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Innovative and Eco-Friendly Concrete Forming Sustainable and Resilient Structures Using Waste Marble Powder

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ABSTRACT: The main constituents of the construction industry usually involve building materials which include cement, bricks, steel, fine and coarse aggregates. The majority of concrete production worldwide incorporates sand as a fine aggregate. Since, all of these materials are obtained from finite natural resources, their ongoing depletion will have a negative impact on the environment. In order to minimize environmental harm and preserve natural resources, this study focuses on the recycling of waste materials through the use of waste marble powder (WMP) as a substitute for fine aggregate (sand) in concrete. The sawing and cutting waste generated by the marble industry is substantial and has a negative impact on the environment. Our research concluded that by replacing sand with waste marble powder, mechanical and durability properties of concrete are enhanced thus, making it more resilient and sustainable. WMP was incorporated to concrete in different amounts. For this investigation sand was replaced in four proportions (10%, 20%, 30%, 40% by weight). The grade of concrete is M30, water-to-cement ratio was maintained at 0.45 and 0.28% superplasticizer was added to cement by weight to increase the workability. The experiments employed both destructive testing (DT) and non-destructive testing (NDT). Following a 28-day curing period, at a 40% replacement ratio, the results of the tests for compressive strength, split tensile strength and flexural strength demonstrated improvements of 17.5%, 27% and 35%, respectively. The maximum value of the rebound hammer test exhibited an increment of 15%; the ultrasonic pulse velocity (UPV) indicated an improvement of 3% and the rate of water absorption declined to 45%, 40% and 36% for cubes, cylinders and beams respectively.

KEYWORDS: Sustainable construction material, Waste marble powder, Waste-recycling, High strength concrete, Compressive strength, Flexural strength, Tensile strength, Rebound hammer, Ultrasonic pulse velocity, Water absorption.

I. INTRODUCTION

Concrete has emerged as the most widely employed substance for construction throughout the globe [1] because of its durability and serviceability [2]. Earth's natural resources are declining on account of the construction industry's ever-growing requirement for concrete manufacturing, which is composed of cement, fine aggregates, coarse aggregates and water [3]. Continuous consumption of aggregates is gradually depleting natural resources (fine and coarse aggregates) much more steadily than they are replenished [2]. In the last 30 years, the global cement industry has experienced a dramatic expansion, with production reaching 4.1 billion tons, indicating how rapidly building construction industry has developed since then [4]. Considering the enormous utilization of concrete and skyrocketing consumption of sand and aggregates, manufacturing eco-friendly concrete is indispensable and researchers are actively looking for better alternatives that can improve qualities of concrete with the goal to cater to the rise in demand for construction [5]. In an effort to conserve natural resources, researchers are investigating the use of waste materials in concrete as substitutes of coarse aggregates and natural sand. During manufacturing of marble in industries, waste marble powder (see Figure 1) is produced and owing to environmental concerns, as it increases pollution, its disposal has emerged as one of the most contentious issues [6][7]. During the stages of mining, processing and polishing, about 70% (see Figure 2) of marble is wasted [8]. Since the beginning of time, it has been utilized for flooring and decorative reasons. An estimated 7 million tons of waste marble is produced annually from 30 to 60% of the stones that are excavated and processed [9]. India is the world's third-largest producer of marble powder, accounting for about 10% of the global supply [10]. Land contamination is a result of disposing of waste marble powder in landfills. Reduced soil fertility and poor soil characteristics could also result from a possible marble powder disposal issue [7]. The negative environmental consequences of marble powder [1] makes it crucially important to devise a solution to cut pollution. WMP can be used to fully or partially replace sand in concrete, conserving natural resources while trimming the carbon emissions stemming from the manufacturing of cement [2]. Investigation carried out by [11] revealed that by partially replacing sand with WMP in concrete results are improved due to its fineness quality [12]. Adding waste marble powder to concrete as a partial replacement enhances its workability [13] and concrete's strength qualities can be enhanced by WMP up to a certain point [14].

Waste marble powder is an important and practical choice to be used as a sustainable construction material in the building industry since it enhances the characteristics of concrete while minimizing the consumption quantity of cement and natural (fine and coarse) aggregates. The fundamental objective of this research endeavor is to manufacture innovative, sustainable and eco-friendly concrete by partially replacing sand with waste marble powder at different percentages by weight of sand.

Figure 1: Waste Marble Powder (WMP)

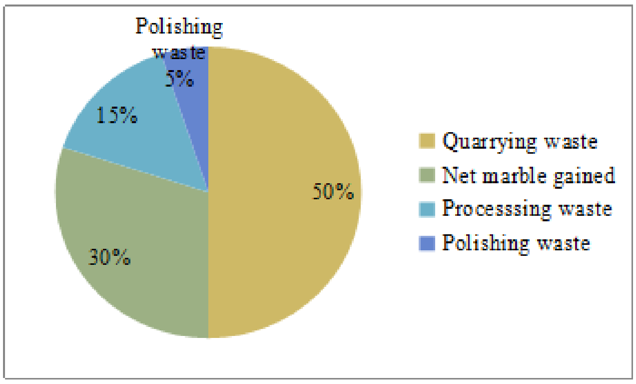

Figure 2: Marble product and waste (% age mined out)[8]

II. OBJECTIVES

The objectives of the research work are as follows:

i) Investigation of strength performance of concrete after 28 days of curing by replacing fine aggregates with Waste Marble Powder at replacement levels of 0%, 10%, 20%, 30% and 40% by destructive testing of concrete.

- Compressive Strength
- Split Tensile Strength
- Flexural Strength

ii) Non-destructive testing of concrete after 28 days of curing at replacement levels of 0%, 10%, 20%, 30% and 40%.

- Rebound Hammer
- Ultrasonic Pulse Velocity (UPV)

iii) Durability Test of concrete mixtures at replacement levels of 0%, 10%, 20%, 30% and 40% for cubes, cylinders and beams.

- Water Absorption

The results of the study will provide the construction industry with valuable insights on how to reduce waste production, improve the performance of concrete and deploy environmentally friendly procedures.

III. LITERATURE REVIEW

The studies of Olutoge et al. states that by incorporating waste marble powder to replace up to 10% by weight of sand in concrete, it is possible to enhance both its tensile and compressive strength. The utilization of marble powder in the production of concrete presents environmental benefits as well. Waste management opportunities are thus showcased, offering potential application in low-traffic roads, stone pitching, earthworks, flexible pavement foundations and smaller-scale concrete works. Following research by Olutoge, Onugba and Ocholi, it was found that concrete's compressive strength improves with the addition of marble powder, provided it is used within an appropriate limit of 15%. Consequently, they concluded that marble powder can indeed serve as a substitute for sand in concrete. Mixtures that contain a concentration of marble powder, specifically less than 15% of Waste Marble Powder (WMP) content, have been found to enhance the mechanical properties of concrete. Additionally, the use of WMP contributes to the conservation of natural sand resources by providing a sustainable method for disposing of waste materials from the construction industry. The mechanical and physical attributes of concrete can be further improved by maintaining a low water-cement ratio [15]. The conclusions drawn from the research conducted by Hebhoub et al. illustrate that the concrete samples, created with the inclusion of marble powder, demonstrated mechanical properties that adhered to the production specifications for concrete. It was found that up to 75% of any given formulation could be composed of marble aggregates as a substitute for natural aggregates, thereby enhancing the concrete's tolerance [16]. Research studies of Valeria Cornialdesi and Giacomo Moriconi found that the substitution of marble powder for sand at a rate of 10% resulted in an enhancement of compressive strength, while maintaining the same level of workability [17]. The investigation led by Demirel Bahar and fellow researchers discovered that, replacement of Waste Marble Powder (WMP) with cement or sand enhances both the fresh and hardened properties of traditional and Self-Compacting Concrete (SCC) and implementation of WMP as a substitute for raw materials sourced from natural resources, like sand and coarse aggregate, results in lower energy consumption and reduced usage of these resources [12]. The exploration carried out by Idress et al. replaced sand with marble powder in amounts of 12.5%, 25% and 50% to produce concrete mixtures and studied impact of marble powder replacements on various factors such as tensile, compressive and flexural strengths, workability and cost were examined and found that the workability was adversely affected by the introduction of WMP at a higher concentration. However, a replacement level of 12.5% resulted in an increased strength, while further substitution led to a decrease in strength, albeit to an acceptable degree. When used in appropriate quantities, marble powder either improved mechanical properties or yielded satisfactory strength results (even at higher percentages). The use of marble powder as a substitute for natural sand can contribute to resolving environmental, economic and ecological issues linked with concrete production, thereby promoting sustainability [18]. Key findings from the study of Basaran et al. research investigations demonstrated that replacing fine aggregates in concrete with marble powder, up to a proportion of 15%, positively influences the compressive strength of the concrete. This advantageous effect ranged from 2% to 26% establishing that marble powder can potentially enhance the compressive strength of concrete by as much as 45% [19]. Ghani et. al. observed notable reductions of 26%, 65%, 93% and 100% at replacement rates of 20%, 40%, 60% and 80% respectively. The incorporation of increasing proportions of marble powder led to a decrease in the overall weight of the concrete, owing to the relatively low density of Waste Marble Powder. This also resulted in an increase in compressive strength up to a 40% substitution of fine aggregate; however, the strength progressively diminishes if the percentage is further increased. A reduction in the permeability of concrete was noted with a higher content of WMP, but a significant surge in permeability was detected at a replacement level of 80%. These researchers advocated for the use of marble powder up to 40% by weight of sand as an alternative material, as excessive usage can weaken the concrete and make it more difficult to manage [14]. Research conducted by Vardhan et al. has indicated that substituting up to 40% of sand with marble waste aggregates results in the optimal increase in compressive strength and reduction in drying shrinkage of concrete mixes. The compressive strength experienced a rise of 20%, while drying shrinkage was reduced by 30%. Experiments were conducted on six different mixtures, each incorporating marble powder at varying percentages ranging from 10 to 60%. These tests evaluated the permeation properties, tensile strength and compressive strength of the concrete after a period of 365 days (about 12 months). X-Ray Diffraction (XRD) and Scanning Electron Microscopy (SEM) investigations were also undertaken. Based on the test outcomes, the addition of Waste Marble Powder (WMP) to concrete was found to enhance its strength and permeability characteristics. A substitution rate of 40% offered the most significant advantages. The findings confirmed that WMP can effectively replace fine aggregate in concrete, thereby augmenting overall performance and promoting consistent progress [20]. Singh & Mehta carried out experiments on mixtures incorporating marble powder as a substitute for 10%, 20%, 30%, 40% and 50% of the fine aggregate. The durability of the geo-polymer concrete was assessed after the first and fourth weeks (7 & 28 days). The findings indicate that the compressive strength is enhanced when Waste Marble Powder (WMP) is used to replace 60% of the fine aggregate. Additionally, both flexural and split tensile strengths experience significant increases, amplifying by 60% and 80% respectively upon replacement [21]. Vigneshpandian et al. research scrutinized the effects of substituting 25%, 50% and 100% of Waste Marble Powder (WMP) on the flexural, tensile and compressive strengths of concrete. The findings suggested that the properties of concrete could be enhanced up to a replacement level of 50%, without compromising its performance [22]. Li et al. conducted a series of tests, including water absorption, drying shrinkage, mini slump cone and carbonation, on a range of mortar mixes formulated with varying mix design volumes and water-cement ratios and the incorporation of marble dust notably amplified the carbonation and water resistances, diminished the shrinkage strain and rate and curtailed the cement content by as much as 33% [23]. The investigation led by Alyamac & Aydin [13] depicted that by replacing up to 40% of sand (by weight) with waste marble powder, yields satisfactory outcomes for compressive strength, slump value, sorptivity and abrasion resistance of concrete. The literature review of the research conducted by Sarkar et al. says that the process of cutting and sawing of marble generates a fine marble dust, which, if relegated to a landfill, can precipitate a myriad of health complications and diminish soil fertility [7]. Research of Sinha et al. [6] has indicated that marble industries frequently discard their waste in verdant and open spaces. This practice could potentially instigate water stagnation problems and escalate soil alkalinity. Consequently, this may lead to issues related to soil fertility and contribute to terrestrial and aquatic pollution. The findings of Maan and Ahed habib demonstrated that the fine-grained nature of marble powder contributes to fostering cohesiveness among particles, even when maintaining a low water-cement ratio and the incorporation of a specific quantity of marble powder in concrete can aid in augmenting its strength and enhancing its microstructural properties [11]. Investigation led by Ali M. Abdullah et al. indicated that the presence of calcium carbonate, a constituent of marble powder, facilitates more efficient particle packing when waste marble powder is incorporated into the mixture [24]. Kanoungo and his fellow researchers designed a mix using fly ash and lime sludge as substitutes for cement, the compressive strength of the prepared mix was determined through compressive strength test. The optimal proportions of cement, fly ash and sludge were found to be 20%, 40% and 40% respectively, significantly reducing the cement content. It was subsequently established that, contingent on the curing technique utilized, the strength of the ideal mix increased by 31% in every case when fly ash and sludge were proportionally substituted for cement confirming the effect of waste materials on the properties of concrete [8]. Topcu et al. found that a marble dust content of 200 Kg/m^3 could enhance the capillarity coefficient when marble dust was employed as a partial substitute for the cement and fly ash binder in Self-Compacting Concrete (SCC) [25].

IV. EXPERIMENTAL SETUP

Components integrated into the concrete, along with the calculations of fineness modulus, specific gravity and moisture content, were calculated and given in Table 1.

- Cement
- Sand
- Coarse Aggregates
- Waste Marble Powder
- Water
- Super plasticizer

A. *Materials Employed*

- ***Cement:*** With reference to the specifications outlined in Bureau of Indian Standard code IS: 269-1976, research was conducted on Ordinary Portland Cement (OPC) 43. Slump test was conducted in compliance with Indian Standard code IS: 1199-1959 and the slump value was determined to be 78mm after ten minutes.
- ***Coarse Aggregate:*** Dolomite, nominally sized at a range of 10mm (minimum) to 20mm (maximum) conforming to the specifications corresponding to the Bureau of Indian Standard code IS: 383-2016.
- ***Fine Aggregate*:** Sand employed was having a fineness modulus of 2.83 conforming to the

specifications as stated by Bureau of Indian Standard code IS: 383-2016 and ASTM C128.

- ***Superplasticizer:*** Shaliplast PCE 200 was added to assist in making concrete more workable.
- **Water:** Potable
- ***Marble powder:*** Powdered marble was obtained from the marble industry.

Table 1: Calculated Fineness modulus, specific gravity, moisture content of cement, coarse aggregate, fine aggregate and waste marble powder

S.No.	Materials Employed	Fineness Modulus	Specific Gravity	Moisture Content
1.	Cement	Less than 2%	3.39	0.7%
2.	Coarse Aggregate	6.25	2.538	2.27%
3.	Fine Aggregate (sand)	2.83	2.08	2.14%
4.	Waste Marble Powder	3.29	2.46	1.01%

Physical characteristics of waste marble powder are given in Table 2 and chemical composition is given in Table 3

Table 2: Physical characteristics of Waste Marble Powder [8]

Color	White
Moisture content	1.01%
Odor	Odorless
Form	Powder
Density	2.80
Specific gravity	2.46

Table 3: Chemical components of Waste Marble Powder [8]

Oxide compounds	Marble powder (Mass %)
SiO_2	28.35
Al_2O_3	0.42
Fe_2O_3	9.70
CaO	40.45
MgO	16.25

B. Concrete Mixtures

For 1m^3 of M30 Grade concrete the quantity of materials required is 332 Kg of cement, 560 Kg of Fine Aggregates, 1213 Kg of Coarse Aggregates, 1.08 Kg of Superplasticizer and 149 liters of water.

Five M30 grade concrete mixtures were formulated in accordance with IS: 1199-1959 and IS: 10262-2019 employing diverse quantities of Waste Marble Powder (WMP). The corresponding mix design calculation is presented in Table 4 below. A consistent water/cement ratio of 0.45 was maintained throughout the laboratory work. Shaliplast PCE 200 was incorporated at a rate of 0.28% of the cement weight. WMP was substituted for sand in the following proportions: 0%, 10%, 20%, 30% and 40%. Table 5, Table 6 and Table 7 display the concrete mixture proportions for cubes, cylinders and beams casting respectively.

Table 4: Mix Design Calculations

Required Quantity	Cement (Kg)	Fine Aggregates (Kg)	Coarse aggregates (Kg)	Water-cement ratio	Super Plasticizer (L)
For 1m^3 of concrete	332	560	1213	0.45	0.996
Mix ratio	1	1.68	3.65		

Table 5: Quantity of material required for cube casting (150 mm x 150 mm x 150 mm)

S. No.	Percentage (%)	Fine aggregates (Kg) Sand	WMP	Cement (Kg)	Coarse Aggregates (Kg)	Water (L)	Super plasticizer (ml)
1.	0%	2.5	0	1.39	4.58	0.62	4.13
2.	10%	2.0	0.25				
3.	20%	2.1	0.50				
4.	30%	1.8	0.75				
5.	40%	1.4	1.00				

Table 6: Quantity of material required for cylinder casting (150 mm x 300 mm)

S. No.	Percentage (%)	Fine aggregates (Kg) Sand	WMP	Cement (Kg)	Coarse Aggregates (Kg)	Water (L)	Super plasticizer (ml)
1.	0%	3.95	0	2.18	7.87	0.98	6.51
2.	10%	3.55	0.395				
3.	20%	3.16	0.79				
4.	30%	2.76	1.185				
5.	40%	2.37	1.58				

Table 7: Quantity of material required for beam casting (100 mm x 100 mm x 500 mm)

S.No.	Percentage (%)	Fine aggregates (Kg) Sand	WMP	Cement (Kg)	Coarse aggregates (Kg)	Water (L)	Super plasticizer (ml)
1.	0%	3.7	0				
2	10 %	3.35	0.37				

3.	20%	2.98	0.74	2.07	6.78	0.93	6.23
4.	30%	2.61	1.11				
5.	40%	2.23	1.49				

V. TESTING

Concrete grade M30 was produced by replacing sand with WMP at ratios of 0%, 10%, 20%, 30% and 40% by sand weight. To represent each percentage (0%, 10%, 20%, 30% and 40%), 30 cubes, 30 cylinders and 30 beams were cast. Six samples (for each %age) were examined and the mean value was determined. On the 28th day of curing, destructive and non-destructive testing of concrete samples was done for assessing compressive strength, splitting tensile strength, flexural strength, rebound hammer, ultrasonic pulse velocity (UPV) and water absorption.
With the application of non-destructive testing, the durability qualities of freshly made concrete were evaluated, while destructive testing assisted in analyzing the mechanical properties of the material of concrete.

A. Destructive Testing

- **Compressive Strength Test**

Following a 28-day curing period, samples were tested for compressive strength in conformity with specifications of IS-456:2000. Cube specimens of 150 mm x 150 mm x 150 mm were used to study the compressive strength. Curing was applied to every sample. Testing was conducted using the compression testing machine. The compression machine had a capacity of 2000 kilo-Newtons (kN).

- ***Split Tensile Strength***

In congruence with the Indian Standards code of practice IS-5816:1999 specifications, cylindrical specimens' (150 mm x 300 mm) tensile strength was assessed after 28 days.

- ***Flexural Strength Test***

Beams measuring 100 mm x 100 mm x 500 mm were evaluated on a flexural strength testing equipment after 28 days of curing. Flexural strength was assessed and evaluated in compliance with Indian standard code IS-516:1999.

B. Non - destructive Testing

- **Rebound hammer test**

Cubes of 150 x 150 mm x 150 mm x 150 mm were subjected to a rebound hammer test or Schimdt hammer test after 28 days of curing, in accordance with IS-13311 Part 2:1992. Nine results were obtained for each cube after testing six cube samples. The average value of all nine values was computed to arrive at the result.

- **Ultrasonic Pulse Velocity test (UPV)**

After twenty-eight days of curing, with the use of a Ultrasonic Pulse Velocity tester the 150mm x 150mm x 150mm size cubes were subjected to an ultrasonic pulse velocity test. Before being affixed on the cubes' faces, the transmitter and receiver were covered in gel. The tester tracked velocity in meters per second (m/s) for all cube percentages. The technique used was direct transmission with opposing faces in accordance with the Indian Standards Code of Practice IS-13311:1992.

C. Durability Test

- **Water Absorption Test**

Following a curing period of 28 days, weight of cube, cylinder and beam specimens were ascertained under dry conditions. The weights were instrumental in calculating the specimens' weight variation.
The formula used for water absorption:

$$\textit{Water absorption (\%)} = [(B-A)/A] \times 100$$

where, A = dry weight, B = weight after being submerged in water for 28 days.
The water absorption test was conducted in compliance with IS-1124:1974, method of test for determination of water absorption of concrete.
All the tests were carried under controlled environment and apart from above listed Indian Standard Codes, code IS-516:1959, ASTM C293 and ASTM C128 were religiously followed for the execution of tests.

VI. RESULTS AND DISCUSSION

A. Results of Destructive Tests

- ***Compressive Strength Test***

Table 8 gives an overview of the measured compressive strengths of the concrete for various WMP ratios. The proportion of marble powder replacement initiates a rapid increase in compressive strength. The results indicate that the combination with the highest compressive strength was attained at a replacement ratio of 40%. At the 28-day curing period, the compressive strengths were 30.17 MPa, 31.32 MPa, 32.14 MPa, 34.32 MPa and 35.45 MPa for 0%, 10%, 20%, 30% and 40%, respectively.

Table 8: Results of compressive strength test after 28 days

Serial No.	Cubes (150×150×150) (mm)	Peak Load (kN)	Compressive strength (MPa)
1.	0%	676.5	30.17
2.	10%	678.9	31.32
3.	20%	681.3	32.14
4.	30%	772.3	34.32
5.	40%	797.8	35.45

- ***Splitting Tensile Strength***

As demonstrated by Table 9, strength increases to its maximum peak value of 2.48 N/mm^2 after 28 days of curing when 40% of the sand is replaced with WMP.

Table 9: Results of Split Tensile Strength after 28 days

Serial No.	Cylinder (300mm×150mm)	Peak load, P (kN)	Compressive strength (MPa)	Tensile strength (in N/mm^2)
1.	0%	138.2	7.82	1.95
2.	10%	144.7	8.18	2.05
3.	20%	148.9	8.28	2.09
4.	30%	164.5	9.30	2.32
5.	40%	175.3	9.92	2.48

- ***Flexural Strength***

Final outcomes of flexural strength test are shown in Table 10. The highest flexural strength was found in an amalgamation that included 40% WMP, an increment of 35%. Following a 28-day curing period, the values for 0%, 10%, 20%, 30% and 40% were 0.68 N/mm^2, 0.74 N/mm^2, 0.78 N/mm^2, 0.85 N/mm^2 and 0.92 N/mm^2 respectively.

Table 10: Results of Flexural Strength Test after 28 days

S. No.	Beam (500mm× 100×100)	Peak load (P) (kN)	Flexural strength (MPa)	Distance between the line of failure and nearest support 'a'
1.	0%	1.70	0.68	160 mm
2.	10%	1.87	0.74	130 mm
3.	20%	2.30	0.78	170 mm
4.	30%	2.55	0.85	155 mm
5.	40%	2.85	0.92	195 mm

B. Results of Non-destructive Tests

- ***Rebound Hammer***

Mixture yielded the highest value for the rebound hammer test was achieved at 40% substitution of sand with WMP. Table 11 below illustrate the test's results.

Table 11: Values of Rebound Hammer Test

Serial No.	Cube	Mean value (N/mm^2)
1.	0%	37.37
2.	10%	40.81
3.	20%	41.37
4.	30%	42.46
5.	40%	42.96

- ***Ultrasonic Pulse Velocity Test (UPV)***

Table 12 convey a schematic representation of the UPV test of the concrete after 28 days of the cure process. As the WMP proportion rises, velocity rises as well. Due to the waste marble powder's filler effect, the greatest velocity is attained when sand is replaced with it by 40%.

Table 12: Values of UPV test after 28 days

Serial No.	Cube	Velocity (Km/hr)
1.	0%	4573
2.	10%	4607
3.	20%	4658
4.	30%	4693
5.	40%	4713

C. Results of Durability Test

- ***Water Absorption Test***

As proportion of WMP in concrete mixture rises, it can be deduced from Table 13, Table 14 and Table 15 that the structure becomes less porous, resulting in a decrease in water absorption. As a result, water cannot damage the structure or flow within signifies low permeability.

- ***Cubes***

Table 13: Water absorption test results of cubes

Serial No.	Percentages (%)	Saturated dry weight (Kg)	Saturated wet weight (Kg)	Water absorption (%) {Formula: dry wt. – wet wt. / dry wt.} × 100
1.	0%	8.12 Kg	8.13 Kg	0.35
2.	10%	8.22 Kg	8.28 Kg	0.33
3.	20%	8.22 Kg	8.27 Kg	0.29
4.	30%	8.27 Kg	8.31 Kg	0.23
5.	40%	8.36 Kg	8.38 Kg	0.19

- ***Cylinders***

Table 14: Water absorption test results of cylinders

Serial No.	Percentages (%)	Saturated dry weight (Kg)	Saturated wet weight (Kg)	Water absorption (%) {Formula: dry wt. – wet wt. / dry wt.} × 100
1.	0%	12.79 Kg	12.87 Kg	0.68
2.	10%	12.29 Kg	12.38 Kg	0.61
3.	20%	12.54 Kg	12.65 Kg	0.53
4.	30%	12.77 Kg	12.83 Kg	0.48
5.	40%	12.94 Kg	13.01 Kg	0.41

- ***Beams***

Table 15: Water Absorption Test Result of Beams

Serial No.	Percentages (%)	Saturated dry weight (Kg)	Saturated wet weight (Kg)	Water absorption (%) {Formula: dry wt. – wet wt. / dry wt.} × 100
1.	0%	12.15 Kg	12.27 Kg	0.98
2.	10%	12.40 Kg	12.50 Kg	0.97
3.	20%	12.35 Kg	12.47 Kg	0.81
4.	30%	12.49 Kg	12.63 Kg	0.79
5.	40%	12.68 Kg	12.76 Kg	0.63

VII. CONCLUSION

Considering above study's findings following developments are established:

- By incorporating Waste Marble Powder concrete's compressive strength boosted by 17.5% at 40% replacement of fine aggregates and reached value of 35.45 MPa. Due to marble powder's enhanced fineness, it was able to occupy more pores, which boosted concrete's compressive strength.
- Employing Waste Marble Powder in designing concrete improved the Split tensile strength of concrete. At substitution level of 40%, highest value turns out to be 2.48 N/mm^2, experiencing a 27% rise.
- Flexural strength of concrete witnessed the maximum gain of 35%. The highest strength recorded is 0.92 MPa at 40% replacement of fine aggregates (sand) with Waste Marble Powder.
- A positive correlation was observed between rebound hammer measurements and compressive strength. Concrete mix at 10% replacement level gained value of 37.37 N/mm^2 and experienced a significant rise at replacement level of 40% of fine aggregates with Waste Marble powder, recording highest value of 42.96 N/mm^2, i.e. an increment of 15%.
- Sound results of Ultrasonic Pulse Velocity test signified better quality and structural integrity of concrete as the velocity increased from 4573 Kilometer per hour (km/hr) to 4713 Kilometer per hour (km/hr) at 0% and 40% replacement level respectively, showing a gain of 3%.
- At 40% replacement, water absorption rate falls by 45% for cubes, 40% for cylinders and 36% for beams. Decline in Water Absorption level in concrete testifies to its enhanced durability. This corresponds to the filler action of Waste Marble Powder thus; it can be concluded using raising marble powder content significantly reduces the porous nature of the concrete.

VIII. FUTURE SCOPE AND LIMITATIONS

- Concrete's mechanical and durability characterstics are improved with the incorporation of waste marble powder. It can be widely used as sustainable construction material and this would solve the concerns regarding WMP landfill disposal.
- Considering the high fineness of waste marble powder, it was helpful in maintaining high cohesion with the constituent parts of concrete when combined with a super-plasticizer.
- Incorporation of waste marble powder in concrete cuts the quantity of sand used and will help in producing eco-concrete.
- Using waste marble powder in the building industry may be a cost-effective option on account of free availability and an easily procurable resource.
- More research in this domain is needed and this could only be practicable through comprehensive research and an understanding in this area of expertise.
- In order to facilitate the use of WMP as an accessible alternative to fine aggregates in concrete, this endeavor requires support from the government at all levels.
- Standard guidelines and guidance are needed to help engineers and professionals in the construction and environmental sectors recognize the use of WMP.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest between them and with any third party.

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