PERFORMANCE AND PROPERTIES OF ECO-FRIENDLY CEMENT BRICKS ADDED WITH POLYESTER FABRIC WASTES

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ABSTRACT

With brick a common construction material, there is a shortage of sources for making bricks. Fabric wastes can serve as replacement for a portion of brick aggregates both for practicality and sustainability. This is especially since the fashion industry has been known to contribute to negative environmental impacts. This paper describes the materials and methods as well as properties of eco-friendly cement bricks added with polyester fabric wastes. The eco-friendly bricks were compared to traditional cement bricks in terms of physical and mechanical properties. Traditional bricks were prepared at a ratio of 1:5 of cement to sand while eco-friendly bricks were prepared at a ratio of 1:5:1 of cement to sand to fabric wastes. All the methods used in this study were based on the standards set by the American Society for Testing and Materials (ASTM, 2006). Statistical analysis using t-test revealed that both bricks were comparable in terms of physical properties of mass (kg) (t=1.780, p=0.086), bulk density (kg/m^3) (t=1.780, p=0.086), and water absorption percentage (%) (t=–0.336, p=0.740) as well as mechanical properties of maximum load (kN) (t=1.000, p=0.326) and compressive strength (Mpa) (t=1.000, p=0.326) with results having no significant differences in their means. In terms of cost, eco-friendly bricks are cheaper by Php 3.00 than traditional bricks. Eco-friendly cement bricks added with polyester fabric wastes can therefore serve as a viable alternative for traditional bricks. Additional testing such as in situ testing can be conducted to determine practical applications of the eco-friendly bricks added with fabric wastes in non-load bearing walls for instance.

Keywords: Eco-friendly, Masonry Bricks, Fabric Wastes, Universal Testing Machine

1.0 INTRODUCTION

Rationale

Brick is one of the oldest and widely used construction materials around the world (Phonphuak and Chindaprasirt, 2015). Historically, the usefulness of mixing together stones, sand, and some form of binder or cement to form concrete has been recognized since Stone Age times (Sims *et al.*, 2019). In the Philippines, conventional bricks are produced with high temperature kiln firing or from ordinary Portland cement concrete, and thus contain high embodied energy and have a large carbon footprint (Zhang, 2013).

In many areas of the world, there is already a shortage of natural source materials for production of conventional bricks. Natural resources have been depleted due to industrialization and economic progress, and the growth of the construction industry is an inevitable component of this (Cabreza *et al.*, 2019). Annually, building construction in the world consumes 25% of the global wood harvest; 40% of stone, sand, and gravel; and 16% of water (Joseph and Tretsiakova-McNally, 2010).

To develop bricks as a form of sustainable construction material, there is a need to integrate it with waste materials such as that from agriculture and other industries (Phonphuak and Chindaprasirt, 2015). Various literature have established the viability of this. To point a few, we have.

The global fashion industry has been established to produce highly negative outcomes for the environment, making clothing one of the highest impact industries on the planet (Pal and Gander, 2018). Pollution occurs in the production of the final good when polluting intermediates are used (Benarroch and Weder, 2006). Specifically, due to wasteful usage of fabric within conventional pattern cutting, clothing manufacturing processes have created a cut-and-sew waste problem (Enes and Kipoz, 2019).

Concrete bricks with fabric wastes can be a type of green and eco-friendly product that has the potential to create buzz for environmental enthusiasts and business investors. It solves both the problem of depleting source materials for brick manufacture and minimizes wastage from the fashion industry.

This is especially since the use of environment-friendly building materials and technology has grown impetus as part of the emerging concept of green economy. In the Philippines, the Green Jobs Act or Republic Act 10771 in support of the concept of the green economy was recently signed into law in 2016. As such, masonry materials can be developed and integrated with wastes to serve as a viable solution not only to environmental pollution but also to add to the economy of building designs.

1.1 Objectives

The primary purpose of the study was to describe the materials and methods used to produce cement bricks added with fabric wastes. Specific objectives were as follows:

1) Evaluate the physical properties of cement bricks added with fabric wastes;
2) Assess the mechanical properties of cement bricks added with fabric wastes; and
3) Compare cement bricks added with fabric wastes with traditional bricks.

2.0 LITERATURE REVIEW

The global fashion industry has been known to produce highly negative outcomes for the environment (Pal and Gander, 2018). For instance, the authors cite that high water usage, pollution from chemical treatments used in dyeing, and preparation and the disposal of large amounts of unsold stocks through incineration or landfill deposits combine to make clothing one of the highest impact industries on the planet. This has led to rise in the research about fashion industry pollution and sustainable technologies. Blasi, Brigato, and Sedita (2020), for instance, explored the convergence between the concepts of fashion and eco-friendliness in consumer perception of a fashion brand. Aivazidou and Tsolakis (2019) identified emerging trends in the clothing industry and their impact on freshwater resources and researched challenges and opportunities for water footprint management across apparel supply chains. Benarroch and Weder (2006) examined the relationship between intra-industry trade in intermediate products, pollution, and increasing returns.

The history of forming concrete by mixing stones, sand, and a form of binder dates back as far as the Stone Age (Sims *et al.*, 2019). The earliest bricks utilized as masonry structure were sun-dried mud bricks recorded at least 10,000 years (Ingham *et al.*, 2013). The application of bricks extend beyond masonry structures as they are also being used for aesthetic and decorative purposes (Ingham, 2013).

Studies modifying bricks and integrating other materials have increased in recent years either to enhance performance, reduce cost, increase sustainability, or a combination of these. For instance, Barros *et al.* (2020) investigated the viability of using dimension stone (limestone) waste by mixing them with polyester resin to produce a new type of ecological brick, in the model of soil-cement bricks. Limestone/polyester composites were compounded in ratios of 70/30, 80/20, 85/15, and 90/10 (weight percentage). The amount of curing agent (methyl ethyl ketone peroxide, MEKP) used for each composition was 0.6, 0.4, 0.3, and 0.2 mL, respectively. The 70/30 composite presented the highest compressive strength, with a value of approximately 54 MPa, followed by 80/20, 85/15, and 90/10. The 90/10 composite, despite presenting a lower result than the other composites, achieved the value required by the standard at 600%, and its use will imply a lower cost due to the use of only 10% resin, plus the benefit of 90% waste no longer discarded in the environment.

El-naggar *et al.* (2019) prepared geopolymer insulating bricks from waste aluminum trimmings from workshops, powder residue from the production of clay bricks (clay bricks waste), and slaked lime waste from acetylene production. De-aluminated kaolin, a waste from the alum industry, was also added as binding agent to substitute part of the clay bricks waste. It was found that using 5% (by weight) aluminum trimmings and substituting 15% of clay bricks waste by de-aluminated kaolin was enough to raise the porosity above 50%, thus producing light bricks of densities in the 1000 $kg.m^{-3}$ range. The compressive strength of these bricks was about 1.4 MPa and their thermal conductivity was as low as 0.26 $W.m^{-1}.K^{-1}$.

Manzur *et al.* (2019) tested microbiologically induced calcite precipitate (MICP) to enhance the performance of brick aggregate concrete. MICP using indigenous urease positive bacteria collected from soil showed promising results in initial researches. The authors used two (2) incubation periods of 24 hours and 48 hours for bacterial culture. Absorptiometric method was used to examine population growth of bacteria due to varying incubation periods. Results of the study showed that 48 hours incubation was more effective than 24 hours. The longer incubation resulted in almost twofold reduction in aggregate absorption test.

Ozturk *et al.* (2019) used tea waste (TW) at different concentrations in the brick clay mixtures to examine its effects on baked brick properties. In addition to micro-structure investigations, physical, mechanical, and thermal properties of bricks produced were investigated. It is concluded that tea waste additives up to 10% in brick body can be used for structural application and isolation while ratios more than 10% tea waste additive for only isolation purposes. Tea wastes can be used as a pore-making additive in the brick production.

Zhang *et al.* (2019) upgraded waste poplar fiber into wooden brick as a green, eco-friendly strategy for waste wood-recovery and construction industry. They recycled waste poplar fiber into biomass bricks with calcium hydroxide ($Ca(OH)_2$) as the adhesive. To study interaction mechanisms between poplar fiber and $Ca(OH)_2$, a series of tests were employed, including scanning electron microscopy, X-ray diffraction, infrared spectroscopy, nuclear magnetic resonance, and others. Poplar fiber and $Ca(OH)_2$ connected with each other tightly through the generated calcification, and poplar fiber played supporting and connecting roles through the generated calcification, contributing to compressive strength of the wooden brick.

3.0 METHODOLOGY

All the methods used in this study were based on the standards by American Society for Testing and Materials (ASTM, 2006). A total of 1 kg of polyester cotton fabric waste materials were collected from the local garments shop in the area. The fabric wastes were separated by its fabric strings and were cut to one inch in length using scissors.

The fabric waste materials were thoroughly mixed with ordinary Portland cement (OPC) as binder and locally available river sand as fine aggregate at a ratio of 1:5:1, respectively, to produce bricks with a volume of 0.0015 m^3. This is a common local construction site ratio. Water was added at an equal ratio to cement. Bricks were cast using a wooden mold with a dimension of 11 cm W x 22 cm L x 7 cm D. Water correction was done by sprinkling water uniformly to all samples. Bricks were compacted by pounding 25 times using a 5-cm-diameter stick and tapping all sides to remove voids and to achieve samples with smooth sides. After one (1) day, bricks were removed from the mold. Bricks were then cured for seven (7) days at atmospheric temperature.

Cement bricks added with fabric wastes were compared to traditional bricks, which were made from 1:5 ratio of cement to sand. Fifteen (15) brick samples of each treatment were made. The following data were gathered:

1) Mass (kg). Measured by weighing the bricks in a digital weighing scale.
2) Bulk density (kg/m^3). Computed using the following formula:

$$Bulk\ Density = \frac{M}{V}$$

where:

M = mass unit in kg
V = volume in m^3

3) Saturated mass (kg). Bricks were immersed in water for 24 hours, removed, and wiped thoroughly with cloth. Bricks were then weighed to obtain the saturated mass.

4) Dry mass (kg). After measuring the saturated mass, bricks were baked in an oven for 2 hours at 150 °C. After which, bricks were allowed to cool at room temperature for 2 days. Dry mass was obtained by weighing the bricks.
5) Water absorption (%). This was computed using the following formula:

$$Absorption\,\% = \frac{A - B}{B}\,x\,100$$

where:

A	=	saturated mass in kg
B	=	dry mass in kg

6) Maximum load (kN). Bricks were placed on a steel plate on the Universal Testing Machine (UTM) (Figure 1), and maximum load was applied on top of the brick surface at a constant rate until failure occurred. The load shown on the UTM was recorded.
7) Compressive strength (Mpa). This was computed using the following formula:

$$Compressive\ Strength\ = \frac{L}{A}$$

where:

L	=	maximum load (kN)
A	=	area mm^2 (constant of 21372.57 mm^2 per brick)

Means and standard deviations were obtained for the two (2) treatments in all of the above parameters. Means were compared using independent t-test. Differences in costs of the two types of bricks were also computed.

Figure 1: Universal testing machine used in obtaining data on the mechanical properties of the two (2) types of bricks

4.0 FINDINGS

Figure 2 shows the eco-friendly cement bricks with fabric waste. The table below compares the means for the eco-friendly bricks with fabric wastes and traditional cement bricks.

Figure 2: Eco-friendly cement brick integrated with fabric waste produced

Table 1: Comparison of the physical and mechanical properties of eco-friendly and traditional cement bricks

	Ratio	N	Mean	Std. Deviation	t	Sig. (2-Tailed)
Mass (kg)	1:5	15	2.35	0.1910796	1.780	0.086
	1:5:1	15	2.24	0.1559518		
Bulk Density	1:5	15	1569.33	127.3864262	1.780	0.086
	1:5:1	15	1493.78	103.9678420		
Saturated Mass (kg)	1:5	15	2.71	0.17476	0.256	0.800
	1:5:1	15	2.70	0.13654		
Dry Mass (kg)	1:5	15	2.47	0.1271370	0.320	0.752
	1:5:1	15	2.45	0.2061368		
Water Absorption Percentage (%)	1:5	15	9.73	2.7924186	-0.336	0.740
	1:5:1	15	10.24	5.3368293		
Maximum Load (kN)	1:5	15	42.29	5.7845066	1.000	0.326
	1:5:1	15	40.32	5.0078616		
Compressive Strength (Mpa)	1:5	15	1.98	0.2706510	1.000	0.326
	1:5:1	15	1.89	0.2343126		

4.1 Physical Properties

In terms of mean mass, the eco-friendly cement bricks with fabric waste were lighter by 0.11 kg from the traditional bricks. This result is expected since sand, which is composed mostly of quartz has a specific gravity of 2.65 to 2.67 and Portland cement, 2.90 to 3.15. Since a portion of sand and cement was replaced in our eco-friendly bricks with polyester fabric wastes, which has a lower specific gravity of 1.38 to 1.40, you can expect the eco-friendly bricks to be lighter. According to Taurino *et al.* (2019), lightweight bricks with reduced thermal conductivity and acceptable physical-mechanical properties have become an important trend for green buildings to reduce the building weight and the energy consumption.

Bulk density refers to the weight of the material including the intergranular air space in unit volume (Bhattacharya, 2013). Data gathered show that the mean bulk density of the eco-friendly bricks was lower compared to the traditional cement bricks. The results are expected given that bulk density is a function of the mass of the bricks and with fabric wastes less dense than sand and cement as discussed previously plus a constant volume of $0.0015m^3$ for both types of bricks, thus the eco-friendly cement bricks are expected to have lower mean bulk density than the traditional bricks.

When both types of bricks were immersed in water, it could be seen that the eco-friendly cement bricks with fabric wastes had lower mean saturated mass compared to traditional bricks with a difference of 0.01 kg. However, looking back at the mass of both bricks, the eco-friendly bricks had a much lower mean mass by 0.11 kg. This means that the eco-friendly bricks were able to absorb more water compared to the traditional bricks as reflected in the higher mean water absorption percentage. According to Zhang and Zong (2014), durability of concrete plays a critical role in controlling its serviceability. Furthermore, durability of concrete is mainly dependent on the capacity of a fluid to penetrate the concrete's microstructure, which is called permeability. Despite, the relatively higher mean water absorption percentage of 10.24% of eco-friendly bricks as compared to the traditional bricks with 9.73%, still both fall within the standard water absorption value of concrete bricks of 8 to 20%.

For all physical properties tested, there was no significant difference in the means of both types of bricks. Therefore, eco-friendly cement bricks are comparable to traditional bricks in terms of important physical attributes of bulk density ($p=0.086$) and water absorption percentage ($p=0.800$)

4.2 Mechanical Properties

As cited by Coronado *et al.* (2015), compressive strength is the bulk unit charge against the breakage under axial compressive strength, and it is one of the most important properties of bricks. Compressive strength tests on bricks are carried out to determine the load carrying capacity of bricks under compression since masonry structures are made to bear load as part of walls, columns, and footings (The Constructor, 2019). In the study, the eco-friendly bricks were slightly lower in mean maximum load and therefore, mean compressive strength with the latter a function of the former. However, looking at the t-test results, there was no significant difference between the two (2) bricks with a p-value of 0.326 for both maximum load and compressive strength means.

4.3 Cost

Using the same method of production, cost estimates revealed that per unit of the eco-friendly brick is Php 3.00 cheaper than the conventional brick. Moreover, the producer of eco-friendly bricks can more likely save Php4,500.00 per production batch (1 $meter^3$) relative to the production cost per unit of conventional bricks.

5.0 CONCLUSION

Eco-friendly cement bricks with polyester fabric wastes produced at a volumetric ratio of 1:5:1 of cement to sand to fabric are comparable to traditional bricks in terms of physical properties of mass (kg) (t=1.780, p=0.086), bulk density (kg/m^3) (t=1.780, p=0.086), and water absorption percentage (%) (t=0.256, p=0.800) as well as mechanical properties of maximum load (kN) (t=1.000, p=0.326) and compressive strength (Mpa) (t=1.000, p=0.326) with results having no significant differences in their means. In terms of cost, eco-friendly bricks are cheaper by Php 3.00 than traditional bricks.

6.0 RECOMMENDATIONS

The eco-friendly cement bricks with fabric wastes can be commercialized after protection of the product and the process for environmental enthusiasts interested in constructing green buildings but not yet as replacement of traditional bricks because of the question of finding steady and viable sources of fabric wastes. In the light of this recommendation, there is also a need to conduct further testing of additional properties of the bricks such as flammability or even in situ testing.

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