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An Innovative Sustainable Approach in the Manufacturing of Recycled Brick Mixture for Buildings

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Abstract- The brick is one of the most often used masonry components in construction due to its unique characteristics. There have been several attempts to produce bricks using only natural resources. This resulted in the creation of waste due to the consumption of natural resources. The manufacture of bricks is one of the significant waste producers in the construction industry. The problem of waste may be effectively solved by recycling these wastes and using them in building materials such as recycled bricks. This paper describes an experimental study that test the potentials of producing new, lightweight brick for the building industry using a blend of brick and plastic waste. The physical and mechanical characteristics of brick mixtures with various ratios of waste are studied. The test findings for compressive strength, unit weight, and water absorption values are measured in accordance with the applicable requirements for regular building bricks based on building codes. The results found out that using broken brick with plastic waste has a great positive impact on the recycled brick component in terms of unit weight and the percentage of water absorption reduction. It was also found to have a high thermal conductivity, thermal diffusivity as well as specific heat compared to red bricks, which can lead to stabilize; giving a new technique for installation and reduce the proportion of the decimated-on running. It could be used in the construction of walls that could participate in the reduction of temperature transfer from external to internal spaces in buildings.

Keywords: Recycled brick; Sustainability; Materials; Buildings; Construction Waste

I. INTRODUCTION

With the increase in population, economic activity intensifies as a result waste quantities augment. This waste managed to pave the way to various projects, such as (recycling projects - fertilizer production - energy production - etc.)[1]. However, individuals frequently dispose their waste in random dumps, where it is subsequently unhygienically burned or buried, “missing the chance for waste management and effective utilization”[2].

Converting wastes into valuable resources, such as construction material, has proven to be a difficult task due to Environmental concerns arose as mismanaged waste accumulated in developing nations. Recycling of some of these wastes into building materials looks to be a workable solution in order to prevent pollution in all its forms. Not to mention the advantages of cost-effective construction design [3]. In a third world country like Egypt the construction industry with its solid residues have been among the most important sources of waste for the past 30 years. The breakdown of bricks as well as concrete generate waste whether in the residential sector, commercial sector, and all humanitarian activities [4]. The volume generated according to the latest inventory is at least 26 million tons per year of solid waste [5]. Hence, the motivation to try to make a mixture of the most relative tailings, namely, brick wastes resulting from the process of manufacturing red bricks, and plastic processes resulting from the use of cans-bags seemed to an ideal solution. This required new technology that allows the improvement of the product's quality and composition of the recycled brick that have superior characteristics compared to the regular red brick [13].

A. History of the Recycling of Waste in the Construction of Buildings

During the First World War, in the years (1914 to 1918), there was a serious lack of basic supplies such as rubber and other materials this resulted in the notion of reusing waste. At that time, wastes were put together for reuse[6]. After the Second World War, there was a need to rebuild what had been destroyed and to use the demolished materials of the destroyed buildings as a substitute such as natural aggregates in new concrete for the reconstruction of Britain and Germany [7]. Accordingly, the recycling hypothesis developed and turned into one of the most significant methods for getting rid of waste. In the 1990s, it seemed that the indirect focus was on manufacturing waste material with properties like those of the original materials such as glass, paper, plastic, aluminum, iron, and other materials that could be recycled [8].

The process of reusing the construction and demolition wastes has many advantages, some of these advantages are [9]:

1-Preservation of raw natural resources used for the production of construction materials.

2-Provision of different types of energy sources used for the production of construction materials.

3-Reduce the cost of banning those wastes to public dumps and resulting fuel consumption.

4-Preserve the environment from environmental and visual pollution resulting from these wastes, especially those that do not reach public dumps.

5-Reducing the cost of producing new materials.

6-Opening prospects for new jobs.

In general recycling has always been known as “the process of recovering components from aggregates of municipal, industrial, and service waste that are safe for further reuse"[10]. It can also be used as a raw material in the manufacturing processes.

II. CASE STUDY

Many countries have started to take significant steps to recycle waste. Unfortunately, third world countries are behind due to the lack of knowledge and limited options[11]. In a country like Egypt, strategic plans for the recycling of wastes to rationalize the use of natural, financial, and human resources are done by statistically recording for all types of wastes which are classified as can be shown In Figure 1. From Figure 1 it can been seen that Municipal solid waste has a share of 34% which represents the highest share. The percentage and classification of the municipal waste in Egypt is shown in Figure 2. From Figure 2 it can be seen that plastic which represents the third type of municipal wastes represents 13% [13].

Based on both figures, this study focuses on integrating municipal wastes (represented in plastic), construction and demolition wastes (represented in red bricks) which corresponds to 4% of the total waste in Egypt. The purpose of this study is to recycle both down into a recycled brick with better characteristics than red bricks.

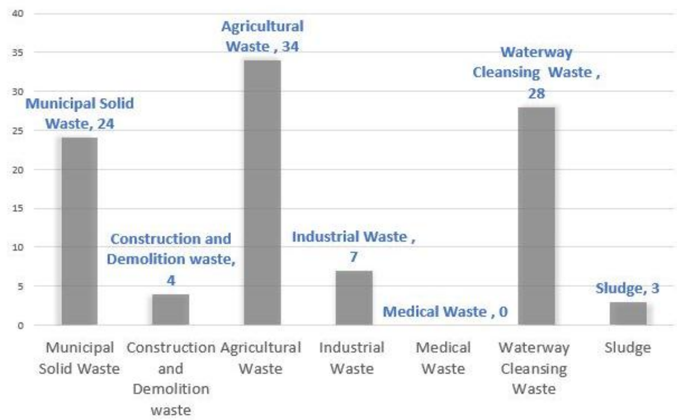

Figure 1. Classification of Wastes in Egypt [13].

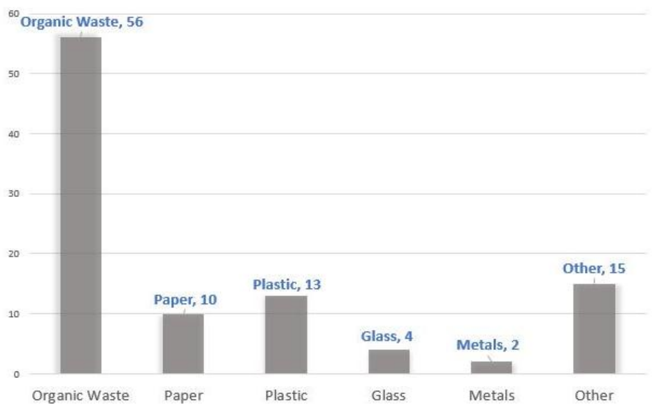

Figure 2. Classification of Municipal Wastes in Egypt [13].

III. MATERIALS OF CASE STUDY

The case study used mixture of two materials. Firstly, broken bricks from construction operation or from the process of brick manufacturing itself are collected. The broken bricks are ground until they reach the size of the sand pellets as can be showed in Figure 3.

Secondly, recycled plastic LDPE (low density polyethylene) is a type of thermoplastic made from the monomer ethylene as shown in figure 4 [14]. Because it is reasonably translucent, flexible, and durable, this type of plastic is frequently used in film applications. It's also utilized in the manufacture of various flexible bottles and lids, as well as cable and wire applications. The most obvious difference, apart from the scientific variations in their makeup, is their strength, weight and high temperature resistance structural.

Figure 3. Grinded broken bricks in its natural form [Source: author]

Figure 4. LDPE (low density polyethylene) [14].

IV. EQUIPMENT OF CASE STUDY

A) Design of the Recycled Brick

The recycled brick is designed with dimension (18*8.5*8.5) cm which is the size of the red brick in order to able to compare them together. The parts dedicated for fixing the recycled brick together is (18*8.5*1.5) cm in size. An image of the design recycled brick can be shown in Figure 5.

b) Brick Mold

A mold was fabricated with 8mm thickness iron borders in which the mixture from the mixing machine is placed and is designed to produce bricks with dimensions (18*8.5*8.5) cm. The mold is designed to fit the brick mounting parts as designed to be part of the recycled brick itself in order to reduce waste resulting from the operation process. as well as the cost compared to red bricks and also to achieve the principles of sustainability in the ability to unwind, install and reuse again Figure 6 shows the designed mold.

c) Hydraulic piston

A hydraulic piston for pressing the mixture inside the mold to ensure that the recycled brick does not contain blanks is shown in Figure 6.

d) Mixing Machine

A dedicated machine for mixing the main components of the brick process is fabricated. The fabricated machine was designed with the ability to provide a suitable temperature while mixing the ingredients and bringing them out in a homogeneous fused mixture. The used machine is shown in Figure 7.

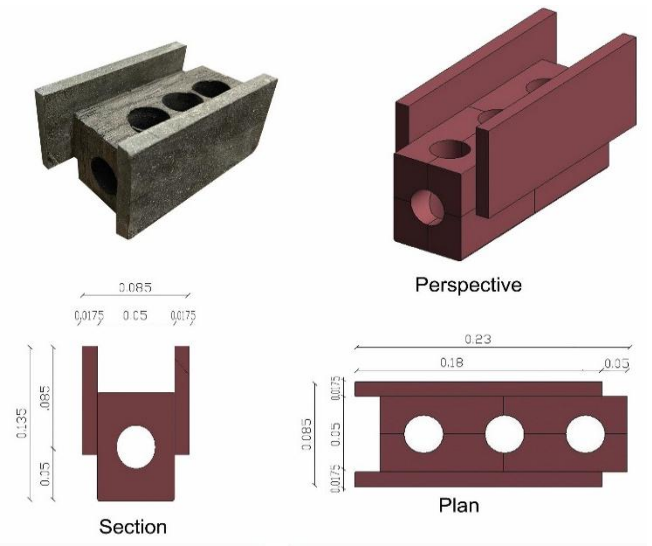

Figure 5. Design of recycled brick [Source: author]

Figure 6. Brick mold, and Hydraulic piston [Source: author]

Figure 7. Mixing machine [Source: author]

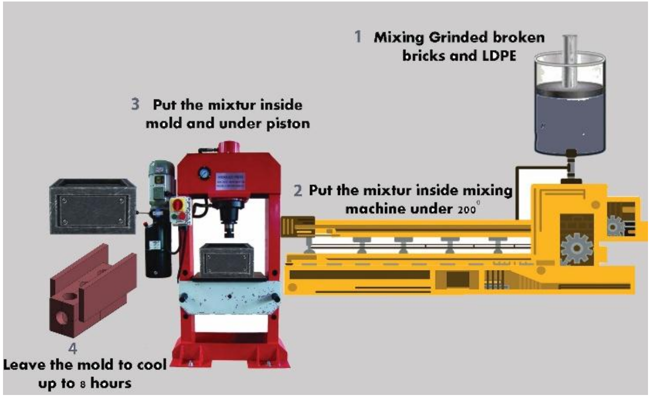

Figure 8. Methods of manufacturing the mixture of recycled materials to create recycled materials [Source: author].

V. METHOD

This experiment relies on mixing the ingredients represented in grinded broken brick and LDPE with 50 % per component equal and mixed at 200^0 to reach a homogeneous and fused mixture. The resulting mixture is then clarified while maintaining its temperature and then the mold is placed on pressure through the hydraulic piston under pressure up to 3 Newton/m2 for up to 1 minute. The mold is then left for up to 8 hours until cool, then the recycled brick is taken out.

The brick specimens are tested to evaluate physical properties (unit weight and the percentage of water absorption); mechanical properties (compressive strength as well as stress-strain relationship in compression); and thermal properties (thermal conductivity, thermal diffusivity as well as specific heat).

The unit weight and the percentage of water absorption are evaluated using ASTMC 138 and ASTM D570. As for the mechanical properties, they were measured according to ASTM C67. A hydraulic universal testing machine of 300 kN is then used to conduct this test. A machine that works under a computer control system and works under both displacement control and load control of 0.5 mm per minute is then used to measure the displacement control rate. On the other hand, the data is recorded using a data acquisition system. The setup of the compressive test is presented in Fig 8.

As for the thermal properties, transient plane source technique which has been widely adopted as a convenient tool for fast characterization of thermal properties of thermal energy storage materials is used [12].This technique is also known as the hot disk method. One of the main advantages of transient technique is that the influence of the contact resistance can be removed in the analysis of the experimental data. This enables accurate measurements over a wide range of thermal conductivity and therefore a wide range of different materials.

The hot disk thermal constants analyzer utilized a set of concentric ring sensors in the shape of a double spiral which acts both as a planar heater for increasing the temperature of the sample. An Ohmic resistance thermometer is also used for recording the time-dependent temperature increase. The spiral, made of nickel is covered on both sides with Kapton for protection and electrical insulation. It is simply placed between two halves of the tested sample. During the test, a small constant current is applied. It was found that the voltage generated by the sensor is proportional to the temperature. The TPS sensor 7577 of radius 2.1 mm is embedded between two identical uniform disks of the same sample (15 mm diameter and surrounded by a 3 mm thickness of nickel). Output power was fixed at 50 mW and the total measurement time varied between 10s and 20s. It is important to notice that the temperature difference on the sample surface was found to be related to the thermal conductivity measured. The output power remained constant in all measurements. The test setup for thermal properties of recycled brick can be shown in Fig. 9 a & b.

The same tests are done on the regular red brick in order to compare it with the recycled brick to clarify differences between them in terms of Unit weight, Water absorption, Compressive strength and Thermal conductivity.

Figure 9. a- Overall setup [Source: author]

Figure 9. b- Specimen under testing [Source: author]

VI. RESULTS AND DISCUSSION

Results from the experiment show that there is an obvious difference between the properties of recycled brick and the properties of the red brick. Firstly, physical properties, represented in unit weight of the recycled brick recorded 21% less weight than red brick weight. Also, the percentage of water absorption of the recycled brick is zero % unlike the red brick, it recorded 20%. Secondly, mechanical properties represented in compressive strength, the recycled brick recorded 15.58 MPa, while the red brick recorded 2.8 MPa. These readings indicate that the recycled brick have achieved higher results up to 5.5 times that of the red brick value. Thirdly, the thermal properties, for recycled brick are recorded. Thermal conductivity was 0.7129W/mK while the red brick recorded 1.31 W/mK. This indicates that the recycled brick has a more effective conductivity level than the red brick as recordings were double the red brick. Table (1) shows the comparison between the properties of red brick and that of the recycled brick.

From these results, it can see that recycled brick is lighter than red brick. In addition, there was no water absorption in the recycled brick. As for the compressive strength of the recycled brick it has recorded almost 6 times more than red brick this represents for high strength of recycled brick, As for the thermal conductivity the recycled brick reaches half the value of red brick .This indicates that the recycled brick records better results in reducing the amount of heat gained from the outside to the inside of buildings, thus achieving thermal comfort within the internal spaces of the building and reducing the amount of energy consumed.

Table 1. Comparison between properties of red brick and recycled brick. (Source: Author)

	Properties	Units	Recycled brick	Red brick
1	Unit weight	Kg /m3	1165.9	1460
2	Water absorption	0%	zero	20%
3	Compressive strength	MPa	15.58	2.8
4	Thermal conductivity	W/mK	0.7129	1.31

VII. CONCLUSION

Brick may frequently be created from a variety of industrial wastes and utilized in construction for several reasons. Not only for its aesthetics, structure, and fire resistance reasons but also for their physical, mechanical, and thermal distinguished properties. Based on the results of this study, it was found that recycled bricks have better features than red bricks physically, mechanically, and thermal characteristics. For example, thermal conductivity rates were less than the red brick by almost half, so that the bricks can reduce the heat load transmitted from the outside to the inside of buildings hence achieving thermal comfort within the architectural spaces. A new way of installing bricks is also found to unwind, install, and reuse again. It was also found that the recycled brick can also reduce the operational dysfunction and operating costs, thereby achieving the principles of preservation and sustainability.

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Conflicts of Interest:
The authors declare that there is no conflict of interest.

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