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# The Study of Workability and Compressive Strength of Concrete with Polypropylene Plastic as Partial Replacement of Fine Aggregates

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## Abstract:

Various studies have explored incorporating different types of plastics, such as PET bottles and PVC pipes, into concrete through methods including powder and fiber integration. This particular investigation aims to assess the impact of substituting polypropylene plastic, commonly found in packaging and daily-use plastics, in concrete at concentrations of 0%, 25%, and 35%. The polypropylene plastics were cut into sizes ranging from 2mm to 5mm. Samples were molded into cylinders measuring 4x8 inches, with each batch yielding three specimens for compressive strength testing. The consistency of each sample batch was determined through slump tests, resulting in a high workability ranging from 7 to 7.5 inches. The findings reveal a decrease in compressive strength of approximately 60% for batch 2 samples (25% polypropylene plastics) and 70% for batch 3 samples (35% polypropylene plastics) compared to batch 1 (0% polypropylene plastics). Consequently, the incorporation of plastics into concrete leads to property alterations, with water absorption showing a slight decrease alongside an inverse relationship between compressive strength and the proportion of polypropylene plastics. Significant disparities in compressive strength were noted across batches, with the first batch boasting robust strength suitable for critical structural elements. Conversely, the second and third batches, with lower strengths, were deemed more fitting for less demanding applications like driveways and walkways.

*Keywords* **—Concrete, Polypropylene Plastic, Fine Aggregates, Replacement**

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## I. INTRODUCTION

Concrete is the second most utilized material globally, necessitating components like cement, sand, gravel, and water for production. With the escalating demand for concrete, a corresponding need for materials arises, prompting extensive research into alternative sources [1]. As a fundamental element in constructing towers, ensuring the longevity and safety of concrete remains imperative. Its capacity to withstand diverse environmental conditions and structural loads cements its pivotal role in contemporary construction practices, facilitating the realization of architectural designs with steadfastness and endurance. Plastics, renowned for their durability, lightweight nature, and cost-effectiveness, have found widespread application in packaging and product preservation by various industries. However, the exponential increase in plastic production over recent decades has become a global concern attributed to inadequate disposal practices and insufficient recycling efforts [2]. Single-use plastics, characterized by their enduring decomposition period of over a thousand years, mainly contribute significantly to plastic pollution [3]. Incorporating recycled plastics into concrete has attracted interest as a sustainable measure to address the environmental repercussions of plastics and reduce the burden on natural resources [4]. Previous research has shown promising results in this area. Subramani and Pugal (2015) explored the use of waste plastic, specifically polyethylene and polypropylene, as a partial replacement for fine aggregates in concrete, examining impacts on workability, compressive strength, and durability [5]. Saikia and de Brito (2018) provided a comprehensive review of various types of recycled plastic waste used in concrete, including polypropylene, and discussed effects on mechanical properties, particularly compressive strength and workability [6].

Additionally, Fraternali et al. (2017) focused on adding waste polypropylene fibers to concrete, investigating its effects on workability, compressive strength, and flexural strength, highlighting potential benefits and drawbacks [7]. While Albano et al. (2011) specifically studied PET plastics, their methodology and findings on the effects on concrete's workability, density, and compressive strength offer valuable insights applicable to polypropylene plastics [8]. Marzouk et al. (2008) reviewed multiple studies on incorporating plastic waste in concrete, covering a range of properties such as workability, compressive strength, and environmental impact [9]. Building on these studies, this research focuses on the partial replacement of fine aggregates with polypropylene plastic, cut into smaller pieces, to assess its effects on concrete properties. Laboratory assessments were examined based on the key parameters such as workability and compressive strength through tests including compression testing and slump testing. By addressing these aspects, the study aims to contribute to the body of knowledge on sustainable construction materials and provide practical solutions to the challenges posed by plastic waste.

### *1.1 Statement of the Problem*

Polypropylene is a thermoplastic polymer widely used in several sectors due to its versatility and affordability. This material is used to make a variety of everyday items such as packaging materials (e.g., pallets, bottles, jars, and yogurt containers) and automotive components (e.g., batteries, bumpers, instrument panels, and interior elements). It is also used to produce medical equipment like disposable syringes and medical vials. As a result, the widespread use of polypropylene is expected to release 1.3 billion tons of carbon dioxide emissions over the next 30 years starting from 2023 into the environment due to the polypropylene production process, which significantly contributes to greenhouse gas emissions. [35] Numerous methods exist for reusing these plastics and employing them as a partial substitute for sand fine aggregate stands out as an effective means of disposal. However, achieving high-quality recycled polypropylene, especially for food-grade applications, requires eliminating all contaminants from post-consumer waste that could harm human health. Recycling polypropylene offers significant environmental advantages, despite some constraints. When one ton of plastic is recycled, it conserves 5,774 kilowatt-hours of energy, 16.3 barrels (685 gallons) of oil, and 30 cubic yards of landfill spaces. [36]

This research aims to examine the compressive strength and workability of concrete incorporating polypropylene plastic as a partial replacement for fine aggregate. Moreover, it seeks to address the following research questions:

1. How can polypropylene plastic as a substitute for fine aggregates affects the concrete in terms of:
   1.1. Workability
   1.2. Compressive Strength
2. What is the workability and compressive strength of concrete with polypropylene as

  

partial replacement of fine aggregates in percentage:
2.1. 0%
2.2. 25%
2.3. 35%
3. Which kinds of structures can be built using this concrete mixed with PP plastics?

### *1.2 Objectives of the Study*

The primary objective of this study is to investigate the effect of plastic (polypropylene) as a partial replacement of fine aggregates in concrete. Furthermore, the researchers seek to evaluate any changes in the compressive strength of concrete to gain deeper insights into its properties and determine suitable infrastructure applications.

The specific objectives of the study are as follows:

1. To assess the workability of concrete incorporating amount of polypropylene plastic (PP) as partial replacement of fine aggregates in percentage using slump test:
   1.1.0% PP
   1.2. 25% PP
   1.3. 35% PP
2. To determine the compressive strength of concrete incorporating amount of polypropylene plastic (PP) as partial replacement of fine aggregates in percentage:
   2.1. 0% PP
   2.2. 25% PP
   2.3. 35% PP
3. To identify suitable infrastructure applications for the concrete-polypropylene blends based on the findings of the study.

### *1.3 Significance of the Study*

**Community.** Plastic waste polypropylene in concrete introduces an eco-friendly alternative that mitigates the environmental impact of both plastic waste and traditional concrete production. The study's initiatives align with the environmental objectives, as it focuses on diminishing plastic waste, thereby fostering a cleaner environment. This commitment reflects a holistic approach that contributes to scientific knowledge and actively addresses pressing environmental concerns.

**Society.** Utilizing waste plastic in concrete offers a tangible advantage to the general public by contributing to a cleaner environment. This innovative practice not only aids in waste reduction but also promotes sustainability, resulting in a positive impact on the overall well-being of communities. By incorporating recycled plastic into construction materials, individuals can actively participate in creating a more eco-friendly and aesthetically pleasing environment for present and future generations. This convergence of environmental consciousness and practical application underscores the potential for widespread benefits in adopting such sustainable practices.

**Future Researchers.** This study serves as a foundational platform for future researchers, providing a groundwork for additional investigations and enhancements in the utilization of plastic waste as a substitute for sand in concrete. The findings and insights gleaned from this research offer a valuable starting point, encouraging a continuous exploration of innovative solutions to address environmental challenges in construction materials. As the scientific community builds upon this research, it opens avenues for refining techniques, exploring diverse applications, and ultimately advancing sustainable practices in the construction industry. The potential for ongoing research in this area holds promise for the continual evolution and improvement of environmentally friendly alternatives in concrete production.

### *1.4 Scope and Limitations*

This investigation solely focuses on the impact of polypropylene plastic on the workability and compressive strength of concrete. Data is collected from slump tests to assess workability and from compressive strength tests using cylindrical mold samples. A total of nine specimens will be produced, with three samples per percentage of polypropylene plastic: 0%, 25%, and 35% mixed with the concrete. It's important to note that the concrete mixture used in this study does not cover all types of concrete mixtures used in construction.

### *1.5 Review of the Related Literatures*

Understanding the amount of plastic waste generated historically and currently aids researchers in visualizing the problem posed by used plastics, which is present not only in this nation but also in other countries.

Material created from plastic is non-biodegradable and takes time to break down, resulting in contamination of the environment. Furthermore, the percentage of plastic garbage keeps increasing as the time flies by. It is estimated that after ten years, the quantity of plastic waste will triple due to the hundreds of grades of plastic that are consumed on a daily basis. On the other hand, plastic waste is reusable and recyclable [12].

Environmental pollution caused by plastic trash is very concerning. Another environmental issue is that the building materials industry is one of the leading producers of $CO_2$ emissions [13]. Also, a growing amount of plastic waste contaminates the natural landscape and is an issue in high mountain communities without a waste disposal system. The natural environment is contaminated as a result of the enormous volumes of plastic that are wasted or consumed in popular tourist attractions. Thus, it is essential to make the most of these discarded plastics. [14].

Due to the widespread usage of residential and business plastic products, plastic trash is spreading at an unprecedented rate. Plastic trash does not have a proper disposal or recycling centers and it ends in landfills that have caused environmental impact and have affected terrestrial resources and increased the pollution [15].

In 2019, the Philippines accounted for the most significant quantity of plastic trash dumped into the world's coastlines. The nation was responsible for 36.38% of the world's oceanic plastic garbage in the same year, which is significantly higher than the secondlargest plastic polluter, the nation of India, which was responsible for approximately 12.92% of the total [16].

Amidst these challenges, there is growing recognition of the potential of utilizing plastic waste in construction materials as a sustainable alternative. By repurposing plastic waste as a partial replacement for fine aggregates in concrete production, it becomes possible to not only address the environmental implications of plastic pollution but also enhance the sustainability of construction practices. By investigating the workability and compressive strength of concrete incorporating polypropylene plastic as a partial replacement for fine aggregates, the study aims to contribute to the development of environmentally friendly construction materials and strategies for plastic waste management.

Plastic wastes, which make up a large amount of municipal solid waste (MSW), have recently been inspected due to worries about environmental safety. Utilizing plastic trash as one of the raw resources to produce construction-related items, primarily bricks, is an innovative approach to waste usage. Plastic is utilized in a wide range of applications, from drinking bottles to household items, but after its useful life is over, it becomes waste. Determining the most effective way to use these plastic wastes is essential to address the problem of their increasing numbers because plastics are not biodegradable. [17].

In construction material testing, the cylindrical mold sample serves as a standard product for testing concrete strength, while hollow blocks, produced by pelletizing plastic and mixing it with other materials, offer an alternative to cylindrical specimens [18]. Such testing methods resonates with our study’s focus on exploring novel materials, such as polypropylene plastic, as partial replacements for fine aggregates in concrete, thereby contributing to advancements in sustainable construction practices.

Bricks play an essential role in construction projects, traditionally crafted from clay, sand, and cement. Plastic sand bricks present an appealing alternative to conventional concrete blocks and bricks. Suriyaa (2021) investigates ongoing research into the formulation of plastic-sand bricks and explores different ratios of plastic to sand [19]. However, there is a scarcity of studies examining the economic feasibility of utilizing plastic sand as a construction material [20]. Given the potential benefits, further research in this area is imperative for the industry to consider investing in and adopting this alternative. By addressing this gap, this study aims to provide valuable insights into the feasibility and potential adoption of plastic sand bricks, thus offering a practical solution to solid waste challenges in construction.

Another relevant aspect is the utilization of hollow blocks produced with plastic as an alternative to cylindrical specimens in construction material testing. This approach underscores the versatility of plastic waste utilization in construction and supports the rationale behind our study's investigation into the incorporation of polypropylene plastic into concrete [18].

Additionally, several studies, such as [5], [6], [7], [8], and [9], review the utilization of recycled plastic waste, including polypropylene, in concrete production. These reviews highlight the importance of sustainable practices in material utilization and provide insights into the environmental benefits and challenges associated with incorporating plastic waste into concrete. By synthesizing findings from these studies, our research aims to build upon existing knowledge and contribute to the ongoing discourse on sustainable construction practices, particularly concerning waste management and material utilization.

Polypropylene (PP) is one kind of polyolefin that is slightly stronger than polyethylene. It is a common plastic that resists heat well and has a low density. It is used in cast films, consumer goods, automotive, packaging, and medicine, among other industries [21]. Nearly everyone uses plastic products, whether in bottles, bags, home items, or a variety of other applications. As a result, almost every other good has been replaced by plastic versions, resulting in further risks to the environment. Polypropylene (PP) makes up 16% of the entire plastic industry. It is a common plastic used to make final products for consumers, including packaging made of plastic [22].

Compared to traditional aggregates like sand, polypropylene plastic is lightweight, which can contribute to reducing the overall density of concrete. This property is beneficial for applications where weight reduction is desired, such as in construction of lightweight structures or precast elements. [23]

With inherent insulating properties, polypropylene plastic can help improve the thermal conductivity of concrete. By incorporating polypropylene plastic into concrete, the resulting material may exhibit better thermal insulation, making it suitable for applications where thermal efficiency is important, such as in building envelopes or structures exposed to varying temperature conditions. [24]

Polypropylene plastic is resistant to many chemicals, including acids, alkalis, and salts. When used as a partial replacement for fine aggregates in concrete, it can enhance the chemical resistance of the resulting material, making it suitable for applications where exposure to aggressive chemical environments is a concern, such as in industrial flooring or wastewater treatment facilities. [25]

Polypropylene plastic fibers can help mitigate plastic shrinkage cracking in concrete by reducing the formation of micro-cracks during the early stages of hydration. This property is particularly advantageous in applications where minimizing cracking and improving durability are critical, such as in pavements, bridge decks, or other infrastructure projects. [26]

Incorporating polypropylene plastic into concrete can improve its workability and cohesiveness, making it easier to place, compact, and finish. This can lead to enhanced construction efficiency and quality, as well as reduced labor costs associated with concrete placement and finishing operations. [27]

In general, polypropylene plastic offers several benefits when used as a partial replacement for fine aggregates in concrete mixtures. Its lightweight nature reduces overall concrete density, making it suitable for lightweight structures. Additionally, polypropylene plastic improves thermal insulation, chemical resistance, and durability, while enhancing workability and reducing labor costs during construction. Therefore, incorporating polypropylene plastic in concrete has the potential to improve both workability and compressive strength, which are key parameters being studied in research on this topic.

Workability can be evaluated through tests such as the slump test or the flow table test, which measure the ease of concrete placement and compaction. Compressive strength, on the other hand, can be assessed through the standard compressive strength test, where cylindrical or cubical specimens of concrete are subjected to axial loads until failure occurs.

American Society for Testing and Materials (ASTM International) defines Compressive Strength Test as a test that determines the ability of concrete to withstand axial loads (i.e., forces acting along the longitudinal axis) without significant deformation. It involves applying a compressive force to cylindrical or cubical specimens of concrete until they fail, typically using a hydraulic testing machine. The maximum load the specimen can withstand before failure is recorded, and the compressive strength of the concrete is calculated by dividing this load by the cross-sectional area of the specimen. Compressive strength is a critical parameter for evaluating the structural integrity and durability of concrete, particularly in applications where it will be subjected to significant loads. [28]

The Slump Test, on the other hand, is defined by ASTM International as a simple and widely used method to assess the consistency and workability of freshly mixed concrete. It measures the consistency, or fluidity, of concrete by observing the change in shape, or slump, of a conical sample of concrete when it is subjected to the removal of a slump cone. During the test, a slump cone is filled with freshly mixed concrete in layers, each layer compacted using a standard rod. After filling, the cone is removed vertically, allowing the concrete to settle. The decrease in height, or slump, of the concrete is measured and recorded. The slump value indicates the relative workability of the concrete: higher slump values indicate more fluid, workable concrete, while lower slump values suggest stiffer, less workable concrete. The slump test helps ensure that concrete has the desired consistency for proper placement and consolidation during construction. [29] By considering these properties of polypropylene plastic and their potential implications in concrete mixtures, our study is guided by valuable insights into the feasibility and effectiveness of using polypropylene plastic as a partial replacement for fine aggregates in concrete construction. Tests such as the compressive strength test and workability assessments, such as the slump test, play a crucial role in gauging the performance of concrete mixtures containing polypropylene plastic.

Numerous researchers have explored the effects of varying plastic percentages in concrete mixtures. These studies investigate how different proportions of plastic additives influence concrete properties such as workability, compressive strength, durability, and shrinkage. By systematically altering the plastic content in concrete mixes, researchers aim to optimize the balance between plastic waste utilization and maintaining the structural integrity and performance of concrete. Their findings provide valuable insights for sustainable construction practices and waste management strategies.

Muruganantham, et. Al (2023) investigated the utilization of chemically treated and untreated recycled plastic waste as partial replacements for fine aggregates in concrete production, aiming to assess their mechanical properties [30]. The study examined M20 and M40 concrete grades with varying percentages (0%, 5% to 20%) of treated and untreated recycled plastic waste (T-RPW and UT-RPW). The researchers looked at how the concrete reacted to different temperatures, ranging from 100°C to 500°C. They wanted to see how adding treated and untreated recycled plastic waste (T-RPW and UT-RPW) affected the concrete's strength and how much mass it lost. They found that initially, the concrete's strength went up until it reached 100°C, but then it started to decrease. At 500°C, there was a big drop in strength — 60.0% for concrete with 20% UT-RPW and 49.2% for concrete with 20% T-RPW. This decrease happened because the recycled plastic waste started to break down. Also, as they used more recycled plastic waste and higher temperatures, the concrete lost more mass.

Tawar, et al. (2021) explored the utilization of polypropylene plastic waste in concrete. [31] It investigates the impact of polypropylene plastic waste on properties such as compressive strength, split tensile strength, flexural strength, and durability of concrete. The study found that incorporating 1% polypropylene plastic waste in concrete resulted in a 12% increase in compressive strength compared to conventional concrete. Additionally, flexural strength increased by 15% with the addition of polypropylene plastic waste. Results indicate that incorporating polypropylene plastic waste can enhance certain properties of concrete, making it a potential sustainable solution for waste management in the construction industry.

Dable and Vidyadhar (2020) has evaluated the mechanical properties of concrete with polypropylene fibers as a partial replacement of fine aggregate. [32] It focuses on properties like compressive strength, flexural strength, and split tensile strength. The research revealed that replacing 10% of fine aggregate with polypropylene fibers led to a 20% improvement in compressive strength compared to standard concrete. Moreover, flexural strength increased by 25% with the incorporation of polypropylene fibers. Findings suggest that the addition of polypropylene fibers can improve the mechanical properties of concrete, contributing to its enhanced performance and durability.

Choudhary and Kumar (2019) examined the effect of polypropylene fibers as a partial replacement of fine aggregate in concrete [33]. It investigates properties such as workability, compressive strength, split tensile strength, and flexural strength. Results showed that concrete containing 5% polypropylene fibers exhibited a 15% increase in compressive strength compared to conventional concrete. Furthermore, split tensile strength improved by 10% with the addition of polypropylene fibers. Results indicate that incorporating polypropylene fibers can improve workability and enhance the mechanical properties of concrete, offering potential benefits for construction applications.

The mention of numerous researchers exploring the effects of varying plastic percentages in concrete mixtures is crucial in our study of investigating the workability and compressive strength of concrete with polypropylene plastic as a partial replacement of fine aggregates. These studies provide valuable insights into how different proportions of plastic additives influence concrete properties, including workability, compressive strength, durability, and shrinkage. By systematically altering the plastic content in concrete mixes, researchers aim to optimize the balance between plastic waste utilization and maintaining concrete's structural integrity and performance.

Polypropylene plastic waste presents a promising avenue for enhancing the properties of concrete mixtures while addressing environmental concerns associated with plastic disposal. Several studies have investigated the procedure for incorporating polypropylene plastic waste into concrete mixtures, detailing the specific types of plastic waste used, the procedures for combining them with concrete constituents, and the rationale behind their incorporation.

Researchers have explored various sources of polypropylene plastic waste for inclusion in concrete mixtures, including post-consumer packaging, discarded consumer goods, and industrial scrap materials. By specifying the origin and characteristics of the plastic waste, studies aim to understand its potential impact on the properties of the resulting concrete. Siddique and Khatib (2008), in their research, concluded that incorporating recycled plastic in concrete can lead to improved sustainability by reducing the consumption of natural resources and landfill space. However, they emphasize the need for further research to optimize the use of recycled plastic and address concerns such as durability and long-term performance. [34]

The procedure for combining polypropylene plastic waste with concrete constituents typically involves shredding or grinding the plastic waste into fine particles to ensure uniform distribution within the concrete matrix. The plastic particles are then blended with aggregates, cement, water, and other admixtures during the mixing process. Some studies have also investigated pre-treating the plastic waste to improve its compatibility with concrete and enhance its bonding properties. Singh, et al. (2016) provided insights into the methodological aspects of combining polypropylene plastic waste with concrete constituents. [35] Their methodological approach includes the preparation of polypropylene plastic waste by shredding or grinding it into fine particles to ensure uniform distribution within the concrete matrix. The mixing procedure involves blending the plastic particles with other concrete constituents, such as aggregates, cement, water, and admixtures, to achieve a homogenous mixture. The proportion of plastic waste in the concrete mixture is carefully considered, and various percentages are evaluated to determine their effects on concrete properties.

### *1.6 Conceptual Framework*

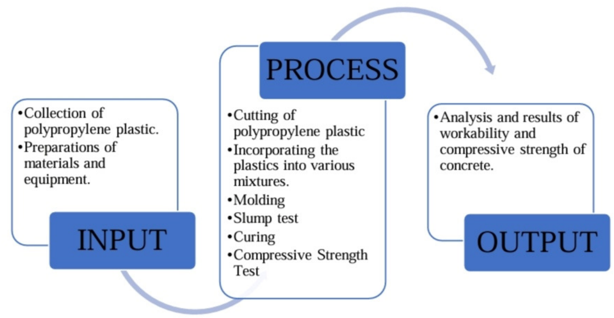


Figure 1: Conceptual Framework

### *1.7 Definition of Terms*

**Compressive Strength.** It refers to the capacity of a material to withstand direct pressure from an applied compressive force.

**Polypropylene.** It refers to a versatile plastic known for its low density and exceptional heat resistance.

**Slump Test.** Utilized for assessing both the workability and consistency of freshly mixed concrete.

**Thermoplastic polymer.** This is capable of softening when heated for processing, followed by cooling and hardening without altering their chemical properties, maintaining their chemical integrity upon cooling, enabling multiple cycles of remelting and reuse.

**Workability**. Describes the ease of placing, consolidating, and polishing freshly mixed concrete with the least amount of uniformity loss.

## II. METHODOLOGY

### 2.1 Methodological Framework

  

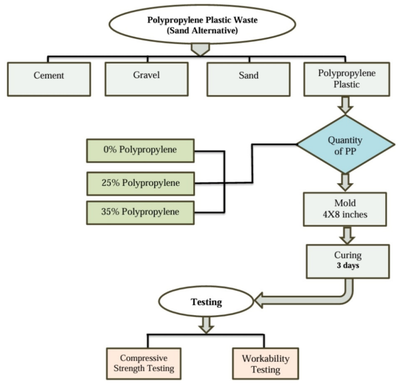


Figure 2: Methodological Framework

### 2.1.1 Research Design

The present study employs an experimental methodology to investigate the influence of polypropylene plastics on concrete. Two laboratory tests were conducted to evaluate the compressive strength and workability of the concrete. The workability (slump) test, conducted using a Slump Test Cone, assesses the concrete's ease of mixing, pouring, and compaction. This test is instrumental in determining the optimal water-to-cement ratio and understanding the impact of plastic ko particles on the concrete mixture.

The compressive strength test was performed using a Universal Testing Machine certified to ASTM C39 standards by an approved geotechnical testing laboratory, with the assistance of a certified operator. This test, typically conducted by applying a hydraulic press or a manual testing instrument, determines the maximum stress capacity of a concrete specimen before failure. Such analysis is pivotal in assessing the structural integrity of the concrete.

### 2.1.2 Collection and Preparation of Material Used

In the process of sourcing Polypropylene plastics, the research team adopted a systematic approach that prioritized safety and public health. This involved door-to-door collections from neighboring households. Subsequently, the collected plastics underwent precision cutting to ensure dimensions within the 2 mm to 5 mm range. The plastic pieces were incorporated into concrete mixes following ASTM standard [28]. Cylindrical specimens measuring 4 inches in diameter and 8 inches in height were then cast for compressive strength testing according to ASTM C39/C39M [28]. Each production batch yielded three specimens, which underwent compressive strength tests. The uniformity and workability of each sample batch were meticulously assessed using slump tests following ASTM C143/C143M [29], leading to the determination of a notably high workability range spanning from 7 to 7.5 inches.

## 2.2Materials, Tools and Equipment

### 2.2.1 Materials

**Cement**- Cement is a crucial binding agent in

construction applications. It is an integral component of mortar and is extensively employed in pointing, masonry work, and plastering. Moreover, it establishes joints for pipes and drains, safeguards buildings against water penetration, and forms the base for various concrete structures such as floors, roofs, posts, beams, stairs, and columns.

Figure 3. Cement

**Sand**- Sand, also known as fine aggregates, is frequently used for building purposes to add strength, weight, and stability to materials such as cement and gravel.

Figure 4. Sand

**Gravel -**Gravel, also known as coarse aggregates, produces concrete, fills construction sites, combines with asphalt, develops new road foundations, and makes other building materials like bricks, pipes, and blocks.

Figure 5. Gravel

| Tools and Equipment | | |
|---|---|---|
| Picture | Name | Use |
|  | Universal Testing Machine | To test the compressive strength of the concrete mix |
|  | Cylinder | It is used to mold the samples. |
|  | Concrete Mixer | It is used to mix the concrete. |

**PolypropylenePlastic**– Standard plastic is used for daily consumption, such as packing for daily needs. Polypropylene plastics are primarily single-use plastics.

Figure 6. Polypropylene Plastic

### 2.2.2 Tools and Equipment

The following list of crucial information was needed for this inquiry, which was conducted using both manual tools and sophisticated equipment for sample processing by the proponent:

| | | |
|---|---|---|
|  | Slump Test Cone | It is used to perform the slump test for workability. |
|  | Calculator | It is used to calculate the volume of the sand that needs to be replaced. |

Table 1. Tools and Its Definition

## 2.3 Material Development

### 2.3.1 Design Proportion

This investigation aims to analyze the impact on the compressive strength of concrete resulting from the partial replacement of fine aggregates in a concrete mix designed for 4000 psi (M20) over three days, facilitated by the utilization of admixture (ACS-PSP-Px3). The acceptable aggregate replacement adheres to ASTM standards, particularly ASTM C33 for aggregates [40] and ASTM C494 for admixtures [41]. Replacement percentages of 0%, 25%, and 35% will be targeted, following ASTM C136 for aggregate grading analysis [42].

### 2.3.2 Production of Samples

A concrete mixer and a 4x8-inch mold were used to make the cylindrical samples of concrete to test for compressive strength, which were labeled accordingly.

1. The polypropylene plastic was cut into sizes ranging from 2 mm to 5 mm using scissors.
2. A batch of concrete was mixed using a concrete mixer following the specified amount of plastics in the mixture.
3. The table below summarizes the materials used in each batch for comparison of each concrete mixture.
4. Following the mixing of freshly batched concrete, a slump test was conducted to assess its consistency.
5. Concrete was poured into the mold in batches after the Slump test. For molds measuring 4 by 8 inches, the initial layer fills half of the container. Then, the concrete is compacted 25 times using a tamping rod, and the sides of the container are tapped with a mallet. The container is then overfilled, and the compacting process is repeated 25 times, tapping the sides of the container 10 to 25 times per sample. Each batch comprises three samples.
6. After leveling the tops of the samples, they are appropriately labeled.

Table 2. Cement Mixture per Batch

| BATCH SAMPLE | CEMENT | SAND | POLYPROPYLENE PLASTIC | GRAVEL | ADMIXTURE (ACS-PSP-PX3) |
|---|---|---|---|---|---|
| Batch 1 | 7.4 kg | 3.3 kg | 0 % | 5.7 kg | 33 mL |
| Batch 2 | 7.4 kg | 2.475 kg | 25% | 5.7 kg | 33 mL |
| Batch 3 | 7.4 kg | 2.145 kg | 35% | 5.7 kg | 33 mL |

Table 2 shows the quantities of materials used in each sample batch, including admixture, sand, gravel, and polypropylene plastics. Batches 1, 2, and 3 use the same amounts of admixture, gravel, and cement—7.4 kg of cement, 5.7 kg of gravel, and 33 ml of admixture, in total. Sand and polypropylene plastics, however, vary in quantity based on the batch number. In batch 1, 3.3 kg of pure sand are used; no polypropylene plastic is used. In batch 2, 2.475 kg of sand are used, and polypropylene polymers are used in place of 25% of the fine aggregates. Batch 3 utilizes 2.145 kg of sand, with 35% replacement of fine particles by polypropylene plastics.

### 2.3.3 Curing of Samples

The procedure of curing of samples:

1. The concrete was poured into the mold and allowed to cure for one day.

2. The samples were taken out of the mold the following day and left in the water to cure for the next thirty hours.

3. They were then removed from the water and left for at least sixteen hours before testing.

### 2.3.4 Laboratory Testing Requirements

In this study, both compressive strength and slump tests are performed. The concrete slump test, commonly known as the slump cone test, determines the workability of a concrete mix. ASTM C143 is the standard test method for the slump of hydraulic cement concrete [29] with a maximum aggregate size of 1-1/2 in (37.5 mm). On the other hand, compressive strength is an essential aspect of concrete that determines its durability and performance. ASTM C39 tests the compressive strength of cylindrical concrete specimens like molded cylinders and drilled cores [28]. It is limited to concrete with a weight of not less than 50 lb/ft3 (800 kg/m3).

## 2.4 Statistical Data

The statistical data utilized in this study comprises the mean derived from data gathered during the slump test and compressive strength assessments. The mean, which is obtained by summing all values and dividing by the total number of values, serves as an average representation. It is instrumental in the summarization and interpretation of the study's results.

  

In Slump Test, it is utilized for the quantification of concrete workability by determining the slump value, which represents the decrease in height of a concrete cone from its initial form.

Regarding the Compressive Strength Test, statistical analysis is applied to ascertain the maximum load a concrete sample can withstand before experiencing failure, typically expressed in pounds per square inch (psi). The calculation of mean compressive strength offers an average metric of the strength exhibited by the concrete samples, facilitating a comprehensive understanding of the concrete's overall performance.

The statistical methodologies employed in assessing the outcomes of both the Slump Test and Compressive Strength Test serve the purpose of ensuring the accuracy, reliability, and significance of the findings.

### 2.5 Ethical Considerations

Evaluating the workability and compressive strength of concrete with polypropylene plastic as a partial replacement of fine aggregates, it is crucial to carefully consider and address the ethical implications. To ensure high-quality recycled polypropylene, particularly for food-grade applications, removing all contaminants from post-consumer waste that could pose a risk to human health is imperative. Throughout the testing process, safety measures are prioritized to minimize potential hazards, including safe handling of materials and adherence to relevant safety protocols. Measuring compressive strength and workability tests at various curing times is essential, as well as using standardized tests that comply with ASTM or ISO guidelines. Meticulous documentation of all procedures and measurements is maintained to ensure transparency and reproducibility of the study's findings, with any irregularities thoroughly documented. Protecting the privacy of sensitive and private information of the contributors, including the manufacturing process, application of standard procedures, and proprietary formulations, was crucial in ethical research practices. Respecting people's privacy and rights is vital in safeguarding against unauthorized access or misuse of personal information.

## III. RESULTS AND DISCUSSIONS

### 3.1 Data Description

The study encompasses two sets of data: the first set originates from variable data, while the second is derived from laboratory testing. The raw data is sourced from the latter and is acquired through laboratory procedures outlined in Chapter II. Each sample batch comprises three units: three units of 0% samples, three units of 25% samples, and three units of 35% samples.

### 3.2 Data Analysis and Findings

In this study, tests were performed to evaluate both the compressive strength and slump characteristics. The data obtained from the conducted tests was subsequently collected for analysis.

#### 3.2.1 Slump Test

The concrete slump test, also known as the slump cone test, is used to determine the workability of a concrete mix. The test ensures uniform quality of concrete during construction and provides immediate results. It has been widely used for workability tests since 1922 and is conducted according to specific procedures. The concrete slump value indicates the water-cement ratio and workability, but other factors such as materials, mixing methods, dosage, and admixtures also affect the value. A slump test is used to determine the workability and consistency of fresh concrete. It is affected by the water content of the concrete. This procedure uses a cone, plate, tamping rod, and ruler to measure the height from the rod to the top of the concrete. This procedure also can be done in real-time and on-site. Some different results interpretations can be recorded according to its height: 0 to 1 inch is very low workability, 1 to 2 inches is low workability, 2 to 4 inches is medium workability, 4 to 7 inches is high workability, and lastly, the collapsed concrete is very high workability.

| BATCH SAMPLES | HEIGHT RECORDED |
|---|---|
| Batch 1: 0% Polypropylene Plastics | 7 inches |
| Batch 2: 25% Polypropylene Plastics | 7.5 inches |
| Batch 3: 35% Polypropylene Plastics | 7.5 inches |

Table 3. Slump Test Result

Table 3 shows the results of the slump test of the Batch samples. The three batches of samples have different percentages of plastics incorporated in the concrete mixture: 0%, 25%, and 35%. The result in the first batch, 0%, is 7 inches. The second batch, the 25%, has a height of 7.5 inches, and the last one, the 35%, has a slump of 7.5 inches. All the slumps have high workability.

### 3.2.2 Compressive Strength Test

The universal testing machine is usually used to test the compressive strength of concrete. This study determines the compressive strength by applying the maximum compressive load in kN to cylindrical concrete samples. Because of the early-strength material used, the curing of samples only lasts for three days. In this study, ASTM C39 is used to determine the compressive strength of samples.

ASTM C39 outlines the standard procedure for determining the compressive strength of cylindrical concrete specimens. These specimens are subjected to axial compression forces until they fail. Prior to conducting the test, it is essential to thoroughlyreview all the specifications in the relevant ASTM publication. The specimen should be positioned on the lower bearing block so that its axis coincides with the center of thrust of the spherically seated bearing block. Before commencing the test, it was ensured that the load indicator read zero. This testing method aims to provide structural engineers and builders with a consistent and reliable way to evaluate the compressive strength of concrete, which is a critical characteristic. The primary objective of this test is to ensure that the concrete used in construction meets rigorous strength standards, thereby safeguarding the structural integrity, durability, and safety of buildings and bridges.

| BATCH SAMPLES | NET AREA ($mm^2$) | MACHINE READING (kN) | COMPRESSIVE STRENGTH | | | |
|---|---|---|---|---|---|---|
| | | | psi | Ave. psi | MPa | Ave. MPa |
| Batch 1, 0% plastic | 8107 | 432.70 | 7739 | 7603.67 | 53.37 | 52.44 |
| | | 406.56 | 7271 | | 50.15 | |
| | | 436.18 | 7801 | | 53.80 | |
| Batch 2, 25% plastic | 8017 | 175.86 | 3145 | 2892 | 21.69 | 19.91 |
| | | 156.54 | 2800 | | 19.31 | |
| | | 151.68 | 2731 | | 18.71 | |
| Batch 3, 35% plastic | 8017 | 130.96 | 2342 | 2277.33 | 16.15 | 15.70 |
| | | 121.28 | 2169 | | 14.96 | |
| | | 129.75 | 2321 | | 16.00 | |

Table 4. Compressive Strength Test Result

The results of the compressive strength test for specimens subjected to three days of curing are delineated in Table 4. The table depicts specimens denoted as Batch 1, Batch 2, and Batch 3, incorporating 0%, 25%, and 35% polypropylene plastics, respectively. In comparison to the other specimens, Batch 1 (0%), serving as the control sample, yielded an average of 7603.67 psi, corresponding to 52.44 MPa. The experimental sample, Batch 2 (25%), exhibited a result of 2892 psi, equivalent to 19.91 MPa, representing a reduction in strength of approximately 60% relative to Batch 1. Similarly, Batch 3 (35%), as an experimental sample, generated values of 2277.33 psi and 15.70 MPa, indicative of a decrease in compressive strength by 70% when compared to Batch 1 and a 10% decrease relative to Batch 2.

  

### 3.3 The Effects of Polypropylene Plastic as Partial Replacement

The findings illustrate the influence of Polypropylene Plastic as a partial substitute for fine aggregates in concrete mixtures ranging from M20 to M25, with a ratio of 1:2:3. An admixture (ACS-PSP-PX3) was incorporated to foster early strength. The compressive strength of the 25% and 35% specimens was observed to be diminished relative to the control samples, devoid of polypropylene plastic. Specifically, the 25% substitution resulted in a 60% reduction in compressive strength, while the 35% replacement yielded a 70% decrease. The 25% and 35% replacements are suitable for structures requiring 2000 to 2500 psi, such as sidewalks and roads to achieve the early strength of concrete. The25% and 35% specimens have descending strength from the control samples, which are the 0% polypropylene plastic. The 25% replacement of PP from the fine aggregates shows a 60% decrease in compressive strength from the 0% samples, while the 35% replacement of PP from fine aggregates shows a 70% decrease in compressive strength. 25% and 35% are suitable for constructing structures that require 2000 to 2500 psi, such as sidewalks and roads.

### 3.4 Cost Analysis

| Batch Samples | Material needed for production | Unit Cost per Material | Percentage of Material Used per Unit | Cost of Material Used | Total Cost of Production per Batch | Cost Impact | Percent Savings |
|---|---|---|---|---|---|---|---|
| Batch 1 0% plastic | Cement | Php 200 / bag | 18.50% | Php 37 | Php 48.30 | 0 | 0 (Baseline) |
| | Sand | Php 950 / m³ | 0.39% | Php 3.68 | | 0 | |
| | Gravel | Php 900 / m³ | 0.67% | Php 6.02 | | 0 | |
| | Admixture | Php 48 / L | 3.33% | Php 1.60 | | 0 | |
| Batch 2 25% plastic | Cement | Php 200 / bag | 18.50% | Php 37 | Php 47.38 | 0 | 1.90% |
| | Sand | Php 950 / m³ | 0.29% | Php 2.76 | | Php 0.92 | |
| | Gravel | Php 900 / m³ | 0.67% | Php 6.02 | | 0 | |
| | Admixture | Php 48 / L | 3.33% | Php 1.60 | | 0 | |
| Batch 3 35% plastic | Cement | Php 200 / bag | 18.50% | Php 37 | Php 47.02 | 0 | 2.70% |
| | Sand | Php 950 / m³ | 0.25% | Php 2.40 | | Php 1.28 | |
| | Gravel | Php 900 / m³ | 0.67% | Php 6.02 | | 0 | |
| | Admixture | Php 48 / L | 3.33% | Php 1.60 | | 0 | |

Table 5. Cost Analysis

Table 5 provides a detailed comparison of the production costs for three batches of concrete, where each batch produces 3 cylinders, with varying percentages of plastic replacement. It outlines several key variables. “Batch Samples” refers to the different batches of concrete, each with a different percentage of plastic. “Material needed for production” lists the essential materials used, including cement, sand, gravel, and admixture. The “Unit Cost per Material” specifies the cost of each material, such as Php 200 per bag of cement and Php 950 per cubic meter of sand. The “Percentage of Material Used per Unit” indicates the proportion of each material used in the mix.

The “Cost of Material Used” calculates the expense based on the quantity and unit cost of each material. “Total Cost of Production per Batch” sums up all material costs to give the overall production cost for each batch. “Cost Impact” shows the reduction in production cost when plastic is incorporated, compared to the baseline batch with no plastic. Finally, “Percent Savings” quantifies the cost savings percentage achieved by using plastic in the concrete mix. These variables collectively demonstrate how varying the percentage of plastic affects the overall cost efficiency of concrete production.

In detail, Batch 1, with 0% plastic, incurs the highest production cost at Php 48.30, acting as the baseline for comparison. Batch 2, incorporating 25% plastic, reduces the production cost to Php 47.38, resulting in a 1.90% cost reduction. Batch 3, with 35% plastic, further decreases the cost to Php 47.02, achieving a 2.70% reduction. Overall, the data highlight that increasing the percentage of plastic leads to reduced production costs, indicating potential cost savings and increased efficiency in concrete production.

In summary, incorporating plastic into concrete mixes leads to notable albeit modest cost savings. The data demonstrate that as the percentage of plastic increases, production costs decrease, suggesting that plastic can be an effective and economical component in concrete production, particularly when produced in industrial quantities.

## IV. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

In this section, a summary of the key findings is presented, followed by drawn conclusions based on the results, and recommendations are provided for future research and practical applications.

### 4.1 Summary

The primary objective of this study is to incorporate polypropylene plastics in concrete and determine how it affects the concrete's consistency and compressive strength.

Data collected is from laboratory tests conducted. Results from the slump test indicate a range of 7 inches to 7.5 inches, signifying high workability in concrete. In the Compressive Strength test, batch 1 (0% plastic content) showed a strength of 7603.67 psi (52.44 MPa); batch 2 (25% plastic content) recorded 2892 psi (19.91 MPa); while batch 3 (35% plastic content) yielded 2277.33 psi (15.70 MPa).

Considering various factors affecting the samples, such as the type and size of plastics used, curing duration, and water content, is crucial for assessing their viability. Consequently, the presence of polypropylene plastics leads to a decrease in the concrete's compressive strength as the plastic content increases, significantly impacting its overall performance.

### 4.2 Conclusions

The proponents of the study found that incorporating plastics into concrete offers both benefits and drawbacks. Polypropylene fibers can effectively control cracking and enhance toughness, improving the durability of concrete structures. Additionally, polypropylene's lightweight nature contributes to reduced concrete. However, increasing the percentage at significantly higher amount of polypropylene can lead to reduced compressive strength, workability issues, and potential dimensional instability. Finding the right balance is crucial to maximize the positive effects while mitigating the negatives. While moderate amounts of polypropylene can be advantageous, excessive usage may compromise long-term durability and structural integrity. Thus, careful consideration of polypropylene content is essential to optimize concrete performance.

According to the findings of the study, significant differences were observed in the compressive strength across various batches of the concrete-plastic mix. The initial batch, with no added PP aggregate, displayed a compressive strength of 7603 psi, indicating its suitability for critical structural components such as slabs, columns, and girders in buildings. However, the second batch, with 25% PP aggregate, exhibited a lower compressive strength of 2892 psi, making it more suitable for applications like driveways and walkways. Similarly, the third batch, with 35% PP aggregate and a compressive strength of 2277 psi, was also found suitable only for use in driveways and walkways.

### 4.3 Recommendations

Based on the findings and conclusions of the study, the researcher recommends several avenues for prospective researchers aiming to enhance similar studies. Firstly, future researchers may explore further variations in cement mixtures by maintaining a constant type of plastic used for replacement while modifying the percentage. Secondly, it is advised to conduct additional mechanical property tests, including assessments of concrete density, flexural strength, and tensile strength. Thirdly, investigating alternative methods of incorporating plastics into the cement mix, such as utilizing powdered forms of plastics, could provide valuable insights along with experimenting with lower percentages of polypropylene plastics, such as 15%, 16%, or 17%. Furthermore, extending the duration of curing to observe any changes in the properties of the concrete over a longer period is recommended. Lastly, incorporating a comprehensive cost analysis of the materials involved would provide insights into the economic feasibility of the approach. These recommendations aim to further the understanding and optimization of plasticmodified concrete mixtures for various applications.

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