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Plastic Wastes, Glass Bottles, and Paper: Eco-Building Materials for Making Sand Bricks

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Abstract – *This study analyzed the possibility of utilizing plastic wastes, glass bottles, and shredded paper in making quality sand bricks since building materials are costly. For a lot of people, solid waste reduction has been a challenge. Utilizing solid wastes to make an eco-friendly and advantageous building material is one way to reduce solid wastes. The researcher endeavored to produce an eco-brick using sand ranging from fifty-five percent (55%) to sixty-five percent (65%) by weight, plastics ranging from twenty-nine percent (29%) to thirty-nine percent (39%) by weight, five percent (5%) crushed glass bottles, and one percent (1%) shredded paper. Various tests such as compression test, water absorption test, efflorescence test, and hardness test were carried out to assess the efficacy of brick specimens. The water absorption on the different brick specimens revealed that the absorption was less than twenty percent (20%) keeping it in good quality. As specified in IS 3495 (Part 2) 1992, bricks of good quality do not absorb more than twenty percent (20%) of water. The efflorescence test indicated that all specimens were classified "Slight" which conformed with ASTM C67. It showed that whitish layers were slightly visible nearly 10%. In addition, the compressive strength of the bricks surpassed the minimum requirement for non-load bearing wall of ASTM C129. Based on the impression made, all of the sand brick specimens were considered "Hard". Thus, utilizing non-hazardous solid waste materials in making sand bricks could be a potential alternative as building material. It is also a workable initiative to combat issues on solid wastes.*

Keywords – *Brick, Compressive Strength, Efflorescence Test, Water Absorption Test*

INTRODUCTION

The aim of this study focus on the utilization of non-hazardous wastes such as plastic, glass bottles, and paper in making an effective and quality sand brick. With this, the researcher performed compression test, water absorption test, efflorescence test and hardness test. Specifically, the problem is how to reduce the plastic wastes, glass bottles, and paper produced from households, schools, commercial, industrial and other establishments. Furthermore, the other option to lessen the impact of pollution on the environment is to reduce, reuse or recycle the plastics.

The industrial-scale production of plastic began in 1950's. As of 2015, the world produced nine (9) billion tons of plastic since 1950s. In 65 years, merely nine percent (9%) of plastic waste was recycled and reused, twelve percent (12%) was incinerated, and the remaining seventy-nine percent (79%) has built up in landfills or ended up elsewhere in the environment (Ferris, 2017). Statistically, the remaining seventy-nine percent (79%) of plastic wastes can be recycled in more than 500 years.

Building and construction material is expensive due to the demand of the growing population with a low supply of the materials. However, sand is abundantly available and the disposal of waste plastics is the biggest challenge (Manjarekar, Gulpatil, Patil, Nikam, & Jeur, 2017). To address this, the use of waste plastic bottles for the production of bricks is an optimal method to solve the problem of storing waste materials and to optimize the cost for the production of building materials (Wahid, Rawi, & Desa, 2015). Subsequently, plastic bottles, plastic containers, and plastic bags are flexible which can be heated and reshape to form a building material. Good characteristics of plastics include versatility, hardness, lightness, and resistance to chemicals and water and impact. Thus, this study focus on the possibility of utilizing non-hazardous wastes such as plastic wastes, glass bottles, and paper in making effective and quality and sand brick as substitute for expensive building material.

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OBJECTIVES OF THE STUDY

This study focused on the possibility of utilizing non-hazardous wastes such as plastic wastes, glass bottles, and paper in making effective and quality and sand brick. With this, the researcher will determine the compressive strength of sand brick as well as its absorption capacity. Specifically, it answered the following questions:

1. Did the sand brick satisfy the minimum requirement of the compressive strength of concrete for the non-bearing wall?
2. Is the result of water absorption of sand brick considered an excellent quality?
3. Is the result of the efflorescence test for sand brick acceptable?
4. How did the sand brick behave during the penetration in the hardness test?

MATERIALS AND METHODS

Sand

Sand is a naturally occurring fragmented material and loose grains from dislodged rocks. It is a sedimentary material which comprises of tiny particles of disintegrated rocks, shells, or corals through soil erosion and wearing-out of huge components of rocks. Besides, this weathering of bedrocks or foundations are greatly affected by temperature changes, salt crystals, wedging of plant roots which can take hundreds or even millions of years depending on other mechanical processes such as temperature changes, wedging by plant roots or salt crystals, and expansive soils that swell due to moisture or ice. In this study, river sand was utilized in making sand bricks. USBR (United States Bureau of Reclamation) Engineering Geology Field Manual affirmed that sand is particles of rock that will pass a No. 4 (4.75-mm) sieve and is retained on a No. 200 (0.075-mm) sieve. Sand is further subdivided into three: Coarse sand—passes No. 4 (4.75-mm) sieve and is retained on No. 10 (2.00-mm) sieve, Medium sand—passes No. 10 (2.00-mm) sieve and is retained on No. 40 (425-µm) sieve, and Fine sand—passes No. 40 (425-µm) sieve and is retained on No. 200 (0.075-mm or 75-µm) sieve. Gravel and sand have essentially the same basic engineering properties, differing mainly in degree (Thomas, 2012) However, sandy soils have low water holding capacity, shows no cohesion when dry, firm when wet (Clohesy, 2018).

Solid Waste

Solid waste refers to the range of garbage arising from animal and human activities that are discarded as unwanted and useless (Leblanc, 2018). It is a waste produced from residential, commercial, and industrial activities. Also, it can be categorized based on material, such as plastic, paper, glass, metal, and organic waste and classification may also be based on hazard potential, including radioactive, flammable, infectious, toxic, or non-toxic (Leblanc, 2018). Waste is any substance that is discarded after primary use, or it is worthless, defective and of no use (Nishikant, Nachiket, Avadhut, & Sangar, 2016). In building and construction industry, if large number of waste materials were utilized instead of natural materials, then the natural resources will be conserved, unappealing waste materials will be lessen, and land will be converted to valuable use (Nishikant, Nachiket, Avadhut, & Sangar, 2016). Municipal Solid Waste (MSW) is usually described as non-hazardous solid waste from a certain locality including private residences, commercial establishments, and institutions that requires the routine collection to processing or disposal site. MSW is also called trash or garbage which does not include wastes from industrial processes, construction, and demolition debris, sewage sludge, mining waste or agricultural wastes (Mondal, n.d.).

PET, HDPE, LDPE Wastes

There are two classes of polymers the thermoplastics and thermosetting plastics. Thermoplastics can be reshaped, remolded, and recycled through the application of heat. However, thermoset plastics once hardened remain in a stable solid condition. The properties of thermoplastics are highly recyclable, high reshaping capacity, chemical resistant, and high-impact resistance. The most extensively produced plastic is polyethylene terephtalate or PET. PET is a plastic used to form bottles which used as containers for liquids like water, soda, and juices with recycling number: 1 (Manjarekar, Gulpatil, Patil, Nikam, & Jeur, 2017). PET materials possess various characteristics such as easy to bond, easy to reshape, recyclable, and lightweight. On the other hand, the main component of plastic bags or grocery bags is HDPE or High-Density Polyethylene with recycled number: 2 and LDPE or Low-Density Polyethylene with recycling number: 4. HDPE plastic materials used are moisture-resistant, impact-resistant, opaque and lower

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risk of leaching as well as considered to be safe. LDPE are impact-resistant, moisture resistant, and chemical resistant. It is also considered to be safe among the recycling symbols.

Paper

A paper is made from wood pulp, fibrous materials from vegetation, rags, or straw typically processed into thin sheets. The paper of good quality is manufactured from hardwood while paper produced from softwood is newsprint and the like. Paper can be recycled up to seven times because it becomes brittle and the fiber becomes shorter beyond this recycling limit. Nowadays, the paper is recycled and utilized as a building and construction material instead of concrete. Due to its durability, it is used to make bricks, charcoal, wallpapers or compressing and stacking the bales of paper to makes walls. However, the paper is susceptible to moisture.

Glass

The main component of glass is sand which is mostly made of silica sand, and quartz sand. Sand melts at an extremely high temperature about 1700°C or 3090°F through the fusion process and it is amorphous in the liquid state. However, it is hard, transparent, and brittle in the solid state. Glass does not display the ordered crystalline structure as compared to other ceramics but then it has a disorderly amorphous structure. Glass can be recycled repeatedly because of its workability to be reheated. In a commercial glass plant, sand is mixed with waste glass from recycling collections, soda ash that is sodium carbonate, and limestone or calcium carbonate and heated in a furnace (Woodford, 2018). Glass is widely used as building and construction material in an engineered structure.

The figure below shows the process of making and sand brick.

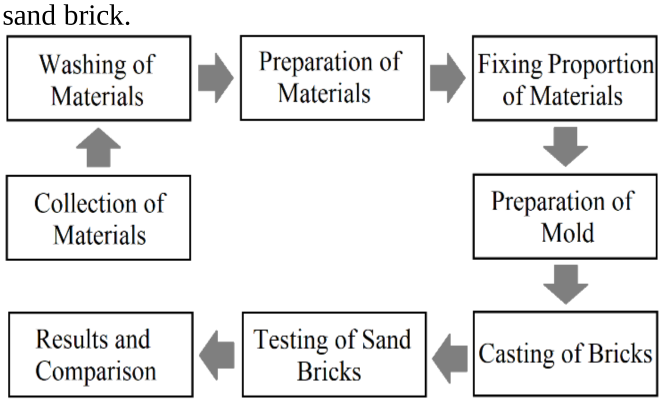

Fig. 1. The Process of Making Sand Brick

Collection and Preparation of Materials

The non-hazardous solid wastes such as plastic bottles, grocery bags, soft drinks, soy milk glass bottles, and used paper were collected. These wastes were then put into separate containers. Likewise, nine (9) kg river sand was sieved using a number 4.75 mm to 0.075 mm sieve. The sand was washed with potable water to remove impurities. Correspondingly, the plastic waste materials and glass bottles were washed separately. Then, the materials were sun-dried to remove water content for better efficacy.

Fig. 2. Materials in Making Sand Brick

Mixing Proportion by Weight

Every brick mixture weighs 2.5 kg. The sand ranges from fifty-five percent (55%) to sixty-five percent (65%) of the mixture. Also, the plastic waste ranges from twenty-nine percent (29%) to thirty-nine percent (39%) of the mixture. On the other hand, the glass bottle weighs five percent (5%) and one percent (1%) paper of the total mixture. With this varying mixture, test results determined the effectiveness and the quality of the brick.

Table 1. Materials' Mixing Proportion by Weight

	Proportion in %

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Brick Code	Sand	Plastic Wastes	Glass Bottle	Paper
A	55	39	5	1
B	60	34	5	1
C	65	29	5	1

Preparation and Casting of Sand Brick

The size of the brick mold used in this study was 15 cm x 10 cm x 5 cm steel mold. All the materials were weighed using the digital weighing scale. For the mixture of brick A, the plastic waste was heated to a molten state and combined with clean sand, crushed glass bottle and shredded paper. Then, all the materials were mixed well into the pot by hand. The brick molds were cleaned and the oil was applied to the mold. Next, the hot mix was poured into the molds. The trowel was used to level the top surface and smoothen the specimen. The bricks were removed from the mold after an hour and air-dried for 24 hours for proper heat dissipation. The same process was performed for specimens B and C.

The amount of aggregate was measured through the use of digital weighing scale

The oil then was applied on each side of the mold

The plastic wastes were heated to a molten state, and combined with clean river sand, crushed glass bottles and shredded papers

Coded brick specimens

Fig. 3. Preparation and Casting of Bricks

Sand Brick Testing

There were four types of testing performed in this study namely: compression test, water absorption test Indian Standard, IS 3495 (Part 2) 1992, Efflorescence Test (American Society for Testing and Materials, ASTM C67), and Hardness test.

A. Compression Test

This test was performed to determine the compressive strength of the sand bricks. Generally, three (3) varied specimens of sand brick were tested at the Department of Public Works and Highways (DPWH) in Antique, Philippines. First, the bearing surface of the testing machine was got cleaned. Then, the specimen was placed centrally on the base plate in the compressive testing machine (CTM) where the load is applied. The load at the rate of 140 $kg/cm^2/min$ was applied gradually without shock and continuously till the brick specimen failed. Finally, each compressive strength of the sample was recorded as well as the uncommon features like the failure of the sand bricks. Moreover, the resistance for crushing varies say, for instance, soft facing brick crushed about 3.5 N/mm^2 until 140 N/mm^2 for engineering bricks.

B. Water Absorption Test

Sand bricks can absorb or discharge moisture content because of dryness and porosity. The brick will absorb water if it is dry, thus making the mortar frail and poor which reduces the general strength of the structure. With this, the water absorption test as per IS 3495 (Part 2) 1992 was performed. First, it had to be noted that specimens were dried and cooled at room temperature before the individual dry mass (M_1) was obtained using the digital weighing scale. Then, the dried specimens were immersed in clean fresh water at a temperature of 27± 2°C for twenty-four (24) hours. The specimens were removed after twenty-four (24) hours of immersion and wiped out any traces of water with a damp cloth. Each specimen was weighed on a digital weighing scale and obtained its wet mass (M_2) three (3) minutes after it has been removed from the water. Bricks of good quality do not absorb more than twenty percent (20%) of water. Lastly, the percentage of water absorption was determined through the formula:

$$[(M_2 - M_1)/M_1] \times 100. \quad (1)$$

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C. Efflorescence Test

A whitish crystalline deposit or foggy salts on bricks consisting of calcium sulfate, magnesium sulfate, and carbonate of sodium and potassium is called Efflorescence. The build-up of alkalis in bricks is harmful to the structure due to. Sometimes, efflorescence appears a few years after the end of construction leaving the building owner face to questions about cleaning or maintenance. The water will tend to dissolve soluble salts in the brick and transport them to its surface where they may be progressively deposited as the water, in which they are dissolved, and evaporates.

The efflorescence test was executed to find out the existence of alkalis in sand bricks. In this test, a brick is immersed in freshwater for 24 hours. Then, it is taken out of the water and allowed to dry in shade. If the whitish layer is not visible on the surface, it proofs that absence of alkalis in brick. If the whitish layer visible about 10% of the brick surface, then the presence of alkalis is in an acceptable range. If that is about 50% of the surface, then it is moderate. If the alkali's presence is over 50%, then the brick is severely affected by alkalis.

One end of the sand brick was placed on a 200 mm diameter by 40 mm depth cylindrical container or dish. Then, it was filled with distilled water at a depth of 25 mm. The whole arrangement was placed in a warm well-ventilated room at a temperature between 20°C to 30°C until the surplus water in the dish is absorbed by the specimen and the surface water evaporated due to capillary action. To avoid excessive evaporation from the dish, the container was then covered with a suitable plastic cylindrical container. A similar quantity of distilled water was poured into the container and allowed to evaporate when the water was absorbed by the sand brick which appeared dry. The specimen was immersed in water for twenty-four (24) hours. The same process was applied to the three (3) sand brick specimens. After the process was performed, the bricks were visually examined and recorded the results. The results of the efflorescence test shall be reported as nil, slight, moderate, heavy or serious:

1) Nil–no noticeable deposit of efflorescence;
2) Slight–less than 10% of the exposed area of brick is covered by a thin layer of salt;
3) Moderate–there is a heavier deposit covering up to 50 percent of the exposed area of the brick surface but unaccompanied by powdering or flaking of the surface;
4) Heavy–there is a heavy deposit of salts covering 50 percent or more of the exposed area of the brick surface but unaccompanied by powdering or flaking of the surface; and
5) Serious–there is the heavy deposit of salt acquired by powdering and/or flaking of the exposed surface.

D. Hardness Test

Hardness is a vague term used in the description of testing of bricks. To consider the brick hard, it has to be associated with good compressive strength and sound resistance to saturation of moisture. In this test, a scratch was made on bricks' surfaces using four (4)-inch common nail. Then, the impression made on the sand brick was recorded.

RESULTS AND DISCUSSION

The Effect of Varied Sand Brick Mixture on Compression Test

Table 2 provides the information on the maximum load and compressive strength of the varied brick mixture. Also, the data on mass and density was provided for the different sand brick specimens.

Table 2. Maximum load and compressive strength of varied brick mixture

Brick Code	Mass, kg	Density kg/m³	Compressive Strength, psi (MPa)	Remarks
A	1.167	1556.00	628.820 (4.34)	Passed
B	1.247	1662.67	824.270 (5.68)	Passed
C	1.259	1678.67	820.020 (5.66)	Passed

This simply showed that, as the amount of sand increases, the density also increases. On the other hand, according to ASTM C129 – Standard Specification for Non-Load-Bearing Masonry Units, for net area compressive strength the minimum requirements lower than ASTM C90, the compressive strength requirements are 500 psi (3.45 MPa) for an individual unit and 600 psi (4.14 MPa) average for three units. Hence, all the sand brick specimens surpassed the requirement of 500 psi for non-load-bearing masonry units for individual brick. Also, the results showed that, as the amount of plastic increases, the compressive strength of brick also

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increases. However, due to the massive amount of plastic for brick A with thirty-nine percent (39%) of plastic by weight gained a compressive strength of 628.82 psi (4.34 MPa). With this, as the plastic reaches its molten state and liquefies the sand and crushed glass settle quickly which the molten plastic with shredded paper floated on the surface of the mixture. This means that, an excessive amount binder may decrease the compressive strength of sand brick.

The Effect of Varied Sand Brick Mixture on Water Absorption

Since sand bricks can absorb or discharge moisture content due to its dryness and porosity. The brick will absorb water if it is dry, thus making the mortar frail and poor which reduces the general strength of the structure.

Table 3. Water Absorption Test Result

Brick Code	Dry Mass, M_1	Wet Mass, M_2	Percentage, %	Remarks
A	1.167	1.182	1.285	Excellent
B	1.247	1.265	1.443	Excellent
C	1.259	1.278	1.509	Excellent

The table revealed an excellent performance on the different sand brick specimens after the water absorption test was performed. The result showed that, as the percentage of plastic wastes increases, the percentage of water absorption decreases. Brick A with thirty-nine percent (39%) of plastic wastes gained a water absorption percentage of 1.285%. While Brick B with thirty-four percent (34%) of plastic wastes got a water absorption percentage of 1.443%. Conversely, Brick C with twenty-nine percent (29%) of plastic wastes got a water absorption percentage of 1.509%. The acceptance criteria for the water absorption test on bricks shall not absorb more than twenty percent (20%). Thus, the existence of plastic wastes helps in the performance of sand bricks.

The Effect of Varied Sand Brick Mixture on Efflorescence Test

All the sand brick specimens classified as “Slight” with the remarks of “Acceptable”. Whitish layers were slightly visible on the surface of the sand bricks which simply showed a deposit of soluble salts or alkalis. However, the whitish thin layer was visible nearly 10% of the brick surface, thus the presence of alkalis was in an acceptable range.

The Effect of Varied Sand Brick Mixture on Hardness Test

In this test, a scratch was made on brick surfaces using a four (4)-inch common nail. There was a very light impression left on the sand brick surfaces with the aid of common nail on the bricks. The hardness of the brick was due to the plastic wastes which acted as a binder as well as the sand and crushed glass bottles as fillers. Thus, all the sand brick specimens were considered “Hard” based on the impression made.

CONCLUSION AND RECOMMENDATION

The findings of this study were anchored from the testing conducted through the utilization of non-hazardous wastes such as plastics, crushed glass bottles, and shredded paper in making sand brick as eco-building and construction material. This study aimed at the possibility of using these materials in making effective and quality sand bricks as non-load-bearing masonry material. For future studies, there should be three samples to be tested to have conclusive results. It is also suggested that the temperature should be measured up to what extent the plastic materials will melt. Based on the results, all the sand brick specimens surpassed the minimum requirement of 500 psi (3.45 MPa) for individual brick according to ASTM C129. Also, this study revealed an excellent performance since specimens gained less than twenty percent (20%) of water absorption on the different sand brick specimens after the water absorption test. Moreover, the result showed that, as the percentage of plastic wastes increases, the percentage of water absorption decreases. Also, all the sand brick specimens were classified as “Slight” (≤ 10%) after the efflorescence test was performed. Finally, there was a very light impression left on the sand brick surfaces with the aid of common nail on the bricks after the hardness test was performed. Thus, this study on creating sand bricks from non-hazardous wastes has a great possibility in employing as an alternative building and construction material for a non-load-bearing wall as well as an effective solution in fighting the problem on reducing the effect of solid wastes.

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