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Preparation and Analysis of Cement Bricks Based on Rice Straw

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Abstract
In Egypt, rice straw is burnt as an easy and the cheap method to get rid of it leads to making a giant black cloud covers Cairo and southern delta governorates. Main purpose of this research is to produce green brick of cement and in-expensive agriculture waste (rice straw) with law price and good characteristics of thermal insulation and acoustic resistance. Different samples of cement brick based on rice straw of many percentage were prepared. First, select best mixture of concrete brick before adding rice straw after preparing and leave for curing time. Then, rice straw is added with various percentage based on total mass of dry mixture to selected concert brick mixture. The selection of best mixture of green bricks criteria is first depending on achieving minimum compression strength according to Egyptian specification then maximizing the percentage of rice straw added. The two mixtures of cement bricks that have maximum compression strength are 1:2:2 and 1:4:5 of 6.2 and 3.1 MPa. The highest percentage of rice straw can be added to later cement mixture is 3% additional quantities based on total mass of mixture dry base of 2.9 MPa. The impact of 3% addition of rice straw on cement bricks enhances thermal by 21.05% by comparing with cement brick of ratio 1:2:2. It decreases sound pressure level inside room from 62 dB to 45 dB. Although, cement bricks reduce sound pressure level to 55 dB. Thousands of cement bricks with 3% rice straw cost is less 8.3% the cost of thousand of cement brick with market ratio 1:4:5. Cement brick of ratio 1:4:5 that used by OPAKI company in Egypt for cement brick manufacturing is used with adding 3% of rice straw. Whatever, it gives very low resistance against compression lower than Egyptian specifications. This mixture of 3% rice straw base is enhanced by nano-silicon addition percentage of sand portion of 2.1 MPa compression test, although cost of thousand bricks is almost equal to the cost of thousands of commercial market bricks. Eventually, life cycle assessment of rice straw is better than normal cement brick mixture materials that helps in reducing greenhouse emissions and energy consumed.

Key Words: Rice straw, Agricultural waste, Pollution, Cement bricks.

1. PROBLEM STATEMENT

Around 9.7% of total agriculture waste produced in Egypt every year are only rice straw. Rice straw one of renewable waste. In Egypt, more than 90% are burnt as an easy and the cheap method to get rid of it. This have a negative impact on environment by causing smokes of CO, CO_2, NOx and SOx. Therefore, rice straw is available inexpensive material that used in construction as mud houses in rural area and in ancient Egypt. Moreover, produce sustainable cement bricks based on good thermal and sound insulation with respecting to the Egyptian minimum compression strength of non-load bearing wall will leads to saving energy.

2. RESEARCH OBJECTIVE & METHODOLOGY

Main purpose of this research is to produce green brick of cement and in-expensive agriculture waste (rice straw) with law price and good durability characteristics of thermal insulation and acoustic resistance. First select best mixture of concrete brick before adding rice straw as a filler. Determine to how much the maximum percentage of adding rice straw from total mass of brick that must achieve Egyptian minimum compression strength of non-load bearing specification and fire resistance. Furthermore, the utilization of rice straw solves its environmental impact.

Thermal insulation performance of bricks is related to energy consumption by reducing the utilization of heaters in winter and air conditionals in summer. These energies are consumed because of changing climate and unsustainable strategy of buildings. Nowadays, it is concerned on energy saving and

environmental issues [1-20]. In Europe, 40% of total energy consumption is inefficient energy loss within building wall. Improving insulating properties of building is important [21-33]. Bricks production consume high energy and resources. Manufacture step is not only effect on environment but also usage step "position", material and their thickness qualify thermal comfort conditions inside buildings [34-56]. Sustainable bricks do not only mean that material should be thermal effectively only, but also sound insulation for decreasing disturbance and noise impact, permeability of water vapor, resistance against fire and effect on human and environment [57-62]. Bricks are solids moulded with different materials. Bricks manufacturing materials are contributing to durability of construction. Todays, world try to replace sand by renewable and non-renewable unrecyclable waste. Aim of sand replacement is to get rid of wastes to reduce pollution, greenhouse emissions and for saving money [61-63]. Green materials should be characterized with prevent toxic and other emissions, safe built environment, saving energy and water, and conserving natural resources according to environmental building news. The utilization of straw bale has many advantages on environment. Although, these advantages are reducing greenhouse emissions during production and thermal insulation, the usage of this bale faces many challenges as organic nature and absorption of water from surrounding must be taken into consideration [64-69].

The types of bricks are important according to type nature of building and aim of this building. Bricks classified into fired and unfired bricks or cement based and clay based. There are different types of bricks; clay, cement, fly ash, sand-lime and fire bricks. Bricks should be sustainable that means building bear for very long time, they should be resisting and withstand any natural effects with minimum damage, and it is studying of bricks based on also environmental emissions, energy consumption and cost, etc. It also could be sustaining the minimum load strength based on specifications [7-9]. Concrete is widely used throughout world with production rate 3.8 million tonne/year. Main properties of bricks are the mechanical and durability that depend on manufacture process. Nowadays, it is focused on upgrading properties of bricks as thermal insulation and sound insulation with meeting compression strength specification. This upgrading depends on adding industrial and agricultural wastes.
The usage of fiber in construction processes occurred from ancient is used as a material of bricks and masonry mortar. fibres may be straw or horsehair. Nowadays, its focused on using these fibres in many engineering processes as ceramics and concrete production. Utilization of fibers improve properties of concrete such as impact resistance, thermal insulation, tensile strength, and shrinkage [10]. Main components of natural organic fibers are cellulose, hemi-cellulose, and lignin.

Natural fibers are renewable wastes available with low cost [11].Rice associates with large quantities of agriculture wastes that is obtained from harvest stage of rice. It is the most causing solid waste problem of rice crop. Average rice consumption is 477 million per year throughout world [12]. So, rice crop is the second production in agriculture crops.Solid wastes that generate are bran, broken rice, straw, ash, and husk. One of them is rice straw of high-volume generation that its disposal makes problems.FAS Cairo forecasts Egypt's marketing year (MY) 2018/19 (October-September) milled rice production is about 3.3 million metric tons (MMT) corresponding to Planting 800,000 feddan (Egypt: Update to Egypt's Rice Production, Consumption, and Trade Figures, 2018). Rice straw is known a fibrous lignocellulosic material that contains 41.8% of cellulose, 21.6% of pentosans, 13.6% of lignin, 18.4% ash and 16.7% of silica (Dry base) based on chemical egyptain rice straw analysis [5, 8, 13-15]. Rice straw is an agriculture waste associated from rice crop. It accumulates during early step which is harvest step. It left to dry by exposing to sunlight or by put it into microwave dryer. This drying is necessary for making grinding into powder is easier. The average length of rice straw after grinding less than 0.5 mm. The rice straw is cleaned and dried at 80 ^{o}C for 8 hr. Rice straw can be treated against NaOH [6, 10, 14-17].

Figure 1 Rice Straw Generation Steps [11]

3. EXPERIMENTAL WORK

3.1 Compression test

Every mix of rice straw cement brick, three samples were examined in the Lab. Another three plugs with tandard commercial cement bricks were examined to

check the compression stresses of these bricks. Bricks dimensions were checked and measured precisely with an average 6*6*6 cm dimensions. The Shumadsu 1000 KN universal tension-compression apparatus, made in China was utilized in examining the bricks compressions. The apparatus is equipped with an output unit of data analysis for output data recordings. The three rice straw bricks combine and mix under examining were prepared and checked for standard pure cement characteristics. Bricks were placed horizontally on the testing machine. A 1 mm/sec rate of applying loadings on each specimen until observing a failure. The compression testing results for all bricks mixings are presented in result chapter. These results were compared to the specified values obtained by the Egyptian Code of Practice ECOP 204-2005.

Figure 2 Cement brick with rice straw and glass powder addition after applying compression test

3.2 Thermal Insulation Test

Two hot plates are faced and separated by about 20 cm distance from each other. Both are adjusted at 250 ^{o}C temperature. Ex-tech 5-in-1 Environmental meter is used for temperature measurements. 15 minutes is sufficient for increasing temperature and making constant reading of Ex-tech 5-in-1 Environmental meter of the surrounding between two plates. Reading of surrounding become constant at temperature 60 ^{o}C after 20 minutes. Small room of 12 cement bricks is built as shown in figure below so that there is no space of air among bricks. Dimensions of room is 25*4*6 cm. Ex-tech 5-in-1 Environmental meter is placed inside this room for 10 minutes. Reading is recorded and repeated for cement bricks with 3% of rice straw addition.

Figure 3 Ex-tech 5-in-1 Environmental Meter

3.3 Sound Insulation Test

Small room of prepared cement bricks is built to cover instrument which act as receiver of sound. This receiver of laboratory scale is Ex-tech 5-in-1 Environmental meter. Range of measuring Ex-tech 5-in-1 Environmental meter is 30 to 130 dB with error ±1.4 dB. Source is loud sound of sound pressure level about 62 dB. Ex-tech 5-in-1 Environmental meter is placed inside room for 5 minutes to give constant reading with high accuracy. Same procedures were repeated for cement brick of base rice straw samples.

4. RESULTS

4.1. Cement bricks

o Compression resistance of cement bricks based on cement and sand on the content of the sand

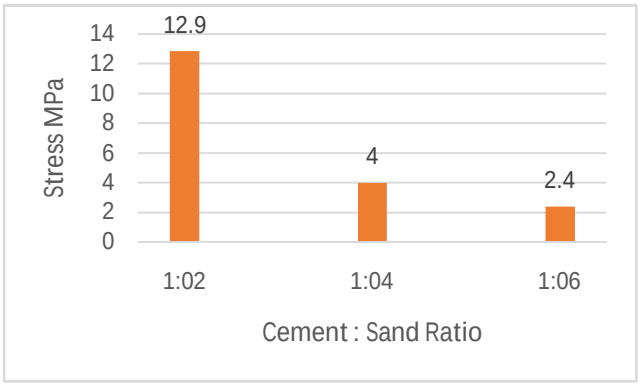


Figure 4 Compression resistance of Cement-Sand bricks with different ratios

It is obvious that the amount of cement in the mixture of the cement bricks effects on the compression strength of the bricks because cement may be responsible of compactness in the brick mixture. As shown in fig, the amount of sand in brick increases the compression decreases due to decrease the concentration of cement which is the binder in Cement–Sand bricks. Therefore, Amount of cement is added in the mixture of cement bricks is directly proportional to the compression strength. Cement-sand bricks are used for smooth surface of interlocks manufacture but for building bricks consists of cement, sand and aggregate as an ingredient according to Opaki Company in Egypt.

Figure 5 Cement-Sand Brick of rice straw based

4.2 Compression strength of cement bricks based on cement, sand, and aggregate on the content of grit with different ratios

Compression strength of cement-sand bricks is put into consideration for comparing them with Concrete bricks that consist of cement, sand and aggregates and show the impact of adding aggregates. From ratio 1:2:2 to 1:4 as shown in figures 5 and 6, it obvious that compression strength of 1:2:2 is 6.2 MPa higher than 1:4 which is 4 MPa. Samples 1:2:6 and 1:4:4 can be compared as a decreasing in aggregates amount added to the mixture of bricks. This decreasing affects negatively by 66.67% of compression from 3.9 MPa of 1:2:6 to 1.3 MPa of 1:4:4. Bricks mixture of different ratios in figure, shows that the addition of aggregates increase the resistance against load until point at which mixing of mixture and binding by cement become difficult. Therefore, figure 8-8 shows there is an optimum point of concrete brick ratio. It is clear the optimum ratio in the curve of figure is 1:4:5.

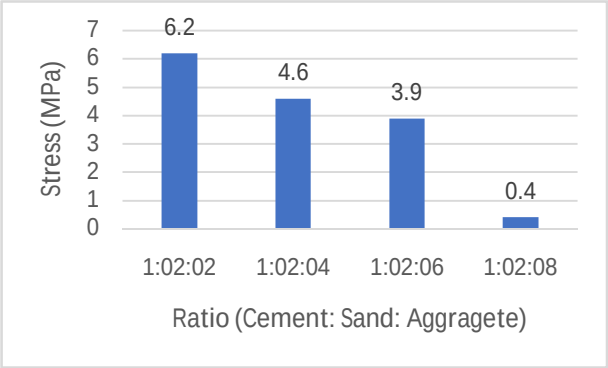
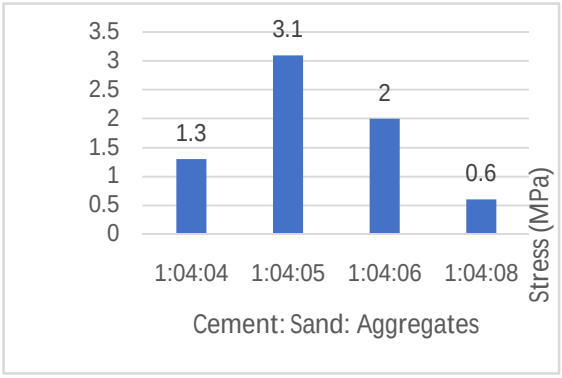


Figure 6 Compression strength based on Contents of Cement bricks consist of cement, sand and aggregates with different ratios (1: 2: no.)

Furthermore, Opaki company for cement bricks manufacturing, in Egypt is producing their bricks for construction of buildings with ratio 1:4:5 also. This test objective provides the best mixture that can be added rice straw. It was chosen 1:2:2 ratio of brick mixture which has highest compression strength of 6.2 MPa for adding rice straw with different



percentage and showing its impact on the brick's behaviour.

4.3 Compression resistance of green bricks "Cement bricks of ratio 1:2:2 with addition rice straw different percentage" comparing with Cement-Sand bricks of ratio 1:4 based on rice straw

Figure 8 Three different percentage of rice straw added to Cement brick 1:2:2 ratio consists of: cement, sand and aggregates

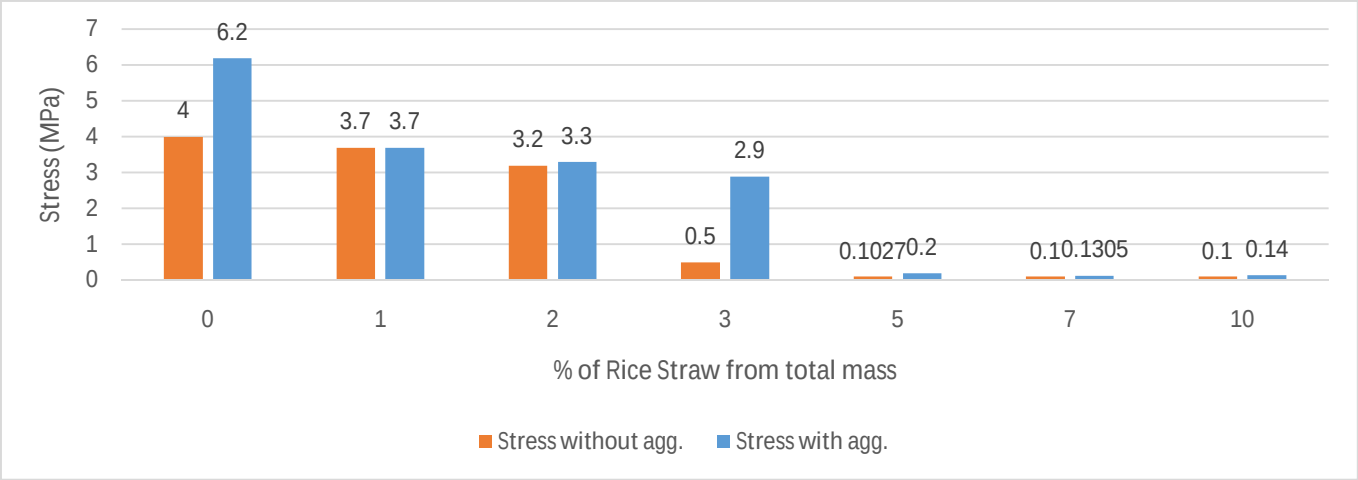


Figure 9 : Dependence of compression resistance on percent of rice straw for the standard brick consists of cement-sand (1:4) and Cement bricks consists of cement, sand and aggregate (1:2:2)

It is clear in figure that as the amount of rice straw added, the compression strength of mixture decreases gradually from 0 to 3% addition of rice straw as show in figure. More than 3% of rice straw added to cement brick mixture leads to drop in compression strength though the difference in the amount of cement between 3% mixture with aggregate comparing.

In addition, chemical analysis of rice straw bricks and cement bricks were investigated by Gihan, 2011. Results were the amount of calcium oxide and silicon oxide in cement bricks slightly higher than the rice straw bricks. Calcium oxide and silicon oxide are responsible of the Cementous activity when reacted with water. Furthermore, properties of both bricks were nearly the same. However, it may depend on the percentage of rice straw addition. Rice straw increase water absorption and consume high amount of water during preparation. Therefore, rice straw decrease efficiency of usage as a material for construction bricks. However, it is overcome permeability of water absorption is by facing mortar of cement lime stucco or may need more time for curing and gain more strength with time.

4.4 Sound Insulation Test

Source sound pressure level= 62 dB

- Sound insulation test for cement bricks of ratio 1:2:2
  Sound pressure level of cement bricks 1:2:2 ratio = 55 dB
  Sound insulation of cement bricks 1:2:2 ratio= 7 dB
- Sound pressure level of 3% rice straw of cement mixture ratio 1:2:2
  Sound pressure level of 3% rice straw of cement mixture ratio 1:2:2 bricks= 45 dB
  Sound insulation of 3% rice straw of cement mixture ratio 1:2:2 bricks= 17 dB

It is clear from experimental result of sound insulation of cement bricks have 3% of rice straw addition is better and higher than sound insulation of cement bricks performance for same ratio of concrete mixture 1:2:2. This is means that rice straw has good sound absorption.

4.5 Thermal Insulation Test

Heater plates are used to heat region that separate them 20 cm. Temperature of the plates adjusted at about 250 ^{o}C. The space temperature between two plates is 60 ^{o}C.

Thermal insulation in door of cement bricks of ratio 1:2:2

Cement brick involve in mixture is cement, sand, and aggregate of ratio 1:2:2. Temperature inside room of cement brick is about 38 ^{o}C after 5 minutes of test.

ΔT= 60-38 = 22 ^{o}C

Figure 10 Thermal insulation test of cement bricks of ratio 1:2:2 by Ex-tech 5-in-1 Environmental meter

Thermal insulation in door of cement bricks of ratio 1:2:2 with 3% of rice straw

Rice straw on cement bricks Influences the thermal insulation. Rice straw-cement bricks consists of

cement, sand, and aggregates of ratio 1:2:2 with addition 3% rice straw. Temperature indoor is 30 ^{o}C after 5 minutes of test.

$\Delta T = 60–30 = 30\ ^{o}C$

Comparison between cement bricks of ratio 1:2:2 with cement bricks with same ratio after adding 3% rice straw:

% Reduction= $\frac{(38-30)*100}{38}$= 21.05%

Thermal insulation is one of the important properties for bricks of constructions. It is directly proportional with energy saving. Thermal conductivity of normal market cement brick is 1.25 Watt/m.K (Akmal T. et al., 2011). According to Elhelece, 2010, studies show that major component in Egyptian rice straw is cellulose with 41.8% wt about half content of rice straw. Cellulose has thermal conductivity of range 0.031 - 0.042 $Wm^{-1}K^{-1}$ (Nguyen, 2014). However, thermal conductivity of market cement brick mixture is 0.5 $Wm^{-1}K^{-1}$. Content of cellulose with high content may have major effect of good performance of cement bricks with rice straw.

4.6 Impact of additives (as: glass powder & nano-silicon) on compression resistance of cement brick with ratio of market 1:4:5 and 3% rice straw.

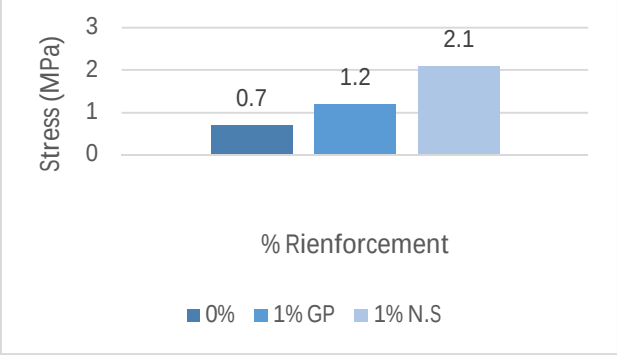


Figure 11 Impact of additives (such as nano-silicon and glass powder) to Cement bricks mixture of ratio (1:4:5) with 3% of rice straw.

Figure 123% Rice Straw-Cement bricks with 1% of Nano-silicon from mass of sand after compression test

Rice straw is added with 3% from total mass of mixture to commercial mixture of cement bricks which is ratio 1:4:5. It is clear that this sample does not achieve the minimum compression specification for non-load bearing bricks. Glass powder and nano-silicon have similar physical properties of sand. However, they have different surface area competing with each other and with sand. This difference may effect on compression strength of bricks. From left to the right on graph figure above, surface area of additive increase for same 1% percentage as a replacing portion of sand. As shown in figure above, the higher surface area, the higher brick resistance against load and this may be due to filling porosity that caused by addition of rice straw. However, Shayan A. et al. 2004, study the effect of adding waste glass powder on cement bricks. Waste glass powder is replaced portion of cement with 10% and 25% comparing with the control bricks.

The result of this research, both bricks with additives gives compression strength greater than 12 MPa but is less than the control sample after 4 days of curing. Although, compression strength of brick with 10% waste glass powder was slightly higher than control after curing 365 days.

% Price reduction of cement brick with 3% rice straw comparing with cement brick of market ratio (1:4:5) = $\frac{(495-454)*100}{495}$= 8.3%

Table 1 Summary Table

Bricks	Compression strength (MPa)	Thermal insulation ΔT (^{o}C)	Sound insulation (dB)	Price (L.E./1000 bricks) of 6*6*6 cm dimension bricks
Cement brick of ratio 1:2:2	6.2	22	7	576
Commercial market bricks based on Opaki Company of ratio 1:4:5	3.8	-	-	495
Cement bricks of ratio 1:2:2 with adding 3% rice straw	2.9	30	17	454

5. CONCLUSION

The main aim of this research is to produce green brick of cement based on rice straw with good characteristics of better thermal insulation and

acoustic resistance than normal cement bricks. First, best mixture of concrete brick is selected before adding rice straw. Then, rice straw is added with various percentage based on total mass of dry mixture to selected concert brick mixture. The choice of cement brick based on rice straw depends on maximizing percentage of rice straw added corresponding to achieve minimum compression strength of non-load bearing Egyptian specification. Final experimental work is determining temperature inside room of those bricks and sound to compare with cement bricks for same ratio of mixture.Results of research are first the presence of aggregates in cement bricks increases its compression strength comparing with cement-sand bricks for same ratio. Second, the selection of highest compression resistance against load of cement bricks are 1:2:2 and 1:4:5 of 6.2 and 3.1 MPa. Those mixture of cement are selected for adding percentage of rice straw. Rice straw slightly affect to compression strength of cement bricks may be because of low density and increasing porosity of brick contains rice straw. The sample that has maximum percentage of rice straw achieving minimum compression strength of cement brick with maximum ratio 1:2:2 amount of rice straw is 3% of rice straw. Whilethe maximum percentage of rice straw added to Cement-Sand brick is 2% of rice straw added. Cement brick based on 3% rice straw improves thermal by 21.05% comparing with 1:2:2 of cement brick.

Sound pressure level inside room of cement bricks 1:2:2 ratio based 3% of rice straw reduces from 62 dB to 45 bB. Comparing with cement brick of rice straw base, cement bricks reduce sound pressure level to 55 dB. Cement brick of 1:2:2 based on 3% of rice straw mixture cost is 23.21% less than cement brick with same ratio and 8.3% less than cement brick of market ratio. This improvement of the characteristics of brick-based rice straw may be due to high content of cellulose in the composition of dry rice straw.Furthermore, green brick optimizes and reduces resources that used as aggregates and most expensive material is cement. However, Sample cement brick of 1:4:5 with 3% of rice straw gives compression result less than minimum Egyptian specification. Glass powder and nano-silicon are used as a filler replace portion of sand contribute to increase strength of bricks against compression. Both are used for improving the compression stress results 1:4:5 of 3% of rice straw. This mixture of 3% rice straw base with 1% nano-silicon addition percentage of sand portion gives highest compression of 2.1 MPa comparing with 1% addition of glass powder and with 3% rice straw only and this may be because nano-silicon has the highest surface area and reduce porosity that caused by rice straw.

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