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Plastic Wastes as Additive Material for Hollow Block Production

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ABSTRACT

This study aimed to investigate the strength of plastic wastes as additive material for hollow block production. The hollow block with plastic wastes was machine made incorporated with shredded plastic wastes gathered from the community. The hollow block with different drying days were tested in terms of maximum load test (kN), compressive strength (Mpa) and strength test (psi). Also as comparison, the machine made commercial hollow block was tested to its maximum load test (kN), compressive strength (Mpa) and strength test (psi). The tests were performed at TERMS Concrete and Materials Testing Laboratory, Inc. Data were analyzed using mean and Mann-Whitney U Test. Results revealed that hollow blocks with plastic wastes dried in 10 days gained the best test results to be used for masonry, especially for tall buildings that require great strength. For commercial hollow block dried in 81 days gained the best test results to be used for masonry works. Hollow block with plastic wastes can be a good substitute for commercial hollow blocks and can also give more strength to the hollow block made. The hollow block with plastic wastes and commercial hollow block does not significantly differ in terms of maximum load test (kN), compressive strength (Mpa) and strength test (psi), therefore, hollow block with plastic wastes can be a good substitute for commercial hollow blocks. Explore other consumer wastes that can be incorporated into hollow blocks to improve the compressive strength of the material and environment-friendly

Introduction

The daily accumulation of solid waste is driven by population growth, inadequate awareness and cooperation, which represents a significant societal challenge despite existing government regulations. This waste is prevalent in urban canals, coastal waters, and natural reserves creating environmental health risks.

In metropolitan regions, common practices like open dumping and burning aggravates the issue. Usage of plastic materials is increasing rapidly and our world is facing the challenge. Moreover, the strength, flexibility and light weight of traditional oil-derived plastics make them ideal materials for a large number of applications, including packaging, medical devices, building, transportation, etc. However, the majority of produced plastics are single-use plastics, which, coupled with a throw-away culture, leads to the accumulation of plastic waste and pollution, as well as the loss of a valuable resource. Furthermore, Chen et al (2021) stated that plastic waste is one of the world's most pressing human health and environmental concerns. Plastic constitutes the third highest waste source globally, with the total volume of plastic waste growing in-line with increases in the global population and per capital consumption. Malaysia is tracking global trends in both the overall generation of plastic waste and the consumption of single-use plastics and since 2017 has been the world's largest importer of plastic waste. These elements create a number of major challenges for the country's waste management system. Furthermore, according to Zhang et al (2019), global plastic production is over 300 million tons, with 20% produced in China. 90% of discarded plastics are not recycled. China's import ban on waste plastics has affected global production and waste management, replacing according to Chen et al (2021), Southeast Asian countries like Malaysia. Moreover, many studies show that Malaysia is one of many countries that are tracking global trends in both the overall generation of plastic waste and the consumption of single-use plastics and has been one of the world's largest importer of plastic waste. These elements create a number of major challenges for the country's waste management system.

Sidhu et al (2021), claimed that the increasing generation of plastic waste at home may pose a problem for these groups, as this type of waste accumulates very rapidly and occupies a considerable amount of space. According to Corracero et al (2021), The Philippines has a continuously rising amount of waste and is expected to further increase in the succeeding years. As reviewed, associated problems with solid waste management in the country include an increasing amount of solid waste, weak law implementation, scarcity of sanitary landfills, and improper disposal. The ultimate solution existing in the country is the RA 9003 or the Ecological Solid Waste Management Act of 2000 which highlights the practices of segregation, proper disposal, and waste diversion. Further, according to Arowana Impact Capital (2023), the plastic pollution problem continues to affect communities across the Philippines. People living in vulnerable areas, such as highly urbanized cities and coastal towns, bear most of the brunt. Fishing communities face declining catches due to plastic contamination in waters and coastal areas. Plastic pollution contributes to health issues, particularly among marginalized communities living near polluted areas.

Requiron. J,C et al (2023) stated that those that involve plastic pollution. It has significant impacts on marine and aquatic organisms, yet management, mitigation, and preventive measures are still challenging due to human intervention. The perceived plastic pollution impacts are a serious concern, to the fishermen, especially to their livelihood. They want the river to be clean and free from plastic pollution. Farmers of environmental threats and their impacts are relevant in mitigating and preventing environmental and human health issues, ensuring the sustainability of the aquaculture sector. Additionally, solid waste disposal remains a significant issue in Davao City, where 47% of the households in the coastal areas contribute much of their waste, including human waste (Cordova, 2024). According to the report, approximately 3,000 sacks of plastic were collected in May 2019 by Bantay Dagat volunteers from the 32 coastal areas of Davao. It was alarming since health and sanitation would be at stake if these concerns were not addressed.

Due to high urbanization in Davao City, people accumulate more plastic waste which can contribute a negative impact on our environment. In reducing these plastic wastes, it is necessary to innovate by utilizing plastic wastes as additive material for hollow block production.

Literature Review

Plastic Waste

Plastic is a polymeric material that has the capability of being molded or shaped, usually by the application of heat and pressure. This property of plasticity, often found in combination with other special properties such as low density, low electrical conductivity, transparency, and toughness, allows plastics to be made into a great variety of products. These include tough and lightweight beverage bottles made of polyethylene terephthalate (PET), flexible garden hoses made of polyvinyl chloride (PVC), insulating food containers made of foamed polystyrene, and shatterproof windows made of polymethyl methacrylate. Many of the chemical names of the polymers employed as plastics have become familiar to consumers, although some are better known by their abbreviations or trade names. Thus, polyethylene terephthalate and polyvinyl chloride are commonly referred to as PET and PVC, while foamed polystyrene and polymethyl methacrylate are known by their trademarked names, styrofoam and plexiglas (or Perspex), (Rodriguez 2024).

Industrial fabricators of plastic products tend to think of plastics as either "commodity" resins or "specialty" resins. (The term resin dates from the early years of the plastics industry; it originally referred to naturally occurring amorphous solids such as shellac and rosin.) Commodity resins are plastics that are produced at high volume and low cost for the most common disposable items and durable goods. They are represented chiefly by polyethylene, polypropylene, polyvinyl chloride, and polystyrene. Specialty resins are plastics whose properties are tailored to specific applications and that are produced at low volume and higher cost. (Rodriguez 2024)

Among this group are the so-called engineering plastics, or engineering resins, which are plastics that can compete with die-cast metals in plumbing, hardware, and automotive applications. Important engineering plastics, less familiar to consumers than the commodity plastics listed above, are polyacetal, polyamide (particularly those known by the trade name nylon), polytetrafluoroethylene (trademark Teflon), polycarbonate, polyphenylene sulfide, epoxy, and polyetheretherketone. Another member of the specialty resins is thermoplastic elastomers, polymers that have the elastic properties of rubber yet can be molded repeatedly upon heating. Thermoplastic elastomers are described in the article elastomer.

Hollow Blocks

Hollow blocks, also referred to as masonry units (CMUs) are building materials commonly utilized in the construction industry. These blocks are distinguished by having one or more spaces, within their structure setting them apart from concrete blocks. The hollow spaces can take on shapes such as square, rectangular or circular. Typically found in the middle or at the edges of the block. Their hollow construction offers benefits like cost effectiveness, sound and thermal insulation properties, fire resistance capabilities and ease of installation. (Naba Buddha Institute, 2024). The defining feature of hollow blocks is the presence of these cavities, which contribute to their lightweight nature and enhance their insulating properties. They are typically manufactured in standardized sizes, making them easy to install and ensuring consistent construction. They are available in various shapes and sizes to suit different applications, from load-bearing walls to partitions and fences. Cement, The primary binding agent in the concrete mixture, providing strength and durability to the block. Aggregates, these include sand, gravel, or crushed stone, which provide bulk and structural integrity to the block. Water, Used to hydrate the cement and initiate the chemical reaction that creates concrete. Additives, Optional ingredients that can be added to modify the properties of the concrete, such as colorants, plasticizers, or water-reducing agents. (Williams, 2024)

The properties of hollow blocks are compressible strength, varies based on their composition and manufacturing process. Density, Lightweight blocks have lower density, making them suitable for insulation, while heavyweight blocks are denser and used for load-bearing applications. Fire resistance, Hollow blocks are fire-resistant, with fire ratings depending on their type and thickness. Sound Insulation, Sound insulation properties vary based on the block design, including cavity arrangement and thickness. Thermal, Insulation Lightweight blocks provide some thermal insulation, with the option to enhance performance by adding additional materials. Water, Absorption Hollow blocks can absorb water, which can affect their strength and durability. Proper waterproofing measures are essential to prevent water damage. (Williams, 2024).

Statement of the Problem

This study aimed to investigate the strength of plastic wastes as additive material for hollow block production. Specifically, this research aimed to answer the following questions:

1. What is the strength of hollow block with plastic wastes when tested according to a number of days dried with:

1.1 Maximum Load Test (Kilonewton, kN)

1.2 Compressive strength (Megapascal, Mpa); and

1.3 Strength test (Pounds per square inch, psi)?

2. What is the strength of the commercial hollow block when tested according to a number of days dried with:

2.1 Maximum Load Test (Kilonewton, kN)

2.2 Compressive strength (Megapascal, Mpa,); and

2.3 Strength test (Pounds per square inch, psi)?

3. Is there a significant difference in the strength between the hollow block with plastic wastes and commercial hollow block produced?

Research Hypothesis

This study was tested at 0.05 level of significance.

H_o: There is no significant difference in the strength between the hollow block with plastic wastes and commercial hollow block produced?

Significance of the Study

This study hoped to give benefits to the Environmental Management Bureau of the Department of Environment and Natural Resources, the public, and future researchers.

Government Officials and Policy Makers. The data gathered may be highly beneficial towards the sustainability and efficiency of proper garbage disposal. The findings may become the basis to be of positive betterment for the environment and allied areas.

Consumers. This study provides an eco-friendly solution to reduce plastic pollution by re-purposing waste into construction materials, helping to clean the environment. The use of plastic in hollow blocks may also lower construction costs, contributing to affordable housing for low-income families. Additionally, it promotes sustainable practices, supports local economies by creating demand for plastic waste, and improves public health by reducing waste-related hazards.

Future Researchers. The findings of this research may provide adequate information regarding the use of hollow blocks with plastic waste as an alternative to those commercial ones. The researchers would also recommend that future researchers experiment with adding more and better ingredients and test results. Furthermore, this may as well give them a direction of their own research endeavors.

Scope and Delimitation

The machine-made hollow bocks with plastic wastes and without plastic wastes were bought from Bantay Dagat Volunteers at Toril, Davao City with different drying days. The number of plastic wastes were uniformly distributed in all hollow blocks with plastic wastes. The researcher brought the samples to the testing center for strength assessment.

METHODS

In this section, the researcher presented the research design, the preparation of materials and production of hollow block with plastic wastes and without plastic wastes by Bantay Dagat Volunteers and testing of the samples.

Research Design

This study utilized an experimental quantitative research method, specifically a true experimental design, to gather relevant data and information. According to Bell (2009), Experimental design is the process of carrying out research in an objective and controlled fashion so that precision is maximized and specific conclusions can be drawn regarding a hypothesis statement. Generally, the purpose is to establish the effect that a factor or independent variable has on a dependent variable. Moreover, according to Varma (2020) Experimental design relies heavily on statistical techniques to analyze data, test hypotheses, and draw meaningful conclusions.

Phase I. Preparation and Production of Materials

The primary materials were plastic waste such as plastic bottles, wrappers and single used plastics, was taken from a cleanup of a local community in Toril, Davao City due to its cost- free effectiveness. Moreover, another primary materials used to make hollow blocks were sand, gravel, and cement, and purchased from S&L hardware in Toril City, ensuring it's accurate measurements, and another material that was purchased from a sugar factory was molasses. This precautionary measure was taken to ensure accuracy as it may diminish the levels of the mentioned component.

Making of the Hollow Blocks with the Plastic Waste

The plastic wastes were initially washed to get rid of the dirt and then was exposed to the sun for it to dry, then, it was shredded into little confetti-like pieces. Further, 2 pails of gravel, half a pail of water with a mixture of 350 ml of molasses, and 3 dipper scoops of cement was added into the mixture as well as 2 dipper scoops of shredded plastic and was manually mixed because the mixture was not fit to be placed into the mixing machine for the reason of not meeting the minimum average of the mixture to be placed in the machine.

After manually mixing, it was placed into a machine that forms it into its hollow block form that should have the size of 40cm X 20cm X 10cm as Maunahan et. al. (2021) documented. Lastly, it was then molded to have its rectangular shape on the top and the newly formed hollow block was then removed out from the machine and left it in the broad daylight where it can dry.

Phase II. Testing the commercial hollow block and hollow block with plastic wastes

The samples were brought to the testing center. There are three indicators to tested for commercial hollow block and hollow block with plastic wastes The indicators include. maximum load test (kN), compressive strength (Mpa) and strength test (psi). According to Radview (2024), Maximum Load testing is a type of non-functional software testing that measures a system's performance under an increased user volume to ensure it can handle expected traffic. It involves evaluating the system's behavior and functionality using various metrics and parameters such as response time, throughput, server health, and stability. Furthermore, As the measure of compressive strength of concrete, Mega pascal (MPa) lets inspectors know the maximum pressure that can be applied to the concrete before it cracks or fails (Dallcon, 2020). Lastly, according to Cor-Tuf (2019), pounds per square inch (psi) measures the compressive strength of concrete. A higher psi means a given concrete mixture is stronger, so it is usually more expensive. But these stronger concretes are also more durable, meaning they last longer.

Phase III. Testing of Parameters

Indicators in Testing

All testing indicators are performed at TERMS Concrete and Materials Testing Laboratory, Inc.. at Mt. Mayon St., Davao City. The laboratory in-charge managed to test the hollow block with plastic wastes and commercial hollow block with different drying days and tested in terms of maximum load test (kN), compressive strength (Mpa) and strength test (psi).

Disposal Procedure

Pre-experimentation. The Bantay Dagat Volunteers proactively engaged in comprehensive planning to anticipate the necessary materials for the experimentation process. They carefully considered their budgetary constraints and adopted strategic measures to minimize potential waste. To ensure efficiency, they abstained from acquiring excessive or unnecessary materials for the production and objectives. This was accomplished through careful data collection from various online sources and personal visits to local hardware.

Experimentation. The Bantay Dagat Volunteers employed diligent measures to minimize the generation of by-products through efficient utilization of each material involved in the experimentation process, including washing the plastics. The other process is making the hollow blocks which includes gravel, cement, sand, plastic waste and water. To ensure precision, a scale balance was utilized to accurately measure the required quantities and proportions of plastic waste, gravel, sand cement, and water by adopting these practices, minimal to no product were wasted. Although there is a water waste due to washing the plastic.

Post-experimentation. The Bantay Dagay Volunteers, due to washing of the plastics, the waste water was filtered and disposed by pouring it on plants.

Data Analysis

In analyzing the result of the study, the researchers used the following statistical tools.

Mean. This was utilized to investigate the strength of hollow block with plastic

wastes and commercial hollow block when tested according to a number of days dried with maximum load test (Kilonewton, kN); compressive strength (Megapascal, Mpa); and strength test (Pounds per square inch), psi.

Mann-Whitney U Test. This was used to determine if there is significant difference in the strength between the hollow block with plastic wastes and commercial hollow block produced.

RESULTS

In this section, presents the findings based on the data gathered. The presentation is organized into (3) parts. First, is the strength of hollow block with plastic wastes when tested according to maximum load test (Kilonewton), compressive strength (Mega pascal) and and strength test (pounds per square inch). Second, is the strength of the commercial hollow block when tested according to maximum load test (Kilonewton), compressive strength (Mega pascal) and strength test (pounds per square inch). Third, is the significant difference in the strength between the hollow block with plastic wastes and commercial hollow block produced.

Strength of hollow block with plastic wastes when tested according to a number of days with maximum load test (Kilonewton, kN), compressive strength (Mega pascal, Mpa) and strength test (pounds per square inch, psi)

Presented in Table 1 is the test result of the strength of the hollow block with plastic wastes when tested according to a number of days dried with maximum load test (Kilonewton, kN), compressive strength (Mega pascal, Mpa) and strength test (pounds per square inch, psi).

Table 1.

Mean Strength of hollow block with plastic wastes when tested according to a number of days dried with maximum load test (Kilonewton), compressive strength (Megapascal) and strength test (pounds per square inch)

Parameters	Samples			
	Sample 1 (3 days)	Sample 2 (10 days)	Sample 3 (81 days)	Average Strength (psi)
1. Maximum Load Test (Kilonewton, kN)	34.9	63.7	49.0	202
2. Compressive strength (Megapascal, Mpa)	0.9	1.6	1.2	
3. Strength Test (Pounds per square inch, psi)	127	231	174	

As presented in table 1, shows the mean strength of hollow block with plastic wastes when tested according to a number of days dried with maximum load test (Kilonewton kN), compressive strength (Megapascal Mpa), and strength test (pounds per square inch psi). For maximum load test, the hollow block with plastic wastes dried in 3 days has 34.9 kN, dried in 10 days has 63.7 kN and dried in 81 days has 49.0 kN. For compressive strength, the hollow block with plastic wastes dried in 3 days has 0.9 Mpa, dried in 10 days has 1.6 Mpa and dried in 81 days has 1.2 Mpa. For strength test, the hollow block with plastic wastes dried in 3 days has 127 psi, dried in 10 days has 231 psi and dried in 81 days has 174 psi. The average strength is 202 psi. The hollow block with plastic wastes dried in 10 days has the highest maximum load test result, which means that it can withstand/support when exerted or loaded with force within the range of 63.7 kN before it breaks. The hollow block with plastic wastes dried in 10 days has the highest compressive strength test result, which means that it can endure compression or pressure on its surface within 1.6 Mpa before it cracks or fails. It also tells us the overall strength of the hollow block. The hollow block with plastic wastes dried in 10 days has the highest strength test result, which means that it can withstand maximum crushing stress within 231 psi. It is noted that when the hollow block with plastic wastes dried in 10 days has the best test results. The average strength of the 3 samples according to drying days is 202 psi.

Strength of the commercial hollow block when tested according to maximum load test (Kilonewton, kN), compressive strength (Mega pascal, Mpa) and strength test (pounds per square inch, psi)

Presented in Table 2 is the test result of the strength of the commercial hollow block when tested according to a number of days dried with maximum load test (Kilonewton, kN), compressive strength (Mega pascal, Mpa) and strength test (pounds per square inch, psi).

Table 2.

Strength of the commercial hollow block when tested according to number of days dried with maximum load test (Kilonewton), compressive strength (Mega pascal) and strength test (pounds per square inch)

Parameters	Samples			
	Sample 1 (3 days)	Sample 2 (10 days)	Sample 3 (81 days)	Average Strength (psi)
1. Maximum Load Test (Kilonewton, kN)	30.9	35.6	45.9	138
2. Compressive strength (Megapascal, Mpa)	0.8	0.9	1.3	
3. Strength Test (Pounds	112	129	182	

per square inch, psi)

As presented in table 2, shows the mean strength of commercial hollow block when tested according to a number of days dried with maximum load test (Kilonewton kN), compressive strength (Megapascal Mpa), and strength test (pounds per square inch psi). For maximum load test, the commercial hollow block dried in 3 days has 30.9 kN, dried in 10 days has 35.6 kN and dried in 81 days has 45.9 kN. For compressive strength, the commercial hollow block dried in 3 days has 0.8 Mpa, dried in 10 days has 0.9 Mpa and dried in 81 days has 1.3 Mpa. For strength test, the commercial hollow block dried in 3 days has 112psi, dried in 10 days has 129 psi and dried in 81 days has 182 psi. The average strength is 138 psi. The commercial hollow block dried in 81 days has the highest maximum load test result, which means that it can withstand/support when exerted or loaded with force within the range of 45.9 kN before it breaks. The commercial hollow block dried in 81 days has the highest compressive strength test result, which means that it can endure compression or pressure on its surface within 1.3 Mpa before it cracks or fails. It also tells us the overall strength of the hollow block. The commercial hollow block dried in 81 days has the highest strength test result, which means that it can withstand maximum crushing stress within 182 psi. The average strength of the 3 samples according to drying days is 138 psi.

Difference in the strength between the hollow block with plastic wastes and commercial hollow block produced

Presented in Table 3 is the difference between the strength of hollow block with plastic wastes and commercial hollow block.

Table 3.

Difference in the strength between the hollow block with plastic wastes and commercial hollow block produced

Hollow block	Mean	W	p-value	Decision on Ho
Hollow block with plastic wastes	177.33	3.00	0.70	Accept
Commercial hollow block	141.00			

Level of significance: 0.05

The table 3 shows that the hollow block with plastic wastes has an average strength of 177.33 while the commercial hollow block has an average strength of 141.00. It also shows that at 0.05 level of significance, do not significantly differ the on the maximum lead test, compressive strength test and strength test. Therefore, the study accepted the null hypothesis. This means that in terms of maximum load test, compressive strength test and strength test between hollow block with plastic wastes and commercial hollow block is the same. It implies that the hollow block with plastic wastes can be a good substitute for commercial hollow blocks and can also give more strength to the hollow block made.

DISCUSSION

The hollow block with plastic wastes dried in 10 days has the highest maximum load test result of 63.7kN, compressive strength test of 1.6 Mpa and strength test of 231 psi. This is the best age of hollow block with plastic wastes to be used for masonry especially for tall buildings that require great strength. As for the relationship of the number of curing days to the hollow blocks' compressive strength, it shows that as the number of the curing days' increases, the compressive strength decreases (Lubas, et al., 2021).

The commercial hollow block dried in 81 days has the highest maximum load test result of 45.9 kN, compressive strength of 1.3 Mpa and strength test of 182 psi. Commercial hollow blocks are commonly used for masonry works. According to (Ata, et al. 2007), machine compacted hollow sandcrete blocks made from mix ratio 1:6 and with up to 10% laterite content is found suitable and hence recommended for building construction having attained a 28-day compressive strength of 2.07N/mm2 as required by the Nigerian Standards.

Hollow block with plastic wastes can be a good substitute for commercial hollow blocks and can also give more strength to the hollow block made. It was inferred that the strength of the plastic material could have a direct contribution to the compressive strength of CHB at low percentage of aggregate replacement (Dolores, et al., 2020).

CONCLUSIONS AND RECOMMENDATIONS

Presented in this section is the conclusions and recommendations drawn based on findings of the study.

1. The hollow block with plastic wastes dried in 10 days has the highest maximum load test result of 63.7kN, compressive strength test of 1.6 Mpa and strength test of 231 psi. This is the best age of hollow block with plastic wastes to be used for masonry especially for tall buildings that require great strength.
2. The commercial hollow block dried in 81 days has the highest maximum load test result of 45.9 kN, compressive strength of 1.3 Mpa and strength test of 182 psi. Commercial hollow blocks are commonly used for masonry works.
3. Hollow block with plastic wastes can be a good substitute for commercial hollow blocks and can also give more strength to the hollow block made.

RECOMMENDATIONS

1. Explore other consumer wastes that can be incorporated to hollow blocks to improve the compressive strength of the material.
2. Apply different ratios of shredded plastic wastes to hollow block production.
3. Use different drying days or curing days for hollow block production.
4. Discover contextualized methods in incorporating waste materials into concrete production that are environment-friendly and economically viable practices.

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