WASTE MANAGEMENT AND MATERIAL RECYCLE AS A POTENTIAL OF SUSTAINABLE BUILDING ENVELOPE FOR LOW INCOME HOUSING

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Abstract *Energy crisis and pollution are two main challenges that hinder sustainable development in Egypt. Electricity represents the major part of Egypt energy; however, the Egyptian electricity consumption is increasing much faster than capacity expansions which causes electrical blackout. Egypt's electricity prices began to rise starting July 2015 as part of a plan to reduce the government subsistence on electricity and force people to rationalize the consumption. Residential buildings are representing 40% of the total energy consumption, in Egypt. This is mainly due to a poor design of buildings, with no concern to neither materials used nor building tightness. This results in high cold bridges that increase the heat transfer from the outside to the inside of building spaces leading to high internal discomfort. Concomitantly, impacting the increase of energy consumption in cooling and heating today in most Egyptian buildings. This paper is part of a multiphase experimental research work that represents an empirical comparative study of different thermal walls' created from recyclable materials. The results would be analyzed in details, developed, and evaluated in terms of; technical, economic and environmental aspects and conditions. As a result of this study; the walls of such economical homes will be able to resist heat transfer with lowest possible cost and consume less energy.*

1. INTRODUCTION

The research presented in this paper explores the potentials of reducing the energy demand of cooling in a low-income housing unit in Cairo, Egypt, through optimizing its outer envelope. The study undertakes an empirical methodological approach using comparative analysis of different thermal walls‟ designs and insulations employing physical modelling and monitoring of physical models. The results would be analysed in details, developed, and evaluated in terms of; technical, economic and environmental aspects and conditions. The final outcomes of this empirical investigation optimises the walls design of such economical homes to resist heat transfer with lowest possible cost; less energy consumption and less reliance on mechanical cooling systems.

2. ENERGY CONSUMPTION IN EGYPT

Egypt is an energy rich nation. Its production of hydro, natural gas and oil totalled 1.87 million barrels in 2012. However, population has skyrocketed from 36 million in 1970 to 81 million in 2012 and 83.3 million in 2014 [1] which consequently led to the increase in energy consumption. [2]

The residential sector that consumes 42% of the total consumption is the main consumer of electricity in Egypt. The consumption has steadily increased over the years and this due to the increase in population, the expansion of residential compounds and development of new communities as well as the use of domestic appliances, air conditioners mostly during hot weather [3]The next high electricity consumer is the industrial sector, which consumes about 28% of the total electricity consumption.

Due to the increasing energy consumption as a result of so many reasons such as the constant use of air conditioners during summer, Egypt has over the last 4 years suffered a lot of blackouts; therefore, serious research and work looking into finding alternative solutions and means for energy savings is currently needed. It‟s worth noting that mechanisms and strategies for implementation of such energy saving techniques within the country are to be clarified.

3. RELATION BETWEEN BUILDING CONSTRUCTION AND ENERGY CONSUMPTION

Around 40% of total energy consumption and greenhouse gas emissions are directly due to construction and operation of buildings. The best method of reducing this impact is the use of green buildings construction techniques and also the use of transparent concrete in buildings as this helps to reduce the use of energy for lighting during day time. [4]

During the building construction, energy is consumed in the process of the site clearance and preparation by the use of machinery and equipment, the construction of the building structure: foundation work and structural framework, interior finishing and commissioning.[5]Energy consumption in building construction differs due to different materials and methods of construction and also environmental issues.

The materials used for wall construction and plastering in Egypt are mainly brick, mortar and concrete. These materials have little thermal resistance for heat loss and heat gain during winter and summer and this immensely contributes to the energy consumption for operational energy.

4. CARBON EMISSIONS IN EGYPT

In the history of Egypt in terms of carbon dioxide emissions, according to country meters and World Bank Egypt total population is currently 86.66 million. [6]Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. Those emissions are from burning of fossil fuels besides burning garbage and straw in Egypt that cause what is known as heat gained, a lot of people refer to it to as the „Black Cloud".

4.1 Burning straw and waste management in Egypt

In Egypt, there are part of a yearly event where famers burn their leftover rice straw, causing several pollution and two to three months of potential complication for respiratory and heart disease patients.[7]. CAIRO, Nov 9 (Reuters)- After the rice harvest each autumn, Egyptians take a deep breath and brace for the "black cloud", a thick layer of smog from burning rice straw that spreads across Cairo and the Nile valley for several weeks. Environmentalists blame the burning of agricultural "waste", mostly rice straw, for the pall of smoke that turns the capital's already noxious air into an even more toxic mix.[7]
Farmers produce about 30 million tonnes of what they see as waste each year. What the y burn is responsible for 42 percent of autumnal air pollution, the environmentalists say. [7]On the other hand, rice straw has plenty of potential uses, experts contend and this should be put in context in Egypt.

The challenge for Egypt, struggling to revive an economy hit by an uprising in 2011 that ousted Hosni Mubarak, who remained president of the country for thirty years, is to develop the cost-effective technologies needed to convert the straw into pulp for paper, fertiliser, active carbon or natural fibre plastic composites -- and to convince farmers not to burn it.[7]
Forecasting possible health problems, an American academy for immunology Abdel Hady Mesbah, said the waste burning could cause autoimmune diseases.[8]

4.2 Waste and recycle management in Egypt.

There is no proper arrangement by government for the recycling of garbage so the Egyptians burn garbage because no one buy it from them. Each year
Recycle management is the implementation of waste Management systems and recycling initiatives in industries. [9]This adds value to the industry and creates further economic opportunities from newly developed products based on the sustainable use of generated waste from the production process.[9] It is likely that all industries have an amount of their output that can be reused or recycled hence recycling save costs and creates both economic and environmental opportunities [10]

Building insulation is commonly realized using materials obtained from petrochemicals (mainly polystyrene) or from natural sources processed with high energy consumptions (glass and rock wools). These materials cause significant detrimental effects on the environment mainly due to the production stage, i.e. use of non-renewable materials and fossil energy consumption, and to the disposal stage, i.e. problems in reusing or recycling the products at the end of their lives[11] Sustainability in building process introduces building materials that are effective insulators and are made from natural or recycled materials, which are environmentally friendly [11]

In this study, straw and paper are used as insulation materials for exterior walls of buildings. The insulation properties of some of these unconventional materials were studied so as to determine the opportunity to re-use or recycle them in the building sector. From a whole life cycle building approach, these materials can be classified into natural and recycled materials. The thermal properties of these materials were studied and it was noticed that some materials had a low measured value of 0.140w/mk [12] This therefore makes them poor thermal insulators and more of structural materials. Some of these materials are; local banana and polypropylene fibres, composite waste grass broom and fibres- reinforced polyester composites.[12]

5. EMPIRICAL STUDY

5.1 Introduction

This research carries an in-depth study on the optimum insulation befitting for poor and low income housing in Egypt, to reduce the energy consumption inside buildings. Based on different criteria as: availability, cost, and durability. The research made use of straw and shredded paper as the insulation materials. Three identical physical models were constructed from bricks; two of them had an insulation layer. The models were constructed in accordance with the conventional method of building in Egypt and were all within a specific time frame. In one of them straw (Figure 1a) was used as an insulation layer and in the other shredded paper (Figure 1b) was used, while the third model was constructed as a reference without insulation (Figure 1c). The three models were constructed and monitored on the roof of the School of Architecture and Design, University of Lincoln, UK. A cross case investigation was undertaken to analyse the three models.

Figure 1. (a) The straw insulation; (b) The shredded paper insulation; (c) Reference model

All the three models are quite comparable in terms of the brick used, height, finish, mortar mix ratio, base and the roof cover. However, the only distinguishing item is the insulation layer used. In addition, all the models were subjected to the same atmospheric/weather condition.

5.2 Insulation materials

The empirical study included two types of recyclable materials as discussed earlier and have been chosen according to certain criteria to be examined as insulation materials, which are straw and shredded paper. Paper Mache was initially used for a day in this research but due to climatic conditions and the high moisture content that did not dry up quickly, we decided to replace it with the shredded paper.

Straw, shredded paper as well as the reference were subjected to various weather conditions in Lincoln, UK. The peculiarity of the period of this research (mid-July to mid-August) is that characteristics of four seasons a day is exhibited in the UK all year round (summer, winter,

autumn, and spring), surfaces within this period. All these strategies were employed to get the optimum result

5.3 Equipment and idea

Three Data logger USB device (RHT10) were set in the three empirical models. This is an environmental and temperature/humidity monitoring device. It is a simple USB data-logging device that is fixed in the same central place in the three models; it is left in an area or space to constantly evaluate humidity and temperature over an identified time period. The use of RHT10 requires choosing sample rates and then leaving the device in the space it captures data and automatically stores it on the device. Its USB nature of the RHT10 makes downloading to PC very easy, that in return makes analysis collation of readings relatively easier and faster [13].For all collated data, the recording were in the following sequence; 10 seconds, 10minutes and 30 minutes with the temperature set at a range of 0 and humidity set at a range of 20 to 80.

5.4 Study limitations

Three brick models were constructed and used for this empirical research study. Two having a distinct insulation material with the third model constructed in the conventional uninstalled way (Egypt). However, the same building process was adopted in building all the models such as the same brick thickness (100mm), same mortar mix ratio (1 portion of cement to 4 portion of sand), same rubber mesh thickness, and the same paint (white emulsion) used for both internal and external finish.

5.5 Models specifications

5.5.1 Model 1 (Reference)

The reference model is used as a basis for the comparison of other models. It represents the conventional way of building in Egypt. This involves the use of brick and the use of mortar (Table 1) for its plastering band bonding.

Table 1. The thermal properties of the reference model [14]

No.	Layer name	Thickness (m)	Thermal conductivity (λ) (w/mk)	Density (kg/m3)
1	Plaster	0.010	0.35	1200
2	Cement Mortar	0.020	1.40	2000
3	Brick	0.100	0.81	1800
4	Cement Mortar	0.020	1.40	2000
5	Plaster	0.010	0.35	1200

5.5.2 Model 2 (Shredded Paper)

The process adopted here is not any different from the others. The same brick specification, mortar mix ratio, wall screed thickness and the same wall finish (white paint). However, the only distinct component is the shredded paper (Table 2) used as an insulation material in the model insulation layer. It is worth noting that all necessary efforts were put in place to make sure that the shredded paper used was compact and not lose to get the best result. The diagrams and pictures below practically illustrate the process.

Table 2. The thermal properties of the shredded paper insulation model **[14]**

No.	Layer name	Thickness (m)	Thermal conductivity (λ) (w/mk)	Density (kg/m3)
1	Plaster	0.010	0.35	1200
2	Cement Mortar	0.020	1.40	2000
3	Shredded paper	0.045	0.04	
4	Brick	0.100	0.81	1800
5	Cement Mortar	0.020	1.40	2000
6	Plaster	0.010	0.35	1200

5.5.3Model 3 (Straw)

In model 3 straw was used as the insulation material (Table 3) and similar to Model 2 all necessary precautions were considered in ensuring that straw components were closely packed and compact.

Table 3. The thermal properties of the straw insulation model [14]

No.	Layer name	Thickness (m)	Thermal conductivity (λ) (w/mk)	Density (kg/m3)
1	Plaster	0.010	0.35	1200
2	Cement Mortar	0.020	1.40	1750
3	Straw	0.045	0.61	
4	Brick	0.100	0.81	1800
5	Cement Mortar	0.020	1.40	2000
6	Plaster	0.010	0.35	1200

5.5.4 Roof Cover

All roof covers are made of styro-foam with a thin layer of aluminum foil. The essence of the foil is to help balance the temperature inside the model and reduce the heat gained or absorbed through the roof of the models.

5.6 The project analysis

5.6.1 Temperature analysis

Comfort Zone is a mental state in which an individual feels at ease with the environment.[15] [16]The comfort zone for indoor air temperature ranges from 20ºC - 25ºC maximum. But insome situations such as summer 27ºC can be considered as tolerable, and 18ºC can be considered as comfortable if the relative indoor humidity and internal wall surface temperatures are properly adjusted.[17]

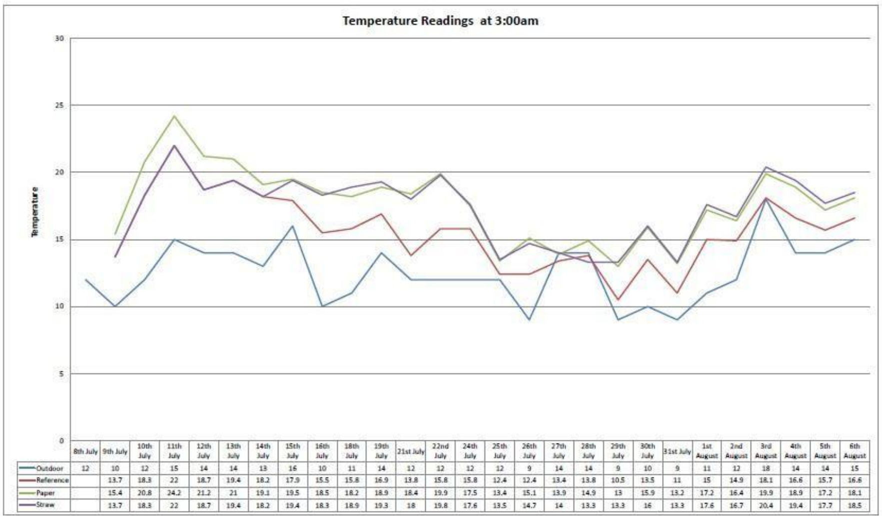


Figure 2. Temperature readings for 3.00am

The results collated from the data logger at 3:00am, the outdoor temperature is cold ranging from 15 ºC to 9 ºC. From this graph, it can be noticed that Paper has the highest temperature ranging from 24.2 ºC to 13 ºC, Straw was also close to paper with its reading ranging from 22 ºC to 13.3 ºC, but the reference seems to be in between with its readings ranging from 22 ºC to 10.5 ºC.

From the readings, it can be noticed that 3am is a period when the environment is very cold and heating system is required indoors, but we can conclude that Paper has the highest capacity to maintain the indoor temperature and keep the room from losing too much heat, thereby requiring less artificial heating system. Straw also maintained the indoor temperature thereby reducing heat loss. But Reference loses heat quickly, which will make the indoor temperature a bit cold and require heating system.

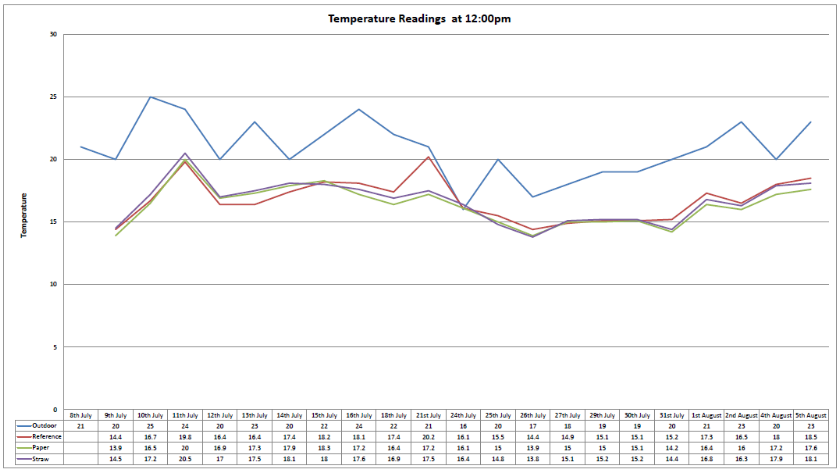
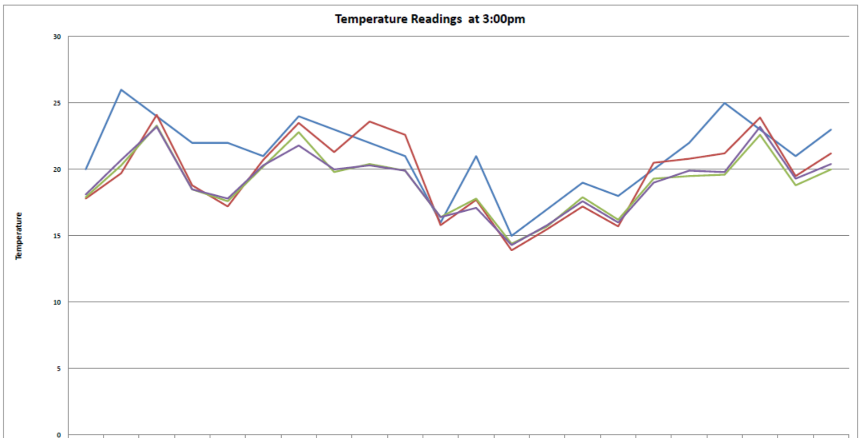


Figure 3. Temperature readings for 12:00pm

At 12:00pm, the outdoor temperature has increased from a range of15 ºC to 9 ºC to a range of 25 ºC to 16 ºC, while paper reduced from a range of 24.2 ºC to 13 ºC to a range of 20 ºC to 13.9 ºC, straw reduced from a range of 22 ºC to 13.3 ºC to a range of 20.5 ºC to 14.5 ºC, and reference reduced from a range of 22 ºC to 10.5 ºC to a range of 20.2 ºC to 14.4 ºC

At 12:00pm the sun is at its peak and perpendicular to the buildings therefore this is a period where the building absorbs heat from the environment. From the readings, it can be noticed that there was a process of heat loss in the buildings between 3:00am and 12:00pm. Calculating the average heat loss between 3:00am and 12:00pm, paper insulation has the highest heat loss with a difference of +1.65 ºC, while straw insulation has a difference of +0.15 ºC, and the reference model has a difference of -1.05 ºC.

This shows that paper insulation has the highest heat loss from the building to the environment, thus keeping the building cooler than the outdoor temperature, that is mainataining the temperature because of heat transfer lag. While the Reference model gained heat from the environment keeping the indoor temperature hot, thus requiring cooling system on a minimal level.



	9th July	10th July	11th July	12th July	13th July	14th July	15th July	18th July	20th July	21st July	24th July	25th July	26th July	27th July	29th July	30th July	31st July	1st August	2nd August	3rd August	4th August	5th August
Outdoor	20	26	24	22	22	21	24	23	22	21	16	21	15	17	19	18	20	22	25	23	21	23
Reference	17.8	19.7	24.1	18.8	17.2	20.7	23.5	21.3	23.6	22.6	15.8	17.7	13.9	15.5	17.2	15.7	20.5	20.8	21.2	23.9	19.5	21.2
Paper	17.9	20.3	23.3	18.5	17.6	20.2	22.8	19.8	20.4	19.9	16.4	17.8	14.4	15.7	17.9	16.2	19.3	19.5	19.6	22.6	18.8	20
Straw	18.1	20.7	23.2	18.5	17.8	20.3	21.8	20	20.3	19.9	16.4	17.1	14.3	15.8	17.6	16	19	19.9	19.8	23.2	19.3	20.4

Figure 4. Temperature readings for 3.00pm

At 3:00pm, the outdoor temperature increased from a range of 25 ºC to 16 ºC to a range of 26 ºC to 15 ºC while paper increased from a range of 20 ºC to 13.9 ºC to a range of 23.3 ºC to 14.4 ºC, straw increased from a range of 20.5 ºC to 14.5 ºC to a range of 23.2 ºC to 14.3 ºC, and reference increased from a range of 20.2 ºC to 14.4 ºC to a range of 24.1 ºC to 13.9 ºC. From the readings, 3:00pm has the highest temperature for the day, therefore there is a process of heat gain from the environment into the buildings. It can be noticed that the Reference model gained more heat, thus keeping the indoor very hot similar to the outdoor temperature, the heat gain in paper was close to straw, but straw gained the least heat, thus keeping the indoor temperature cooler than the outdoor temperature.

Calculating the average heat gain between 12:00pm and 3:00pm, Reference model and paper model had an average heat gain of +1.9ºC, while straw has an average heat gain of +1.25ºC. The difference between the heat gain in the two models Paper and Straw insulation is 0.65ºC which is negligible.

6. DISCUSSION

This paper presented part of a multiphase project investigating alternative approaches of waste management particularly rice hay and straw in Egypt in an attempt to bring it back to the cycle through reusing it as an insulation material in low income housing. Waste management and material recycle as a potential of sustainable building envelope for low-income housing. The paper serves to present validated results through monitoring and data analysis of the potential possibility of using rice straw as an insulation materials (instead of burning it) for poor and low income housing in Egypt.

During this research, the following problems were encountered:

- Continuously changing weather, which had effect on the readings.
- High humidity.

Materials used as insulation are from farming waste in Egypt with specific reference to rice straw, which are readily available. In the course of this research, three buildings were constructed at a scale of 1:10 in the form of solid boxes and were separated from each other appropriately to avoid any of them overshadowing the other. Readings were taken and downloaded with the use of Data logger USB device RHT10. This was done regularly every third day round the month on the excel sheet with a new set -up entered to take the next reading. During this period, readings were also taken to for the outdoor temperature and weather conditions.

7. CONCLUSION

This research study is part of on-going research work looking work looking into the use of recyclable material in the insulation of building. The study looks at identifying alternative insulation materials for building exterior and interior walls using unconventional and recycled materials which are disposed-off as waste product and are environmental friendly for buildings in the hot arid regions.

From the list of unconventional materials, Straw and Shredded paper were selected based on certain criteria set up for this research. There were high interest in the use of rice straw as a material abundantly available in Egypt and the way it is disposed of cause high pollution and black cloud all over Cairo as discussed in this paper.

The empirical investigation carried out in this study concluded that:

- Out of the three models, the Paper insulation model has the highest level of heat resistance. It reduced heat loss when the outdoor temperature was cold, and it reduced heat gain when the outdoor temperature was hot.

The model with Straw insulation was also close to that of Paper insulation. However, its worth noting that Paper insulation gave the optimal results, while the reference model (which represents the conventional way of construction in Egypt) gains and loses heat at a much faster pace.

The models have shown poor response to humidity, as a result of the fact that all three models had very high humidity level, which was above the comfort zone. However, out of all three models, the model with Straw insulation material demonstrated the best results in reducing the indoor humidity, while the reference model and the Paper insulation model had almost the same level of reducing humidity.

8. RECOMMENDATION

1. For future researches, the research team recommends more work and strategies to be used on the material treatment to improve the efficiency of straw and paper as insulation materials against humidity. More attention must also be paid to the general quality of insulation materials used and the compactness of the insulation layer to avoid any possible errors.

2. This will help improve the insulation quality and optimize the energy benefits of buildings.

3. The extension of monitoring over a one-year period would help in getting more precise results and a full picture of the performance of the construction system and the insulation materials. Accordingly, getting the average yearly cooling and heating exchanges with respect to the seasons in the year will be possible allowing to estimate the offset of mechanical heating or cooling required.

4. In reference to the humidity, the research team recommends the combination of shredded paper and straw to see the possible outcome in future researches.

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