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ANALYZING THE RELATIONSHIP BETWEEN STRENGTH AND MICROSTRUCTURE IN BINARY CEMENT BLENDS WITH THE ADDITION OF WASTE MARBLE POWDER

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ABSTRACT

The marble industry generates stone slurry and solid waste, typically disposed of improperly in open areas, resulting in land contamination. The deposition of marble waste represents a significant environmental challenge in this sector. Waste materials in concrete. The primary focus of this study is on the partial replacement of cement with marble powder (0%, 5%, 10%, and 15% by weight) to produce M40 grade concrete with a water-cement ratio of 0.45. The study assessed the compressive, flexural, and split tensile strengths of the concrete at 7, 14, and 28 days. The findings reveal that initially, a 5% substitution of cement with marble dust powder led to a remarkable strength improvement of up to 25% for both 7 and 28 days of curing. However, as the substitution of marble dust increased, the strength exhibited an irregular decline in all the concrete mixtures. Microstructural analyses indicated an enhanced pore structure due to the filling effect of marble powder at lower substitution levels. The experimental findings suggest the judicious use of marble powder for enhancing concrete strength. Consequently, incorporating marble powder into concrete can mitigate its adverse environmental impact and facilitate the production of economically advantageous green concrete.

I. INTRODUCTION

In recent years, the construction industry has increasingly focused on sustainable and environmentally friendly practices to minimize the ecological footprint of building materials. One promising approach involves the incorporation of waste materials from industrial processes into construction materials, thereby mitigating environmental hazards and promoting resource efficiency. Among these waste materials, waste marble powder, generated as a byproduct of the marble industry, has emerged as a potential supplementary cementitious material. The improper disposal of waste marble powder poses significant environmental challenges, including land contamination and ecological degradation. However, recent research has highlighted the possibility of utilizing this waste material as an additive in cement blends to enhance the performance and sustainability of concrete.

Understanding the intricate relationship between the mechanical strength and microstructural characteristics of cementitious materials enriched with waste marble powder is critical for optimizing its utilization in construction applications. Through comprehensive analysis and experimentation, this study aims to investigate the effects of incorporating waste marble powder into binary cement blends. The investigation will focus on assessing the resulting changes in the strength properties and microstructural features of the cementitious matrix, thereby providing valuable insights into the feasibility and potential benefits of utilizing waste marble powder in sustainable construction practices. By establishing a clear understanding of the interplay between strength and microstructure in these cement blends, this research contributes to the development of eco-friendly and high-performance construction materials.

India stands as one of the foremost global producers of marble, with Rajasthan assuming a significant role in this industry. The production process, which involves mining, cutting, and sawing of marble, results in the generation of substantial hazardous wastes. These wastes primarily include solid waste or marble dust and stone slurry. Solid waste is a byproduct of mining operations and on-site production, while slurry emerges from the amalgamation of solid waste with water during marble processing stages, such as sawing and polishing. The accumulation of this waste in open spaces not only poses a threat to the local ecosystem but also to the

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environmental balance. The dried waste marble powder slurry poses a considerable risk to the surrounding habitat.

Furthermore, the incorporation of Waste Marble Powder (WMP) in construction materials has exhibited several beneficial effects. WMP not only enhances the durability of concrete but also mitigates the overall economic costs linked with material production. Although reduced workability and expansion have been noted in mixtures containing WMP, the utilization of plasticizers in conjunction with WMP has demonstrated an increase in strength and sulphate resistance, particularly when sand is substituted by 35% to 50% of WMP. To achieve a significant cost-saving of 9.07%, it has been recommended to replace 15% of the marble powder, leading to an approximate 1.05% reduction in energy consumption. Moreover, WMP has proven effective in reducing setting time compared to brick powder. When used within specified limits (up to 20% for fine aggregates and up to 10% for brick powder as fine aggregate replacement), no detrimental impact on the fresh and hardening properties of concrete has been observed. Notably, mixtures containing WMP have demonstrated improved self-compacting properties in terms of slump flow and flow time. Additionally, cement substitution with WMP has been found to reduce both the plastic viscosity and the yield stress.

Objectives of Research work

1. The first objective of this study is to assess the distinct physical and chemical attributes of Marble Powder.
2. The second aim is to employ SEM and EDX techniques to analyze the microstructure characteristics of Marble Powder.
3. To evaluate the feasibility and Optimum proportion of Marble Powder as a partial cement substitute.

This research project focuses on M35 grade concrete and aims to replace some of the cement with marble dust. As a partial substitute for cement, the prepared mixtures contain 0%, 5%, 10%, and 15% marble dust. The concrete mix that results is used to make cubes (Fig. 3), cylinders (Fig. 5), and beams (Fig. 6). The concrete samples are then immersed in water for 7, 14, and 28 days.

II. MATERIALS USED

Cement

The manufacturing process of cement involves subjecting a mixture of limestone, clay, and other minerals to extreme temperatures of up to 1500 degrees Celsius within a kiln. This high-temperature treatment results in the formation of a substance known as clinker, which is subsequently finely ground into powder form. To regulate the setting time of the cement, gypsum is introduced into the powdered mixture. In India, the specification for 43 Grade Ordinary Portland Cement (OPC) is detailed in the Indian Standard IS 8112: 1989 under the title "Specification for 43 Grade Ordinary Portland Cement."

Table 1: Physical Properties of cement

Details	Result
Initial setting time (minutes)	70
Specific Gravity	3.14
Consistency of cement	28%
Final Setting Time (minutes)	390
Color	Grey
Fineness	3%

Marble Powder Marble powder is a fine, white or off-white, powdery substance that is a byproduct of the marble industry. It is typically produced during the cutting, shaping, and polishing of marble, and consists of finely ground particles of marble. Marble powder is known for its high calcium carbonate content and is often utilized in various applications, including construction, as a filler material in concrete and cement-based products.

Table 2: Physical Composition of Marble Powder

Details	Results
Fineness Modulus	2.18
Density (Kg/m3)	1218
Moisture Content (%)	1.73
Particles Size	Passed through 90mm Sieve
Specific Gravity	2.30

Table 3: Chemical Composition of Marble Powder

S.No.	Component	MP(%)
1	SiO_2	0.79
2	Al_2O_3	0.21
3	Fe_2O_3	0.06
4	CaO	55.42
5	MgO	0.25
6	SO_3	0.24
7	K_2O	0.02
8	Na_2O	0.10
9	TiO_2	0.00
10	Mn_2O_3	0.00
11	Cl	0.07

Fig 1: Particle size Distribution of Marble Powder

Coarse Aggregate

In India, the IS code used for coarse aggregate is IS 383: 1970, titled "Specification for Coarse and Fine Aggregates from Natural Sources for Concrete. Coarse aggregate consists of larger particles, typically ranging from about 3/16 inch (4.75 mm) to 2 inches (50 mm) in size.

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Table 4: Coarse Aggregate (Physical characteristics)

Details	Result
Water Absorption (%)	1.45
Density (Kg/m3)	1670
Specific Gravity	2.65
Fineness Modulus (%)	6.45
Particle Size	Retained on 4.75mm Sieve

Fine Aggregate

IS 383:2016[25] is the most commonly used IS code in India for conducting sieve analysis of fine aggregates. Our fine aggregate analysis included determining parameters such as moisture content, silt content, fineness modulus, and specific gravity using sieve analysis. Table 2 provides a comprehensive summary of the experimental results obtained, and Fig 1 shows a Sieve analysis chart:

Table 5: Fine Aggregate (Physical Properties)

Details	Result
Water Absorption (%)	1.10
Density (Kg/m3)	1646
Specific Gravity	2.7
Fineness Modulus	2.313
Particle Size	Passed on 4.75 mm Sieve

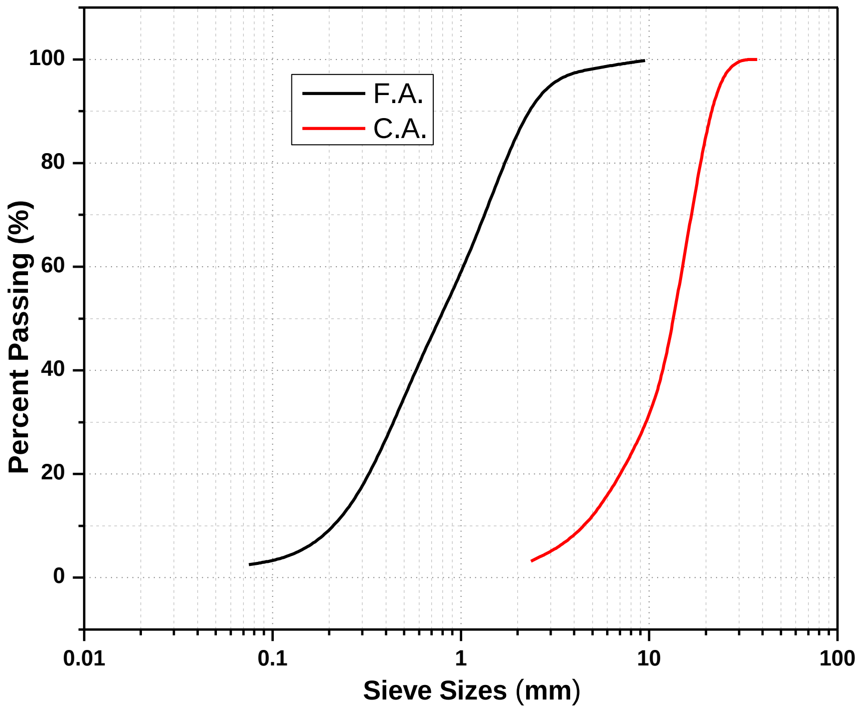

Fig 2: Sieve analysis of Fine aggregate and Coarse aggregate

III. METHODOLOGY

In this study, cement (OPC 43 Grade) is used for concrete preparation. Zone 2 was assigned to the sand. The mixture contained coarse aggregates ranging in size from 10 to 20 mm. Locally available drinking water was used in this study. WMP was obtained as sludge from marble processing industries and dried for 72 hours to produce a fine powder. Table 2 shows the physical properties of marble powder.

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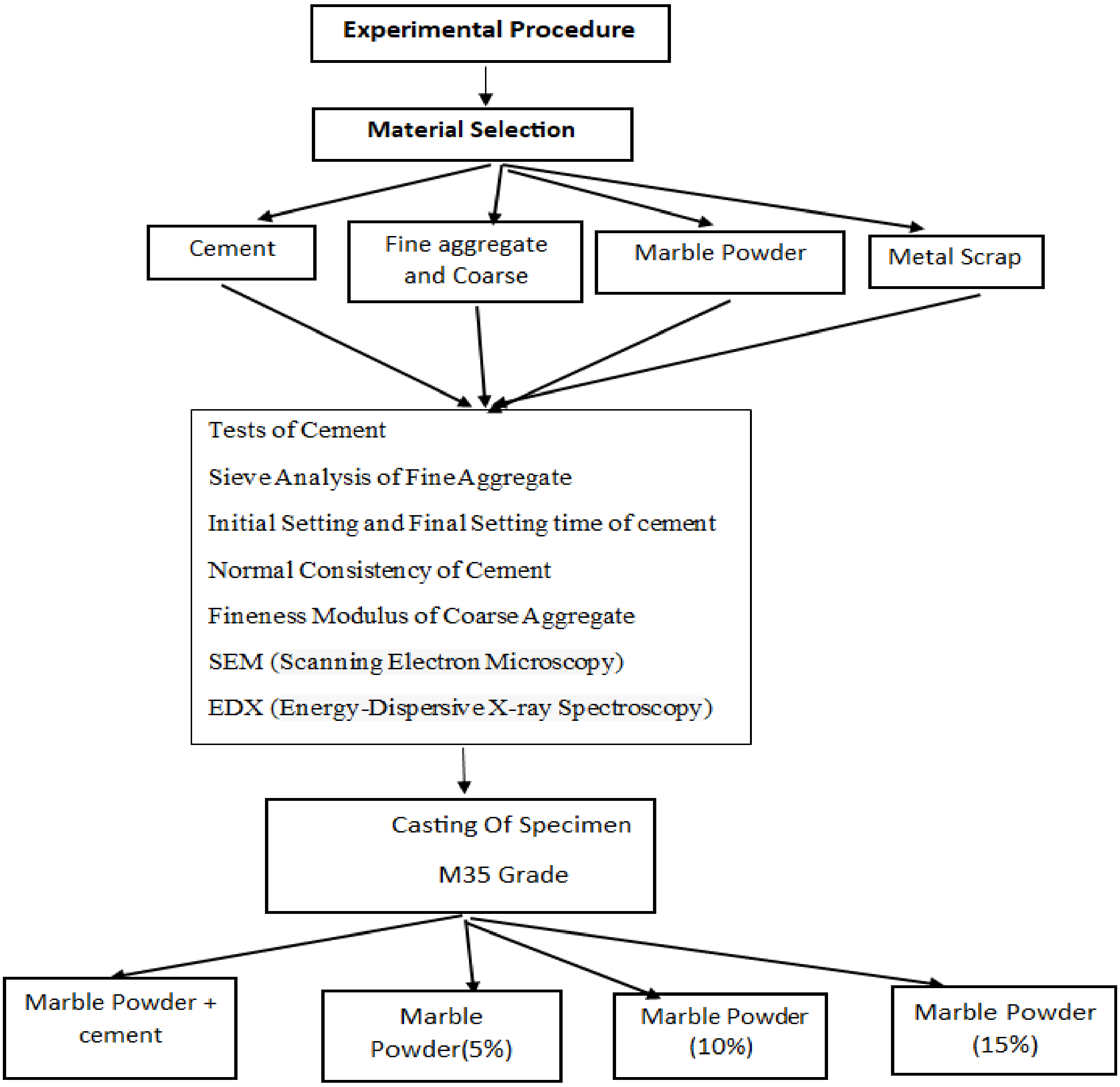
Fig 3: Specimen of cubes

Fig 4: Specimen of Beams

Table 6: Mix design and proportions in (Kg/m3

Mix	Mix Designation	Water	Cement	Fine Aggre.	Coarse Aggreg.	Marble Powder
M 1	OPC 43 100%	157.6	394	714.98	1157.82	0
M 5	OPC 43-95%, MP 5%	157.6	374.3	714.98	1157.82	19.7
M 10	OPC 43-90%, MP10%	157.6	354.6	714.98	1157.82	39.4
M 15	OPC 43-85%, MP 15%	157.6	334.9	714.98	1157.82	59.1



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IV. RESULTS AND DISCUSSION

Compressive Strength Test

For sample preparation, testing methods, and acceptance criteria for measuring the compressive strength of concrete cubes, the guidelines provided in IS 516:1959[28] were followed. The compressive strength of the samples with varying percentages of waste marble powder (WMP) replacing the cement is shown in Figure 7. The compressive strength of the concrete increased up to a 10.0% replacement of WMP before decreasing gradually as the percentage of marble powder increased. Samples with 5.0% and 10.0% WMP as a replacement for cement showed strength improvements of 10% and 2.0% after 7 days, and 9.0% and 3.0% after 28 days, respectively, when compared to standard concrete. In contrast to the control mix, specimens containing 15.0% WMP as a replacement for cement demonstrated a 5% reduction in strength after 7 days and a 12% reduction after 28 days.

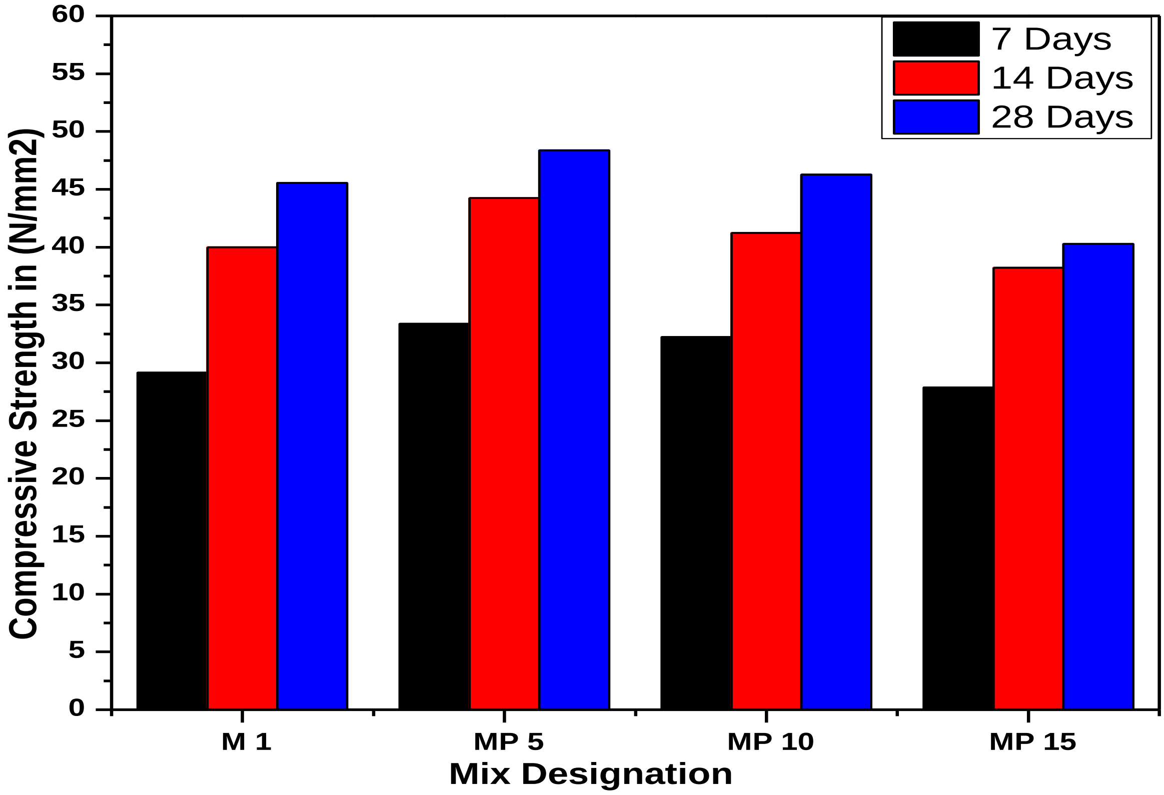

Fig 5: Compressive Strength of Marble Powder

Split tensile strength Test

The standard code used in India to determine the split tensile strength of concrete cylinders is IS 5816:1999[29]. This code provides guidelines for measuring the split tensile strength of concrete. Figure 6 illustrates the split tensile strength of concrete samples with varying percentages (0%, 5%, 10%, and 15%) of waste marble powder (WMP) replacing cement. Initially, the split tensile strength increased by 10.0% when 10.0% of cement was substituted with marble powder, but it gradually decreased as the percentage of marble powder increased. Compared to the control mixture, replacing cement with 5% waste marble powder (WMP) led to a 7% strength improvement after 7 days and an 18% improvement after 28 days. Similarly, substituting 10% WMP for cement resulted in a 4% increase in strength after 7 days and a 6% increase after 28 days. However, when compared to the control mixture, the samples with 15.0% WMP showed a 10% decrease in strength after 7 days and a 10% decrease after 28 days.

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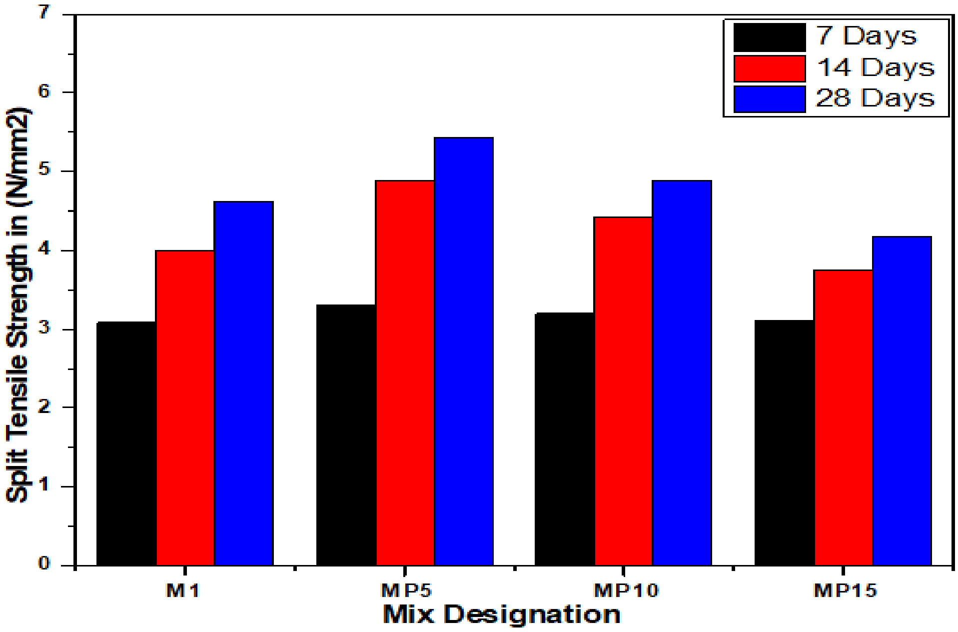

Fig 6: Split Tensile Strength of Marble Powder

Flexural strength Test

In India, beam flexural strength is typically determined using the codes IS 456:2000 and IS 516:1959[30]. The researcher examined concrete specimens by replacing various percentages of cement with waste Marble powder (WMP) ranging from 0% to 5%, 10%, and 15% in a study. The results of the analysis revealed distinct patterns in flexural strength. The flexural strength of the specimens increased initially when the cement was partially replaced with waste marble powder (WMP) at a maximum substitution level of 10.0%, reaching its maximum value at a 5.0% WMP substitution. In comparison to the control mix, when the cement was partially replaced with waste marble powder (WMP) at a maximum substitution level of 10.0%, the flexural strength of the specimens increased initially, reaching its maximum value at a 5.0% WMP substitution after 7 days and a 10% increase after 28 days. Figure 8 shows that the increase was 4.0% at 7 days and 3.0% at 28 days for specimens with a 10.0% cement replacement. However, specimens with a 15.0% WMP substitution for cement showed an 18% decrease in strength at 7 days and a 20% decrease at 28 days.

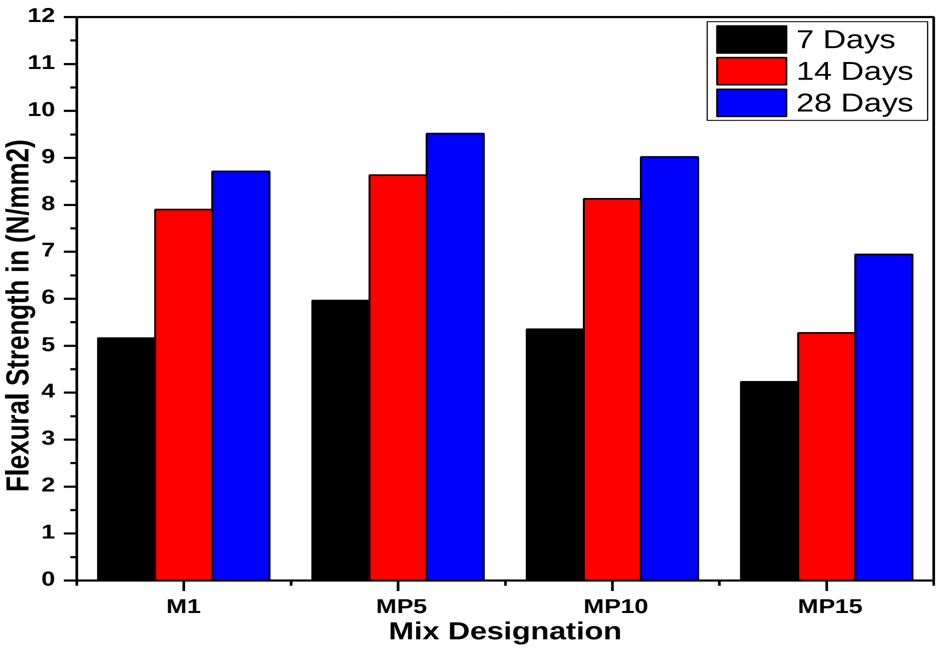

Fig 7: Flexural Strength of Marble Powder

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Microstructure analysis of Marble Powder

The impact of a uniform dispersion of WMP (a calcium-rich source) in cementitious concrete is demonstrated by EDX (Energy dispersive X-ray) analysis. As shown in Fig.2 (d), the presence of silicon, along with a significant concentration of calcium, greatly contributes to the formation of concrete. Scanning Electron Microscopy (SEM) was used to examine the morphological properties of concrete composites and establish their relationship with concrete compressive strength. The analysis results show that there is a strong affinity between Marble Powder and cement, which effectively promotes the early stages of ettringite formation and subsequent growth. The micrographs in Figs. 2(a), 2(b), and 2(c) support this observation.

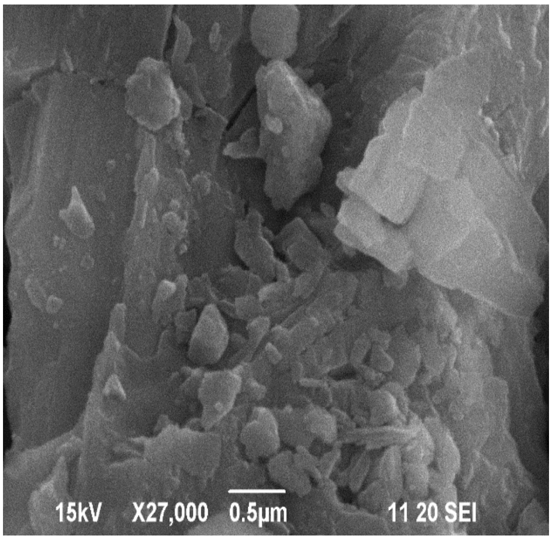

Fig 8: **(a)**SEM Of Marble Powder X27000

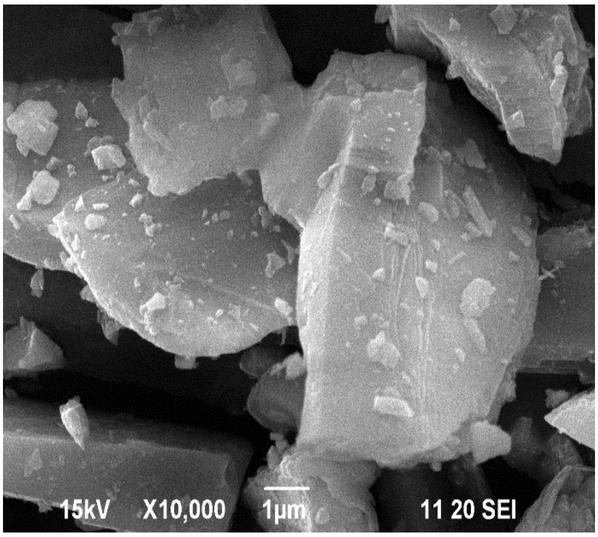

Fig 8: (b) SEM of Marble Powder X10000

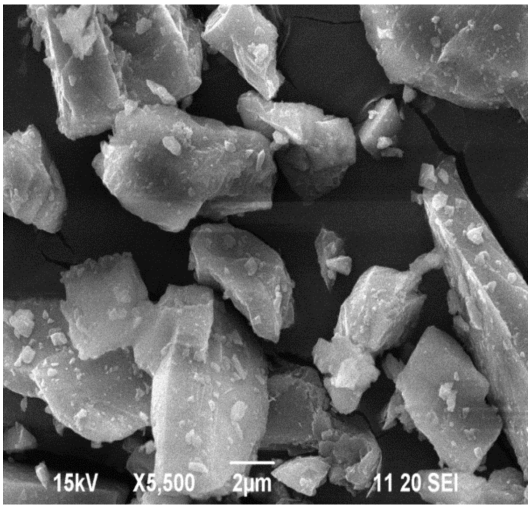

Fig 8:(c) SEM of Marble Powder X5500

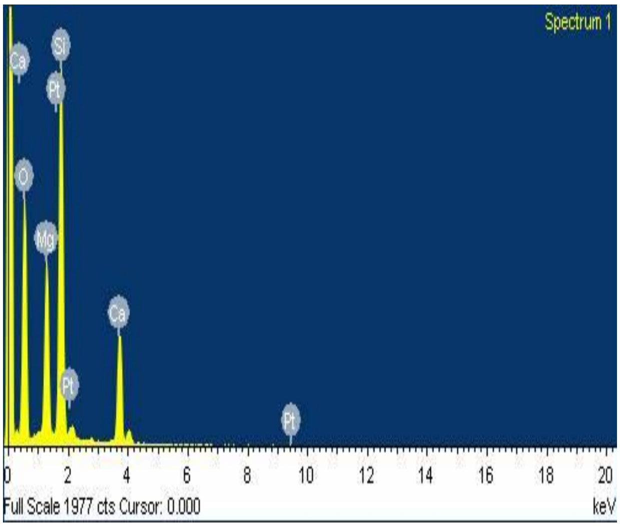

Fig 8: (d) EDX analysis of Marble Powder

V. CONCLUSION

1. Incorporating marble powder into concrete had a positive impact on its mechanical characteristics. Following a 28-day period, the replacement of 5% of cement with marble dust yielded a notable 9% increase in compressive strength. In contrast, substituting 10% of the cement resulted in a modest 3% enhancement, but a further increase in marble content led to a decrease in compressive strength.

2. The introduction of marble powder into concrete brought about enhancements in its mechanical properties. After 28 days, substituting 5% of the cement with marble powder increased Split Tensile strength by 21%. Similarly, replacing 10% of the cement with marble powder resulted in a 16% improvement, and a 15% replacement led to a 4% increase in split tensile strength. However, using higher proportions of marble powder resulted in a reduction in Split Tensile strength.

3. The inclusion of marble powder in concrete contributed to the enhancement of its mechanical properties. Following 28 days, the replacement of 5% of the cement with marble powder resulted in a substantial 10% increase in Split Tensile strength. Likewise, a 10% substitution yielded a minor 3% improvement, while replacing 15% of the cement with marble powder caused an 18% reduction in Flexural strength. Nevertheless, increasing the amount of marble powder led to a decline in Flexural strength

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