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EXPERIMENTAL STUDY ON STRENGTH OF CONCRETE USING SLAG SAND AND PARTIAL REPLACEMENT OF CEMENT WITH ALCCOFINE

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ABSTRACT

Supplemental cementitious materials (SCM) are gaining popularity in the construction sector. Because they are bringing about a technological revolution in the area of civil engineering. Alccofine is an innovative kind of micro-fine concrete material designed for high strength concrete, where workability and strength are equally significant considerations. Alccofine is a specifically processed product with high strength concrete that is based on slag with high glass content and high reactivity that was created via the method of controlled granulation. Because of its distinct chemistry and very tiny particle size, Alccofine offers less water consumption for a given workability, meeting the demands of concrete performance.

Alccofine is an ultra-fine supplemental cementitious material with an optimum particle size distribution that is based on slag. Alccofine increases the mix's flow ability and improves its workability of the blend retention. Additionally, it aids in lowering the mix's heat of hydration and segregation. In addition to its strength, Alccofine has the benefit of reducing the water/binder ratio. The concrete used in this project's design mix is M60 grade. Use slag sand in your concrete and substitute 0%, 5%, 10%, 15%, and 20% of the cement with Alccofine. Various amounts of Alccofine were used for compressive strength, split tensile strength, and flexural strength tests throughout the duration of 3, 7, and 28 days of curing.

Keywords: Alccofine, Slag sand, Workability, Compressive strength, Split tensile strength, flexural strength.

1. INTRODUCTION

1.1. GENERAL

The global construction industry, vital for modern civilization, faces a dual challenge: enhancing concrete performance while reducing its environmental impact due to cement's greenhouse gas emissions. Alccofine, created by heating kaolin clay and finely grinding the resulting metakaolin, bolsters concrete strength and durability. Its composition boasts high silica and alumina content, promoting chemical reactions when mixed with cement and water. Alccofine, used as a pozzolanic material, improves concrete properties by forming calcium silicate hydrate and other cementitious compounds. Slag, a by-product from various industries, particularly Granulated Blast Furnace (BF) slag, often used in Portland slag cement, offers an innovative solution for sustainable concrete production. By substituting river sand in fine aggregate, slag

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minimizes waste. These slag materials, often a mix of coarse and fine particles, are typically discarded, leading to resource depletion, pollution, and ecological harm. Recycling industrial slag supports sustainable development, environmental protection, and responsible resource management, ultimately conserving natural resources and safeguarding the environment.

1.2. OBJECTIVES OF RESEARCH

1. To substitute a portion of cement with Alccofine in M60 grade concrete, aiming to develop high strength concrete.
2. To determine the workability properties of freshly mixed concrete.
3. To determine the optimal mix proportion by partial replacement of cement with Alccofine at 0%, 5%, 10%, 15% and 20% weight of cement, that provides excellent hardened properties for concrete.
4. To identify the most suitable proportions of Alccofine to be incorporated into the M60 grade concrete mix. This determination seeks to optimize the concrete mixture for performance and strength.
5. To determine the compressive strength, split tensile strength and flexural Strength of concrete for 3, 7 and 28 days of curing.

2. LITERATURE REVIEW

1. **P.R. Kalyana Chakravarthy, R. Raj (2017),** the primary goal of this study is to examine the compressive strength of concrete that has some of its cement replaced with aluminum oxide. The project's main objective is to investigate concrete experimentally by substituting increasing percentages of Alccofine for cement. for seven and twenty-eight days: 0%, 4%, 8%, 16%, 17%, 20%, 25%, 50%, 75%, and 100%. M25 was the design mix used for the duration of the trial. When compared to traditional curing, the increase in compressive strength percentage for 7 and 28 days of curing was observed to peak at 16% replacement, showing values of 50.95% and 60.95%.
2. **S. Kavitha and T. Felix Kala (2016),** have provided an explanation of the usage of alcofine as a strength booster inside the SCC. The findings of their research demonstrated that alccofine may be used as a strength enhancer inside the SCC. They also observed an improvement in strength qualities with an increase in alccofine dose.
3. **D. Sharma, S. Sharma, and Ajay G. (2016),** investigated how to increase the strength of concrete by substituting cement with alccofine and foundry slag for traditional fine aggregate. They came to the conclusion that replacing cement with 15% alccofine and fine aggregate with 10% to 45% foundry slag would provide concrete with a respectably high strength.
4. **Chepuri Jaswanthi Yoga, B Ajitha (2022)** had done experimental work on partial replacement of cement with Metakaolin, Marble dust and Slag sand for M40 Grade concrete. The Metakaolin is replaced at 0%, 5%, 10%, 15% & 20% with cement and Marble dust as 0%, 10% & 20%. The conclusion summarizes that the addition of Metakaolin and Marble dust indicates an early strength gaining capacity and is ecofriendly to nature. Metakaolin and

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Marble dust showed greater results then compared with conventional concrete in long term strength properties.

3. MATERIALS AND METHODOLOGY

The blends are casted with the goal of giving concrete its maximum strength. The mix proportions of the different materials used in the concrete mixes are considered based on the IS 10262-2019 Code approach.

3.1. MATERIALS USED

3.1.1. Ordinary port land cement (grade 53)

The type of cement used in the study is OPC 53 grade cement. The individual properties of the cement were determined to ensure that they met the limits specified in the IS: 12269-1987 standard. The preliminary test results are presented in table 1.

Table 1. Preliminary Tests on Cement.

Preliminary Tests	Results
Fineness of Cement	6.5%
Standard Consistency	32%
Initial Setting Time	35 Min
Final Setting Time	450 Min
Soundness of Cement	5 mm
Specific Gravity	3.11

3.1.2. Slag Sand

Slag sand derived at JSW Company in India, is used. Fifty percent of finer variety & Fifty percent of coarser variety is utilized in combination. For sustainability, in the present work Natural River sand is not used. Slag sand is tried as total fine aggregate. Slag sand belonging to Zone II are used. The specific gravity of slag sand is achieved as 2.58 and bulking of sand as 46.15%.

3.1.3. Coarse aggregate

The coarse aggregates originate from a combination of naturally existing rock fragments and crushed granite. Concrete strength qualities may also be affected by the coarse aggregate form. As per IS: 383-1970, in the study, two proportions of coarse aggregate are used as 20 mm and 12 mm aggregates. The preliminary test results are presented in table 2.

Table 2. Preliminary Tests on Coarse Aggregate.

S.No	Preliminary Tests	Results for 20mm	Results for 12mm

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1	Specific Gravity	2.90	2.55
2	Water Absorption	0.25%	1.0%
3	Flakiness Index	10	18
4	Elongation Index	17.3	21
5	Fineness Modulus	5.61	3
6	Bulk Density	1566.3Kg/m^3	1553.14Kg/m^3

3.1.4. Alccofine

Alccofine is not a waste or byproduct material but rather a specially engineered supplementary cementitious material (SCM) developed for use in the concrete industry. It is derived from high-quality metakaolin, which is a type of pozzolan. Pozzolans are materials that react with calcium hydroxide (lime) in the presence of water to form additional cementitious compounds. The specific gravity is obtained as 2.86. Fineness modulus of allcofine is achieved as 3.35 and Bulk density as 700 Kg/m^3

3.1.5. Water

The primary ingredient in making concrete is water. Concrete was mixed and cured using drinkable water. Oils, acids, alkalis, salts, biological matter, and other pollutants that might harm concrete should not be present in the water used to mix concrete, including the free water on the aggregates.

3.1.6. Super Plasticizer

In order to make high-strength concrete, Super Plasticizers (SP) are added to fresh concrete to enhance its workability and enable the water content to be dropped. Conplast SP 430 Dis is the Super plasticizer utilized in this investigation. The specific gravity of Super plasticizer is obtained as 1.145.

3.2. METHODOLOGY

In this study to evaluate the effects of Alccofine as partial replacement to cement and slag sand as complete replacement to fine aggregate respectively four stages are given below.

1. Calculation of mix proportions for M60 grade concrete mix containing cement, slag sand, coarse aggregate, water and super plasticizer.
2. Moulding of specimens required for casting the cubes, cylinder and beam specimens.
3. Determination of workability properties (Slump cone, Compaction factor) of M60 grade concrete at fresh state.
4. Casting of specimen under controlled conditions.
5. Demoulding of specimens after 24 hrs. of casting and preparing the samples for curing in curing tank for 3, 7 and 28 days of curing.
6. Determination of strength properties (Compressive, Split tensile, Flexural) of conventional M60 grade concrete at hardened state at 3, 7 and 28 days.
7. Determination of strength properties (Compressive, Split tensile, Flexural) of concrete with Alccofine and slag sand at hardened state at 3, 7 and 28 days.

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4. RESULTS & DISCUSSIONS

4.1. FRESH PROPERTIES OF CONCRETE

4.1.1. Slump test

The workability properties of freshly mixed concrete were assessed through the slump cone test for all five groups of concrete mixes. The results followed trends for the conventional concrete mix, the slump value measured 112 mm. interestingly, as the proportion of Alccofine gradually replaced with cement at rates of 0%, 5%, 10%, 15%, and 20%, the slump value steadily decreased. At the 20% Alccofine replacement level, the slump value reached 100 mm presented in table 3 and figure 3.

Table 3. Variation of Slump

% of Alccofine	Slump in mm
0	112
5	110
10	107
15	104
20	100

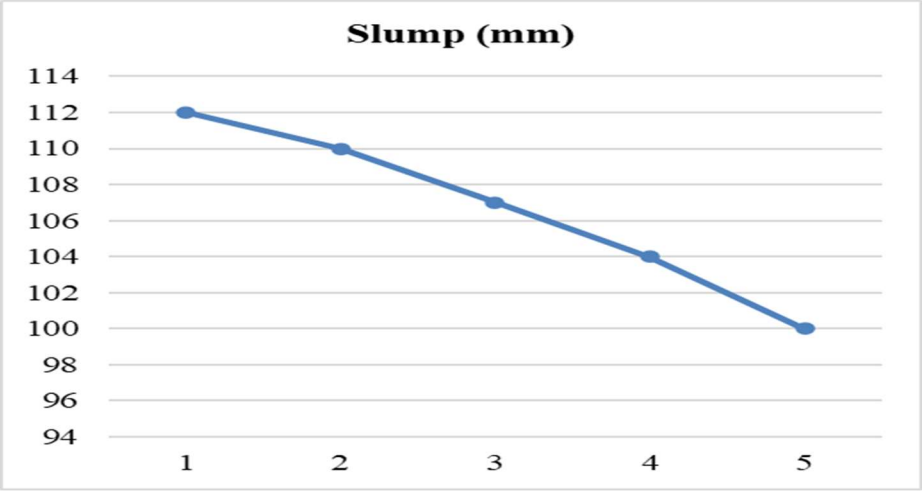

Fig 3. Variation of Slump

4.1.2. Compaction factor test

A similar trend like slump test was observed in the compaction factor test. The conventional concrete exhibited a compaction factor of 0.92. However, as the cement was progressively substituted with Alccofine at the specified rates (0%, 5%, 10%, 15%, and 20%), the compaction factor exhibited a gradual decrease. At the 20% Alccofine replacement level, the compaction factor measured 0.853 presented in table 4 and figure 4.

Table 4. Variation of Compaction factor

% of Alccofine	Compaction Factor
0	0.92
5	0.894
10	0.862
15	0.859
20	0.853

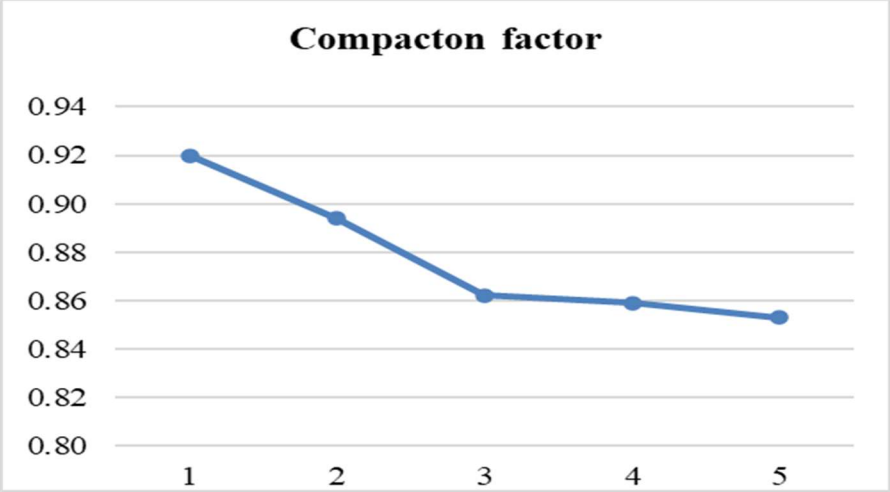

Fig 4. Variation of Compaction factor

4.2. HARDENED PROPERTIES OF CONCRETE

4.2.1. Compressive strength test

The table 7 presents the compressive strength data for curing periods of 3, 7 and 28 days. It is evident that the conventional mix achieved a compressive strength of 60.25 N/mm². Notably, the mix incorporating 15% Alccofine as partial replacement to cement in conjunction with 100% slag sand as a substitute for natural sand surpassed all other mixtures, attaining a compressive strength of 71.98 N/mm², depicted in table 5 and figure 5. This represents an enhancement of 8.122% in compressive strength at 28 days.

Table 5. Variation of Compressive strength

% of Alccofine	3 Days	7 Days	28 Days
0	23.66	38.91	60.25
5	25.68	42.51	62.99
10	25.97	43.6	68.98
15	26.59	46.9	71.98
20	22.80	38.6	66.48

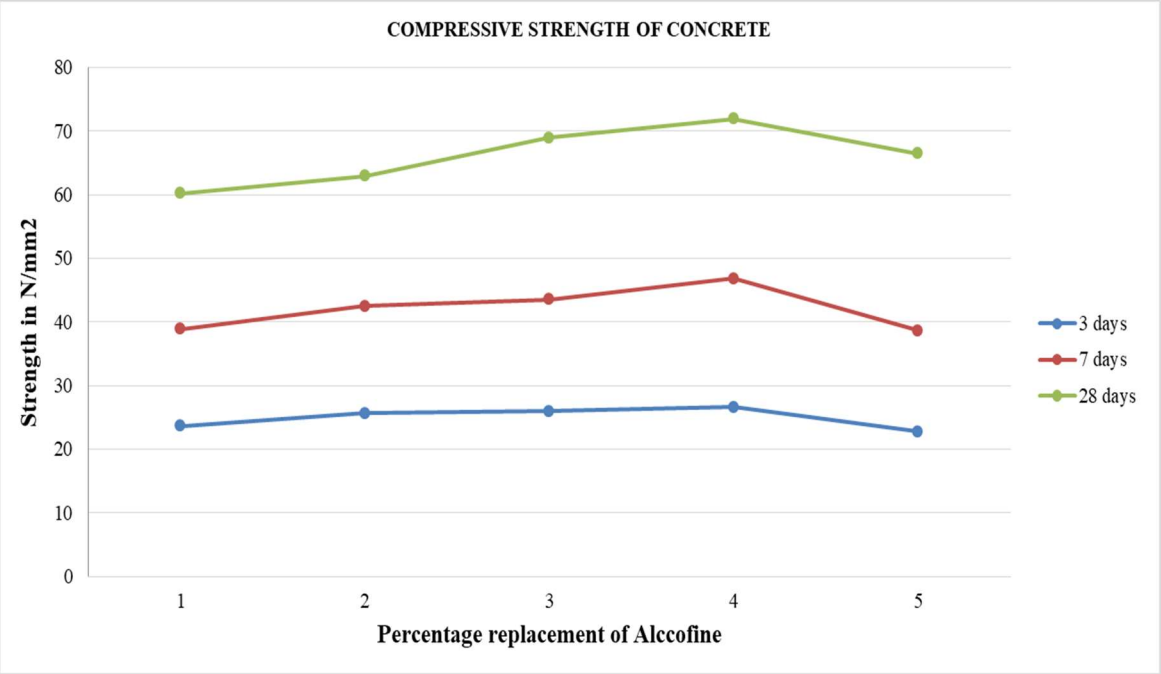

Fig 5. Variation of Compressive strength

4.2.2. Split tensile strength test

The table 8 presents the split tensile strength values for curing periods of 3, 7 and 28 days. It is evident that the conventional mix exhibited a split tensile strength of 5.512 N/mm². Remarkably, the mix incorporating 15% Alccofine as partial replacement to cement alongside 100% slag sand as a substitute for natural sand outperformed all other mixtures, achieving a split tensile strength of 7.259 N/mm², depicted in table 6 and figure 6. This represents an enhancement of 9.65% in split tensile strength at 28 days.

Table 6. Variation of Split tensile strength

% of Alccofine	3 Days	7 Days	28 Days
0	2.116	3.488	5.512
5	2.255	3.604	5.821
10	2.272	3.681	6.231
15	2.471	3.898	7.259
20	2.182	3.409	5.499

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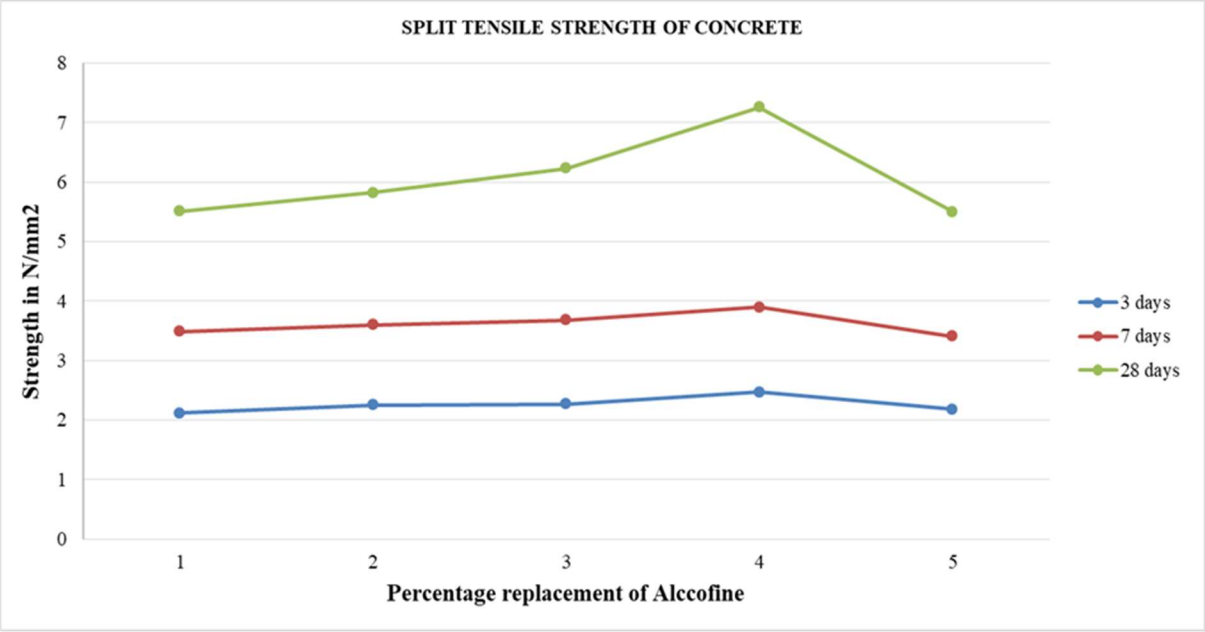

Fig 6. Variation of Split tensile strength

4.2.3. Flexural strength test

Table 9 presents the flexural strength values for curing periods of 3, 7 and 28 days. It is evident that the conventional mix achieved a flexural strength of 6.125 N/mm². Notably, the mix incorporating 15% Alccofine as partial replacement to cement in conjunction with 100% slag sand as a substitute for natural sand surpassed all other mixtures, attaining a flexural strength of 7.982 N/mm², depicted in table 7 and figure 7. This represents an enhancement of 10.69% in flexural strength at 28 days.

Table 7. Variation of Flexural strength

% of Alccofine	3 Days	7 Days	28 Days
0	2.411	3.934	6.125
5	2.519	4.117	6.475
10	2.836	4.541	6.876
15	3.121	4.981	7.982
20	2.365	3.861	6.086

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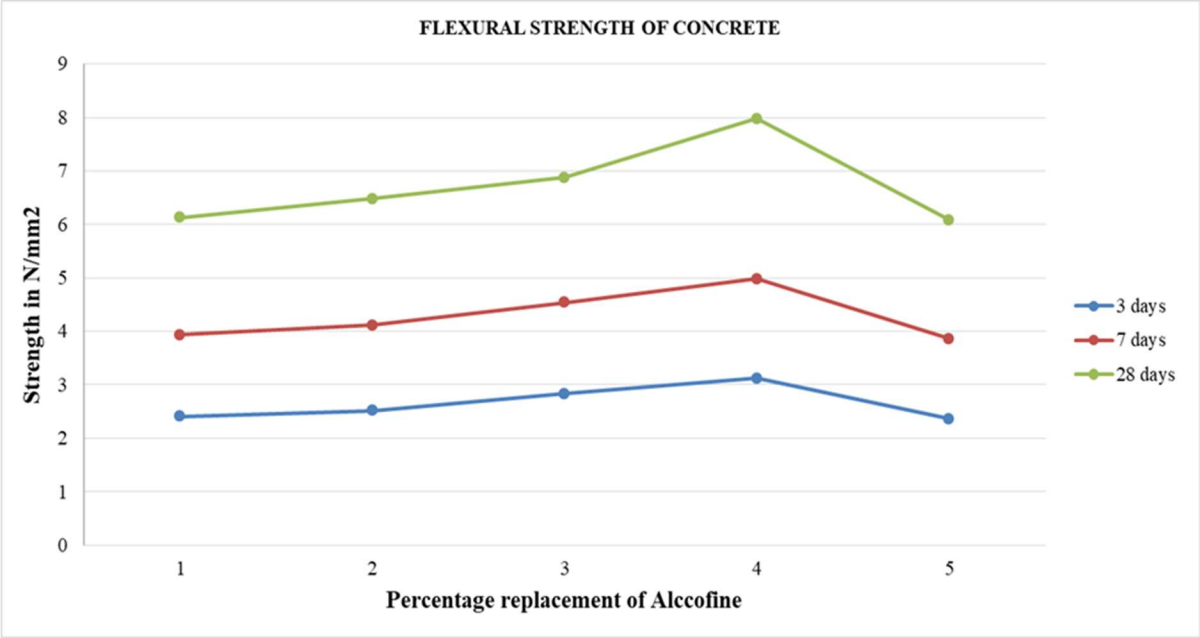

Fig 7. Variation of Flexural strength

5. CONCLUSIONS

After analyzing the strength properties over the curing period of 3, 7 and 28 days the following conclusions are made.

1. The Workability results show that for the conventional concrete mix, the slump value measured as 112 mm. interestingly, as the proportion of Alccofine gradually replaced with cement the slump value steadily decreased and reached 100 mm minimum at the 20% of replacement.
2. The Workability results show that for the conventional concrete mix, the compaction factor value measured as 0.92. Interestingly, as the proportion of Alccofinegradually replaced coarse aggregate the slump value steadily increased and reached 0.853 minimum at the 20% of replacement.
3. The mix incorporating 15% Alccofine as partial replacement to cement in combination with 100% slag sand as a substitute for natural sand achieved the highest compressive strength, reaching 71.98 N/mm². This represents an improvement of 8.112% in compressive strength at 28 days curing compared to conventional mix.
4. Among all the mixtures, the combination of 15% Alccofine as partial replacement to cement and 100% slag sand as a replacement for natural sand yielded the highest split tensile strength, measuring 7.259N/mm². This represents an enhancement of 9.65% in split tensile strength at 28 days curing compared to conventional mix.
5. The mix featuring 15% Alccofine as partial replacement to cement along with 100% slag sand as a substitute for natural sand displayed the highest flexural strength among all combinations, reaching 7.982N/mm². This represents an improvement of 10.69% in flexural strength at 28 days curing compared to conventional mix.

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4. After conducting an analysis of the workability in its fresh state and assessing the strength properties throughout a curing period of 7, 14, 21, and 28 days, the following conclusions have been drawn:
5. 1. The mix incorporating 15% E-waste replacement in combination with 100% slag sand as a substitute for natural sand achieved the highest compressive strength, reaching 41.67 N/mm². This represents a remarkable improvement of 62.07% compared to other mixtures.
6. 2. Among all the mixtures, the combination of 10% E-waste replacement and 100% slag sand as a replacement for natural sand yielded the highest split tensile strength, measuring 5.34 N/mm². This represents an enhancement of 24.76%.
7. 3. The mix featuring 10% E-waste replacement along with 100% slag sand as a substitute for natural sand displayed the highest flexural strength among all combinations, reaching 9.11 N/mm². This represents a substantial improvement of 71.56% when compared to other mixtures. Dolomite is a common rock-forming mineral. It is a calcium.

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