International Journal of Innovative Research in Technology and Science
ISSN: 2321-1156 www.ijirts.org Volume 12 Issue 2, March 2024

# Experimental Determination of Plastic Granules and Marble Powder on the Characteristics of Concrete

Sapna Verma[1], Shubha Bhargava[1], Sanjeev Kumar Verma[1,2*]

[1]*Department of Civil Engineering, School of Engineering and Technology, Sanjeev Agrawal Global Educational (SAGE) University, Bhopal (Madhya Pradesh), India*
[2]*Dean Academics, SAM Global University, Raisen, Bhopal Road (M.P.) India*

*Selection and peer review of this article are under the responsibility of the scientific committee of the International Conference on Current Trends in Engineering, Science, and Management (ICCSTEM-2024) at SAM Global University, Bhopal.*

**Abstract:** The incorporation of waste materials into concrete production provides an innovative solution to environmental and sustainability challenges. This study investigates the effects of Low-Density Polyethylene (LDPE) granules as a partial replacement for coarse aggregates and marble powder as a partial substitute for cement. Concrete mixes were prepared with plastic granules replacing coarse aggregates at 0%, 12%, 18%, 24%, 30%, 36%, 42%, 48%, 54%, and 60%, and marble powder replacing cement at 5%, 10%, and 15%. Compressive strength, split tensile strength, and workability were evaluated for all mixes. The results reveal that increasing the proportion of plastic granules reduces compressive strength and workability, while marble powder enhances compressive strength at lower replacement levels but decreases workability. This study provides insights into optimizing waste material use in concrete to balance sustainability and performance.

**Keywords**: Concrete, Plastic granules, Marble powder, Compressive strength, Sustainability.

## 1. Introduction

With increasing environmental concerns, sustainable construction practices have gained significant attention. One such approach is the incorporation of waste materials into concrete to enhance sustainability while maintaining structural integrity. Low-Density Polyethylene (LDPE) granules, commonly found in disposable plastic products, are non-biodegradable and pose serious environmental threats. Similarly, marble powder, a by-product of the stone-cutting industry, is often discarded, leading to waste management issues. This study explores the combined use of LDPE granules as a partial replacement for coarse aggregates and marble powder as a partial substitute for cement in concrete. The research focuses on evaluating their impact on the mechanical properties and workability of concrete to optimize their use in sustainable construction practices.

The key objectives of this study are to evaluate the effects of plastic granules and marble powder on the compressive strength, split tensile strength, and workability of concrete. By systematically analyzing these properties, the research aims to understand how the incorporation of these waste materials influences the overall performance of concrete. Additionally, the study seeks to optimize the proportions of plastic granules and marble powder to achieve a balance between sustainability and mechanical performance. By determining the ideal replacement levels, this research contributes to the development of environmentally friendly concrete while ensuring structural integrity and durability.

The rapid urbanization and industrialization of the modern world have led to an exponential increase in plastic waste and industrial by-products. Addressing these waste disposal issues through innovative construction materials can significantly reduce environmental impact. LDPE, being non-biodegradable, accumulates in landfills and oceans, causing severe ecological damage. Similarly, marble powder, which is generated in large quantities from stone-cutting industries, often remains underutilized. The motivation behind this research is to investigate whether these waste materials can be effectively repurposed to enhance the durability and sustainability of concrete while mitigating their adverse environmental effects.

This study makes several significant contributions to sustainable construction research. Firstly, it provides an experimental evaluation of the mechanical behaviour of concrete incorporating varying proportions of LDPE granules and marble powder. This investigation helps to understand how these materials affect the performance of concrete. Secondly, the study contributes to the optimization of waste utilization by identifying the optimal replacement levels that balance sustainability, strength, and workability, offering practical solutions for material substitution. Additionally, it addresses environmental concerns by promoting the reduction of plastic and industrial waste through innovative reuse in construction materials. Finally, the study offers valuable guidelines for incorporating plastic granules and marble powder into concrete, providing a foundation for future research and applications in the construction industry.

**2. Related Work**

The use of waste materials in concrete has garnered significant attention as researchers and industry professionals aim to find sustainable alternatives that reduce environmental impact while maintaining the performance of concrete. Various studies have explored the incorporation of industrial by-products, including plastic and marble powder, in concrete mixes to enhance sustainability. Bajad and Desai (2012) explored the effects of marble powder on concrete properties, noting improvements in compressive strength with marble powder replacement levels of up to 10%. They highlighted the potential of marble powder as a partial replacement for cement, although they also observed that beyond a certain threshold, the improvement in strength plateaued or even declined. Similarly, Khatib et al. (2012) investigated the use of marble powder in concrete, concluding that the material improves the packing density and pozzolanic activity, thereby enhancing the compressive strength of concrete when used in limited amounts. Plastic waste, especially from non-biodegradable materials like Low-Density Polyethylene (LDPE), has also been widely studied as a replacement for conventional aggregates in concrete. Muhit et al. (2013) examined the use of plastic aggregates in concrete and observed a reduction in compressive strength and workability with increasing plastic content. They attributed the decrease in strength to the lower stiffness of plastic, which hindered the bond between the aggregates and the cement matrix. Similarly, Vyawahare and Modani (2009) highlighted the challenges associated with plastic aggregates, particularly their irregular shape and low water absorption, which led to reduced workability and strength.

Several studies have also investigated the combined effects of these materials. For example, research by Mohd and Al-Harthy (2014) examined the synergistic effects of plastic aggregates and waste marble powder on concrete, suggesting that the incorporation of both materials could balance the negative effects of each. The use of marble powder enhanced compressive strength at lower replacement levels, while plastic aggregates, despite reducing strength, contributed to sustainability by reducing plastic waste. Their findings suggested that the optimal mix for balanced performance involved small amounts of both materials—plastic aggregates up to 20% and marble powder up to 10%. In line with these findings, our study expands upon existing research by systematically evaluating various replacement levels of LDPE granules and marble powder. The results show that increasing the proportion of plastic granules reduces compressive strength and workability, while marble powder improves compressive strength at lower replacement levels but negatively affects workability. This research confirms the potential for optimizing the use of waste materials in concrete to achieve a balance between sustainability and mechanical performance. However, similar to previous studies, it is clear that the combined use of both materials requires careful consideration of the replacement levels to avoid diminishing returns in strength and workability. These contributions to the literature provide valuable insights into the practical application of waste materials in construction, paving the way for future research to explore the long-term durability of such mixes, as well as the economic and environmental feasibility of using waste materials in large-scale concrete production.

**2. Materials and Methods**

This section outlines the materials used and the experimental methodology followed to evaluate the impact of plastic granules and marble powder on the properties of concrete.

**Materials:** The cement used in this study was Ordinary Portland Cement (OPC) 53-grade, which conforms to IS:455-1989 standards, ensuring its quality and suitability for high-strength concrete mixes. The plastic granules used were Low-Density Polyethylene (LDPE) granules, which had a uniform particle size to facilitate easy incorporation into the concrete mix. LDPE is a commonly used plastic, primarily found in disposable products. It is an ideal candidate for waste repurposing in construction materials. Marble powder, the third waste material, was sourced from the stone-cutting industry. It was finely ground to a specific gravity of 2.6, allowing it to behave similarly to fine aggregates in concrete. The aggregates used in the study consisted of natural river sand with a fineness modulus of 2.27 and crushed stone aggregates conforming to IS:383-1970 standards, ensuring uniformity and consistency in the concrete mix.

**Experimental Design:** The concrete mixes were designed by replacing coarse aggregates with plastic granules and cement with marble powder at varying replacement levels to evaluate their effects on the properties of concrete. For plastic granules, the replacement levels ranged from 0% (control mix) to 60% in increments of 6%, including 12%, 18%, 24%, 30%, 36%, 42%, 48%, 54%, and 60%. For marble powder, the replacement levels were set at 5%, 10%, and 15%. These replacement levels were chosen based on prior research and the aim of exploring both the effects of low and higher amounts of these waste materials in the concrete mix. The concrete mixes were prepared using the conventional method, ensuring that the materials were thoroughly mixed and homogeneous before testing. Testing Methodology: Several standard tests were conducted to assess the workability and mechanical properties of the concrete mixes.

**Workability:** The workability of the concrete mixes was measured using the slump cone test, as per IS:1199 standards. The slump cone test indicates the ease with which concrete can be placed and compacted, which is critical for achieving uniformity in the finished product. The test results measured the concrete’s consistency and ability to flow when subjected to external forces, with lower slump values generally indicating reduced workability.

**Compressive Strength**: To evaluate the strength of the concrete, cubes measuring 150mm x 150mm x 150mm were cast for each mix and cured for 7 and 28 days in a controlled environment. The compressive strength was determined by subjecting these cubes to compression tests as per IS:516 standards. Compressive strength is a fundamental property that indicates the concrete’s ability to withstand axial loads and is essential for structural applications.

**Split Tensile Strength:** To further assess the concrete’s durability and ability to resist tensile stresses, cylindrical specimens were prepared and tested according to ASTM C496 standards. This test is particularly important because concrete, being weak in tension, often fails under tensile stresses. The split tensile strength test provides insight into the concrete's behaviour under such conditions, which is crucial for designing concrete elements subject to bending or other tensile forces.

The experimental design and testing methodology allowed for a comprehensive evaluation of how plastic granules and marble powder affect the key properties of concrete, including workability, compressive strength, and tensile strength. These tests provided valuable data for optimizing the use of waste materials in concrete and understanding the trade-offs between sustainability and structural performance.

**3. Experimental Results**

The experimental results of the study highlight the significant effects of plastic granules and marble powder on the workability and mechanical properties of concrete. The findings are categorized into workability, compressive strength, and split tensile strength, followed by a comprehensive summary of the experimental data obtained for each mix.

**Workability:** A clear trend was observed in the workability of concrete mixes with increasing content of plastic granules and marble powder. As the proportion of plastic granules in the mix increased, workability decreased significantly. This is attributed to the irregular shape, low water absorption, and smooth surface texture of plastic granules, which reduce the cohesion of the concrete mixture and hinder its flow. The slump values, which serve as a measure of workability, decreased as the percentage of plastic granules rose. The control mix (M1), with no plastic granules, had a slump of 110 mm. As the plastic granule content increased, the slump gradually decreased, reaching as low as 60 mm for the mix with 60% plastic granules (M10). Similarly, the addition of marble powder further reduced the workability of the mix. Marble powder, due to its fine texture and increased water demand, contributed to the reduction in slump. The slump values for mixes with marble powder replacement ranged from 110 mm for the 5% marble powder mix to 60 mm for the highest 60% plastic granule and 15% marble powder combination.

**Compressive Strength:** The compressive strength of the concrete exhibited varying trends depending on the type and proportion of the waste materials used. The replacement of coarse aggregates with plastic granules resulted in a decrease in compressive strength as the plastic content increased. For the control mix (M1), which had no plastic granules, the compressive strength was 21.2 MPa. As plastic granule content increased, the compressive strength of the mixes declined progressively. At 12% plastic granules (M2), the strength decreased to 20.6 MPa, and at higher proportions of plastic granules (up to 60% in M10), the compressive strength further decreased, reaching a reduction of 15% to 25%. The decrease in strength can be attributed to the lower stiffness of plastic granules compared to traditional aggregates, which results in weaker bonding within the concrete matrix.

On the other hand, the addition of marble powder showed a different effect on compressive strength. At lower replacement levels of 5% and 10%, marble powder contributed positively to the compressive strength of the concrete, with strengths of 21.2 MPa and 20.3 MPa for the mixes M1 and M3, respectively. The improved strength can be attributed to the pozzolanic activity of marble powder, which enhances the packing density of the concrete and contributes to stronger hydration products. However, as the marble powder content reached 15%, the compressive strength plateaued or slightly decreased, indicating that higher marble powder content might lead to an excess of fine particles, which could negatively affect the concrete's performance by increasing water demand and reducing its workability.

**Split Tensile Strength:** Similar trends were observed in the split tensile strength of the concrete mixes. The addition of plastic granules caused a reduction in tensile strength as the percentage of plastic increased. For the control mix (M1), the split tensile strength was 5.9 MPa. As the plastic granule content increased, the tensile strength gradually decreased. For instance, in mix M2, with 12% plastic granules, the tensile strength reduced to 5.3 MPa, and it continued to decrease with higher plastic granule proportions, reaching 2.3 MPa in mix M10 (with 60% plastic granules). The reduction in tensile strength is likely due to the inability of plastic granules to effectively bond with the cement matrix, which results in weaker resistance to tensile forces.

In contrast, the incorporation of marble powder showed an improvement in tensile strength at lower replacement levels. For mixes M1 to M4 (with marble powder replacement of 5% and 10%), the split tensile strength increased, peaking at 5.9 MPa for the control mix and 5.3 MPa for the 12% plastic granule replacement with 5% marble powder (M2). However, as the marble powder content increased to 15% in mixes M5 and M6, the split tensile strength started to decrease, reflecting the same trend as in compressive strength. This suggests that excessive amounts of marble powder may weaken the concrete's ability to resist tensile stresses, possibly due to the increased water demand and reduced workability. The results from the experimental mixes are summarized in Table 1.

**Table 1.** Effect of marble powder and plastic granules on concrete properties.

| Mix No. | Marble Powder (%) | Plastic Granules (%) | Compressive Strength (MPa) | Split Tensile Strength (MPa) | Slump (mm) |
|---|---|---|---|---|---|
| M1 | 5 | 0 | 21.2 | 5.9 | 110 |
| M2 | 5 | 12 | 20.6 | 5.3 | 105 |
| M3 | 10 | 18 | 20.3 | 4.8 | 98 |
| M4 | 10 | 24 | 20.0 | 4.5 | 93 |
| M5 | 15 | 30 | 19.9 | 3.9 | 89 |
| M6 | 15 | 36 | 19.5 | 3.5 | 82 |
| M7 | 10 | 42 | 19.0 | 3.1 | 76 |
| M8 | 10 | 48 | 18.9 | 2.8 | 73 |
| M9 | 5 | 54 | 18.6 | 2.5 | 68 |
| M10 | 5 | 60 | 18.0 | 2.3 | 60 |

## 4. Discussion

The incorporation of plastic granules and marble powder into concrete mixes has notable effects on its workability, compressive strength, and overall performance. This section discusses the key observations from the experimental results, focusing on the individual and combined impact of these materials on the concrete properties.

### 4.1 Workability

The workability of concrete is a critical factor influencing its ease of placement, compaction, and finishing. In this study, the addition of plastic granules significantly reduced the workability of the concrete mixes. This reduction can be attributed to the irregular shape and low water absorption of the plastic granules, which interfere with the cohesion of the concrete mixture. Plastic granules, being smooth and non-porous, do not bond as effectively with the cement paste, leading to a less fluid mix. As the proportion of plastic granules increased, the slump values of the concrete mixes decreased significantly, indicating a decrease in workability. The control mix (M1) with no plastic granules exhibited a slump of 110 mm, but as the plastic content increased to 60%, the slump dropped to just 60 mm (M10), indicating a considerable loss of fluidity. The inclusion of marble powder further exacerbated this reduction in workability. Marble powder, due to its fine texture and increased surface area, requires more water for proper mixing and hydration. This high water demand reduces the flowability of the concrete mix, resulting in even lower slump values when higher proportions of marble powder are used. The combination of plastic granules and marble powder in the mix led to a significant decrease in slump values, particularly when the marble powder content was 15%. This demonstrates that both materials, when used in higher proportions, reduce the ability of the mix to flow and settle properly, making it more challenging to work with during placement.

### 4.2 Compressive Strength

The effects of plastic granules and marble powder on compressive strength were found to differ.

**Plastic Granules:** The incorporation of plastic granules resulted in a reduction in compressive strength. The main reason for this reduction is the lower stiffness of plastic granules, which are not as strong or rigid as traditional aggregates. As plastic granules replace a portion of the coarse aggregates, they reduce the overall strength of the concrete mix. The weak bonding between the plastic granules and the cement matrix further weakens the material, leading to a significant decrease in compressive strength. At 60% plastic granule replacement (M10), the compressive strength was reduced by 15%–25%, with a final value of 18.0 MPa compared to 21.2 MPa in the control mix (M1).

**Marble Powder:** The impact of marble powder on compressive strength was more positive, particularly at lower replacement levels. At 5% and 10% replacement, marble powder enhanced the packing density of the concrete mix and contributed to pozzolanic activity, which improved the compressive strength. At these levels, the enhanced hydration reaction between marble powder and cement resulted in stronger bonds and a denser microstructure. However, when the marble powder replacement exceeded 10%, the benefits plateaued, and the compressive strength either stabilized or slightly declined. At higher replacement levels (15%), the excess fine particles could lead to reduced workability and increased water demand, which negatively affected the hydration process, thereby limiting any further strength gains.

### 4.3 Combined Effects

The combined effect of plastic granules and marble powder on concrete performance showed that there was an optimal range for both materials. The best performance in terms of strength and workability was achieved when the plastic granule replacement ranged from 12% to 24%, with marble powder replacement levels of 5% to 10%. Within these ranges, the strength of the concrete remained relatively high, and the workability, though reduced, was still manageable. Beyond these optimal levels, however, the performance of the concrete deteriorated. Higher proportions of plastic granules (above 24%) and marble powder (above 10%) caused a significant reduction in both strength and workability. This suggests that while these materials can enhance sustainability by repurposing waste products, their effects must be carefully balanced to ensure that concrete maintains its required mechanical properties.

In conclusion, the use of plastic granules and marble powder as partial replacements in concrete offers a promising approach to enhancing sustainability in construction. However, careful consideration of the proportions used is necessary to achieve a balance between environmental benefits and structural performance. Optimal replacement levels, as identified in this study, allow for a concrete mix that remains workable and strong without compromising durability or environmental goals.

## 5. Conclusions and Future Recommendations

In conclusion, the use of plastic granules and marble powder as replacements in construction materials offers significant potential for enhancing sustainability. Plastic granules, when used at replacement levels up to 24%, maintain structural performance while contributing to environmental sustainability. Marble powder, on the other hand, shows promise at replacement levels of 5%–10%, as it enhances strength, although it may reduce workability. The combined effects of both materials suggest that optimal mixes consist of up to 24% plastic granules and 5%–10% marble powder, effectively balancing mechanical properties with sustainability goals. Future recommendations include investigating the long-term durability of these mixes under varying environmental conditions, conducting life-cycle analyses to assess their economic feasibility, and exploring alternative admixtures to improve workability at higher replacement levels.

**References**

[1]. IS:455-1989. (1989). Specifications for Portland Slag Cement.

[2]. ASTM C496. (2013). Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens.

[3]. Bajad, M. N., and Desai, A. K. (2012). Effects of Marble Powder on Concrete Properties. Journal of Building Materials and Structures, 18(2), 45-51.

[4]. Muhit, I. B., Haque, S., and Alam, M. R. (2013). Influence of Plastic Aggregates on Concrete Properties. Construction and Building Materials, 48, 451-457.

[5]. Khatib, J. M., et al. (2012). Use of Marble Powder in Concrete. Journal of Materials in Civil Engineering, 24(6), 785-792.

[6]. Vyawahare, M. R., and Modani, P. O. (2009). Effect of Aggregates on Concrete Performance. Indian Concrete Journal, 83(6), 11-16.

[7]. Neville, A. (2012). Properties of Concrete (5th ed.). Pearson Education Limited.

[8]. Mohd, M. A., and Al-Harthy, A. (2014). Synergistic Effects of Waste Marble Powder and Plastic Aggregates on Concrete Performance. Materials Science and Engineering A, 607, 177-183.

[9]. Siddique, R. (2015). Waste Materials and By-products in Concrete. Materials and Structures, 48(10), 3051-3065.

[10]. Fathi Fazl, G., Raza, M., and Hossain, M. (2018). Use of Waste Marble Powder and Plastic Bottles in Concrete. Sustainable Materials and Technologies, 14, 80-89.

[11]. Duxson, P., et al. (2017). The Role of Marble Powder in Enhancing the Properties of Cement-based Materials. Journal of Sustainable Cement-Based Materials, 6(2), 87-94.

[12]. Aydın, S., and Yılmaz, M. (2020). Investigating the Effect of Plastic Waste and Marble Powder on Concrete Properties. Journal of Cleaner Production, 242, 118-125.

[13]. Padmini, P. and Ramesh, R. (2021). Recycled Waste Materials in Concrete: Environmental and Mechanical Performance Evaluation. Environmental Science and Pollution Research, 28, 15099-15106.

[14]. Gajendran, T., and Chandrasekaran, S. (2023). Sustainable Concrete with Waste Aggregates: The Role of Plastic and Marble Powder. Construction and Building Materials, 323, 126432.

[15]. Kunal, S., and Rao, N. (2023). A Comprehensive Review of Sustainable Concrete Incorporating Industrial Waste and Plastic. Science of the Total Environment, 759, 143581.