A Study on Partial Replacement of Cement with Rice Husk Ash & Fine Aggregates with Ground Granulated Blast Furnace Slag

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Abstract: ***Partial replacement of cements and fine aggregates by industrial wastes are the current trend of preparing sustainable concrete since production of cement produce large amounts of carbon di-oxide and other greenhouse gasses that cause global warming. The present work explores the suitability of industrial waste Rice Husk Ash (RHA) and Ground Granulated Blast Furnace Slag (GGBS) as an alternative material for the cement and fine aggregate in the production of concrete. The Ordinary Portland Cement (OPC) has been replaced by 0-30% with RHA and 20%, 40%, 60% GGBS in place of fine aggregate. The objective of the paper is to study the partial replacement of cement with Rice Husk Ash & Fine Aggregates with GGBS of concrete. Experimental result shows that concrete mix consisting 40% GGBS with 10% RHA produce similar or even more compressive strength of normal concrete and all mixes at 28 days of curing age. However, considering all the properties of concrete, R10G40 gives robust performance than that of other mixes and it was recommended percentage for the concrete.***

Keywords: Rice Husk Ash, Ground Granulated Blast Furnace Slag, rebound hammer test, ultrasonic pulse velocity, water absorption.

1. Introduction

Concrete is an end product of intimate mixture of mainly three components namely cement, water and aggregates. Around 70-80% of the total volume of concrete is occupied by aggregates. Because of its large proportion in concrete, properties of aggregates are of considerable importance as they can affect the workability, strength, durability and structural performance of concrete. Aggregate was initially treated as inert and cheaper material in the concrete as it contributed to the large volume of concrete [1-3]. However, it has been found that the performance of concrete is influenced by the physical, chemical and thermal properties of aggregate [4]. The use of Granulated blast furnace slag (GGBS) in concrete by replacement of fine aggregates is very promising concept because its impact strength is quite more than natural fine aggregates [5-6]. Also RHA is widely used as supplementary cementitious material to increase the strength of concrete [7]. Rajith and Amrita [8] studied that the partial replacements of cement and fine aggregate by GGBS and showed that up to 25% of replacement strength are gradually increases. Past researchers showed that as partial Later, Nandagawali and Dhamge [9] also reported that the mechanical and durability properties of concrete can be improved by using GGBS as a replacement of fine aggregate. Sujivorakul et al. [10] partially replaced with Fly Ash, Rice Husk Ash, and Palm Oil Fuel Ash in Glass Fiber–Reinforced concrete and observed that at 0-20% replacement of cement strength and durability properties are increases at 28days curing ages. Sakr [11] studied the by using of silica fume and rice husk ash as partial replacement of cement and observed that concrete mixed with RHA shows higher strength than silica fume.

Hence, the objective of this paper is to study the Partial Replacement of Cement with Rice Husk Ash & Fine Aggregates with Ground Granulated Blast Furnance Slag in concrete.

2. Experimental Program

Materials:
Ordinary Portland Cement (OPC) 43 grade conforming to the requirements of IS: 8112-1989 [12] and manufactured by Ramco Cement Co., India is used in the entire experimental study. Ordinary sand has maximum size 4.5 mm as per the Indian code IS 383-1970 [13]. The available drinking water is used in the production of concrete also for the curing of concrete same water is used.

Rice Husk Ash
For this experiment, RHA is collected from rice sheller shown in figure 1 and processed to size less than 45 microns to be replaced with cement. Rice husk has burnt into ash to get their physical and chemical properties to be used as mineral admixture in concrete. Pozzolanic activity of RHA rest on silica content, silica crystallization phase, size and surface area of RHA particles. The most common use of RHA is to provide strength to the concrete and to decrease the cost of construction. Use of Rice husk ash in construction works will decrease the environmental pollution, strengthen the concrete quality and optimize the cost of concrete as well as resolving the problem of agricultural waste management.

Figure 1: Rice Husk Ash

Ground Granulated Blast Furnace Slag

GGBS is made from the product of iron in a blast furnace where iron ore, limestone and coke are heated up to 1500°C. Two products named molten iron and molten slag are produced after the melting of these materials in black furnace. The molten slag is lighter and floats on the top of the molten iron. The molten slag comprises mostly silicates and alumina from the original iron ore, combined with some oxides from the limestone. The granulated slag is further processed by drying and then ground to a very fine powder, which is GGBS cement shown in figure 2. Grinding of the granulated slag is carried out in a rotating ball mill. The GGBS is collected from the source is sieved through 4.75 mm, 2.36 mm, 1.18 mm, 600 µ, 300 µ and 150 µ IS sieves. Sizes which are greater than 4.75 mm are discarded. The sieve analysis was carried out as per the standard sieve analysis IS: 2386-1963 [14].

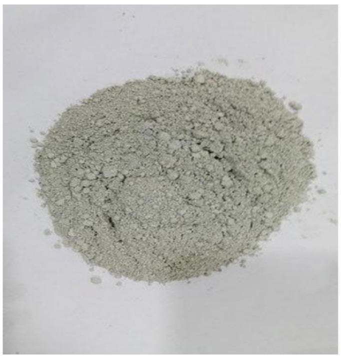

Figure 2: Ground Granulated Blast Furnace Slag

Preparation of concrete samples

Two types of concrete mixes were prepared with 0-30% RHA in place of cement and 20%, 40%, 60% GGBS in place of fine aggregate. Normal concrete mix prepared with natural aggregate without any replacement was known as reference. In all the mixes locally available natural sand was used as fine aggregate. All mixes were designed for M30 grade of concrete as per IS: 10262-2009 [15]. This study uses a mixing ratio of 1: 1.55: 2.99, 1-part cement, 1.55-part fine aggregate, 2.99-part coarse aggregate with a constant cement to water ratio (w\c) of 0.45. Detail of mix proportion and combination for concrete containing different percentages of RHA and GGBS are given in table 2 and 3. Based on the mix proportion cubes of 150 mm are cast for the purpose of compressive strength, ultrasonic pulse velocity test and dynamic modulus of elasticity. All mixes were tested for workability in terms of slump. The concrete was placed in three layers into the standard steel moulds and each layer was compacted manually with tapping rod with 25 number of tamping until sufficient compaction was achieved after completion of mixing. Specimens were coded before they were covered with polythene sheets. After a day, all specimens were demoulded and cured under water for a specified period of curing at 27º C ± 2º C and 90% ± 1% relative humidity. Some of the specimens for compression test were cured in water for 7 days after demoulding and then cured in air till the testing age.

Table 1: Physical Properties of OPC, RHA and GGBS

Physical Properties	OPC	RHA	GGBS
Specific gravity	3.15	2.30	2.90
Fineness (Blaine's p ermeability method) (m^2 kg−1)	370		463
Colour	Dark grey	Blackish	Off-white
PH	11	7.3	9.2
Density (g/cm3)	3.10	0.088	1.157

Table 2: Chemical Composition of OPC, RHA and GGBS (% by weight)

Sl. No	Constituent	OPC	Rice husk ash (RHA)	GGBS
1	SiO2	20.61	66.5	34.4
2	Al2O3	5.028	1.21	21.5
3	CaO	62.61	1.12	33.2
4	Fe2O3	3.329	0.75	0.2
5	MgO	2.237	1.67	9.5
6	SO3	2.723	0.63	0.66
7	Na2O	0.328	3.71	0.34
8	K2O	0.577	3.16	0.39
9	P2O5	0.32	0.12	0.19
10	TiO2	0.27	0.08	0.13

Table 3: Physical Properties of Aggregates

Sl No	Properties	Coarse aggregate	Fine aggregate
1	Bulk density (Kg/m3)	1698	1652
2	Specific gravity	2.83	2.63
3	Water absorption %	0.2	0.73
4	Fineness modulus	6.47	2.39

Table 4: Details of mix proportions for w/c=0.45 (kg/m3)

Mix Composition	Cement (Kg)	Coarse Aggregate (Kg)	Fine aggregate (Kg)	RHA (Kg)	GGBS (Kg)
R0G0	423	1268	659	0	0
R10G0	380.7	1268	659	42.3	0
R20G0	338.4	1268	659	84.6	0
R30G0	296.1	1268	659	126.9	0
R10G20	380.7	1268	527.2	42.3	131.8
R20G20	338.4	1268	527.2	84.6	131.8
R30G20	296.1	1268	527.2	126.9	131.8
R10G40	380.7	1268	395.4	42.3	263.6
R20G40	338.4	1268	395.4	84.6	263.6
R30G40	296.1	1268	395.4	126.9	263.6
R10G60	380.7	1268	263.6	42.3	395.4
R20G60	338.4	1268	263.6	84.6	395.4
R30G60	296.1	1268	263.6	126.9	395.4

Table 5: Descriptions of Combination of Concrete Mixes

Mix No.	Mixes	Mix composition
Partial replacement of cement with Rice husk ash		
1	R0G0	100% OPC
2	R10G0	10% RHA+ 0% GGBS
3	R20G0	20% RHA+ 0% GGBS
4	R30G0	30% RHA+ 0% GGBS
Partial replacement of cement and fine aggregate with Rice husk ash and GGBS		
5	R10G20	10% RHA+ 20% GGBS
6	R20G20	20% RHA+ 20% GGBS
7	R30G20	30% RHA+ 20% GGBS
8	R10G40	10% RHA+ 40% GGBS
9	R20G40	20% RHA+ 40% GGBS
10	R30G40	30% RHA+ 40% GGBS
11	R10G60	10% RHA+ 60% GGBS
12	R20G60	20% RHA+ 60% GGBS
13	R30G60	

Test Procedure

For obtaining the workability of concrete, the slump cone specified by IS: 7320-1974 [16], in this work, slump value was taken as 72 ± 98 mm. According to IS: 516-1959 [17] for compressive strength, the samples were prepared. The UPV and rebound hammer test is the most frequently used practice among all the non-destructive test of concrete samples were performed as per IS 13311 (1992) part-1 [18].

3. Experimental Result and Discussion

Fresh property

The workability of a concrete mix is the relative ease with which concrete can be placed, compacted and finished without separation or segregation of the individual materials. It is not possible to measure workability but the slump test, together with an assessment of properties like stone content, cohesiveness and plasticity, gives a useful indication. The variation of workability of concrete mixes with respect w/c ratio for different percentages of RHA and GGBS as replacement of cement and river sand is presented in Figure 3.

Effect of workability by using RHA and GGBS of normal concrete

The measurement of workability was done after 15-20 minutes of mixing with respect of slump. It can be seen the workability of control concrete at w/c ratio 0.45 is 98 mm, which decreases to 72 mm when the replacement level is 20% GGBS and 10% RHA. Moreover, the slump value of concrete is further reduced with the increase in replacement level. This reduction of workability of concrete could be attributed to the fact that water absorption of RHA and GGBS is higher as compared to natural fine aggregate. Due to the higher water absorption of GGBS the slump value of concrete mixes decreases with the increase in GGBS content.

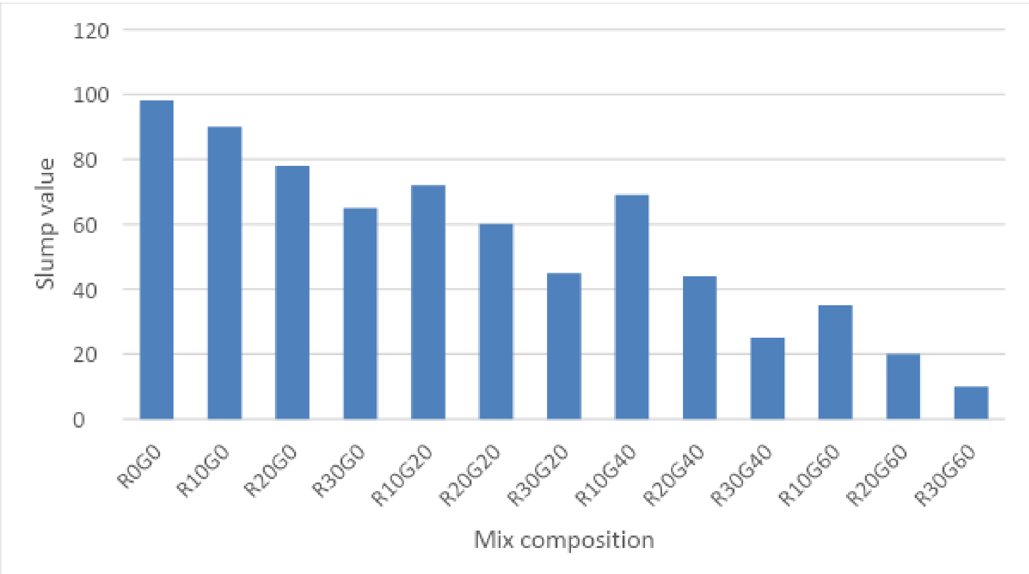

Figure 3: Workability of concrete mixes with different percentages of RHA and GGBS

4. Mechanical Properties

The effects of brick aggregate and SF on different properties of concrete are reported below.

Compressive strength of concrete:-

Compressive strength of concrete is directly related to the age after casting is completed and it increases with the age. The rate of development of compressive strength depends mainly on the hydration process of cement which in turn depends on the fineness and surface area of the cement. The main aim of the present study is to understand the development of strength with age with different amount of RHA and GBFS. For the use of concrete in any particular application, the characteristic compressive strength of concrete at 28 days is the main requirement. But the development of strength beyond 28 days is also very important when the structure is subjected to full loading after construction. The test results of compressive strength of concrete prepared with 0%, 10%, 20%, 30% RHA and 0%, 20%, 40%, 60%, 80% GBS with curing age of 150 mm cube.

Effect on compressive strength of concrete by using different percentages of RHA and GGBS

Figure 4 represents the compressive strength of 150 mm

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cubes after 7, 28 and 56 days of curing period. It is observed from the figure that at curing age 28days, the compressive strength for normal mix (R0G0) is found to be 39.70 N/mm2. The other mixes such as R10G0, R20G0, R30G0, R10G20, R20G20, R30G20, R10G40, R20G40, R30G40, R10G60, R20G60, R30G60 is found to be compressive strength 40.3, 37.7, 30.6, 39.3, 38.9, 29.7, 41.2, 40.1, 31.2, 38.2, 37.3, 25.2 N/mm2 at 28days curing. From above mixes R10G0, R20G0, R10G20, R20G20, R10G40, R20G40, R10G60, R20G60 achieved the target strength of the normal M30 grade concrete at 28 days. With age, the strength development of these two mixes R10G40 and R20G40 is found similar to or even more than (1.5 % and 0.41 %) the normal mix (R0G0). Similarly at 56days curing age, these two mixes R10G40 and R20G40 is found 4.3% and 3.6% more strength as compared to the control mix. The mix R10G40 which consists of 10%RHA with 40% GGBS gives highest strength as compared to other mixes. The increase in strength may be due partially to the pozzolanic reaction as reported by many researchers and partially to high specific surface area and the presence of reactive silica in RHA. The performance of rice husk ash in concrete is of factors influencing the amount of silica added. This is because rice husk ash contains 85% to 95% weight percent of amorphous silica. Rice husk ash as a pozzolanic reactive material can be used to improve surface area of transition zone between the microscopic structure of cement paste and aggregate in the high-performance concrete.

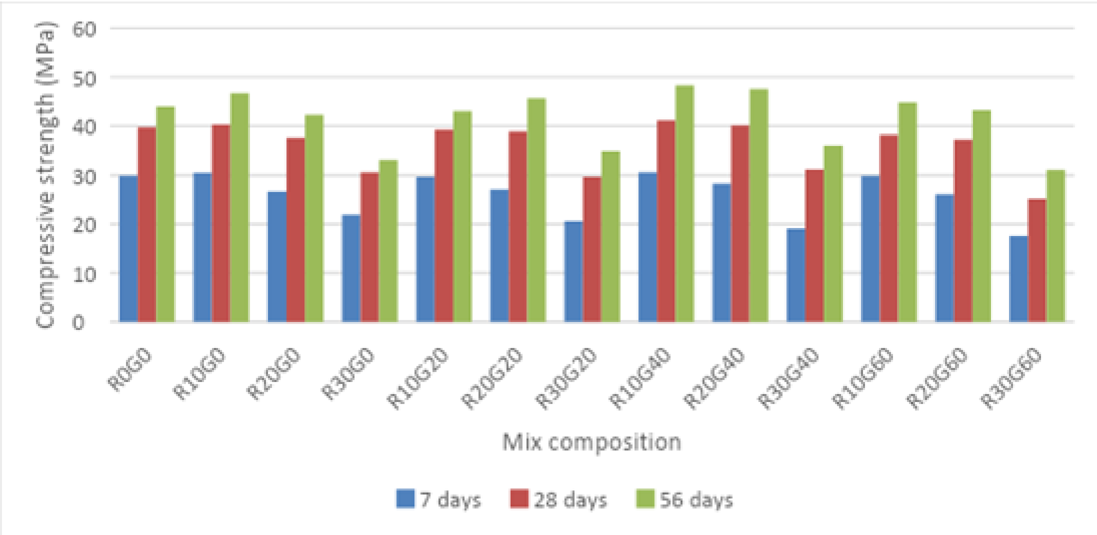

Figure 4: Compressive strength of concrete mixes with different percentages of RHA and GGBS

Ultrasonic Pulse Velocity Test:
Ultrasonic pulse velocity test is the non-destructive test of concrete conducted on built concrete structure. The equipment consists of transmitter and receiver prove and time measuring device. The transmitter and receiver probes are pressed against concrete surface.

Effect on UPV test of concrete by using different percentages of RHA and GGBS: Figure 5 represents the UPV test of 150 mm cubes after 7, 28 and 56 days of curing ages. It is observed from the figure that the mix R0G0 (which contains 0% RHA with 0% GGBS) gives pulse velocity is 5202 m/sec at 28 days of curing ages. The other mixes such as R10G0, R20G0, R30G0, R10G20, R20G20, R30G20, R10G40, R20G40, R30G40, R10G60, R20G60, R30G60 is found to be 5109, 4892, 4112, 4994, 4877, 4226, 5190, 4907, 4302, 4739, 4490, 4020 m/sec at curing age 28days. But the mix R10G40 (which contains 10% RHA with 40% GGBS) gives 5390 m/sec velocity which is 30 m/s higher velocity as compared to the normal mix (R0G0) at 56 days curing age.

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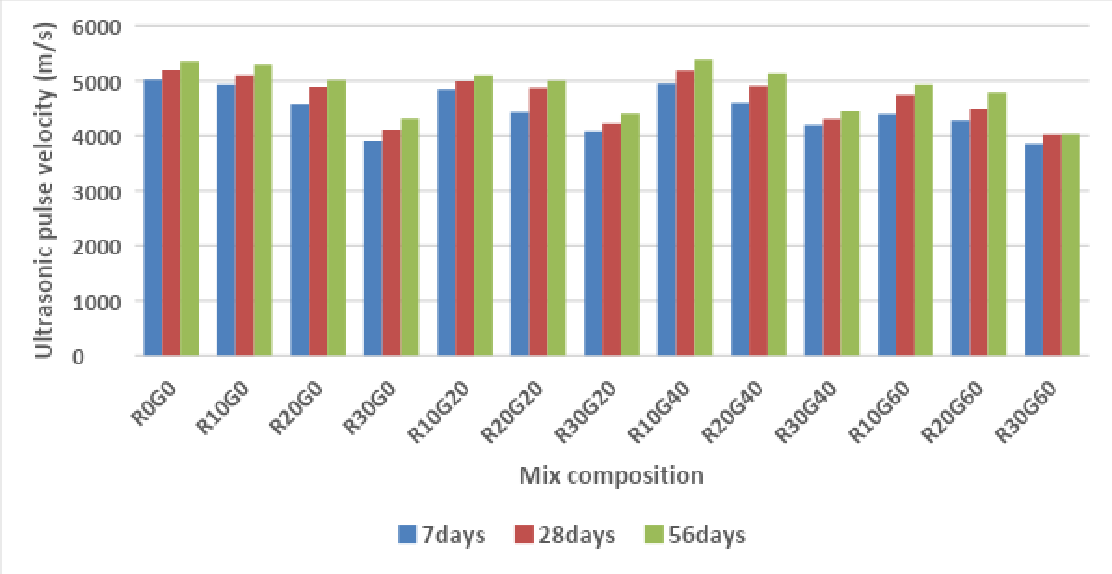

Figure 5: UPV test of concrete mixes with different percentages of RHA and GGBS

Rebound hammer test

To estimate the compressive strength of concrete is the rebound hammer test, also known as Schmidt Hammer test. It is one of the most useful Non Destructive techniques in evaluation of concrete structures. According to the rebound number obtained, corresponding compressive strength value was determined from the calibration graph provided along with the instrument. Initially the instrument was calibrated using 150x150x150 mm concrete cubes. The results were verified using compression testing machine and these were reliable. It is found that the use of NDT techniques like Rebound Hammer Test is much reliable and can well be fit to assess the quality of concrete structures.

Effect on test of concrete by using different percentages of RHA and GGBS:

Figure 6 shows that at in 28 days of curing 0% replacement the value of rebound hammer is 36.5. At 10% RHA replacement rebound hammer value is 38.8. when the % replacement of RHA increases the rebound hammer value decreases. In concrete mix of 10% RHA and 20% GBFS (R10G20) the value of rebound Index is 39.7. Similarly the result shows that the concrete mix which give maximum rebound hammer value is (R10G40 which is 40.1. At 28 days the mixes R10G0, R10G20, R20G20, R10G40, R20G40, R10G60, R20G60 respectively achieved higher strength and even or more 2%, 3.5%, 2.1%, 3.9%, 2.1%, 3.5%, 1.7% more strength than that of normal concrete mix (R0G0). However, R10G40 mix gives highest strength above all the mixes and at 56 days curing age this mix gives 4.3% more strength than the normal mix.

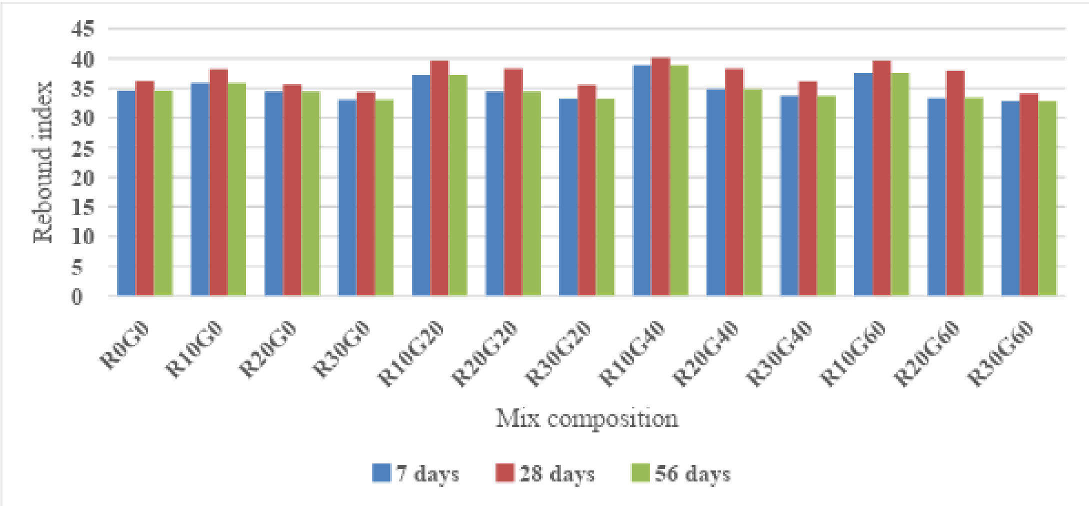

Figure 6: Rebound value of concrete mixes with different percentages of RHA and GGBS

5. Conclusion

In the present work a detailed and systematic experimental investigation is carried out on properties of concrete containing different percentages of Rice Husk Ash and Granulated Blast Furnace Slag (GGBS) obtained from Rourkela steel plant. The characteristics of natural aggregates both coarse as well as fine, RHA and GGBS are studied. Based on the test results, the following conclusions may be drawn:

- The workability of concrete mixes is influenced with the addition of RHA in concrete. The workability decreases with increasing percentage of RHA. Workability of GGBS incorporated concrete is less than the normal concrete and it is reduced with the increase in GGBS percentage. The optimum value for addition of slag is 40%. Due to the higher water absorption of GGBS the slump value of concrete mixes decreases with the increase in GGBS content.

- R10G40 mix (10% RHA and 40% GGBS) gives 1.5% and 4.3% more compressive strength as compared to normal concrete at 28 and 56 days curing age.
- The mix R10G40 gives maximum ultrasonic pulse velocity and rebound index at 28 and 56 days of curing age.
- However, R10G40 gives robust performance than that of other mixes and it was recommended percentage of concrete.

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