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Utilization of sustainable materials for development of High Strength Concrete

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Abstract. Concrete is the mostly used material in all the construction activities and thus resulted in scarcity of raw materials for future infrastructure development. The entire problematic condition is balanced by utilization of different alternatives such as by products from various industries resulting towards sustainable development. Hence in order to develop an innovative concrete with improved properties, granite dust and alccofine are used in this present study. Conplast SP550 is used as super plasticizer for workability. M40 grade concrete is considered as reference concrete mix. In the first phase, cement is replaced with granite dust by 10, 20, 30, 40 and 50% and followed by second phase where alccofine is also utilized as an alternative for cement by 5, 10, 15, and 20 % respectively. In the final phase, an innovative concrete with improved compressive strength at 7, 14, 28 and 56 days curing periods is obtained by replacing cement with optimum contents of granite dust and alccofine at 20 % and 15 % respectively. Non-destructive testing such as rebound hammer test is also performed on the concrete mixes. The use of materials such as alccofine and granite dust has shown enhancement of strength resulting in development of new sustainable concrete.

1 Introduction

Alccofine is an ultra-fine supplementary material, which helps in enhancement of overall properties of concrete by contributing to the pozzolanic reaction and increasing calcium silicate hydrate formation. It reduces heat regarding hydration , segregation, and permeability while lowering cement consumption and CO_2 emissions. Ideal for high-strength and high-performance concrete, Alccofine improves mechanical properties and supports sustainability[1].Alccofine, a reactive microfiller and pozzolanic material, enhances concrete's workability, durability, and strength by filling voids and reducing permeability by enhancing the formation of calcium silicate hydrate during hydration. By lowering cement content and carbon emissions, Alccofine promotes sustainability and ensures superior performance in aggressive environments [2][3]. Alccofine, a high-

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performance microfine material, enhances concrete's durability, strength, and workability, making it ideal for high-performance and self-compacting concretes. Its pozzolanic nature increases resistance against various durability elements. By lowering cement content and carbon emissions, Alccofine supports sustainable construction while ensuring superior durability in industrial floors, pavements, and precast elements [4].Alccofine develops additional improvement in the concrete durability. It boosts compressive strength, especially at later curing stages, making it ideal for high-strength applications. Additionally, Alccofine improves workability by lowering water demand, reduces heat of hydration for mass pours, and minimizes drying shrinkage to prevent cracks [5]. Its accelerated setting time and early strength development benefit precast concrete and fast-track construction projects [6].Despite its benefits, Alccofine faces challenges such as variability in performance due to mix proportion inconsistencies and a lack of standardized dosage guidelines [7]. High reactivity can affect workability at larger dosages, and its production involves high energy consumption. Additionally, its relatively high cost limits widespread adoption, necessitating further research to optimize its use in concrete[8] [15].

Tinesh et al [8] studied Alccofine-1203 (ALC-1203) in M30 concrete, replacing up to 30% of cement, and found improved slump and no adverse effect on workability. The A15 mix showed a 15% increase in compressive strength and reduced water absorption. Alccofine enhanced mechanical properties by improving particle packing and pore structure, boosting both strength and durability. Ibrahim et al [9]. investigated sugarcane leaf ash (SLA) and granite dust (GD) in eco-friendly UHPC, replacing 20%-50% cement. SLA outperformed GD in strength and durability, with optimal performance at 20% replacement and enhanced microstructure through pozzolanic reactions. Sai Srinath et al [10] tested Alccofine in M20, M30, and M40 concrete, finding optimal strength at 15% replacement. Strength tests showed significant improvements, with M20 achieving 28-day strength in 7 days, highlighting Alccofine's sustainability benefits. Ganesan et al [11] used coal bottom ash (CBA) and Alccofine in concrete, achieving optimal results with 40% CBA and 15% Alccofine. This mix enhanced strength, durability, and pore structure while promoting sustainability, despite a slight cost increase. Priyanka et al [12] examined GFRSCC for M30 and M40 grades, finding optimal performance at 0.15%-0.2% glass fiber content. Fibers improved strength, durability, and load-deflection behaviour but reduced workability at higher contents. Using Alccofine and granite powder as partial cement replacements promotes sustainable construction by reducing carbon emissions and utilizing industrial waste[14]. Alccofine improves concrete strength, durability, and workability, while granite powder enhances density and manages stone industry by-products. Both materials lower production costs and environmental impact [13]. This project aligns with green building trends, offering eco-friendly, high-performance concrete solutions. It also addresses waste management challenges and contributes to long-lasting, cost-effective structures.

The objective of the work is to evaluate compressive strength regarding M40 grade concrete with alccofine and granite dust as partial cement replacements, optimizing their respective percentages. Additionally, the study seeks to compare the obtained results with conventional concrete. Non-destructive tests, such as rebound hammer test, which is adopted for assessing rebound strength of optimized mix, providing a comparison with standard concrete.

2 Materials Utilized

Cement, fine aggregate, coarse aggregate, alccofine powder, granite dust, super plasticizer (Conplast SP550) and water are materials chosen in the work. Cement is of OPC 53 grade. Specific gravity and fineness are 3.11 and 7% respectively. Natural river sand procured from Vamsadara River (Srikakulam) is used in the study. The specific gravity of sand is 2.62. Locally available graded 20 mm and 10 mm aggregate pertaining to specific gravity of 2.78 and 2.74 is adopted. Alccofine is considered from by-products of the steel industry, primarily granulated slag which is procured from Chennai. Granite dust is procured from Granite industries near to Tekkali.

3 Methodology and Experimental Investigation

The entire study as well as experimental investigation is represented in the below Fig.1.

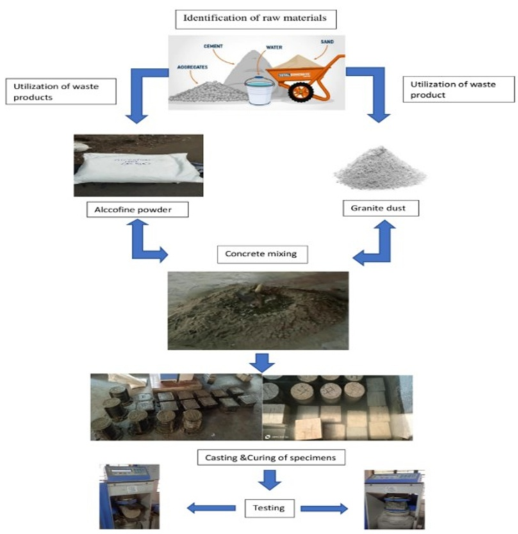

Fig.1. Step by step procedure for the experimental study

The flowchart outlines a structured methodology for incorporating industrial waste products into concrete production to enhance sustainability and performance. The process begins with the identification of essential raw materials which form the base of conventional concrete. To improve resource efficiency, supplementary materials like Alccofine powder and granite dust, both industrial by-products, are selected for utilization. The selected raw materials and waste products are thoroughly blended through a concrete mixing process to ensure uniformity and consistency. Once mixed, the fresh concrete is poured into standardized moulds to create specimens for testing. The standard moulds size used in the study are 150 mm cubes. These specimens then subjected to curing under controlled conditions to achieve the required hydration and strength development. After sufficient curing for 7, 14, 28, 56 days, the hardened concrete cubes are tested to evaluate key mechanical properties like compressive strength. Then the specimens are subjected to hardened concrete tests as per IS codal provisions. These tests include destructive and non-destructive tests. The destructive tests are performed on concrete specimens to determine the compression characteristics of concrete with alccofine and granite dust. The non-destructive test include Rebound Hammer experiment for obtaining the strength of concrete mixes. Results from testing phase provide insights into the effectiveness of incorporating Alccofine and granite dust into concrete. This methodology demonstrates a practical approach to sustainable construction by reusing waste materials, reducing landfill load, and conserving natural resources.

Fig.2. Cube test in Compression Testing Machine

4 Results and Discussions

The results obtained have been analysed and discussed to compare the behaviour of M40 grade concrete using Alccofine, Granite dust and SP550. The concrete of M40 grade is tested for compressive strength when concrete specimens are cured at different ages of 7, 14, 28 and 56 days. The entire experimental study is carried out in two phases. In phase I, the concrete specimens are cast by replacing cement with granite dust by 10, 20, 30, 40 and 50% respectively and also replaced with alccofine by 5, 10, 15, and 20 % respectively. The optimum percentages of alccofine and granite dust are obtained from the maximum compressive strength values. In phase-II the concrete specimens are cast using the combination of alccofine and granite dust. Nomenclature of all the mixes used in the study are as follows:

- M1 Cement+ River sand+ Coarse aggregate+ Water
- M2 Cement + 5% Alccofine + River sand+ Coarse aggregate+ Water
- M3 Cement + 10% Alccofine + River sand+ Coarse aggregate+ Water
- M4 Cement + 15% Alccofine + River sand+ Coarse aggregate+ Water
- M5 Cement + 20% Alccofine + River sand+ Coarse aggregate+ Water
- M6 Cement + 10 % Granite dust + River sand+ Coarse aggregate+ Water
- M7 Cement + 20 % Granite dust + River sand+ Coarse aggregate+ Water
- M8 Cement + 30 % Granite dust + River sand+ Coarse aggregate+ Water
- M9 Cement + 40 % Granite dust + River sand+ Coarse aggregate+ Water
- M10 Cement + 50 % Granite dust + River sand+ Coarse aggregate+ Water
- M11 Cement (65%) + 15 % Alccofine +20 % Granite dust+ River sand+ Coarse aggregate+ Water
- Super plasticizer Conplast SP 550 is added as 0.8 % by weight of cement.

Table 1 Compressive strength values of Trail Mixes of M40 Grade Concrete with Alccofine

Compressive Strength (N/mm^2) at days						
S.No.	**% Alccofine**	**Mix type**	**7**	**14**	**28**	**56**
1	0	M1	25.51	35.17	48.63	51.40
2	5	M2	26.12	37.13	49.21	52.28
3	10	M3	26.94	38.09	51.46	53.62
4	15	M4	28.23	38.74	52.40	54.11
5	20	M5	25.42	36.33	49.24	50.27

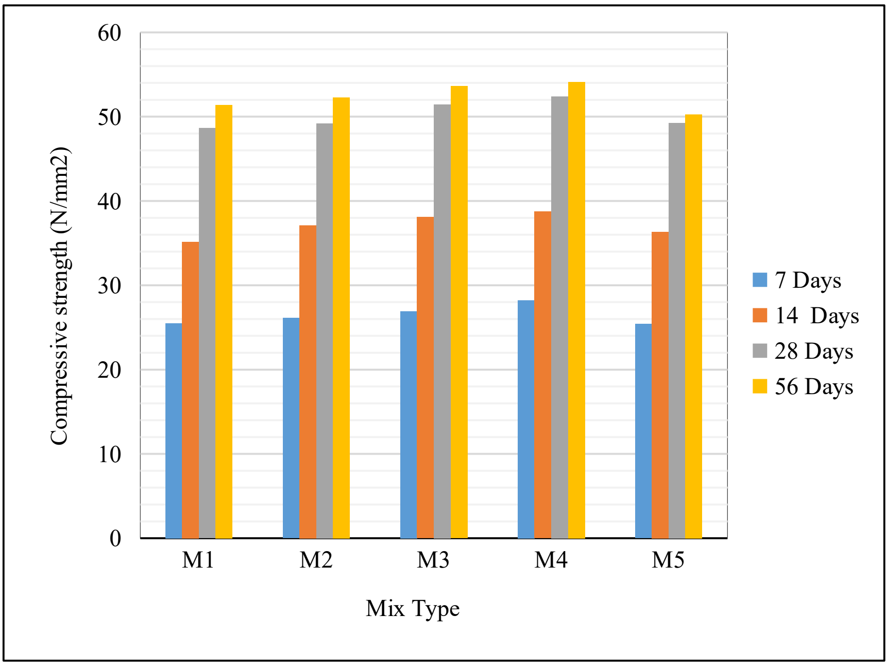

Fig.3. Variation of compressive strength of Trail Mixes of M40 Grade Concrete with Alccofine

The Table 1 and Fig.3. shows the compressive strength variation for different percentages including Alccofine replacement in concrete mixes (M1 to M5) over curing at 7, 14, 28, and 56 days. The results depict consistent increase in strength with Alccofine addition up to 15%, after which a slight decrease is observed. Mix M4 with 15% Alccofine attains more strength. This indicates that 15% Alccofine replacement is the optimum dosage for enhancing compressive strength in M40 grade concrete.

Table 2 Values of compressive strength of Trail Mixes of M40 Grade Concrete with Granite dust

Compressive Strength (N/mm²) at days						
S.No .	**% Granite Dust**	**Mix type**	**7**	**14**	**28**	**56**
1	0	M1	25.51	35.17	48.63	51.40
2	10	M6	26.23	37.10	49.12	52.46
3	20	M7	28.35	39.68	52.16	53.92
4	30	M8	27.42	36.95	50.64	51.25
5	40	M9	25.41	32.92	46.51	47.14
6	50	M10	23.21	30.58	42.26	43.72

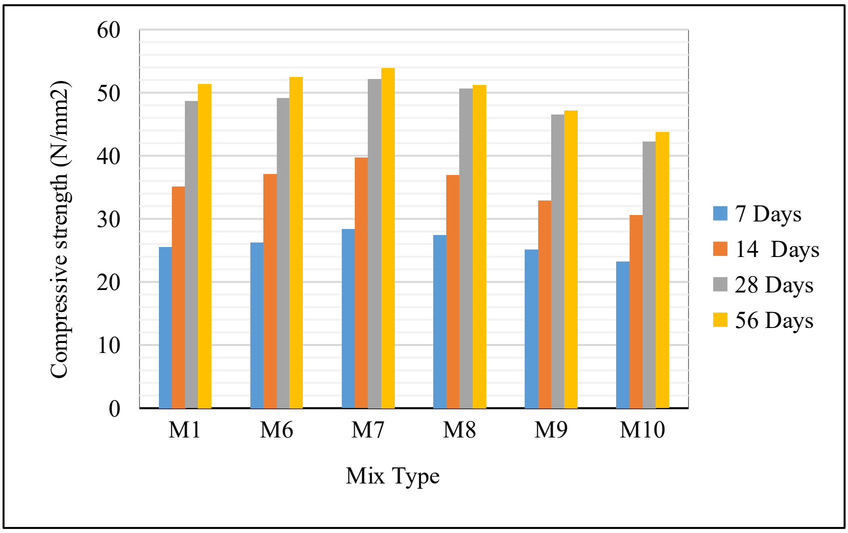

Fig.4. Values of compressive strength of Trail Mixes of M40 Grade Concrete with Granite dust

The Table 2 and Fig. 4. display compressive strength of mixes (M6 to M10) constituting different percentages of granite dust replacement over 7, 14, 28 and 56 days. Results indicate that compressive strength increases with granite dust replacement up to 20%, with Mix M7 showing the highest strength values. Beyond 20%, a gradual decline in strength is observed, suggesting reduced effectiveness at higher replacement levels. Thus, 20% granite dust replacement is found to be the optimum for enhancing compressive strength.

Compressive strength for optimum concrete M11 are obtained at 7, 14, 28 and 56 days and compared with conventional concrete mix M1. The values of compressive strength and variations of its results are depicted in Table 3 and Fig. 5.

Table 3 Values of compressive strength of M40 grade optimum concrete mix with Alccofine and Granite dust at various curing periods

Age of Curing	Compressive strength (N/mm^2)	
	Mix M1	Mix M11
7 days	25.51	29.22
14 days	35.17	39.34
28 days	48.63	55.39
56 days	51.40	58.24

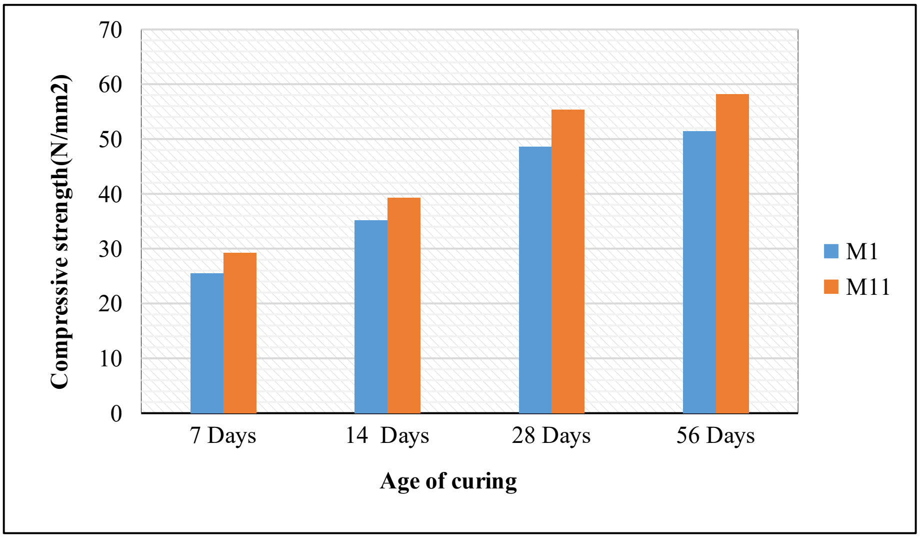

Fig.5. Variation of compressive strength of M40 grade concrete with Alccofine and Granite dust at various curing periods

Compressive strength of concrete mix M11 exhibited maximum values when compared to mix M1 at all the curing ages. Utilisation of the Alccofine and Granite dust has improved compressive strength and also resulted in development new innovative concrete with sustainable materials.

The Rebound compressive strength of cube specimens after 28 days of curing for concrete mixes M1 and M11 of M40 grade concrete with Alccofine and granite dust are shown in Table 4. The variation of Rebound compressive strength with 28 days of curing for the concrete mixes are also shown in Fig. 6.

Table 4 Values of Rebound compressive strength of M40 grade optimum concrete with Alccofine and Granite dust at 28 days curing period

Age of Curing	Rebound compressive strength(N/mm^2)	
	Mix M1	**Mix M11**
28 days	46.40	50.60

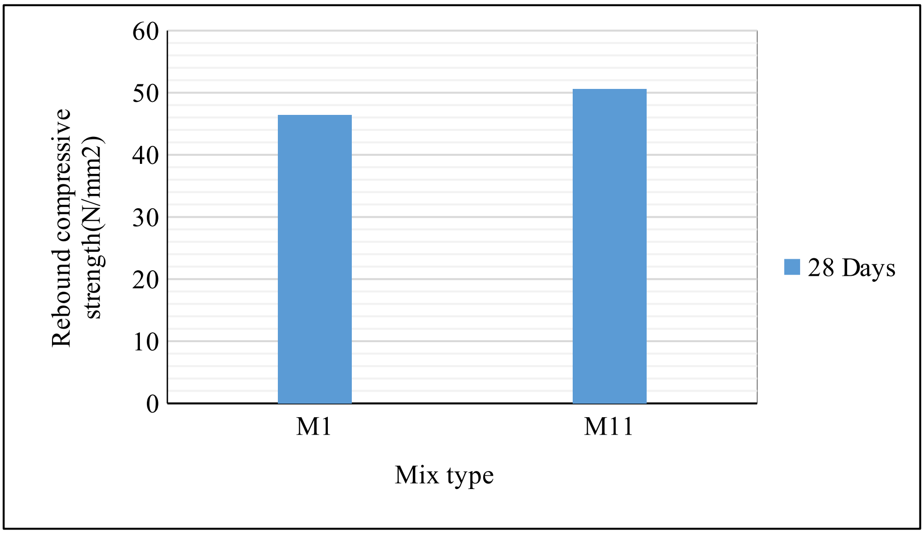

Fig. 6. Variation of Rebound compressive strength of M40 grade optimum concrete mix with Alccofine and Granite dust at 28 days curing period

The rebound compressive strength of concrete mix M11 has increased by 8.3 % when compared to the conventional mix M1. Application of cement with alccofine and granite dust at optimum percentages has increased the compressive strength due to more binding property which enhanced the hydration process.

5 Conclusions

1. The optimum content of Alccofine is attained at 15 % replacement of cement for M40 grade concrete.
2. 20% replacement of cement with granite dust has shown more strength results.

3. Utilisation of the Alccofine and Granite dust has improved compressive strength and also resulted in development of new innovative concrete.
4. The new innovative concrete developed from the optimum mixes of alccofine and granite dust has exhibited remarkable strength improvement properties.
5. The final optimum concrete mix is maximum by 12.20% with respect to the conventional concrete with respect to compressive strength.
6. The rebound compressive strength of final optimum concrete mix is increased by 8.3% when compared with the conventional concrete.
7. Alccofine and granite dust together act as substitutes of cement, which in turn develop eco-friendly concrete without any global effects.

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