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EXPERIMENTAL INVESTIGATION ON THE BEHAVIOUR OF SELF-CURING CONCRETE USING PEG-400, ROBO SAND, RICE HUSK ASH (RHA) AND ALCCOFINE.

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Abstract — Self-curing concrete is a specialized type designed to address inadequate curing due to human negligence, water scarcity in arid areas, unavailability of structures in difficult terrains, and the presence of fluorides in water that can negatively affect concrete properties. This study investigates the use of polyethylene glycol (PEG-400) as a shrinkage-reducing admixture to enhance self-curing, hydration, and strength. Additionally, rice husk ash (RHA) and Alccofine are used as partial replacements for cement at 10% each, while the Robo sand is used as a partial replacement at 25% of fine aggregate. The compressive strength, flexural strength and split tensile strength of these modified specimens of concrete are evaluated and compared with those of conventionally cured concrete.

Keywords: Self-Curing Concrete, Polyethylene Glycol (PEG-400), Robo Sand, Alccofine, Rice Husk Ash (RHA), Compressive Strength, Flexural Strength and Split Tensile Strength.

INTRODUCTION

Concrete is one of the most broadly used construction materials due to its excellent compressive strength and durability (Neville, 2011) [1]. The typical composition of concrete includes cement, coarse aggregate, fine aggregate and water mixed in specific proportions depending on the requirements of the construction project (Mindess, Young, & Darwin, 2003) [2]. To achieve the desired strength and durability, concrete must be properly cured, which involves maintaining a moist environment for a minimum of 28 days to ensure adequate hydration of the cement (Kosmatka, Kerkhoff, & Panarese, 2002). The curing process significantly impacts the properties of hardened concrete, especially its durability (Taylor, 2013). Improper curing can adversely affect both the durability and strength of concrete structures (Klieger & Lamond, 1994) [3]. Traditional external curing methods require careful monitoring and management to maintain appropriate moisture levels in the concrete (Aïtcin, 1998) [4]. Internal curing (IC) is an innovative approach that introduces additional moisture from within the concrete mix, enhancing the hydration process and reducing self-desiccation (Bentur, Igarashi, & Kovler, 2001) [5]. This method is particularly beneficial in situations where external curing is challenging due to human error, water scarcity, difficult terrain, or water quality issues such as fluoride contamination (Jensen & Hansen, 2001) [6]. Self-curing concrete is designed to mitigate issues associated with insufficient curing by retaining moisture within the concrete matrix, thereby ensuring better hydration and strength development. Polyethylene glycol (PEG-400) has been durability studied for its effectiveness as a shrinkage-reducing admixture in self-curing concrete. Research indicates that PEG-400 significantly reduces autogenous shrinkage and enhances the overall hydration process, resulting in improved mechanical properties (Lura & Jensen, 2006; Jensen & Hansen, 2001). The use of PEG-400 in concrete not only addresses the problem of inadequate external curing but also simplifies the curing process, especially in regions with limited water availability. In recent studies, Al-Gahtani (2020) [7]. Examined the use of PEG-400 in self-curing concrete and reported significant improvements in both compressive and tensile strengths. Another study by Reddy et al. (2021) [8]. confirmed these findings and highlighted the reduction in shrinkage and improved durability properties of PEG-400 modified concrete.

Rice husk ash (RHA) is a by-product of rice milling and has been recognized for its pozzolanic properties, which contribute to the durability and strength of concrete. RHA contains a high amount of silica, which reacts with calcium hydroxide in the cement paste to form additional calcium silicate hydrate (C-S-H), enhancing the concrete's strength and durability (Ganesan, Rajagopal, & Thangavel, 2008) [9]. Studies have shown that absorb RHA as a partial replacement for cement in concrete can improve its mechanical properties and resistance to chemical attack (Ganesan, Rajagopal, & Thangavel, 2008) [10]. Recent research by Kumar et al. (2019) demonstrated that RHA improves the microstructure of concrete, leading to increased compressive strength and reduced permeability. Similarly, Mehta and Siddique (2020) found that RHA-modified concrete exhibits superior resistance to sulphate attack and chloride ion penetration.

Alccofine is a micro-fine material derived from slag, known for its capacity to improve concrete's mechanical qualities. It has been shown to improve both compressive and flexural strengths because of its fine particle size and high pozzolanic activity (Shah & Vyas, 2017) [11]. The addition of Alccofine to concrete results in a denser microstructure, which reduces permeability and enhances durability. This makes Alccofine an attractive option for producing high-performance concrete with superior mechanical and durability characteristics. A recent study by Patel and Shah (2020) highlighted the benefits of using Alccofine in concrete mixtures, noting significant improvements in early strength development and durability under aggressive environmental conditions. Furthermore, Soni et al. (2021) confirmed the positive impact of Alccofine regarding the mechanical characteristics and long-term performance of concrete. Robo sand, also known as manufactured sand, is produced by crushing rocks to a fine particle size. It is considered a sustainable alternative to natural river sand, which is increasingly scarce due to over-extraction and environmental regulations. Studies have demonstrated that Robo sand can improve the strength and workability of concrete while also addressing the environmental issues related to river sand mining (Salmon & Johnson, 1996; Oehlers & Bradford, 1995) [12]. Research by Thomas and Ramesh (2018) indicated that Robo sand enhances the compressive and flexural strengths of concrete, making it a viable alternative to natural sand. Similarly, studies by Anand and Ramamurthy (2019) have shown that concrete incorporating Robo sand exhibits improved durability and resistance to abrasion.

Overall, the integration of these materials in self-curing concrete presents a promising approach to producing high-performance concrete with enhanced mechanical and durability properties. This comprehensive understanding of their effects on concrete will guide future research and practical applications, leading to more sustainable and efficient construction practices. This study aims to evaluate the mechanical properties of self-curing concrete incorporating RHA, Alccofine, and Robo sand as partial replacements for fine aggregate and cement. Self-curing concrete utilizes shrinkage-reducing admixtures such as polyethylene glycol (PEG-400) to improve hydration and strength (Lura & Jensen, 2006) [13]. Additionally, supplementary materials like rice husk ash (RHA), Alccofine, and Robo sand are incorporated as partial replacements for fine aggregate and cement to enhance the characteristics of the concrete (Ganesan, Rajagopal, & Thangavel, 2008) [14]. The focus will be on assessing compressive strength, split tensile strength, and flexural strength, and compared these characteristics with those of concrete that has been traditionally cured. By investigating these parameters, the study seeks to provide a comprehensive understanding of the potential benefits and performance enhancements offered by self-curing concrete with these supplementary materials.

EXPERIMENTAL PROGRAM

A. Materials

1) Cement

Ordinary Pozzolana Cement (OPC) of 53 grade was used when casting the Specimens (Cubes, cylinder and beams).

2) Fine Aggregate

River sand of size less than 4.75 mm size was used as fine aggregate.

3) Coarse Aggregate

Coarse Aggregate of less than 20mm size were used as coarse aggregate.

4) Water

Potable water available in laboratory with pH value of not less than 6 and conforming to the requirement of IS 4562000 was used for mixing concrete and curing the specimen as well.

5) Self-Curing Agent: The typical formula for polyethylene glycol is a condensation polymer of ethylene oxide and water with the general formula H $(OCH_2\ CH_2)$n OH, where n is the normal number of oxyethylene groups that repeat, which ranges from 4 to around 180. It appears to be water soluble. It is nontoxic and odourless. The specific gravity is 1.13. The polyethylene-glycol is used to reduce water evaporation from concrete and increase water retention capacity.

6) Robo sand: Robo sand, also known as manufactured sand, is a type of artificial sand produced by crushing rocks, quarry stones, or larger aggregates into sand-sized particles.

7) Rice husk ash: Rice Husk Ash (RHA) is a byproduct obtained from the burning of rice husks. It is a highly reactive pozzolan that is rich in silica (SiO_2), The elemental constitution (wt%) of rice husk ash is (Biswas et.,2017). The chemical composition (%) of RHA of Median particle size (µm) is 5-10% and specific gravity of RHA is 2.02 - 2.2.

8) Alccofine: If the average particle (µm) size of the alccofine is 4 to 6 microns, and specific gravity of alccofine is 2.2 to 2.4. And bulk density of the Alccofine is 600 – 700Kg/m^3. The specific surface area of Alccofine is high, usually around 12000 cm²/g, which contributes to its high reactivity.

B. Mix Design

The mix design is carried out to achieve specified age, workability of fresh concrete and its durability requirements by using IS 10262-2009. Mix Proportion Details are given in table no.1

Table no.1 Mix proportion details

Water	Cement	Fine aggregates	Coarse aggregates
192 lit/m^3	389.2 kg/ m^3	820 kg/ m^3	1090 kg/ m^3
0.46	1	2.1	2.79

C. Test Specimen

Upon completion of the necessary curing time, the specimens were removed from the curing tank, dried and tested on Compression testing Machine (CTM) to find mechanical properties such as compressive strength on cubes, spit tensile strength on cylinders and flexural strength on beams. 150 mm x 150 mm x 150 mm standard cube mould is used for compressive strength test, cylinders of size 150 mm x 300 mm is used for split tensile strength and beams of 500 mm x 100 mm x 100 mm flexural strength test. Total no. of specimen casted are given below in table 2.

Total no.2 of specimen casted

S.no	Mix	Compressive strength no. of cubes (N/mm^2)	Split tensile strength no. of Cylinders (N/mm^2)	Flexural strength no. of beams (N/mm^2)
S.no	**MIX**	3	3	2
1	**MR**	3	3	2
2	**MRR**	3	3	2
3	**MRRA**	3	3	2
4	**MRRAP1**	3	3	2
5	**MRRAP2**	3	3	2
6	**MRRAP3**	3	3	2

D. Test Set Up

Compressive strength:

The compressive strength test is conducted on a cube specimen of size 150cmX150cmX150cm to determine the compressive strengths. The specimens were removed after 28 curing. The specimens were positioned in the compressive testing machine (CTM) in a way that load is applied other than the side of cast. The load must be applied carefully and increased gradually at a rate of approximately 140kg/cm^2/min. until the specimen's capacity to deal with increasing stress fails and no greater load can be sustained. The maximum load that the specimen can resist is recorded. Similarly, the procedure is repeated with other concrete trail mixes. The average of strengths for 3 trails is considered as the strength of concrete.

Fig no.1 Specimen placed in CTM for compressive strength

Split-Tensile Strength Test:

Concrete is a brittle material which cannot provide resistance against direct tensile forces or loads. When the concrete cannot take tensile loads then cracks can be formed. Split tensile strength of a concrete is obtained by conducting split tensile strength test on cylindrical specimens conforming to IS 516-1959. The split tensile strength test is done on a cylinder of size 150mm diameter and 300mm height. Specimens are removed from the curing after 28 days and air-dried. Specimens were tested in compressive strength testing machine (CTM) with a uniform load of 2kN is applied. The maximum load obtained at the breaking of the specimen is noted and the formula to determine the split tensile strength is given below.

$$T = \frac{2P}{\pi LD}$$

Where,

T = Splitting tensile strength N/mm^2

P = Max. applied load, KN

L = Length, mm

D = Diameter.mm

. Fig 2 Specimen placed in CTM for Split-Tensile strength

Flexural Strength test:

As per IS 516-1959, flexural strength of the specimens is tested. This method is an alternative to find the tensile strength of concrete. A beam is casted which has 100mmX100mmX500mm as dimensions. This test is used to determine the resistance to bending that the unreinforced beam offers. For each of the 28 days tests, two beams are taken into consideration. A three-point loading is applied to measure the flexural strength of the specimen. The arrangement should be such that there is a third of the distance between each roller and the beam edges, or approximately 5 cm. The loading rate should be optimal be of value 180Kg/min. the pace value for testing is 0.3kN/sec. The code states that when applying a certain calculation, the distance between a crack or fracture line and the closest support is taken into consideration. This means that the flexural strength value is dependent on the crack pattern.

$F = \frac{PL}{bd^2}$, when value of a >13cm

$F = \frac{3Pa}{bd^2}$, when value of 11cm < a < 13 cm

Where,

F = Flexural strength, N/mm^2

P = Load, KN

L = Length of the span

B = width of the beam

D = effective depth of the beam

A = shear span of the beam.

Fig 3. Specimen Flexure testing machine for Flexural strength.

RESULTS AND DISCUSSION

The following are the mix designation given below

MIX DESIGNATION:

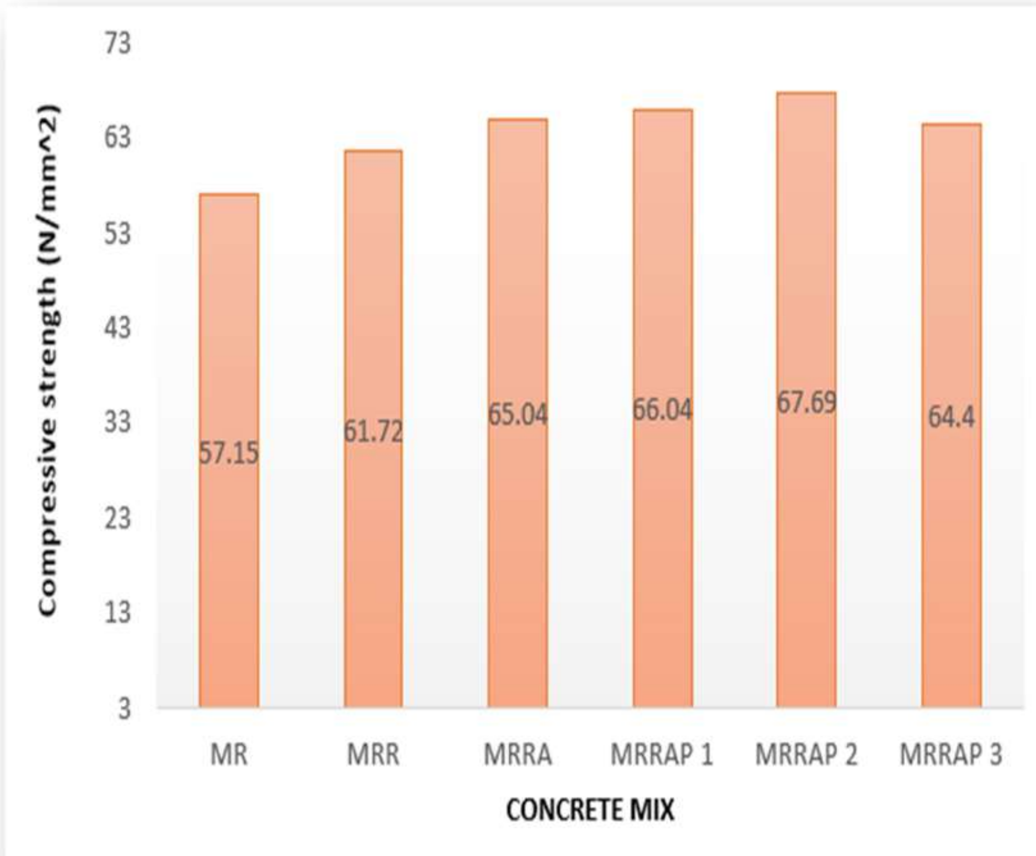
- MCC - Mix Conventional Concrete
- MR - Mix Robo Sand
- MRRHS - Mix Robo Sand + Rice Husk Ash
- MRRHAAP0 - Mix Robo Sand + Rice Husk Ash + Alccofine
- MRRHAAP0.5 - Mix Robo Sand + Rice Husk Ash + Alccofine + 0.5% PEG-400
- MRRHAAP1.0 - Mix Robo Sand + Rice Husk Ash + Alccofine + 1.0%PEG-400
- MRRHAAP1.5 - Mix Robo Sand + Rice Husk Ash + Alccofine + 1.5% PEG-400

1 Compressive strength test:

Table 3 Compressive strength test results

S.no	MIX	Percentage (%) of PEG-400	compressive strength (N/mm^2)
1	MR	-	57.15
2	MRR	-	61.72

3	**MRRA**	-	65.04
4	**MRRAP 1**	0.5%	66.04
5	**MRRAP 2**	1.0%	67.69
6	**MRRAP 3**	1.5%	64.4



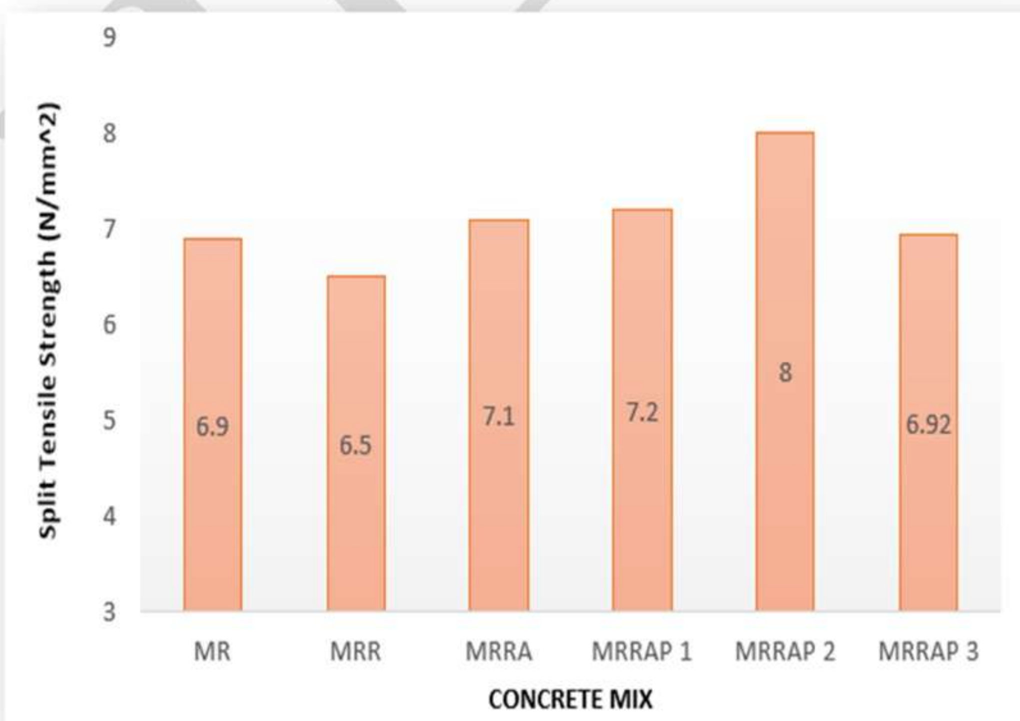
Graph 1: Comparison between Compressive strength test results

Table 3 shows The different concrete mixtures' compressive strength values. After the curing period of 28 days the percentage increase in compressive strength of MRR, MRRA, MRRAP1, MRRAP2 MRRAP3. Concrete mixes is 8.0%, 13.8%, 15.6%, 18.4% and 12.7% percent compared to MR mix. MRRAP2 concrete mix showed the highest compressive strength of 67.69MPa. While the MR concrete mix showed the least compressive strength of 57.15MPa. The results show a clear trend where the addition of MRRAP additives (at 0.5% and 1.0%) has generally improved compressive strength compared to MR, MRR, MRRA. It indicates that the strength of the concrete can be effectively increased by these additives. MRRAP2 (at 1.0%) demonstrates the highest strength gain of 18.4% compared to MR mix, suggesting that this dosage level could be optimal for achieving maximum strength improvement without compromising other properties. MRRAP3 (at 1.5%) shows a decrease in strength compared to MRRAP2. The results suggest that incorporating MRRAP additives at appropriate dosages can significantly enhance the compressive strength of concrete, with MRRAP2 (1.0%) showing the most promising results in this study.

2 Split-Tensile strength test:

Table2: Split-tensile strength test results after 28 days

S.no	MIX	Percentage (%) of PEG-400	Split tensile strength(N/mm^2)
1	MR	-	6.9
2	MRR	-	6.5
3	MRRA	-	7.1
4	MRRAP 1	0.5%	7.2
5	MRRAP 2	1.0%	8.0
6	MRRAP 3	1.5%	6.92



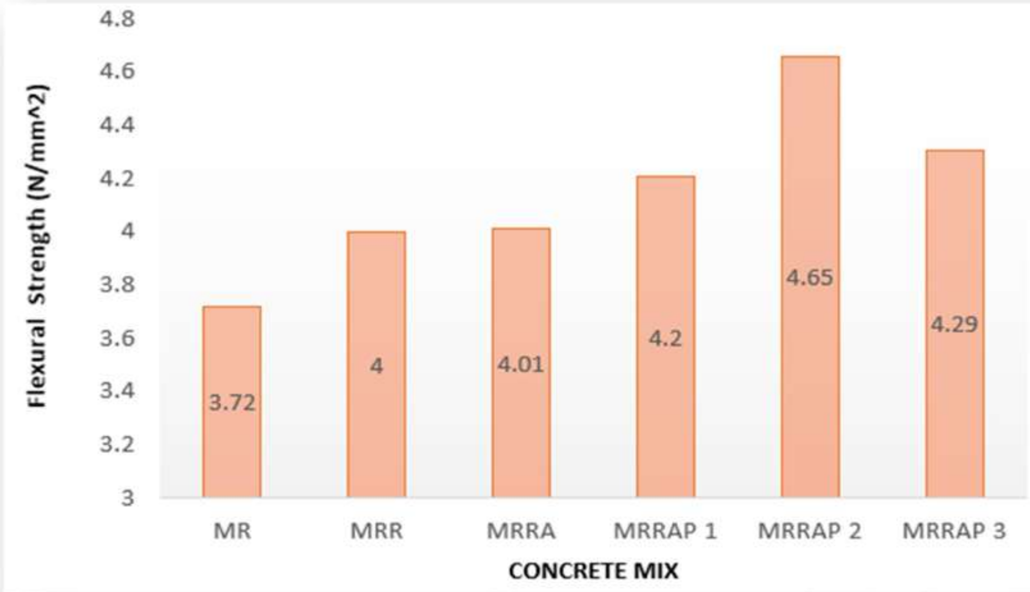
Graph 2: Comparison between Split-Tensile strength test results

Table 4 shows the Split-Tensile strength values of different concrete mixes. After the curing period of 28 days the percentage increase in Split-Tensile strength of MRR, MRRA, MRRAP1, MRRAP2 MRRAP3. MRRAP2 concrete mix showed the highest Split-Tensile strength of 8.0 MPa. While the MRR concrete mix showed the least Split-Tensile strength of 6.5 MPa. The results show a clear trend where the addition of MRRAP additives (at 0.5% and 1.0%) has generally improved Split-Tensile strength compared to MR, MRR, MRRA. This indicates that these additives are effective in enhancing the concrete's strength. MRRAP2 (at 1.0%) demonstrates the highest strength gain of 15% compared to MR mix, suggesting that this dosage level could be optimal for achieving maximum strength improvement without compromising other properties. MRRAP3 (at 1.5%) shows a decrease in strength compared to MRRAP2. The results suggest that incorporating MRRAP additives at appropriate dosages can significantly enhance the Split-Tensile strength of concrete, with MRRAP 2 (1.0%) showing the most promising results in this study.

3 Flexural strength test:

Table 5: Flexural strength test results after 28 days

S.no	**Mix**	**Percentage (%) of PEG-400**	**Flexural strength (N/mm^2)**
1	**MR**	-	3.72
2	**MRR**	-	4.0
3	**MRRA**	-	4.01
4	**MRRAP 1**	0.5%	4.2
5	**MRRAP 2**	1.0%	4.65
6	**MRRAP 3**	1.5%	4.29



Graph 3: Comparison between Flexural strength test results

Table 5 shows the Flexural strength values of different concrete mixes. After the curing period of 28 days the percentage increase in Flexural strength of MRR, MRRA, MRRAP1, MRRAP2 MRRAP3. MRRAP2 concrete mix showed the highest Flexural strength of 4.65 MPa. While the MR concrete mix showed the least Flexural strength of 3.72 MPa. The results show a clear trend where the addition of MRRAP additives (at 0.5% and 1.0%) has generally improved Flexural strength compared to MR, MRR, MRRA. This suggests that these additives are effective in enhancing the concrete's strength. MRRAP2 (at 1.0%) demonstrates the highest strength gain of 25% compared to MR mix, suggesting that this dosage level could be optimal for achieving maximum strength improvement without compromising other properties. MRRAP3 (at 1.5%) shows a decrease in strength compared to MRRAP2. The results suggest that incorporating MRRAP additives at appropriate dosages can significantly enhance the Flexural strength of concrete, with MRRAP2 (1.0%) showing the most promising results in this study.

CONCLUSIONS

Overall, the integration of these materials in self-curing concrete presents a promising approach to producing high-performance concrete with enhanced mechanical and durability properties. This comprehensive understanding of their effects on concrete will guide future research and practical applications, leading to more sustainable and efficient construction practices. The aim of this study is to assess the mechanical characteristics of self-curing concrete that uses Robo sand, Alccofine, and RHA in place of some of the fine aggregate and cement. Self-curing concrete utilizes shrinkage-reducing admixtures such as polyethylene glycol (PEG-400) to improve hydration and strength (Lura & Jensen, 2006). Additionally, supplementary materials like rice husk ash (RHA), Alccofine, and Robo sand are incorporated as partial replacements for cement and fine aggregate to enhance the properties of the concrete (Ganesan, Rajagopal, & Thangavel, 2008). Compressive strength, split tensile strength, and flexural strength will be evaluated, and these characteristics will be contrasted with those of concrete that has been traditionally cured. By investigating these parameters, the study seeks to provide a comprehensive understanding of the potential benefits and performance enhancements offered by self-curing concrete with these supplementary materials.

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