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EXPERIMENTAL INVESTIGATION ON COMPRESSIVE STRENGTH OF CONCRETE BY PARTIALLY REPLACING CEMENT BY GGBS AND RHA AND NATURAL SAND BY QUARRY DUST

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Abstract: In this paper, concrete of grade M_{40} is studied by using Ground Granulated Blast furnace Slag (GGBS)(10%, 20%, 30% and 40%) and Rice Husk Ash (RHA) (5%, 7.5% and 10%) as partial replacement of cement and by using Quarry dust(0%, 15%, 30%, 45%, 60%, 75%, 90% and 100%) as partial replacement of sand. Compressive Strength properties are studied. Study is carried out in three phases and the optimum replacement level is found out.

Index Terms **- GGBS, RHA, Quarry Dust, Compressive Strength**

I. Introduction

The focus nowadays is on mitigating the environmental impact of concrete production. Indeed, incorporating alternative materials like Rice Husk Ash (RHA), Ground Granulated Blast Furnace Slag (GGBS), and quarry dust can significantly reduce the carbon footprint associated with traditional Portland cement production. RHA and GGBS, offer valuable properties that make them suitable partial replacements for cement. RHA, with its pozzolanic properties, can enhance the strength and durability of concrete while reducing the amount of cement needed. Similarly, GGBS being industrial by-product by nature not only provides strength but also contributes to lower CO_2 emissions. The use of quarry dust as a substitute for natural sand is another sustainable approach. By utilizing this waste product, not only are environmental concerns regarding its disposal addressed, but it also helps conserve natural resources by reducing the demand for river sand. These strategies not only contribute to reducing greenhouse gas emissions but also promote the efficient use of resources in the construction industry. It's encouraging to see advancements in sustainable practices within the civil engineering sector.

II. Literature review

Sam Joel (2020) [1] The findings from the study suggest that both fly ash and rice husk ash can effectively enhance the compressive strength of concrete when used as partial replacements for cement. The optimal percentage of substitution was determined to be 10% for both materials. This indicates that at this particular level of substitution, the concrete achieved the highest compressive strength. Beyond this point, increasing the percentage of ash substitution may not lead to further improvements in compressive strength. The conclusion drawn from this analysis underscores the importance of carefully determining the appropriate dosage of supplementary materials like fly ash and rice husk ash in concrete mixtures. This balance ensures that the desired mechanical properties, such as compressive strength, are optimized while also achieving the desired environmental benefits associated with reducing cement usage. Overall, these findings contribute valuable insights to the field of sustainable construction practices, providing guidance on the effective utilization of industrial byproducts to enhance concrete performance while mitigating environmental impact.

Rathod Ravinder et.al., (2018) [2] The study highlights the use of Ground Granulated Blast Furnace Slag (GGBS) as a partial replacement for cement in concrete, specifically focusing on M_{30} grade concrete with a water-to-cement (w/c) ratio of 0.45. The experimental investigation involved testing the compressive strength of the concrete mix at 7, 14, and 28 days. The results indicated that replacing 50% of the cement with GGBS led to a notable increase in compressive strength by approximately 5%. This improvement in strength suggests that GGBS contributed positively to the mechanical properties of the concrete. Additionally, the use of GGBS as a by-product is highlighted as an eco-friendly alternative, aligning with sustainability goals in construction. Furthermore, it's noted that GGBS replacement also enhances the durability of concrete. This aspect is crucial for ensuring the longevity and performance of concrete structures, especially in harsh environmental conditions or applications where durability is a priority. Overall, the findings of this study underscore the benefits of incorporating GGBS into concrete mixes, not only for improving mechanical properties like compressive strength but also for enhancing the sustainability and durability of concrete structures. This supports the growing trend towards using alternative materials in construction to reduce environmental impact and improve overall performance.

Ramayanam Naresh et. al., (2016) [3] This study investigated the effects of incorporating rice husk ash (RHA) and ground granulated blast furnace slag (GGBS) as partial replacements for ordinary Portland cement in concrete mixes. The experimental approach involved varying the replacement levels from 0% to 25% for both RHA and GGBS to assess their impact on compressive strength and split tensile strength. For the concrete mix with 5% RHA (trial mix M-5) combined with a super-plasticizer, the study found that it achieved the maximum compressive strength and split tensile strength, surpassing even the designed compressive strength for M_{60} grade concrete. This suggests that a small percentage of RHA, along with appropriate additives, can significantly enhance the mechanical properties of concrete. However, as the percentage of RHA replacement increased to 10%, 15%, 20%, and 25%, the compressive and split tensile strengths decreased. This indicates that there may be an optimal level of RHA replacement beyond which the mechanical properties of the concrete begin to decline. Similarly, for GGBS replacement, the study identified that the optimum replacement level was 10%, resulting in the highest compressive and split tensile strengths compared to the control mix and other trial mixes of RHA and GGBS after 28 days of curing. However, it's noted that beyond this optimal level, the mechanical properties may diminish, as evidenced by a decrease in compressive and split tensile strengths for the M-25 trial mix after 56 days of curing. These findings highlight the importance of carefully selecting the replacement levels of RHA and GGBS to achieve the desired mechanical properties and durability in concrete mixes. Additionally, the use of super-plasticizers alongside RHA can further enhance the performance of the concrete. Overall, this research provides valuable insights for developing high-strength and durable cement concrete using sustainable mineral admixtures like RHA and GGBS.

P.N. Rao and Venu Malagavelli (2010) [4] The study you described highlights the beneficial effects of incorporating Ground Granulated Blast Furnace Slag (GGBS) and ROBO sand (crusher dust) as partial replacements for cement and natural sand, respectively, in M30 grade concrete. Both compressive and tensile strengths were evaluated for concrete specimens containing varying percentages of GGBS and ROBO sand. The results indicate that substituting 30% of the natural sand with ROBO sand, along with 1.5 percent admixture, led to a significant increase in compressive strength by 19.64% and 8.03% at ages 7 and 28 days, respectively. Additionally, the split tensile strength showed an improvement of 1.83% at both ages. Furthermore, when 50% of the cement was replaced with GGBS and 25% of the sand was replaced with ROBO sand, the concrete exhibited notable enhancements in compressive strength, with increases of 11.06% and 17.6% at 7 and 28 days, respectively. These findings suggest that both GGBS and ROBO sand contribute positively to the mechanical properties of the concrete, leading to improvements in both compressive and split tensile strengths. The study concludes that ROBO sand can serve as a viable alternative source for fine aggregate, and increasing the percentage of ROBO sand in the concrete mix results in further improvements in compressive and split tensile strengths. Overall, this research provides valuable insights into the use of alternative materials like GGBS and ROBO sand in concrete production, offering potential benefits for enhancing concrete performance while reducing reliance on traditional cement and natural sand resources.

Azmat Ali Phul et.al., (2019) [5] The study you described focused on evaluating the optimal levels of Ground Granulated Blast Furnace Slag (GGBS) and Fly Ash as partial replacements for cement in M25 grade concrete. Various percentages ranging from 0% to 30% of GGBS and Fly Ash were considered, while maintaining a constant water-to-cement ratio of 0.47. Tests were conducted for slump, compaction factor, Vee-bee, and compressive strength at different curing days (3, 7, 14, and 28 days).The results indicated that as the curing time increased, the workability (as indicated by slump, compaction factor, and Vee-bee) and compressive strength of the concrete containing GGBS and Fly Ash also increased. Specifically, the workability of the concrete improved significantly when the slump value reached 30% compared to the control mix without any replacement (SF0). Additionally, the compressive strength showed a notable increase of 26.30% in the mix containing 20% GGBS and 10% Fly Ash (SF9) compared to the control mix (SF0).These findings suggest that the addition of GGBS and Fly Ash positively affects both the workability and compressive strength of the concrete, leading to overall improvements in its mechanical qualities. The use of these supplementary cementitious materials not only enhances the performance of the concrete but also contributes to sustainability by reducing the reliance on traditional cement and utilizing industrial byproducts.Overall, this research underscores the potential benefits of incorporating GGBS and Fly Ash in concrete mixtures, highlighting their role in improving both workability and compressive strength, which are essential for achieving high-quality and durable concrete structures.

III. MATERIALS USED

M_{40} grade concrete is prepared and after conducting basic tests on the materials that are selected and procured. This is an important step to ensure the quality and suitability of each material for your concrete mix.

1) Cement (Confirming to IS 8112-1989)
2) Natural Sand (Confirming to IS 2386 Part III-1963)
3) Coarse Aggregate (Confirming to IS 2386 Part III-1963)
4) Quarry Dust (Confirming to IS 2386 Part III – 1963)
5) Rice Husk Ash (RHA) [Conforming to IS 12669-2013]
6) Ground Granulated Blast Furnace Slag (GGBS)) (Conforming to IS 12669-2013)
7) Water (Confirming to IS 456-2000)
8) Super Plasticizer (Conplast SP 430 DIS)

IV. METHODOLOGY

The approach to conducting the study in three phases is systematic and thorough, aiming to optimize the mix design for M_{40} grade concrete by assessing the effects of various material replacements on strength. Here's a breakdown of each phase:

Phase One: Replacement of Natural Sand with Quarry Dust

This phase involves replacing different percentages of natural sand with quarry dust (0%, 15%, 30%, 45%, 60%, 75%, 90%, and 100%).The objective is to determine the optimum percentage replacement of natural sand with quarry dust that achieves maximum strength for the concrete mix. Tests will likely include compressive strength, flexural strength, and durability tests to assess the performance of concrete mixes with varying levels of quarry dust replacement.

Phase Two: Partial Replacement of Cement with GGBS

In this phase, different percentages of cement will be partially replaced with Ground Granulated Blast Furnace Slag (GGBS) (10%, 20%, 30%, and 40%).The aim is to identify the optimal percentage replacement of cement with GGBS that maximizes the strength of the concrete mix. Similar tests as in Phase One will be conducted to evaluate the effects of GGBS replacement on concrete properties.

Phase Three: Combination of GGBS and RHA Replacement

This phase involves replacing cement with a combination of GGBS and Rice Husk Ash (RHA) to determine the optimum percentage replacement. The study will assess how the combination of GGBS and RHA affects the strength and other properties of the concrete mix. Tests will again include compressive strength, flexural strength, and durability tests to evaluate the performance of concrete mixes with combined GGBS and RHA replacements.

Based on the findings from each phase, conclusions will be drawn regarding the optimal mix design for M_{40} grade concrete.

Recommendations may be made regarding the percentage replacements of natural sand, cement with GGBS, and combination of GGBS and RHA to achieve desired strength and performance characteristics. Overall, this structured approach will provide valuable insights into the effects of material replacements on concrete strength and guide the development of an optimized mix design for M_{40} grade concrete.

4.1 Mix Design

Choosing a mix proportion that achieves the desired 28-day cube compressive strength while maintaining the required workability of 100 mm is crucial for producing high-quality concrete.

Table 4.1 Details of Mix Proportion

Cement	Fine Aggregate	Coarse aggregate
1	1.7	3.4

Table 4.2 Details of Mix Proportion of Phase I where Natural Sand (NS) is partially replaced by Quarry Dust (QD) (0%, 15%, 30%, 45%, 60%, 75%, 90% & 100%) with Constant Cement, Coarse Aggregate (CA) and Water.

SI. No	Mix Designation	% of Natural sand replaced with Quarry Dust
1	A_0	0% replacement
2	A_1	15% replacement
3	A_2	30% replacement
4	A_3	45% replacement
5	A_4	60% replacement
6	A_5	75% replacement
7	A_6	90% replacement
8	A_7	100% replacement

Table 4.3 Various mix proportion of Phase II concrete where Cement is partially replaced with GGBS with constant NS (40%), QD (60%), Coarse aggregate and water.

SI. No.	Mix Designation	Cement is replaced with GGBS
1	B_1	10% replacement
2	B_2	20% replacement
3	B_3	30% replacement
4	B_4	40% replacement

Table 4.4 Various mix proportion of Phase III concrete where mixture of GGBS and RHA is coupled with Optimum percentages of Natural Sand (NS) and Quarry Dust (QD)

SI. No	Mix Designation	Cement is replaced with GGBS	Cement is replaced with RHA
1	C_1	20% replacement	10% replacement
2	C_2	22.5% replacement	7.5% replacement
3	C_3	25% replacement	5% replacement

V. RESULTS AND DISCUSSION

5.1 PHASE I

Table 5.1 Compressive Strength Results of Phase I Mix Designations

SI. No.	% of Quarry Dust (QD)	Compressive Strength of Cubes in N/mm²	
		At 7 Days (N/mm²)	At 28 days (N/mm²)
1	0	31.11	43.55
2	15	32.00	44.44
3	30	32.00	46.54
4	45	33.33	47.56
5	60	36.60	49.77
6	75	22.22	26.66
7	90	16.44	18.22
8	100	14.22	17.33

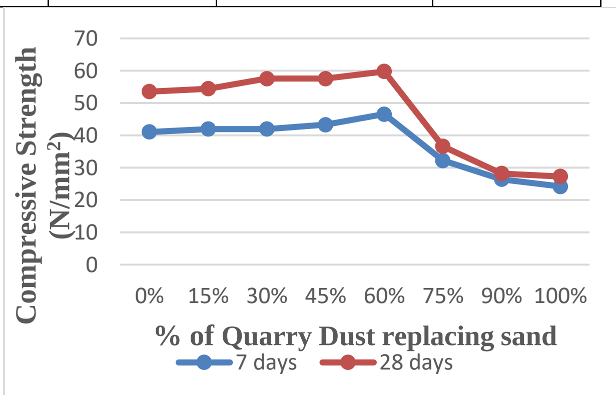

Fig 5.1 Line chart showing the variation of Compressive Strength values of Phase I Mix Designations

The specified compressive strength of 40 N/mm² for M_{40} grade concrete is achieved with 60% replacement of natural sand by quarry dust. This mix, termed as the critical mix, represents the optimum combination of materials for achieving the desired strength while maintaining workability. It's noteworthy that beyond 60%

replacement of natural sand by quarry dust, the concrete mixes did not achieve the required strength. This suggests that there may be limitations to the extent of replacement, possibly due to factors such as particle size distribution, chemical composition, or other properties of quarry dust.

5.2 PHASE II

Table 5.2 Compressive Strength Results of Phase II Mix Designations

SI. No.	% of Quarry Dust (QD)	Compressive Strength of Cubes in N/mm^2	
		At 7 Days (N/mm^2)	At 28 days (N/mm^2)
1	10	27.11	44.00
2	20	32.44	46.00
3	30	30.66	42.22
4	40	28.85	40.46

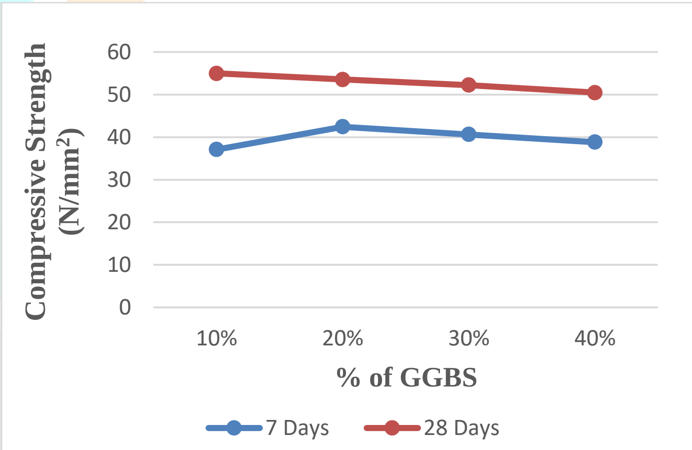

Fig 5.2 Line chart for the Compressive Strength values of Phase II mix designations

From the observations of Phase II it's interesting to note that the compressive strength of concrete mixes increased upto the B_3 mix designation, which corresponds to 30% replacement of cement with Ground Granulated Blast Furnace Slag (GGBS). After this point, the strength gradually decreased. Several factors could contribute to the decrease in compressive strength with higher GGBS replacement percentages. These may include changes in hydration kinetics, pore structure, or other properties of the concrete mix as a result of increased GGBS content.

5.3 PHASE III

Table 5.3 Compressive Strength Results of Phase III Mix Designations

SI. No.	% of Quarry Dust (QD)	Compressive Strength of Cubes in N/mm²	
		At 7 Days (N/mm²)	At 28 days (N/mm²)
1	(GGBS 20% +10% RHA)	21.77	42.67
2	(GGBS 22.5% +7.5% RHA)	24.44	48.00
3	(GGBS 25% +5% RHA)	22.67	45.33
4	(GGBS 20% +10% RHA)	21.77	42.67

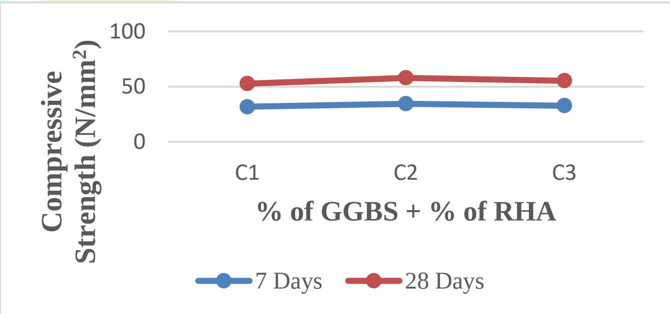

Fig 5.3 Line chart showing the variation of Compressive Strength values of Phase III mix designations

It's notable that the optimum compressive strength was achieved for the C_2 mix designation, which corresponds to 22.5% Ground Granulated Blast Furnace Slag (GGBS) and 7.5% Rice Husk Ash (RHA) replacement. The combination of GGBS and RHA in the C_2 mix likely resulted in a synergistic effect, where the two supplementary cementitious materials complement each other to enhance the overall performance of the concrete mix.

VI. CONCLUSION

Critical mix proportions for achieving maximum compressive strength in concrete, both individually and in combination with supplementary cementitious materials like GGBS and RHA is identified.

- **Critical Mix with Quarry Dust:** The study found that replacing 60% of natural sand with quarry dust resulted in the highest compressive strength, termed as the critical mix. This mix represents the optimum combination of materials for achieving maximum strength while maintaining workability.
- **Effect of GGBS Replacement:** By adopting the critical mix and replacing cement with GGBS, the study observed that maximum compressive strength was obtained with up to 30% replacement of cement by GGBS. Beyond this percentage, the strength gradually decreased. This suggests that there may be limitations or adverse effects associated with higher GGBS replacement percentages.
- **Combination of GGBS and RHA:** It was observed that adopting the critical mix and combining 22.5% GGBS with 7.5% RHA resulted in maximum compressive strength for the concrete. This indicates a synergistic effect between GGBS and RHA, where the combination enhances the strength properties of the concrete mix.

Overall, these observations provide valuable insights into the optimization of concrete mixtures using various supplementary materials. By identifying critical mix proportions and understanding the effects of different material replacements, the study contributes to the development of sustainable and high-performance concrete mixes. Moving forward, it will be important to validate these findings through further testing and potentially explore additional factors that may influence concrete performance.

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