Properties of Concrete Incorporating PVA & Basalt Fibre with Partial Replacement of Cement by GGBFS

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ABSTRACT

This paper focuses on the mechanical properties of concrete incorporating mixture of PVA and Basalt fibres with partial replacement of cement by GGBFS. Total thirty two (32) mixes of concrete were prepared including two control mixes, Thirty mixes were containing cement replacement by GGBFS as 10 to 50% and mixture of Basalt fibre 1%, 2% and 3% by volume with PVA fibre 0.25% by volume for M30 and M50 grade of concrete respectively. The mechanical properties investigated in current study include compressive strength, splitting tensile strength and flexural strength (modulus of rupture) and also study on durability.

Keyword:- *Geo – polymer concrete; Fibre reinforced concrete; GGBFS; PVA Fibre; Basalt Fibre; Mechanical properties of concrete.*

1. INTRODUCTION

Ordinary portland cement concrete is a mixture of cement, aggregates and water. Concrete is the most frequently used construction material. The world wide consumption of cement was expected to be about 4100000 million tons (U.S. Geological Survey, Mineral Commodity Summaries, January 2016) [1]. Due to increase in infrastructure developments, the demand for concrete would increase in the future.

The manufacture of portland cement release carbon dioxide (CO_2) that is a significant contributor of the greenhouse gas emissions to environment. The cement manufacturing industry contributes about 5% to global anthropogenic CO_2 emissions, making the cement industry an important sector for CO_2 emission mitigation strategies. In order to address the environmental effect associated with portland cement, there is a need to use other binders to make concrete.

Several efforts had been taken to decrease the use of portland cement in concrete in order to reduce CO_2 emission. These include the utilization of supplementary cementing materials such as fly ash, silica fume, metakaolin, granulated blast furnace slag, rice husk and the development of alternative binders to portland cement.

To reproduce environmental friendly concrete, ours has been replace the cement with the industrial by products such as fly ash, ground granulated blast furnace slag etc. In this respect, the new of technology geo-polymer concrete is a promising technology.

In this respect, the geo-polymer technology proposed by davidovits shows promise for concrete industry as an alternative binder to the portland cement. In term of global warming, the geo-polymer technology could significantly reduce the CO_2 emission to the environment caused by the cement industries.

Geopolymer concrete has highly desirable structural engineering properties, which can lead to significant environmental and economic benefits. Its use is, however, limited by concerns regarding an increased brittleness compared to OPC concrete. Cementitious materials are generally brittle in behaviour and are inherently weak in resisting tensile forces. Low amounts of tensile force can cause a sudden failure which is usually caused by the proliferation of cracks. The addition of fibres to cementitious materials works on a similar theory whereby fibres act to transmit tensile forces across a crack. Fibres in particular have gained popularity in recent years for use in concrete, mainly owing to their low price and excellent characteristics, but also because they reduce the shrinkage, and improve cracking resistance and toughness of plain concrete.

2. LITERATURE REVIEW

In the past number of research and development has been done on Geo-polymer concrete and FRC has to a substantial and increasing number of publications of all types. Those research papers are useful for new research in combination of these both. In this chapter those considered most relevant to the current study are reviewed and summarized here.

In the context based on GGBFS conclude that the effect of GGBFS partial replacement with cement in concrete was investigate to show increment in result compared to normal concrete up to 50% replacement than after shown decrement in result [2-3]. In the context based on PVA and Basalt fibre conclude that the effect of these fibres addition in concrete separately or/and partial replacement of cement by other cementitious material in concrete was investigate to show increment in result compared to normal concrete up to some proportion (obtain optimum result of PVA fibre – 0.25% and Basalt fibre – increase with basalt fibre volume) on mechanical properties of concrete [4-5]. PVA fibre strength improvement was using shorter fibre other than longer length fibre. Basalt fibre found that to be increase with the increasing fibre volume and strength improvement was using longer fibre other than shorter length fibre [6-8].

3. EXPERIMENTAL PROGRAM

3.1 Material Used

In this various materials used for the study, their properties, test conducted and results are discussed. This section also explains the mix proportions used for the study.

3.1.1Cement

Cement was used to work according to IS:12269 – 2013 – Ordinary Portland Cement, 53 Grade –Specification.

Table – 1: Physical Properties of Cement

Sr. No.	Property	Test Result
1	Specific Gravity	3.15
2	Fineness	308 m^2/kg
3	Standard Consistency	28%
4	Initial Setting Time	140 min
5	Final Setting Time	195 min
6	Soundness Le – Chat Expansion	1 Mm

3.1.2Fine Aggregate

Fine aggregate was used to work according to IS:383 – Specification for Coarse and Fine Aggregate from Natural Sources for Concrete which fraction is from 4.75 mm to 150 µ. Some basic test conducted on F.A. in laboratory. which results are given below.

Table – 2: Physical Properties of Fine Aggregate

Sr. No.	Property	Test Result
1	Specific Gravity	2.66
2	Water Absorption of Fine Aggregate (%)	0.122
3	Surface Moisture of Fine Aggregate (%)	0.137
4	Fineness Modulus	2.74
5	Zone	II

3.1.3Coarse Aggregate

Coarse aggregate was used to work according to IS:383 – Specification for Coarse and Fine Aggregate from Natural Sources for Concrete which fraction is from 20 mm to 4.75 mm. Some basic test conducted on C.A. in laboratory. which results are given below.

Table – 3: Physical Properties of Coarse Aggregate

Sr. No.	Property	Test Result
1	Specific Gravity	2.62
2	Water Absorption of Fine Aggregate (%)	0.028
3	Surface Moisture of Fine Aggregate (%)	0.04
4	Fineness Modulus	5.36
5	F.I. & E.I.	14.84 & 15

3.1.4Super Plasticizer

In modern concrete practice, It's essentially impossible to make high performance concrete at adequate workability in the field without the use of super plasticizers. The super plasticizer used in the study was Conplast P211.

3.1.5PVA Fibre

The fibres used were chopped PVA fibres which are randomly distributed in the concrete mix. The fibre content were chosen 0.25% by volume. Chopped PVA fibres are shown in figure 1.

Figure – 1 & 2: PVA (Polyvinyl Alcohol Fibre) & Basalt Fibre respectively

3.1.6Basalt Fibre

The fibres used were chopped Basalt fibres which are randomly distributed in the concrete mix. The fibre content were chosen 1%, 2% & 3% by volume. Chopped Basalt fibres are shown in figure 2.

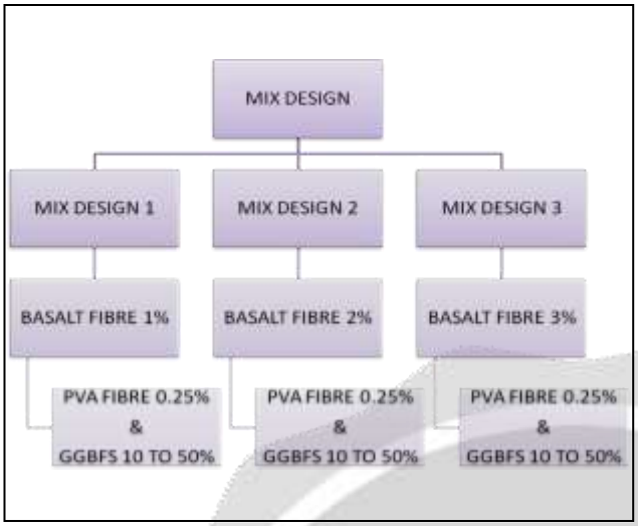
Table – 4: Properties of Fibres

Sr. No.	Test Description	PVA Fibre	Basalt Fibre
1	Diameter	14 µm	18 µm
2	Length	12 mm	22 mm
3	Color	White	Light Brown
4	Specific Gravity	1.29 gm/cm^3	2.75 gm/cm^3
5	Density	1.25 gm/cm^3	2.63 gm/cm^3
6	Tensile Strength	1495 MPa	3450 MPa
7	Elastic Modulus	41.7 GPa	79 GPa
8	Elongation of Break	7 %	3.1 %

3.2 Concrete Mix Proportions

The mixture proportioning was done according the IS Method IS:10262 – 2009. The target mean strength was 30 MPa for the control mixture, the total cement content was 457 kg/m3, F.A. and C.A. content was taken 643 kg/m3 and 1106 kg/m3 respectively, the W/C ratio was kept 0.42. Similarly the target mean strength was 50 MPa for the control mixture, the total cement content was 445 kg/m3, F.A. and C.A. content was taken 651 kg/m3 and 1179 kg/m3 respectively, the super plasticizer content was 6 kg/m3, the W/C ratio was kept 0.36. 150 mm x 150 mm x 150 mm cube, 500 mm x 100 mm x 100 mm beam and 150 mm diameter and 300 mm height cylinder moulds were used for casting. The total mixing time was 5 minutes, the samples were then casted and left for 24 hrs before demoulding. They were then placed in the curing tank until the day of testing. The concrete specimen were cured in the tank for 7, 28, 56 days.

Table – 5: Phase Wise Casting Schedule



As mentioned in Table 5, total three series of concrete mixes were prepared and name as series “M1”, series “M2” and series “M3”. Series “M1” represents concrete mix in which adding basalt fibre content of 1% by volume, PVA fibre content of 0.25% by volume and cement replacements by GGBFS content of 10 to 50%. Series “M2” represents concrete mix in which adding basalt fibre content of 2% by volume, PVA fibre content of 0.25% by volume and cement replacements by GGBFS content of 10 to 50%. Series “M3” represents concrete mix in which adding basalt fibre content of 3% by volume, PVA fibre content of 0.25% by volume and cement replacements by GGBFS content of 10 to 50%.

Table – 6: Necessary Specimen Casted for Various Test

Identification Mark	Number of Specimen	Specimen Size	Test
G0P0B0 to G50P0.25B3	2 X 6	150 X 150 X 150	Compressive Strength at 7 days & 28 days
	2 X 3	150 X 300	Splitting Tensile Strength at 28 days
	2 X 3	100 X 100 X 500	Flexural Test at 28 days
	2 x 6	150 x 150 x 150	Durability Test at 56 days

Where,

G = GGBFS contents of 10 %, 20 %, 30 %, 40 % and 50 % with partial replacement of cement respectively.

P = PVA Fibre contents of 0.25 % by volume.

B = Basalt Fibre content of 1 %, 2 % and 3 % respectively.

4. EXPERIMENTAL RESULTS AND DISCUSSION

Table 7 shows the 28 days compressive strength, splitting tensile strength and flexural strength of the specimen without fibre reinforced and those reinforced with 0.25% of PVA fibres (added by volume of concrete) and 1%, 2% and 3% of Basalt fibres (add by volume of concrete).

Table – 7: Results of the fresh and hardened properties of concrete

Mix	Identification Mark	M30					M50				
		Slump	**C.T.**		**S.T.**	**F.T.**	**C.F.**	**C.T.**		**S.T.**	**F.T.**
			7d	**28d**	**28d**	**28d**		**7d**	**28d**	**28d**	**28d**
M0	**G0P0B0**	65	24.24	31.74	2.91	4.87	0.93	34.25	46.65	4.15	5.85
	Series "M1": Concrete with 10 to 50% GGBFS as partial replacement of cement and adding 0.25% PVA and 1% Basalt fibre by volume of concrete										
M1	**G10P0.25B1**	57	23.14	28.70	2.51	4.92	0.92	31.85	42.70	3.51	3.82
	G20P0.25B1	62	21.81	32.99	2.49	5.05	0.93	35.16	43.51	4.00	4.03
	G30P0.25B1	54	25.53	33.57	2.73	3.98	0.91	34.39	42.10	4.23	5.47
	G40P0.25B1	58	25.73	34.55	3.71	4.68	0.92	37.01	47.24	4.67	6.23
	G50P0.25B1	50	26.64	35.48	4.06	5.32	0.90	38.27	49.44	4.78	6.43
	Series "M2": Concrete with 10 to 50% GGBFS as partial replacement of cement and adding 0.25% PVA and 2% Basalt fibre by volume of concrete										
M2	**G10P0.25B2**	52	23.01	30.31	3.20	3.9	0.89	34.50	48.40	3.97	5.95
	G20P0.25B2	47	24.30	31.48	3.62	4.53	0.86	37.16	50.43	4.39	6.37
	G30P0.25B2	47	25.94	34.79	3.92	4.63	0.86	38.64	52.80	4.50	6.93
	G40P0.25B2	54	22.74	31.60	4.27	5.08	0.89	37.24	57.78	4.72	7.72
	G50P0.25B2	48	21.05	26.55	4.34	5.55	0.85	34.37	57.76	5.90	7.9
	Series "M3": Concrete with 10 to 50% GGBFS as partial replacement of cement and adding 0.25% PVA and 3% Basalt fibre by volume of concrete										
M3	**G10P0.25B3**	43	26.41	35.84	3.94	2.47	0.82	37.59	64.71	5.21	7.43
	G20P0.25B3	40	26.23	34.19	3.16	2.62	0.83	35.69	53.70	5.08	6.6
	G30P0.25B3	42	23.73	31.38	2.85	2.3	0.85	33.54	53.10	4.52	6.75
	G40P0.25B3	41	22.56	27.63	2.67	2.53	0.85	31.36	52.04	4.70	5.88
	G50P0.25B3	40	21.39	26.33	2.59	2.37	0.84	29.73	47.35	4.35	3.8

4.1 Compressive Strength

The compressive strength at 7 days for M30 grade of concrete, when M1 used the compressive strength increased was about -5.16, -10.02, 5.32, 6.14, 9.90% of GGBFS 10 to 50% replacement respectively compared to control mix. When M2 used the compressive strength increased was about -5.07, 0.25, 7.01, -6.19, -13.16% of GGBFS 10 to 50% replacement respectively compared to control mix. When M3 used the compressive strength increased was about 8.95, 8.21, -2.10, -6.93, -11.76% of GGBFS 10 to 50% replacement respectively compared to control mix. The compressive strength at 28 days, when M1 used the compressive strength increased was about -9.58, 3.94, 5.77, 8.53, 11.78% of GGBFS 10 to 50% replacement respectively compared to control mix. When M2 used the compressive strength increased was about -4.51, -0.85, 9.61, -0.44, -16.35% of GGBFS 10 to 50% replacement respectively compared to control mix. When M3 used the compressive strength increased was about 12.92, 7.72, -1.13, -12.95, -12.34% of GGBFS 10 to 50% replacement respectively compared to control mix.

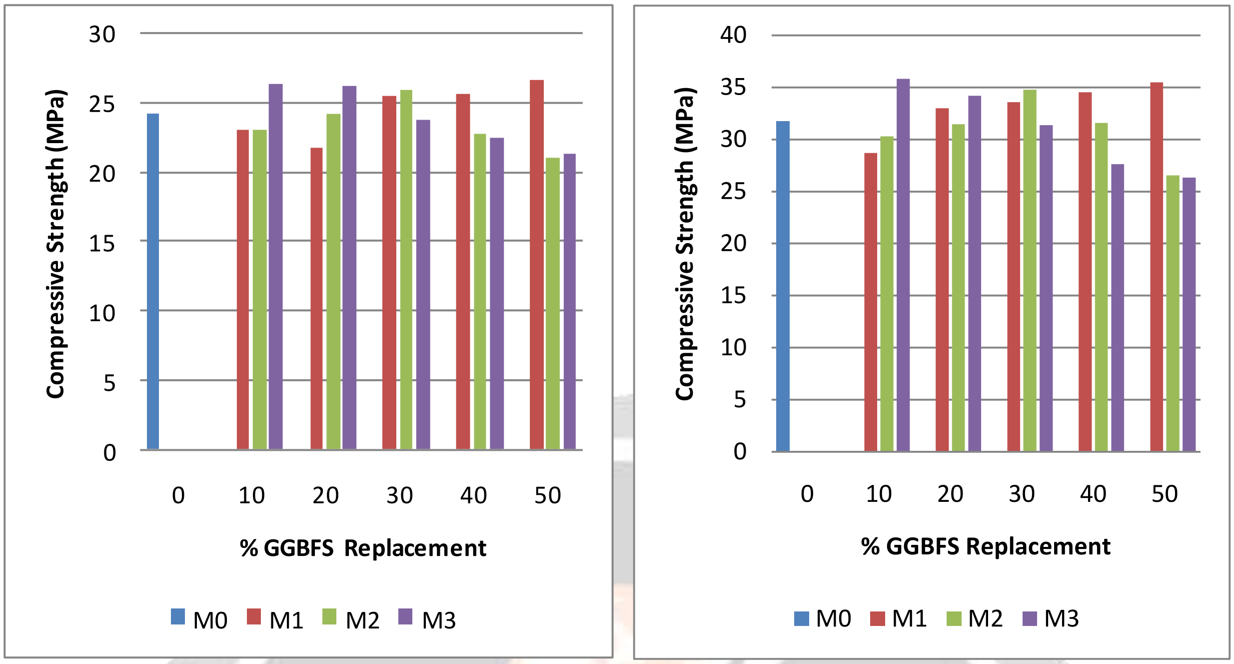


Chart – 1 & 2: Compressive Strength of M30 Grade of Concrete Control Mixture & Various Mixture at 7 days & 28 days respectively

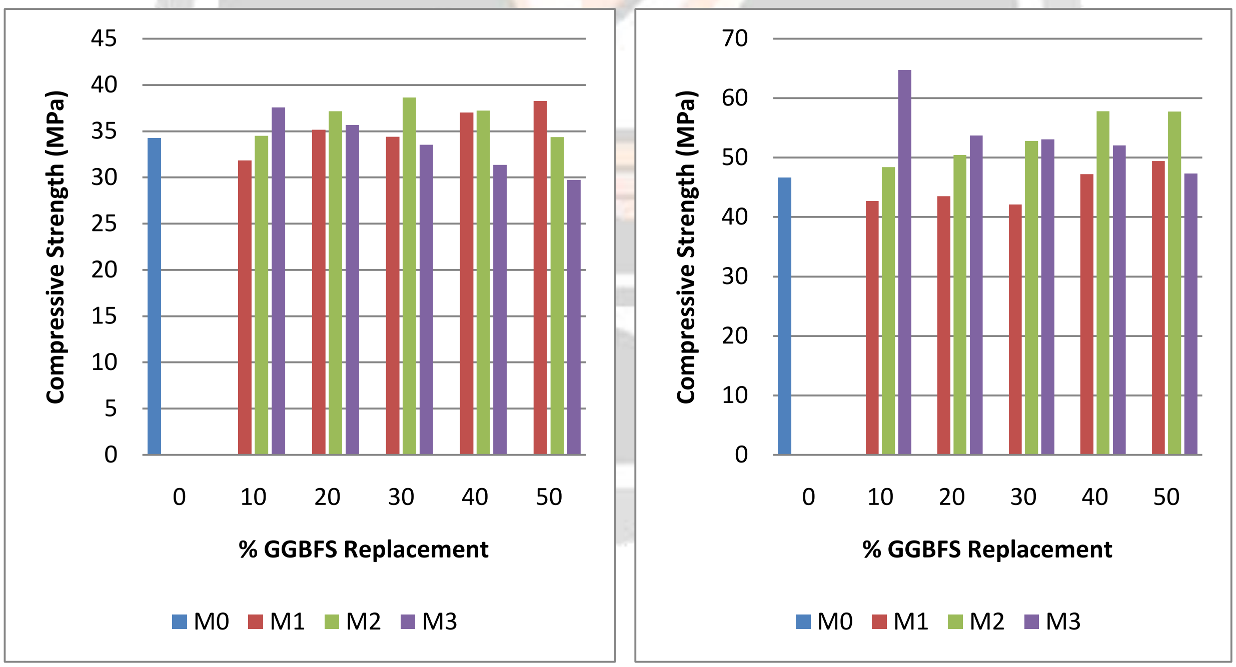
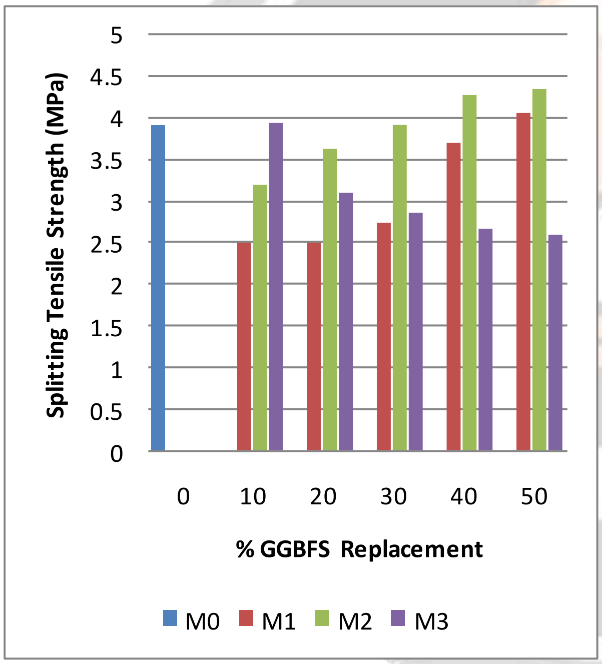


Chart – 3 & 4: Compressive Strength of M50 Grade of Concrete Control Mixture & Various Mixture at 7 days & 28 days respectively

The compressive strength at 7 days for M50 grade of concrete, when M1 used the compressive strength increased was about -7.01, 2.66, 0.41, 8.06, 11.74% of GGBFS 10 to 50% replacement respectively compared to control mix. When M2 used the compressive strength increased was about 0.73, 8.50, 12.81, 8.73, 0.35 % of GGBFS 10 to 50% replacement respectively compared to control mix. When M3 used the compressive strength increased was about 9.75, 4.20, -2.07, 8.44, -13.20% of GGBFS 10 to 50% replacement respectively compared to control mix. The compressive strength at 28 days, when M1 used the compressive strength increased was about -8.47, -6.73, -9.75, 1.26, 5.98% of GGBFS 10 to 50% replacement respectively compared to control mix. When M2 used the compressive strength increased was about 3.75, 8.10, 13.18, 23.89, 23.82% of GGBFS 10 to 50% replacement respectively compared to control mix. When M3 used the compressive strength increased was about 38.71, 15.11, 13.83, 11.55, 1.50% of GGBFS 10 to 50% replacement respectively compared to control mix.

4.2 Splitting Tensile Strength

The splitting tensile strength at 28 days for M30 grade of concrete, when M1 used the compressive strength increased was about -13.75, -14.43, -6.18, 27.49, 39.52% of GGBFS 10 to 50% replacement respectively compared to control mix. When M2 used the splitting tensile strength increased was about 9.97, 24.40, 34.41, 46.74, 49.14% of GGBFS 10 to 50% replacement respectively compared to control mix. When M3 used the splitting tensile strength increased was about 35.40, 8.59, -2.06, -8.25, -11% of GGBFS 10 to 50% replacement respectively compared to control mix. The splitting tensile strength at 28 days for M50 grade of concrete, when M1 used the compressive strength increased was about -15.42, -3.61, 1.93, 12.53, 15.18% of GGBFS 10 to 50% replacement respectively compared to control mix. When M2 used the splitting tensile strength increased was about -4.34, 5.78, 8.43, 13.73, 42.17% of GGBFS 10 to 50% replacement respectively compared to control mix. When M3 used the splitting tensile strength increased was about 25.54, 22.41, 8.92, 13.25, 4.82% of GGBFS 10 to 50% replacement respectively compared to control mix.



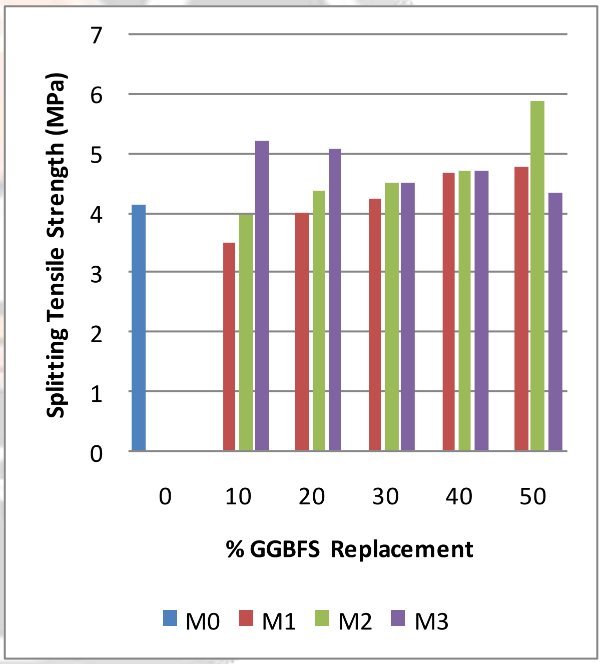
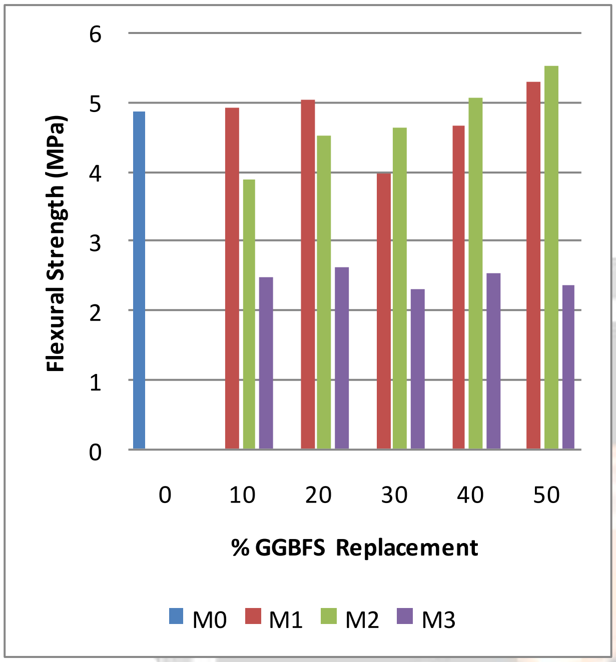


Chart – 5 & 6: Splitting Tensile Strength of M30 & M50 Grade of Concrete Control Mixture & Various Mixture at 28 days respectively

4.3 Flexural Strength

The flexural strength at 28 days for M30 grade of concrete, when M1 used the compressive strength increased was about 1.03, 3.70, -18.28, -3.90, 9.24% of GGBFS 10 to 50% replacement respectively compared to control mix. When M2 used the flexural strength increased was about -19.92, -6.98, -4.93, 4.31, 13.96 % of GGBFS 10 to 50% replacement respectively compared to control mix. When M3 used the flexural strength increased was about -49.28, -46.20, -52.77, -48.05, -51.33% of GGBFS 10 to 50% replacement respectively compared to control mix. The flexural strength at 28 days for M50 grade of concrete, when M1 used the compressive strength increased was about

-34.70, -31.11, -6.50, 6.50, 9.91% of GGBFS 10 to 50% replacement respectively compared to control mix. When M2 used the flexural strength increased was about 1.71, 8.89, 18.46, 31.97, 35.04 % of GGBFS 10 to 50% replacement respectively compared to control mix. When M3 used the flexural strength increased was about 27.00, 12.82, 15.38, 0.51, -35.04% of GGBFS 10 to 50% replacement respectively compared to control mix.



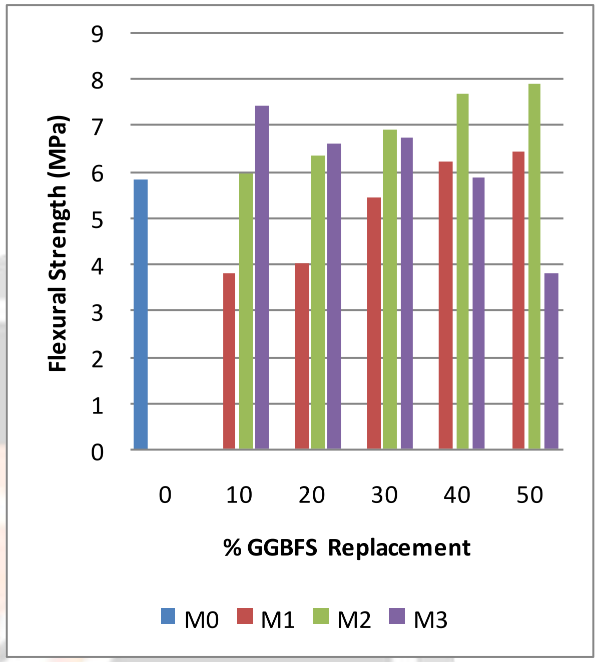


Chart – 7 & 8: Flexural Strength of M30 & M50 Grade of Concrete Control Mixture & Various Mixture at 28 days respectively

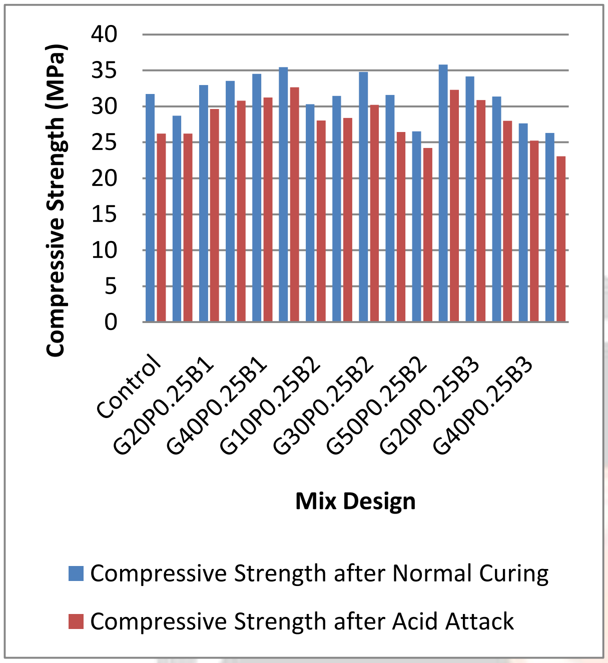
4.4 Acid Resistance Test

The compressive strength after acid attack for M30 grade of concrete, when M1 used the compressive decrease about 8.57, 10.09, 8.31, 9.52, 7.95% of GGBFS 10 to 50% replacement respectively compared to normal curing. When M2 used the compressive strength decrease about 7.42, 9.78, 13.14, 16.30, 8.74% of GGBFS 10 to 50% replacement respectively compared to normal curing. When M3 used the compressive strength decrease about 9.85, 9.71, 10.71, 8.69, 12.42% of GGBFS 10 to 50% replacement respectively compared to normal curing. The compressive strength after acid attack for M50 grade of concrete, when M1 used the compressive strength decrease about 4.05, 4.76, 3.42, 2.54, 2.51% of GGBFS 10 to 50% replacement respectively compared to normal curing. When M2 used the compressive strength decrease about 2.42, 2.00, 4.41, 4.36, 5.26% of GGBFS 10 to 50% replacement respectively compared to normal curing. When M3 used the compressive strength decrease about 2.41, 1.75, 3.39, 5.46, 1.14% of GGBFS 10 to 50% replacement respectively compared to normal curing.

4.5 Sulphate Resistance Test

The compressive strength after sulphate attack for M30 grade of concrete, when M1 used the compressive increase about 6.59, 3.91, 6.20, 3.18, 3.78% of GGBFS 10 to 50% replacement respectively compared to normal curing. When M2 used the compressive strength increase about 4.29, -2.83, 2.21, -6.33, 6.25% of GGBFS 10 to 50% replacement respectively compared to normal curing. When M3 used the compressive strength increase about 5.22, 0.91, 1.88, 4.20, 5.89% of GGBFS 10 to 50% replacement respectively compared to normal curing. The compressive strength after sulphate attack for M50 grade of concrete, when M1 used the compressive strength increase about 8.83, 9.86, 10.59, 8.68, 8.54% of GGBFS 10 to 50% replacement respectively compared to normal curing. When M2 used the compressive strength increase about 8.88, 10.79, 8.20, 6.77, 7.57% of GGBFS 10 to 50%

replacement respectively compared to normal curing. When M3 used the compressive strength increase about 7.51, 7.24, 8.53, 6.84, 11.74% of GGBFS 10 to 50% replacement respectively compared to normal curing.



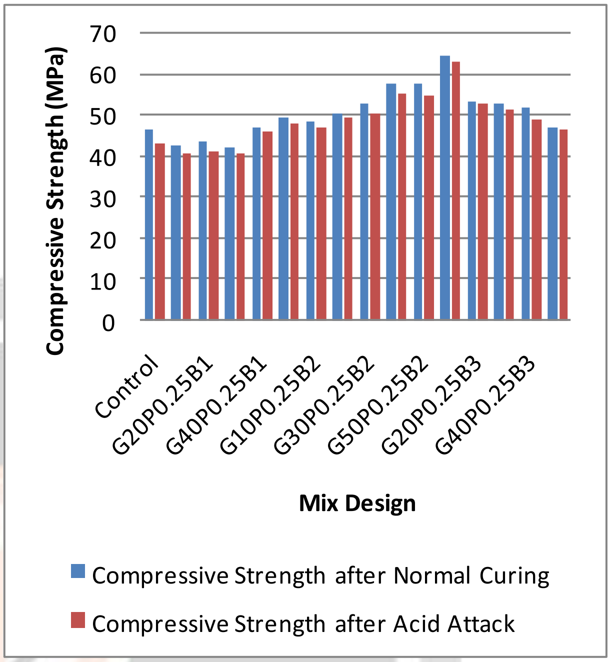
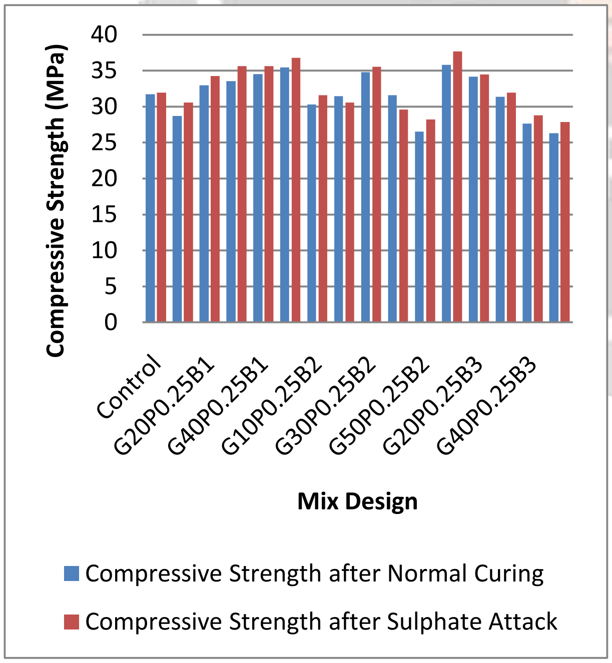


Chart – 9 & 10: Comparison between Compressive Strength of M30 & M50 Grade of Concrete after Normal Curing and Acid Attack respectively



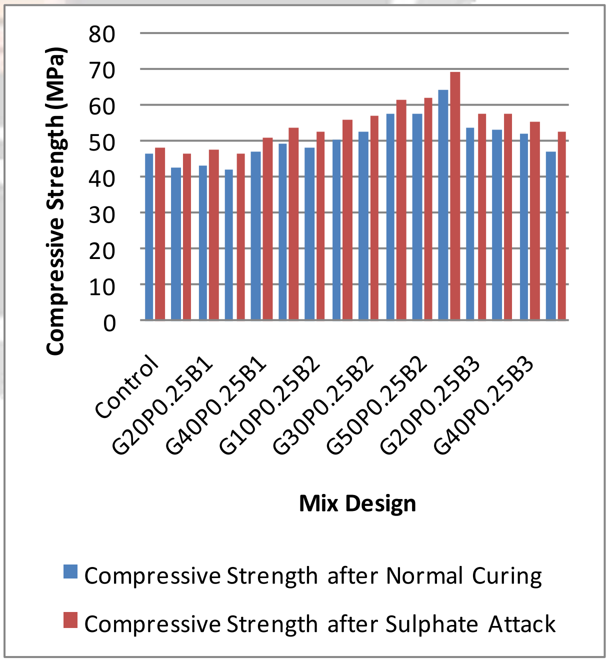


Chart – 11 & 11: Comparison between Compressive Strength of M30 & M50 Grade of Concrete after Normal Curing and Sulphate Attack respectively

5. CONCLUSION

Based on the research studies the following conclusion can be made:

I. For M30 grade of concrete,

- It concluded that workability is not major effect with replacing GGBFS but it's decreasing with increasing combination of fibre content.
- In Compressive Strength, Optimum result are obtain by using GGBFS content of 10% and Combination of fibre (PVA & Basalt Fibre) is 0.25 & 3% respectively (+12.92% compared to control mix).
- In Splitting Tensile Strength, Optimum result are obtain by using GGBFS content of 50% and Combination of fibre (PVA & Basalt Fibre) is 0.25% & 2% respectively (+49.14% compared to control mix).
- In Flexural Strength, Optimum result are obtain by using GGBFS content of 50% and Combination of fibre (PVA & Basalt Fibre) is 0.25% & 2% respectively (+13.96% compared to control mix).

II. For M50 grade of concrete,

- It concluded that workability is not major effect with replacing GGBFS but it's decreasing with increasing combination of fibre content.
- In Compressive Strength, Optimum result are obtain by using GGBFS content of 10% and Combination of fibre (PVA & Basalt Fibre) is 0.25 & 3% respectively (+38.71% compared to control mix).
- In Splitting Tensile Strength, Optimum result are obtain by using GGBFS content of 50% and Combination of fibre (PVA & Basalt Fibre) is 0.25% & 2% respectively (+42.17% compared to control mix).
- In Flexural Strength, Optimum result are obtain by using GGBFS content of 50% and Combination of fibre (PVA & Basalt Fibre) is 0.25% & 2% respectively (+35.04% compared to control mix).

Optimum result of Compressive Strength, Splitting Tensile Strength, Flexural Strength are obtain by using GGBFS content of 50% and Combination of fibre (PVA & Basalt Fibre) is 0.25% & 2% respectively.

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7. REFERENCES

[1] U.S. Geological Survey. "Mineral Commodity Summaries 2016".

[2] R. Rughooputh, J. Rana. "Partial replacement of cement by ground granulated blast furnace slag in concrete". *Journal of Emerging Trends in Engineering and Applied Sciences*, Vol. 5(5), pp. 340-343.

[3] Gengying Li, Xiaohua Zhao. "Properties of concrete incorporating fly ash and ground granulated blast-furnace slag". *Cement & concrete composites.* Vol. 25(2003), pp. 293-299.

[4] Amin Noushini, Bijan Samali, Kirk Vessalas. "Effect of polyvinyl alcohol (PVA) fibre on dynamic and material properties of fibre reinforced concrete". *Construction and Building Materials.* Vol. 49(2013), pp. 374-383.

[5] A. Noushini, B. Samali, K. Vessalas. “Influence of polyvinyl alcohol fibre addition on fresh and hardened properties of concrete”. *Hokkaido University Collection of Scholarly and Academic Papers.*

[6] John Branston, Sreekanta Das, Sara Y. Kenno, Craig Taylor. “Mechanical behaviour of basalt fibre reinforced concrete”. *Construction and Building Materials.* Vol. 124(2016), pp. 878-886.

[7] Ahmet B. Kizilkanat, Nihat Kabay, Veysel Akyuncu, Swaptik Chowdhury, Abdullah H. Akca. “Mechanical properties and fracture behavior of basalt and glass fiber reinforced concrete: An experimental study”. *Construction and Building Materials.* Vol. 100(2015), pp. 218-224.

[8] Tehmina Ayub, Nasir Shafiq, M. Fadhil Nuruddin. “Mechanical properties of high – performance concrete reinforced with basalt fibres”. *Procedia Engineering.* Vol. 77(2014), pp. 131-139.

[9] M.S. Shetty. “Concrete Technology – Book”.

[10] IRICE. “Hand Book of Material Testing”.

[11] IS: 10262 – 2009. “Concrete Mix Proportioning – Guidelines”

[12] IS: 4031 (Part 1 to 5) – 1996. “Method of Physical Tests for Hydraulic Cement” – for Fineness, Soundness, Consistency, Initial & Final Setting Time.

[13] IS: 2386 (Part – 1 & 3) – 1963. “Methods of Test for Aggregates for Concrete” – Partical Size, Specific Gravity, Water Absorption.

[14] IS: 1199 – 1959. “Methods of Sampling and Analysis of Concrete”.

[15] IS: 516 – 1959. “Methods of Tests for Strength of Concrete”.

[16] IS: 5816 – 1999. “Splitting Tensile Strength of Concrete - Method of Test”.

[17] IS: 9013 – 1978. “Method of Making, Curing and Determining Compressive Strength of Accelerated - Cured Concrete Test Specimens”.