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The Behavior of Non-Hazardous Wastes in Concrete Bricks for Load Bearing Wall

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ABSTRACT

As the world continues to grow, so does the demand for building materials necessary for building homes. About 20% of the population needs adequate housing. On the other hand, the problem with solid waste management has become a constant challenge over the years. As a result, innovators always try to resolve these issues while putting out economical and environment-friendly materials. This study aims to determine the feasibility of utilizing the following non-hazardous household wastes; PET, HDPE, and LDPE plastic wastes; bones from fish, poultry, and livestock animals; shredded used paper and tin cans in making an effective a practical concrete brick for load-bearing wall. The researchers tested the possibility of creating a concrete brick using cement, sand, and non-hazardous household wastes through compressive strength, water absorption, and efflorescence tests. The findings showed that using non-hazardous household wastes in concrete brick has a great significance in alleviating the effect of solid wastes conforming to the standards of ASTM C90 – Standard Specification for Load-Bearing Masonry Units, IS 3495 (Part 2) 1992 and ASTM C67. The study shows the great possibility of the produced sand brick as a building material and an excellent tool for resolving the issue of solid waste management.

INTRODUCTION

The study focuses on utilizing non-hazardous household wastes, PET, HDPE, and LDPE wastes, animal bones from fish, poultry, and livestock animals, and shredded used paper and tin cans in making effective concrete bricks for the load-bearing wall. Specifically, the study aims to address the issue of reducing non-hazardous wastes and utilizing them effectively as components of reusable structural elements that will substitute expensive concrete bricks. Moreover, the study aims to decrease the effect of pollution on the environment by reducing, reusing, and recycling these non-hazardous wastes.

Countries around the globe continuously generate large amounts of waste as their populations grow and their economies expand. Municipal solid waste (MSW), currently produced yearly in the world at 1.3 billion metric tons, is anticipated to reach 4.3 billion urban residents generating about 1.42 kg/capita/day of municipal solid waste by 2025 (Hoornweg, & Bhada-Tata, 2012; Kawai, & Tasaki, 2016).

Waste generation may rise by up to 70% by 2050, from 2.01 billion tonnes to 3.40 billion (Wowrzeczka, 2021; Iqbal, Naz, & Naseem, 2021). It is hard to control this massive number, thus, the effective usage of non- hazardous waste and its usage as reusable structural elements can alleviate the issue on solid waste management and minimize the necessity to utilize primary resources. This problem is not only from a local/regional perspective, but especially from a global point of view. In the last eight years, developing countries' material footprint per capita nearly doubled, representing a significant and much-needed improvement in material standards of living (Pavlu, Fortova, Divis, & Hajek, 2019). These are essential environmental factors in complying with one of the core objectives of the 2030 UN Agenda on Sustainability Development—Goal 12: Ensure sustainable consumption and production patterns. Homelessness and the lack of adequate housing arise due to many contributing factors, including the affordability of housing structural components. National reports show that no less than 150 million people, or about 2% of the world's population, are homeless. However, about 1.6 billion, more than 20% of the world's population, lack adequate housing (Chamie, 2017).

Objectives

This study aims to determine the effectiveness of utilizing these non-hazardous wastes such as PET, HDPE and LDPE plastic waste, bones from fish, poultry and livestock animals, paper, and tin cans in making concrete bricks that conform to the quality standards set by the American Society for Testing and Materials (ASTM) for load bearing wall. Specifically, the study sought to:

1. determine the compressive strength of concrete brick using non-hazardous wastes for load bearing wall;
2. determine the water absorption rate of a concrete brick using non-hazardous wastes for load bearing wall; and
3. determine the efflorescence level of concrete bricks using non-hazardous wastes for load-bearing wall.

MATERIALS AND METHODS

This section presents the materials in making concrete bricks for load-bearing wall from non-hazardous wastes.

Sand

Sand is a naturally occurring loose granular material generated from disintegrated rocks. Soil erosion is the key process of why sand is formed. Also, sand is formed by

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decomposing rocks components into tiny particles. This process is called weathering. However, a huge amount of sand comes from mechanical and chemical interruption of the substrate or foundation. Moreover, this weathering of bedrocks is greatly affected by temperature changes, salt crystals, squeezing of plant roots in rock cracks and can take hundreds to millions of years, depending on other mechanical processes such as temperature changes, wedging by salt crystals, and expansive soils that swell due to moisture or ice. River sand was used in this study in making concrete bricks.

USBR Engineering Geology Field Manual affirmed that sand are 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, 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.

Municipal Solid Waste

Municipal solid waste is one of the classifications of solid waste and includes urbanized domestic solid waste, junk, or such waste that can be considered city MSW as indicated by the city's laws (Ahmed, Ibraheem, & Abd-Ellah, 2022). Moreover, it was stated that municipal solid waste is usually produced in various sources where different human activities are practiced, further asserting that 55-80% of these in third-world countries comes from domestic solid waste and 10-30% is from by market or business regions. These wastes are apparently heterogeneous, ranging from yard materials, inactive materials, food leftovers, wood, to plastics, batteries, metals, etc. In a constant condition where the world population is swelling, it is paralleled with this waste mounting to high levels. With this, the issue on solid waste management continues to significantly affect the world. Non-hazardous solid waste like plastic bottles, plastic bags, soft drink bottles, used paper, animal bones, and tin cans were collected.

PET, HDPE, LDPE Wastes

Synthetic polymers like plastics as highly resistant to chemicals, acids, and bases and are insusceptible to naturally occurring decomposers, making them non-biodegradable (Jabir, Hadi, & AL-Zubiedy, 2020). Further, it was discussed the following three types of plastics; PET (Polyethylene Terephthalate), HDPE (High-Density Polyethylene), and LDPE (Low-Density Polyethylene). Plastic bottles, plastic bags, and soft drink bottles were used because of their high chemical resistance and are ductile and lightweight. PET has good gas barrier properties and good chemical resistance (Sulyman, Haponiuk, & Formela, 2016). Compared to the reference concrete, WPET concretes have a similar workability profile, a little lower compressive strength and splitting tensile strength, and a marginally better ductility (Frigione, 2010). On the other hand, HDPE is more linear and crystalline and is used in commodities, thermoplastic, and industrial and household usage. Its good mechanical properties make it an ideal ingredient for molding products. LDPE is a highly flexible material.

This section includes the process in making concrete bricks from non-hazardous wastes for load bearing walls. These are collection and preparation of materials, mixing and proportion by weight, casting of concrete bricks, and testing.

The following figure details the concrete-brick making process from non-hazardous wastes.

Collection and Preparation of Materials

Non-hazardous solid waste like plastic bottles, plastic

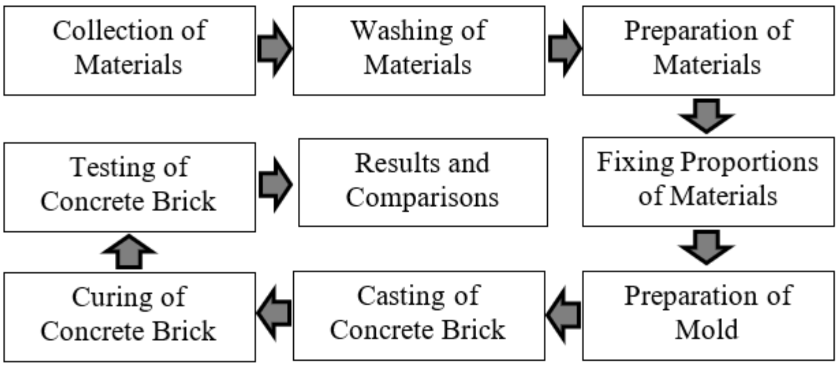

Figure 1: The Process of Making Concrete Bricks

bags, soft drink bottles, used paper, bones from fish, livestock, and poultry animals, and tin cans were collected. The waste was then segregated into different containers. Plastics and paper were cut into 0.50-1.00 cm square. Furthermore, twenty (20) kilograms of river sand was collected and then sieved using a Number 4.75 mm to 0.075 mm sieve. It was then washed with potable water to take out the impurities. Similarly, the collected waste materials were washed individually and sun-dried to remove the excess water on their surfaces. Materials were then weighed with the use of a digital weighing scale accordingly.

Mixing Proportion by Weight

Produced brick mixture weighs three (3) kilograms. Cement is fixed to 33.33% or 1 kg of the brick mixture. The sand ranges from 1.4 kg (46.67%) to 1.7 kg (56.67%) of the mixture. The household wastes range from 0.3 kg

(10%) to 0.6 kg (20%) of the mixture. Water weighs 0.55 kg for every mixture however the amount of water may be increased if the mixture is dry.

Table 1: Materials' Mixing Proportion by Weight and Percentage

Brick Code	**A**		**B**		**C**	
	Kg	**%**	**Kg**	**%**	**kg**	**%**
Cement	1.0	33.33	1.0	33.33	1.0	33.33
Sand	1.7	56.67	1.55	51.67	1.4	46.67
Wastes	0.3	10.00	0.45	15.00	0.6	20.00
Total	3.0	100.00	3.0	100.00	3.0	100.00
Water	0.55	0.00	0.55	0.00	0.55	0.00
Breakdown of Wastes	**at 10 % Wastes**		**at 15 % Wastes**		**at 20 % Wastes**	
	Mass, g	**Mass, %**	**Mass, g**	**Mass, %**	**Mass, g**	**Mass, %**
Plastic Wastes	150.00	50.00	225.00	50.00	300.00	50.00
Bones	75.00	25.00	112.50	25.00	150.00	25.00
Tin Cans	69.00	23.00	103.50	23.00	138.00	23.00
Paper	6.00	2.00	9.00	2.00	12.00	2.00

Concrete Brick Testing

Four types of testes that were performed for the concrete bricks in this study are as follows: Compression Test as per American Society for Testing and Materials, ASTM C90, Water Absorption Test following the Indian Standard, IS 3495 (Part 2) 1992, and Efflorescence Test, under the conditions of American Society for Testing and Materials, ASTM C67.

Compression Test

This test aimed to determine the compressive strength of the produced concrete bricks. It is a way of measuring how much load a surface or material can sustain. The test is performed by exerting a downward force on top of an object, paired with an equal and opposite force exerted upward on the bottom. Basically, three (3) varied samples of the produced concrete bricks were brought and tested at the Department of Public Works and Highways (DPWH), Antique, Philippines. Initially, the bearing surface of the testing machine (Compressive Testing Machine) was cleaned with the use of a clean cloth. The sample was then placed centrally on the base plate of the testing machine. A load was gradually applied at the rate of 140 kg/cm2/min. This was done with no initial shock and continuously applied until the sample explodes. Lastly, the compressive strengths of the samples were recorded and assessed with the conditions provided in the American Society for Testing and Materials, ASTM C90. The compressive strength requirement for load-bearing components is 1900 psi or 13.10 MPa (ASTM Specifications for Concrete Masonry Units, 2012).

Preparation and Casting of Concrete Brick

The brick mold used in this study was a 15 cm x 10 cm x 5 cm steel mold. The materials were weighed with the use of a digital weighing scale and were mixed proportionally. For the mixture of brick A, 1 kilogram of cement which is 33.33% of the whole mixture, 1.7 kilogram of sand which is 56.67% of the whole mixture, 0.3 kilogram of non-hazardous household waste materials which is only 10.00% of the whole mixture and 0.55 kilogram of potable water were applied. For brick B, the mixture consists 1 kilogram of cement which is 33.33% of the whole mixture, 1.55 kilogram of sand which is 51.67% of the whole mixture, 0.45 kilogram of non-hazardous household waste materials that is only 15.00% of the whole mixture and 0.55-kilogram potable water. For brick C, the mixture consists 1 kilogram of cement which is 33.33% of the whole mixture, 1.4 kilogram of sand which is 46.67% of the whole mixture, 0.6 kilogram of non-hazardous household waste materials which is only 20.00% of the whole mixture and 0.55-kilogram potable water. After mixing of each test samples, it was then put in the molder and let it consume its curing period for the accuracy of test.

Water Absorption Test

Bricks can absorb or discharge water due to its moisture content level and porosity. When a brick absorb water, the mortar weakens and becomes frail, significantly reducing its overall strength. Following IS 3495 (Part 2) 1992, water absorption test was performed on the sample bricks. The samples were dried and exposed to room temperature. Individual dry mass (M1) of each sample were acquired with the use of a digital weighing scale. The samples were then immersed in clean fresh water of temperature ranging 27 2 °C. After twenty-four (24) hours, the samples were ± released from immersion and surface-dried using a damp cloth. Three (3) minutes after release from water, the samples were weighed in the digital weighing scale and the wet mass (M2) were recorded. The moisture content of the bricks was determined using the formula

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

Bricks absorbing not more than twenty percent (20%) of water are considered in good quality.

Efflorescence Test

On concrete surfaces, efflorescence is a white, crystalline build up that typically consists of water-soluble salts (Raja Abdullah, 2017). Efflorescence as not damaging on a normal level but is aesthetically undesirable. The substance may appear a few years after construction, making the client concerned about the building sustainment and cleaning. Under the conditions of ASTM C67, efflorescence test was performed to determine the presence of alkalis in the sample bricks. In this test, the samples were immersed in fresh water for twenty-four (24) hours. The bricks were then taken out and set aside to dry in shade. The samples will then be assessed along with the following conditions. The brick is free of alkali if a whitish layer is not visible on the surface. If the layer comprises about ten percent (10%) of the brick surface, then the presence of alkali is acceptable. If the presence of alkali is about fifty percent (50%), then it is in moderate amount. Percentages going above fifty percent suggest that the brick is critically contaminated with alkali.

A 200 mm diameter by 40 mm deep cylindrical container was used. With a depth of 25 mm, the container was filled with distilled water. One end of the sample was then immersed in the setup. The test was performed in a well-ventilated room of temperature ranging from 20°C to 30°C. It was done until the water in the dish was absorbed by the sample and the water in the surface evaporated due to capillary action. The container was then covered with a plastic cylindrical container to avoid extreme evaporation from the dish. The same process was done wherein a similar amount of distilled water was poured into the container. The whole setup was then set aside for twenty-four (24) hours. The same procedure was performed with the three (3) remaining concrete brick samples. After twenty-four (24) hours, the bricks were observed and assessed as follows:

1) **Nil** – There were no visible deposits of efflorescence present;

2) **Slight** – Less than ten percent (10%) of the exposed area of the sample was covered by a thin layer of salt;

3) **Moderate** – Fifty percent (50%) of the exposed area of the brick surface was contaminated suggesting a heavier deposit but unaccompanied by powdering or flaking of the surface;

4) **Heavy** – More than fifty percent (50%) of the exposed area of the brick surface showed a heavy deposit of salts but unaccompanied by powdering or flaking of the surface; and

5) **Serious** – A heavy deposit of salt is acquired by powdering and/or flaking of the exposed surface.

RESULTS AND DISCUSSION

This section deals with the results of different tests performed to the concrete brick such as compressive strength, water absorption test, and efflorescence test. Also, this part deals with the minimum requirements for bricks for comparison to determine its effectiveness and quality. Besides, this investigates the feasibility of using non-hazardous waste materials such as PET, HDPE, and LDPE waste, bones from fish, poultry, and livestock animals, and used paper and tin cans in making concrete bricks that conform to the quality standards set by the American Society for Testing and Materials (ASTM) for load bearing wall.

The Results of Varied Concrete Brick Mixture on Compression Test

Table 1 below provides the details on the maximum load and the corresponding compressive strength of each brick mixture. Mass and density of each concrete brick mixture is also shown.

Table 2 shows that the mass and density vary due to the amount of sand and household wastes in every mixture. Brick C with 1.4 kg (46.67%) of sand and 0.6 kg (20%) of household wastes was denser compared to Bricks A and B. It has a mass and density of 1.341 kg and 1,788.44 kg/m3 respectively. It was followed by Brick B with 1.55 kg (51.67%) of sand and 0.45 kg (15%) of household wastes resulted a mass of 1.175 kg and a density of 1,566.67 kg/m3. Then, Brick A with 1.7 kg (56.67%) of sand and 0.3 kg (10%) of household wastes is considered the lightest with a mass of 1.341 kg and a density of 1,463.56 kg/m3.

Table 2: Maximum Load and Compressive Strength of Different Ratio of Varied Brick Mixture

Brick Code	Mass, kg	Density	Maximum Load at Crushing, kN	Average Compressive Strength in MPa or N/mm2	Average Compressive Strength in psi	Remarks
A	1.098	1,463.56	202.55	13.50	1,958.53	Passed
B	1.175	1,566.67	189.77	12.65	1,834.89	Failed
C	1.341	1,788.44	148.80	6.61	1,438.77	Failed

The data suggests that as the amount of household wastes increases, the density of the mixture increases. On the other hand, ASTM C90 – Standard Specification for Load-Bearing Masonry Units, for net area, compressive strength should be higher than what is required, with it being a thousand and nine hundred pounds per square inches, 1900 psi or 13.10 MPa (ASTM Specifications for Concrete Masonry Units, 2012). Hence, only brick A exceeded the standard compressive strength of 1900 psi for load-bearing masonry unit for an average of three bricks. Brick A attained an average compressive strength of 1,958.53 psi. Data suggests that the compressive strength of the brick significantly drops as the amount of household waste is increased.

The Results of Varied Concrete Brick Mixture on Water Absorption

Table 3 below provides the details on the dry mass, wet mass, absorption percentage, as well as the remarks on the bricks.

Table 3 displays outstanding results of the varied concrete mixtures after the water absorption test was performed. Results showed that as the percentage of household wastes is increased, the percentage of water absorption of the brick decreases. Concrete brick with low water absorption rate is considered of outstanding quality. Brick A with 10% of household waste showed a water absorption percentage of 7.197%. Brick B with 15% of household waste displayed a water absorption percentage of 5.050%. Likewise, Brick C with 20% of household waste obtained the lowest water absorption percentage of 2.584%. All the brick specimen passed the minimum requirement of Indian Standard, IS 3495 (Part 2) 1992 with the acceptance criteria for the water absorption test on bricks of being not more than twenty percent (20%). Thus, the existence of household waste significantly benefits the performance of the brick on this test.

Table 3: Water Absorption Test Result

Brick Code	Dry Mass, M1	Wet Mass, M2	Percentage, %	Remarks
A	3.293	3.530	7.197	Passed
B	3.525	3.703	5.050	Passed
C	4.024	4.128	2.584	Passed

The Results of Varied Concrete Brick Mixture on Efflorescence Test

Table 4 reveals the details on the results of the efflorescence test performed on the bricks. This test was executed to find out the existence of alkalis in concrete bricks. The table shows acceptable results of the efflorescence test performed on concrete brick specimens. All the samples were assessed "Slight" and remarked "Acceptable." White layers of alkalis were slightly visible on the surface of the concrete bricks. However, the layers were visible for only 10% of the brick surface, suggesting the presence of alkalis in an acceptable range. Consequently, the results of the efflorescence test were reported as "Slight." This suggests that the produced bricks were not critically contaminated with alkali which further suggests that in the long run, the presence of alkali deposits in the brick would not be aesthetically undesirable.

Table 4: Efflorescence Test Result

Brick Code	Nil	Slight	Moderate	Heavy	Serious	Remarks
A		< 10%				Acceptable
B		< 10%				Acceptable
C		< 10%				Acceptable

CONCLUSION

The findings of the study were anchored with the utilization of the following non-hazardous household waste – PET, HDPE, and LDPE waste, animal bones, shredded used paper, and tin cans in making concrete brick as a load–bearing masonry unit. Based on the findings, it was proven that the utilization of non-hazardous household waste has a great significance in the production of concrete bricks and can be used to alleviate the adverse effects of solid waste to the environment. Based on the compressive strength test results, only Brick A passed the standard set by the ASTM C90–Standard Specification for Load-Bearing Masonry Units which is 1,900 psi (13.10 MPa). The study unveiled an outstanding performance of the bricks in the water absorption test as per IS 3495 (Part 2) 1992, with all the samples gaining less than twenty percent (20%) of the water. Results showed that as the percentage of household wastes is increased, the percentage of water absorption of the brick decreases. Concrete brick with low water absorption rate is considered of outstanding quality. With the efflorescence test based on ASTM C67 was performed, all the samples were classified as "Slight" and remarked as "Acceptable". White layers of alkalis were slightly visible on the surface of the concrete bricks. However, the layers were visible for only 10% of the brick surface, suggesting the presence of alkalis in an acceptable range. Therefore, this study, centered on producing concrete bricks from non-hazardous household waste has proven its great feasibility as an alternative building and construction material for load-bearing wall. Consequently, it is an efficient way of resolving the issue on solid waste management while putting out an economical product.

RECOMMENDATIONS

Based on the results, MSW as partial replacement for sand and full replacement for gravel satisfied the minimum requirement of compressive strength (1,900 psi), water absorption (<20%), and efflorescence (<10%).

It is hereby recommended that plastic wastes must be powdered to achieve fine texture of the specimen which can be tested if there is a significant difference between larger and smaller shredded plastics in terms of compressive strength and water absorption. Bones must be pulverized to obtain the maximum density, water absorption and compressive strength. Steel mold must be conformed to the ASTM standards.

More thorough research on the effectiveness and quality of concrete brick be made by future researchers in terms of workability, methods, materials, proportion, and testing.

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