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ANALYSIS OF STRENGTH OF CONCRETE BY DETERMINING EFFICIENCY FACTOR OF GROUND GRANULATED BLAST FURNACE SLAG

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ABSTRACT

Concrete is the most broadly utilized construction development material in structural building industry in view of its high structural quality and solidness. The civil industry is always searching for supplementary cementitious material with the target of lessening the strong waste transfer issue. Therefore to overcome these issues there is a need of financially savvy, elective and imaginative materials. It is additionally important to accomplish extensive quality. To overcome from this emergency, the utilization of (SCMs) is gaining advantages because of different preferences, for example, enhanced workability, higher compressive Strength, better durability and so forth when such SCMs are consolidated in concrete, the hydration process is affected by the physical and compound properties of SCMs utilized and are reflected in quality advancement. In this study, comprehensive effort is made to determine efficiency factor of GGBS using regression analysis. It's based on the consideration that efficiency factor depends on GGBS percentage and compressive strength depends on water binder ratio. It is found that efficiency factor goes on decreasing by increasing GGBS percentage in concrete made with GGBS. Characteristics of fresh concrete that is workability is improved by increase in the GGBS percentages in concrete.

Keywords: *Concrete, GGBS, Compressive strength, Efficiency factor, Regression analysis.*

I. INTRODUCTION

Cement is a material when it contacts with water, then he possess cohesive and adhesive properties and capacity to bonding material to compact whole. The interest for cement is very high in creating nations attributable to fast infrastructural development which brings about supply shortage and deliver ecological issues because of emanation of carbon dioxide in the air during manufacturing of cement. The civil industry is always searching for SCMs with the target of lessening the solid waste transfer and disposal issue. TraditionallyusedSCMs are rice husk ash (RHA), silica fume, GGBS, fly ash and ash from timber etc. These wastes can be found as normal materials, by-product or industrial waste; these materials are additionally acquired with requiring minimal effort, vitality and time.Energy saving and cost effective objectives are achieved when we use waste or by-product as partial replacement of cement.Therefore partially replaced cement with industrial waste such as GGBS it contributes to significant reduction in the carbon dioxide during manufacturing of cement. Thus GGBS is ecologically benevolent development material. GGBS concrete has better water impermeability qualities and additionally enhanced protection from erosion and sulfate attack. Thus, the administration life of a structure is improved and the maintenance cost decreased. This experiment was done to determine the efficiency factor of GGBS such that a partial replacement of ordinary Portland cement (OPC) with GGBS could result equal compressive strength as that of OPC concrete at 7 days. Once specimens are made to have same strength, workability properties can be logically compared based on test data.

II. LITREATURE REVIEW

Smith shows that the "cementing efficiency of fly ash relative to cement was such that the mass of a given fly ash was equivalent to the mass of cement. This made the w/c ratio of OPC concrete equal to "effective w/c ratio", of fly ash concrete which resulted in same or similar strength for both concretes [1]. He concludes that, some ashes are better than others but the results suggest that a value of0.25 for Kwould be suitable for use in preliminary design. Babu and rao described "overall efficiency factor" as the sum of "general efficiency factor" and "percentage efficiency factor"[2-4]. At 28 days, it varied from 1.15 to 0.33 for 15% to 75% replacement range. They showed gradual decrease of efficiency factor with increasing fly ash percentage and reported similarity in behaviour of class F and Class C fly ashes. In experimental investigation, it is consider that, compressive strength was mainly depend on w/b ratio and efficiency factor depends on fly ash percentages. They found that efficiency factor decreased with increase in fly ash percentage and use of efficiency factor is effective to predict compressive strength of concrete.

To minimizes the difficulties in conventional decomposition approaches, creator proposed a novel unification approach. In that by using optimization techniques and regression (non-linear) simultaneously compressive strength and efficiency model was generated or in other words efficiency factor is a part of compressive strength model. The efficiency factor model will be useful in the design of fly ash concrete at various age, at various replacement levels, and different water-binder proportion with more level of confidence [5].

Author limited fly ash percentage from 25% and 45% for experimental study. In this research 0% fly ash concrete are made using w/c ratio 0.30 to 0.45 and assuming efficiency factor 1.00. From large experimental investigation the 28 days compressive strength based efficiency factor is 0.54 for 25 % fly ash and 0.35 for 45 % fly ash.Obtained propose k value is applied to many other concrete design for different water/cement ratio range from 0.29 to 0.45 for 25% and 45% fly ash concrete. They evaluate equation for prediction of strength of concrete using regression analysis by considering w/b ratio as an independent factor [7].

Utilizing k value, an endeavor for the plan for the fly ash concrete with various percentage of fly ash replacement is made. She found that the cementitious effectiveness factor of fly ash in concrete is reliable. In this manner the efficiency factor could be useful in the design of fly ash concrete of a particular strength and at any rate of replacement by endeavoring to unite the cementitious material proportion to strength relations for both typical and fly ash concrete [6].

III. ASSUMPTIONS

To explain methodology, following three cases are described for mix designing of GGBS concrete. The condition where GGBS is used to partially replace cement (OPC) following relationship equation is to be used (Eq. 1). The first case shows that a control mix with water and cement contents, denoted by W0 and C0, respectively. The second case represents a mix with same water quantity, but by decreasing cement content from C0 to C1 and introducing GGBS, g1 and efficiency factor K1.. The third case represents any other case with different water w2, cement c2 and GGBS g2. A new efficiency factor, k2 is used with GGBS, g2 in order to obtain same w/B ratio as the other two cases.

$$\frac{W0}{C0+0} = \frac{W1(=W0)}{C1+k1g1} = \frac{W2}{C2+k2g2} \quad (1)$$

It is assumed that all these three cases would give similar compressive strength as they have same w/B ratio. In this research, a combination of only GGBS and OPC is considered. Experiment is limited to early age of concrete that is only for 7 days compressive strength results.

IV. REGRESSION ANALYSIS

Regression analysis is standout amongst the most broadly utilized statistical method for creating connection amongst dependent and independent variables. Generally, regression is the way toward fitting models to information. The behavior of dependent variable is expressed as a function of other variable responsible for that behavior called independent variable. In this study for evaluating efficiency factor, dependent variable is Efficiency factor and independent variable is GGBS [15].

V. MATERIALS PROPERTIES

A. Cementitious material

cementitious material used were ordinary Portland cement of grade 53 conforming to the specification of IS 12269:1987 and siliceous GGBS conforming to the specification of BS 6699:1992. The physical and chemical properties of GGBS are presented in table I Cement had specific gravity of 3.15 while GGBS had 2.77.

Table 1. Physical and chemical properties of GGBS

Sr. No.	Characteristics	Requirement as per BS:6699	Test Results
1	Fineness (m2/kg)	275 (min)	384
2	Initial Setting time (min)	Not less than 30 min	86
3	Final Setting time (min)	Not more than 600 min	305
4	Insoluble residue (%)	1.50 (max)	0.26
5	Magnesia content (%)	14.0 (max)	8.2
6	Sulphidesulphur (%)	2.00 (max)	0.48
7	Sulfate content (%)	2.50 (max)	0.2
8	Loss on ignition (%)	3.00 (max)	0.35
9	Manganese Content (%)	2.00 (max)	0.28
10	Chloride content (%)	0.10 (max)	0.001
11	Moisture content (%)	1.00 (max)	0.01
12	Glass content (%)	67 (min)	98.2
13	Cao + Mgo + Sio2	66.66 (min)	78.92
14	Cao + Mgo/Sio2	>1.00	1.29
15	Cao/Sio2	<1.40	1.05
16	Standard Consistency	-	32.50

Table 2. Physical and chemical properties of cement

Sr. No.	Characteristics	Requirement as per BS:6699	Test Results
1	Fineness (m2/kg)	275 (min)	349
2	Initial Setting time (min)	Not less than 30 min	38
3	Final Setting time (min)	Not more than 600 min	280
4	Insoluble residue (%)	3.00 (max)	0.80
5	Magnesia content (%)	6.00 (max)	0.8
6	% Soluble Silica	-	21.40
7	% Alumina	-	5.10
8	Loss on ignition (%)	4.00 (max)	1.6
9	% Iron Oxide	-	3.60
10	% lime	-	63.80
11	% Sulphur calculated as SO3	Not more than 2.5	2.3
12	Standard Consistency	-	27.50

B. *Aggregates*

Local crush sand having a specific gravity 2.61 was used as fine aggregate and its under grading zone I as per IS 383 also crush granite used as coarse aggregate having specific gravity 2.90. Fine aggregate and coarse aggregates are confirmed to the IS 383:1970

Table 3. Physical properties of Aggregates

IS Sieve (mm)	Crush Sand		20 mm		10 mm	
	Cumulative % Passing	Limits, Zone I IS 383-1970	Cumulative % Passing	Limits IS 383-1970	Cumulative % Passing	Limits IS 383-1970
20			89.9	85-100		
16			37.2			
12.5			8		100	100
10	100	100	0.5	0-20	85.65	85-100
4.75	100	100	0	0-5	1.5	0-20
2.36	63	65-95	0		0	0-5
1.18	30	30-70				
0.600	21	15-34				
0.300	15	5-20				
0.150	11	0-20				
Pan	0					
Specific Gravity	2.61		2.90		2.90	
Water Absorption	3.00%		1.01%		1.21%	

C. Water

Water used in this experiment was potable. The test results confirmed to the requirement of IS 456:2000

D. Admixture

Admixture used in this experiment is of polycarboxylate ether (PCE) based superplasticiser and their PH value exceeding 6. Specific gravity of admixture is 1.15. Admixture was store in cool and dry place in concrete laboratory which is not exposed to direct sunlight. It confirmed to the specifications of IS 9103:1999.

VI. EXPERIMENTAL PROCEDURE

To carry out casting of concrete of required grade firstly water correction for both coarse aggregate and fine aggregate was done. Cement and GGBS were then added along with appropriately 70% of the design water. Normally after 30 seconds to one minutes of mixing, admixture was added to the remaining water and use in the mix. Table vibrator which is available in concrete lab was used to vibrate the moulds for full compaction. Tilting drum type mixer was used for mixing concrete ingredients and preparation of concrete. Cubical specimens of 150 mm side were used for compressive strength test. Compressive strength Test was done at 7 day for all set of experiment. The specimens in the moulds were removed after 24 hours and then cured in open water tank at ambient condition until the testing day.

VII. EXPERIMENTAL RESULTS AND DISCUSSION

In thisexperiment, early age efficiency factor (k-value) of GGBS was calculated. For this, the w/b ratios used were 0.48 and 0.3556 while GGBS percentage (G) were 0%, 30%, 40, and 50% of the total cementitious material. In this, k-values of 0.30, 0.70 and 1.00 were assumed each for all three cases; 30%, 40% and 50% GGBS. The aggregate were proportioned to get the best possible mix having pumping characteristics and reasonable admixture dosage. Table 4 shows the details of mix design and figure 1 is graphical representation of estimate efficiency factor.

Table 4.Mix Proportion and Test Results

Mix No.	GGBS Percentage (G)	K-Value Assumed	w/b	Weight (Kg/m3)						Compressive strength (MPA)
				Water	Cement	GGBS	Aggregate			
							20mm	10mm	sand	7 days
1	0%	1	0.48	172.8	360	0	792	427	763	27.12
2	30%	0.3			319	137	751	404	723	29.77
3		0.7			277	119	776	417	746	24.59
4		1			252	108	788	425	759	20.29
5	40%	0.3			300	200	734	396	704	31.4
6		0.7			245	163	767	414	737	25.63
7		1			216	144	787	424	754	19.4
8	50%	0.3			277	277	711	383	682	37.62
9		0.7			212	212	760	409	732	22.81
10		1			180	180	785	422	755	17.48
11	0%	1	0.3556	160	450	0	837	451	652	35.4
12	30%	0.3			399	171	779	420	607	39.11
13		0.7			346.5	148.5	810	436	631	32.74
14		1			315	135	829	446	646	31.7
15	40%	0.3			375	250	756	407	581	41.18
16		0.7			307.2	204.8	801	432	624	34.37
17		1			270	180	827	445	644	2948
18	50%	0.3			346.5	346.5	723	389	563	41.92
19		0.7			265	265	795	435	620	33.33
20		1			225	225	826	445	643	32.14

Table 5.Early Age Efficiency Factor of GGBS

Set No.	w/b	GGBS Percentage (G)	Calculated K-Value
			7 days
1	0.48	30%	0.51
2		40%	0.6
3		50%	0.58
4	0.3556	30%	0.53
5		40%	0.63
6		50%	0.6

The compressive strength of concrete was plotted against the assumed k-values. The graph of OPC concrete was represented by a straight line while those of GGBS concrete were represented by curved line. The k-value at which GGBS concrete line bisect the OPC concrete line was consider as the correct value for efficiency factor. The estimated k-values for two W/b ratios for three different GGBS percentage are presented as k-value calculated in table 5.

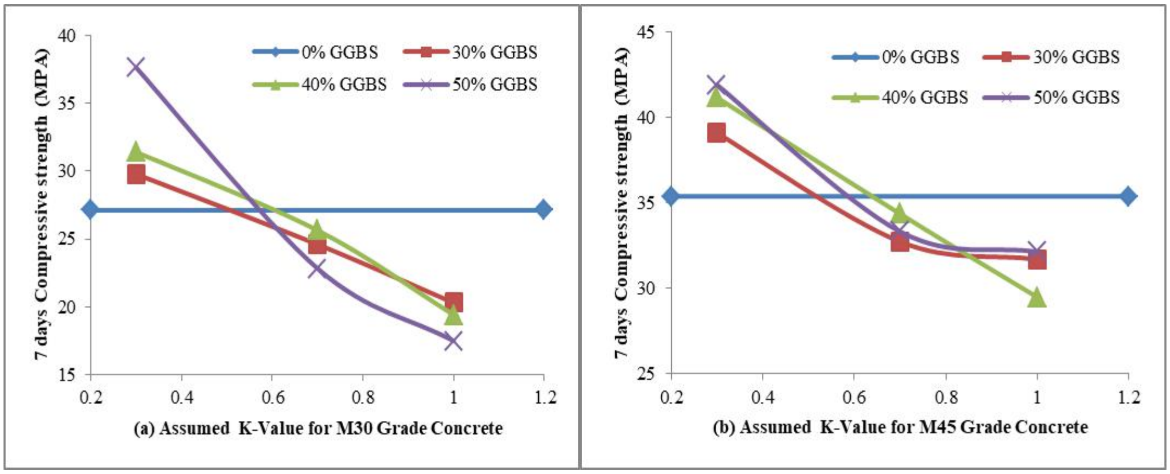

Figure 1.Estimation of efficiency factor of GGBS

The graphical representation of compressive strength of concrete to assumed efficiency factor shows that, increase in the efficiency factor result in decreasing the 7 days compressive strength of concrete. Increase in the GGBS percentage and efficiency factor, compressive strength achieved at 7 days GGBS concrete is less as compared to OPC concrete.For GGBS concrete, 7 days compressive strength of OPC concrete is lies in between concrete made using efficiency factor 0.30 and 0.70.From table 5 one can see that K-Values for 20%, 30% and50% GGBS were similar for both M30 and M45 grade concrete and were also similar for 7days.Therefore K-Values for different GGBS percentage were proposed as shown in table 6. Figure 2 is the graphical representation of the proposed efficiency factor varying with GGBS percentage. Accordingly, polynomial equation was obtained (Eq. 2)

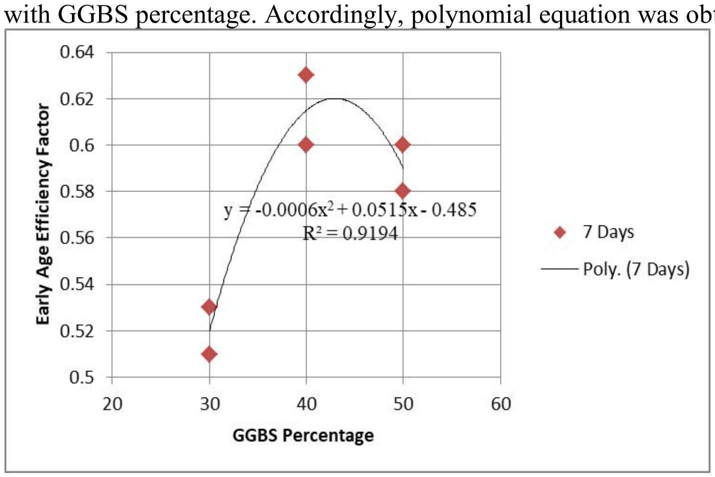

Figure 1.Regression for proposed efficiency factor

$$Y = -0.0006x^2 + 0.0515x - 0.485 \quad (2)$$

Table 6. Proposed Early Age Efficiency Factor of GGBS

Serial number	GGBS Percentage (G)	Corrected K-Value
		7 days
1	30%	0.52
2	40%	0.61
3	50%	0.59

Efficiency factors for GGBS percentage below 30% and above 50% were not studied. The coefficient in these expressions for efficiency factor would not be the same with change in finesse and other influencing properties of GGBS.

VIII. CONCLUSION

In this experimental investigation, determination of efficiency factor of GGBS had been described. Based on this study Efficiency factor decreased with increasing GGBS percentage in concrete.Cementitious material increased with decreasing the efficiency factor to achieve the same compressive strength of OPC concrete. Strength difference between OPC concrete and fly ash concrete at early age was minimum.Workability characteristics of concrete improve with increase in the efficiency factor of GGBS and GGBS percentage in concrete.Rate of gain of compressive strength in early age is less in GGBS concrete as compared to OPC concrete.

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