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Evaluating The Compressive Strength Of Green Concrete Containing Calcium Carbide Residue And Rice Husk Ash As Fully Cement Replacement

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Abstract
The compressive strength of green concrete (GC), which is made using rice husk ash (RHA) and calcium carbide residue (CCR) instead of conventional cement, is investigated in this work. According to IS 456:2000, the control mix's objective compressive strength was 26 MPa. Five mixes with varying percentages of CCR and RHA were activated using a 1 molar of sodium hydroxide solution and sodium silicate at $Na_2SiO_3/NaOH$ ratios of 2. According to IS 516:2021's compressive strength tests performed on days 7, 28, and 90, Mix 5 (45% CCR, 45% RHA, and 10% cement) demonstrated the best overall performance, with high compressive strengths when compared to standard concrete. According to this study, Green Concrete is a sustainable and feasible substitute for traditional Portland cement concrete [2][4].

Keywords: *Green concrete (GC), compressive strength, calcium carbide residue (CCR), rice husk ash (RHA), alkali activation solution (AAS), sustainable construction.*

1. Introduction

With cement manufacturing accounting for about 8% of world emissions, it is one of the most leading sources of CO_2 emissions. The urgency to reduce these emissions has driven research on the development of eco-friendly building materials. Green concrete is being used today as an alternative to conventional concrete as part of a global effort to reduce the environmental footprint of building materials [1]. This concrete presents both economic and environmental advantages as it partially substitutes, in the cement mixture, the industrial by products that are normally used in conventional cement. This paper investigates the use of (RHA) and (CCR) as cement replacements in concrete focusing at the compressive strength as well as the water absorption characteristics. [2] [4]. Nowadays, Portland cement is the prevailing cementitious binder in most construction projects worldwide. To produce Portland cement, raw materials must be heated to temperatures as high as 1,500 degrees Celsius; the actual heating happens in a rotary lime kiln, which is typically fuelled by a natural gas. Portland cement therefore causes several problems that exacerbate global warming, including soil pollution and ozone layer depletion. Cement producers have been trying to develop a new type of composite that would contain a lower percentage of Portland cement by adding fly ash and a variety of local pozzolans (substitute volcanic ash) for part of Portland cement with a focus on lowering the environmental impact of producing cement [14] [11]. By-product from acetylene synthesis, calcium carbide residue (CCR) as seen in figure 1, is a calcium-rich solid material and can act as the source of alkalinity for the polymerization of modifier. Original rice husk ash (RHA) - Rice husk ash is the main ingredient of geopolymer matrix presented in figure 2 which is a high amorphous silica and prepared from burning rice husk carefully. India produces abundant CCR and RHA per year; as an environmental-friendly management approach, it could limit that trash with green concrete [9][10].

2. Literature Review

In recent years there are several studies of possibilities of using industrial wastes as CCR and RHA in concrete technology. When used as a binder, the high level of active calcium oxide found in CCR as a byproduct from the production of acetylene gas may add water and other substances to cement and harden the concrete. Related to this aspect, RHA has been recognized for its high silica content that can form pozzolanic reactions enhancing concrete durability upon activation [19][13]. Many studies have investigated RHA as a partial substitute and have obtained a beneficial effect with respect to the long-term strength and durability of concrete. Some tests employing CCR instead of standard cement have found strength comparable to or even better than conventional concrete, particularly when combined with alkaline activators [5] [7]. Since the use of CCR and RHA in green concrete activated by alkaline solutions as a complete cement substitute is still understudied, it is necessary to integrate the impacts of such mixes on the characteristics of both fresh and hardened concrete [2][4]. Some research has focused on replacing cement with RHA and CCR. Research by Nath and Sarker [13] indicates that RHA assets for durability and mechanical qualities are associated with a high silica concentration. Similarly, calcium hydroxide, which is provided by CCR, improves strength in the early years. The long term and different shrinkage control of the geopolymer utilized in RHA and CCR-based concretes were extensively investigated by Mehta [4]. In 2021, Adamu et al. looked on the impacts of using RHA in addition to CCR to replace cement in concrete [14]. In 2014, Kulkarni MS et al. discussed the impacts of RHA as a supplement cement element in concrete [16]. Yunusa et al. (2015) state that replacing PC with CCR at a rate of 0% yields positive results. Water absorption rises in tandem with the mix's RHA content [17]. The advantages of combining slag and calcium carbide as cement replacement in concrete were examined by Sethu et al. (2020) [15].

3. Environmental Considerations

The use of sustainable construction materials is a growing trend around the world to help promote better sustainability and energy efficiency in the construction sector. Reduction in the carbon of the production of concrete that is associated with the use of industrial waste products like CCR and RHA are not only achieved but also finds application to dispose off waste materials that are otherwise environmental pollutions. This research presents green concrete as a sustainable building material, and demonstrates a direction for sustainable construction. Therefore, additional studies on the optimization of the compositions and the use of other environmentally friendly materials are necessary to achieve GC that can compete with those non-green concretes used in the field [12].

Fig.1 Calcium Carbide (CCR)

Fig.2 Rice Husk Ash (RHA)

Fig.3 Conventional Cement (C)

4. Materials and Methods

4.1 The Materials

1. Calcium Carbide Residue (CCR): CCR was obtained from a local industrial plant producing acetylene gas. It is a by-product of the calcium carbide process, containing high levels of thr calcium oxide (CaO) [3][5].
2. Rice Husk Ash (RHA): Rice husk ash was procured from a local source and was burned at 700°C for hours to make certain a complete combustion and enhance the silica content. The chemical composition of the RHA showed a high percentage of silica (SiO2), which contributes to the pozzolanic activity in concrete [3][6][16].
3. Aggregates: IS 383:2016 [25] must be followed for both aggregates. In accordance with IS 2386:1963 [26], the samples' physical and chemical characteristics were assessed [21].
4. Alkali Activators Solution (AAS): Alkali Activators Solution (AAS) was made by preparing one molar of (NaOH 1M) and (Na_2SiO_3)[9, 13].
5. Superplasticizer: To improve workability, a 2% superplasticizer was utilized [14].
6. Cement: 43 grade Type I Portland Cement (OPC) according to IS 269:2015, shown in figure 3.
7. Water: Potable water used in all mixes, adhering to IS 456:2000's specifications for mixing and curing concrete.

Fig.4 Alkaline activator solution

4.2 Mix Design

The control mixture was designed according to IS 10262:2019 and IS 456:2000 [22][23]. The binder content for each mix was based on a target of 26 Mpa strength for conventional concrete. Water to cement was at 0.51 for the mixtures. The proportions are summarized in Table 3 below.

Table 3 Mix Proportions (by Weight)

Mix	Conventional Cement (%)	CCR (%)	RHA (%)	NaOH (Molar)	Na_2SiO_3/NaOH
Mix 1 (Control)	100	0	0	-	-
Mix No.2 (75% RHA, 25% CCR)	0	25	75	1M	2:1
Mix No.3 (50% RHA, 50% CCR)	0	50	50	1M	2:1
Mix No.4 (25% RHA, 75% CCR)	0	75	25	1M	2:1
Mix No.5 (45% RHA, 45% CCR, 10% Cement)	10	45	45	1M	2:1

With a very low cement percentage, Mix No. 5 comprises 10% OPC to examine the different properties of the concrete and determine whether or not this reduced cement content significantly alters the final concrete's behavior and features, including whether or not it has better binding [13].

4.3 **Preparation and Curing of the Samples**

The concrete specimens have been created following the standards of IS 516:2021 [24]. After the dry components have been uniformly blended, sodium hydroxide (NaOH) and sodium silicate (Na2SiO3) are merged to create an alkaline activator solution. The relation between Na2SiO3 to NaOH was 2:1. Concrete cubic moulds with dimensions of 150 x 150 x 150 mm were exposed to curing in a pressor and evaluated for compressive tests at 7, 28, and 90 days [4][9]:

- Moist Curing: Keeping the concrete moist is critical in the initial curing period to allow sufficient time for the alkali-activated binder to complete its reaction. This can be done by:
  - Submerging the cubes in water.
  - Keeping **the cubes under a wet cloth or polyethylene sheets to maintain moisture.**

Fig.5 concrete cubic plastic moulds

The grade of concrete M20 will be created to attain a compressive strength of about 26 MPa in 28 days. First, conventional concrete will be made using OPC. Cement will be replaced with (CCR-RHA) in four different proportions between (0-100) %, the ratio of (CCR-RHA) will be (25:75, 50:50, 75:25) respectively, water to binder ration is given 0.51 can be used as a standard value. In case of maximizing and enhancing the compressive strength, materials bonding and accelerating the pozzolanic reactions, for that purpose, Ordinary Portland Cement is incorporated at a percentage of 10% of the binder's weight (CCR-RHA). A superplasticizer must be applied to retain the concrete's fluidity and workability. Initial preparations of all samples are identical [6][8].

Fig.6 concrete moulds after casting

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4.4 Testing

1. Compressive Strength: In accordance with IS 516:2021 [24], tests were performed to figure out the compressive values of the concrete mixtures at 7, 28, and 90 days for different combinations of conventional cement, CCR, and RHA. Table 4 presents the specific findings [27].
2. Workability: A number of slump tests were conducted in accordance with IS 1199:2018; the solution was aimed at a slump of 50–100 mm [28].

Fig.7 Compression testing machine

5. Results and Discussion

5.1 Compressive Strength

Table 4 depicts the values of compressive strength. Replicate strength measurements were made, and the strength over time is presented in Figure 1.
Figure 2 displays standard deviations to highlight the statistical significance of the evolution of strength.

Table 4 Compressive Strength values (MPa)

Mixes	Compressive values (MPa) 7 Days	Compressive values (MPa) 28 Days	Compressive values (MPa) 90 Days
Mix 1 (Control 100% Cement)	18.42	26.30	30.24
Mix 2 (75%CCR+25%RHA)	13.80	23.00	25.45
Mix 3 (50%CCR+50%RHA)	23.16	38.26	42.14
Mix 4 (25%CCR+75%RHA)	21.83	36.08	41.84
Mix 5 (45%CCR+45%RHA+10%Cement)	26.64	39.4	44.4

Fig.8 Compressive strength testing

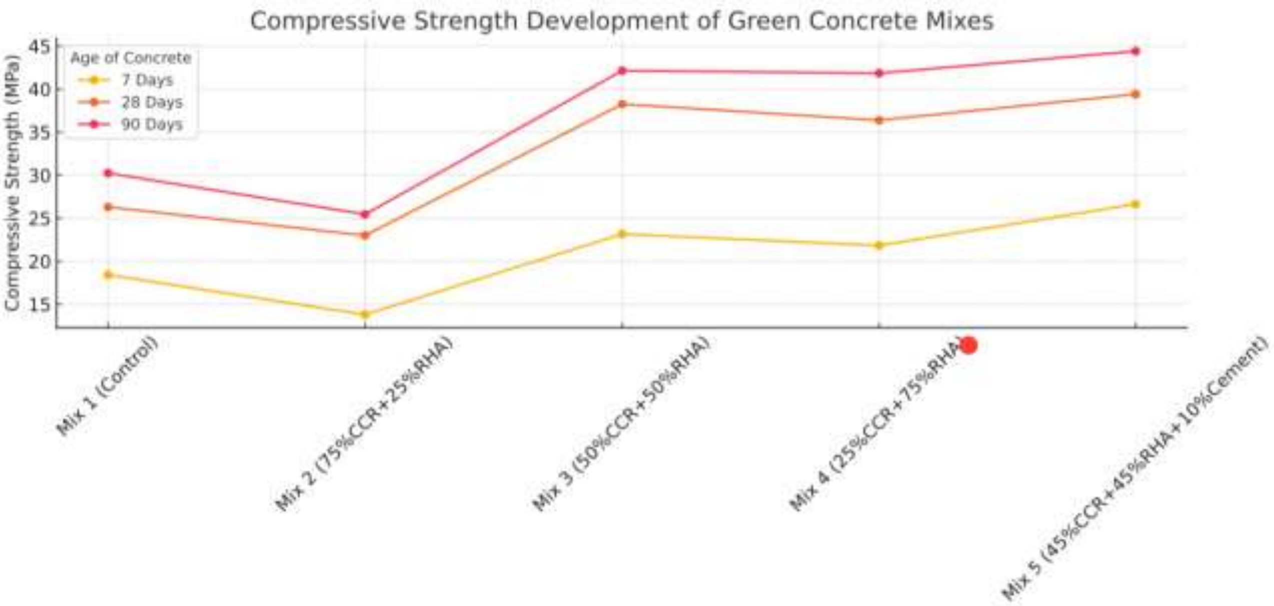

Fig.9 A line graph demonstrates strength enhancement

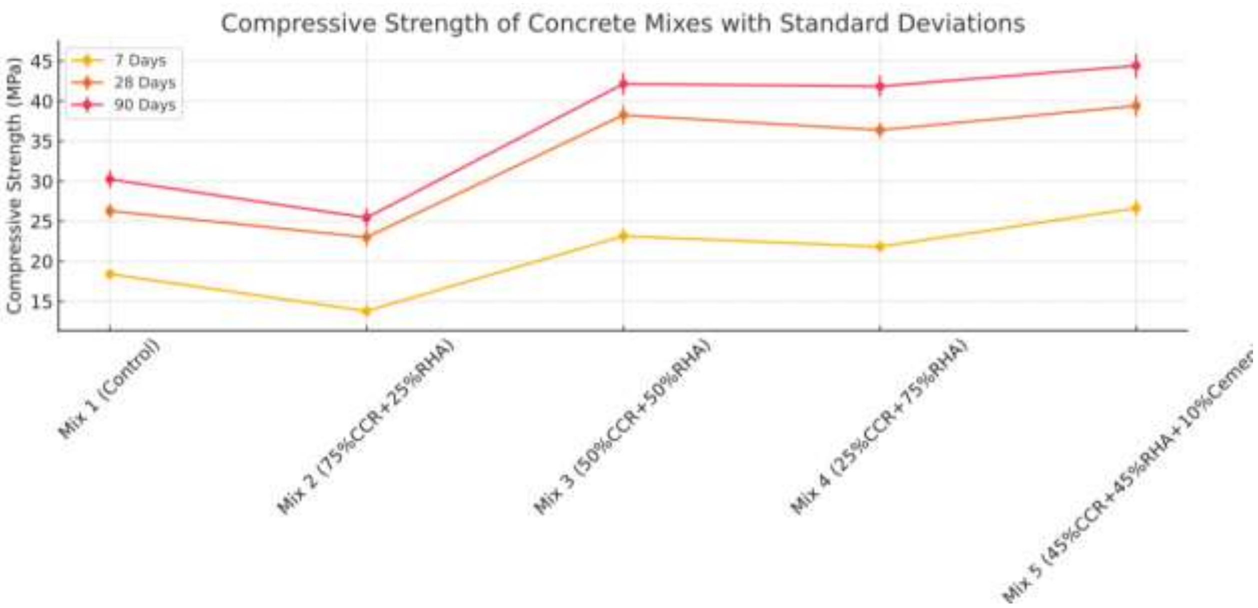

Fig.10 Compressive strength of mixtures with error bars represents standard deviations

5.2 **Scanning Electron Microscopy (SEM) Analysis**

Scanning Electron Microscopy (SEM) was used to inspect the micro-structural features of two concrete systems: the conventional OPC-based mix and the green concrete incorporating CCR and RHA. The SEM scan images provide some insights into the morphology, pore structure, and gel formation of the hydration products, directly correlating with mechanical performance.

5.2.1 **SEM of Conventional Concrete (B1, B1-1, B1-2, B1-3, B1-4)**

The SEM micrographs of the control mix (100% OPC) show the following key characteristics:

Dense C-S-H Formation: Images B1 and B1-1 exhibit a compact matrix with well-formed calcium silicate hydrate (C-S-H) gel structures that appear as fibrous, gel-like masses filling the capillary pores.

- Presence of Microcracks and Capillary Voids: Images B1-2 and B1-3 reveal some microcracks and small voids, which are typical in OPC concrete due to internal stresses during hydration and drying.

- Calcium Hydroxide Crystals (Portlandite): Hexagonal-shaped crystals observed in image B1-4 indicate the existence of calcium hydroxide, a product of OPC hydration. While necessary for strength, excess portlandite can contribute to long-term durability concerns due to leaching.

General Microstructure: The overall texture is relatively dense and uniform, which correlates with the decent compressive strength observed in Mix 1.

Interpretation: The dense microstructure supports the mechanical performance of conventional concrete. However, the presence of crystalline portlandite and microcracks may compromise durability over time. SEM scan images of conventional concrete are shown in Figures 11, 12, 13, and 14, respectively.

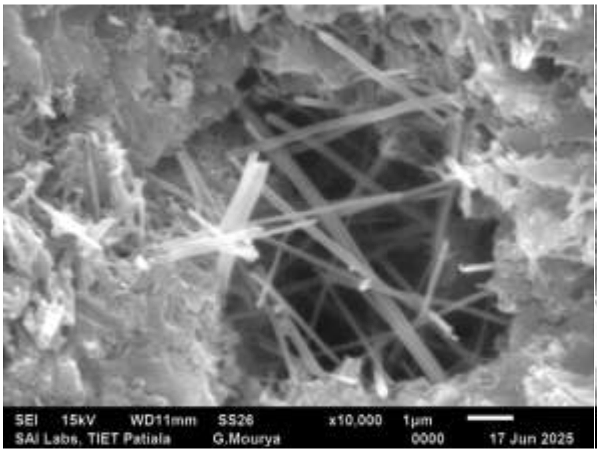

Fig.11 SEM B1

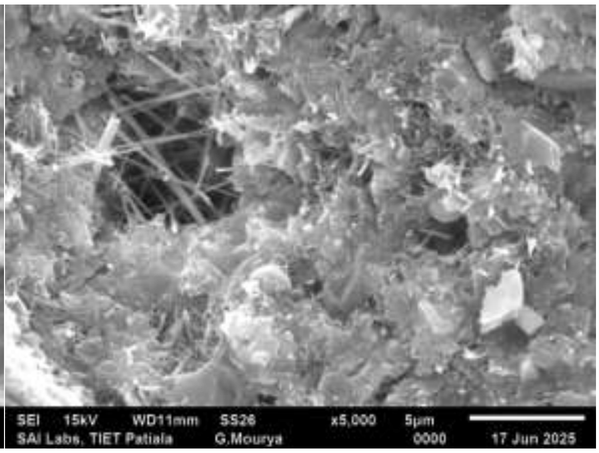

Fig.12 SEM B1-1

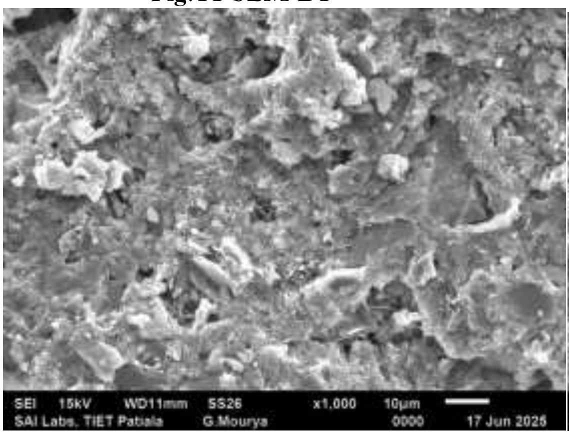

Fig.13 SEM B1-3

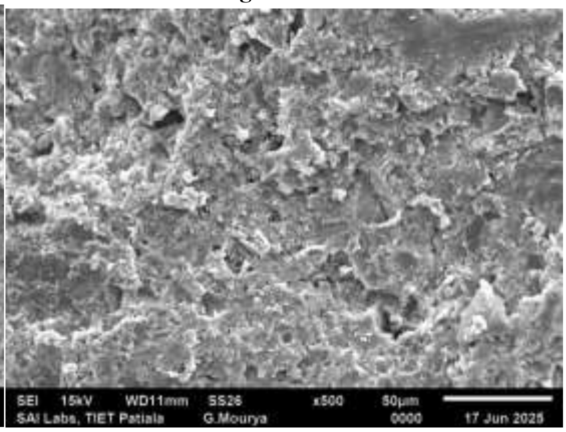

Fig.14 SEM B1-4

5.2.2 **SEM of Green Concrete with CCR-RHA (B3, B3-1, B3-2, B3-3, B3-4)**

The SEM scans of Mix No.5 (45% CCR, 45% RHA, 10% OPC) show significantly altered microstructural characteristics due to geopolymerization:

- Geopolymeric Gel Formation: Images B3 and B3-1 demonstrate the presence of an amorphous, glassy matrix typical of geopolymeric gels (N-A-S-H and C-A-S-H types). These gel particles form through the alkaline activation of RHA and CCR, providing high binding potential.
- Reduced Crystalline Portlandite: Unlike the OPC mix, image B3-2 shows minimal portlandite presence, indicating more complete utilization of calcium ions in the gel network, improving durability.
- Unreacted or Partially Reacted Particles: In image B3-3, a few residual particles of CCR or RHA can be seen embedded in the matrix, suggesting partial reaction. This is common in alkali-activated materials and can act as fillers.
- Denser Matrix with Fewer Voids: Image B3-4 shows a more cohesive structure with fewer microvoids and better particle packing than the conventional mix, contributing to the higher compressive strength noted in Mix 5.

Interpretation: The SEM of the green concrete reveals a well-developed geopolymer network with fewer weaknesses. The compact gel structure and reduced crystalline phases contribute to its improved long-term

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strength and durability. Figures 15, 16, 17, and 18 show SEM scan images of (CCR-RHA-Cement) concrete, respectively.

Conclusion from SEM Analysis:
The SEM characterization confirms that green concrete with CCR and RHA produces a more homogenous, compact, and chemically stable matrix. The geopolymeric gels formed improve the durability and mechanical properties, validating the experimental results where Mix 5 outperformed the OPC-based mix at later ages.

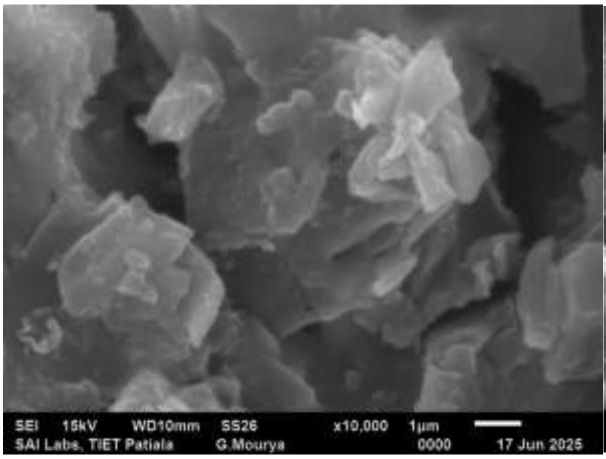

Fig.15 SEM B3

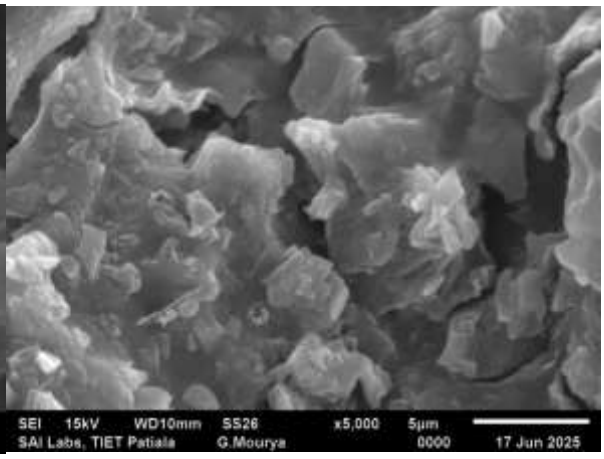

Fig.16 SEM B3-1

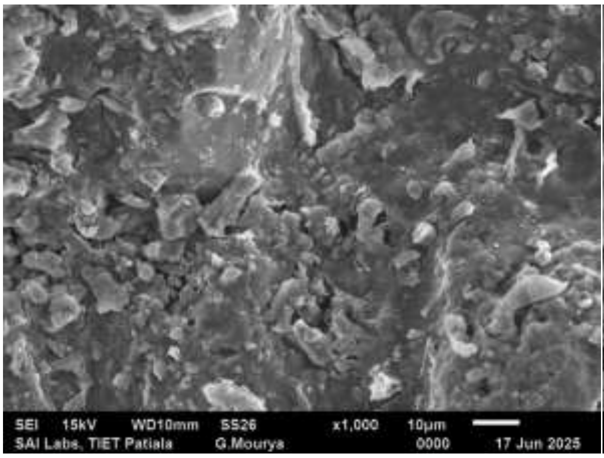

Fig.17 SEM B3-3

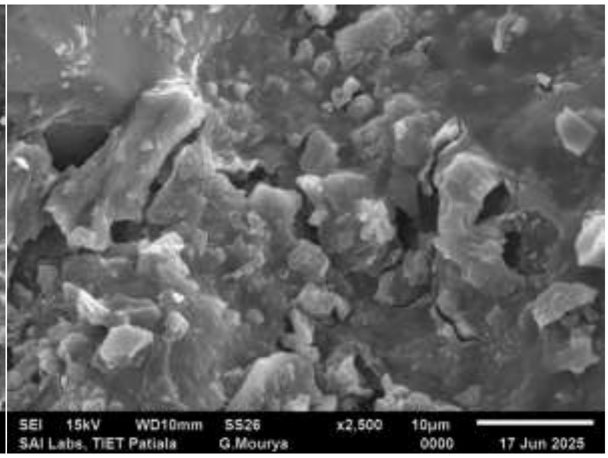

Fig.18 SEM B3-2

5.3 **Discussion**
The experimental data indicate that the inclusion of CCR and RHA as full replacements for cement in concrete results in a reduction in the compressive values for the second mixture in comparison with conventional concrete (Mix 1). However, certain mixes, particularly Mix 5 (containing 45% CCR, 45% RHA, and 10% cement), demonstrated significant improvements in strength at both 28 and 90 days. This suggests that a balanced combination of CCR and RHA, along with a small percentage of conventional cement, can yield promising strength characteristics for green concrete. Mix 3, with 50% CCR and 50% RHA, exhibited high compressive strength at 90 days, indicating that the pozzolanic effect of RHA and the very high calcium content of CCR Participate to the improvement of the strength over time. Additionally, the water absorption data shows that Mix 5 exhibited slightly higher absorption, which is a common characteristic in sustainable concrete formulations due to the porous nature of the by-products used. Mix 5, comprising 10% cement, 45% RHA, and 45% CCR, exhibited the highest compressive strength of 44.40 MPa at 90-day. This is due to RHA's reactive silica and CCR's calcium, which improved gel formation and improved C-S-H synthesis, hence enhancing different properties. The mechanical properties and cohesion of the final concrete have been improved by the incorporation of cement

and the synergistic effects of these two components on compressive strength. Furthermore, cement-free mixtures (mixtures 2–4) exhibited acceptable performance, particularly Mix 3, which preserved an optimal CCR–RHA ratio [18][20].

6. Conclusion

This research successfully illustrates that the utilization of CCR and RHA as full replacements for cement in concrete offers a sustainable and viable alternative to traditional concrete. The values show that the incorporation of CCR and RHA, activated with alkaline activators, can lead to compressive strengths similar to or greater than conventional concrete. In particular, Mix 5 (45% CCR, 45% RHA, and 10% cement) exhibited the best overall performance, with high compressive strengths and acceptable water absorption values [5][7]. Calcium carbide (CCR) comprises a significant amount of $Ca(OH)_2$. Rice husk (RHA), owing to its elevated silica (SiO_2) concentration, is capable of undergoing pozzolanic reactions to establish a calcium-silicate-hydrate gel. Alkaline activators must dissolve calcium ions from CCR and silica ions from RHA to accelerate their reaction and expedite the creation of gels, which is essential for activating pozzolanic processes and producing improved hydrate gels.

7. Future Work

The long-term performance of concrete based on CCR-RHA in many environmental settings should be the main focus of future studies. Green concrete's performance could also be improved by research on mix proportion optimization and the addition of additional sustainable materials like slag or fly ash. It is also essential to perform experimental studies on how climate variables like UV exposure and freeze-thaw cycles affect a long lifespan of these concrete structures.

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