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PROPERTIES OF CONCRETE INCORPORATING WITH GROUND GRANULATED BLAST FURNACE SLAG AND FORTA FERRO FIBER

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Abstract
Mechanical properties of concrete incorporating with ground granulated blast furnace slag (GGBFS) and forta ferro fiber are presented in this investigation. In this study the concrete mixture is produced by partially replacing ordinary Portland cement with GGBFS with different percentage of 0%, 20%, 40% and 60% based on weight. To test the bending property forta ferro fiber also used in the concrete mixes with the percentage of 0 %, 0.25%, 0.5% and 0.75% as weight of concrete. The conventional concrete is prepared with water cement ratio of 0.45 and slump of the concrete is kept under 60 to 70 mm. Detail investigations are done to evaluate the influences of both GGBFS and Forta ferro fiber on behavior of concrete. The compressive strength of concrete is obtained after seven, twenty eight and fifty six days of curing. After 28days of curing the flexural strength and split tensile strength of harden concrete are determined. Nondestructive test of concrete as ultrasonic pulse velocity test (UPV) and rebound hammer test have been done for all mix. All the results are compared with the value of control mix. It is observed that the workability of concrete gives batter slump at 20% replacement of GGBFS and it decreases with increasing the percentage of forta ferro fiber. The hardened properties like flexural, split tensile and compressive strength shows optimum strength with replacement level of 20% GGBFS and 0.5% of fiber.
Keywords: GGBFS; forta ferro fiber; compressive strength; flexural strength; split tensile strength; nondestructive test.

Introduction

Current concrete production surroundings focus more on using environmentally friendly concrete. Blast-furnace Slag, has good cementitious property. So cement in usual concrete can be partially replaced by ground granulated blast furnace slag (GGBFS). A lesser amount of energy is needed for the preparation of GGBFS and it produces less green house gases, in contrast to ordinary Portland cement (OPC). Thus compared to an OPC concrete a GGBFS-blended concrete is more environmental friendly. To have a longer life span of concrete, it should be more durable in addition to it mechanical properties. Internal micro cracks are present in the concrete due to its low tensile strength. The cracks in concrete can be control by using fiber in concrete. Forta ferro fibers are made of 100 % virgin copolymer/ polypropylene and are noncorrosive.

The influences of fly ash and blast furnace slag on the compression properties of concrete were carried out by Tan and Pu [1]. Wainwright and Rey [2] investigated the influences of addition of GGBFS on the bleeding of concrete. The behaviour of high-strength concrete containing fly ash and GGBS were studied by Li and Zhao [3]. Oner and Akyuz [4] reported the maximum quantity of GGBS content as 55-59% of the cement quantity for enhancement of the strength of the concrete. Chidiac and Panesar [5] investigated the effect of GGBFS on mechanical properties of concrete. Behviour of concrete containing GGBFS at elevated temperatures were examined by Siddique and Kaur [6]. The effects of fine GGBFS on durability and mechanical properties of high strength concrete was investigated by Teng et al [7]. The previous studies on utilization and efficiency of GGBS on concrete properties were reviewed by Ozbay et al. [8] through 2016, Patra and Mukharjee [9] through 2017. Shahmansouri et al.[10] used response surface method to study mechanical properties of GGBFS-based geopolymer concrete incorporating natural zeolite and silica fume. Arafa et al [11] investigated the effects of forta ferro fibers on behaviour of self compacting concrete. Influence of forta ferro fibers on erosion resistance of high strength concrete was investigated by Nematzadeh and Valukolaee [12]. Bankir and

Sevim [13] investigated performance optimization of hybrid fiber concretes against acid and sulfate attack. Kathirvel and Murali [14] studied effects of GGBFS, silica fume, quartz powder and steel fibres on the fracture behavior of sustainable reactive powder concrete. Plenty of studies are reported on the utilisation of GGBS as partial replacement of cement in the production of concrete. The studies on the utilization of forta ferro fiber on concrete are few in the literature. In the present investigation, the authors study for the first time, the influence of GGBFS and forta ferro fiber on mechanical properties of concrete. The aim of the present study is to determine the effects of GGBFS and forta ferro fiber on concrete properties by preparing 16 different mix designs in two different stages. In the first stage the concrete is produced by partially replacing ordinary Portland cement with GGBFS, with different percentage of 20%, 40% and 60% based on weight. In the second stage forta ferro fibers are used to the concrete mixes with the percentage of 0.25%, 0.5% and 0.75% as weight of concrete.

2. Experimental investigation

2.1. Materials

OPC grade 53 as per IS: 269:2015 provided by RAMCO Cement Company is used for making concrete mixes in the present experimental work. Standard testes have been carried out to find different cement properties as given in table1.

Table1. Properties of cement

Fineness (m^2/kg)	Specific gravity	Consistency (%)	Initial setting time (min)	Final setting time (min)	Soundness (mm)	Compressive strength (MPa)		
						3days	7days	28days
306	3.14	27.96	176	269	1	30.1	40.3	57.5

River sand which confirms to ZoneII as per the IS: 238 (part-I) (1963) is used as fine aggregate for producing concrete. Natural coarse aggregates of 20mm nominal size are used. The GGBFS used in current experimental work is obtained from Toshali cement Pvt. Ltd, Choudwar plant, Cuttack, Odisha, India. The standard test results for various properties of fine aggregates, coarse aggregates and GGBFS are given in table 2.

Table 2. Properties of aggregates and GGBFS

Materials	Specific gravity	Water absorption (%)	Fineness modulus (m^2/kg)	Impact value (%)	Crushing value (%)
Fine aggregate	2.7	0.8	2.98	-	-
Coarse aggregate	2.81	0.26	7.52	-	-
GGBFS	3.1	1.1	352	17.1	19.2

Forta ferro fiber as shown in Fig.1 is used for the present concrete mixes to enhance the durability of concrete. Table3 shows the properties of forta ferro fiber used in this study.

Fig. 1. Forta ferro fiber

Table 3. Properties of forta ferro fiber

Length(mm)	Specific gravity	Colour	Melting point	Alkali/ Acid resistance	Tensile strength (MPa)	Form
57.1	0.91	Gray	160^{o} C	Excellent	583	Monofilament

2.2 Preparation of Concrete Mixes

For the fulfilment of the aim of the present investigation 16 concrete mixes were prepared as per provision given in IS 10262 (2016). The conventional concrete is prepared with water cement ratio of 0.45 and slump of the concrete is kept under 60 to 70 mm.In the mixes "G" stands for GGBFS and "F" stands for forta ferro fiber. GGBFS is partially replaced at the percentage of 20%, 40% and 60% of weight of cement, and forta ferro fibers are added to concrete as 0.25 %, 0.5 % and 0.75 % of the weight of the concrete. G0F0 is the conventional concrete made of OP. The mix design is done for M30 grade concrete. Surface dry condition aggregates are used. Then G20F0, G40F0 and G60F0 are the concrete specimen without any addition of fiber. All the combinations of ingredients were calculated for 1m^3 and were given in the Table 4**.**

Table 4. materials per cubic meter of concrete

Mix Designation	GGBFS (%)	Fiber (%)	Cement (Kg)	GGBFS (Kg)	Coarse aggregate (Kg)	Fine aggregate (Kg)	Water (Kg)	Fiber (Kg)
G0F0	0	0	390	0	1197.264	793.691	184.24	0
G20F0	20	0	312	78	1197.264	793.691	184.24	0
G40F0	40	0	234	156	1197.264	793.691	184.24	0
G60F0	60	0	154	234	1197.264	793.691	184.24	0
G0F0.25	0	0.25	390	0	1197.264	793.691	184.24	3.331
G20F0.25	20	0.25	312	78	1197.264	793.691	184.24	3.331
G40F0.25	40	0.25	234	156	1197.264	793.691	184.24	3.331
G60F0.25	60	0.25	154	234	1197.264	793.691	184.24	3.331
G0F0.5	0	0.5	390	0	1197.264	793.691	184.24	6.667
G20F0.5	20	0.5	312	78	1197.264	793.691	184.24	6.667
G40F0.5	40	0.5	234	156	1197.264	793.691	184.24	6.667
G60F0.5	60	0.5	154	234	1197.264	793.691	184.24	6.667
G0F0.75	0	0.75	390	0	1197.264	793.691	184.24	6.667
G20F0.75	20	0.75	312	78	1197.264	793.691	184.24	9.979
G40F0.75	40	0.75	234	156	1197.264	793.691	184.24	9.979
G60F0.75	60	0.75	154	234	1197.264	793.691	184.24	9.979

2.3 Testing of specimens

The workability of the concrete is checked by Slump cone test as per IS 1199 (1959). Compressive strength of concrete is determined by using 2000 kN compression testing machine for 150 mm cube mould after 7, 28 and 56days of curing according to IS: 516 (1959). After 28days of curing the flexural strength for prism mould (100mm x 100mm x 500mm) is determined as per IS: 516 (1985) and the split tensile strength test for cylindrical specimen of size 150mm x 300mm is found according to IS:5816 (1999). For 150 mm cube specimens the rebound hammer test as per the provision of IS: 13311 9 (part-2) and the ultrasonic pulse velocity (UPV) test in accordance with (IS: 1331 (part-2): 1992) are done after 28 days of curing.

2.4 Workability

The workability of concrete with different percentage of GGBFS and forta ferro fiber are presented in Fig. 2. It is found that the concrete with incorporation of GGBFS is more workable than conventional concrete when no fiber is added to the concrete. It is also found that the slump value of concrete with GGBFS replacement decreases with increasing the forta ferro fiber.

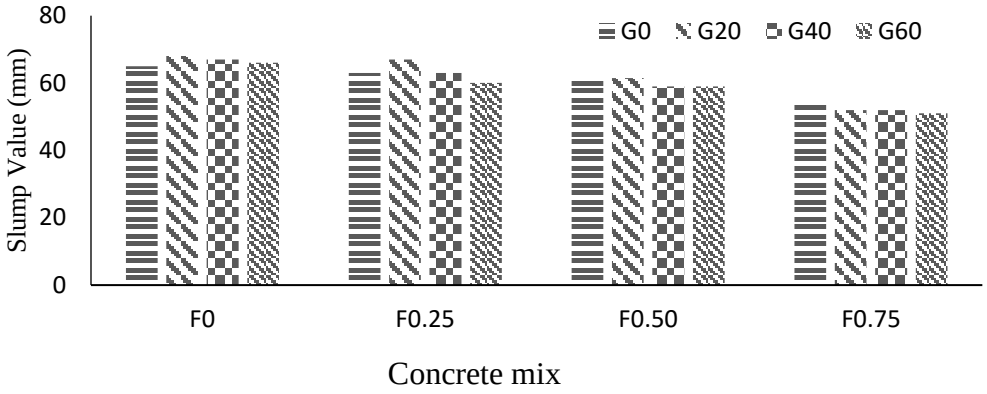

Fig. 2. Slump value of concrete

2.5 Compressive strength of concrete

Fig. 3, Fig.4 and Fig. 5 represent the compressive strength (CS) of concrete having different percentage of GGBFS and forta ferro fiber after 7days, 28days and 56days of curing respectively**.** It is observed that the CS of control of mix is 30.78, 42 and 46 MPa after 7days, 28days and 56days curing respectively. It is increased to 33.7, 50.00 and 51.67 MPa at 7, 28 and 56 days of curing which is 9.5%, 19% and 12.33% more than the control concrete mix respectively at 20% replacement of GGBFS. For 40% replacement of cement with GGBFS the CS after 7days of curing is decreased by 10% of control concrete, whereas after 28days and 56days of curing it is increased by 13.76% and 4.6% than the control concrete mix respectively. For 60% replacement of cement by GGBFS the strength is reduced by 29.5%, 4.23% and 8.9% of the control concrete after 7days, 28days and 56days of curing respectively. With the inclusion of 0.25% of forta ferro fiber (G0F0.25) into the concrete mix the CS is found to be 29.78, 36.67 and 38.56MPa after 7, 28 and 56 days of curing, which is 3.2%, 12.7% and 16.17% less than the conventional concrete. But for G20F0.25 mix means for 20% inclusion of GGBFS along with 0.25% of fiber the CS is increased by 32.8%, 26.97% and 13.52% of the control mix after 7days, 28days and 56days of curing respectively. For G40F0.25 mix the strength is reduced by 13.35%, 0.26% and 2.17% with respect to control mix after 7days, 28days and 56days of curing respectively. The concrete CS is lowered by 24.2%, 4.7% and 7.23% as compared to conventional concrete for G60F0.25 mix after seven, twenty eight and fifty six days of curing respectively. The control concrete compressive strength is found to be 14.1%, 16.66% and 16.67% less after seven, twenty eight and fifty six days of curing respectively after 0.5% addition of forta ferro fiber (G0F0.5). For 0.5% addition of forta ferro fiber along with 20% incorporation of GGBFS (G20F0.5) the strength is improved by 19.13%, 20.57% and 16.65% than conventional concrete after seven, twenty eight and fifty six days of curing respectively. For G40F0.5 mix the strength of conventional concrete is reduced

by 24.2%, 8.47% and 2.9% after 7days, 28days and 56days of curing respectively. The compressive strength is decreased by 32.84%, 23.8% and 17.39% at 7days, 28days and 56days of curing respectively for G60F0.5 mix. For 0.75% addition of forta ferro fiber (G0F0.75) without any inclusion of GGBFS, after 7days, 28days and 56days of curing the compressive strength is found to be reduced by 27.12%, 21.42% and 23.9% of the control concrete respectively. At 0.75% addition of forta ferro fiber (G20F0.75) in combination with 20% GGBFS the strength is found to be 1.1%, 0.78% and 5.8% less than that of control concrete at 7days, 28days and 56days of curing. Similar CS reduction trends are also observed for G40F0.75 and G60F0.75 concrete mixes.

In general from Fig .3-5, it is found that, the CS of concrete is increased by the incorporation of 20-40% of GGBFS due to the pozzolanic action of GGBFS and the strength increase is higher as the curing period extend. Further found that the CS of concrete is reduced by adding forta ferro fiber, because the addition of fiber creates voids in the concrete, which ultimately reduce the strength. But, up to 0.5% addition of fiber along with replacement of OPC with GGBFS the CS of concrete is improved as compared to control concrete, as the voids created by fiber is fill by the fibrous particles present in the GGBFS which ultimately helps to improve the strength.

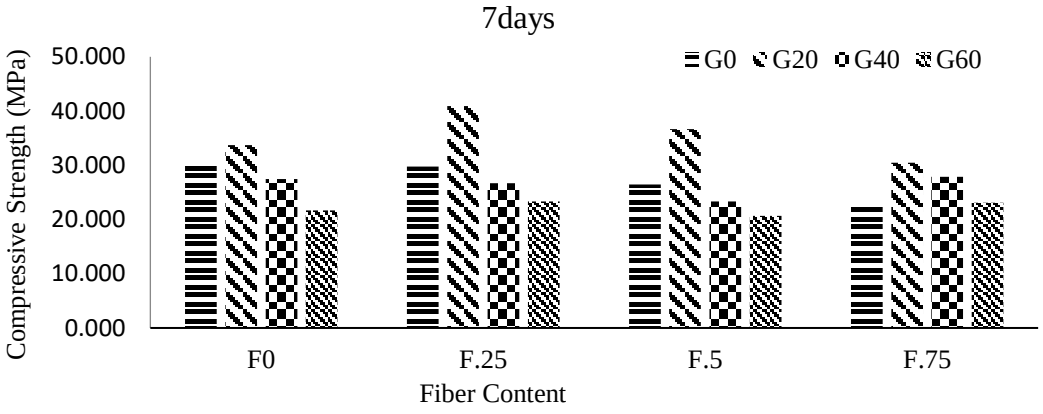

Fig.3. CS development of concrete at seven days of curing

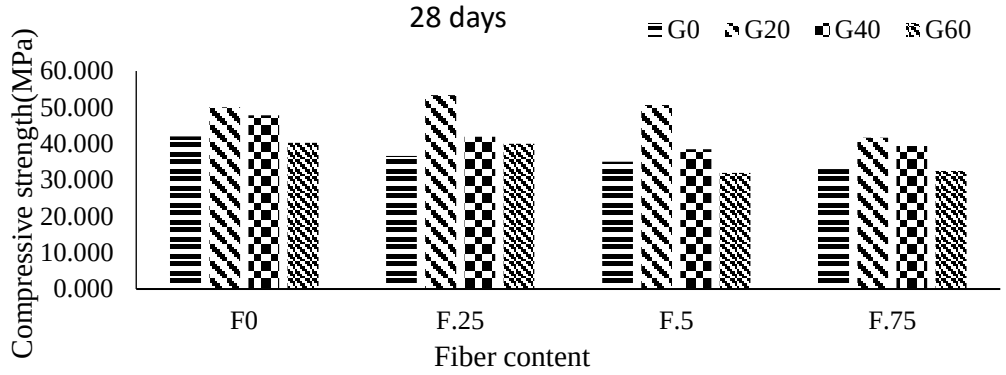

Fig.4. CS development of concrete at twenty eight days of curing

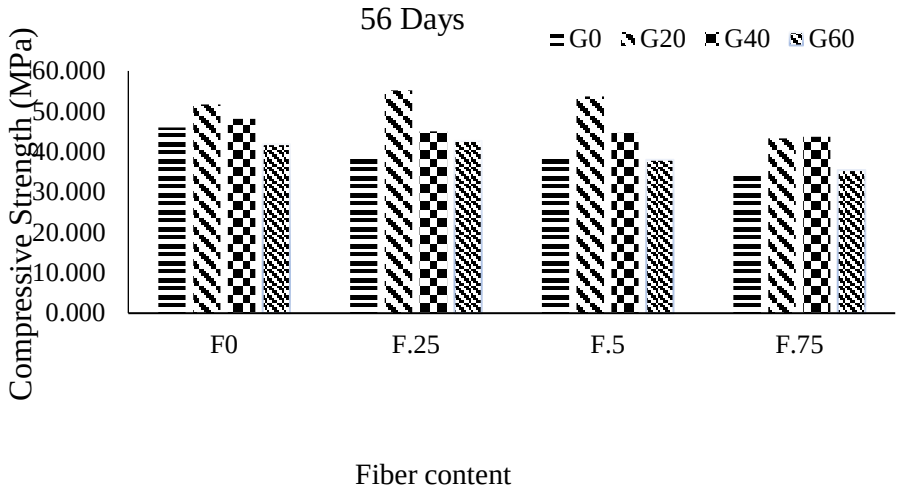

Fig.5. CS development of concrete at fifty six days of curing

2.6. Split tensile strength

The splitting tensile strength of concrete after twenty eight days of curing with different percentage of forta ferro fiber and GGBFS are presented in Fig 6. The splitting tensile strength of control concrete is observed as 4.08MPa after 28 days of curing. It is obtained that addition of 0.25%, 0.50% and 0.75% forta ferro fiber with OPC cement gives split strength of 4.07 MPa, 3.78 MPa and 3.1 MPa respectively. Reduction in strength is due to the poor bonding of mortar and aggregates of concrete. As increase in fiber value increase the honeycomb effect in concrete. However, it is found that the replacement of OPC with GGBFS improve the split tensile strength. For 20% incorporation of GGBFS at 0%, 0.25%, 0.50% and 0.75% fiber addition the splitting tensile strength is found to be 4.25MPa, 4.2MPa, 4.1MPa and 3.67MPa respectively. Concrete containing 40% and 60% replacement of GGBFS along with fiber addition show less improvement on splitting tensile strength than control concrete.

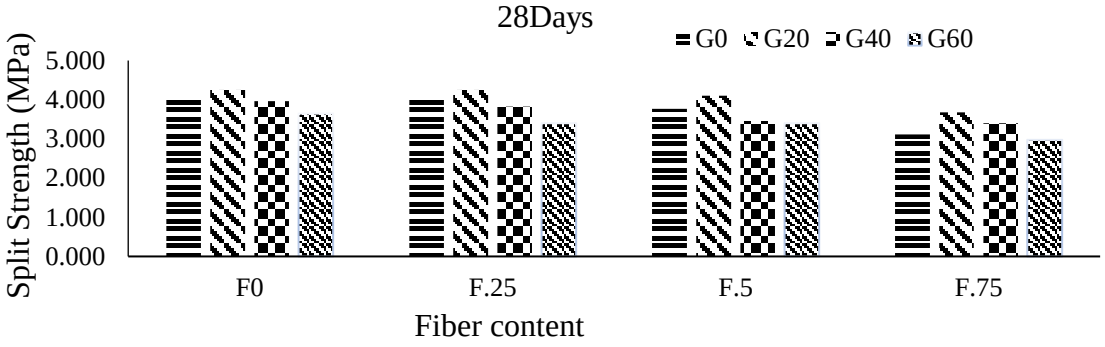

Fig.6. Split tensile strength development of concrete at twenty eight days of curing

2.7 Flexural strength

The flexural strength of concrete containing different amount of GGBFS and forta ferro fiber after 28days of curing is illustrated in Fig. 7. The flexural strength of only OPC based fiber reinforced concrete reduces with increasing the fiber amount. The flexural strength of control mix is observed as 6.43 MPa at 28days of curing. For 20% inclusion of GGBFS with 0%, 0.25%, 0.5% and 0.75% addition of fiber the flexural strength are improved by 8.86%, 13.53%, 5.75% and 0.47% respectively than the control mix. At 40% replacement of GGBFS along with inclusion of fiber the flexural strength of control concrete is not improved significantly. However at 60% replacement of OPC by GGBFS in the

presence of 0.25%, 0.5% and 0.75% fiber the flexural strength is reduced by 6.3%, 12.9% and 14.46% respectively.

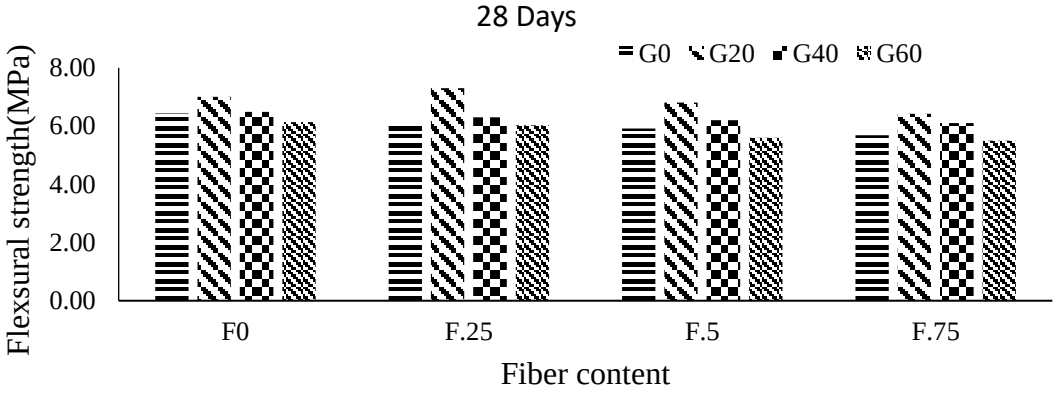

Fig.7. Flexural strength development of concrete at twenty eight days of curing

2.8. Rebound hammer test

The rebound hammer test results after twenty eight days of curing are presented in the Fig.8. Here observed that the rebound hammer number is increased by 5.57%, 21.56% and 37% for G20F0, G20F0.25 and G20F0.5 concrete mix respectively than G0F0 concrete. For G40F0, G40F0.25, G40F0.5 and G40F0.75 mixes the rebound hammer number is improved by 2.37%, 0.58%, 5.01% and 3.1% of G0F0 concrete respectively. The rebound hammer number of G60F0 and G60F0.25 mixes is nearly same as that of G0F0, whereas the rebound hammer number decreases for all other mixes.

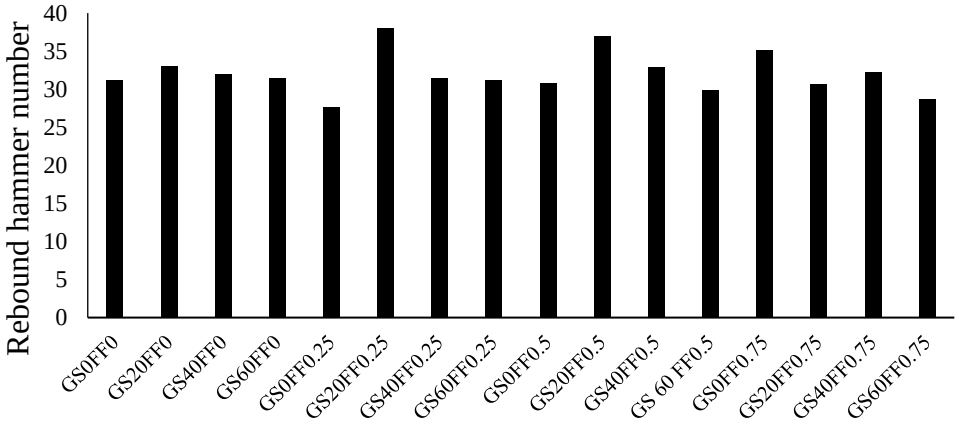

Fig.8. Rebound hammer test of concrete at twenty eight days of curing

2.9. Ultrasonic pulse velocity test

Ultrasonic pulse velocity test **(**UPV) test is carried out to check the homogeneity and quality of concrete by passing the wave through the concrete. Fig. 9 gives the results of UPV test . The UPV of conventional concrete (G0F0) is 4.22 km/s, which is improved to 4.97 km/s and 4.78 km/s for 20% and 40% GGBFS which gives 17.77% and 13.22% more value than the conventional concrete respectively. Whereas the addition of forta ferro fiber with 0% GGBFS show lesser UPV value than the control concrete. But the addition of 0.25% and 0.5% of forta ferro fiber along with 20% GGBFS enhanced the UPV value by 18.72% and 17.5% of the control concrete respectively. In the presence of GGBFS the wave takes less time to travel through the concrete as the fibrous particles present in the GGBFS reduce the voids created due to addition of forta ferro fiber, hence the UPV is improved for G20F0.25 and G20F0.5. The UPV value reduces for all the other concrete mixes. The relation between UPV value and compressive strength of twenty eight days cured concrete is given in Fig. 10.

Comparing two factors the linear trend line gives a co-relation coefficient value (R^2) as 0.97 which is good. The relationship is given by

$$C_s = 10.767UPV - 2.7079$$

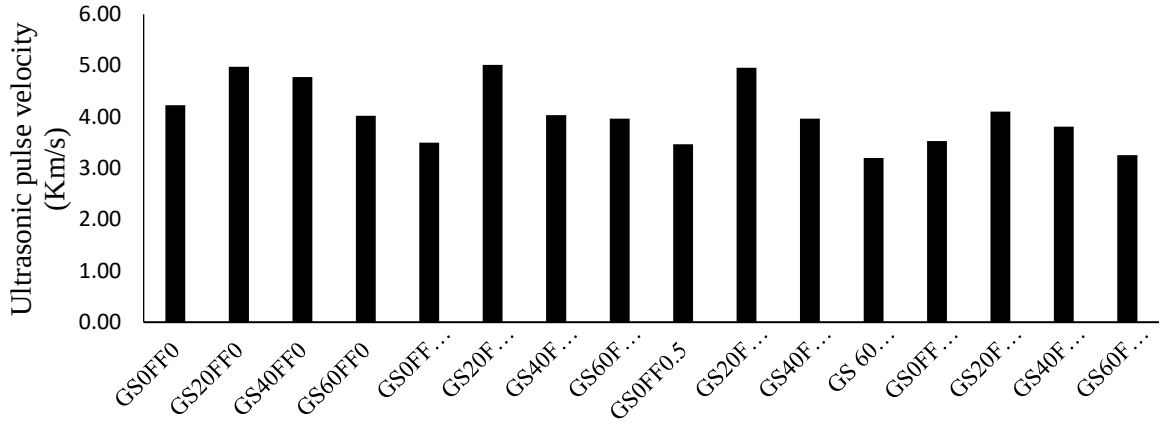

Fig.9. Ultrasonic pulse velocity at twenty eight days of curing

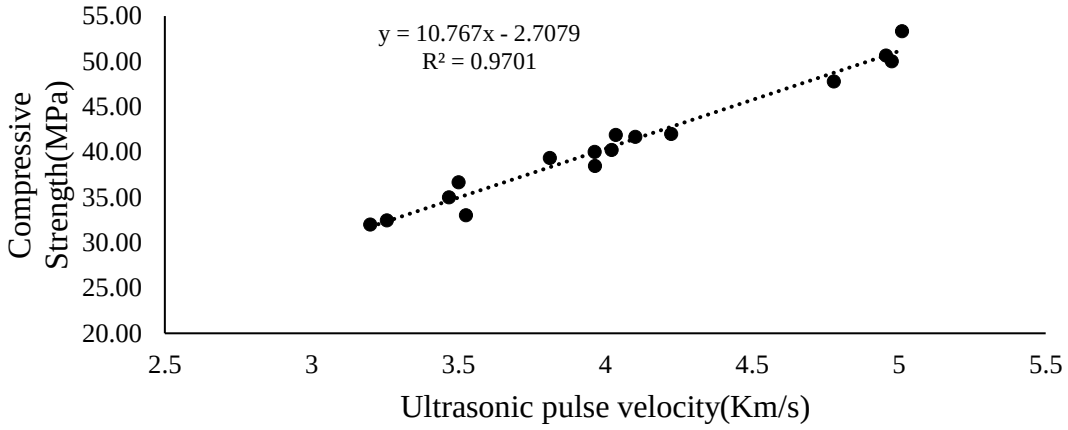

Fig.10. Correlation between UPV and twenty eight days compressive strength

Conclusions

The present study describes an experimental investigation on influence of GGBFS as partial replacement of ordinary Portland cement and addition of forta ferro fiber on fresh and hardened properties of concrete. The workability, compressive strength, splitting tensile strength, flexural strength, rebound hammer test and UPV of concrete having different percentage of GGBFS along with forta ferro fiber have been determined and compared with the control concrete. The conclusions found from the present investigation are mentioned as follows.

- At particular water cement ratio addition of GGBFS increases the workability of the concrete, as fineness of GGBFS is more than OPC.
- Workability of the concrete decreases by adding forta ferro fiber, because fibers create lump and do not mix properly with concrete.
- Compressive strength of concrete after twenty eight days and fifty six days of curing increases with 20% and 40% replacement of OPC by GGBFS.
- Twenty eight days and fifty six days compressive strength of concrete is increased with addition of forta ferro fiber up to 0.5% during the inclusion of GGBFS up to 40% replacement of OPC.

- The seven days compressive strength of concrete having up to 0.5% forta ferro fiber with 20% GGBFS achieved more strength then conventional concrete.
- The twenty eight days split tensile strength and flexural strength of concrete can be enhanced by adding forta ferro fiber up to 0.5% in combination with 20 % replacement of OPC as GGBFS.
- From the non-destructive test results it is found that the quality of concrete is improved by the addition of forta ferro fiber and replacement of OPC with GGBFS
- Hence, we can conclude that the replacement level of 20 % of OPC cement as GGBFS and up to 0.5 % addition of fiber produce good quality of concrete with higher mechanical property.

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