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Research Article

Assessment of Mechanical and Physical Properties of Concrete with Polypropylene Plastic Granule Aggregates

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ABSTRACT

The increasing use of plastic materials has significantly contributed to the global accumulation of plastic waste. Incorporating plastic waste into concrete offers a partial yet promising solution to this environmental challenge. This study investigates the use of polypropylene (PP) plastic granules as a partial replacement for fine aggregates in concrete. The primary objective is to evaluate the physical and mechanical properties of concrete incorporating PP granules, focusing on parameters such as compressive strength, split tensile strength, workability, and density. Mixes were prepared with 10%, 20%, 30%, and 40% replacement levels of fine aggregates by PP granules. The corresponding slump values observed were 8.10 cm, 8.40 cm, 8.60 cm, and 8.80 cm, indicating a slight improvement in workability with increased plastic content. However, the inclusion of PP granules adversely affected the mechanical properties, with compressive and split tensile strength showing significant reductions at 40% replacement, the compressive strength decreased by up to 60%, suggesting that high levels of substitution may not be suitable for structural applications.

Keywords: Polypropylene (PP) Plastic Granules, Plastic Waste,Mechanical Properties,Fine Aggregates,Plastic Granule Aggregates, Coarse Aggregates

1. INTRODUCTION

Concrete is the most widely used construction material globally, prized for its strength, versatility, and durability. It is composed primarily of cement, water, fine aggregates (such as sand), and coarse aggregates (such as gravel or crushed stone). However, the widespread use of concrete comes with significant environmental challenges. The extraction of natural aggregates depletes non-renewable resources, disrupts ecosystems, and contributes to environmental degradation. At the same time, the world is grappling with a growing crisis of plastic pollution, largely driven by the exponential increase in the production and disposal of single-use plastic products.

Polypropylene (PP), a common thermoplastic polymer, is extensively used in packaging, automotive components, textiles, and consumer products. Despite its utility, polypropylene is one of the major contributors to plastic waste due to its low biodegradability and the challenges associated with its recycling. As a result, vast amounts of PP waste end up in landfills and oceans, causing serious environmental and ecological harm. Addressing this dual challenge the overuse of natural aggregates in construction and the mounting plastic waste problem requires innovative and sustainable approaches.

Recent research has explored the potential of using plastic waste as a partial replacement for aggregates in concrete. This approach not only provides an avenue for reusing non-biodegradable waste materials but also reduces the dependence on natural resources. Among the various types of plastics, polypropylene shows promising characteristics such as low density, chemical resistance, and thermal stability, making it a potential candidate for use in concrete.

This study focuses on assessing the feasibility of using polypropylene plastic granules as a partial substitute for fine aggregates in concrete. The primary objective is to examine how varying proportions of PP granules affect the concrete's physical and mechanical properties, including compressive strength, split tensile strength, workability, and density. By replacing sand with PP granules at different percentages—10%, 20%, 30%, and 40%. The research aims to identify an optimal mix that balances environmental sustainability with structural integrity. Understanding

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the performance of concrete with polypropylene plastic granules is essential for its practical application in the construction industry. If successful, this approach could lead to more sustainable construction practices and contribute to the global effort to manage plastic waste. Moreover, the study provides valuable insights for engineers, architects, and policymakers looking to adopt greener building materials and methods.

2. OBJECTIVE OF THE STUDY

The primary objective of this study is to evaluate the feasibility of using polypropylene (PP) plastic granules as a partial replacement for fine aggregates in concrete. Specifically, the research aims to:

1. Investigate the effects of incorporating PP plastic granules at varying replacement levels (10%, 20%, 30%, and 40%) on the workability of concrete through slump tests.

2. Analyze the influence of PP granules on the compressive strength and split tensile strength of concrete to assess structural performance.

3. Examine the changes in density of the concrete with increasing PP content.

4. Identify an optimal replacement level that offers a balance between sustainability and acceptable mechanical performance.

3. MATERIALS & METHODS

3.1 Materials

- **Cement:** Ordinary Portland Cement (OPC), Grade 43. The cement used in all mix designs was Type II Portland cement from India, with a specific gravity of 3.01 g/cm³.
- **Fine Aggregate:** Clean river sand, conforming to IS 383:2016.
- **Coarse Aggregate:** Crushed granite, 20 mm nominal size.
- **Polypropylene Plastic Granules:** Sourced from recycled packaging and containers, washed, shredded, and sieved to match coarse aggregate size.
- **Water:** Potable water used for mixing and curing.

3.2 Mix Desginging

The test specimens used in this study are cylindrical concrete samples with dimensions of 10 cm in diameter and 20 cm in height. A total of five different mix variations were prepared, as detailed in Table 1. The concrete was prepared using the dry mixing method, where all dry components including cement, fine and coarse aggregates, and polypropylene (PP) plastic granules were thoroughly mixed in a concrete mixer before the addition of water. The water was then gradually introduced to the dry mix to achieve the desired consistency.

In this study, polypropylene plastic granules were used as a partial replacement for fine aggregates, based on volume percentages. Each mix variation was tested at curing ages of 7 and 28 days to evaluate the influence of PP content on the mechanical properties of concrete. The polypropylene granules, used as a sustainable substitute for sand, are shown in Figure 1.

Figure 1: Physical appearance of Polypropylene Granule

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On the based of the physical material test results, the normal concrete mix design was calculated for a target compressive strength of f'c = 20 MPa, following the guidelines outlined in SNI 7656:2012 [12]. This standard also specifies the gradation limits for coarse aggregates [13]. From the physical testing of materials, the unit weight of the polypropylene (PP) plastic granules was determined to be 547.93 kg/m³. Detailed physical properties of the aggregates, including the PP granules, are presented in Tables 2 and 3.

Table 1: Physical Properties of Fine Aggregate

Sr, No	**Sample**	**Water (kg)**	**Cement (kg)**	**coarse aggregate (kg)**	**Sand (kg)**	**Polypropylene granule (kg)**
1	PPG0 (Normal Concrete)	10,500	20550	70,000	50,400	-
2	PPG10(Polypropylene 10%)	10,500	20550	70,000	48700	2990
3	PPG20 (Polypropylene 20%)	10,500	20550	70,000	42500	5890
4	PPG30 (Polypropylene 30%)	10,500	2120550	70,000	35800	8996
5	PPG40 (Polypropylene 40%)	10,500	20550	70,000	31400	10200

Table 2: Physical Properties Of Coarse Aggregate

Physical Properties	**Value**
Water Content	2.8 %
Particle size	25 mm
Density	1405,825 kg/m³
Fine Modulus	6.01
Sieve Analysis	Zone 3
Specific gravity	2.2

Table 3: Physical Properties Of Fine Aggregate (sand)

Physical Properties	**Value**
Water Content	4.6%
Specific gravity	2.29
Density	1640,78 kg/m³
Fine Modulus	2.65
Sieve Analysis	Zone 2

Concrete quality was assessed using a split tensile strength test and a compressive strength test show in Figure 2. The highest compressive strength per unit area is known as concrete's compressive strength. Concrete's age, workability, maintenance, aggregate type, and other factors all affect its split tensile and compressive strengths. After 28 days of soaking, the concrete is cured. It is possible to assess the concrete's strength after 28 days. However, the density may be computed by dividing the specimen's weight by its volume. The slump test measures the height of the freshly mixed concrete after the Abrahams cone is raised in order to ascertain the consistency or thickness of the concrete.

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Figure 2: Different Types of Test

4. RESULTS & DISCUSSION

4.1 Result of Density and workability test

One of the physical characteristics of concrete is its density. The unit of measurement for density is kilograms per cubic meter. Density may have an impact on the structure's dead load. Weighing the concrete's dry weight and dividing it by the specimen's volume yields the density. The density measurement results are shown in Figure 3.

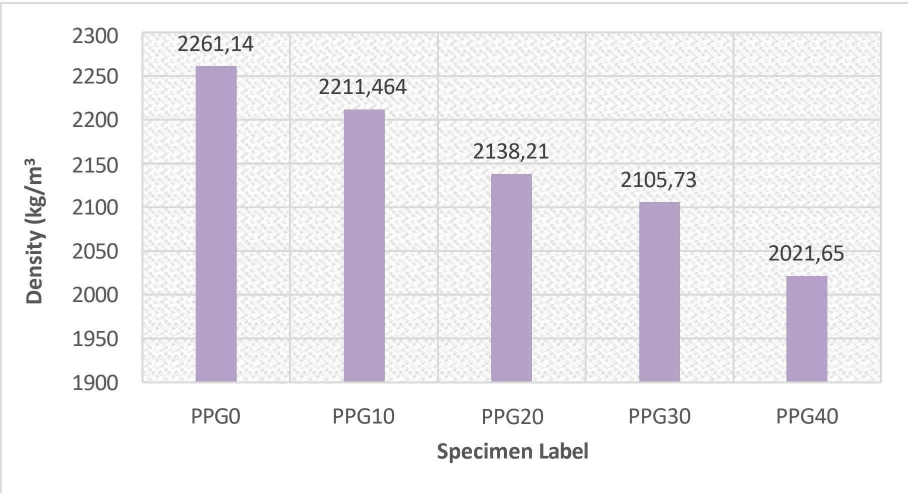

Figure 3: Test result of Density of Specimen

Figure 3 shows the density of each specimen. It is evident that adding a certain amount of polypropylene plastic grains lowers the concrete's density. The densities of the PPG0 and PPG40 specimens are the greatest and lowest, respectively, at 2261.14 and 2021.65 kg/m3. 40% of the PPG40 specimen is made up of plastic granules. The density of PP-G0 was reduced by 2.2% when 10% Polypropylene Plastic Granules were added to the PPG10. However, density may be decreased by up to 10% when 40% plastic granules are added to PPG40. Concrete's density is decreased by the proportion of PP plastic grains in the mixture. This is due to the fact that plastic granules are less dense than sand.

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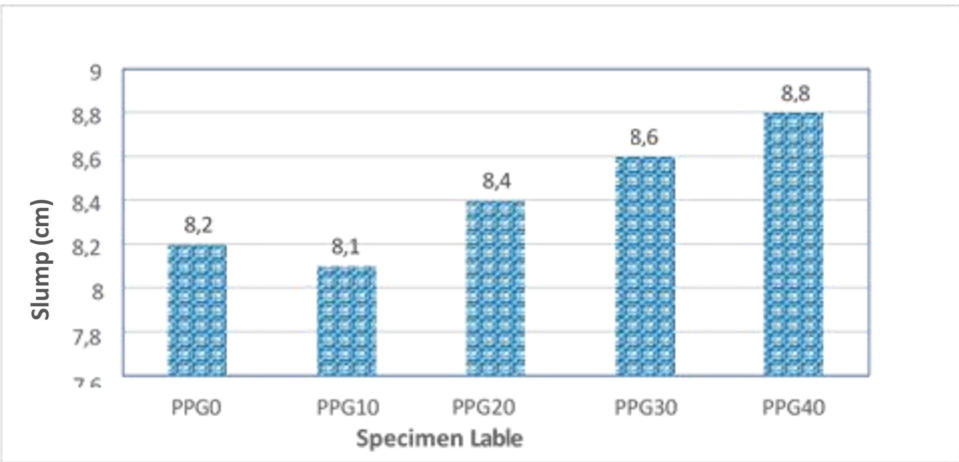


Figure 4: Test result of Slump Value

Practicality Concrete exhibits its qualities of consistency. The workability is evaluated using a slump test. The Slump test results for the test object are shown in Figure 4. None of them are below or above the established threshold of 7.5 cm to 10 cm, based on the results of the slump test. Granules increase the workability of concrete. The slump value rises in tandem with the growing proportion of plastic granules. PPG10 specimens, however, exhibited distinct behavior. The mixing procedure for each specimen was finished on a different day. The aggregate water content in each specimen's SSD condition may be the root cause.

4.2 Result of compressive strength and split tensile strength Test

The specimen's compressive strength is shown in Figure 5. Both the 7-day and 28-day concrete's compressive strengths decreased as the proportion of polypropylene in the mixture increased. The strength of PPG0 control specimen concrete can be lowered by as much as 60% when 40% PP granules are used. The specimen made of PPG40 exhibited the lowest compressive strength. There is no statistically significant difference in each specimen's compressive strength after seven days. The PPG40 specimen also showed that the concrete's strength was almost the same after seven and twenty-eight days. One of the many possible causes of this phenomenon is an imperfect compaction process. Better results will be obtained if fresh concrete is compacted using a vibrator during the molding process.

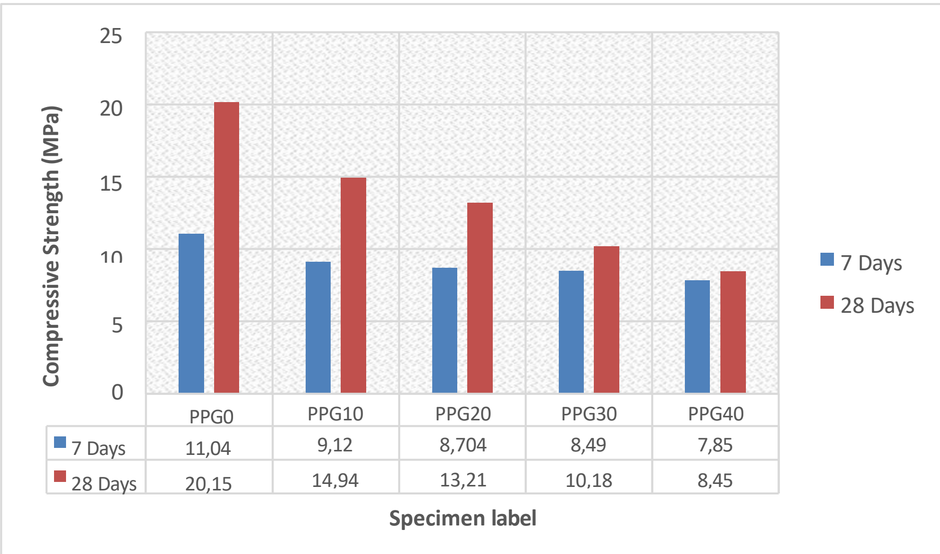
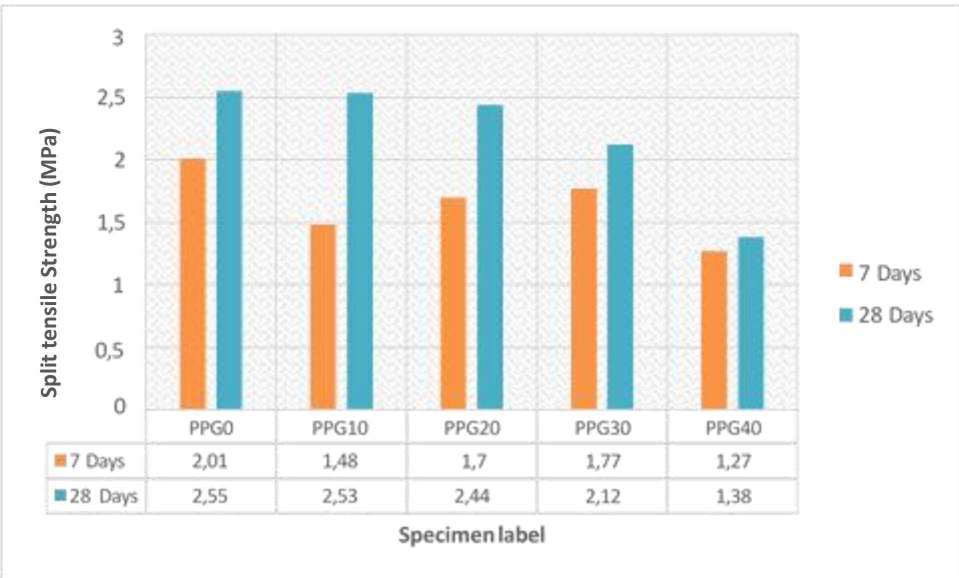


Figure 5: Test result of Compressive strength of specimen



	PPG0	PPG10	PPG20	PPG30	PPG40
7 Days	2,01	1,48	1,7	1,77	1,27
28 Days	2,55	2,53	2,44	2,12	1,38

Figure 6: Test result of Split tensile strength of specimen

The 28-day specimen's split tensile strength show in Figure 6 as the same pattern. The split tensile strength dropped by 40 percent at PPG40. Nevertheless, the test object's compressive strength decreased more than the split tensile strength did. The actions of 7 day. Concrete samples varied. PPG30 strength rose by 16.4%, while PPG10 strength was initially lower. The specimen with the lowest splitting strength is the PPG40 one. Variations in split tensile strength at 7 days of age may be due to an error in the molding of the test object or to the non-uniform distribution of PP granules. The trend of compressive strength is different from that of split tensile strength. After the concrete hardens, it is brought on by the matrix or unequal dispersion of PP plastic granules in the mixture.

5. CONCLUSIONS

Drawing inferences from the data and discussion of various issues is feasible.

- Concrete's self-weight may be decreased by using plastic granules to decrease the concrete's density when applied to structural parts.
- Following an increase in slump value, the fraction of polypropylene granules also rises. A 40% polypropylene granule addition raised the test slump rate by as much as 5%.
- The compressive strength may be decreased by up to 60% when 40% polypropylene granules are substituted.
- Compared to the test object's compressive strength, the split tensile strength drop is less significant. The split tensile strength trend, which usually corresponds to the concrete compressive strength trend, may be influenced by the distribution of plastic particles in the mixture.

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