Experimental Investigation of Plastic Waste Concrete Using Non-Destructive Testing Techniques

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Abstract - *The increasing accumulation of plastic waste has become a major environmental concern worldwide, necessitating the development of sustainable waste management solutions. One promising approach is the utilization of plastic waste as a partial replacement for conventional aggregates in concrete. This study investigates the feasibility of incorporating recycled plastic waste into concrete and evaluates its performance using non-destructive testing (NDT) techniques. Concrete specimens were prepared with varying percentages of plastic waste replacing coarse aggregate, including 0%, 5%, 10%, and 15%. A series of tests were conducted to assess the quality and strength characteristics of the concrete. Non-destructive tests such as the Rebound Hammer Test and Ultrasonic Pulse Velocity (UPV) Test were employed to evaluate surface hardness and internal integrity of the concrete specimens. The results obtained from these tests were analyzed and compared with conventional concrete to determine the effect of plastic waste incorporation. The findings indicate that a limited replacement of coarse aggregate with plastic waste can produce concrete with acceptable strength and durability characteristics. Furthermore, the NDT results demonstrated a correlation with the expected mechanical performance of the concrete. This study highlights the potential of plastic waste as a sustainable construction material while also demonstrating the effectiveness of non-destructive testing methods in evaluating concrete quality.*

***Keywords*: Plastic waste concrete, Sustainable construction, Rebound hammer test, Ultrasonic pulse velocity**

1. INTRODUCTION

The rapid growth in urbanization and industrialization has led to a significant increase in the consumption of plastic materials across the globe. Plastics are widely used due to their lightweight, durability, and cost-effectiveness; however, their non-biodegradable nature poses serious environmental challenges. Improper disposal of plastic waste leads to land pollution, blockage of drainage systems, and adverse impacts on ecosystems. As a result, there is an urgent need to develop sustainable and eco-friendly methods for the effective utilization of plastic waste. The construction industry, being one of the largest consumers of natural resources, offers a potential solution to this problem through the incorporation of waste materials into construction products. Concrete, which is the most widely used construction material, requires large quantities of natural aggregates.

The excessive extraction of these aggregates has resulted in the depletion of natural resources and environmental degradation. Therefore, the partial replacement of conventional aggregates with recycled materials such as plastic waste presents a promising approach toward sustainable construction. In recent years, several studies have explored the use of plastic waste as a partial replacement for coarse aggregates in concrete. The inclusion of plastic waste not only helps in reducing environmental pollution but also contributes to resource conservation. However, the addition of plastic materials can influence the mechanical and durability properties of concrete, including compressive strength, workability, and bonding characteristics. Hence, it becomes essential to evaluate the performance of plastic waste concrete to ensure its suitability for structural and non-structural applications.

Traditional methods of testing concrete, such as compressive strength testing, are destructive in nature and require the specimen to be loaded until failure. While these methods provide accurate results, they are not always practical for in-situ evaluation of structures. In this context, non-destructive testing (NDT) methods have gained significant importance in the field of civil engineering. NDT techniques allow the assessment of concrete properties without causing damage to the structure, making them highly suitable for quality control and structural health monitoring. Among the various NDT methods available, the Rebound Hammer Test and Ultrasonic Pulse Velocity (UPV) Test are widely used due to their simplicity, reliability, and cost-effectiveness. The Rebound Hammer Test provides an estimate of surface hardness, which is related to the compressive strength of concrete, while the UPV Test evaluates the internal quality and uniformity of the material by measuring the velocity of ultrasonic waves passing through it. These methods offer valuable insights into the condition of concrete and can be effectively used to assess the performance of modified concrete mixtures. The present study focuses on the experimental investigation of concrete incorporating plastic waste as a partial replacement for coarse aggregates. Different percentages of plastic waste are used to prepare concrete specimens, and their performance is evaluated using non-destructive testing techniques.

The results obtained from the Rebound Hammer and UPV tests are analyzed to understand the effect of plastic incorporation on the quality and strength characteristics of concrete. The study aims to determine the optimum percentage of plastic replacement that can be used without significantly compromising the performance of concrete. This research contributes to the development of sustainable construction practices by promoting the utilization of plastic waste in concrete production. Additionally, it highlights the effectiveness of non-destructive testing methods in evaluating innovative construction materials. The findings of this study are expected to provide useful insights for researchers and engineers working in the field of sustainable materials and concrete technology.

2. LITERATURE REVIEW

The growing environmental concerns associated with plastic waste disposal have encouraged researchers to explore its potential utilization in construction materials, particularly concrete. Several studies have investigated the feasibility of incorporating plastic waste as a partial replacement for conventional aggregates, with a focus on both sustainability and performance.

Batayneh et al. (2007) examined the use of various waste materials, including plastic, in concrete mixtures. Their study revealed that while the incorporation of waste materials contributes positively to environmental sustainability, an increase in replacement percentage leads to a reduction in compressive strength. This highlights the importance of identifying an optimum replacement level that balances performance and sustainability. Choi et al. (2005) studied the use of waste polyethylene terephthalate (PET) bottles as aggregate in concrete. The results indicated a decrease in density and compressive strength with the inclusion of plastic aggregates; however, improvements in ductility and impact resistance were observed. This suggests that plastic-modified concrete may be more suitable for non-structural and lightweight applications.

Marzouk et al. (2007) investigated the performance of cementitious composites containing post-consumer plastic waste. Their findings confirmed that plastic waste can be effectively utilized as a partial replacement for aggregates, although a gradual decline in mechanical strength was observed with increasing plastic content. Despite this, the environmental benefits of recycling plastic waste in construction were considered significant. Ramadevi and Manju (2012) explored the use of plastic fibers derived from PET bottles in concrete. Their research demonstrated improved tensile strength and crack resistance due to fiber reinforcement, although compressive strength showed a slight reduction. This indicates that the form in which plastic is used (aggregate vs fiber) plays a crucial role in influencing concrete properties.

Neville (2011) emphasized that the properties of concrete are highly dependent on the characteristics of aggregates, including their shape, texture, and bonding ability. The introduction of plastic materials, which are typically smooth and non-reactive, affects the interfacial bonding between aggregate and cement paste, thereby influencing the overall strength and durability of concrete. In addition to material-based studies, non-destructive testing (NDT) methods have been widely used for evaluating concrete quality. Standards such as IS 13311 (Part 1 and Part 2) provide guidelines for conducting Ultrasonic Pulse Velocity (UPV) and Rebound Hammer tests. These methods offer reliable and efficient means of assessing surface hardness and internal integrity without damaging the specimen.

From the above studies, it is evident that plastic waste can be effectively utilized in concrete, particularly at lower replacement levels (generally below 10%). However, most research primarily focuses on mechanical properties, with limited emphasis on the evaluation of plastic waste concrete using non-destructive testing techniques. Therefore, the present study aims to bridge this gap by investigating the performance of plastic waste concrete using both Rebound Hammer and Ultrasonic Pulse Velocity methods. This approach not only contributes to sustainable material development but also provides a practical framework for assessing concrete quality using non-destructive techniques.

3. MATERIALS AND METHODOLOGY

3.1 Materials

The materials used in the present study include cement, fine aggregate, coarse aggregate, plastic waste, and water. All materials were selected in accordance with standard construction practices.

3.1.1 Cement

Ordinary Portland Cement (OPC) of grade 43 was used for the preparation of concrete. The cement used was fresh, free from lumps, and stored in dry conditions. The properties of cement were assumed to conform to relevant Indian Standard specifications.

3.1.2 Fine Aggregate

Natural river sand was used as fine aggregate. The sand was clean, well-graded, and free from impurities such as silt, clay, and organic matter. It was sieved to remove oversized particles before use.

3.1.3 Coarse Aggregate

Crushed stone aggregate of nominal size 20 mm was used as coarse aggregate. The aggregates were angular in shape and free from dust and deleterious materials. Proper grading was ensured to achieve good workability and strength.

3.1.4 Plastic Waste

Plastic waste in the form of discarded bottles and packaging materials was collected, cleaned, and shredded into small pieces of approximately 5–10 mm size. The processed plastic waste was used as a partial replacement for coarse aggregate in the concrete mix.

3.1.5 Water

Potable water free from harmful substances such as oils, acids, and salts was used for mixing and curing of concrete.

3.2 Mix Proportion

Concrete of grade M20 was used in this study. A nominal mix proportion of **1:1.5:3** (cement: fine aggregate: coarse aggregate) was adopted. Mix design was carried out in accordance with IS 10262:2019 guidelines. Plastic waste was used as a partial replacement of coarse aggregate at different percentages as shown below:

Mix ID	Plastic Replacement (%)
M0	0%
M1	5%
M2	10%
M3	15%

3.3 Preparation of Specimens

Concrete was mixed manually by thoroughly blending cement, sand, coarse aggregate, and plastic waste in dry condition. Water was then added gradually and mixed until a uniform consistency was achieved. The fresh concrete was placed in cube moulds of size **150 mm × 150 mm × 150 mm** in three layers, and each layer was compacted properly to remove air voids. The top surface was leveled and finished smoothly. After 24 hours, the specimens were demoulded and transferred to a curing tank containing water. All concrete specimens were cured in water for a period of **7 days and 28 days**. Proper curing was ensured to maintain adequate moisture conditions required for hydration.

3.4 Non-Destructive Testing Methods

3.4.1 Rebound Hammer Test

The Rebound Hammer Test was conducted to evaluate the surface hardness of concrete. The test was performed by placing the rebound hammer perpendicular to the surface of the cube. Multiple readings were taken at different points on the surface, and the average rebound number was calculated for each specimen.

3.4.2 Ultrasonic Pulse Velocity (UPV) Test

The Ultrasonic Pulse Velocity test was carried out to assess the internal quality and uniformity of concrete. In this method, ultrasonic pulses were transmitted through the specimen, and the time taken for the pulse to travel was measured. The pulse velocity was calculated and used to determine the quality of concrete.

3.5 Number of Specimens

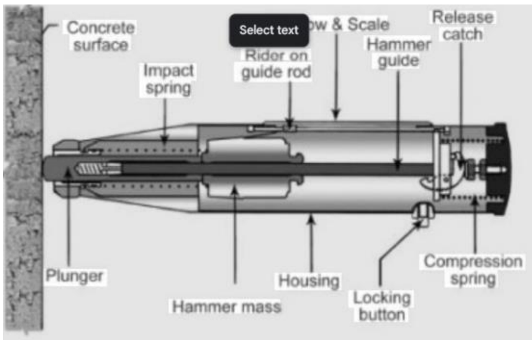
A total of **12 concrete cubes** were cast for the study, with 3 specimens for each mix proportion. The results obtained from the tests were averaged to ensure accuracy and reliability. All experimental work was carried out in the laboratory under controlled conditions to ensure consistency in results.

4. RESULTS AND DISCUSSION

4.1 Rebound Hammer Test Results

Table 4.1: Rebound Hammer Values

Mix ID	Plastic %	Avg Rebound Number
M0	0%	32
M1	5%	30
M2	10%	27
M3	15%	24



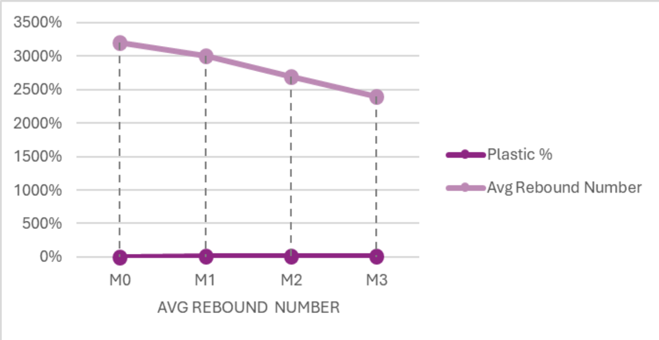


Chart-1: Variation of Rebound Number with Plastic Content

Discussion: The rebound hammer test results indicate a gradual decrease in rebound number with an increase in plastic content. The control mix (M0) exhibited the highest rebound value, indicating greater surface hardness. As the percentage of plastic waste increased, a reduction in surface hardness was observed. This can be attributed to the lower stiffness and bonding characteristics of plastic compared to natural aggregates. However, the values obtained for mixes up to 10% replacement remain within acceptable limits, indicating feasible usage.

4.2 Ultrasonic Pulse Velocity (UPV) Results

Table 4.2: UPV Test Results

Mix ID	Plastic %	Velocity (km/s)	Quality
M0	0%	4.6	Excellent
M1	5%	4.3	Good
M2	10%	3.8	Good
M3	15%	3.2	Medium

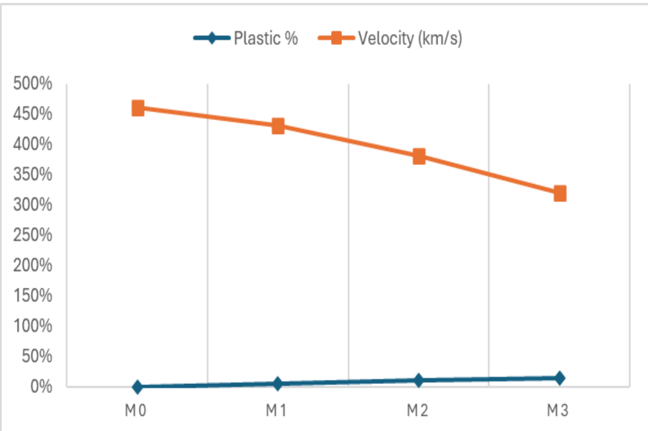


Chart-2: Variation of Ultrasonic Pulse Velocity (UPV) with Plastic Content

Discussion: The UPV test results show a decreasing trend in pulse velocity with an increase in plastic content. The control mix exhibited excellent quality with the highest velocity, while mixes with plastic replacement showed slightly reduced values. This reduction is due to increased voids and weaker bonding introduced by plastic particles. However, mixes up to 10% replacement still fall under the "good" category, indicating satisfactory internal structure and uniformity.

4.3 Compressive Strength

Table 4.3: Compressive Strength

Mix ID	Plastic %	7 Days (MPa)	28 Days (MPa)
M0	0%	18	26
M1	5%	17	24
M2	10%	15	22
M3	15%	13	19

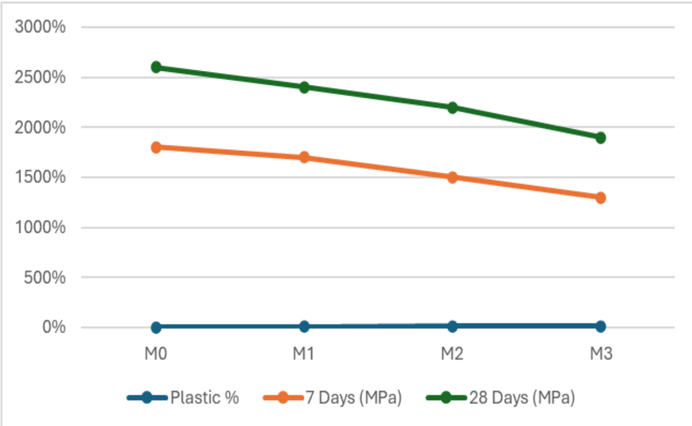


Chart-3: Effect of Plastic Content on 28-Day Compressive Strength

Discussion: The compressive strength results show a decrease in strength with increasing plastic content. The reduction is mainly due to the weak bonding between plastic particles and cement paste, as plastic is non-reactive and smooth in texture. However, up to 5–10% replacement, the strength remains within acceptable limits for non-structural applications.

5. CONCLUSIONS

Based on the experimental investigation carried out on concrete incorporating plastic waste as a partial replacement for coarse aggregate, the following conclusions are drawn:

1. The study demonstrates that plastic waste can be effectively utilized in concrete as a sustainable alternative to conventional aggregates, thereby

contributing to waste management and environmental protection.

2. The results obtained from the Rebound Hammer Test indicate that surface hardness of concrete decreases with an increase in plastic content. However, mixes containing up to 10% plastic replacement exhibit acceptable rebound values, indicating satisfactory surface quality.

3. Ultrasonic Pulse Velocity (UPV) test results reveal that the internal quality and uniformity of concrete are slightly affected by the inclusion of plastic waste. Nevertheless, mixes with up to 10% replacement fall within the "good" quality range, confirming their suitability for practical applications.

4. A reduction in compressive strength is observed with increasing plastic content due to the weaker bonding characteristics and lower stiffness of plastic materials. Despite this reduction, concrete with 5–10% plastic replacement maintains adequate strength for non-structural purposes.

5. A good correlation is observed between non-destructive testing results and compressive strength values, indicating that NDT methods such as Rebound Hammer and UPV can be reliably used to assess the quality of plastic waste concrete.

6. The optimum percentage of plastic waste replacement is found to be in the range of **5% to 10%**, where a balance between strength, durability, and sustainability is achieved.

7. The use of plastic waste in concrete is particularly suitable for applications such as pavements, footpaths, and non-load bearing structures, where high structural strength is not the primary requirement.

In conclusion, the incorporation of plastic waste in concrete presents a promising approach toward sustainable construction. Additionally, the application of non-destructive testing techniques proves to be effective in evaluating the performance of modified concrete, making this approach practical for real-world engineering applications. Further studies are recommended to evaluate long-term durability and field performance of plastic waste concrete.

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REFERENCES

[1] M. Batayneh, I. Marie, and I. Asi, "Use of selected waste materials in concrete mixes," Waste Management, vol. 27, no. 12, pp. 1870–1876, 2007.

[2] S. Choi, B. Moon, S. Chung, and J. Cho, "Effects of waste PET bottles aggregate on the properties of concrete," Cement and Concrete Research, vol. 35, no. 4, pp. 776–781, 2005.

[3] A. M. Neville, Properties of Concrete, 5th ed., London, U.K.: Pearson Education, 2011.

[4] IS 13311 (Part 1): 1992, "Non-Destructive Testing of Concrete – Methods of Test, Part 1: Ultrasonic Pulse Velocity," Bureau of Indian Standards, New Delhi, India.

[5] IS 13311 (Part 2): 1992, "Non-Destructive Testing of Concrete – Methods of Test, Part 2: Rebound Hammer," Bureau of Indian Standards, New Delhi, India.

[6] IS 10262: 2019, "Concrete Mix Proportioning – Guidelines," Bureau of Indian Standards, New Delhi, India.

[7] O. Y. Marzouk, R. M. Dheilly, and M. Queneudec, "Valorization of post-consumer waste plastic in cementitious concrete composites," Waste Management, vol. 27, no. 2, pp. 310–318, 2007.

[8] K. Ramadevi and R. Manju, "Experimental investigation on the properties of concrete with plastic PET bottle fibres as fine aggregate," International Journal of Emerging Technology and Advanced Engineering, vol. 2, no. 6, pp. 42–46, 2012