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Sustainable Alternative Materials to Concrete Masonry Partition Walls: Light-Weight Wall Panel Using Polymethyl Methacrylate (PMMA) and Shredded Waste Metalized Film Packaging

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ABSTRACT

The amount of plastic waste produced yearly is significantly increasing. Approximately 300-400 million metric tons of plastic waste are produced yearly. One of the dominant plastic wastes is a metalized film, a shiny, non-homogeneous polymer used in packaging that is considered the least recycled. Meanwhile, partition walls in buildings are traditionally made of concrete masonry, one of the most utilized materials in the construction industry globally, consumed yearly by about 11 billion metric tons. Because of the excessive use of concrete, the necessary raw materials are undeniably depleting, therefore demanding some alternatives. Polymethyl methacrylate (PMMA) is one option that can be utilized as an alternative because of its remarkable characteristics better than that of the traditional. This paper proposed the utilization of PMMA in fabricating the hollow panel filled with shredded waste metalized film packaging resulting in the lightweight wall panel being used as an alternative to concrete masonry for constructing partition walls. After the experiment, PMMA produced compressive strength of 75.30-84.30MPa, a tensile strength of 52.00-59.10MPa, a flexural strength of 102.00-107.00MPa, and water absorption of 0.80-0.90%. Also, shredded waste metalized films add aesthetic to the panel and are complemented by the remarkable transparency of PMMA. In conclusion, using this lightweight wall panel instead of traditional concrete masonry partition walls will reduce plastic waste in landfills and the raw materials necessary to produce concrete.

INTRODUCTION

The high demand for better plastic packaging led to the invention of Metallized film, a non-homogeneous plastic with a thin layer of metals (Alyousef et al. 2022), usually aluminum metals that give the packaging a shiny and metallic appearance with a lighter weight and cheaper cost, but with excellent moisture and oxygen barring properties (Flexpack Mag 2020). However, metalized film packaging is considered single-use plastic that contributes to the accumulation of plastic waste in our landfills, resulting in harmful environmental effects (Bhogayata & Arora 2019). Approximately 300-400 million metric tons of plastic waste are produced every year (UNEP 2018, EAPM 2018, Payne et al. 2019, Awoyera & Adesina 2020, Alhazmi et al. 2021, Silva et al. 2021, Lamba et al. 2021). In fact, in 2018, a study conducted by United Nations Environment Programme (UNEP) highlighted that 50% of the total weight of plastic waste on our planet comes from plastic packaging, and 32% of this packaging is expected to enter the environment. Around 8 million tons from this percentage go straight into the ocean (Guillard et al. 2018). Meanwhile, one of the considered significant contributors to the fast-growing economy of one country is the construction industry. According to a recent study, it is estimated to become the third-largest industry in the world by 2025 (Durgalakshmi & Janani 2019). Concrete, for instance, the traditional construction material utilized to build any infrastructure (Goyal & Kumar 2018), particularly in partition walls, requires cement consumed every year of about 4.1 billion metric tons (Garside 2023). Because of the excessive use, the chances for the depletion of the necessary raw materials over time is undeniably inevitable, therefore demanding some alternatives. Polymethyl methacrylate (PMMA) or simply acrylic is one option that can be utilized as an alternative because of its remarkable characteristics better than traditional ones, such as outstanding clarity, glass-like transparency, high scratch resistance (Shen et al. 2020), high mechanical strength (Sivanathan et al. 2020), shatter resistance (Shaari et al. 2021), durability and low cost (Leão et al. 2019) and is generally available in the form of particles, sheets, pipes, tubes and rods (Lianghua 2021).

This paper has three objectives. The first is to use shredded waste metalized film packaging and PMMA sheets to construct partition walls as alternative materials to concrete masonry. This will reduce the volume of the accumulating plastic wastes in our landfills and will eliminate the painting works in constructing partition walls due to the outstanding clarity of PMMA complemented by the aesthetic appearance of shredded waste metalized film packaging. The second is to determine which, among 3mm, 10mm, and 18mm PMMA sheets, is the best for compressive strength, tensile strength, flexural strength, and water absorption. Thirdly and lastly, eliminate the utilization of any concrete masonry materials in constructing partition walls. This results in conserving raw materials necessary for producing concrete and reducing the carbon dioxide emitted into the atmosphere due to cement production. Unlike the previous research studies, the shredded waste metalized film in this research will not be incorporated into the concrete as an alternative reinforcement to steel bars nor as a partial replacement for cement, sand, or gravel. The shredded waste metalized film, once deposited to the wall panel made of PMMA, will significantly increase the aesthetic appearance of the wall because of the outstanding clarity and illuminance of PMMA that will eliminate the necessary painting works. Also, because of the expected high mechanical properties of PMMA, the wall panel is suitable as an alternative construction material in constructing partition walls.

Research Significance

The result of this study will be of value to the community first because this paper will participate in eliminating some harmful factors risking the community's health by reducing the accumulating plastic waste in landfills and dumpsites. Second, the government will help them to appropriately take action in dealing with the problems brought by the accumulating plastic wastes in landfills and dumpsites, causing detrimental effects on the environment third to the environment, because this study will further promote the protection, conservation, and rehabilitation of the environment towards sustainable development. Lastly, to future researchers, this paper will serve as a guide in conducting further studies to increase understanding of sustainable practices and may be a source of related literature.

MATERIALS AND METHODS

To achieve the desired product, two primary materials are required. First is waste metalized film packaging. This material will be collected from litter, landfills, and dumpsites. First, clean the collected waste metalized film packaging to remove

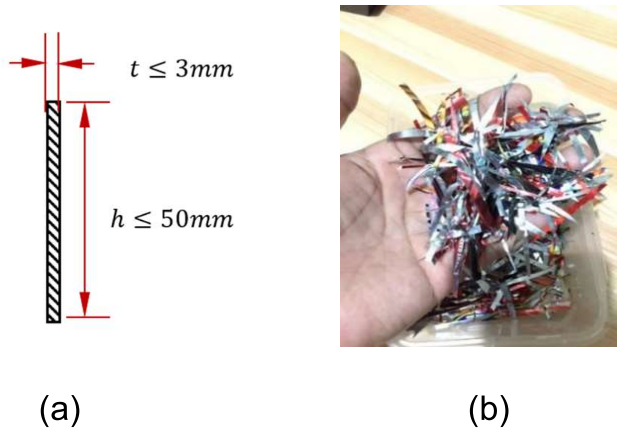

Fig. 1: Dimensions for the waste metalized film packaging strips.

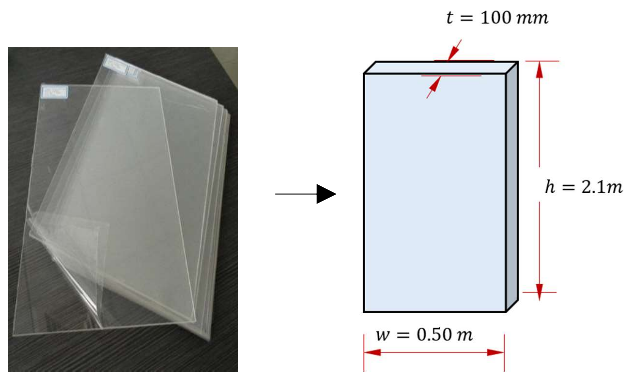

Fig. 2: Cut PMMA sheets (left) to hollow parallelepiped-liked wall panel (right).

all foreign materials. Next, dry the waste metalized film packaging and cut it into small and thin strips with thickness and height not exceeding 3mm and 50mm, respectively. Refer to Fig. 1 (a) and (b). The second primary material is 4ft x 8ft PMMA sheets with thicknesses varying from 3mm, 10mm, to 18mm. The good news is that woodworking tools can also be used to cut PMMA sheets (The Plastic People 2021) into panels having the dimensions shown in Fig. 2. Assemble the cut sheets using a screw and solvent to bond one another to create the hollow parallelepiped-like panels.

Research Design

Fig. 3 shows the process followed during the research work. It shows the steps followed starting with bringing the specimen samples to the testing center to developing of PMMA sheets hollow parallelepiped light-weight wall panel.

PMMA Specimen Details

Specimen samples have the following dimensions conforming to ASTM standards. 13mm × 50mm × t for compression test

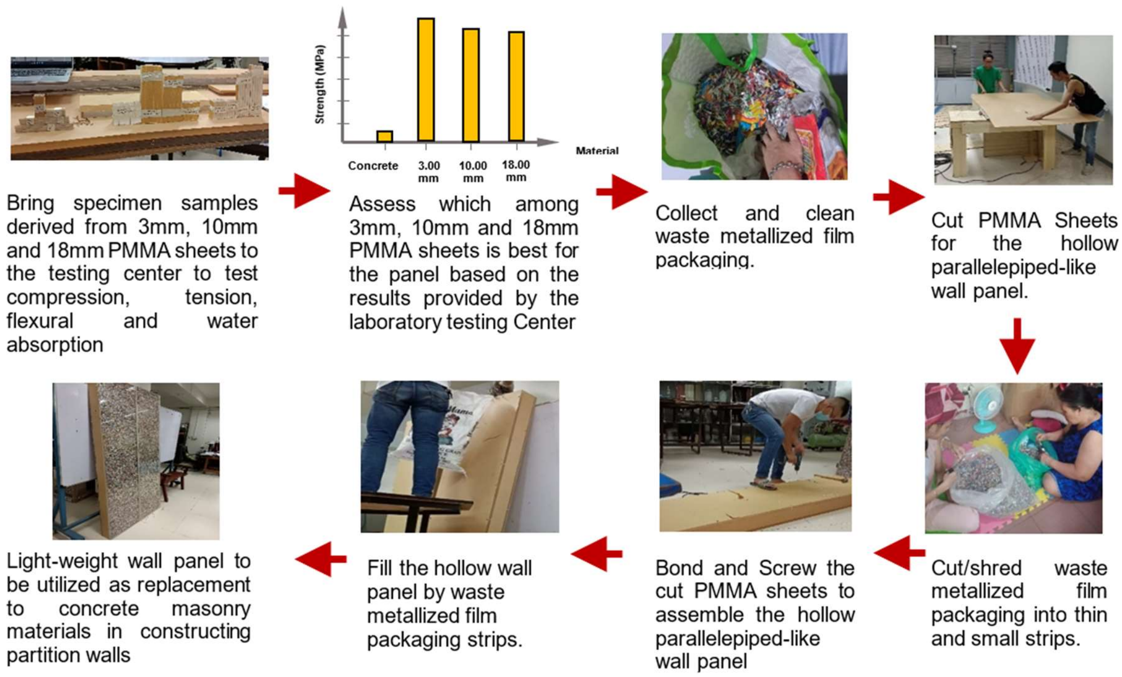

Fig. 3: Distribution flow of PMMA sheets hollow parallelepiped light-weight wall panel.

(ASTM D695) where “t” denotes the thickness of 3 PMMA variables: the 3mm, 10mm, and 18mm. 13mm × 150mm × t for tension test (ASTM D638), 13mm × 125mm × t for flexural strength (ASTM D790), and 25mm × 50mm × t for water absorption test (ASTM D570). All specimen samples are sent to the Standards and Testing Division (STD) under the Department of Science and Technology (DOST) and waited 20 working days for the results.

RESULTS AND DISCUSSION

Compressive Strength Comparison

A typical concrete masonry’s compressive strength ranges from 20 to 50 MPa (Bošnjak et al. 2019, AlQudah & Freewan 2020). Unfortunately, no data was gathered relative to the 3mm PMMA sheet due to its minimal thickness the UTM cannot support, whereas the compressive strength of 10mm and 18mm PMMA is 75.30 MPa and 84.30 MPa, respectively, based on the results provided by the testing center. Note that the higher the compressive strength, the better. Therefore, the two variables’ compressive strength is higher than traditional concrete masonry. Refer to the data shown in Table 1.

Tensile Strength Comparison

The tensile strength of a typical concrete masonry ranges

Table 1: Mechanical properties comparison among 3mm, 10mm, 18mm PMMA, and typical concrete masonry.

Materials		Compressive Strength [MPa]	Tensile Strength [MPa]	Flexural Strength [MPa]	Water Absorption [%]	Observation
PMMA						
Thickness	3mm	-	59.10	107.00	0.205	No discoloration of the deformity was observed in all the tested specimens after the 24h immersion test
	10mm	75.30	53.70	102.00	0.188	No discoloration of the deformity was observed in all the tested specimens after the 24h immersion test.
	18mm	84.30	52.00	102.00	0.090	No discoloration of the deformity was observed in all the tested specimens after the 24h immersion test.
Concrete Masonry		20-50	2-5	2-5	0.80-0.90	Note: Values are obtained based on the study conducted by Bošnjak et al. (2019), AlQudah and Freewan (2020), Onyeka (2019), and the recommendations given by NSCP in 2015.

only from 2 to 5 MPa (AlQudah & Freewan 2020), whereas the tensile strength of 3mm, 10mm, and 18mm PMMA are 59.10 MPa, 53.70 MPa, and 52.00 MPa, respectively, based on the results provided by the testing center. Adapting the principles of Mechanics, note that the higher the tensile strength, the better. Therefore, by analyzing the data, it is noticeable that the tensile strength of PMMA decreases as the thickness increases; however, the values of the three variables are still way higher than that of concrete masonry. Refer to the data shown in Table 1.

Flexural Strength Comparison

Like the tensile strength, the flexural strength of typical concrete masonry ranges from 2 to 5 MPa (AlQudah & Freewan 2020). On the other hand, the flexural strength of 3mm, 10mm, and 18mm PMMA are 107 MPa, 102 MPa, and 102 MPa, respectively, based on the results provided by the testing center. By adopting the principles of Mechanics again, note that the higher the flexural strength, the better. Therefore, by analyzing the data, the flexural strength of PMMA decreases as the thickness increases. However, just like the tensile strength, the values of the three variables are still way higher than that of concrete masonry. Refer to the data shown in Table 1.

Water Absorption Comparison

The water absorption of a typical concrete masonry ranges from 0.80% to 0.90% (Onyeka 2019), whereas that of 3mm, 10mm, and 18mm PMMA are 0.205%, 0.188%, and 0.09%, respectively, based on the results provided by the testing center. Note that the lower the water absorption, the better. Therefore, by analyzing the data, 18mm has the best property in terms of water absorption. Refer to the data shown in Table 1.

CONCLUSION

Based on the presented results, the mechanical properties of all 3 PMMA variables (3.00mm, 10.00mm, and 18.00mm) are far better than that of the concrete masonry. However, considering the bending characteristic, a 3mm PMMA sheet cannot be suggested because of its small thickness resulting in significant sagging. Also, an 18mm PMMA sheet cannot be suggested considering it is the most expensive among the 3 PMMA variables. Therefore, the most recommended is a 10mm PMMA sheet. Since half of the needed materials to manufacture this panel comes from waste metalized film packaging, the volume of waste plastics accumulating in landfills and dumpsites will be reduced. Also, since no cement will be utilized during the entire construction of partition walls, less carbon dioxide will be emitted into the atmosphere. Painting works for partition walls will also be eliminated because of the aesthetically pleasing appearance of the metalized film strips complemented by the outstanding clarity and illuminance of PMMA. Other miscellaneous concluded benefits of the proposed sustainable construction material are the following; (1) electricity consumption for lighting will be minimized (2) The panel is long-lasting and requires lesser maintenance (3) Because the wall panel is light-weight, dead loads being carried by the beams or floor systems coming from partition walls will be lessened, thus resulting to fewer reinforcements and concrete volume from the supporting elements (4) Since the proposed material is a ready-made light-weight panel, the duration for the construction of partition walls will be faster compared to that when using traditional concrete masonry materials (5) Huge amount of money will be saved from the entire construction cost.

Recommendation for Future Studies

It is evident that using fabricated lightweight wall panels using polymethyl methacrylate as waste metalized film strips receptacle is a sustainable replacement to concrete masonry materials. However, there are some points that the researcher/s figured out, upon executing the experiments, that require improvements which are no anymore entertained due to the lack of time, resources, and budget, thus, included in this part as recommendations to the future researchers. (1) The design width of the panel, which is 500mm, can be increased up to 1 meter since the panel has sufficient compression, tensile and flexural strength. It will also reduce units to be installed during the construction of partition walls, expediting the installation process. (2) The researcher/s also used PMMA material for the edges of the panel, which was later on figured out not advised because the physical attributes of PMMA, such as its outstanding clarity and illuminance, will just get wasted since the edges of the panel are purposely used to bond it to the ceiling, floor, and other panels. Therefore, the researcher recommends using other construction materials, such as metal, aluminum, or other polymers, for the edges of the panel. (3) The waste metalized film strips with the designed dimensions not greater than 3mm and 50mm for thickness and height are not recommended because strips with varying thickness and height compromise the panel's aesthetic. The strips' dimensions must be uniform; thus, the recommended thickness and height of the strips must be strictly equal to 3mm and 50mm, respectively. The values, therefore, that are less (or greater) than the said dimensions are not advised. (4) Because the researcher did not focus on the bonding methodology of the panel to the ceiling or flooring, this particular area can be recommended to future researchers. (5) the researcher recommends that future researchers study the sagging attributes of PMMA with the thickness varying from 5mm to 9mm for a better alternative to 10mm thick in terms of economical cost.

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