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Assessment of Concrete Hollow Blocks Incorporating Polyethylene Terephthalate (PRT) and Copper Slag as a Commercial Concrete Alternative

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Abstract

The increasing demand for durable and sustainable concrete driven by population growth and urbanization, highlights the need for an environmentally friendly alternative to traditional concrete, by innovating and recycling the top waste made by industries, given the country's vulnerability to natural disasters and the environmental impact of concrete production. Polyethylene Terephthalate (PET) waste accounts for up to 13.9% of all waste plastics, posing a serious hazard to the environment and ecology both on land and in oceans (Ye et al., 2023); similarly, copper slag, a by-product of the smelting and processing of copper ore, is generated at a rate of 2.2 tons per ton of copper produced, leading to an annual figure of 24.6 million tons of slag (Gabasiane et al., 2021). With this, researchers are still finding ways to search for an alternative to lessen the environmental waste whilst contributing to the construction industry. Subsequently, this study aims to test the viability and effectiveness of Polyethylene Terephthalate and Copper Slag-induced concrete hollow blocks as an alternative to traditional commercial concrete hollow blocks. The researchers used a Post-Test Only Controlled Group Design, providing a complete understanding of their effect on concrete performance. By utilizing purposive sampling, the researchers were able to select shredded PET as their chosen samples. The raw data from the test results of varying ratios were treated using ANOVA. In terms of compressive strength and water absorption percentage, the 30-70 ratio emerged as the most durable, while in density, the commercial concrete displayed the highest amount. Upon comparative analysis, the results from the data treatment shows a significant difference in incorporating Polyethylene Terephthalate and Copper slag into concrete, specifically the 30% PET and Copper slag to 70% cement ratio, therefore rejecting the null hypothesis. It is advised to explore more ratios to accommodate different construction demands and have a minimum curing time of 28 days before testing the qualities of the said concrete hollow blocks.

Keywords: sustainable, waste, alternative, environmentally friendly, concrete, concrete hollow blocks, Polyethylene Terephthalate (PET), copper slag

INTRODUCTION

Background of the Study. One of the factors underlying long-lasting, durable, and less permeable commercial and domestic types of structures is due to the employment of concrete. Concrete encompasses an increased demand because of population growth and urbanization expansion (Miller, Cunningham, and Harvey, 2019).

The "Build-Build-Build" (BBB) program was a significant venture for the improvement of the country's extensive infrastructure established by the Rodrigo Duterte administration. According to the International Monetary Fund (2020), the advancement in transport and mobility, power and energy, water, information and communications technology, and urban development and renewal are projected to advance the improvement of the country's economy and Filipino citizens' life quality. In the journal published by Lamudi Philippines Inc. in 2022, the status of 119 flagship projects' current progress and cost allocated are extensively discussed. Therefore, the concrete's demand is immense, rendering it a necessary commodity in the Philippines, a developing nation.

In addition, the Philippines is also one of the valuable countries exposed to natural disasters due to its geographical location along the Pacific Ring of Fire resulting in seismic activities and volcanic eruptions, and on the top of the equator resulting in various destructive typhoons each year. This entails the significance of concrete's usage in providing shelters for individuals in terms of disaster. However, there is a necessity to provide an alternative to traditional concrete that can deliver equivalent or greater efficiency considering specific constituents that compose concrete possess detrimental influences on the environment (Miller, Cunningham, and Harvey, 2019).

Carbon Dioxide (CO2) is a prominent human contribution to the production of greenhouse gasses in the atmosphere. According to the Organization for Economic Cooperation and Development (2016), CO2 emissions are produced through the energy-producing processes of burning fossil fuels, and from deforestation and cement production. By adding more CO2 to the atmosphere, human activities modified the carbon cycle and contributed to climate change since the Industrial Revolution in 1750 according to the EPA United States Environmental Protection Agency in 2023. Concrete consists of a variety of components, including cement and water. The cement industry contributed approximately 8% of CO2 emissions (Tracy and Novak, 2023). This component has an advantageous effect on the concrete but impairs the environment. With the integration of plastic waste, Polyethylene Terephthalate (PET), and construction waste, copper slag, into commercial concrete, the impacts and advantages of the concrete will be altered, which will be highlighted in this study.

Concrete is a fundamental construction material known for its durability and structural integrity. In recent years, there has been a growing interest in developing sustainable and innovative alternatives to conventional concrete. This literature review explores the incorporation of PET and copper slag as alternative components in concrete to assess their impact on chemical, structural, and mechanical properties. The study focuses on sustainability, environmental impact, and performance enhancement as key themes in the context of both local and international research.

The ever-increasing global consumption of plastics has resulted in a surge of plastic-based waste, posing a severe environmental threat. Portugal, for instance, witnesses post-consumer packaging accounting for nearly 40% of total domestic waste, with approximately 10-14% of generated waste being plastic (Saikia and Brito, 2014). Disposing of plastic waste in landfills is not feasible due to its bulk and slow degradation rate. Recycling plastic waste to produce new materials, such as aggregates in concrete, has emerged as a promising solution with economic and ecological advantages. This literature review explores the incorporation of PET and copper slag into concrete, aiming to assess their impact on chemical, structural, and mechanical properties. The study emphasizes sustainability, environmental impact, and performance enhancement, within both local and international contexts.

As society places greater emphasis on sustainability, the construction industry is adapting by implementing responsible waste management practices. Consequently, researchers have explored the use of waste materials, particularly PET and copper slag in concrete, to reduce waste and enhance concrete properties. According to Rohith and Ravikumar (2022), incorporating and increasing the amount of plastic waste and copper slag in the mixture of concrete improves workability. This underscores the effectiveness of waste materials, particularly copper slag, in enhancing the strength of concrete when compared to traditional commercial concrete. In addition, the utilization of these waste materials highlights its significant trait of low water absorption resulting not only in durability but also the improvement of the concrete for resistance against water-related factors, such as corrosion (de Silva et al., 2021).

The existing obstacles in traditional concrete emphasize the prevalent issues of inadequate mix design, honeycombing, bugholes, disintegration, and scaling (Lysett, 2021). These issues, caused by poor construction practices and weathering, contribute to water infiltration and long-term damage, especially during freezing and thawing cycles. Concerns such as alkali-silica interactions causing surface cracking, efflorescence, and structural fractures also emphasize traditional concrete's vulnerability to environmental conditions. Weathering and cavitation abrasion and erosion effects further degrade hydraulic structure integrity.

Conventional concrete materials, which are frequently utilized in building, have a number of intrinsic issues that call for the investigation of alternate solutions. A noteworthy problem is the incomplete knowledge of how long-term replacements like copper slag and PET affect concrete's structural integrity. Most of the current research focuses on immediate mechanical and structural properties, like fire resistance, earthquake resistance, and compressive strength. There is still a substantial study gap, though, regarding a thorough examination of the long-term effects of various alternatives on the stability and durability of concrete.

Furthermore, a large portion of the existing study is based on information from particular Colegio and construction site sources. There are questions over the findings' applicability in more diverse environments due to their dependence on constrained resources. Future studies should investigate a wider range of PET and copper slag sources in order to address this. This method would allow for a more thorough examination of variances in their chemical makeup, illuminating potential variations that might have an impact on the material's performance over time.

Moreover, the research recognizes the constraints of the utilized testing methodology. Comparative studies with various testing techniques are therefore desperately needed for a more solid and trustworthy evaluation of the effectiveness of PET and copper slag-induced concrete. Investigating different testing strategies would help create concrete formulas that are long-lasting by providing a more comprehensive understanding of these substitute construction materials' performance.

Statement of the Problem. This study aims to test the viability and effectiveness of Polyethylene Terephthalate and Copper Slag-induced concrete hollow blocks as an alternative to traditional commercial concrete. Specifically, it sought to determine:

1. How do the different ratios of Polyethylene Terephthalate (PET) and Copper Slag (CS) in relation to cement content affect the viability and effectiveness of the concrete hollow block?

2. What is the difference between the test results of commercial concrete, and the Polyethylene Terephthalate and Copper Slag-induced concrete in terms of:

    2.1. Compressive Strength
    2.2. Absorption Percentage
    2.3. Density

3. What are the environmental impacts associated with the production and use of Polyethylene Terephthalate (PET) and Copper Slag-induced concrete compared to traditional commercial concrete?

Hypotheses

H_o: There is no significant difference in the viability and effectiveness between Polyethylene Terephthalate and Copper Slag-induced concrete compared to traditional commercial concrete.

H_a: There is a significant difference in the viability and effectiveness between Polyethylene Terephthalate and Copper Slag-induced concrete compared to traditional commercial concrete.

LITERATURE REVIEW

Sustainability and environmental impact. Avinc and Kumartasli (2020) emphasized the significant environmental challenges that human history has encountered due to industrialization, industrial development, population growth, and other contemporary societal factors. They highlight the role of Polyethylene Terephthalate (PET) recycling in addressing these issues. Recycling PET reduces the need for virgin PET production, conserving valuable resources like petroleum and reducing energy consumption. This conserves non-renewable resources and helps lower greenhouse gas emissions associated with PET production. It diverts plastic waste from landfills and incineration, reducing the burden on
waste management systems. This helps mitigate the negative environmental impacts of plastic waste disposal. It reduces the release of pollutants associated with PET production, such as greenhouse gases and harmful chemicals. This leads to a cleaner environment and improved air and water quality. It also reduces the release of pollutants associated with PET production, such as greenhouse gases and harmful chemicals. The focus on PET recycling drives research and development in recycling technologies, leading to innovations that make recycling more efficient and effective.

According to Caminoc et al. (2021), the production of polyethylene ground plastics has increased markedly in the Philippines. However, current levels of their usage and disposal generate several environmental problems. Incorporating polyethylene ground plastic waste into concrete helps reduce the amount of plastic waste that would otherwise end up in landfills or oceans. This contributes to waste reduction and minimizes the environmental burden of plastic disposal. By diverting plastic waste from traditional disposal methods like landfills and incineration, the environmental impact of plastic pollution is mitigated. Polyethylene plastics are known for their persistence in the environment, so finding alternative uses for them can help reduce their negative effects. The long-term performance and durability of concrete with polyethylene ground plastic should also be assessed. If the concrete degrades or releases microplastics over time, it could have unintended environmental consequences.

These findings underscore the critical role of recycling PET and utilizing waste materials like copper slag in mitigating environmental issues caused by industrialization and population growth. These practices help conserve resources, reduce emissions, divert waste from landfills, and drive innovation in sustainable technologies, contributing to a cleaner and more environmentally responsible future.

Enhancing concrete performance. Concrete is a material that undergoes modifications over time, and as a result, correspondingly changes its qualities, which include versatility, adaptability, durability, plasticity, endurability, and economy (Eid and Saleh, 2021). The components of concrete are cement, sand, and fine aggregates, which are the variables that can be upgraded with unorthodox substances. The three varieties of concrete—ordinary concrete, lightweight concrete, and high-density concrete—were further distinguished by Eid and Saleh according to their densities, with ordinary concrete comprising the type that is most often employed in industrial settings. Although limestone and clay account for the majority of cement's composition, certain chemical properties possess a range of influence on it. These include tricalcium silicate (C3S) for initial strength, dicalcium silicate (C2S) for strength improvement after a week, tricalcium aluminate (C3A) for the ability to resist sulfate, magnesia (MgO) for rendering it unsound, expand, and stronger, alumina for tolerating exceptionally low temperatures, and silica fume for compressive capacity, damage resistance, and bond strength. Concrete is an essential element in both industrial and commercial constructions as this provides a long-lasting foundation for establishments. Hence, this study concentrates on the testing of the effectiveness of plastic waste, polyethylene terephthalate (PET), and metallic waste, copper slag, as alternative components in commercial concrete through the concrete compressive strength test.

An assortment of destructive or non-destructive approaches can be applied when assessing a concrete structure's sustainability. Celerinos et al. (2023) assert that the destructive digital direct compression test and the non-destructive rebound hammer test both have the capacity to demonstrate the compressive strength of concrete. Therefore, the procedures executed before the testing weigh beyond the tests after determining the robustness of the concrete. Celerinos et al. additionally expands that the temperature of the environment, calibration, maintenance of the tools or machines, and over-all behind process impact the data that will be acquired. Thus, control over the factors that influence concrete in various manners is essential in order to accurately assess the compressive strength, water absorption, and density of the material for its advancement.

The aforementioned studies by Eid and Saleh (2021), and Celerinos et al. (2023) have relevance to one another and deliver insights into the enhancement of commercial concrete. Concrete's fundamental characteristics can be improved by integrating various components that foster its existing features. In order to supply reliable data while employing testing equipment, studies additionally accentuated the importance of accurately performing the operations. As a result, this study aims to establish an exemplary commercial concrete alternative with the assistance of PET and copper slag. The findings gathered by means of the concrete compressive strength test will subsequently be used to determine the material's efficacy and durability.

According to Portland Cement Association (2023), aggregates are abecedarian factors of concrete, comprising grainy accoutrements like beach, clay, or crushed gravestone, in confluence with water and portland cement. To ensure a high-quality concrete blend, summations must retain certain characteristics; they should be clean, sturdy, and devoid of absorbed chemicals or complexion coatings that might vitiate concrete continuity. Constituting a substantial 60 to 75 percent of concrete's total volume, summations are distributed as either fine or coarse. Fine summations, generally comprising natural beach or crushed gravestone, point patches passing through a 3/ 8-inch sieve, while coarse summations encompass patches exceeding 0.19 inch in periphery, generally used as coarse summations, with crushed gravestone filling the remainder. These summations can be sourced from natural deposits, including recesses, gutters, lakes, or seabeds, or produced by crushing chase gemstone, boulders, or cobbles. Likewise, recycled concrete serves as a feasible total source for colorful operations, similar as grainy subbases, soil- cement, and new concrete. Especially, the bruise and descent resistance of summations are vital considerations, especially in high-wear and tear conditions, where opting harder summations can alleviate wear and tear and maintain concrete performance.

Humanitarian Shelter Working Group (2014) stated that Concrete Hollow Blocks (CHB) are extensively favored as a primary walling material in the Philippines due to their cost-effectiveness and rapid-fire installation by semi-skilled sloggers. Still, their vulnerability to side forces, similar to those from typhoons or earthquakes, necessitates underpinning with perpendicular and vertical sword bars to enhance their resistance. The use of crushed coarse beach or clay is recommended for optimal CHB product, with a caution against swash and littoral beach. The quality of CHBs varies among suppliers, emphasizing the significance of conducting compressive strength tests to ensure compliance with needed norms. Selection should prioritize robust CHBs, identifiable by their absence of cracks and worsening corners. Rejecting CHBs that break when dropped from head height is advised. The advantages of CHBs include ready vacuity, excellent thermal and sound sequestration, high fire resistance, eventuality for earthquake and typhoon resistance through underpinning, and a lifetime exceeding two decades.

Aggregates are fundamental components of concrete, comprising grainy materials such as sand, clay, or crushed gravel, in combination with water and Portland cement. To ensure high-quality concrete, aggregates must be clean, sturdy, and free from contaminants or coatings that could compromise its integrity. They make up a significant 60 to 75 percent of the concrete's total volume and are categorized as fine or coarse, with fine aggregates passing through a 3/8-inch sieve and coarse aggregates exceeding 0.19 inches in diameter. These aggregates can be sourced naturally or produced by crushing various materials, including quarry rock. Recycled concrete is also a viable aggregate source. Notably, selecting appropriate aggregates with good abrasion and skid resistance is essential for concrete performance. In parallel, CHB are extensively used in the Philippines due to their cost-effectiveness and quick installation. However, their susceptibility to lateral forces necessitates reinforcement with steel bars. Optimal CHB production involves using crushed coarse gravel or clay, while CHB quality varies among suppliers, necessitating compressive strength testing. CHB offers advantages such as availability, thermal and sound insulation, fire resistance, and potential for enhanced earthquake and typhoon resistance, with a lifespan exceeding two decades.

Innovations in concrete technology. In a study conducted by Jassim (2017), the ongoing issue of plastic waste was explored, highlighting its continuous increase over the years, which is considered a substantial global challenge faced by nations worldwide. The study observed that these plastic waste sources are frequently linked to food packaging and other essential human needs, which are inescapable to consume. As a result, experts are seeking innovative methods or approaches to address the problem of plastic waste disposal. One of the approaches they considered is the utilization of plastic waste as an alternative to sand in cement production. This innovative method not only offers a solution to the challenge of plastic waste disposal but also focuses on producing a sustainable cement concrete. Moreover, the result of the study shows the effectiveness and impact of polyethylene materials as a replacement for sand in terms of density, ductility, and workability.

Joya, Buan, and Noroña (2021) examined the use of waste materials as an additional component in the production of concrete hollow blocks. To investigate the impact of waste materials on concrete cement, three mixtures were utilized—rubber waste, glass, and plastic waste materials. These materials served as substitutes for sand in the concrete mix, and observed their potential effects on the strength, resistance, cost, and density of the concrete hollow block. On the other hand, one notable effect of using these materials is the change in the compressive strength. Concrete hollow blocks utilizing waste materials as substitutes for sand are stronger compared to the standard concrete hollow blocks. Additionally, these modified concrete blocks also exhibited increased strength for carrying heavier loads than the standard concrete. Furthermore, in the investigation of production of hollow blocks using rubber, glass, and plastic waste as alternative materials to replace sand, it was evident that this approach has a significant impact on the overall quality and performance of the concrete hollow blocks.

The findings highlighted the effectiveness and impact of waste materials, specifically plastic or polyethylene materials, as substitutes for sand in concrete production. Consequently, both studies underscored the importance of innovation in producing better products while simultaneously addressing the challenges related to environmental sustainability.

The research conducted by de Pedro, Lagao, and Ongpeng (2023) significantly contributes to the construction industry's innovation and sustainability efforts by exploring the use of copper slag (CS) as a partial cement substitute, offering an eco-friendly alternative to traditional cement in concrete production. This innovation addresses environmental concerns tied to cement manufacturing, where cement production contributes notably to global carbon emissions. Furthermore, the study applies a thorough life cycle assessment (LCA), an innovative method that assesses the environmental consequences of concrete systems across their entire life cycle, offering a comprehensive understanding of CS's environmental implications in construction. Moreover, by taking into account both economic and environmental factors via the Triple Bottom Line (TBL) sustainability concept, the research ensures a well-rounded assessment of CS's potential as a cement substitute, meeting the industry's desire for sustainable and cost-effective solutions. Furthermore, the study investigates the impact of varied concrete strengths and CS percentages, offering significant insights for optimizing material selection and concrete mix designs in a variety of building projects.

This study underscores the significance of copper slag in advancing the development of sustainable and innovative concrete technologies. CS emerges as a key player in the quest to combine strength, durability, and environmental responsibility, ultimately driving advancements in construction methods.

Challenges in the construction industry. In the face of challenges in the construction industry, including rising raw material and equipment costs, securing competitive bids, and the need for increased productivity, a recent survey conducted by Procore Technologies sheds light on the perspectives of construction executives in the Philippines. The survey revealed that 80% of Philippine respondents anticipate an increase in the number of projects over the next 12 months, with 83% expecting projects of higher value. Notably, 46% of industry executives mentioned concerns about rising raw material and equipment costs as a top challenge, while 35% emphasized the need to secure competitive bids and tenders at sustainable margins. Despite these obstacles, the survey revealed optimism, largely attributed to the robust economy and modernization efforts of the administration. As the industry anticipates a rise in the number and value of projects, there is a growing need for sustainable practices and resilient structures. This underscores the significance of innovating for resilient structures, which shall explore potential solutions through alternative concrete materials, addressing these pressing challenges faced by the construction industry today (Procore Technologies, 2023).

As evidenced by Fritz Benachio, Freitas, and Tavares (2020), the construction industry is currently facing challenges, marked by its substantial contribution to natural resource extraction and solid waste generation, accounting for 30% and 25% respectively, on a global scale. Historically, the industry has adhered to a linear economic model, characterized by a "Take, Make, Dispose" approach, utilizing materials for building projects and ultimately discarding them after single use. This disposability-oriented practice has prompted an imperative paradigm shift towards a Circular Economy model, focused on maintaining materials within a closed loop to preserve their maximum value and minimize waste generation and resource extraction. Therefore, this study serves as an introductory exploration of the critical challenges confronting the construction industry today. It lays the foundation for potential solutions that revolve around the utilization of alternative concrete materials.

Amidst the challenges faced by the construction industry, including cost escalation and the growing demand for sustainability and resilience, there is a pressing need for innovative solutions. These issues are compounded by the industry's historical "Take, Make, Dispose" approach, which has contributed significantly to resource depletion and waste generation. To address these challenges, there is a growing focus on adopting a Circular Economy model that preserves material value and minimizes environmental impact. In this context, the exploration of alternative concrete materials emerges as a promising avenue for enhancing sustainability and resilience in construction practices.

Carbonation is one of the most common problems in the construction industry and a significant source of degradation in concrete. It refers to the reaction of atmospheric carbon dioxide with cement containing calcium hydroxide, which produces calcium carbonate and lowers the pH to around 9, causing corrosion by destroying the protective oxide layer of the reinforcing steel. Where it also occurs in an environment that has enough moisture but not enough to function as a barrier (Collins, 2023).

In the Philippines, a study was carried out to develop eco-blocks of concrete made out of ground-up plastic cellophane and sawdust, with the goal of reducing plastic waste and serving as an alternative to commercial hollow blocks. The findings show that there is no noticeable difference in durability between commercial hollow blocks and eco-blocks, which contain 9.69% less moisture than the 45% limit, showing that eco-blocks have the same potential and capability as standard concrete (Lobitos et al., 2023).

Carbonation, caused by atmospheric carbon dioxide reacting with calcium hydroxide in cement, is the primary cause of concrete deterioration. On the other hand, eco-blocks made from plastic cellophane and sawdust offer similar properties as commercial hollow blocks and are resistant to carbonation due to their low moisture content.

Theoretical Framework. Circular Economy Theory and Particle Packing Theory are the two pillars that underpin this research, providing the theoretical foundation for understanding the interplay between sustainable resource management and the optimization of concrete materials.

According to Suárez-Eiroa et al. (2019), circular economy (CE) is a mechanism for sustainable development, aiming to minimize raw material inputs and waste outputs, retain resource value, and reintroduce products through sustainable development by implementing recycled materials, renewables, and cascade-type energy flows into the linear system. Moreover, there are three common theoretical strategies under the CE paradigm: first, decreasing raw material inputs and waste outputs; second, retaining resource value as long as possible within the system; and third, reintroducing products into the system through sustainable development, which implies creating environmental quality, economic prosperity, and social equity for current and future generations.

In addition, Mohammed et al. (2012) defines the Particle Packing Theory as a systematic study of the arrangement and distribution of aggregate particles within a concrete mixture, influencing factors like workability, strength, durability, and cost-effectiveness. The goal is to identify optimal aggregate materials and mix ratios for low cement content and to better understand the relationships between particle packing, concrete performance, and rheology. This understanding can lead to more sustainable and cost-effective concrete mixtures.

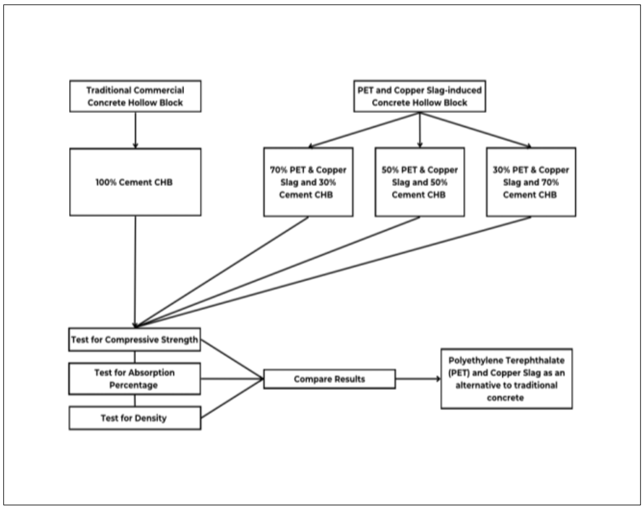

Figure 1. Conceptual Framework

Scope and Limitations. The purpose of the study is to evaluate the performance and viability of concrete made with copper slag and polyethylene terephthalate (PET) as substitute ingredients. This study's scope includes a thorough analysis of the mechanical, structural, and durability characteristics of concrete mixes made up of these two unusual ingredients. To evaluate the overall mechanical behavior of the concrete, the examination will also analyze the compressive, moisture content, and density. In addition, the study will look at variables like water resistance and pressure durability to see how PET and copper slag affect the durability of the concrete. To find the ideal mixture that best balances strength and durability, the research will entail the development of several concrete mix designs, as shown in Figure 1, with variable concentrations of PET and copper slag.

While the study seeks to illuminate the possible advantages of using these materials, it is crucial to recognize some restrictions. The characteristics of PET and copper slag from various sources may vary, there may be difficulties in attaining homogeneity in concrete mixes, and a complete study of the long-term consequences on structural integrity is required. The outcomes of this study will have a significant impact on the development of environmentally friendly concrete substitutes in the area of sustainable building materials.

This experimental study possesses certain limitations, excluding PET and copper slag's chemical components; added properties will not be taken into consideration as the variables are waste materials sources from the Colegio and from construction sites. The viability and effectiveness of the commercial concrete incorporated with PET and copper slag will only be tested by performing a concrete hollow block compression test, water absorption test, and density test which are the methods that will be employed. It is worth noting that alternative testing methods may differ and have an impact on the outcomes obtained.

The study faces limitations due to uncontrollable external factors like air quality and weather, which may influence the material's efficiency. Additionally, the allotted time constrains the depth of data expansion, presenting a limitation. Future researchers could address these gaps, making their work relevant to this subject. Despite these limitations, the research provides valuable insights and practical guidance, serving as a valuable resource for diverse methodologies and approaches.

Significance of the Study. The study is found to be significant to the following sectors:

1. *Students.* Students, particularly those studying engineering, architecture, or similar professions, can profit from our research by becoming acquainted with cutting-edge construction materials methods. The research can inspire students to participate in research projects, internships, or practical experiments connected to sustainable construction. It has the potential to prepare students to become future leaders in the sector who promote environmentally responsible and economically viable building approaches.

2. *Construction Industry.* The utilization of plastic waste materials and copper slag in producing commercial concrete will have a significant impact on the construction industry by enabling the production of more sustainable and higher-quality concrete cement. This will enhance the effectiveness of the products and its ability to maintain its characteristics or features over an extended period of time. Furthermore, alternatives, particularly plastic waste, offer the potential for cost-efficiency, given their easy availability and accessibility compared to the traditional materials used to produce concrete.

3. *The Colegio.* The study's findings will have a substantial impact on the colegio's future scholars, particularly STEM students, by exposing them to real-world challenges in the fields of construction and engineering which will create opportunities to further solidify Colegio's reputation as an innovative institution. Additionally, it can be used to enhance the construction of facilities within the institution, including buildings, gymnasiums, and benches, greatly benefiting the Colegio's community.

4. *Waste Management Companies.* Waste management companies that recycle and dispose of materials may find this research useful. The research shows how PET, a common plastic waste, can be recycled in construction to reduce the volume of plastic trash in landfills. The findings can be used by waste management firms to explore new options for recycling and processing PET materials, potentially leading to partnerships with the building sector for responsible material disposal and reuse. An example of this in the Philippines is the Metro Clark Waste Management Corporation (MCWMC) which manages garbage disposal and recycling facilities in the Philippines, with a focus on environmentally responsible waste management.

5. *Environmental Advocacy Groups and Organizations.* The research may be of interest to environmental advocacy groups and organizations focused on sustainability and conservation. The research demonstrates a viable strategy to decrease the environmental impact of the building sector through the use of recycled materials such as PET and copper slag. These groups can utilize the findings to advocate for policy changes and create awareness among stakeholders about the relevance of sustainable building materials in alleviating environmental concerns. Example of this is Greenpeace Southeast Asia in the Philippines; Greenpeace is well-known for its environmental campaigning worldwide, and the Southeast Asia branch, which includes the Philippines, actively works on pollution and sustainability issues.

6. *Future Researchers.* This study will provide baseline data for evaluating the viability and effectiveness of employing plastic waste and copper slag as sustainable substitutes for traditional commercial concrete. This will also serve as a valuable source of information for forthcoming studies related to exploring innovative approaches to incorporating waste materials into concrete production, contributing to environmentally friendly and economically viable construction practices.

METHODOLOGY

Research Design. To quantifiably assess the disparity between commercial concrete and Polyethylene Terephthalate (PET) and copper slag-induced concrete, this study will employ a Post-Test Only Controlled Group Design. This approach serves the dual purpose of evaluating the viability and effectiveness of PET and copper slag-induced concrete as an alternative to traditional commercial concrete in terms of compressive strength test, water absorption, and density, providing a comprehensive understanding of their potential impact on concrete performance.

Bhattacherjee (2019) defined experimental research as one of the most precise and demanding research designs since it requires one or more independent variables that will either be subject to a treatment or not, depending on the researchers, where the results on the dependent variables will be monitored; this manipulation in the intervention links cause and effect and is referred to as the internal validity. In a Post-Test Only Control Group Design, the control and experimental groups commence as identical, and variables are randomly categorized and conditioned (Campbell, 1957, as cited in Flannelly, Flannelly and Jankowski, 2018).

After conducting comprehensive assessments on compressive strength, water absorption, and density, the implementation of the Post-Test Only Controlled Group design will facilitate a precise comparison between the concrete incorporating Polyethylene Terephthalate (PET) and Copper Slag and the traditional concrete. This comparative analysis will enable a full understanding of the recommended ratio, durability, and environmental implications of the PET and Copper Slag-infused concrete, ultimately providing valuable insights into the practicality and effectiveness of these alternative materials in commercial construction applications.

Sampling Method. To ensure the validity and accuracy of the data needed for this study, the researchers will utilize purposive sampling in order to accurately select the appropriate samples that align with the objectives of this study, which are to find the effectiveness of inducing Polyethylene Terephthalate and Copper Slag mix into the concrete as an alternative to commercial concrete. This can help in obtaining a targeted group of samples that possess the required traits necessary.

Purposive sampling, also known as judgment sampling, is a nonrandom sampling technique in which participants are specifically picked based on the researchers' requirements and the characteristics required to achieve the study's objectives (Tongco, 2007). This approach allows researchers to intentionally target individuals or groups with particular attributes or experiences relevant to the study, enabling a focused exploration of the research topic.

This study will involve all of the seven researchers to get more accurate information. The PET samples will all be sourced from the Colegio's plastic waste management facilities, chosen based on their quality and uniformity. Similarly, the selection of copper slag samples will involve a meticulous process to identify sources with consistent properties and compositions, reflecting those commonly integrated into the concrete manufacturing industry. Careful consideration will be given to the physical and chemical properties of the PET and copper slag materials, ensuring that they align with the intended purpose of the research. By carefully curating the samples, the study endeavors to provide comprehensive insights into the performance and viability of PET and copper slag as alternative materials in the production of commercial concrete, thereby contributing to the advancement of sustainable and innovative construction practices.

RESULTS

Table 1
Test results of the compressive strength, water absorption, density test of traditional commercial concrete hollow block and PET and copper slag-induced concrete hollow block with three varying ratios of PET and copper slag and cement

		Compressive Strength Test (PSI)			Water Absorption (%)	Density ($\frac{Kg}{m^3}$)
4" Concrete Hollow Block	Ratio	Trial 1	Trial 2	Average	Trial 1	Trial 1
Commercial Concrete	0: 100	92 PSI	84 PSI	88 PSI	29.4%	1587$\frac{Kg}{m^3}$
PET and Copper Slag-induced Concrete	30: 70	120 PSI	129 PSI	124.5 PSI	25.7%	1355$\frac{Kg}{m^3}$
PET and Copper Slag-induced Concrete	50: 50	109 PSI	81 PSI	95 PSI	27.0%	1250$\frac{Kg}{m^3}$
PET and Copper Slag-induced Concrete	70: 30	70 PSI	71 PSI	70.5 PSI	28.1%	1131$\frac{Kg}{m^3}$

In this study, the compressive strength test was utilized since it measures the entire qualities of a concrete, particularly its durability. Table 1 shows that two trials were performed to compare the durability of commercial concrete, and PET and copper slag-induced concrete. The performance of the PET and copper slag-induced concrete with a 30:70 ratio demonstrated that it could endure pressure loads before failing, with 120 PSI in the first trial and 129 PSI in the second trial. This concrete has the highest PSI results when compared to commercial concrete and other PET and copper slag-induced concrete ratios. With 30% of PET and copper slag, and 70% of cement, this concrete is the strongest and most durable in contrast to other variables. Hence, it can be an alternative to commercial concrete.

Water absorption concerns a material's ability to absorb moisture from its surroundings under certain conditions, without outside influences, and in an unsaturated state. The water absorption of commercial concrete and PET and copper slag-induced concrete in various ratios is evaluated in this study. This table indicates that the percentage of water absorption of the commercial concrete, 29.4%, is the highest among the four variables. On the other hand, the PET and copper slag-induced concrete with different ratios had less amount of water absorption suggesting that these variables have low density while having low slump loss and high workability, falling under the commercial concrete.

A density test was conducted on the three different ratios of PET and copper slag-induced concrete and commercial concrete, where it showed a density of 1355 kg/m3 for the 30:70 ratio, 1250 kg/m3 for the 50:50 ratio, 1131 kg/m3 for the 70:30 ratio of PET and copper slag-induced concrete, and 1587 kg/m3 for commercial concrete, respectively. Consequently, commercial concrete has the highest density of all the variables. In contrast, the concrete that was produced by a 70:30 PET and copper slag mixture has the lowest strength and the most permeability.

Table 2
Data Summary of the compressive strength, water absorption, density test of traditional commercial concrete hollow block and PET and copper slag-induced concrete hollow block with three varying ratios of PET and copper slag and cement

Groups	N	∑x	Mean	∑x²	Std. Dev.	Std. Error
Group 1	4	378	94.5	37239.5	22.4981	11.2491
Group 2	4	110.2	27.55	3043.46	1.5759	0.7879
Group 3	4	5323	1330.75	7196255	193.7978	96.8989
Total	**12**	**5811.2**	**484.26666666667**	**7236537.96**		

A thorough review of the compressive strength, water absorption, and density test findings for both conventional commercial concrete and concrete generated by PET and copper slag in different ratios is given in the data summary in Table 2. Group 2, which consists of various ratios of PET and copper slag-induced concrete, has a lower mean of 27.55 PSI than Group 1, which represents commercial concrete, which has a mean compressive strength of 94.5 PSI. The aggregate mean compressive strength of Group 3, which includes all data points, is 484.27 PSI. This summary aids in comparing the overall performance of the different concrete types and ratios, laying the groundwork for further analysis and conclusion drawing in the research.

Table 3

ANOVA Summary of the compressive strength, water absorption, density test of traditional commercial concrete hollow block and PET and copper slag-induced concrete hollow block with three varying ratios of PET and copper slag and cement

Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	F-Stat	P-Value
Between Groups	2	4308168.8067	2154084.4034	169.7634	0.0000
Within Groups	9	114198.7	12688.7444		
Total	11	4422367.5067			

By the use of the ANOVA test (Table 3), the calculated F-statistic of 169.7634 with a Between and Within Groups of 2 and 9 far exceeds the critical F-value of 4.256 at the chosen significance level, indicating a rejection of the null hypothesis. This suggests that there is a statistically significant difference among PET and Copper Slag-induced concrete hollow block and Commercial Concrete Hollow Block in terms of Compressive Strength, Water Absorption, and Density.

DISCUSSION

Conclusion. Throughout the extensive testing and evaluation, the 30:70 PET and Copper Slag-induced concrete hollow block emerged as the most promising alternative among the three variants, surpassing the physical properties of the commercial concrete hollow block. This particular composition demonstrated superior performance across multiple parameters, showcasing notable strengths in compressive strength, reduced absorption percentage, and an optimal density profile. Its balanced blend of PET and Copper Slag in the 30:70 ratio exhibited commendable structural integrity and durability, aligning closely with the desired criteria for a sustainable and effective concrete alternative.

This research study shows that the different ratios of polyethylene terephthalate (PET) and copper slag (CS) in relation to cement content in terms of 30:70 ratio, 50:50 ratio, and 70:30 ratio have a significant effect on the resultant concrete in terms of compressive strength, water absorption percentage, and density, citing a viable alternative to traditional commercial concrete.

According to the analysis of compressive strength, all concrete hollow block ratios induced by PET and copper slag outperform the conventional commercial concrete, with the 30:70 ratio having the highest compressive strength. The absorption percentage of 70:30 indicates a higher resistance to moisture, indicating that this ratio has the potential to be a long-lasting substitute. Higher ratios of PET and copper slag also result in a drop in density; of particular note is the 70:30 ratio, in which the PET has played a role in producing a lighter concrete without sacrificing structural integrity.

A water absorption test was conducted on four concrete hollow blocks with varying ratios of PET and copper slag in order to determine how they could affect commercial concrete in terms of water absorption. In these results, a lower absorption percentage indicates better concrete resistance to water penetration, meaning, reduced permeability. The highest percentage is observed in the concrete without any PET and copper slag, while the lowest is in the 30:70 ratio of PET and copper slag-induced concrete. With this being the lowest percentage among all ratios, it means that the mixture with 30% PET and copper slag and 70% cement is the most resilient in terms of water absorption. Therefore, incorporating PET and copper slag into commercial concrete has a valuable effect on improving resistance against water absorption compared to traditional commercial concrete.

The density of a concrete is its mass per volume when constituent components are considered. As shown in the results, commercial concrete has the greatest density test findings, whereas concrete induced by PET and copper slag containing a 70:30 ratio, 70% PET and copper slag; and 30% cement, has the lowest density test findings. The commercial concrete recorded the highest density among the variables. The concrete generated by a 70:30 ratio of PET and copper slag has the least amount of strength and the greatest permeability. In light of the density test, the PET and copper slag-induced concrete is still a commendable alternative in terms of density.

The integration of PET and Copper Slag into concrete formulations presents a promising avenue for reducing the environmental footprint of construction practices. PET, a recycled plastic, offers a viable solution to the burgeoning issue of plastic waste while potentially enhancing the mechanical properties of concrete. Meanwhile, the utilization of Copper Slag as a supplementary material not only addresses the challenge of industrial by-products but also contributes to the overall improved qualities of concrete.

In evaluating the environmental implications, this study discerns noteworthy differences between the production and utilization of Polyethylene Terephthalate (PET) and Copper Slag (CS) induced concrete versus traditional commercial concrete. The findings underscore a more eco-conscious profile associated with PET and CS induced concrete, showcasing reduced energy consumption, minimized greenhouse gas emissions, and diminished waste generation during production compared to traditional concrete methods. These results illuminate the potential of PET and Copper Slag-induced concrete in aligning with sustainability goals, promising further exploration and consideration for wider adoption in construction practices.

Recommendations. While it is proven in this study that PET and Copper Slag-induced concrete can be an alternative to the traditional commercial concrete, different construction jobs have different needs. Throughout the findings, it is recommended to explore more different ratios of PET and Copper Slag to cement for the concrete alternative to tailor them for specific construction needs. Testing various ratios will provide a clearer understanding of how each combination influences concrete properties. Understanding how different ratios may impact specific concrete characteristics that are crucial for customizing these options to suit the unique requirements of diverse construction projects.

To add, maintaining consistency in the production timeline for the tested concrete variants to ensure unbiased data shall also be given focus. It's suggested that future studies of this nature involve a longer curing time, ideally spanning at least 28 days. This extended curing period allows the concrete to reach its maximum potential, crucial for infrastructure to withstand diverse challenges over an extended duration post-construction.

Considering the research outcomes, investigating the effect of other different ratios of PET and copper slag in concrete, alongside exploring alternative PET that are also known to have the property to enhance the concrete's water resistance, emerges as a viable recommendation and approach to further improve water absorption resistance in commercial concrete.

In order to ensure the highest quality of concrete, it is advisable to conduct a broader spectrum of tests beyond the ones explored in this study. Consideration should be given to tests evaluating the concrete's resistance to environmental factors, such as freeze-thaw cycles, earthquake resistance, and fire resistance. Additionally, exploring tests related to long-term durability and sustainability, including carbonation resistance or leaching potential, could provide a more comprehensive understanding of the concrete's performance over time. Incorporating these diverse tests will offer a more holistic evaluation, ensuring that the concrete's quality meets the demands of construction scenarios.

To comprehensively assess the environmental implications of Polyethylene Terephthalate (PET) and Copper Slag (CS) induced concrete compared to traditional commercial concrete, a broader evaluation is necessary. Consider conducting a life cycle assessment (LCA) encompassing the entire production cycle, from raw material extraction to disposal. This LCA should analyze factors like energy consumption, greenhouse gas emissions, and waste generation. Conducting this assessment will provide a detailed understanding of the environmental footprint, enabling informed decisions about the sustainability and eco-friendliness of these concrete alternatives in real-world construction scenarios.

It is crucial to advocate for the widespread adoption and utilization of sustainable alternatives such as PET and Copper Slag-induced concrete in the construction industry. Emphasizing the environmental benefits and demonstrating the effectiveness of these alternatives through case studies and real-world applications can significantly influence industry stakeholders. Encouraging policies or initiatives supporting the use of environmentally friendly construction materials could further incentivize their adoption. Collaborating with industry associations, policymakers, and environmental advocates to raise awareness and promote the benefits of sustainable concrete options will foster a positive shift towards more eco-conscious construction practices.

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