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Enhancing Concrete Performance through Chemical and Mineral Admixture: A Study on Rice Husk Ash and Graphene Oxide Incorporation

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ABSTRACT

Concrete, a vital construction material, is composed of fine and coarse aggregates bound together by a cement paste. While Portland cement is commonly used, alternative hydraulic cements like calcium aluminates cement find occasional application. However, Portland cement, the second most environmentally harmful component in concrete after water, faces challenges such as resource scarcity and durability issues. To address these challenges, additives known as admixtures have emerged.

This study investigates the efficacy of chemical and mineral admixtures, including rice husk ash (RHA) and graphene oxide (GO), in enhancing concrete performance. RHA and GO, derived from industrial by-products and carbon materials, respectively, offer promising prospects for improving concrete properties while mitigating environmental impacts. The study examines their impact on concrete characteristics such as compressive strength, flexural strength, and durability.

This study investigates the efficacy of incorporating graphene oxide (GO) and rice husk ash (RHA) into concrete mixtures to enhance their strength and suitability for construction applications. Experimental testing reveals that concrete compositions containing 15% RHA and 2.5% GO exhibit improved compressive strength, modulus of elasticity, flexural strength, and split tensile strength compared to control mixes. The addition of 15% RHA and 2.5% GO results in a maximum compressive strength of approximately 49.80 MPa, with subsequent decreases in strength observed with higher RHA content. Similarly, flexural strength peaks at approximately 29.88 MPa for the same composition but decreases with higher RHA content. Split tensile strength reaches a maximum of approximately 6.07 MPa for the 15% RHA and 2.5% GO mixture, with a decline observed beyond 15% RHA content.

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1. INTRODUCTION

Concrete is a composite material typically created from fine and coarse aggregates joined by a cement paste. Cement used in concrete has a fluid state that gradually solidifies. While Portland cement is typically utilized, other hydraulic cements, including calcium aluminates cement, are occasionally also employed in concrete. Portland cement is the second-most environmentally harmful artificial ingredient used in concrete after water. As more infrastructures is built around the world, there is an enormous demand for concrete over time. Due to a lack of resources, there is a temporary scarcity of cement as a result of these demands. On the other hand, after extensive use, cement's drawbacks became apparent.

Even though cement has a high thermal mass, is extremely strong, and can build structures quickly, it is prone to failure due to cracking and is not appropriate for situations when settling is anticipated.

Admixtures entered the picture to help with these problems. After so many years of study, it was determined that chemical and mineral admixtures might be utilized in concrete as a cement substitute. By decreasing pollutants and assisting in the preservation of land and other natural resources, the use of admixtures in concrete offers still another answer. Considering that the mineral admixtures utilised, such as fly ash, rice husk ash, etc., are by-products of industrial waste. The use of these wastes as admixtures helps to address a long-standing problem with waste disposal in our nation.

1.1. CONCRETE

- The cement glue structure is dense, impermeable, and has the capacity to withstand freeze-thaw cycles under extreme conditions. It is made from reviewed, stable, and inert materials.
- The blend's fixings contain the fewest debasements possible, including antacids, chlorides, sulphates, and silt.

1.1.1. Types of Concrete

Concrete is divided into many categories based on its composition and design, including plain concrete, reinforced concrete, high strength and high performance concrete, light weight concrete, pressurized concrete, and air entrained concrete. Simply said, reinforced concrete is manufactured with reinforcement and is referred to as RC while plain concrete, often known as conventional or ordinary concrete, is made without reinforcement. Reinforcements are used to counter tension because, while concrete is strong in compression, it is weak in tension and generally cracks when subjected to tensile forces. Based on its composition and design, concrete can be categorized into a wide range of subgroups, such as plain concrete, reinforced concrete, high strength and high performance concrete, light weight concrete. Simply said, plain concrete, also known as conventional or ordinary concrete, is produced without reinforcement while reinforced concrete, often known as RC, is formed with reinforcement. When fissures are exposed to tensile pressures, where concrete is weak in tension but strong in compression, reinforcements are usually used to counteract these tensile forces. In the tension zones, these tensile powers are commonly applied.

2. OBJECTIVE OF THE STUDY

The objectives outlined in the current study are:

1. To assess the performance of concrete when cement is partially substituted by both Rice Husk Ash (RHA) and Graphene Oxide (GO).
2. To determine the ideal substitute for Rice Husk Ash (RHA) and Graphene Oxide (GO) in each M45 concrete mix.
3. To replace admixtures (RHA and GO) in different combinations to achieve the desired qualities in concrete.

3. LITERATUREREVIEW

Xiaojiang Hong, et al **(2023) t**his study aimed to investigate the combined effect of incorporating different contents of graphene oxide (GO) as a reinforcement in a high-strength lightweight concrete (HSLWC) mixture using steel slag aggregate (SC). The primary objective was to design an initial mixture of HSLWC with SC as an aggregate and analyze the enhancement of mechanical properties and durability through the addition of six different low contents of GO. The microstructure of HSLWC with different GO contents was also examined. The specimens with varying GO contents exhibited an oven-dry density ranging from 1696 to 1728 kg/m3 and a compressive strength between 61.88 and 74.32 MPa, meeting the classification requirements of HSLWC. Interestingly, GO not only adjusted the crystal morphology at an early stage but also maximized the 28-day compressive strength by 20.1%. The flexural strength of the specimens ranged from 6.47 to 8.69 MPa, with an increase of 11.7-34.3% attributed to the addition of GO. Furthermore, the specimens with different GO contents demonstrated a splitting tensile strength ranging from 4.21 to 5.23 MPa, with an enhancement of 10.5-24.2% resulting from GO incorporation. The chloride-ion migration coefficient of HSLWC with different GO incorporation contents fell within the range of 4.07 × 10−12–7.18 × 10−12 m2/s, indicating the applicability of HSLWC in marine environments. The addition of GO contributed to a maximum reduction of 43% in the chloride-ion migration coefficient and improved the freeze-thaw resistance and sulfate attack resistance of HSLWC. The study revealed that when the content of GO increased from 0 to 0.08%, all the performance indices of HSLWC displayed a nonlinear trend, with the optimal GO addition for HSLWC produced from SC determined to be 0.05%. Moreover, the study emphasized the importance of controlling the oxygen content of GO for precise adjustment of the performance of HSLWC. Overall, the findings of this study suggest that a low content of GO can significantly enhance the mechanical properties and durability of HSLWC, thus presenting promising applications in the construction industry for extending the service life of buildings and reducing maintenance costs.

Yanchun Miao, et al **(2022)** This study investigates the chemical shrinkage characteristics of graphene oxide (GO)/cement composite paste (GO/CP) by measuring the chemical shrinkage of cement-based composite paste with varying water/cement ratios, GO mass fractions, and polycarboxylate superplasticizer

(PC) content. The results show that the chemical shrinkage of GO/CP increases with higher water/cement ratios. The addition of PC affects the GO/CP chemical shrinkage, with an initial augmentation followed by reduction. Compared to normal cement paste (NCP), the GO/CP specimen exhibits lower chemical shrinkage. The analysis highlights the refinement of pore structure and bonding behavior as the main effects of GO on cement-based materials. A prediction model for GO/CP chemical shrinkage is established. This study contributes to improving cement-based material performance and understanding the function mechanism of GO.

Ali Bagheri, et al **(2022)** This study focuses on the incorporation of graphene oxide (GO) in cement composites and its impact on various physical, mechanical, and durability-related characteristics. The research investigates parameters such as flowability, setting time, ultrasonic pulse velocity, electrical resistivity, compressive strength, flexural strength, water sorptivity, apparent density, and volume of permeable voids (VPV) in cement composites reinforced with different weight percentages (0.01% to 0.5%) of GO. The findings reveal that the addition of GO reduces the setting time and flowability of the composites while improving the compressive and flexural strength by up to 28% and 50% respectively. The electrical resistivity is higher in GO-incorporated specimens, with the highest resistivity observed at 0.05% GO content. Furthermore, the inclusion of GO enhances transport properties by reducing VPV and water sorptivity by up to 15% and 66% respectively, depending on the GO percentage. The study demonstrates the potential of GO as a carbon-derived nanomaterial to enhance the performance of cement composites in terms of mechanical strength and durability properties, suggesting its promising application in cement and concrete technology.

P Reddy and D. Prasad, (**2022)**
This study explores the effects of incorporating graphene oxide (GO) and fly ash as a cost-effective mineral admixture on the workability, mechanical properties, and microstructure of high-strength concrete. The addition of fly ash improves fluidity and workability, while GO counterbalances the decrease in fluidity caused by its inclusion. The combination of 20% fly ash replacement and 0.15% GO addition demonstrates enhanced compressive, split tensile, and flexural strengths compared to control concrete. Microstructure analysis indicates the formation of better hydration phases and densification in the GO-fly ash concrete. The study highlights the synergistic role of GO and fly ash in improving concrete properties and addressing each other's drawbacks.

Changjiang Liu, et al **(2021)** Explored the potential of graphene oxide (GO) and nanomaterials in enhancing the performance of cement-based materials. Traditional cement-based materials suffer from limitations such as poor crack resistance, brittleness, and low toughness, along with concerns related to energy consumption and environmental impact. The emergence of nanomaterials opens up new avenues for improving cement-based materials at the nanoscale level. GO, with its high surface area and exceptional physical properties, demonstrates a significant impact on enhancing cement-based materials. The paper also discusses the influence of GO on cement paste dispersion, as well as its effects on working performance, mechanical strength, microstructural characteristics, and durability of cement-based materials. Additionally, the synergistic effects of nanohybrid materials, combining GO with nanosilica (NS) and carbon nanotubes (CNTs), are explored. The review aims to provide valuable insights and guidance for researchers studying and utilizing GO-modified cement-based materials and nanohybrid materials.

Nolan C. Concha and Andres Winston C. Oreta (2019) discovered the ideal ratio of concrete components for increased strength qualities. However, admixtures, particularly those used during the creation of self-compacting concrete to enhance certain unique properties of freshly mixed and cured concrete, may have unfavourable impacts on the behaviour of the concrete's workability. Super plasticizers were added to the mix together with accelerating and air-entraining admixtures, and the results of slump, V-funnel, L-box, U-box, and screen firmness tests were used to determine how they affected the rheological characteristics of the self-compacting concrete. According to the experiment's results, admixtures that contain small bubbles that act as ball bearings between the particles improve the workability of self-compacting concrete. The maximum concentration of 5.0% super plasticizers produced the greatest results across all tests as a result of the mixture's dispersing effects reducing flow resistance. Due to the accelerating admixture's preparation of fresh concrete with less flow ability due to the concrete's quick hydration and early strength development, self-compacting concrete became less resistant to segregation. In all workability tests, the air entraining admixtures combined with 3.7% super plasticizer shown improved behaviour.

4. MATERIALUSED
MATERIALS USED
The following are the resources we used to conduct our suggested study:

- OPC 53 grade cement

➢ Rice Husk Ash, Graphene Oxide, Fine, Coarse Aggregates

Aggregates

Fine aggregate

As a fine aggregate, river sand that was accessible locally was employed. According to IS: 383- 1987, the following tests are performed on natural fine aggregate. According to BIS, The Sand is verified to meet specified criteria.

Tests on Fine Aggregates

A. Sieve analysis of Fine aggregate
B. Specific Gravity of Fine aggregate

Sieve analysis of Fine aggregate

Table displays the sieve analysis of natural fine aggregate. The fine 2386(PART I)-1963 particle size distribution can be found via sieve analysis.

The fine aggregate has a fineness modulus of 3.22.

Sieve Analysis of Fine Aggregate

S. No.	Sieve Size (mm)	Weight Retained (gm)	% Weight retained	Cumulative% weight Retained (F)	% passing (100 – F)
1.	4.75	28.0	2.80	2.80	97.20
2.	2.36	23.7	2.37	5.17	94.83
3.	1.18	292.1	29.21	34.38	65.62
4.	600μ	468.0	46.80	81.18	18.82
5.	300 μ	170.8	17.08	98.26	1.74
6.	150 μ	16.4	1.64	99.9	0.1
7.	Pan	-	-	-	-
	Total	1000		321.69	

Fineness Modulus of F.A = Sum of Cumulative percentage weightretained / 100
= 321.69 / 100
= 3.22

Specific Gravity of Fine aggregate

The specific gravity of fine aggregate is determined as shown in Table 3.2.

Table Specific gravity of Fine Aggregate

Specific Gravity Offine Aggregate (FA)		
S. No.	**Sample Description**	**Weight in gms**
1	weight of Dry and Empty pycnometer	W1 = 600
2	weight of pycnometer + Sand	W2 =1105
3	weight of pycnometer + Sand + Water	W3 =1760
4	weight of pycnometer + water	W4 =1449.5
5	weight of Oven Dry Aggregate Sample	W5 = 515

Specific Gravity of Fine Aggregates = $\frac{w5}{((w2-w1)-(w3-w4))}$

Specific Gravity of Fine Aggregates = $\frac{515}{((1105\ \ 600)\ (1760\ \ 1449.5))}$

The Specific Gravity of Fine Aggregate is 2.65

The Physical Properties of Fine aggregate are shown in Table-3.3

Table Physical Properties of Fine aggregate

S. No.	Properties	Results
1	Size	**5mm**
2	Bulk density (kg/m^3)	**1510**
3	Specific gravity	**2.65**
4	Fineness modulus	**3.22**
5	Water absorption	**1.2%**

Coarse aggregate

In the current research, the crushed aggregate available from the nearby quarry was employed as a natural coarse aggregate. The aggregate used in this experiment was 12.5mm down and tested in accordance with IS: 2386-1963 (I, II, III) specifications. On coarse aggregate, the following tests are carried out.

Tests on Coarse Aggregates

A. Sieve analysis of coarse aggregate
B. Specific gravity of coarse aggregate

Rice Husk Ash

Rice grains are protected by their husks, which are burned at high temperatures to produce rice husk ash. The cost of rice husk is lower and it is produced in big quantities. 20 kilogrammes of rice husk are produced from 100 kg of rice. More than 80–85% of the rice husk ash is silica. RHA concrete has a high pozzolanic content, which lowers the permeability of the material.

Figure Rice Husk Ash (RHA)

Graphene Oxide

Graphene is a hexagonal structure comprised of a single layer of carbon atoms. Graphene is the strongest substance ever tested and the fundamental component of other significant allotropes of carbon, like diamond, graphite, etc. In this study, graphene oxide solution was created using flake graphite. Metamorphic rocks found at Rasayan Ghar, Delhi, are the primary source of flake graphite.

Figure Natural graphite flakes`

5. RESULTS AND DISCUSSIONS

Combinations of RHA – 10%, 15% and 20% and GO-1.5%,2% and 2.5% with M45 were tested in this chapter. As a cement substitute in concrete, various ratios of rice husk ash and graphene oxide are used. Concrete is made using the right amount of cement, water, and particles. The concrete mix contained 53-grade Ordinary Portland Cement (OPC), tap water, fine aggregate measuring 5 mm, and coarse aggregate measuring 20 mm. The predicted water-cement ratio was set at 0.35. Cube-shaped metal moulds with dimensions of 150 mm x 150 mm x 150 mm were used to create the specimens.

The fresh and hardened qualities of these specimens, which are manufactured without reinforcement, are tested. This specimen testing aids in assessing the calibre of concrete made using GO and RHA and determining which mix proportions yield superior results to traditional concrete. To acquire the greatest results, each step of the testing process should be done carefully. This chapter investigated and evaluated the workability, compaction factor, and water absorption of fresh concrete. After 14 and 28 days, hardened properties including compressive strength, flexural strength, and split tensile strength were evaluated.

Mix Ratio

Mix	Cement(kg/m^3)	FA (kg/m^3)	C.A (kg/m^3)	RHA	GO
M1	400	157.74	441.97	0	0
M_{R10G0}	360	157.74	441.97	40	0
$M_{R10G1.5}$	356	157.74	441.97	40	6
M_{R10G2}	348	157.74	441.97	40	8
$M_{R10G2.5}$	340	157.74	441.97	40	10
M_{R15G0}	340	157.74	441.97	60	0
$M_{R15G1.5}$	334	157.74	441.97	60	6
M_{R15G2}	332	157.74	441.97	60	8
$M_{R15G2.5}$	330	157.74	441.97	60	10
M_{R20G0}	320	157.74	441.97	80	0
$M_{R20G1.5}$	314	157.74	441.97	80	6
M_{R20G2}	312	157.74	441.97	80	8
$M_{R20G2.5}$	310	157.74	441.97	80	10

Compressive strength test results

Mix	Cement	RHA	GO	Compressive strength	
				14 days	28 days
	%	%	%	N/mm^2	N/mm^2
M1	100	0	0	38.49	46.19
M_{R10G0}	90	10	0	39.65	47.58
$M_{R10G1.5}$	88.5	10	1.5	39.94	47.93
M_{R10G2}	88	10	2	40.12	48.14
$M_{R10G2.5}$	87.5	10	2.5	40.58	48.69
M_{R15G0}	85	15	0	39.96	47.95
$M_{R15G1.5}$	83.5	15	1.5	40.47	48.56
M_{R15G2}	83	15	2	40.87	49.04
$M_{R15G2.5}$	82.5	15	2.5	41.50	49.80
M_{R20G0}	80	20	0	40.47	48.56
$M_{R20G1.5}$	78.5	20	1.5	40.23	48.28
M_{R20G2}	78	20	2	40.19	48.23
$M_{R20G2.5}$	77.5	20	2.5	39.33	47.19

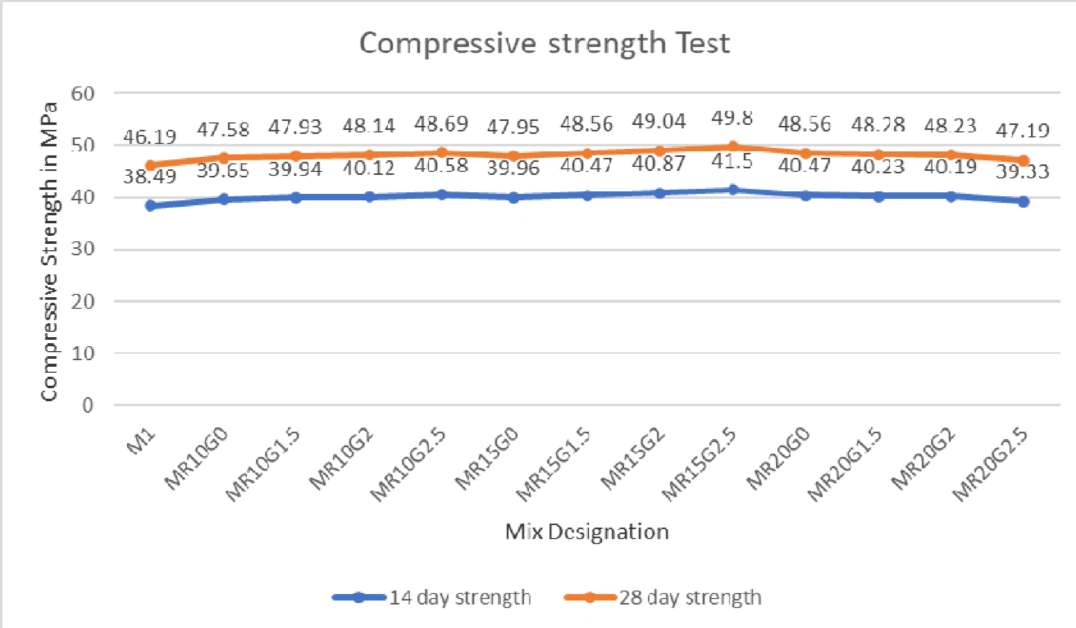


Figure Compressive strength various mix proportion

Compressive strength various mix proportion

Compressive strength in the $M_{R15G2.5}$ – 2.5%-15% of GO-RHA resp. in a concrete sample is a maximum of about 49.80MPa. Concrete's compressive strength decreased when it had more than 15% RHA.

Flexural strength after 28 days

Mix.	Cement	Modifier		Flexural strength	
		RHA	GO	14 days	28 days
	%	%	%	N/mm^2	N/mm^2
M1	100	0	0	23.10	27.71
M_{R10G0}	90	10	0	23.79	28.55
$M_{R10G1.5}$	88.5	10	1.5	23.97	28.76
M_{R10G2}	88	10	2	24.07	28.88
$M_{R10G2.5}$	87.5	10	2.5	24.35	29.21
M_{R15G0}	85	15	0	23.98	28.77
$M_{R15G1.5}$	83.5	15	1.5	24.28	29.14
M_{R15G2}	83	15	2	24.52	29.42
$M_{R15G2.5}$	82.5	15	2.5	24.90	29.88
M_{R20G0}	80	20	0	24.28	29.14
$M_{R20G1.5}$	78.5	20	1.5	24.14	28.97
M_{R20G2}	78	20	2	24.12	28.94
$M_{R20G2.5}$	77.5	20	2.5	23.60	28.31

Figure Flexural strength of various mix proportion

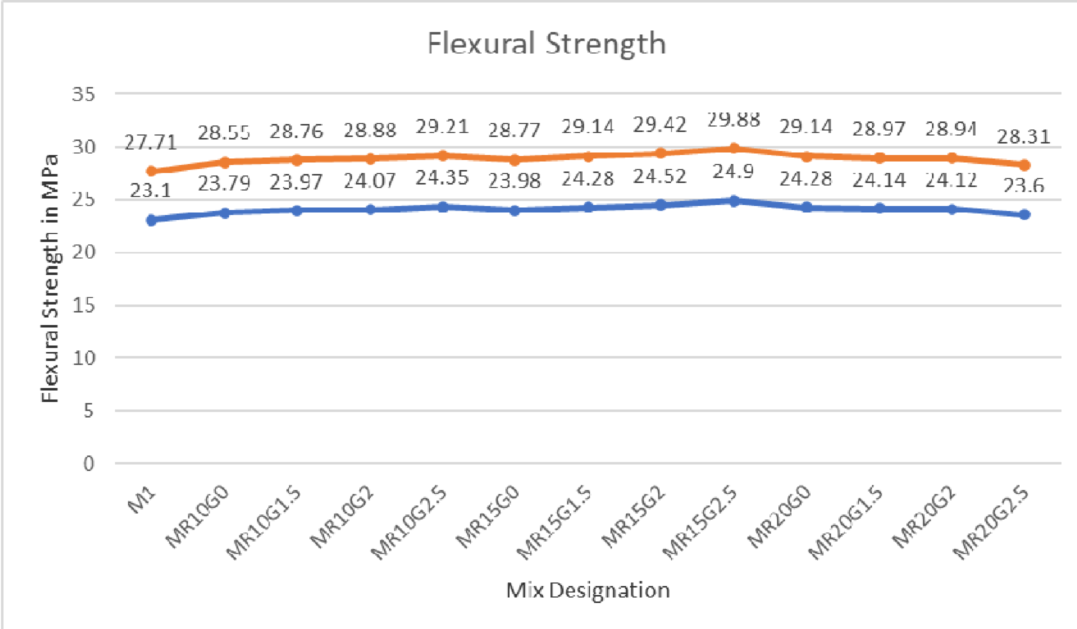


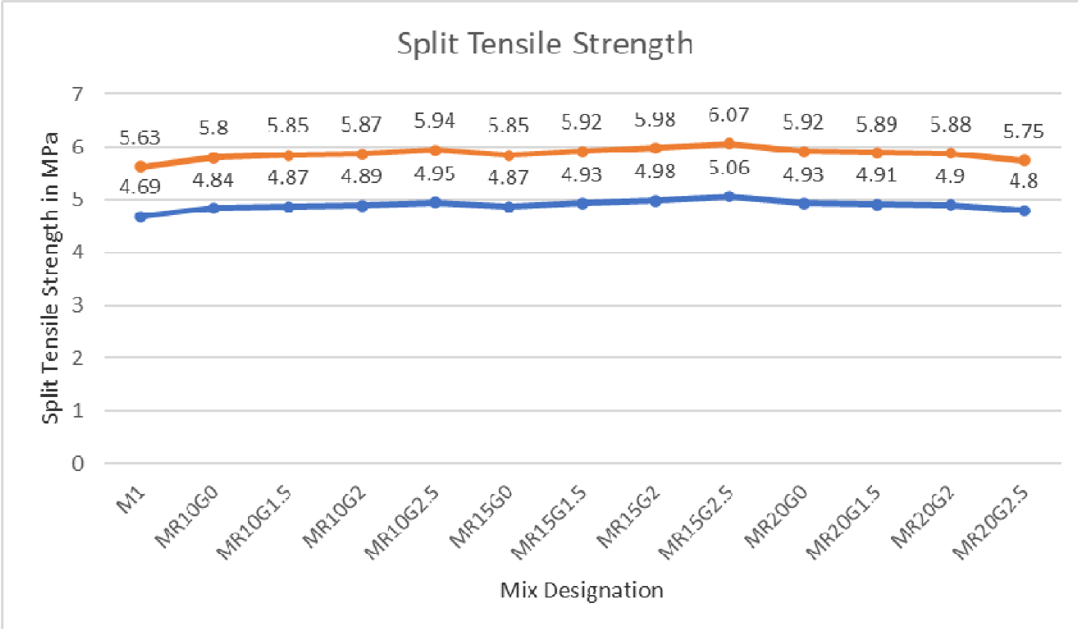
Figure Flexural strength of various mix proportion

Tensile strength in the form of flexural strength of $M_{R15G2.5}$ – 2.5%-15% of GO-RHA resp. in a concrete sample is a maximum of about 29.88MPa. Concrete's flexural strength decreased when it had more than 15% RHA, likewise the compressive strength.

Split tensile strength after 14 and 28 days

Mix.	Cement	Modifiers		Split tensile strength	
		RHA	GO	14 days	28 days
	%	%	%	N/mm^2	N/mm^2
M1	100	0	0	4.69	5.63
M_{R10G0}	90	10	0	4.84	5.80
$M_{R10G1.5}$	88.5	10	1.5	4.87	5.85
M_{R10G2}	88	10	2	4.89	5.87
$M_{R10G2.5}$	87.5	10	2.5	4.95	5.94
M_{R15G0}	85	15	0	4.87	5.85
$M_{R15G1.5}$	83.5	15	1.5	4.93	5.92
M_{R15G2}	83	15	2	4.98	5.98
$M_{R15G2.5}$	82.5	15	2.5	5.06	6.07
M_{R20G0}	80	20	0	4.93	5.92
$M_{R20G1.5}$	78.5	20	1.5	4.91	5.89
M_{R20G2}	78	20	2	4.90	5.88
$M_{R20G2.5}$	77.5	20	2.5	4.80	5.75

Figure Split tensile strength of various mix proportion



Tensile strength in the form of split tensile strength of $M_{R15G2.5}$ – 2.5%-15% of GO-RHA resp. in concrete sample is maximum about 6.07MPa. Concrete's split tensile strength decreased when it had more than 15% RHA, likewise the compressive strength.

Also, the greatest compressive, flexural and split tensile strength is obtained when the Mix was modified by 15% RHA and 2.5% GO. Additionally, graphene oxide serves as a barrier against environmental deterioration, increasing durability.

According to the aforementioned findings, concrete made with graphene oxide was the strongest of all the mixes. To strengthen corrosion resistance and stop the transit of aggressive elements, graphene oxide is deposited to provide a protective layer, increasing durability.

The utilization of secondary materials, such as rice husk ash, which are produced as byproducts in industry, lessens environmental risks and the waste disposal dilemma. The final result will be between 2.5 and 15 percent GO-RHA because it may be utilized as an additive for concrete and is a better cement replacement in concrete.

6. CONCLUSION

According to the conclusions drawn from prior investigations, adding graphene oxide and rice husk ash to concrete increases its strength and suitability for usage. The findings of our experimental testing revealed that the amount of cement containing 15% rice husk ash and 2.5% graphene oxide boosts concrete's compressive strength. At this composition, the graph demonstrates maximum values of modulus of elasticity, compressive strength, flexural and split tensile strength at 28 days than the control mix.

The major conclusions are enlisted below:

- The GO-RHA mixed with 15% RHA or more with GO produces a value between 100 and 150, demonstrating its great workability and suitability for use in construction.
- Compressive strength in the $M_{R15G2.5}$ – 2.5%-15% of GO-RHA resp. in the concrete sample is a maximum of about 49.80MPa. Concrete's compressive strength decreased when it had more than 15% RHA.
- Tensile strength in the form of flexural strength of $M_{R15G2.5}$ – 2.5%-15% of GO-RHA resp. in the concrete sample is a maximum of about 29.88MPa. Concrete's flexural strength decreased when it had more than 15% RHA.
- Tensile strength in the form of split tensile strength of $M_{R15G2.5}$ – 2.5%-15% of GO-RHA resp. in the concrete sample is a maximum of about 6.07MPa. Concrete's split tensile strength decreased when it had more than 15% RHA.

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