EFFECT OF M-SAND AND GGBS ON STRENGTH AND COMPACTION CHARACTERISTICS OF ROLLER COMPACTED CONCRETE PAVEMENT (RCCP)

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Abstract

Roller Compacted Concrete (RCC) is a new construction methodology than a construction material used for paving applications across the world. Manufactured Sand (M-Sand) is produced from stone crusher units contains considerable amounts of finer material of size less than 0.075mm and more angular than river sand. M-Sand can be used as alternate material for River sand. In the present paper an investigation was done on the effect of M-Sand on the strength and compaction characteristics of RCC using GGBS as mineral admixture. The Mix design is done with soil compaction Principles and based on ACI 211.3R guidelines. Ordinary Portland cement was partially replaced with GGBS at 10%, 20%, 30%, 40%, 50%, and 60 % by weight. Compaction characteristics are analyzed using OMC and MDD curve. Variation of Optimum Moisture Content with increase in GGBS content is studied. The relationship between density and percent replacement of cement with GGBS is established. With increased levels of GGBS content caused the increase in Flexural, Compressive and split tensile Strength values at 28 days and 90 days of curing.

Keywords: *Roller Compacted Concrete Pavement; Optimum Moisture Content; Maximum Dry Density; GGBS; M - Sand; Flexural Strength.*

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1. INTRODUCTION

Roller compacted concrete pavement material is very stiff mixture and requires vibratory roller compaction and normal methods of compaction are not suitable to apply. There is an urgent need to use alternate materials to conserve ever depleting natural reserves in the construction of various structures. This will reduce the cost of construction, effective utilization of waste materials and maintains ecological balance. M-Sands are produced by crushing various rocks into a fine aggregate of more angularity with rough textured surface. In the production of M-Sand the finer particles of size less than 0.075mm has been in the range of 5% to 20%. The practice of using of M-sand in the production of cement concrete is to wash out to eliminate finer particles[7]. Use of Mineral admixture in RCC production has been increased in the recent past. Atis[1] has investigated the effect of high volume fly ash on the strength and uses in pavement applications. Ganesh Babu K[2] proposed that with increase in fly ash content in RCC at high workability and with low cement content decreases the water cement ratio. Cheng, Cao et al [3], studied the effect of high volume fly ash an strength properties of RCC. Cement is replaced at 45%, 55%, 65%, 75%, 85% and 95% with fly ash and reported the increase in water contents from 106 kg to 133 kg per one m^3 of concrete. Also the density of concrete is varying from 2526 kg/m^3 to 2581 kg/m^3 with varying properties of fly ash from 45% to 95%. Luc Couraad et al [4] studied the effect of concrete road recycled aggregates for RCC production. They observed that RCC with natural and concrete road recycled aggregates are similar for solid compactness. The density of concrete used was varying between 2124-2229 kg/m^3 using recycled aggregates corresponding OMC are 5.54% to 7.85%.

Rafat Sidique[5] Examined the effect of class F fly ash as fine aggregate replacement on the mechanical properties of concrete. He reported that with fine aggregate replacement by fly ash at 10%, 20%, 30%, 40% and 50% levels strengths are increased at all levels. Also the densities of mixture with fly ash varied from 2215 kg/m^3 to 2312 kg/m^3. Corresponding water content is varying from 185 kg/m^3 to 195 kg/m^3. M.Madhkhan et al[6] investigated the effect of pozzolans with steel and polypropylene fibres on mechanical properties of RCC pavements. For various mixtures used in the investigation the OMC varies from 5.05% to 6.03% and MDD varies between 2360 kg/m^3 to 2505 kg/m^3. The compressive strength decreased with addition of pozzolans at 28 days age. Also rupture modulus decreased.

Ganesh Babu K et al [8] studied the efficiency of GGBS in concrete. They replaced the cement with GGBS at 10% to 80% levels and found the possibility that the GGBS concrete can be designed for design strength at any given percentage of replacement. Karimpour.A [9] studied the effect of time span between mixing and compacting on roller compacted concrete with GGBS as mineral admixture. He found that delay in concrete compacting does not affect the properties with GGBFS and improved the compressive strength, permeability, absorption and adsorption. A.Oner et al [10] studied the optimum usage of GGBS in concrete and found that the compressive strength is increased with increase in GGBS content up to an optimum level of 55% and beyond this level the contribution of GGBS on strength is negligible.

From the detailed review of Literature it was concluded that an extensive research work was done on RCC with Fly ash as Mineral admixture. Little research was done on the compaction characteristics of RCC with GGBS as mineral admixture, and hence this experimental work is mainly focusing on strength and compaction behavior of GGBS roller compacted concrete with M-sand as fine aggregate by replacing the river sand fully (100%). Considering the Roller Compacting Concrete Materials as a particulate interacting material, standard soil mechanics methods can be employed to evaluate the properties of Roller Compacted Concrete Pavement (RCCP) with different volumes of GGBS. This is discussed in the present investigation.

1.1 Objectives of the experimental work

1. To Proportionate the RCC material for a specified flexural strength(5 MPa) with M-sand as fine aggregate
2. To study the effect of GGBS and M-sand on the Compaction Characteristics of RCC
3. To study the effect of GGBS and M-sand on strength properties of RCC.

2. EXPERIMENTAL INVESTIGATIONS

2.1 Materials

2.1.1 Cement

Ordinary Portland Cement OPC 53 Grade was used in the present experimental investigation. Physical Properties of cement were presented in Table 1. Cement was tested as IS 4031[12]

Table 1: Physical properties of cement

S. No.	Test Property	Result	Requirement as per IS: 12269-2013[11]
1	Fineness (a) Sieve test (b) Blaine	 2% 285m^2/kg	 a) < 10% b) > 225 m^2/kg
2	Normal Consistency	30.0%	-
3	Specific Gravity	3.15	-
4	Initial setting time	105minutes	> 30 Min
5	Final setting time	285minutes	< 600 Min
6	Compressive strength (a) 3days (b) 7days (c) 28days	29N/mm^2 40 N/mm^2 58N/mm^2	> 27 N/mm^2 > 37 N/mm^2 > 53 N/mm^2

2.1.2 Fine Aggregate:

Manufactured sand(M-sand) was used as fine aggregate and was tested as per IS 383[13]. It was collected from V.N.S Ready Mix plant, Vijayawada, India. The specific gravity of M-sand was 2.713. Its particle size distribution was shown in Fig 1.

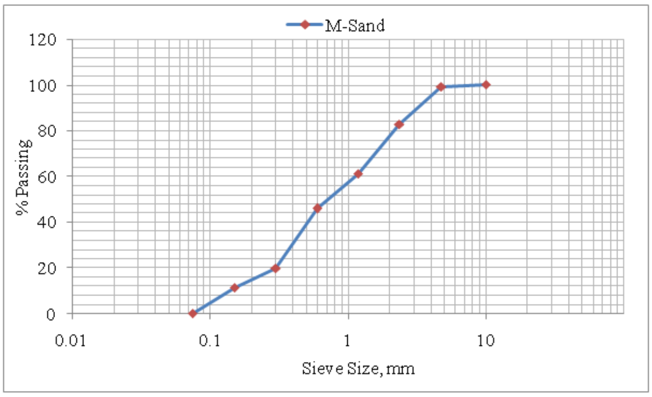

Figure.1 Particle Size Distribution Curve for M-sand

2.1.3 Coarse Aggregate

Crushed angular stone aggregate with NMSA of 19mm and downgraded was used. Coarse aggregates passing 20mm 10mm and 6mm sized were combined (40:40:20). The combined grading is given in Table.2 [14]. Particle size distribution curve is shown in Figure. 2

Table 2. Sieve Analysis of All in Aggregate

Sieve Size	% Passing			
	M-sand (40%)	Combined coarse Aggregate (60%)	Combined Grading	As Per ACI 211-3R
25mm	100	100	100	100
19mm	100	100	100	82-100
12.5mm	100	88.8	93.28	72-93
9.5mm	100	65.94	79.56	66-85
4.75mm	99.30	33.78	59.98	51-69
2.36mm	82.70	14.76	41.93	38-56
1.18mm	61.15	7.02	28.67	28-46
0.600mm	45.90	4.86	21.27	18-36
0.300mm	19.85	2.62	9.51	11-27
0.150mm	11.40	0.98	5.14	6-18
0.075mm	2.60	0.12	1.11	2-18

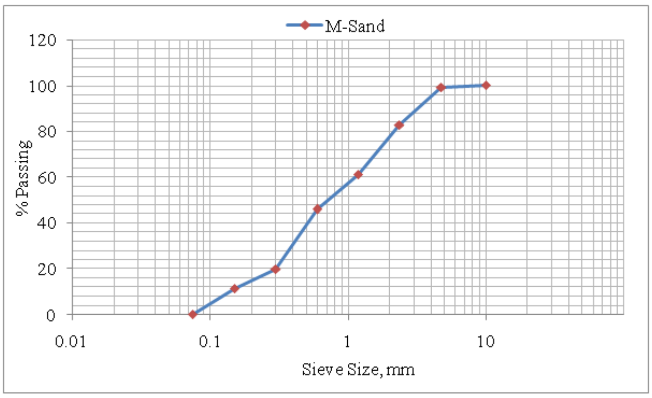

Fig.2. Particle Size Distribution curve of All in Aggregate

2.1.4 Water:

The water used in RCC mix design was potable and drinking water.

2.1.5 Ground Granulated Blast furnace Slag (GGBS):

The GGBS used in this research project was collected from the TOSHALI CEMENTS PVT LTD located at Visakhapatnam District, Andhra Pradesh, India. The GGBS was ground in a laboratory mill to a Blaine fineness of 4222 cm2/g. The Physical properties of GGBS are given in Table 3.

Table 3: Physical Properties of GGBS and Cement

Property	**GGBS**	**Cement**
Specific gravity	2.82	3.15
Specific Surface (cm^2/g)	4222	2850
Color (Figure.3)	Whitish	Gray

Figure 3. GGBS & Cement

3. METHODOLOGY:

The Experimental work has been carried out in the following stages

Stage 1: Evaluation of Optimum Moisture Content of the RCC mixtures with M-sand as fine aggregate was considered. The OMC of Control mix Concrete and Mixtures containing GGBS as replacement of Cement were determined.

Stage 2: Evaluation of flexural, compressive and split tensile strength values at the ages of 3 days, 7 days, 28 days and 90 days was done in this stage.

3.1 Determination of Optimum Moisture Content

Mix design of RCC was done using ACI 211.3R-02-2004[14] specifications. The method was developed for RCC pavements of roads and is limited to mix design with maximum NMSA of 19mm as per ACI 325.10R-95 [15]. The details of mixes are given in Table 6. The mix was proportioned for specified target flexural strength of 5.0 M Pa [16, 17, 18, 19]. The Cement Content of control mix was 295 kg/ m3. Cement was replaced at 10%, 20%, 30%, 40%, 50%, and 60 % by weight with GGBS. Using seven different water binder ratios seven mixture were prepared. 28 RCC mixtures were prepared using standard cylindrical specimens. For casting cylindrical specimens, split moulds of 15.0cm diameter and 12.7cm length, were used. This satisfies the IS: 2720 (Part 8) – 1983[20] standards for Modified compaction test. Casting was done before setting occurred. The whole mass of mix was compacted in 5 layers (Fig.4). After compaction of each layer, the top surface was scratched with a knife have good bonding with the next layer. A modified Proctor's rammer was used for this purpose in order to simulate field conditions. The type and other details of the rammer used are as mentioned in Table 4.

Table 4: Details of Rammer

S. No	**Details of Rammer**	
1	Rammer used	Modified Proctor type
2	Weight	4.90 kg
3	Height of drop	450 mm

To find the OMC of each mixture, representative samples were taken from the compacted specimens and kept in oven at 105 OC. The water content, wet density and dry density of each proposed mix were calculated using the following equations.

$$w = \frac{(w_w - w_d)100}{w_d},$$

w is water content in %; w_w = Weight of wet concrete(g) ;

w_d = Dry weight (g)

$$\gamma_{wet} = \frac{\text{Weight of Wet concrete in kg}}{\text{Volume of Concrete } m^3}$$

$$\gamma_{dry} = \frac{\gamma_{wet}}{(1+w)}$$

Figure.4 Compaction of RCC using modified Proctor's Rammer

The relationship between dry density and corresponding water contents were plotted for each mixture. From the moisture- density curve the optimum moisture content corresponding to the maximum dry density was determined and it is shown in Figures 5-13. And the results of the compaction test were given in Table 5.
The mixture proportions of the RCCP are given in Table 5.

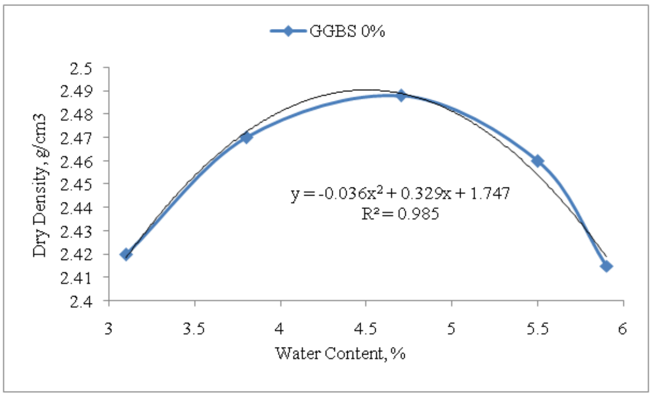

Figure.5 Relation between OMC and MDD of Control Mix

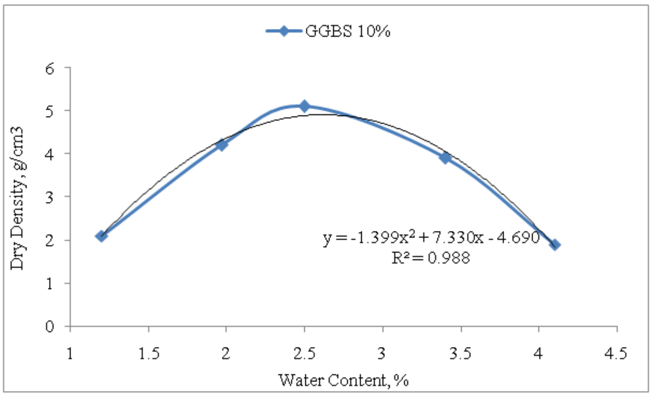

Figure.6 Relation between OMC and MDD for 10% GGBS

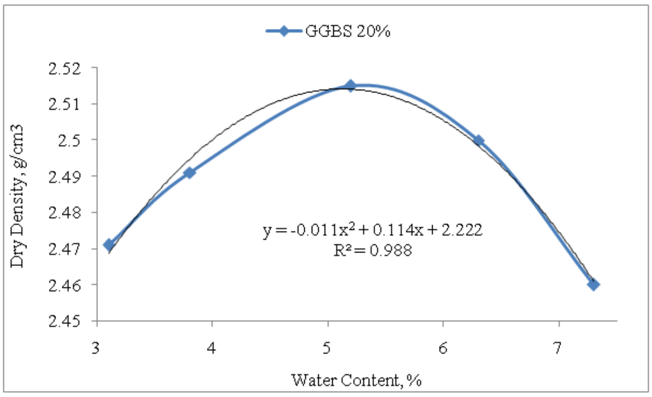

Figure.7 Relation between OMC and MDD for 20% GGBS

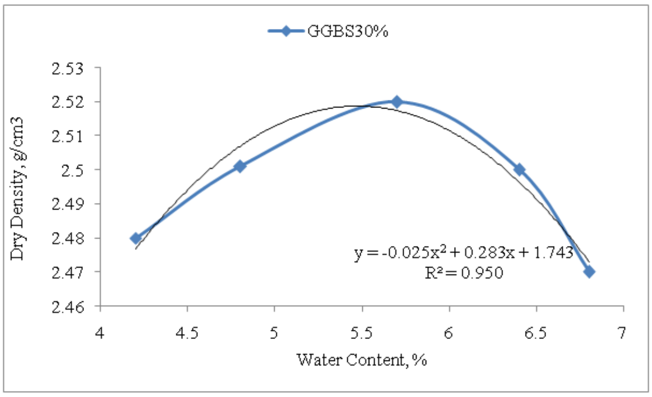

Figure.8 Relation between OMC and MDD for 30% GGBS

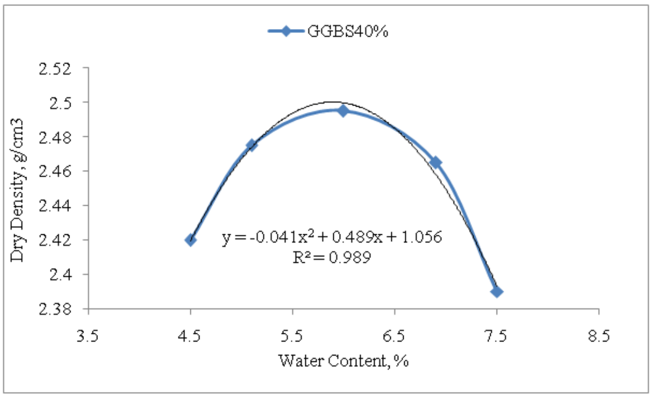

Figure.9 Relation between OMC and MDD for 40% GGBS

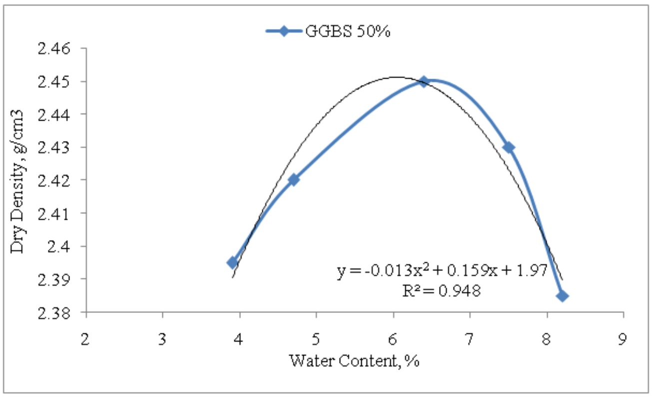

Figure.10 Relation between OMC and MDD for 50% GGBS

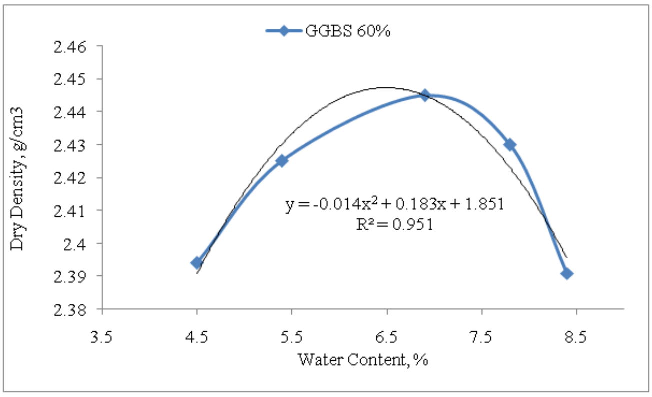

Figure.11 Relation between OMC and MDD for60% GGBS

Table 6: OMC, MDD and w/b ratio of the Mixtures

Mixture	Optimum Moisture Content, %	Maximum Dry Density, kg/m^3	Water, kg/m^3	Water Binder Ratio
R0	4.7	2.480	114	0.39
R10	5.1	2.495	117	0.39
R20	5.2	2.515	119	0.40
R30	5.7	2.520	126	0.43
R40	6.0	2.495	130	0.44
R50	6.4	2.450	147	0.51
R60	6.9	2.445	155	0.54

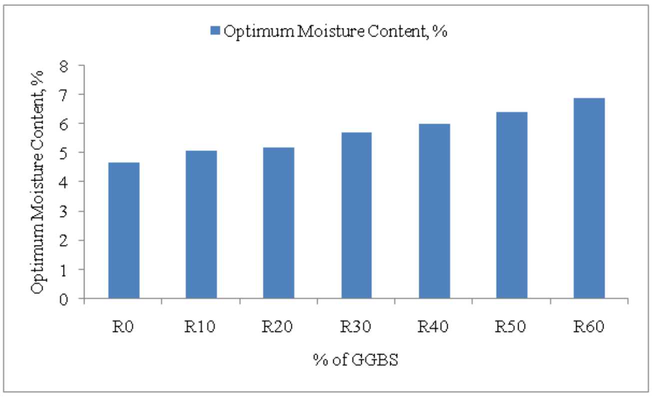

Figure.12 Relation between OMC and % of GGBS

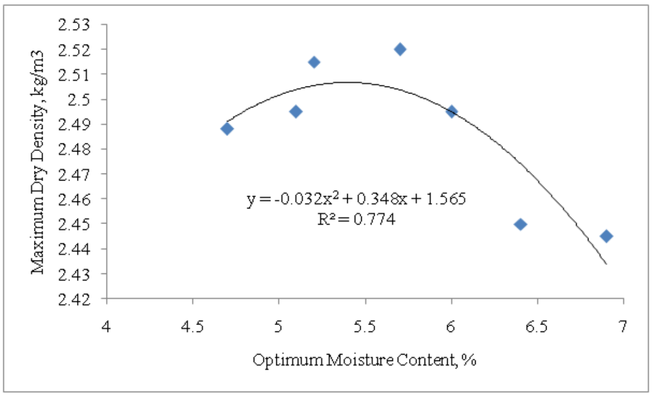

Figure.13 Relation between OMC and MDD

Table 6: Mix Proportions of RCCP Mixtures

Mixture	Cement (Kg/m^3)	GGBS (Kg/m^3)	Fine Aggregate, Kg/m^3	Coarse Aggregate, Kg/ m^3	Water, kg/m3	Water Binder Ratio
R0	295	0	801	1209	114	0.32
R10	265	30	822	1233	117	0.35
R20	235	60	820	1230	119	0.37
R30	205	90	813	1220	126	0.40
R40	175	120	810	1215	130	0.41
R50	145	150	794	1190	147	0.42
R60	115	180	786	1178	155	0.45

3.2 Test Procedure

The Compressive Strength of 150 x 150 x 150 mm cube Specimens, Split Tensile Strength of 150 x 300 mm Cylinders and Center point loading of 100 x 100 x 500 mm Prism specimens(Figure 14) were obtained at 7, 28 and 90 ages in accordance with IS : 516-1959 Specifications [21]

Figure.14 Failure of specimen at the end of the Compression, Split, Flexure tests

4. TEST RESULTS AND DISCUSSION

The mechanical properties of the RCCP mixtures were presented in Table 7. It is observed that the minimum strength results at all ages are obtained at 60 % GGBS level. This reduction in strength levels is higher at 7 day age specimens. This is due to the fact that the contribution of GGBS to the strength of concrete is lower than that of cement at 28 days.

The relationship between GGBS content and strength of the mixtures are plotted in Figures 15 to 17. As it can be observed from the figures, increasing the GGBS content caused increase in strength up to 10% replacement level.

Table 7: Compressive, Splitting Tensile and Flexural Strength Results (MPa)

Mix	Compressive Strength(MPa)				Split Tensile Strength(MPa)				Flexural Strength (MPa)			
	3-d	7-d	28-d	90-d	3-d	7-d	28-d	90-d	3-d	7-d	28-d	90-d
R0	18.67	22.22	33.74	45.2	2.55	3.12	5.11	7.01	3.8	4.4	6.8	8.6
R10	17.5	29.9	45.22	52.11	1.97	3.41	5.27	7.23	3.12	4.88	7.58	8.89
R20	15.1	30.11	45.98	53.55	1.81	3.57	5.45	7.45	2.86	5.05	7.66	9.12
R30	14.8	32.02	46.21	56.90	1.64	3.88	5.75	8.78	2.78	5.23	7.97	9.34
R40	14.1	34.50	47.10	59.56	1.44	3.94	5.86	8.90	2.45	5.38	8.25	9.56
R50	13.8	34.02	46.31	57.41	1.27	3.78	5.62	8.58	2.11	5.24	7.98	9.44
R60	11.40	33.41	45.12	55.71	1.12	3.66	5.44	8.41	1.97	5.02	7.64	9.35

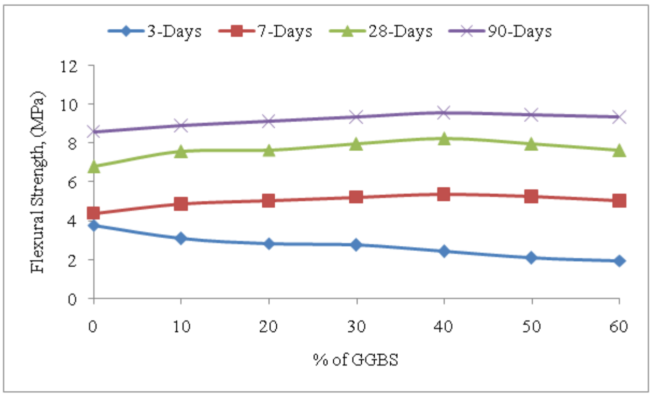

Figure.15 Variation of flexural strength with % GGBS

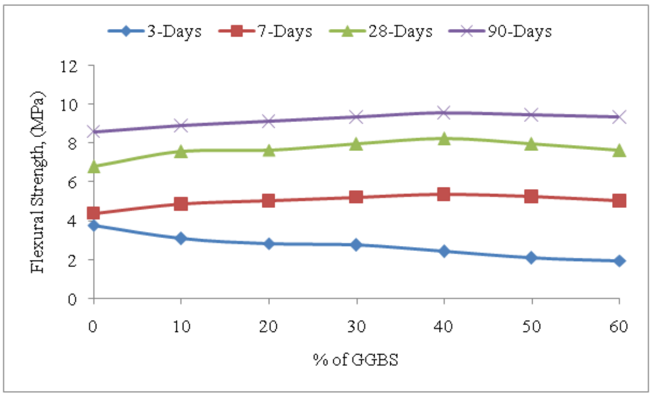

Figure.16 Variation of Compressive strength with % GGBS

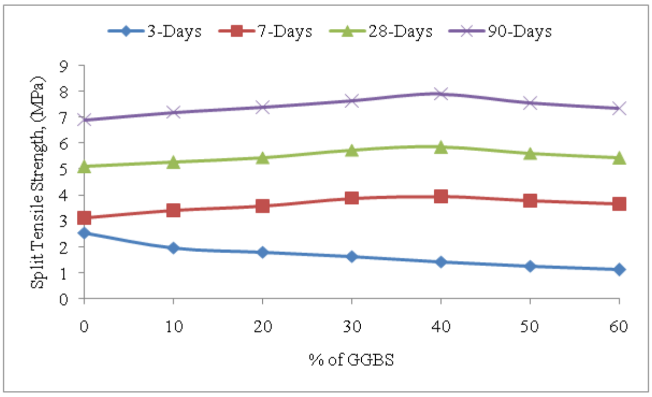

Figure.17 Variation of Split tensile strength with % GGBS

5. CONCLUSIONS

From the experimental work, following conclusions were drawn:

1. The Optimum moisture content of the GGBS mixtures is increased with increase in GGBS content when compared to those of control mixtures
2. The maximum dry density is increased with increase in GGBS content up to 30% replacement level.
3. When cement was partially replaced with GGBS, strength values were increased with increase in GGBS content at 28 days and 90 days of curing. At early ages of 3 days, 7 days these strength values are lower than control mix due to the slow pozzolanic reaction of GGBS at younger age of concrete.

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