Investigation of Abrasion Test and Mechanical properties of Concrete using GGBFS as a Partial Replacement of Cement

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Abstract - *Concrete is a crucial component of many different forms of construction, including multi-story high rise buildings to the flooring of huts. One of the most versatile heterogeneous materials is concrete. Civil engineering has reached the pinnacle of technology with the introduction of concrete. When strength, durability, impermeability, fire resistance, and abrasion resistance are needed, it is the material of choice. Reinforced concrete is susceptible to degradation in a number of locations where rigorous applications reduce durability. As a result, researchers from all around the world are working to create a new material to solve this issue. The global development of major building facilities and machinery boosted the consumption of materials. Due of this situation, additional materials are being used to enhance the quality. One such material that is incorporated as a partial replacement of cement is Ground Granulated Blast Furnace Slag .Inclusion of GGBFS as a partial replacement of cement solves many challenges coming in the construction industry .firstly it improves the strength parameters of concrete, also it also reduces the consumption of cement at the same time, subsequently reducing the emission of carbon dioxide in the preparation of cement thus minimizing environmental problems related to cement industry. The present experimental work is performed on M35 Grade concrete. Firstly, concrete mixes is prepared by using Ordinary Portland cement(OPC 53) as a referral concrete mix and then blended concrete mixes is prepared by partial replacement of cement using GGBFS in range of 10%, 20%, 30%, 40% by the weight of cement. The optimum percentage of using GGBFS with cement in the concrete mixes is determined. The blended concrete mix is investigated for Abrasion resistance , workability of freshly prepared concrete mixes, compressive strength, split tensile strength and flexural strength.*

Key Words: *workability, Abrasion, GGBFS, Compressive strength, Split tensile strength, flexural strength, Durability, workability, Ordinary Portland cement.*

1.INTRODUCTION

The mix design of concrete plays a significant role in the preparation of concrete and provides a standard design for enhanced performance and better durability of concrete. Currently the development of concrete is dependent on the application of industrial wastages such as GGBFS that is used as a pozzolanic admixture improving the concrete strength, responsible for improved workability, low heat of hydration and adaptability in wider areas of construction. At the same time, its application also provides a sustainable method of concrete preparation as its reduces the consumption of cement thereby reducing Greenhouse gases emission, thus minimizing environmental issues.. Rao et al.[1] reported that on increasing the GGBFS content, the surface abrasion was increased by upto 50% for 28 and 90 days. Ashwini t bhosale [2] reported that on replacement of cement with 40% of GGBFS, the 7 days compressive strength is increased by 6.09% as compared to referral concrete. Awasare and nagendra[3] reported that the optimum percentage of replacing cement with GGBFS is 30% at which there is maximum increment in compressive and flexural strength in concrete as compared to referral concrete mixes.. Gahlot ,Sankla et al.[4] reported that the compressive strength considerably increased till 20% replacement of cement by GGBFS in M30 and M35 grade of concrete. Kamaldeep et al.[5] reported that on the replacement of cement by 45% GGBFS, the 7 and 28 days strength of concrete was highest among other replacement level.M rajaram et al.[6] investigated that on replacement of GGBFS at 35% replacement level, the flexural strength increased by 54% with respect to nominal concrete strength. V.santa rao et al.[7] reported that on replacement of cement at 40% replacement level with 20%GGBFS and 20% Fly ash increased the compressive, split and flexural strength by 4%,17%and 22% respectively .Karri,rama rao, et al.[8] reported that the strength parameters shows maximum values at 40% replacement of cement by GGBFS in M20 and M40grade concrete. Ozbay et al.[9] studied that on 40% substitution of cement with GGBFS, there is 20% increment in abrasion resistance of concrete. Sharma et al.[10] reported that on replacement of 25% and 20% cement by GGBFS, compressive strength is increased by 14.4% and flexural strength is increased by 40.26% with respect to conventional concrete mixes.This experimental investigation is performed to study the effect of including GGBFS (as a partial replacement of cement) in fresh and mechanical properties of concrete, mainly for abrasion resistance. Referral concrete mixes prepared from OPC and blended concrete mixes are prepared from using GGBFS partially replacing cement. The concrete mixes are casted and tested at 7 and 28 days for Compressive strength, Split tensile strength, flexural strength at 28 days. Workability of freshly prepared concrete mixes is also determined. The optimum percentage of using GGBFS with cement is determined and then at optimum percentage of GGBFS, 70.6 mm cubes are casted for both referral and blended concrete mixes for determining the abrasion resistance of concrete mixes.

2. EXPERIMENTAL STUDY

Conventional Concrete mixes (Referral concrete mixes) is prepared by using Ordinary Portland Cement (OPC) of grade 53 as a binding material, coarse aggregate, fine aggregate, water, super plasticizer. GGBFS is used as a partial replacement of cement in the preparation of blended concrete mixes.

2.1 Raw Materials and their Properties

I. Cement:

OPC of brand BIRLA UTTAM of Grade 53 is used for this study. The cement test results are: normal consistency = 28 %; initial setting time = 115 minutes; final setting time = 235 minutes; specific gravity = 3.10; CS = 45.25 MPa (28 days). These test values are in accordance with the provisions of IS: 12269-1987 [11]. The chemical compositions of OPC is shown in Table 1 as provided by suppliers.

II. Fine Aggregate:

Natural Fine aggregate of rounded shape is used and the surface texture of fine aggregates used is smooth. (conforms to

zone II, IS: 383-1970 [12]) It's bulk density is 1680 kg/m^3 and specific gravity is 2.65 The Fineness Modulus of Fine aggregate was 2.45.The water absorption of fine aggregate is 1.1%.

III. Coarse aggregate:

The Coarse aggregates of size 10 mm and 20 mm having Specific gravities = 2.67 and 2.75 respectively; water absorptions= 0.21% and 0.30% respectively were used and satisfied IS 383-1970 [12]. The surface texture of coarse aggregates is rough.The bulk density of 10 mm and 20 mm size aggregate were 1600 kg/m^3 and 1640 kg/m^3 & its fineness modulus values for the coarse aggregates of size 10 mm and 20 mm was 6.25 and 7.07 individually.

IV. Ground granulated blast furnace slag (GGBFS)

GGBFS, a pozzolanic admixture of off white color having specific gravity 2.82. Moisture content is 0.23%. it is procured from jindal steel & power limited, hisar,harayana.

V. Superplasticizer

A Superplasticizer, Sika-ViscoCrete having density approximately 1.08kg/l. was used

3. METHODOLOGY

In this study, M35 grade concrete mixes are prepared using OPC 53 Grade using IS 10262-2019 [13] with required proportions: Total cement binder content = 362 Kg/m^3, Fine Aggregate = 696 Kg/m^3, Coarse Aggregate =1261 Kg/m^3, super plasticizer = 1.16 litre/m^3 and w/c = 0.42. The experimental work was carried on referral concrete of M35 grade mix concrete. Initially Concrete mixes of grade M35 were made using OPC 53 alone as Control cube and then replacing cement by weight 10%, 20%, 30% and 40% with GGBFS . The mechanical parameters of concrete mixes examined are Workability of freshly prepared concrete, Compressive Strength at 7 and 28 days, Split Tensile Strength at 28 days, Flexural Strength at 28 days and Abrasion Resistance at 28 days .Cubes of 150 mm were casted to determine Compressive Strength at the age of 7 and 28 days. In the same manner cylinders of diameter 100 mm and height 200 mm. is casted to determine the Split Tensile Strength. Beams of 700mm×150mm×150mm are casted to determine Flexural Strength. The specimen was tested after curing them in-tap water for 7 and 28 days. The Compressive Strength of concrete cubes was determined using compression testing machine (capacity 2000 KN) as per the provisions contained in IS: 516-1959 [14]. To determine the Flexural Strength , Three point load method

of testing was done after 28 days curing as per theprovisions contained in IS: 516-1959 [14]. Split Tensile Strength was determined as per the provisions of IS: 5816-1999 [15] Final mix proportions for M35 grade concrete are shown in Table 2. The optimum percentage of using GGBFS (optimization) used as a partial replacement of cement is to be determined. After the optimization of GGBFS with Cement, the Abrasion resistance of blended Concrete mixes at that optimum percentage is determined using tile abrasion machine as per the provision of IS 1706-1972.[16]

Table -1: Chemical Properties of OPC & GGBFS

Chemical Composition	OPC (%)	GGBFS (%)
Silicon Dioxide	20.1	36.4
Calcium Oxide	62.0	34.12
Aluminum Oxide	5.3	10.39
Iron Oxide	4.3	0.69
Magnesium Oxide	2.7	10.26
Potassium Oxide	0.9	0.97
Sodium Oxide	0.2	0.35
Loss of ignition	3.12	1.64

Table 2. Mix Proportion of M35 Concrete

Design mix	Quantity per M^3
W/C ratio	0.42
OPC	362 kg/m^3
Workability	100 mm
Coarse Aggregate	1261 kg/m^3
Fine Aggregate	696 kg/m^3
Water	152 Litres
Superplasticizer	1.16 Litre/m^3

4. RESULT AND DISCUSSION

4.1 Fresh Properties of Concrete

Workability of GGBFS blended Concrete

The effect of including GGBFS on workability of concrete is given in Fig 4.1 in which slump height Is increased upto 40% replacement level . This is due to the addition of finer GGBFS particles which causes the water demand decreased and improving cohesiveness of concrete mixes.

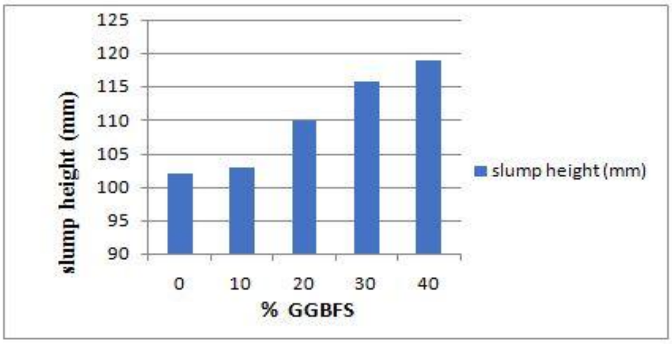

Fig. 4.1 Slump Vs % of GGBFS in concrete

4.2 Hardened Mechanical Properties of GGBFS blended Concrete

Optimization of GGBFS in Concrete

Compressive strength of GGBFS blended concrete at 7 and 28 days is listed in table 3, Compressive strength , Split Tensile Strength and Flexural Strength at 28 days are given in Table-4 . The substitution of OPC with GGBFS is done at 0%, 10%, 20%, 30% and 40%. It is clear from the Table that the Compressive Strength increases with the addition of GGBFS till 30% and later decreases considerably at further replacement level. It is also observed from this Table that increment in Compressive Strength is 13.32% and 8.17 % at 7 and 28 days respectively with respect to the referral concrete. Split Tensile Strength and Flexural Strength of concrete at the age of 28 days are also given in Table-4.

It is evident from this Table that Split Tensile Strength and Flexural Strength increases upto 30% replacement of OPC with GGBFS in concrete and after further addition of GGBFS at 40% replacement of cement, the respective strength decreases However, strength is higher at all replacement levels as compared to that of referral concrete. Percentage increase in Split Tensile Strength and Flexural Strength is found to be 11.41% and 14.60% respectively higher with respect to referral concrete mix at 28 days.

Table 3 Compressive strength at 7 and 28 days at various % of GGBFS

% GGBFS	Compressive strength at 7 days (MPa)	Compressive Strength at 28 days (MPa)
0	30.31	45.25
10	32.12	46.10
20	33.15	46.57
30	34.35	48.95
40	29.50	46.53

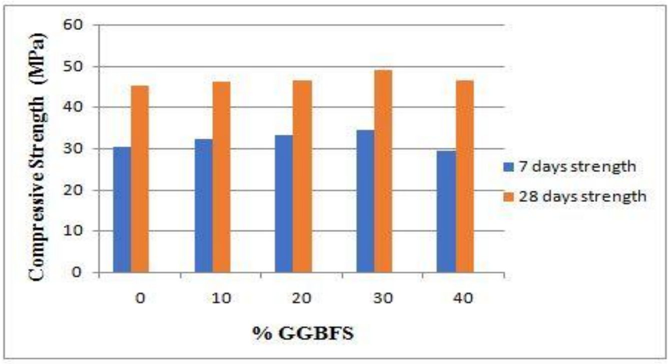

FIG 4.2 Relation between % GGBFS and Compressive Strength of concrete at 7 and 28 days

Table 4 Compressive Strength, Split Tensile Strength & Flexural Strength of 28 Days at various % of GGBFS

% GGBFS	Compressive strength at 28 days (MPa)	Split Tensile Strength at 28 days (MPa)	Flexural Strength at 28 days (MPa)
0	45.25	3.24	6.23
10	46.10	3.34	6.65
20	46.57	3.42	6.89
30	48.95	3.61	7.14
40	46.53	3.44	6.86

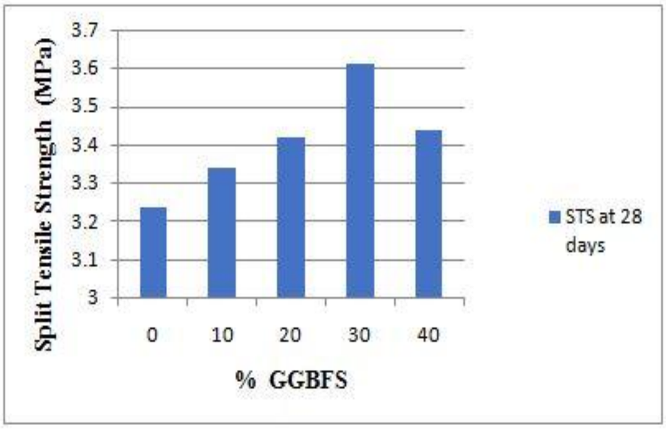

FIG 4.3 Relation between %GGBFS and Split tensile strength at 28 days.

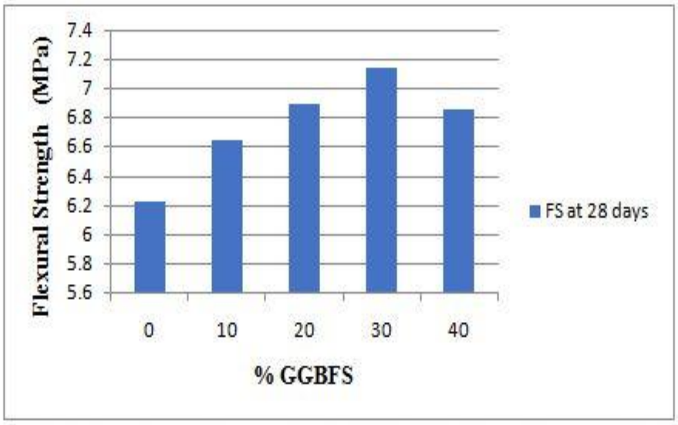

FIG 4.4 Relation between % GGBFS and Flexural strength at 28 days.

4.3 Relation among Strength parameters of Fly ash blended Concrete

Relation between Flexural Strength & Compressive Strength, Split Tensile Strength & Flexural Strength , Compressive Strength & Split Tensile Strength of GGBFS blended concrete mixes developed & plotted and are given in Figs 4.5 - 4.7. Regression coefficient , R^2 values among the different strength parameter is found 0.906, 0.913 and 0.931 respectively. The high values of correlation coefficient indicates that there is a strong relationship with each of the strength properties (compressive, flexural and split tensile strength).

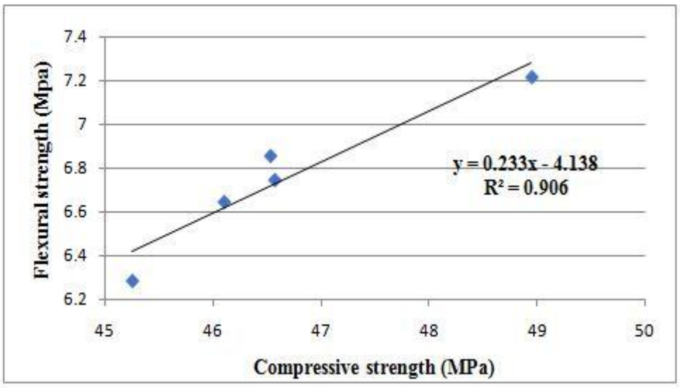

Fig. 4.5 Relation between Flexural Strength & Compressive Strength at 28 days

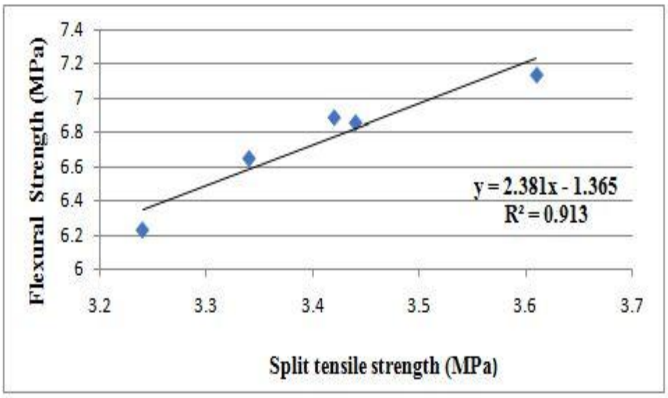

Fig. 4.6 Relation between Split Tensile Strength & Flexural Strength at 28 days

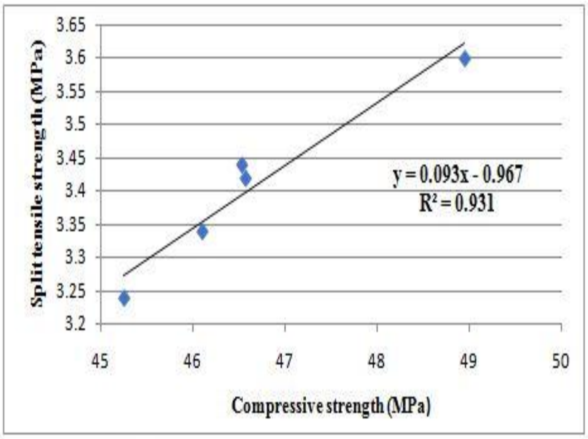

Fig. 4.7 Relation between Split tensile strength & Compressive Strength at 28 days

4.4 Abrasion Resistance of Concrete

Abrasion resistance test is determined using tile abrasion machine as per IS code :1706-1972.for each samples of concrete mixes(referral and GGBFS blended concrete mixes), cubes of 70.6mm were casted and subjected to grinding path of abrasion machine after 28 days curing. Depth of cubes is measured at 5 points (four at corners and one at the center).weight of cubes and loss in depth of cubes(depth of wear) is measured before abrasion test and recorded after every 22 sets of revolutions. This process is repeated till 220 revolutions shown in table 5. The extent of abrasion was determined from the difference in values of thickness measured before and after the abrasion test.

The variation of depth of wear (mm) increases with the no.of revolutions and decreases with age of curing. The depth of wear and loss in weight of cubes in referral concrete mixes is 2.48mm and 32.24 gms. Relation between

No. Of revolution and depth of wear at 0% and 30% replacement of GGBFS is shown in fig.4.9. Relation between No. Of revolution and loss in weight at 0% and 30% replacement of GGBFS is shown in fig.4.10. On the replacement of OPC with 30% GGBFS ,the depth of wear is decreased to 2.04 mm and loss in weight is also decreased at 26.35 gms .Thus there is enhancement in abrasion resistance in GGBFS blended concrete mixes with respect to referral concrete mixes as the depth of wear and loss in weight Is decreased in GGBFS blended concrete mixes As shown in fig 4.8

Table 5 : Relation between No. Of revolutions, loss in weight (gms) and Depth of wear(mm) in concrete mixes

No. Of Revolution	Referral concrete		GGBFS blended concrete (30% replacement of GGBFS)	
	Loss in depth (mm)	Loss in weight (gms)	Loss in depth (mm)	Loss in weight (gms)
0	0.00	0.00	0.00	0.00
22	0.27	3.61	0.18	2.34
44	0.52	6.80	0.40	5.39
66	0.73	9.57	0.61	7.89
88	1.02	13.34	0.78	10.14
110	1.27	16.46	0.98	13.09
132	1.36	17.88	1.19	14.65
154	1.55	20.53	1.38	17.80
176	1.89	24.68	1.59	20.62
198	2.23	28.96	1.81	23.40
220	2.48	32.24	2.04	26.35

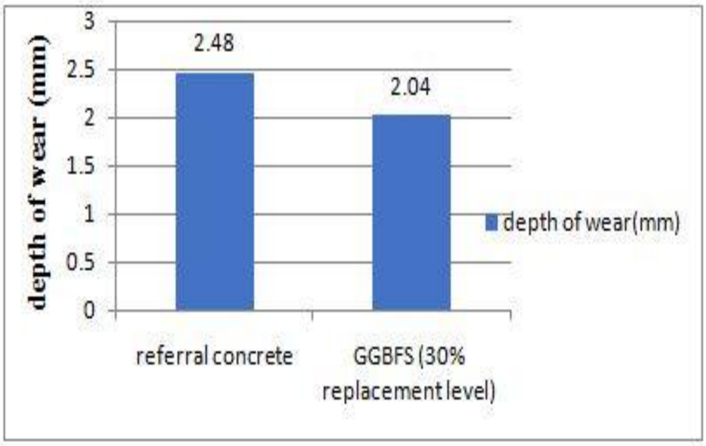

Fig. 4.8 Relation between depth of wear (mm) at 28 days With its corresponding concrete mixes

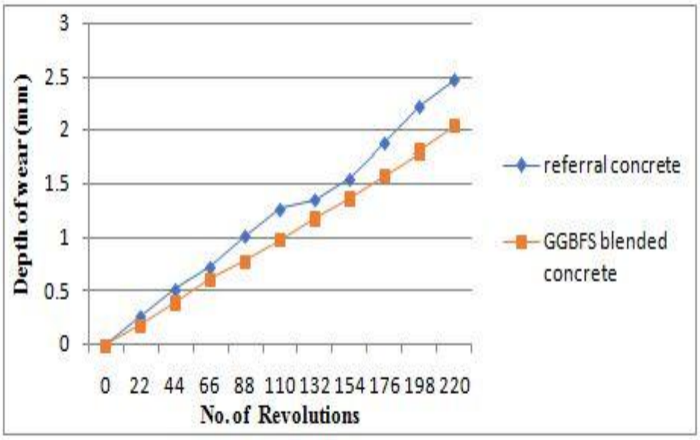

Fig. 4.9 Relation between No. Of revolutions and depth of wear

In Referral concrete and GGBFS blended concrete mix.

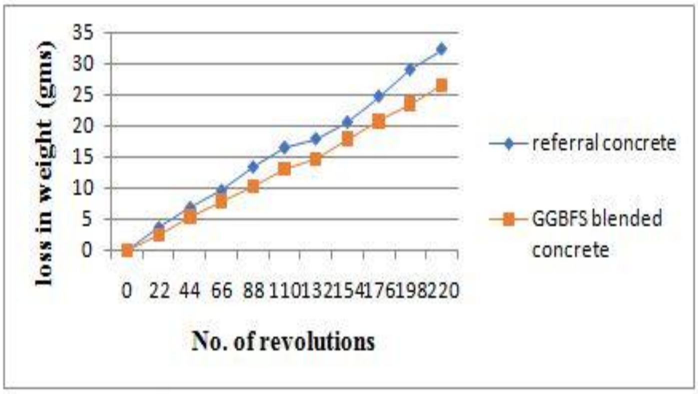

Fig. 4.10 Relation between No. Of revolution and loss in

weight in Referral concrete and GGBFS blended concrete mix

4.5 Relation between Compressive strength and Abrasion resistance

There is a relation between the compressive strength and abrasion resistance (depth of wear) as shown in fig.4.11. it is evident from the fig.4.11 that abrasion resistance is closely related with its compressive strength as the The depth of wear decreases with increment in compressive strength of concrete mixes. The depth of wear has decreased from 2.48mm (Referral concrete, CS = 45.25 MPa) to 2.04 mm (GGBFS blended concrete mix, CS = 48.95 MPa) (30% replacement of OPC with GGBFS) is higher as compared to referral concrete mixes.

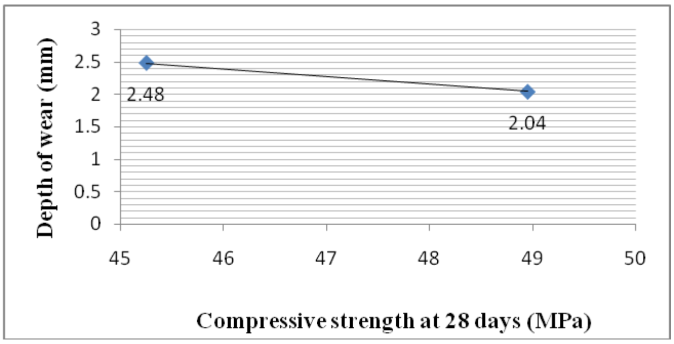

Fig.4.11 Relationship between compressive strength at 28 days and depth of wear(mm)

5. CONCLUSION

Workability (slump height) of concrete mixes after the replacement of cement with GGBFS is increased considerably at all replacement levels. The optimum percentage level of replacing cement with GGBFS is found to be at 30% .Compressive Strength of GGBFS blended concrete mixes at 30% replacement of cement is increased by 13.32 % and 8.17 % as compared to referral concrete at 7 and 28 days respectively. Split Tensile Strength and Flexural Strength of GGBFS blended concrete mix is increased by 11.41% and 14.60 % at 28 days with respect to referral concrete mix. Regression coefficient (value of R^2) is determined among strength properties ie. Flexural Strength & Compressive Strength, Flexural Strength & split tensile strength and Compressive Strength & Split Tensile Strength and is 0.906, 0.913 and 0.931 respectively. Increment in regression coefficient, R^2 values of blended concrete mixes is increased by the addition of GGBFS. Abrasion resistance of concrete mix at 30% replacement of cement with GGBFS is increased as depth of wear has decreased considerably from 2.48mm (in referral concrete) to 2.04 mm (in GGBFS blended concrete mix). On the optimization of GGBFS (at 30%) in concrete mixes, the depth of wear is reduced upto 17.74 %.Thus Abrasion resistance is higher in GGBFS blended concrete mixes with respect to referral concrete. Abrasion resistance of concrete is strongly correlated with % of GGBFS content used and its compressive strength.

REFERENCES

[1] Rao, S.K., Sravana, P. and Rao, T.C., 2016. Abrasion Resistance and mechanical properties of Roller Compacted Concrete with GGBS. *Construction and Building Materials*, *114*, pp.925-933

[2] Ashwini T Bhosale, Ground Granulated Blast Furnace Slag Concrete, International Journal for Research in Engineering Application & Management (IJREAM),

ISSN : 2454-9150 Vol-02, Issue 10, Jan 2017

[3] Vinayak Awasare, Prof. M. V. Nagendra, ANALYSIS OF STRENGTH CHARACTERISTICS OF GGBS CONCRETE, International Journal of Advanced Engineering Technology, E-ISSN 0976-3945

[4] Praveen Kumar Gahlot, Suresh singh Sankhla, Krishan Kumar Saini Use of GGBS as Partial Replacement of Cement in Concrete While using Master REHO Build 823PQ International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249-8958 (Online), Volume-9 Issue-3, February 2020

[5]M .G. Kamaldeep, K. Shyam Chamberlin Experimental Study on Performance of Concrete by using Combination of Flyash and Ggbs as Blended Material, International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-7, Issue-6C2, April 2019

[6] M.Rajaram ,A.Ravichandran, A.Muthadhi , Studies on Optimum Usage of GGBS in Concrete Volume 2, Issue 5, May – 2017 International Journal of Innovative Science and Research Technology

ISSN No: - 2456 – 2165

[7] V. Santa Rao, G. Lakshmana, K. Bhanuji Rao, G. Himala Kumari. Effect of strength parameters in concrete using double blending fly ash and GGBFS, *International Journal For Technological Research In Engineering Volume 5, Issue 6, February-2018 ISSN (Online): 2347 – 4718*

[8] Santosh Kumar Karri , G.V.Rama Rao, P.Markandeya Raju ,Strength and Durability Studies on GGBS Concrete, *SSRG International Journal of Civil Engineering (SSRG-IJCE) – volume 2 Issue 10 October 2015*

[9] Erdogan Ozbay, Mohamed Lachemi ,Umur Korkut Sevim, Compressive strength, abrasion resistance and energy absorption capacity of rubberized concretes with and without slag , Materials and Structures (2011) 44:1297–1307 DOI 10.1617/s11527-010-9701

[10] Balram Sharma, S. D. Thanvi Influence of Microfine GGBS on Concrete of Grade M35 & M40 Made with Pozzolana Cement, International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181

IJERTV5IS100252 Vol. 5 Issue 10, October-2016

[11]IS: 12269-1987.: Specification for 53 grade Ordinary Portland Cement. Bureau of Indian Standards,New Delhi, India

[12]IS:383-1970.: Specification for Coarse & Fine aggregate from Natural Sources for Concrete, Bureau of Indian Standards, New Delhi, India

[13]IS: 10262-2019. Code of Practice for Mix Design, Bureau of Indian Standards, New Delhi, India.

[14]IS: 516-1959: Methods of Tests for Strength of Concrete, Bureau of Indian Standards, New Delhi India

[15]IS: 5816-1999 Splitting Tensile Strength of Concrete-Method of Test, Bureau of Indian Standards, New Delhi, India

[16]IS: 1706-1972 Method for determination of resistance to wear by abrasion of Concrete- Method of Test, Bureau of Indian Standards, New Delhi, India