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ECO-FRIENDLY CONCRETE INNOVATIONS: THE ROLE OF MARBLE POWDER AND RICE HUSK ASH IN ACHIEVING SUSTAINABLE CONSTRUCTION PRACTICES

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ABSTRACT

Research on substitute materials for concrete manufacturing, such as rice husk ash (RHA) and marble powder (MP), has been spurred by the growing building waste and the demand for sustainable resources. Using these waste components, this study investigates the workability and mechanical characteristics of M40 grade concrete. The workability and strength characteristics of the mixture are affected when steel slag and dolomite are substituted, according to the experimental results. Because of its tiny particles, increasing steel slag content initially made the concrete less workable; nevertheless, in M30 grade concrete, 20% dolomite and 15% steel slag replacement produced the best results. With a 30% dolomite and 5% steel slag combination, the compressive strength peaked at 33.6 N/mm² after 28 days. At the same replacement level, the split tensile strength and flexural strength also attained their greatest values, demonstrating steady advancements in the overall performance of the concrete. This study emphasizes how MP and RHA can be used in concrete as affordable, environmentally beneficial substitutes that support sustainable building methods.

Keywords: sustainable concrete, waste material utilisation powder, rice husk ash, mechanical properties of concrete.

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INTRODUCTION

Due to waste production and raw material depletion, the construction sector is one of the biggest users of natural resources and a major contributor to environmental issues [15]. The need for sustainable construction approaches has never been greater, given the world's population expansion and infrastructural development. The use of substitute materials, which can lessen dependency on conventional resources while reducing the negative environmental effects connected to construction operations, is a major area of attention in this endeavour [16].

Using waste materials and industrial by-products as partial replacements in concrete is one of the most promising ways to achieve sustainability in the building industry [18]. Among these, rice husk ash (RHA) and marble powder (MP) have drawn interest because of their accessibility, affordability, and advantageous characteristics when applied in cement-based applications [20]. By recycling waste, these materials not only offer a sustainable alternative, but they also have the potential to improve concrete's performance characteristics [17].

A by-product of the marble processing industry, marble powder is frequently disposed of in enormous amounts, which poses health and environmental risks [19]. Similar to this, even though rice husk ash-a by-product of burning rice-has pozzolanic qualities that can increase the strength and durability of concrete, disposing of it can be difficult [21]. The building sector may transition to more environmentally friendly methods, use less cement, and efficiently manage waste by adding these components to concrete mixes [23].

The impact of rice husk ash and marble powder on the mechanical qualities and workability of M40 grade concrete is examined in this study [25]. It specifically looks at how the concrete's compressive, tensile, and flexural strengths are impacted by varying ratios of steel slag and dolomite replacements [22]. Prior studies have demonstrated that these waste components can improve specific concrete performance characteristics, but it is still unclear how much of each should be replaced and how they work together [24].

According to the experimental research, M30 grade concrete performed best when 20% dolomite and 15% steel slag were substituted. With a 30% dolomite and 5% steel slag mix, the greatest compressive strength measured at 28 days was 33.6 N/mm2, and split tensile and flexural values were significantly improved. According to these results, concrete's mechanical qualities can be preserved and even enhanced by the thoughtful application of rice husk ash and marble powder, which also supports environmentally friendly building practices.

This study adds to the expanding body of information on sustainable concrete, which advances the use of alternate materials in building [26]. It draws attention to the possibilities of using waste materials in building procedures to improve the mechanical performance of concrete while lessening the environmental effect of waste disposal and cement manufacture. This study is a step in the direction of creating a more resilient and sustainable building industry that adheres to resource efficiency and the circular economy.

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LITERATURE REVIEW

Numerous studies have been conducted on the utilization of waste materials in concrete to improve its sustainability and mechanical qualities. The use of industrial and agricultural waste materials as partial substitutes for cement or aggregates in concrete has been the subject of numerous investigations.

When Rahmat Madandoust and Reza Ghavidel examined the mechanical characteristics of concrete that contained waste glass powder and rice-husk-ash, they found that the pozzolanic reactions of the rice-husk-ash increased the concrete's compressive strength and durability [1]. The use of rice-husk-ash in concrete has also been shown to have positive environmental effects, with Khan *et al*. highlighting how it can lower carbon emissions while improving the mix's mechanical qualities [2].

Ali Ergun investigated the effects of diatomite and leftover marble powder as a partial substitute for cement and found that these additives greatly enhance the mechanical qualities of concrete, such as its durability and compressive strength [3]. The advantages of utilizing leftover marble powder in hardened concrete were further emphasized by Ulubeyli and Artir, who demonstrated how it improved the density and strength of the concrete [4].
Talha *et al*. investigated the impact of marble powder on high-performance concrete and found that it improves the microstructure of the concrete matrix and creates a filler effect, which increases the mechanical properties, especially the compressive strength [5]. Furthermore, Omar et al. concentrated on using limestone waste in concrete to partially replace sand and marble powder, which increased the material's workability and strength characteristics [6].

After researching the strength properties of high-strength rice husk ash concrete, Ravande Kishore and associates discovered that adding rice husk ash considerably improved the concrete's compressive strength and decreased its permeability [7]. When rice husk ash and dolomite were mixed to treat concrete, Sathawane *et al*. saw a significant increase in strength when 30% less cement was used [8].

Kore and Vyas investigated the use of leftover marble as a coarse aggregate in lean cement concrete and observed improved performance in terms of durability and compressive strength [9]. Improved resistance to chloride penetration was found in the rice husk ash-blended concrete studied by Muthadhi and Kothandaraman [10]. This is important for the longevity of concrete constructions in harsh settings.

Research on the fineness of rice husk ash has demonstrated how it affects cement mortar's strength and ability to withstand carbonation. Finer rice husk ash particles have been shown by Rukzon and Chindaprasirt to have superior pozzolanic activity and, as a result, improved strength properties [11]. In their investigation, Wahyuni et al. found that adding bamboo fiber and sea shell ash to concrete containing rice husk ash improved its mechanical and durability properties [12].

Additionally, Chandan Kumar *et al*. examined the strengths of various rice husk ash concrete grades and proposed that it might be used in a variety of applications as a sustainable substitute for conventional cement [13]. In their discussion of the combined effects of recycled concrete aggregate and copper slag on CIR mixes, Behnood *et al*. [14] emphasized the contribution of rice husk ash to improving the mixture's mechanical qualities and environmental sustainability.

The pursuit of sustainable construction practices has led to a great deal of attention being paid to the use of alternative materials in concrete. In a study, the effects of adding marble powder and rice husk ash (RHA) to concrete were examined by Raikwar and Tare [27]. According to their research, adding these components to concrete improved its mechanical qualities as well as its workability. Similar to this, Babu *et al*.'s study [28] examined the impact of RHA on the strength and workability of concrete, finding favourable correlations that lend credence to RHA's use as a partial cement substitute.

The Bureau of Indian Standards' concrete mix proportioning rules [29] stress how crucial it is to choose the right materials to get the necessary concrete qualities. The coarse and fine aggregate specifications, which outline the requirements for natural sources in the manufacturing of concrete, further support this [30]. Furthermore, creative approaches to concrete composition are supported by the fundamental principles provided by the Indian Standard Code of Practice for plain and reinforced concrete [31].

Sakr [32] evaluated the effects of RHA and silica fume on the characteristics of heavyweight concrete, emphasizing how these substances may improve strength without sacrificing durability. Jaturapitakkul's study [33] investigated the feasibility of using RHA and calcium carbide residue as cementing agents and showed that they could both improve the structural integrity of concrete.
Anwar *et al*. [34] made additional contributions to the subject by examining the compressive strength of concrete by partially substituting dolomite for cement, demonstrating the impact of different aggregates on performance. Santhakumar [35] and Shetty [36] offered thorough texts that highlight the theoretical and practical elements of concrete formulations in the context of concrete technology.

Felixkala and Partheeban [37] investigated the use of granite powder as a substitute in concrete mixes and documented the effects of this substitution on several concrete properties. By examining the characteristics of self-compacting concrete (SCC) manufactured with dolomite and quarry dust, Raju *et al*. [38] also contributed, showing that these components can significantly improve the performance of concrete.

The combined results of these investigations highlight the potential of substitute materials to enhance concrete's overall performance while simultaneously lessening its negative effects on the environment. For the development of sustainable construction methods that satisfy modern technical requirements, more research in this field is necessary.

In summary, adding waste materials like marble powder, rice husk ash, and other industrial by-products to concrete improves its mechanical qualities while simultaneously lowering the carbon footprint of building materials and promoting sustainability. Collectively, these investigations indicate that these waste materials can successfully substitute traditional cement and aggregates without sacrificing the structural integrity of concrete when mixed and proportioned appropriately.

Objective

- Examine the impacts of using rice husk ash (RHA) and marble powder (MP) in place of some of the cement in M40 grade concrete.
- Determine the ideal ratios of MP and RHA to improve the workability, compressive, tensile, and flexural strengths of concrete.
- Examine the combined effects of steel slag and dolomite on the mechanical characteristics of concrete.
- Create a sustainable, high-performing concrete mix that may be used in contemporary building.

Scope

- Examine M40 grade concrete experimentally using replacements for cement, such as steel slag, dolomite, RHA, and MP in different proportions.
- Examine how well concrete works and its mechanical characteristics, such as its flexural, tensile, and compressive strengths, throughout a range of curing times.
- Determine the optimal replacement levels that maximize concrete performance while promoting waste reduction and sustainability.
- Support the development of eco-friendly concrete mixes aligned with sustainable development, resource efficiency, and reduced environmental impact in the construction industry.

METHODOLOGY

Standard tests were employed in the experimental procedures to evaluate the concrete's strength and workability. The Compaction Factor Test and the Slump Test were used to assess workability. The Compaction Factor Test establishes the density to which fresh concrete may be compacted, demonstrating its compatibility, whereas the Slump Test gauges the vertical settling of a fresh concrete cone, offering insights into its mobility. For the concrete mixes, the values for the compaction factor and slump were noted as 0.97 and 220 mm, respectively.
Oil-lubricated moulds were used to cast cubes, cylinders, and beams for destructive testing on hardened concrete. The samples underwent vibration treatment after being compressed into layers. Using a compression testing machine, a progressive load of 140 kg/cm² per minute was applied to cubes of 15 cm by 15 cm by 15 cm till failure. The values of strength were computed and tallied. Similarly, a Universal Testing Machine was used to quantify the modulus of rupture for beams of 750 mm by 150 mm by 150 mm during Flexural Strength tests. The fracture site about the support span was used to calculate the flexural strength.

Split Tensile Strength tests, using cylindrical specimens of 15 cm diameter and 30 cm height, were conducted by applying a compressive load until failure. The tensile strength was derived using the splitting method, a standard approach for indirect measurement. All tests were repeated for various mixes, including those with different percentages of granite powder as a fine aggregate replacement, and the results were systematically recorded.

RESULTS

Workability of Concrete

The workability of concrete was assessed through slump and compaction factor tests on fresh mixes containing varying amounts of dolomite and steel slag, maintaining a water-to-binder (w/b) ratio of 0.35. Results indicated that both the slump and compaction factor values increased progressively with higher proportions of dolomite and steel slag in the concrete mixtures. Notably, the mix containing 15% dolomite and 5% steel slag exhibited the highest values for both the compaction factor and slump.

Table-1. Workability values for different mixes.

S. No	Mix designation	Slump value(mm)	Compaction Factor
1	P_1	60	0.83
2	P_2	72	0.85
3	P_3	90	0.88
4	P_4	80	0.86

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The above data indicate that both the slump and compaction factor values increased with higher dolomite and steel slag contents. However, in the P4 mix, these values decreased compared to the P3 mix. Graphs illustrating these results are shown in Figures 1 and 2.

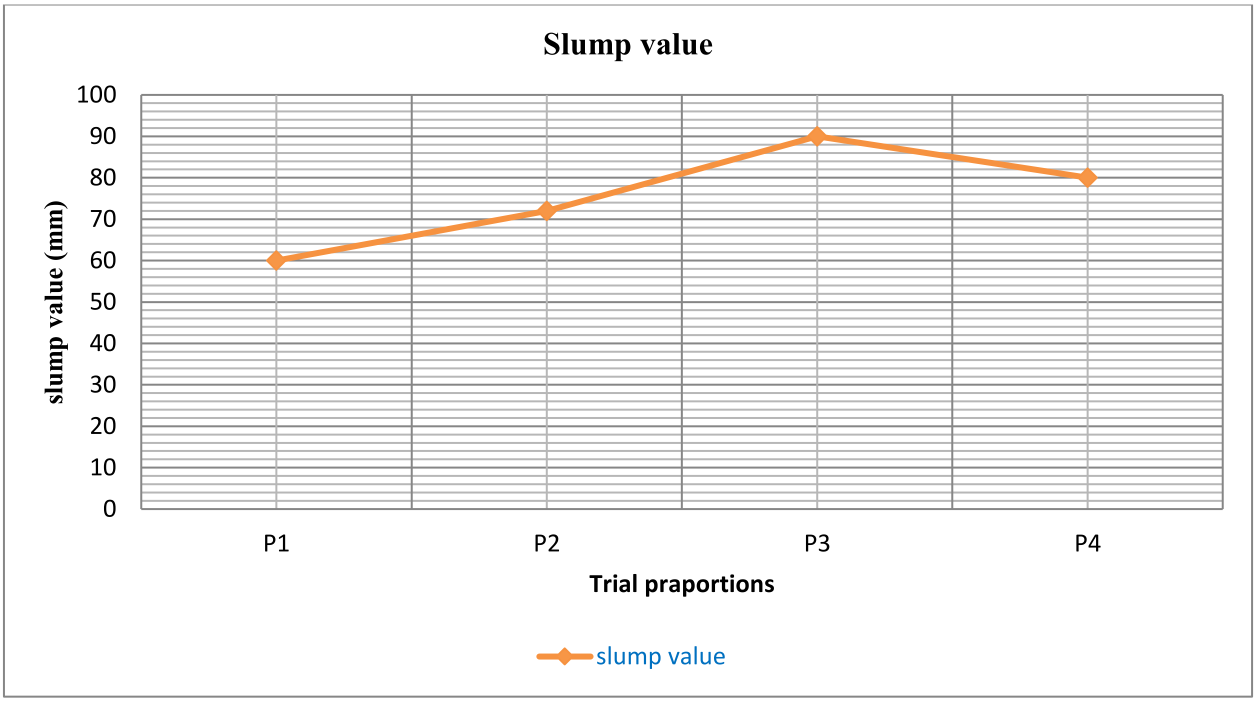

Figure-1. Slump values for mix proportions.

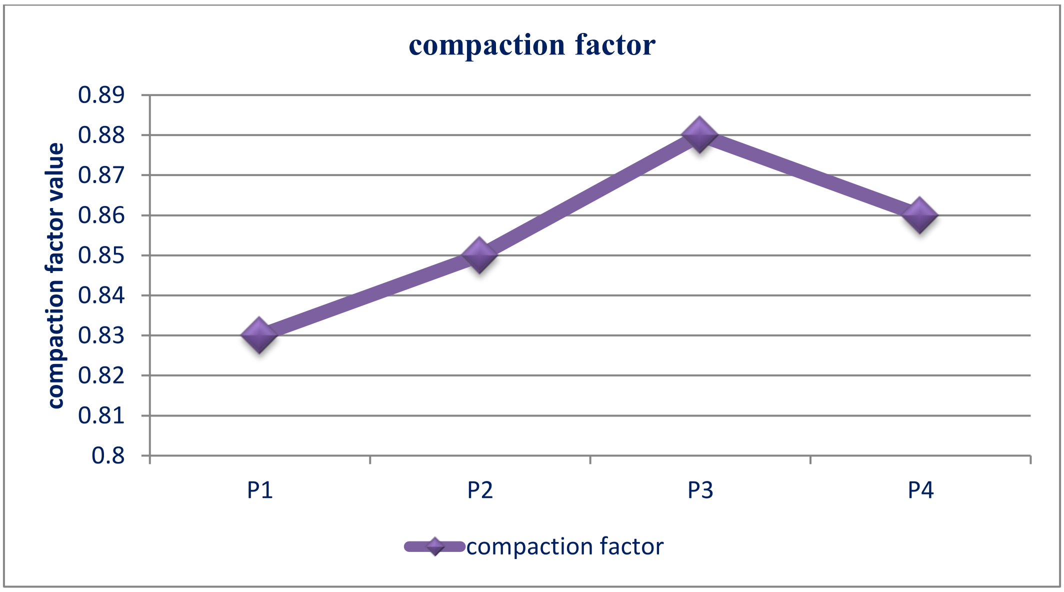

Figure-2. Compaction factor values for mix proportions.

Compressive Strength Test

The compressive strength of various concrete mixes was assessed at 7, 14, and 28 days of curing. The N.D Mix demonstrated the highest strength, starting at 24.83 MPa at 7 days and reaching 39.18 MPa by 28 days. In contrast, the 20D Mix showed lower strengths of 21.36 MPa, 27.18 MPa, and 32.62 MPa at the respective curing ages. Incorporating 5% coarse aggregates in the 20D+5CS Mix yielded slightly better results (23.13 MPa at 7 days) but stabilized at 32.62 MPa by 28 days. The 20D+10CS and 20D+15CS mixes exhibited significantly reduced strengths, particularly the latter, which only reached 25.76 MPa at 28 days. The 30D Mix provided a moderate performance (33.57 MPa at 28 days), while adding 5% coarse aggregates in the 30D+5CS Mix enhanced its strength to 33.60 MPa. The 40D series mixes generally showed lower compressive strengths, with the 40D+15CS Mix recording only 21.24 MPa at 28 days. Notably, the 5% and 10% coarse aggregate mixes performed well, achieving strengths of 31.90 MPa and 34.96 MPa at 28 days, respectively. Overall, the results indicate that the inclusion of coarse aggregates can influence the compressive strength of concrete, with optimal proportions necessary for enhancing performance.

Table-2. Compression test values for different mixes.

S. No	Mix proportions	Compressive Strength		
		7 DAYS	14 DAYS	28 DAYS
1	N.D	24.90	32.49	39.19
2	20D	22.39	27.19	32.66
3	20D+5CS	243.99	26.45	32.65
4	20D+10CS	16.75	20.04	27.04
5	20D+15CS	13.77	17.36	25.75
6	30D	22.39	27.83	33.56
7	30D+5CS	25.14	30.33	33.63
8	30D+10CS	22.24	27.44	31.06
9	30D+15CS	15.33	18.76	22.77
10	40D	17.72	22.55	28.96
11	40D+5 CS	17.25	20.08	26.54
12	40D+10 CS	14.98	17.85	23.73
13	40D+15CS	11.99	15.33	21.22
14	5% CS	21.46	28.77	31.93
15	10% CS	23.78	30.66	34.95
16	15% CS	17.55	24.48	27.38

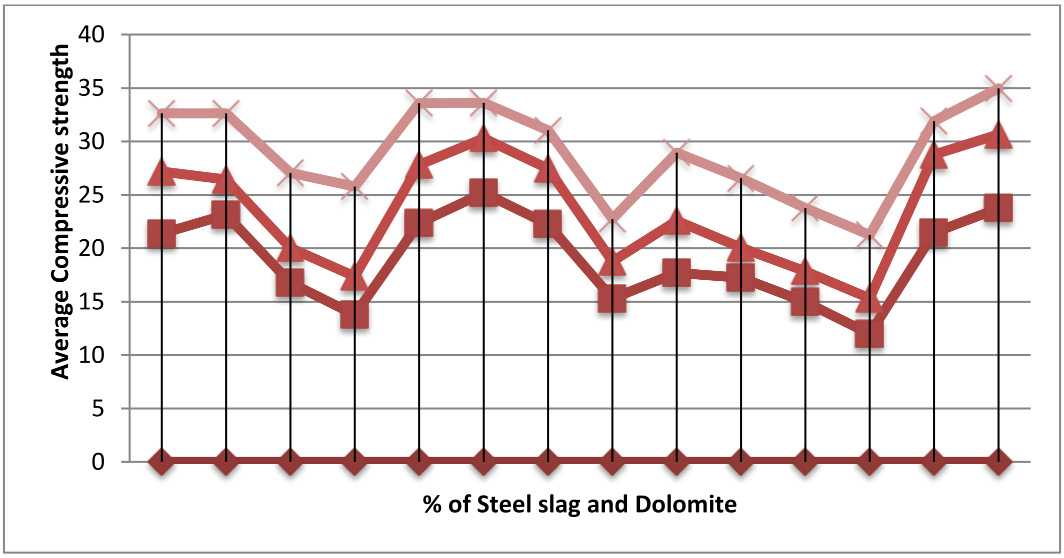

Figure-3. Average compressive strength of cube.

The cube's compressive strength was tested at 33.6 N/mm² after 28 days when there was no replacement of steel slag and 39.18 N/mm² when there was no cement. After 28 days, the maximum strength of 33.6 N/mm² was reported, up from 27.8 N/mm² after 14 days, when 30% dolomite and 5% steel slag replacement were added. With up to 30% dolomite and 5% steel slag replacement, the compressive strength improved gradually at 14 and 28 days, and it kept rising as the replacement percentages climbed.

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Split Tensile Strength Test

After 28 days, the split tensile strength of the concrete with copper slag addition was progressively raised to 30% + 5% (replacement of dolomite and steel slag) and roughly 3.69 N/mm2. For every composition, the cylinder's split tensile strength behaved similarly to the cube's compressive strength.

Table-3. Values of the split tensile strength test for various combinations.

S. No	Mix proportions	Split tensile Strength		
		7 DAYS	14 DAYS	28 DAYS
1	N	2.51	3.32	3.82
2	20D	2.03	3.07	3.25
3	20D+5CS	2.53	2.90	3.77
4	20D+10SC	2.26	1.91	2.33
5	20D+15SC	1.57	2.25	2.42
6	30D	2.03	3.12	3.44
7	30D+5SC	2.46	3.1	3.69
8	30D+10SC	2.04	2.46	2.87
9	30D+15SC	1.34	1.95	2.23
10	40D	1.55	1.93	2.94
11	40D+5 SC	1.69	2.04	2.62
12	40D+10 SC	1.72	2.12	2.36
13	40D+15SC	1.79	1.99	2.23
14	5% SC	2.00	2.57	3.06
15	10% SC	2.40	2.95	3.52
16	15% SC	1.40	2.01	2.68

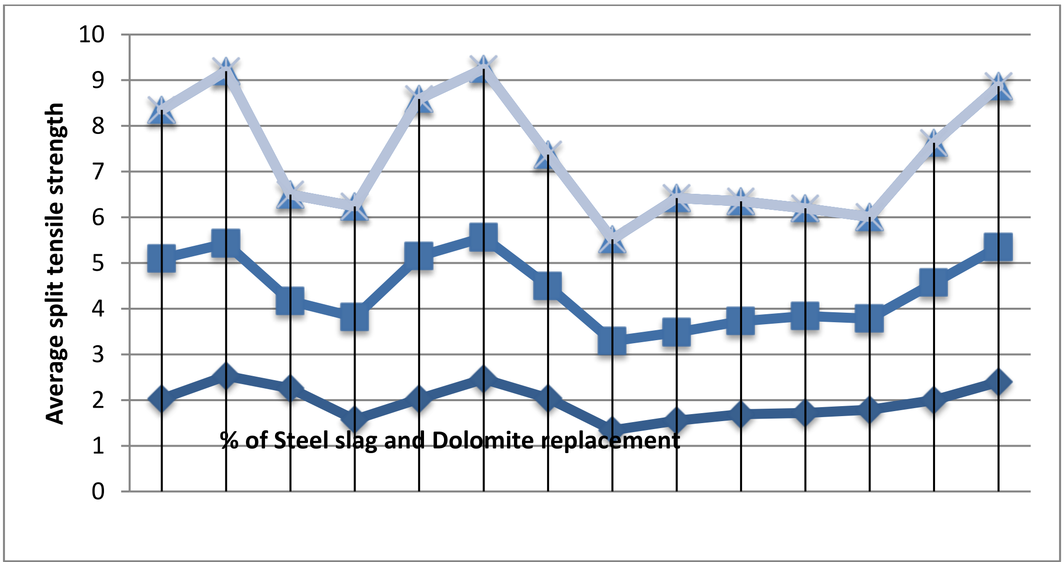

Figure-4. Average Split Tensile strength of cylinder.

Flexural Strength Test

It was discovered that the maximum flexural strength of the beam was approximately 7.7 N/mm2 and 30% + 5% (replacement of steel slag and dolomite). The beam's flexural strength increased at 30% + 5% replacement of steel slag and dolomite. All blends' flexural strengths behaved similarly to the compressive strength findings.

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Table-4. Flexural Strength test values for different mixes.

S. No	Mixing proportions	Flexural strength
		28 DAYS
1	N.C	7.67
2	20D	5.19
3	20D+5SC	4.36
4	20D+10SC	5.11
5	20D+15SC	5.10
6	30D	8.85
7	30D+5SC	6.75
8	30D+10SC	5.47
9	30D+15SC	5.48
10	40D	5.37
11	40D+5 SC	4.86
12	40D+10 SC	4.62
13	40D+15SC	4.52
14	5% SC	6.02s
15	10% SC	6.32
16	15% SC	5.52

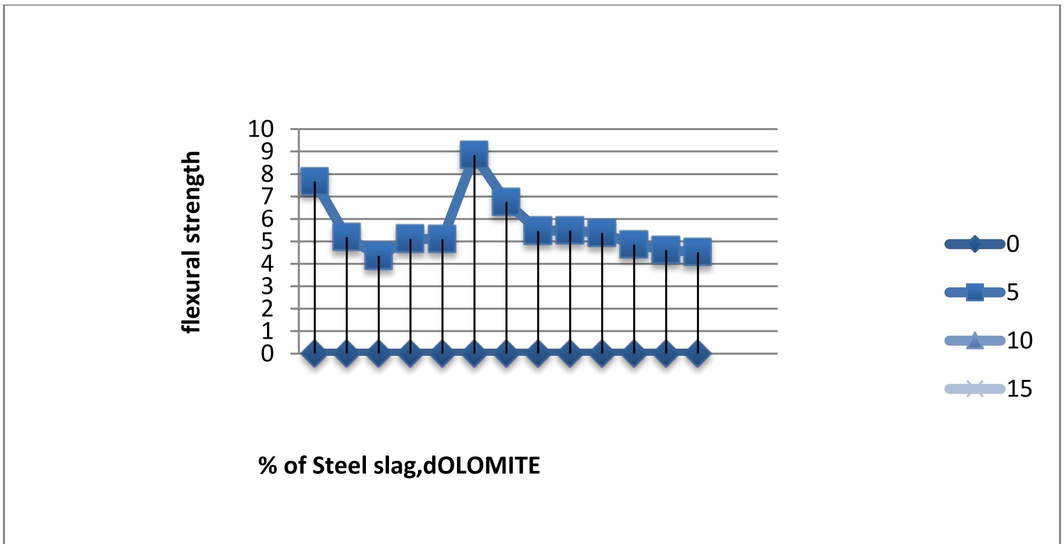

Figure-5. Average flexural strength of beam.

Weight of Cube Results

The maximum weight was found to be at 30% + 5% (Dolomite and Steel slag) replacement and about 8.900 KG for 28 days. The weight of the cube showed higher strength at different proportions of Dolomite and Steel slag replacement. All blends' weight cubes exhibited behavior that was comparable to the compressive strength findings.

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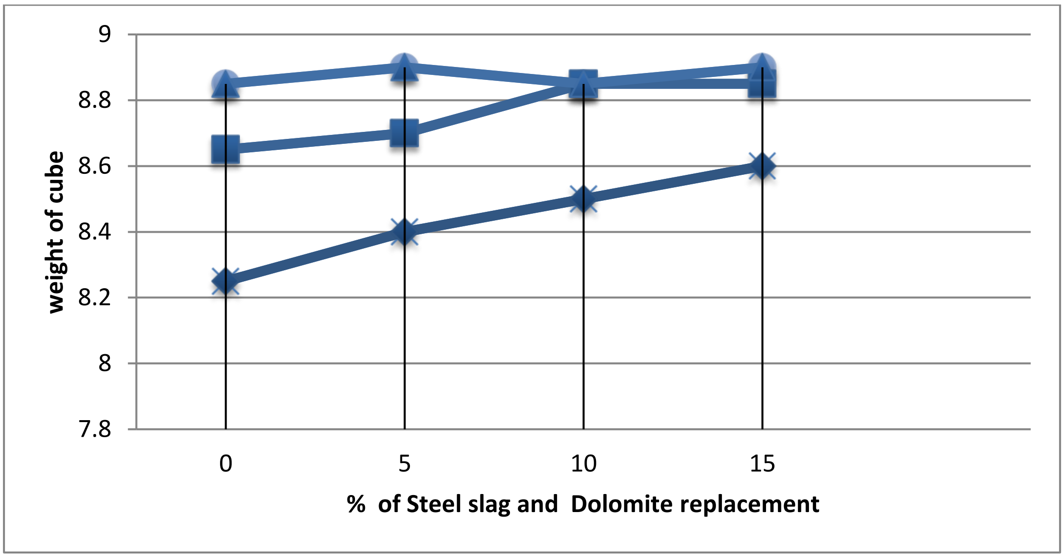

Figure-6. Average weight of the cube.

CONCLUSIONS

Given the increasing amount of trash produced by expanding infrastructure development and growing populations, research into the use of waste construction materials, in particular marble powder and rice husk ash (RHA), is essential. Not only are these ingredients easily accessible, but they are also less expensive than regular cement. The purpose of this study was to assess the mechanical qualities and workability of M40 grade concrete that had been mixed with RHA and marble powder. The experiment analysis led to the following conclusions being made:

a) Compared to the reference concrete mix, the initial workability was good but decreased as the proportion of dolomite and steel slag increased. This reduction in workability is attributed to the finer particles of steel slag, which effectively fill the voids within the concrete.

b) For M30 grade concrete, workability showed an improvement with up to 20% dolomite and 15% steel slag replacement of cement.

c) The control mix obtained 33.6 N/mm² at 28 days without replacing the steel slag and 39.18 N/mm² with the replacement of cement, according to the compressive strength tests. At 28 days, a blend of 30% dolomite and 5% steel slag showed the highest compressive strength of 33.6 N/mm². With up to 30% dolomite and 5% steel slag replacement, this trend showed a progressive rise in compressive strength. After this replacement level, the material continued to perform consistently.

d) After 28 days, the concrete's split tensile strength reached a maximum of 3.69 N/mm², gradually rising to a combination of 30% dolomite and 5% steel slag replacement. The concrete mixtures' tensile strength behavior followed the trends in compressive strength that were seen.

e) The top performance of the beam specimens' flexural strength tests, conducted at 30% dolomite and 5% steel slag replacement, was 7.7 N/mm². Like the compressive strength, all of the combinations' flexural strengths increased noticeably at this replacement level, demonstrating a constant relationship between the two properties in all of the different concrete mixtures.

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