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RESEARCH ARTICLE

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EXPERIMENTAL ASSESSMENT ON PROPERTIES OF CONCRETE USING GGBS AND CERAMIC POWDER

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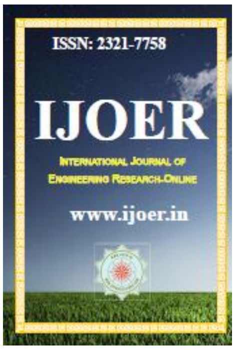

ABSTRACT

Production of residues from industries and construction sectors has increased during last few years. Much of this waste has been thrown to landfill, without considering its potential for reuse, recycling or valuation. Considering the high prices of Portland cement, there is a considerable need in our country for promoting cementitious materials cheaper than ordinary Portland cement. Planners, economists and scientists are keenly alive to the need of materials to meet the ever-increasing demand and very high prices of Portland cement. The aim of this research is to study the physical and mechanical properties of different laboratory-mixed concretes, using various proportions of supplementary materials generated from industrial waste. The added materials are included either as admixtures or in partial substitution of cement. The laboratory tests have followed the standard IS protocols. The result varies according to the proportion of supplementary material added to the mix. It is to present that the 30% of finely ground GGBS and ceramic waste powder in the range of 10%, 20%, 30% 40%, & 50% by volume of cement replacement. The research work overall aimed at to compare the different properties of hardened concrete made with different cement replacement levels of Ground Granulated Blast iron Slag and ceramic waste powder, with concrete having pure OPC (Ordinary Portland cement). The Mechanical properties such as compressive strength, flexure strength, and E for concrete and durability properties such as Acid resistance test, Sulphate attack and Rapid Chloride penetration test were conducted to compare the results with the control concrete.

Keywords: Ceramic powder, GGBS, durability properties, mechanical properties.

INTRODUCTION

Concrete is a construction material that consists, commonly Portland cement as well as other cementitious material such as fly ash and slag cement, coarse aggregate such as gravel, limestone or granite, fine aggregate such as sand or manufactured sand and water and chemical admixtures. Generally in design of concrete mix, cement, fine aggregates and coarse aggregates are using from long back, which plays a crucial role in designing of a particular grade of concrete. But now-a-days there is a scarcity in aggregates. So, some new materials which are locally available for low cost have to introduce for replacing the fine aggregates, coarse aggregates and as well as cement to get the same strength as that these basic materials can give. So, we have to search for different materials to reduce the quantity of basic natural materials in the concrete mix without changing any mix design procedure and considerations. Use of cheaper material without loss of performance is very crucial to the growth of developing countries. We cannot replace the whole basic material in the concrete, but we can replace with other materials to some extent. In the present study, to understand the behaviour and performance of ceramic solid waste in concrete. To understand the combined behaviour of ceramic powder and GGBS with partial replacement of cement at different compositions are also studied.

MATERIALS USED

Cement: The ordinary Portland cement of 43 grade whose specific gravity of cement is 3.01, normal consistency of the cement was found as 28% and the initial and final setting times were found as 120 min and 238 min respectively was used.

Coarse aggregate: The coarse aggregate with 20 mm nominal size having specific gravity 2.71 was used. The impact value is 20.44%. And the water absorption of the coarse aggregate is 0.38%.

Fine aggregate: Locally available river sand is used. As per IS 383:1970, sand is confirming to Zone III. Specific gravity of the sand used is 2.615. And the water absorption value is 0.45%.

GGBS: GGBS comprises mainly of calcium oxide, silicon di-oxide, aluminium oxide, magnesium oxide. It has the same main chemical constituents as ordinary Portland cement but in different proportions. Blast furnace slag and steel slag make up the largest portion of by-products in an integrated steel mill. GGBS slag is a granular material formed when molten iron blast furnace slag is rapidly chilled by immersion in water and having specific gravity 2.85 was used.

Ceramic powder: From the crushed waste ceramic, powder passed through 300 µm IS sieve to use as partial replacement to the fine aggregate. Specific gravity of ceramic powder is 3.10. The ceramic waste is durable, hard and highly resistant to biological, chemical and physical degradation forces. The substitution or partial replacement of cement with ceramic waste produces significant increases in compressive strength, making them suitable for the manufacture of concrete.

EXPERIMENTAL PROGRAM

Total 7 types of mixes were prepared by changing percentage of replacement by waste ceramic powder and GGBS in cement respectively as shown in Table 1.

Table 1. Mix proportions of concrete

Sl.No.	Mix	OPC	GGBS	CP	FA	CA	Water	SP	W/C	Slump
1	CC	445.53	-	-	631.67	1135.64	191.58	NIL	0.43	70
2	CRC1	311.87	133.65	-	662.30	1190.71	153.26	10	0.43	65
3	CRC2	267.31	133.65	44.55	661.34	1188.98	153.26	10	0.43	62
4	CRC3	222.76	133.65	89.10	659.43	1185.54	153.26	10	0.43	56
5	CRC4	178.21	133.65	133.65	657.52	1182.10	153.26	10	0.43	53
6	CRC5	133.65	133.65	178.21	656.56	1180.38	153.26	10	0.43	52
7	CRC6	89.10	133.65	222.76	654.65	1176.94	153.26	10	0.43	50

Workability

Workability is the ability of a fresh (plastic) concrete mix to fill the form mould properly with the desired work (vibration) and without reducing the concrete's quality. Workability depends on water content, additives, aggregate (shape and size distribution) and age (level of hydration). Raising the water content or adding plasticizer will increase the workability. Too much water will eat to bleeding (loss of water) and/or Segregation (concrete start to get in homogeneous) and resulting concrete will have reduced quality. Workability normally tested by slump measurement. High flow concrete, selfcompacting concrete, are normally tested by one several flow measuring methods.

PREPARATION OF CONCRETE AND CASTING OF SPECIMENS

Portable water was used to mix with the different ingredients of concrete. The slump of the fresh concrete was determined to ensure that it would be within the designing value on the workability of concrete and lies between 50–75 mm. The slump values were determined for various mixes. The fig4.4 shows the slump contest conducted. To maintain the slump value between 50-70mm, superplasticizer conplast 430 (G) compiling with IS9103:1999 was used at the range of 0.6-1.5lit/100Kg cement. Superplasticizer gives increase in workability without significant change in compressive strength and reduction in W/C ratio thus enhancing durability of concrete. Crude black oil was applied along the inner surfaces of the mould for easy removal of casted cubes from the mould. Conventional concrete cubes were cast in moulds of 150x150x150 mm size and allowed to dry for 24hours. The specimens were de-moulded after 24hours, cured in water and tested at room temperature at the required period of curing such as 7days, 28days and 56days.

PROPERTIES OF CONCRETE

Mechanical Properties of Concrete

(a) Compression Test

(b) Flexure test

(c) E for concrete

Compression Test(Ref:IS:516-1959)

Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristics properties of concrete are qualitatively related to its compressive strength. Compressive strengths were attained as a result of the compressive tests conducted on the cube specimens of size 150mmx150mmx150mm. The specimens are subjected to compressive loads in compression testing machine as per IS: 516-1969 and the crushing load is noted. The compressive strength is the ratio of crushing load to the surface are of the specimens expressed in N/mm2 and the results are tabulated in table and figure shows the compressive strength test for cubes.

The compressive strength can be determined using the formula

$$P_u = P_c / A$$

Flexural test (Ref: IS: 516-1959)

The flexural strengths of the respective specimens have been obtained from the flexural tests performed on the prism specimens of size 100mmx100mmx500mm the modulus of rupture can be determined by using the formula

$$f_{cr} = (P_{max} \times l) / bh^2$$

f_{cr} = Flexural strength

P_{max} = maximum loading (N) kg.

B = width of the prism in mm

H = depth of the prism in mm

L = span of the prism in mm

The loading must be applied centrally and without subjecting the specimen to any torsional stresses and restraints. The axis of the specimen shall be carefully aligned with the axis of the loading device. The load shall be applied without any shock and increasing continuously at specified rate.

Modulus of elasticity for concrete (Ref: IS: 516-1959)

The Elastic Modulus for Concrete test is the most common test conducted on hardened concrete, partly because it is an easy test to perform. Concrete is not really an elastic material, i.e., it does not fully recover its original dimensions upon unloading. Hence, the elastic constants are necessarily considered for conventional design of reinforced concrete structures.

The young's modulus of elasticity is a constant defined as the ratio, within the linear elastic range, of axial stress to axial strain under uniaxial loading. In the case of concrete under uniaxial compression, it has some validity in the very initial portion of stress-strain curve, which is particularly linear, i.e., when the loading is of low intensity and of very short duration. If the loading is sustained for very long duration, in elastic creep effects come into play, even at relatively low stress levels. This test is normally conducted by using the cylinder specimens of size 150mmx300mm.

DURABILITYPROPERTIES

Durability of the concrete is its ability to resist weathering, abrasion, chemical attack or any process of deterioration. The concrete is said to be durable, if it has the ability to retain its original form, quality and serviceability when exposed to its working environment. Out of all the factors influencing the durability of concrete chemical attack is the chief factor which is responsible for deterioration of structures by causing volume change and cracking. The primary factor determining durability is, a good-quality concrete with low porosity i.e. low permeability. The other advantages of durable concrete include resistance to acid reaction and Sulphates, increased corrosion protection, and reduced heat of hydration.

The tests for durability that were conducted are

(a) Acid Resistance
(b) Sulphate attack
(c) Rapid chloride permeability Test

(a) Acid Resistance: The liquids, whose pH value less than 5.5 and 4.5 cause serious damage to the concrete, such liquids speed up the disintegration process and ultimately destruct the structures. The intensity of corrosion caused by HCL at equal concentration is more in comparison with sulphuric acid. Cubes were cast in moulds of 150x150x150mm size and after curing in water for 28days, they are immersed in HCL acid solution for 28days and then dried thoroughly. Then the cubes are weighed and tested for its compressive strength.

(b) Sulphate attack: Most of Soils contain sulphate residues in the form of Calcium, Sodium, Potassium and magnesium. Most of them are present either in soil or groundwater. Industrial structures exclusively concrete cooling towers are subjected to sulphate attack. Therefore the effect of sulphate on concrete structures is unavoidable. The intensity of sulphate attack is moreover when it attacks in solution form by entering the porous concrete and reacts with hydrated cement products, rather than its effect in solid form. The test specimens of 150X150X150 mm cubes were immersed in 5% of Sodium sulphate solution over a period 28 days. The effect of sulphate attack on performance and properties of concrete are identified.

(c) Rapid chloride penetration test: The test method consists of monitoring the amount of electrical current passed through 50 mm thickslices of 100mm nominal diameter cores or cylinders during 6 hours at 30 minutes interval. A potential difference of 60 VDC is maintained a cross the ends of the specimens, one of which is immersed in a sodiumchloride solution, the other in a sodium hydroxide solution. The total charge passed in coulombs, has been found and the results are compared to the values in table 2.

Table 2. Results for RCPT test

Charge passed (coulombs)	Chloride penetration
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Verylow
<100	Negligible

REGRESSION MODELING

Regression analysis had been employed to several civil engineering problems in construction field. It is one of the most widely used statistical tools for developing relationship between dependent and independent variables. Generally, regression is the process of fitting models to data. In this study, dependent variable is 28 days compressive strength data.

RESULTS AND DISCUSSION

Based on the experimental investigations, the results of specimens with partial replacement of cement by ground granulated blast slag and ceramic powder were observed and their mechanical and durability characteristics are compared with the conventional concrete properties.

Compressive Strength

The compressive strength tests were performed on compression testing machine using cube specimens. Three samples per mix were tested and the average strength values were arrived as tabulated in table 3. The 28 days compressive strength of cube specimens has attained the required target strength with replacement levelupto30% GGBS and 10% & 20% ceramic powder (ie., CRC 2 & CRC 3) and on further increase in the percentage level of ceramic powder, the compressive strength decreases on comparison with the conventional concrete.

Table 3. Compression test results for all ages

Sl.No.	Mix	7 Days strength		28 Days strength		56 Days strength	
		Comp. St	Average comp. St	Comp. St	Average comp. St	Comp. St	Average comp. St
1	CC	26.44	26.52	38.00	38.07	38.44	38.52
		26.44		38.00		38.44	
		26.67		38.22		38.67	
2	CRC1	24.89	24.59	35.20	35.32	36.67	36.96
		24.44		35.20		37.11	
		24.44		35.56		37.11	
3	CRC2	24.89	25.04	36.00	36.15	37.33	37.33
		25.11		36.22		37.33	
		25.11		36.22		37.33	
4	CRC3	26.44	26.15	36.67	37.11	38.44	38.67
		26.00		37.33		38.89	
		26.00		37.33		38.67	
5	CRC4	23.56	23.41	26.67	26.59	27.56	27.11
		23.33		26.44		26.67	
		23.33		26.67		27.11	
6	CRC5	20.00	20.45	25.56	25.56	26.22	26.30
		20.67		26.00		26.67	
		20.67		25.11		26.00	
7	CRC6	18.22	17.63	20.67	21.11	21.33	21.85
		17.11		20.89		21.78	
		17.56		21.78		22.44	

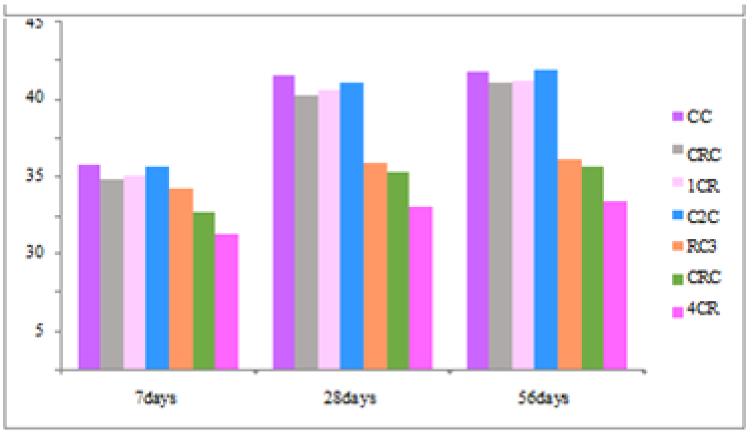

Fig 1 Compressive strength in N/mm^2

Flexural Strength

The flexural strength of all mixes have been tabulated in table 4 and the chart showing the variation in strength levels of various mix proportion is presented in fig 4.

Table 4. Flexural strength results

Sl. No.	Mix	Division	Load in N	Flexural strength	Average flexural strength
1	CC	32	16000	6.4	6.47
		33	16500	6.6	
		32	16000	6.4	
2	CRC1	33	16500	6.6	6.5
		32	16000	6.4	
		33	16500	6.5	
3	CRC2	32	16000	6.4	6.3
		31	15500	6.2	
		32	16000	6.4	
4	CRC3	31	15500	6.2	6.0
		30	15000	6.0	
		30	15000	6.0	
5	CRC4	28	14000	5.6	5.5
		27	13500	5.4	
		28	14000	5.6	
6	CRC5	26	13000	5.2	5.0
		24	12000	4.8	
		25	12500	5.0	
7	CRC6	24	12000	4.8	4.6
		23	11500	4.6	
		22	11000	4.4	

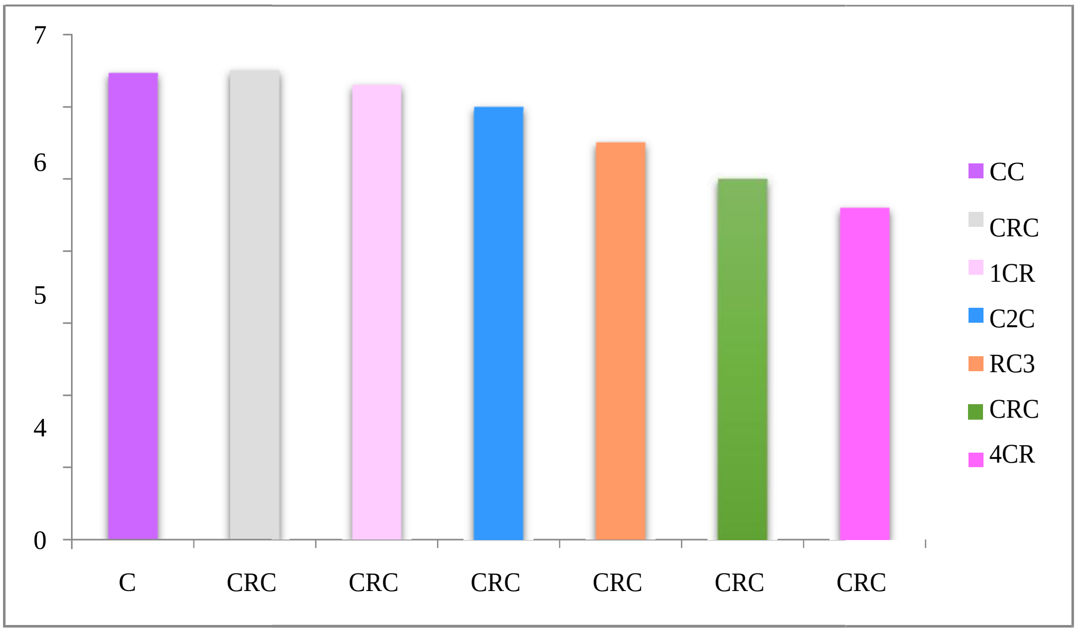

Figure 2 Flexural strength in N/mm^2

Elastic Modulus of concrete

The Elastic modulus of concrete for various mix proportion are listed in table 5.

Table 5. Results for Elastic modulus of concrete

Sl. No.	Mix	Elastic modulus of concrete N/mm^2	Theoretical value of E in N/mm^2
1	CC	2.71x10^4	3.08x10^4
2	CRC1	2.65x10^4	2.97x10^4
3	CRC2	2.67x10^4	3.00x10^4
4	CRC3	2.70x10^4	3.04x10^4
5	CRC4	2.60x10^4	2.57x10^4
6	CRC5	2.55x10^4	2.52x10^4
7	CRC6	2.50x10^4	2.29x10^4

DURABILITY RESULTS

Acid Resistance

Concrete cube specimens with 30% GGBS and with 10 % & 20% ceramic powder along with 30% GGBS immersed in Hcl acid solution were dried thoroughly and weighed and its compressive strength was found. With the introduction of GGBS and ceramic powder, the concrete possesses higher resistance to acid attack. The loss in mass as a result of exposure to acid is tabulated in table 5.6. Mass loss gave a very clear illustration that the 100% OPC specimens lost mass at a faster rate when compared with the specimens of 30 % GGBS and 10 – 20 % ceramic powder.

Table 6. Results for Acid Attack test for all mixes

Sl. No.	Mix	Loss in weight (gm)	Average loss in weight (gm)	Compressive strength N/mm^2	Compressive strength after acid immersion N/mm^2	Average comp. strength N/mm^2	% Loss in Compressive Strength
1	CC	16.54	16.57	38.07	34.82	34.69	9.92
		16.60			34.56		
2	CRC1	18.25	18.28	35.32	31.58	31.34	11.27
		18.30			31.10		
3	CRC2	17.65	17.59	36.15	32.10	32.51	10.06
		17.54			32.92		
4	CRC3	16.85	16.77	37.11	34.06	34.32	7.51
		16.68			34.57		

Sulphate Attack

The deterioration of the specimens is estimated by finding out the percentage reduction in weight of the specimens. A characteristic whitish appearance is the indication of sulphate attack. The term sulphate attack denote an increase in the volume of cement paste in concrete or mortar due to the chemical action between the products of hydration of cement and solution containing sulphates. In hardened concrete, calcium sulphoaluminate, forming within the framework of hydrated cement paste. Because of the increase in volume of the solid phase which can go up to 227 percent, a gradual disintegration of concrete takes place. The reduction in compressive strength of the specimens immersed in Sodium sulphate solution was also identified and tabulated in table 7.

Table 7. Results for Sulphate Attack test for all mixes

Sl.No.	Mix	Loss in weight (gm)	Average loss in weight (gm)	Compressive strength N/mm^2	Compressive strength after sulphate immersion N/mm^2	Average comp. strength N/mm^2	% Loss in Compressive Strength
1	CC	16.40	16.44	38.07	34.95	34.84	8.48
		16.49			34.72		
2	CRC1	18.05	18.08	35.32	31.64	31.55	10.67
		18.10			31.46		
3	CRC2	17.46	17.39	36.15	32.58	32.82	9.21
		17.32			33.05		
4	CRC3	16.66	16.45	37.11	34.24	34.49	7.06
		16.24			34.73		

Rapid chloride Penetration test

Cube testing alone is not the criteria for the durability of concrete structure. A durable concrete is one that perform satisfactorily in the working environment during its anticipated exposure conditions during service. The materials and mix proportions specified and used should be such as to maintain its integrity. Both strength and durability have to be considered explicitly. The cumulative current readings and chloride permeability ratings have been presented in table 8 and 9.

Table 8. RCPT results for all mixes

Time (min)	Current readings (Coulombs)							
	CC		CRC 1		CRC 2		CRC 3	
0	45	52	42	40	38	39	32	32
30	65	67	62	64	42	42	33	34
60	87	84	70	76	44	42	36	35
90	96	98	86	85	47	44	38	37
120	110	108	94	89	50	46	42	43
150	121	128	96	96	51	49	43	44
180	128	139	98	98	51	51	46	46
210	135	142	99	98	52	55	48	49
240	146	156	100	100	57	56	51	50
270	146	145	102	102	56	60	54	53
300	152	149	105	108	58	60	54	56

330	152	157	110	113	58	65	57	57
360	165	166	119	121	63	66	61	60
Cumulative Current	1548	1591	1183	1190	667	675	595	596

Table 9. Results for RCPT test for all mixes

Mix	Cumulative current (I)	Charge passed (Q)	Chloride permeability rating
CC	1548	2786	Moderate
	1591	2864	Moderate
CRC1	1183	2129	Moderate
	1190	2142	Moderate
CRC2	667	1201	Low
	675	1215	Low
CRC3	595	1071	Low
	596	1073	Low

Analytical Results

An artificial neural network is an artificial intelligence technique. It is a simulation of human brain- like architecture. An artificial neural network is a massively distributed processor made up of interconnection of simple processing elements i.e. neurons outputs are connected, through weights, to all other neurons including themselves, It resembles brain in mainly in the aspects of. In a large network the contribution of a single weight is often slight; it is the effect of combination of connection weights that determines the output. The process of training a network is that of finding a set of values for the weights that make the network do what you want it to do. Mathematicians are still working on this, but is appears that given enough hidden units and connections there is little that a net is unable to do. Then the problem is in finding the right box to train generalized regression neural networks to solve specific problems.

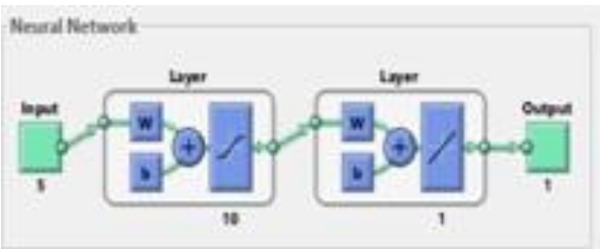

Fig 3. ANN Network Output dialog box

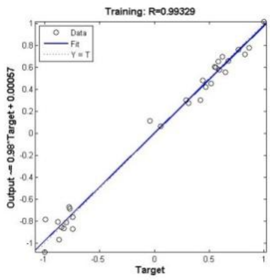

Fig 4. Network Training regression

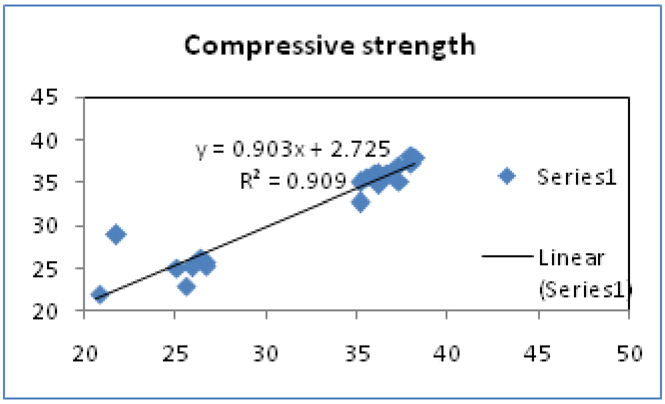

Fig 5. Relationship between Actual & Predicted compressive strength of concrete at 28 days

Conclusion

The conclusions arrived on performing the experimental assessment on the mechanical and durability properties of concrete using GGBS and ceramic powder are

- Partial replacement of cement with GGBS and ceramic powder can solve the environmental problems caused by the production of Portland cement.
- Concrete with partial replacement of cement by GGBS and ceramic powder has initial strength loss which can be negligible.
- The difference in percentage of compressive strength of CRC1, CRC2, CRC3 are 7.2 %, 5.0 % and 2.52 % respectively when compared with CC.
- On further increase in percentage of replacement of CP from 30 % to 50%, the percentage of compressive strength decreases by 30 %, 32 % and 44 % respectively.
- Flexural strength of CRC2, to CRC 6 decreases from 2.63 % to 28.9 % when compared to CC.
- Modulus of elasticity of CRC 2 to CRC 6 decreases from 1.9 % to 23.95 % when compared to CC.
- CRC 1 has 7.28 % less compressive strength when compared with CC but with increase in duration of curing, the compressive strength increases by 30.38 % at 28 days curing and 33.52 % at 56 days curing.
- CRC 3 has 1.39 % less compressive strength when compared with CC, but is increased by 29.53 % at 28 days curing and 32.37 % at 56 days of curing, than 7 days curing of specimens.
- As a result of increase in replacement levels of CP from 30 % to 50 %, the 28 days compressive strength decreases by 30.15 %, 32.86 % and 44.5 % respectively.
- The weight loss of CRC 1 and CRC 2 are 18.28 gm and 17.59 gm respectively. But the weight loss of CRC 3 is only 1.1 % when compared to CC.
- The % loss in compressive strength is 7.51 % only for CRC 3 whereas the % loss in compressive strength is increased in CRC 1 and CRC 2 by 11.27 % and 10.06 % respectively.
- The weight loss of CRC 1 and CRC 2 are 18.08 gm and 17.39 gm respectively. But the weight loss of CRC 3 is only 0.06 % when compared to CC.
- The % loss in compressive strength is 7.06 % only for CRC 3 whereas the % loss in compressive strength is increased in CRC 1 and CRC 2 by 10.67 % and 9.21 % respectively.
- The permeability is moderate for the specimen CC & CRC 1. But for CRC 2 & CRC 3 the permeability rating is low which concludes that the 10 % & 20 % partial replacement of cement with CP along with 30 % GGBS has less chloride penetration & therefore the strength of CRC 2 & CRC 3 is not affected with the chloride exposure of specimens.

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