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"To Study the Partial Replacement of Cement by GGBS & RHA and Natural Sand by Quarry Sand In Concrete"

Sonali K. Gadpalliwar[1], R. S. Deotale[2], Abhijeet R. Narde[3]
[1] *M.Tech Student, (structural Engg.) Civil Engineering Department, Yeshwantrao Chavan College of Engineering Nagpur, INDIA.*
[2]*Associate Prof. ,Civil Engineering Department, Yeshwantrao Chavan College of Engineering Nagpur, INDIA.*
[3] *Research Scholar and Lecturer, Rajiv Gandhi Engineering College, Wanadongri, Nagpur, INDIA.*

Abstract: *Concrete is the most widely used construction material in civil engineering industry because of its high structural strength and stability. The concrete industry is constantly looking for supplementary cementitious material with the objective of reducing the solid waste disposal problem. Ground granulated blast furnace slag (GGBS) Rice husk ash (RHA) and Quarry sand (QS) are among the solid wastes generated by industry. To overcome from this crisis, partial replacement of natural sand (NS) with Quarry sand and partial replacement of cement with GGBS and RHA can be an economic alternative. This research is carried out in three phase, in first phase mix of M40 grade concrete with replacement of 0%,15%,30%,45%,60%,75%,90% and 100% of quarry sand with natural sand is carried out to determine the optimum percentage of replacement at which maximum compressive strength is achieved. It is observed that when natural sand is partially replaced with 60% quarry sand maximum strength is achieved. In second phase, cement is partially replaced with GGBS by 10%, 20% and 30%. In phase three, combination of GGBS and RHA is partially replaced with cement. The composition of 22.5% GGBS + 7.5% RHA with 60% of quarry sand gives good strength results.*

Keywords: *Admixture, Cement, Ground granulated blast furnace slag (GGBS), Quarry sand (QS), Rice husk ash (RHA).*

I. Introduction

Concrete is a heterogeneous mix of cement, aggregates and water. The global consumption of natural sand is too high due to its extensive use in concrete. The demand for natural sand is quite high in developing countries owing to rapid infrastructural growth which results supply scarcity. To overcome from this crisis, partial replacement of natural sand with quarry sand is economic alternative. The concrete industry is constantly looking for supplementary cementitious material with the objective of reducing the solid waste disposal problem. Ground granulated blast furnace slag (GGBS), Rice husk ash (RHA) and Quarry sand (QS) are among the solid wastes generated by industry. Substantial energy and cost savings can result when industrial by-products are used as partial replacements for the energy- intensive Portland cement. This investigation attempts to study the feasibility of using locally available GGBS, RHA and QS as partial replacements for cement and sand in concrete. In this research we prepared specimen of cubes for compressive strength test, cylinder for split tensile strength test, beams for flexure strength test and permeable voids test. Three samples for each set of percentage have been taken for conducting test and average of results are taken. The samples were tested at the age of 7 days, 28 days and 56 days. The test on hardened concrete are destructive test while the destructive test includes compressive strength test as per IS: 516-1959, split tensile strength test as per IS: 5816-1999, flexure strength test as per IS: 516-1959, permeable voids test as per ASTM C642-97.

The objectives and scope of present study are –

1. To find the optimum percentage of replacement of natural sand with quarry sand at which maximum strength is obtained.
2. To use pozzolanic material such as GGBS and RHA in concrete by partial replacement of cement.
3. To conduct compressive strength test, split tensile strength test, flexural test.
4. To study and find permeable voids of the concrete mix and its relation with compressive strength of concrete.
5. To provide economical construction material.
6. Provide safeguard to the environment by utilizing waste properly.
7. To conduct acid resistant test.

II. Materials Used

The materials used in experimental investigation include:

2.1. Cement

Ordinary Portland cement of 43-grade was used in this study conforming to IS:8112-1989 which has Specific gravity 3.15, Normal consistency 32%.

Chemical Properties:

Table No.1: following are the chemical properties of Cement (OPC 43 Grade), RHA and GGBS

Material	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	LOI
Cement	19.71	5.20	3.73	62.91	2.54	2.72	0.90	0.25	0.96
RHA	83.87	(SiO2+ Al2O3+ Fe2O3) = 86.19		0.20	0.52	0.11	0.13	0.16	0.44
GGBS	33.46	(SiO2+ Al2O3+ Fe2O3) = 48.63		25.02	7.97	0.85	1.28	1.32	13.61

2.2. Ground Granulated Blast Furnace Slag (GGBS)

The GGBS used in research is obtained from Bhilai Steel Plant (Bhilai, Chattisgarh). Ground granulated blast-furnace slag is the granular material formed when molten iron blast furnace slag is rapidly chilled by immersion in water. It is a granular product with very limited crystal formation, is highly cementitious in nature and, ground to cement fineness, and hydrates like port land cement. The specific gravity of GGBS is 2.85.

2.3. Rice Husk Ash (RHA)

Rice husk ash used was obtained from Ellora Paper Plant located in Tumsar, Bhandara . RHA, produced after burning of Rice husk (RH) has high reactivity and pozzolanic property. The Specific gravity of rice husk ash is 2.12 and fineness of 71.80.

2.4. Aggregate

Good quality river sand was used as a fine aggregate conforming to Zone- II of IS: 383- 1970 have fineness modulus of 2.735, specific gravity of 2.5 and water absorption 0.98%. Quarry sand from sidheshwar quarry plant Pachgaon, Nagpur, conforming to Zone- II of IS: 383- 1970 have fineness modulus of 2.85 , specific gravity of 3 and water absorption 1%. The coarse aggregate passing through 20 mm and retained on 10 mm sieve was used in research. Its specific gravity is 2.85 and water absorption 0.8%.

2.5. Water

In this research potable water free from organic substance was used for mixing as well as curing of concrete.

2.6. Superplasticizer

AC-PLAST-BV M4 PLASTICIZER as a high range water reducing admixture for obtaining a workable mix was used in research, Strength increased 0.20 and Specific gravity 1.14.

III. Experimental Programme

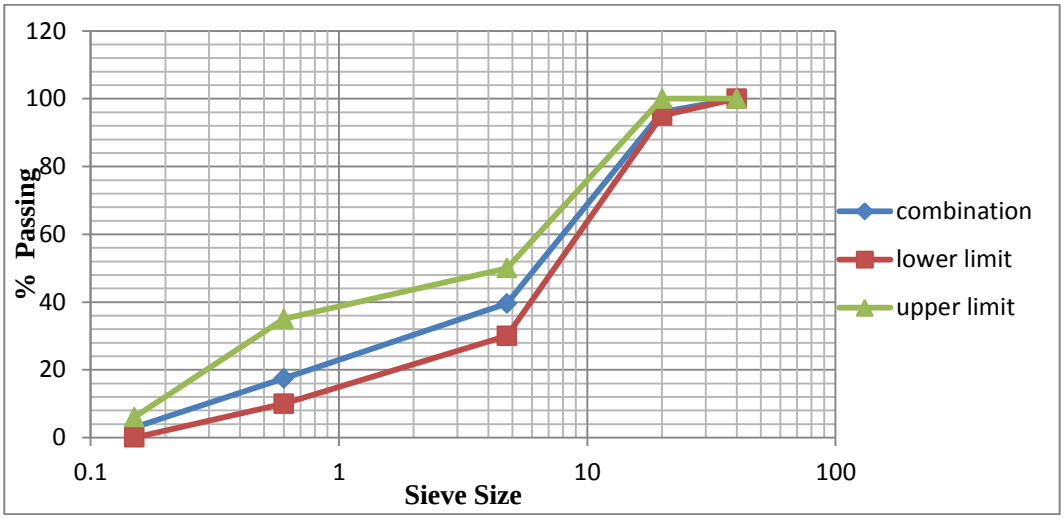
3.1. Mixture Proportioning

The M40 mix proportioning is designed as per guidelines, according to the Indian Standard Recommended Method IS 10262- 2009. The total binder content was 400 kg/m³, fine aggregate is taken 668.9529 kg/m³ , coarse aggregate is taken 1301.122 kg/m³. The super plasticizer content was varied to maintain a slump of 60 mm for all mixtures. This research is carried out in three phase, in first phase mix of M40 grade concrete with replacement of 0%,15%,30%,45%,60%,75%,90% and 100% of quarry sand with natural sand is carried out to determine the optimum percentage of replacement at which maximum compressive strength is achieved. In second phase, cement is partially replaced with GGBS by 10%, 20% and 30%. And in third phase combination of GGBS and RHA is partially replaced with cement. Cubes, beams and cylinder moulds were used for casting. The total mixing time was 5 minutes; Compaction of concrete in three layers with 25 strokes of 16mm rod was carried out for each layer is done. The concrete was left in the mould and allowed to set for 24 hrs before the cubes were demoulded and placed in curing tank until the day of testing.The three specimens of each set was prepared and left for curing in the curing tank for 7,28 and 56

days. Aggregates are graded not only to maintain cohesiveness of mix, but also to meet the grading requirements of IS:383. According to mix design the finalized proportion is 66.044% of coarse aggregate 60:40 (20mm:10mm) with 33.955% of sand content (45% quarry sand and 55% natural sand).

Table No. 2 Combined Gradation of All in Aggregates

Sr. No	45% Quarry Sand And 55% Natural Sand			
	Sieve Size (mm)	Combined	Upper Limit	Lower Limit
1.	40	100	100	100
2.	20	96.0406	95	100
3.	4.75	39.54	30	50
4.	0.60	17.45	10	35
5.	0.150	3.022	0	6



Graph 1: The combined grading of QS (45%) and NS (55%)

Table No. 3: Workability of concrete (slump 60mm)

Sr.no	Identification of Specimens	Replacement of Quarry sand	(w/c)
1	A	0%	0.3931
2	A1	15%	0.3933
3	A2	30%	0.3940
4	A3	45%	0.3950
5	A4	60%	0.3960
6	A5	75%	0.3963
7	A6	90%	0.3965
8	A7	100%	0.3969

Table No. 4: Details of mix proportions of replacements of GGBS and RHA with cement

Sr. No	Identification of Specimens	Replacement of GGBS	Replacement of RHA	QS:NS
1.	A	0%	0%	00:100
2.	A4	0%	0%	60:40
3.	B1	10%	0%	60:40
4.	B2	20%	0%	60:40
5.	B3	30%	0%	60:40
6.	C1	25%	5%	60:40
7.	C2	22.5%	7.5%	60:40
8.	C3	20%	10%	60:40

3.2. TESTING METHOD

Testing is done as per following IS code. The testing is carried out for compressive strength on cubes as per IS : 516 – 1959, split tensile strength on cylinder as per IS : 5816 – 1999, flexural strength on beam of as per IS: 516 – 1959. Permeable voids tests is carried out as per ASTM C642-97.

3.2.1 Durability Test

The durability of concrete with the optimum percentage replacement of natural sand with quarry sand, partial replacement of cement with GGBS , and combination of GGBS and RHA partially replaced with cement and control mix is studied by the following tests.

3.2.1.1 Acid Resistant Test

In this study concrete cubes of control mix and maximum compressive strength with replacement of Quarry sand by natural sand and replacement of GGBS and RHA and 20%, 30% replacement of GGBS with cement and combination of GGBS and RHA is partially replaced with cement with optimum percentage of quarry sand is tested for Acid Resistant Test. These specimens were weighted after 28 days of curing and immersed in diluted 1% of sulphuric acid solution for 30 days. Then the cubes are taken out and before testing each specimen is removed from the bath and brushed with the soft nylon brush and rinsed in a tap water and weighed. The percentage loss in weight and percentage reduction in compressive strength are calculated and compared with that of control mix.

3.2.1.2. Chloride Attack Test

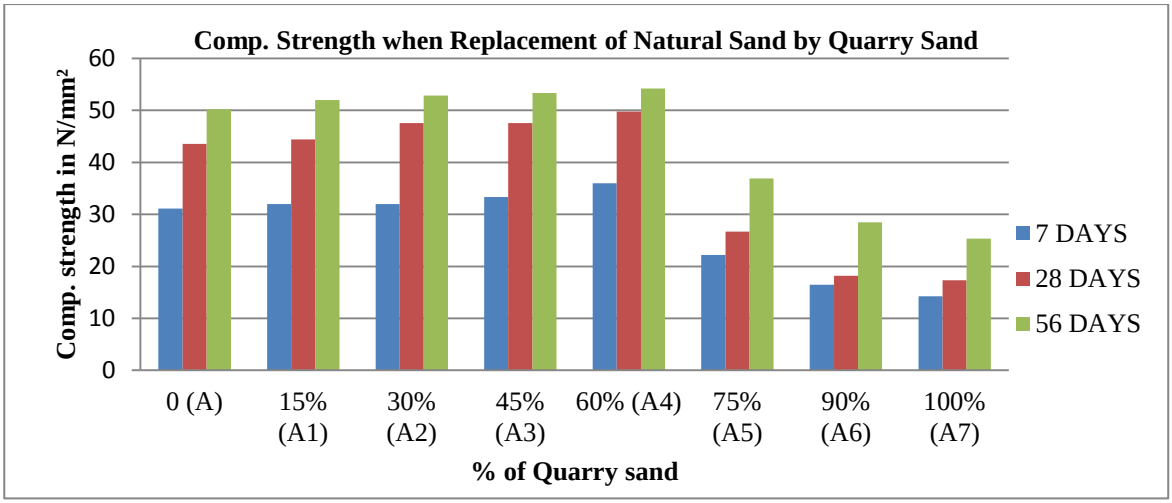
Chloride attack is one of the important aspects to be considered while dealing with the durability of concrete because it primarily causes corrosion of reinforcement. concrete cubes of control mix and maximum compressive strength with replacement of Quarry sand by natural sand and replacement of GGBS and RHA and 20%, 30% replacement of GGBS with cement and combination of GGBS and RHA is partially replaced with cement with optimum percentage of quarry sand is tested for chloride attack test . The cubes are immersed in a solution of 3% hydrochloric by weight of water for 28-days.then the cubes are taken out and weighted and percentage loss in weight percentage reduction in compressive strength are calculated.

3.2.2. Permeable Voids Test

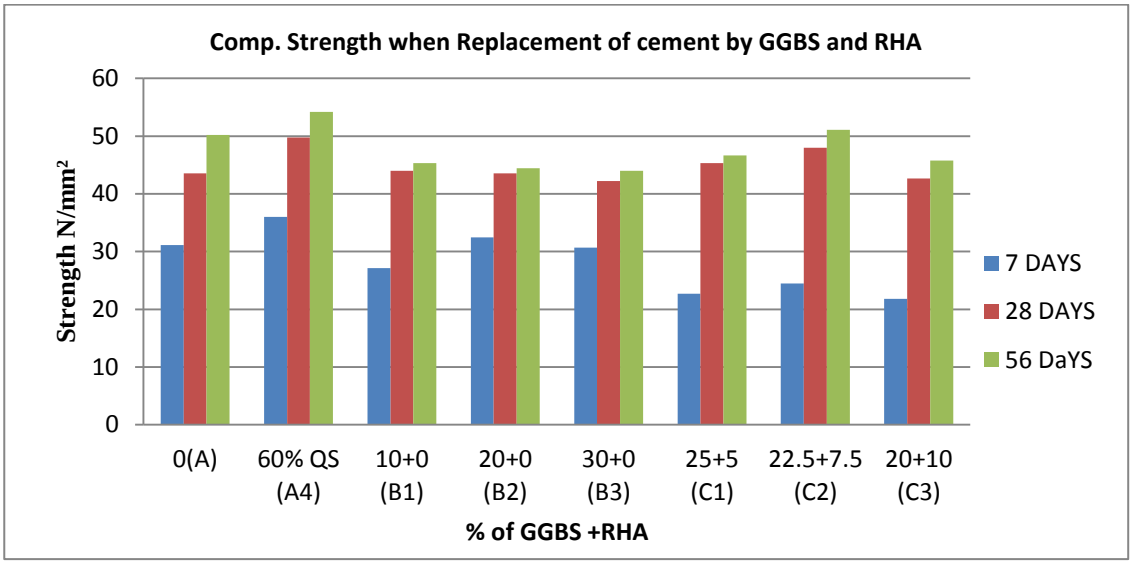
This test method covers the determination of density, percent absorption, and percent voids in hardened concrete. This test method is useful in developing the data required for conversions between mass and volume for concrete. It can be used to determine conformance with specifications for concrete and to show differences from place to place within a mass of concrete. The sample consist of any desired shape or size, except that the volume of each portion shall be not less than 800gm and each portion is free from observable cracks, fissures or shattered edges. In this research permeable voids test is carried out for each sample as per ASTM C 642-97.

Table No. 5: Compressive strength, Flexural strength, Split tensile strength

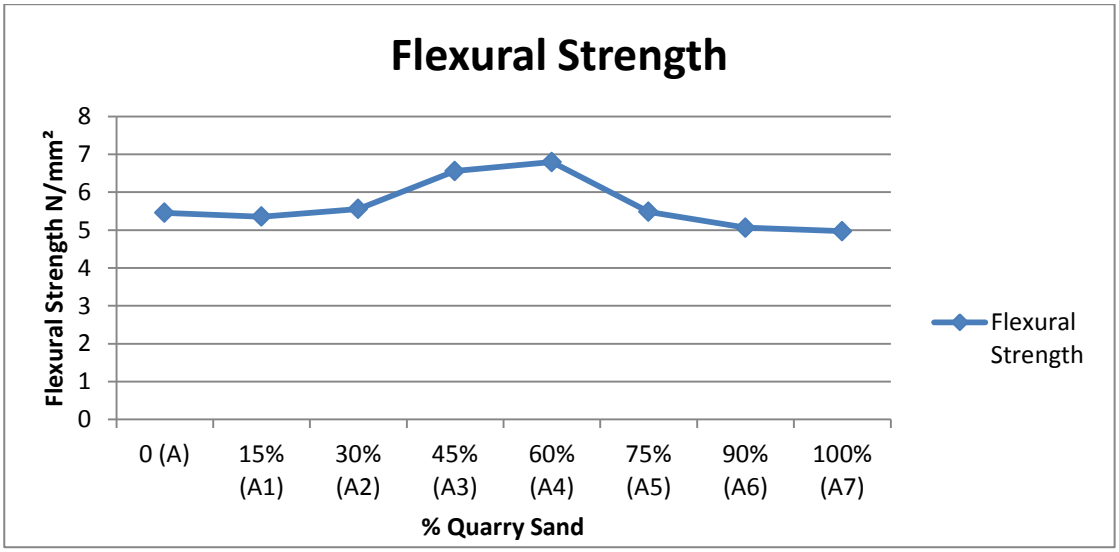
Sr. No	MIX	7 DAYS N/mm²	28 DAYS N/mm²	56 DAYS N/mm²	FLEXURE STRENGTH AFTER 28 DAYS N/mm²	SPLIT TENSILE TEST AFTER 28 DAYS N/mm²
1.	A	31.11	43.55	50.22	5.454	3.8197
2.	A1	32.00	44.44	52.00	5.355	3.961
3.	A2	32.00	47.55	52.88	5.555	3.961
4.	A3	33.33	47.55	53.33	6.558	3.961
5.	A4	36.00	49.77	54.22	6.796	4.102
6.	A5	22.22	26.66	36.88	5.481	2.546
7.	A6	16.44	18.22	28.45	5.061	2.546
8.	A7	14.22	17.33	25.33	4.971	2.405
9.	B1	27.11	44.00	45.33	4.720	4.244
10.	B2	32.44	43.55	44.44	6.796	4.385
11.	B3	30.66	42.22	44.00	5.188	4.668
12.	C1	22.67	45.33	46.67	6.541	3.961
13.	C2	24.44	48.00	51.11	6.171	3.961
14.	C3	21.77	42.67	45.78	4.601	3.678



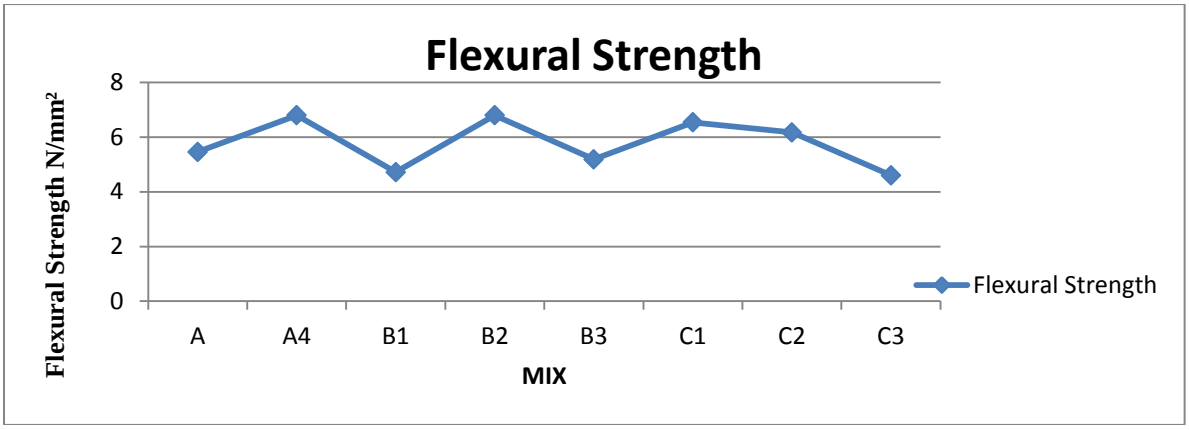
Graph 2: Compressive Strength when replacement of Natural Sand by Quarry Sand



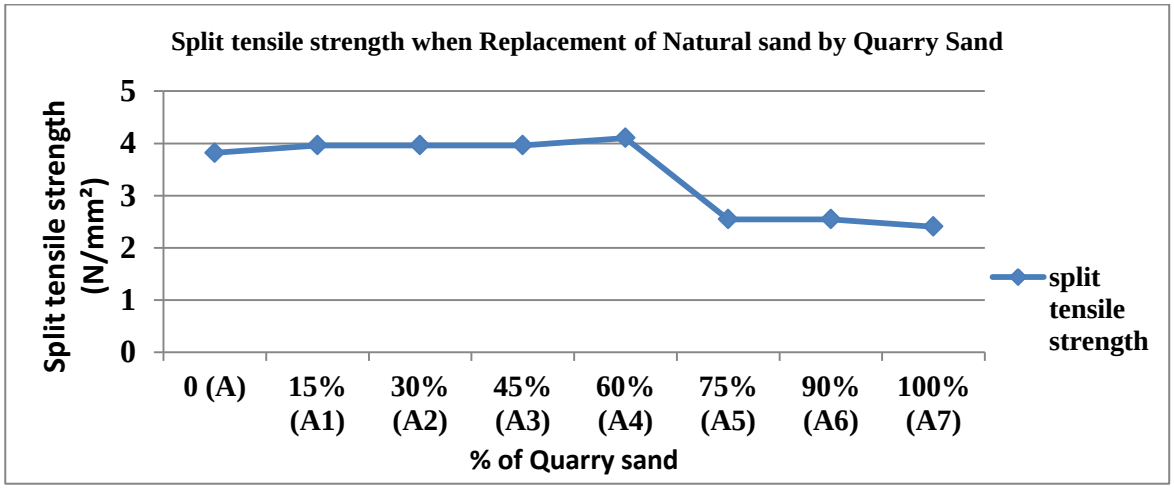
Graph 3: Compressive Strength when replacement of cement by GGBS and RHA



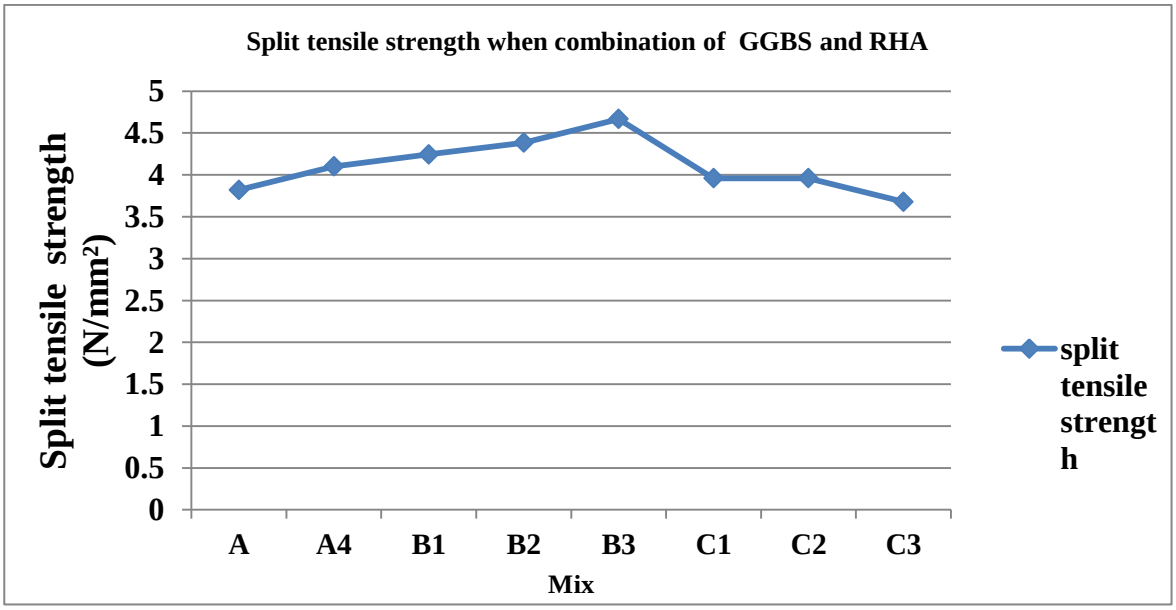
Graph 4: Flexural Strength when replacement of Natural Sand by Quarry Sand



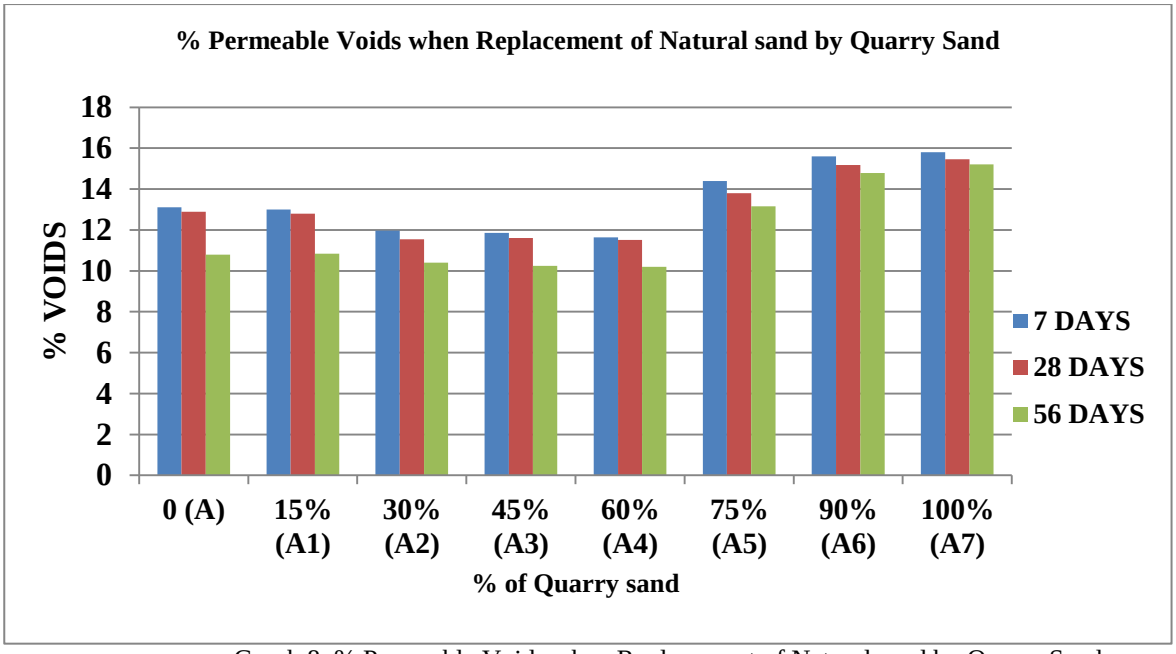
Graph 5: Flexural Strength when replacement of cement by GGBS and combination of GGBS and RHA



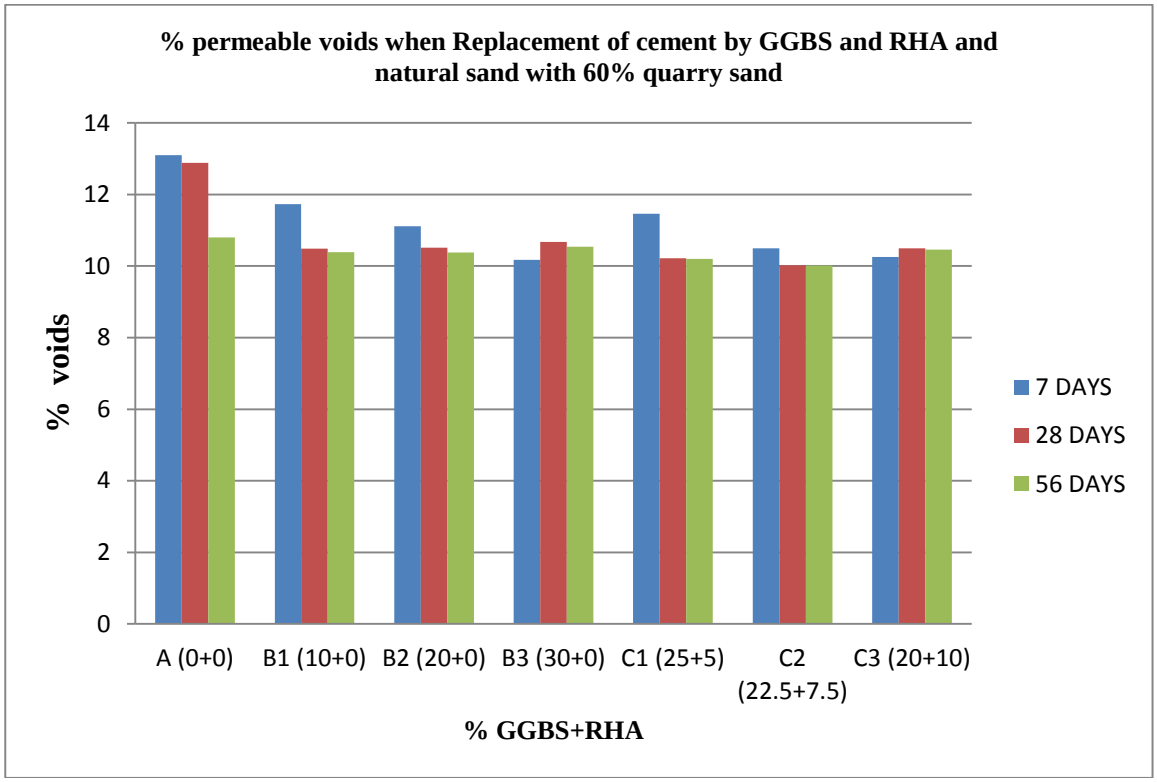
Graph 6: Split tensile strength when Replacement of Natural sand by Quarry Sand



Graph 7: Split tensile strength when replacement of cement by GGBS and combination of GGBS and RHA



Graph 8: % Permeable Voids when Replacement of Natural sand by Quarry Sand



Graph 9: % permeable voids when Replacement of cement by GGBS and RHA and natural sand with 60% Quarry Sand

Table No. 6: Reduction in weight and compressive strength of concrete cubes immersed in 1% Sulphuric acid solution.

SR no	Mix designation	Avg. Weight of cubes before immersion in Kg	Avg. Weight of cubes after immersion in Kg	Reduction in weight %	Avg. Compressive strength of cubes before immersion in N/mm^2	Avg. Compressive strength of cubes after immersion in N/mm^2	Reduction in Compressive strength %
1.	Control mix **(A)**	8.350	8.237	1.35	43.55	40..888	6.112
2.	60%QS&40% NS **(A4)**	8.700	8.586	1.31	49.78	47.111	5.361
3.	20% GGBS +60%QS&40% NS **(B2)**	8.680	8.582	1.132	43.222	41.333	4.370
4.	30% GGBS +60%QS **(B3)**	8.640	8.545	1.093	42.222	40.44	4.22
5.	22.5%GGBS+7.5%RHA+60%QS **(C2)**	8.950	8.882	0.759	48.00	47.111	1.85

Table 7: Reduction in weight and compressive strength of concrete cubes immersed in 3% Hydrochloric solution.

SR no	Mix designation	Avg. Weight of cubes before immersion in Kg	Avg. Weight of cubes after immersion in Kg	Reduction in weight %	Avg. Compressive strength of cubes before immersion in N/mm^2	Avg. Compressive strength of cubes after immersion in N/mm^2	Reduction in Compressive strength %
1.	Control mix **(A)**	8.950	8.856	1.06	43.55	41.33	50.97
2.	60%QS&40% NS **(A4)**	8.860	8.768	1.033	49.78	47.555	4.479
3.	20% GGBS +60%QS&40% NS **(B2)**	8.860	8.762	1.1	43.222	41.333	4.370
4.	30% GGBS +60%QS **(B3)**	8.850	8.749	1.1412	42.222	40	5.262
5.	22.5%GGBS+7.5%RHA+60%QS **(C2)**	8.540	8.436	0.66	48.00	46.67	2.771

IV. Conclusion

Based on the results presented above, the following conclusion can be drawn:

1. Compressive strength increases with increase of percent of quarry sand upto certain limit.
2. Concrete acquires maximum increase in compressive strength at 60% quarry sand replaced by natural sand for M40 grade of concrete. This mix is named as critical mix.
3. By adopting same critical mix and replacing cement by GGBS, it is found that by increasing the percentage of GGBS; workability increases but strength decreases.
4. According to mix the combine gradation of 45% QS and 55% NS meets the grading limits of IS: 383, But it has been found that on adding more percent of QS i.e 60% QS and 40% NS in concrete gives maximum compressive strength.
5. In order to increase the strength cement is replaced by combination of GGBS and RHA.
6. Good compressive strength is obtained when 22.5% GGBS + 7.5% RHA is replaced with cement and natural sand is replaced by 60% quarry sand.
7. The maximum 28 days split tensile strength was obtained with 30% GGBS replaced with cement.
8. The maximum 28 days flexural strength was obtained at A4 mix (60% QS and 40% NS) and B2 mix (20% cement is replaced with GGBS)

9. The workability of concrete had been found to be decrease with increase of quarry sand in concrete.
10. The workability of concrete had been found to be decrease with increase of RHA but the GGBS increases the
    workability of concrete.
11. Permeable voids are decreasing with the age of curing.
12. Durability test carried out in the investigation through acid attack test and chloride test with 1% sulphuric acid and 3% hydrochloric reveled that 22.5%GGBS+7.5%RHA replaced with cement and 60% quarry sand replaced with natural sand in concrete is more durable in terms of durability factors than control mix.
13. It is observed that combination of GGBS and Rice Husk Ash with QS concrete will be durable as compared to control concrete.

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