bales, the rice straw compact panel and cement straw brakes.

4. Rice straw bales construction provide efficiency of in thermal insulation, rabid low cost construction, renewable resource It is also has a high environmental properties compared with many other traditional materials used in construction.

5. Rice cement brick (R- brick) is one of the best building materials used in construction, its weight is 25% lighter than the traditional ones, and its cost 25% less than the standard cement brick, with the same resistance to load and fire.

6. By keeping straw bale in walls dry, durable and beautiful buildings can be erected. Then the significant environmental benefits to be gained from highly insulated low energy consumption buildings can be realized using straw bales.

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RIce Straw in Building

The Egyptian environmental friendly house as a case study

البناء بقش الارز

دراسة تجربة مصر في بناء منزل صديق للبيئة

Heidi Ahmed Shalaby, PhD.

Lecturer of Urban Planning, Architecture Department, Faculty of Engineering

Zagazig University, Egypt.

e.mail: Heidi.shalaby@yahoo.com, Tel.: 00201060601052

الملخص العربي :

يعتبر الأرز من المحاصيل الاستراتيجية في مصر، حيث تزرع مصر حوالي ٢ مليون فدان أرز سنوياً ، والتي تنتج حوالي ٦.١٢ مليون طن ارز سنوياً، وبالتالي تنتج حوالي ٤ مليون طن مخلفات من قش الارز سنوياً، ويتم الاستفادة فقط من ٢٥% من هذا الانتاج ويتم التخلص من الباقي وهي كمية هائلة لايمكن التخلص منها الا بإعادة التدوير واستخدامها بطريقة غير ملوثة وصديقة للبيئة.

يهدف البحث لتقديم أحد التجارب الهامة لحل مشكلة التخلص من مخلفات الزراعية الصلبة، وبالأخص قش الارز، والذي يتسبب حرقه في ظهور السحابة السوداء التي تغطي سماء مصر عقب إنتهاء موسم حصاد الأرز كل عام، والتي تعتبر من أكبر المشاكل البيئية الناتجة عن التخلص من المخلفات الزراعية بالحرق، على الرغم من القيمة الاقتصادية العالية لهذه المخلفات إذا ما تم إعادة تدويرها والاستفادة منها لتوفير مصادر جيدة لغذاء الحيوان والأسمدة العضوية والطاقة الحيوية، فضلا عن المحافظة على البيئة ومنع القدر الكبير من التلوث الذي يُحدثه حرق هذه المخلفات، والتخلص منها بالطرق التقليدية.

ويتم اعادة تدوير العديد من المخلفات الزراعية لإستخدامها فى صناعة العلف الحيوانى والسماد العضوى الذى يحل محل الأسمدة الكيماوية، مثل مخلفات القمح والشعير والذي يتم فرمها وانتاج التبن الذي يستخدم كعلف للحيوانات يمتاز بقيمته الغذائية العالية. وهناك أنواع اخرى تستخدم كوقود لمصانع الأسمنت، مثل حطب القطن والذرة وبقايا تقليم النخيل، إلا أن قش الأرز يمكن ان يدخل بقوة فى صناعة طوب البناء والواح البناء، كما يمكن معالجته ليكون غير قابل للحرق والتعفن ولا يتاثر بالرطوبة ويمتاز بقدرته على عزل الصوت والحرارة. كما يمكن انتاجه بكثافات مختلفة من ٥٠٠ الى ١٨٠٠ كلغ على المتر المكعب. ومع ذلك فإن اجمالي ما يتم الاستفادة منه من قش الارز لا يتجاوز ٢٠% من إجمالي القش المنتج سنوياً.

ويتناول البحث تجربة البناء بقش الارز، ويعرض بعض التجارب المختلفة للبناء به في العالم، سواء بطوبة قش الارز المخلوطة بالاسمنت أو بالات قش الارز المضغوطة، في محاولة للوصول الى نموذج اقتصادي لبناء منازل صديقة للبيئة وغير ملوثة. ويوفر هذا النموذج حوالي ٤٠% من تكلفة البناء لنفس الوحدة بطرق البناء العادية. بالاضافة الى توفيير الطاقة المستهلكة، والعزل الحراري الجيد لهذا النموذج.