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Experimental Exploration of the Impact of Metal Scrap Inclusion in Concrete, Based on Marble Dust, As A Replacement for Cement

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Abstract

In the contemporary age, concrete is synonymous with strength and longevity. The use of cement and its production is a significant contributor to environmental pollution. To address these challenges, industrial waste materials are frequently employed as partial replacements for cement in concrete construction, reducing the carbon footprint and enhancing structural integrity. This study focused on M35 grade concrete mixes, where marble dust was incorporated at levels of 0%, 5%, 10%, 15%, and 20%, in combination with varying steel wire ratios. These mixes were tested for their mechanical properties at 7, 14 and 28 days. The research findings highlight that the combination of ,75% metal scrap and a 10% replacement of marble dust with cement produced the highest mechanical strength compared to conventional concrete and other ratios. Notably, increasing these proportions beyond the specified levels resulted in a substantial decrease in strength. The results indicate that the inclusion of a specific amount of marble dust with steel fiber improved the compactness and interlocking of aggregate particles, resulting in greater durability compared to ordinary cement concrete**.** The study assessed key mechanical properties such as compressive strength, flexural strength, and split tensile strength, along with considerations of workability and durability.

Introduction

In the realm of modern construction practices, concrete has earned an eminent reputation as a material synonymous with strength, versatility, and durability. Cement, a primary component of conventional concrete, is, however, a double-edged sword. While it provides the necessary binding agent for concrete, its production is a leading contributor to environmental pollution. The ever-increasing demand for construction materials has intensified the need for sustainable alternatives to reduce the ecological footprint associated with traditional cement production.

In response to these environmental concerns, the construction industry has been increasingly drawn to innovative solutions that not only enhance the mechanical properties of concrete but also mitigate its adverse environmental impact. One such solution involves the incorporation of waste materials as partial or complete replacements for cement, reducing the carbon emissions associated with its production. Among the materials gaining attention for their potential in this context is marble dust, a byproduct of marble processing, which, when repurposed, can serve as a cement substitute.

This research embarks on an experimental journey, investigating the effects of integrating metal scrap, a readily available industrial waste material, into concrete compositions that primarily rely on marble dust as a cement replacement. The rationale behind this exploration lies in the synergy of two waste materials: metal scrap, which often finds itself underutilized and in need of responsible disposal, and marble dust, which can provide valuable sustainability benefits. Together, they represent a potential avenue for improving the mechanical properties of concrete while simultaneously contributing to the reduction of waste and environmental pollution.

The primary objective of this study is to scrutinize the mechanical properties of concrete compositions with metal scrap and marble dust as key components. By examining the compressive strength, flexural strength, and split tensile strength, among other critical parameters, this research aims to shed light on the feasibility and potential advantages of this innovative composite material. As a result, this study will provide valuable insights into the possibility of creating more sustainable and environmentally friendly construction practices that rely less on traditional cement and more on recycled materials, all while maintaining or enhancing the structural integrity of concrete.

Objectives of study

1. To determine the different Physical and chemical characteristics of Marble Powder and Metal Scrap.
2. To evaluate the feasibility and Optimum proportion of waste metal scrap as a reinforcing material and the incorporation of marble powder as a partial substitute for cement.
3. Enabling the construction sector to align more closely with environmental concerns through the partial substitution of cement with Marble Dust.
4. Incorporating small steel wire fragments to achieve optimal strength in concrete.

Materials used

Metal Scrap

Steel fiber-reinforced concrete (SFRC) is a composite material made up of cement, sand, coarse aggregates, and discrete discontinuous steel fibres . Only when the steel fibre is broken or pulled out of the cement matrix does SFRC fail in tension. The aspect ratio, type of fibre, fibre volume, and aggregate size all have an impact on the mechanical properties of SRFC.. Steel fibres have a positive effect on the mechanical properties of concrete, but they have a negative effect on workability. Slump test concrete workability decreases proportionally to the fraction of waste steel scrap. Steel scraps are waste materials and industrial products produced on a lathe. These waste materials have no scrap value and are not reused properly. This type of waste can be used effectively in reinforced concrete . The physical properties of steel scrap provide additional reinforcement to the concrete, resulting in increased tensile strength. The quantity with an increase in population and industrialization, the amount of waste fibres produced by various metal industries will increase.

Marble Powder

Marble powder, also known as marble dust, is a fine powder made from the grinding of marble rocks. It is typically a waste product produced during the cutting and polishing of marble for various applications, such as in the construction and sculpture industries. The process of obtaining marble stones involves extracting metamorphic rocks and then subjecting them to polishing, cutting, and shaping. This leads to the production of marble dust as a byproduct, as a portion of the stones is transformed into fine particles. India is the third-largest country in the world for producing marble stones. Table1 shows the chemical properties of marble powder and Fig 1 shows particle size distribution of marble powder.

Table 1 Chemical Composition of Marble Dust

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

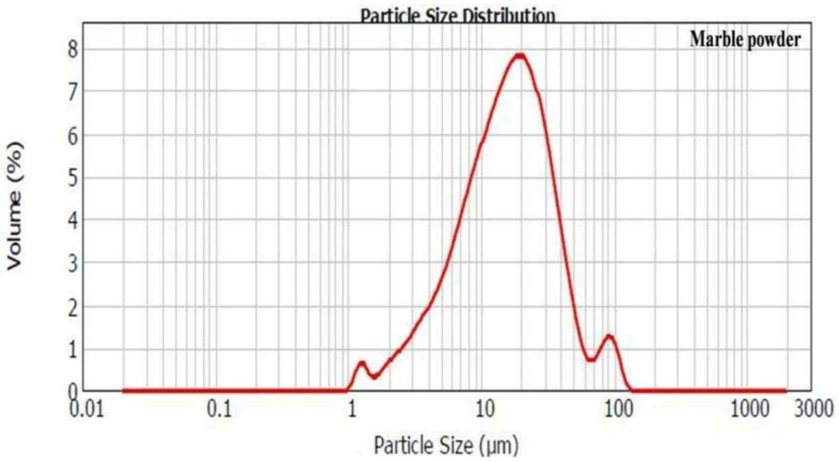

Fig. 1 Particle size Distribution of Marble Powder

Cement

Cement is a fundamental construction material that plays a vital role in the building and infrastructure industry. It is a key component in the production of concrete, mortar, and various construction products. IS 8112:2013[18] is the most common IS code for Ordinary Portland Cement (OPC) 43 in India. The requirements for OPC 43 grade cement are specified in this code, including its composition, physical properties, and testing methods. In this study, OPC 43 grade cement was used, and its physical properties are listed in table 2 below.

Table 2 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%

Coarse Aggregate

Sieve analysis is commonly used in India to examine coarse aggregates in accordance with the IS code IS 383:2016. Coarse aggregate is a fundamental construction material used in the production of concrete and other construction products. It is one of the two main types of aggregates used in concrete. Coarse aggregate refers to the portion of the aggregate that remains after passing through a sieve with a 4.75mm opening. This category includes materials like boulders, gravel, and cylinders. The physical characteristics and test results of the coarse aggregate used in this research study, specifically of sizes 20 mm and 10 mm, are provided in Table 3.

Table 3 Coarse Aggregate (Physical characteristics)

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

Fine Aggregate

Sieve analysis is commonly used in India to examine fine aggregates in accordance with the IS code IS 383:2016 Fine aggregate is a key component in the production of concrete and other construction materials. It is one of the two primary types of aggregates used in concrete, with the other being coarse aggregate. Fine aggregate, typically consisting of sand, serves several important functions in construction. Table 4 shows the physical properties of Fine aggregate.

Table 4 Fine Aggregate (Physical Properties)

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

Water

In conducting the study municipal water was used in mixing and curing concrete. The amount of water that comes into contact with cement affects the slump of concrete and is determined by the water to cement ratio. Water cement ratios for fibrous mixtures must be carefully controlled, and ratios in the 0.35 to 0.50 range are typical**.**

Methodology

For the preparation of concrete in this study, OPC 43 Grade cement was used. The mixture contained Zone 2 sand with a specific gravity of 2.7 and a fineness modulus of 2.313, as well as coarse aggregates with a specific gravity of 2.65 ranging in size from 10 to 20 mm. Locally available drinking water was used, and waste marble powder (WMP) from marble processing industries was dried for 72 hours to create a fine powder. Table 1 lists the physical properties of marble powder. Metal scraps from lathe operations, which are typically considered waste, were used in the reinforced concrete to increase tensile strength and provide additional reinforcement. The design mix used was

M35, according to IS Code10262, with a cement: fine aggregates. Fig 2 and Fig 4 shows the compressive strength test of cubes and split tensile strength of cylinder respectively.

Table 5 Concrete mix design and proportions of Conventional concrete

Materials	**weight (kg/m3)**
Waste Metal scrap volume	0%
Cement	394
Coarse aggregate	1157.82
Water	157.6
Fine aggregate	714.98
Super Plasticizer	3.152

Fig.2 compressive strength of cube

Fig.3 split tensile strength of cylinder

Mix	**Mix Designation**	**Water (Kg/m3)**	**Cement (Kg/m3)**	**Fine Aggregate (Kg/m3)**	**Coarse Aggregate (Kg/m3)**	**Marble Powder (Kg/m3)**	**Metal Scrap (Kg/m3)**
0.50%	**Metal Scrap Addition**						
MP (5+.5)	OPC 43 -95%, MP 5%, MS 0.5%	157.6	374.3	714.98	1157.82	19.1	12.13
MP (10 +.5)	OPC 43-90%, MP 10%, MS0.5%	157.6	354.6	714.98	1157.82	39.4	18.20
MP (15+.5)	OPC 43-85%, MP 15%, MS 0.5%	157.6	334.9	714.98	1157.82	59.1	36.41
0.75%	**Metal Scrap Addition**						

MP (5+.75)	OPC 43-95%, MP 5%, MS .75%	157.6	374.3	714.98	1157.82	19.1	12.13
MP (10+.75)	OPC 43-90%, MP 10%, MS .75%	157.6	354.6	714.98	1157.82	39.4	18.20
MP (15+.75)	OPC 43-85%, MP 15%, MS .75%	157.6	334.9	714.98	1157.82	59.1	36.419
1.50%	**Metal Scrap Addition**						
MP (5+1.5)	OPC 43-95%, MP 5%, MS1.5%	157.6	374.3	714.98	1157.82	19.1	12.13
MP (10 +1.5)	OPC 43-90%, MP10%, MS1.5%	157.6	354.6	714.98	1157.82	39.4	18.20
MP (15+1.5)	OPC 43-85%, MP 15%, MS 1.5%	157.6	334.9	714.98	1157.82	59.1	36.419

Table 6 Concrete Mix Design and Proportions of Marble Powder and metal Scrap

Results and Discussion

Compressive Strength

IS 516:1959 guidelines were followed to determine the compressive strength of concrete cubes. The samples were prepared and tested according to the specifications, and the acceptance criteria were followed**.** When 5% marble powder was replaced with cement and mixed with 0.75% metal scrap, however, the resulting compressive strength increased by 17% after 7 days, 16% after 14 days, and 11% after 28 days. Similarly, when 10% marble powder was replaced with cement and mixed with 0.75% metal scrap, the compressive strength increased by 22% after 7 days, 20% after 14 days, and 16% after 28 days when compared to the standard mix. **Figures4** shows the combined compressive strength of marble powder and metal scrap**.**

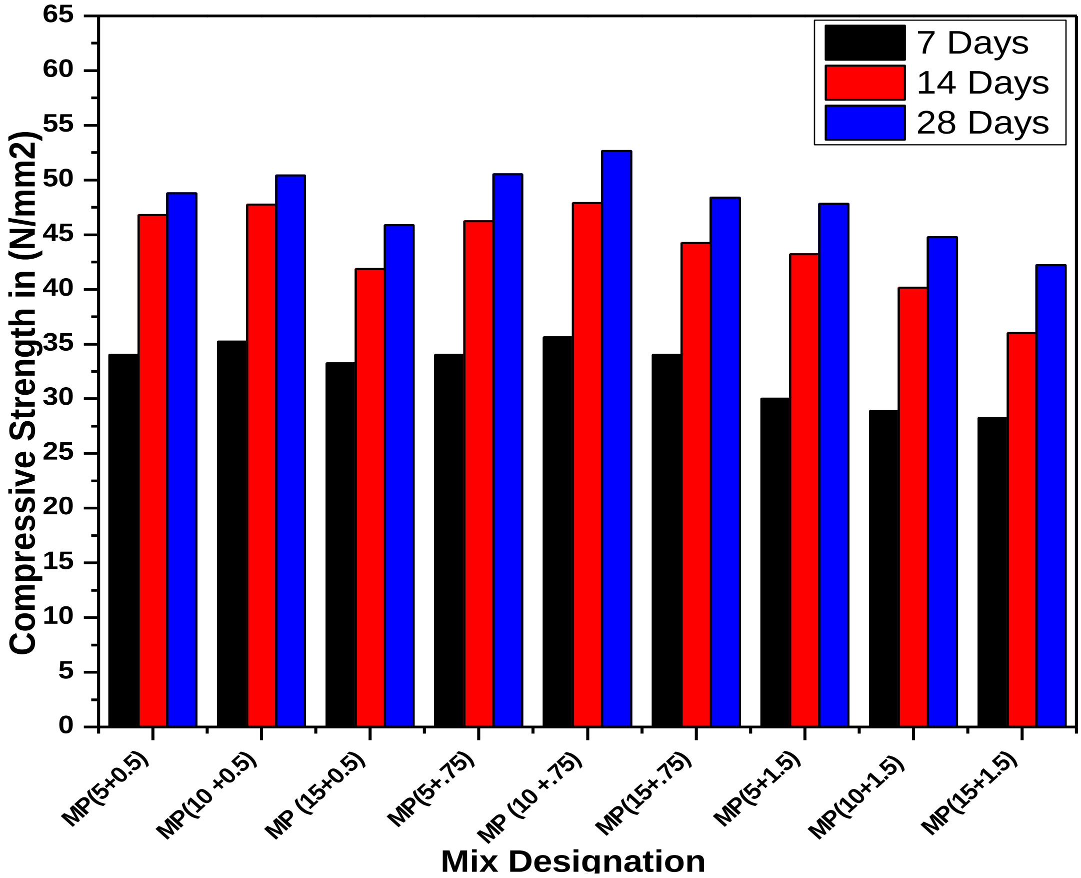

Fig. 4 Compressive Strength of Marble Powder and Metal Scrap

Split Tensile Strength

IS 5816:1999 is the Indian standard code for calculating the split tensile strength of concrete cylinders. However, compared to the control mixture, the samples with 15.0% WMP showed a 10% strength decline after 7 days and a 10% decline after 28 days. However, the split tensile strength increased when 5% of the marble powder was replaced with cement and mixed with 0.75 percent metal scrap. After 7 days, the strength increased by 30%; after 14 days, 15%; and after 28 days, 16%. Similar to the standard mix shown in **Figure 5**, the split tensile strength increased by 40% after 7 days, 34% after 14 days, and 31% after 28 days when cement was used to replace 10% marble powder and mixed with 0.75 percent metal scrap.

Flexural strength Test

Flexural strength, also known as modulus of rupture or bend strength, is a measure of the tensile strength of concrete. It represents the maximum stress that concrete can withstand before it fails in bending or stretching. Flexural strength of beams is typically determined in India using the codes IS 456:2000 and IS 516:1959. When 5% marble powder was replaced with cement and mixed with 0.75% metal scrap, the resulting flexural strength showed positive effects. The flexural strength increased by 26% at 7 days, 10% at 14 days, and 14% after 28 days. Similarly, when 10% marble powder was replaced with cement and mixed with 0.75% metal scrap, the flexural strength increased by 40% at 7 days, 39% at 14 days, and 43% after 28 days compared to the standard concrete mix, as shown in **Figure 6**

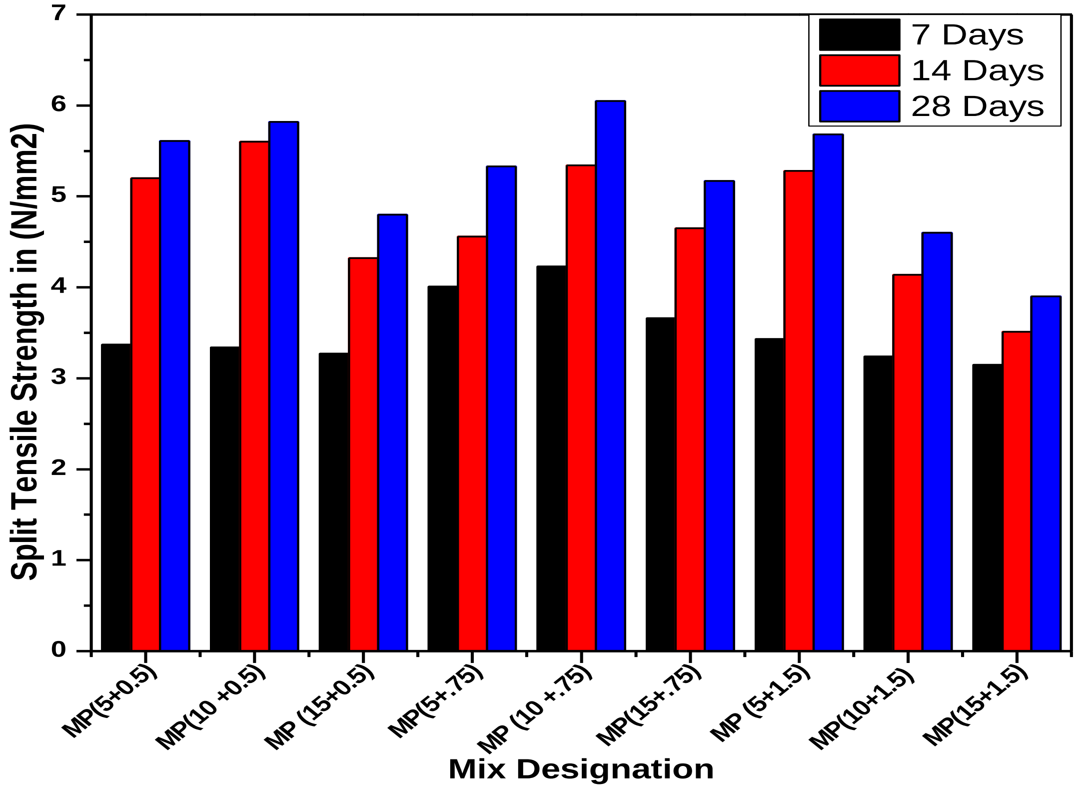

Fig.5 Split Tensile Strength of Marble Powder and Metal Scrap

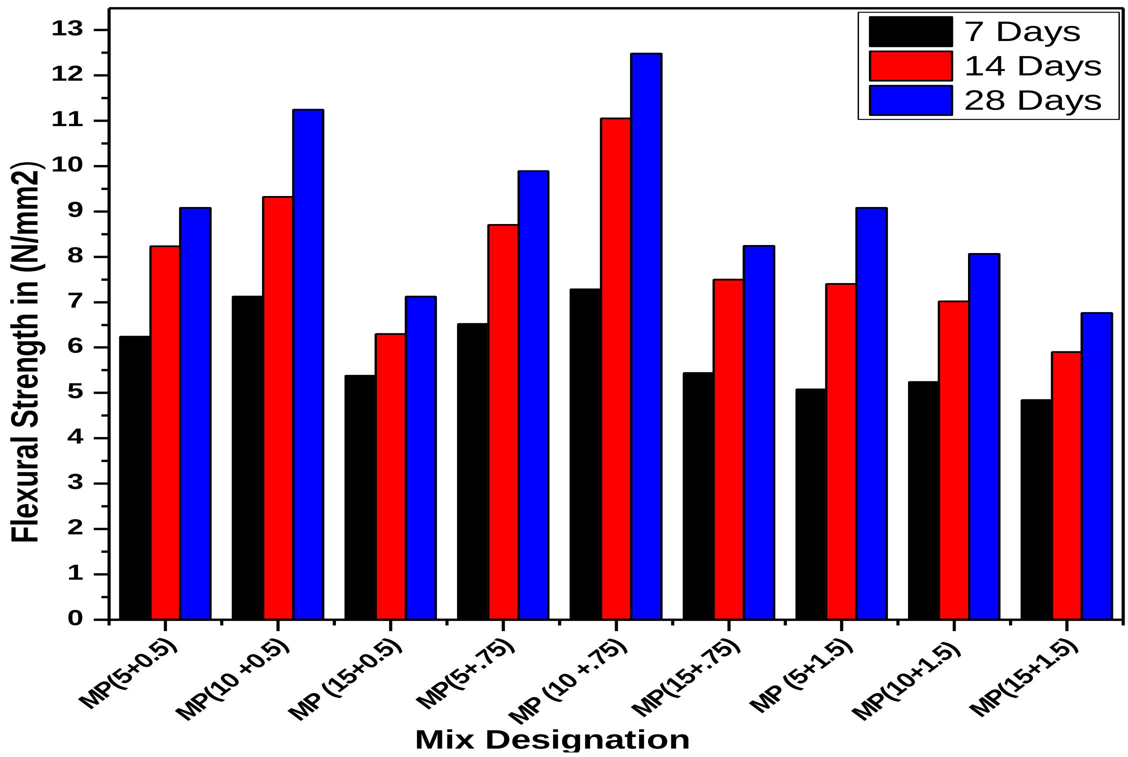

Fig.6 Flexural Strength of Marble Powder and Metal Scrap

Conclusion

1. The addition of metal scrap to concrete can lead to a substantial enhancement in its strength. Optimal outcomes are achieved when a mixture containing 0.75% metal scrap and 10% marble powder is used. This specific blend demonstrates a notable improvement in compressive strength, with increases of 16% after 7 days, 20% after 14 days, and 16% after 28 days.
2. The inclusion of metal scrap in concrete can lead to a substantial enhancement in its strength. Optimal outcomes are achieved when a mixture containing 0.75% metal scrap and 10% marble powder is used. This specific combination results in a remarkable increase in split tensile strength, with improvements of 25% after 7 days, 35% after 14 days, and 36% after 28 days.
3. The introduction of metal scrap into concrete can considerably enhance its strength. Optimal outcomes are achieved when a blend consisting of 0.75% metal scrap and 10% marble powder is utilized. This specific mix leads to a notable boost in flexural strength, with improvements of 26% after 7 days, 10% after 14 days, and 14% after 28 days.

References

[1] Y. W. Shewalul, "Experimental study of the effect of waste steel scrap as reinforcing material on the mechanical properties of concrete," *Case Studies in Construction Materials*, vol. 14, Jun. 2021, doi: 10.1016/j.cscm.2021.e00490.

[2] X. Xun, Z. Ronghua, and L. Yinghu, "Influence of curing regime on properties of reactive powder concrete containing waste steel fibers," *Constr Build Mater*, vol. 232, Jan. 2020, doi: 10.1016/j.conbuildmat.2019.117129.

[3] B. Pavan Prasad, P. Sai Maanvit, D. C. K. Jagarapu, and A. Eluru, "Flexural behavior of fiber reinforced concrete incorporation with lathe steel scrap," in *Materials Today: Proceedings*, Elsevier Ltd, Jan. 2020, pp. 196–200. doi: 10.1016/j.matpr.2020.03.793.

[4] G. Wang, C. Yang, C. Meng, Z. Xia, Y. Pan, and M. Wang, "Experimental study on the mechanical and self-sensing behaviors of prestressed carbon fiber–reinforced polymer reinforced concrete composite structures," *Advances in Structural Engineering*, vol. 23, no. 8, pp. 1507–1520, Jun. 2020, doi: 10.1177/1369433219895915.

[5] B. Pavan Prasad, P. Sai Maanvit, D. C. K. Jagarapu, and A. Eluru, "Flexural behavior of fiber reinforced concrete incorporation with lathe steel scrap," in *Materials Today: Proceedings*, Elsevier Ltd, Jan. 2020, pp. 196–200. doi: 10.1016/j.matpr.2020.03.793.

[6] S. Varadharajan, "Determination of mechanical properties and environmental impact due to inclusion of flyash and marble waste powder in concrete," *Structures*, vol. 25, pp. 613–630, Jun. 2020, doi: 10.1016/j.istruc.2020.03.040.

[7] S. K. Amin, M. E. Allam, G. L. Garas, and H. Ezz, "A study of the chemical effect of marble and granite slurry on green mortar compressive strength," *Bull Natl Res Cent*, vol. 44, no. 1, Dec. 2020, doi: 10.1186/s42269-020-0274-8.

[8] M. Singh, K. Choudhary, A. Srivastava, K. Singh Sangwan, and D. Bhunia, "A study on environmental and economic impacts of using waste marble powder in concrete," *Journal of Building Engineering*, vol. 13. Elsevier Ltd, pp. 87–95, Sep. 01, 2017. doi: 10.1016/j.jobe.2017.07.009.

[9] M. Singh, A. Srivastava, and D. Bhunia, "Long term strength and durability parameters of hardened concrete on partially replacing cement by dried waste marble powder slurry," *Constr Build Mater*, vol. 198, pp. 553–569, Feb. 2019, doi: 10.1016/j.conbuildmat.2018.12.005.

[10] K. Kumar, S. Jain, and A. Professor, "Combined Effect of Marble Dust and Steel Fiber on the Mechanical Properties of High Strength Concretes." [Online]. Available:

[11] Yasin Onuralp Ozkılıc¸, Ozer Zeybek, Alireza Bahrami, Ali _ Ihsan C¸ elik, Md Azree

Othuman Mydin, Memduh Karalar, Ibrahim Y. Hakeem g, Krishanu Roy h, P. Jagadesh "Optimum usage of waste marble powder to reduce use of cement toward eco-friendly concrete"Journal of material science and technology Elsevier June 2023.

[12] Boğaçhan Başaran, Ceyhun Aksoylu , Yasin Onuralp Özkılıç , Memduh Karalar , Ahmad Hakamy "Shear behaviour of reinforced concrete beams utilizing waste marble powder"vol.54 elsevier Aug 2023.

[13] Naraindas Bheel, Omrane Benjeddou , Hamad R. Almujibah , Suhail Ahmed Abbasi , Samiullah Sohu d, Mahmood Ahmad , Mohanad Muayad Sabri Sabri "Effect of calcined clay and marble dust powder as cementitious material on the mechanical properties and embodied carbon of high strength concrete by using RSM-based modelling"Elsevier March 2023.

[14] Amit Kumar Sharma, Nitin Mishra, Luv Chaudhary "Effect of adding marble-dust particles (MDP) as a partial cement replacement in concrete mix" Elsevier 25 May 2023.