Experimental Study on Glass Fiber Reinforced Concrete With Partial Replacement Of Cement With Ggbs And Fly Ash

K.Anand kumar[1], C.Sudha[2]

[1]*SRM University, Kattankulathur*
[2] *Assistant Professor, SRM University, Kattankulathur*

Abstract - *In the whole world concrete is mostly used in mass quantity for a construction. It is expected that in the near future, the civil engineering community will have to produce structures in harmony with the concept of sustainable development. A number of studies have been carried out to investigate the possibility of utilizing a broad range of materials as partial replacement material for cement in the production of concrete using various different materials like fly ash, silica fume, GGBS etc. Glass fiber reinforced concrete or GFRC is a composite that has glass fibers instead of steel stands for its reinforcement. AR Glass fibers are designed specifically for use in concrete.*

The present paper deals with investigating characteristics of M40 concrete with partial replacement of cement with GGBS, Fly ash and glass fiber. The scope of present investigation deals with strength properties of concrete, on the effect of partial replacement of cement by fly ash with 10%, GGBS with different percentage (i.e 10%, 20%, 30%) was used in concrete mix containing composite glass fibers are different percentage (i.e 0%,0.5% and 1.0%).Each series consists cubes, cylinders and beams as per IS standard. The tests are conducted to find out the flexural strength, split tensile strength, compressive strength at the age of 7days, 14days and 28days. Water absorption, acid and sulphate resistance tests are conducted to find out the durability strengths at the age of 28 days. Concrete is mixture of cement, fine aggregate, coarse aggregate and water. It is found that by the partial replacement of cement with fly ash, GGBS and Glass fiber helped to improving the strength of concrete substantially compared to normal mix concrete.

***Key Words*:** Cement, coarse aggregate, compressive strength, Glass fibre reinforced concrete, split tensile strength

1.INTRODUCTION

Concrete is most widely used man-made construction material in the world. It is obtained by mixing of two components i.e. aggregate and paste. Usually the paste is mix of Portland cement and water, binds the aggregate (usually sand and gravel or crushed stone) into a rocklike mass known as Concrete. The hardening is because of the chemical reaction of the cement and water, which continue for long period leading too stronger with age. The usefulness, elegance and the durability of concrete structures, built during the first half of the last century with ordinary portland cement (OPC) and plain round bars of mild steel. The easy availability of the ingredients (compromising quality) of concrete was used. Strength was emphasized without a thought of the durability of structures. As a consequence of the liberties taken, the durability of concrete was highly affected. After 1970 or thereabout the use of high strength tensile bars with surface deformation started. Significant changes in constituents and properties of concrete were initiated and Engineers started using supplementary cementitious materials and admixtures in concrete, often without adequate considerations.

1.1. Alkali Resistant Glass fiber

Glass fibers are very numerous extremely fine fibers of glass. Ordinary glass fiber cannot be used in portland cement mortars or concretes because of chemical attack by the alkaline cement paste. Zirconia and other alkali-resistant glass fibers possess better durability to alkaline environments, but even these are reported to show a gradual deterioration with time. Similarly, most natural fibers, such as cotton and wool, and many synthetic polymers suffer from lack of durability to the alkaline environment of the portland cement paste.

It is well known that the addition of any type of fibers to plain concrete reduces the workability. Since fibers impart considerable stability to a fresh concrete mass, the slump cone test is not a good index of workability. For example, introduction of 1.5 volume percent steel or glass fibers to a concrete with 200 mm of slump is likely to reduce the slum of the mixture to about 25 mm, but the place ability of the concrete and its compatibility under vibration may still be satisfactory. Therefore, the Vee be test is considered more appropriate for evaluating the workability of fiber-reinforce concrete mixtures.

1.2. Ground granulated blast-furnace (GGBS)

Ground granulated blast-furnace slag also called slag cement, is made from iron blast-furnace slag; it is a nonmetallic hydraulic cement consisting essentially of silicates and alumina silicates of calcium developed in a molten condition simultaneously with iron in a blast furnace. The molten slag at a temperature of about 1500°C is rapidly chilled by quenching in water to form a glassy sand like granulated material. Which is ground to less than 45 microns, has a surface area fineness of about 400 to 600 m2/kg. The relative density (specific gravity) for ground granulated blast furnace slag is in the range of 2.85 to 2.95. The bulk density varies from 1050 to 1375 kg/m3.

1.3 Fly ash

Fly Ash is a by-product of the combustion of pulverized coal in electric power generation plants. When the pulverized coal is ignited in the combustion chamber, the carbon and volatile materials are burned off. However, some of the mineral impurities of clay, shale, feldspars, etc., are fused in suspension and carried out of the combustion chamber in the exhaust gases. As the exhaust gases cool, the fused materials solidify into spherical glassy particles called Fly Ash. Due to the fusion-in-suspension these Fly Ash particles are mostly minute solid spheres and hollow ecospheres with some particles even being plerospheres, which are spheres containing smaller spheres. The size of the Fly Ash particles varies but tends to be similar to slightly larger than Type I Portland cement. The Fly Ash is collected from the exhaust gases by electrostatic precipitators or bag filters. Chemical makeup of Fly Ash is primarily silicate glass containing silica, alumina, iron and calcium. Color generally ranges from dark grey to yellowish tan for Fly Ash used for concrete. ASTM C 618 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as Mineral Admixture in Concrete has two designations for Fly Ash used in concrete - Class F and Class C.

Class F Fly Ash is normally produced from burning anthracite or bituminous coal that meets the applicable requirements. This class of Fly Ash has pozzolanic properties and will have a minimum silica dioxide plus aluminum oxide plus iron oxide of 70%.

Class C Fly Ash is normally produced from subbituminous coal that meets the applicable requirements. This class of Fly Ash, in addition to having pozzolanic properties, also has some cementitious properties and will have a minimum silica dioxide plus aluminum oxide plus iron oxide content of 50%. Most state and federal specifications allow, and even encourage, the use of Fly Ash; especially, when specific durability requirements are needed. Fly Ash has a long history of use in concrete. Fly Ash is used in about 50% of ready mixed concrete (PCA 2000). Class C Fly Ash is used at dosages of 15 to 40% by mass of the cementitious materials in the concrete. Class F is generally used at dosages of 15 to 30%.

2. EXPERIMENTAL INVESTIGATION

2.1 Mix Design

The selection of suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible is termed the concrete mix design. The mix design of the concrete has been carried out based on IS 10262 – 2009. In this Experimental study we are using M-40 grade concrete. The factors affecting the strength of concrete at a given age and cured at prescribed temperature is the degree of compaction.

2.2 Mix Design / Material Proportions (Codes)

It was found that the cement concrete was dark in color and was cohesive. The amount of water in the mixture played an important role on the behavior of fresh concrete. When the mixing time was long mixture with high water content bleed and segregation of aggregates and the paste occurred. This phenomenon was usually followed by compressive strength of hardened concrete.

2.3 Materials Used

The materials used in the preparation of concrete mix includes cement, fine aggregates, coarse aggregates and glass fibers. Each material was tested & it's physical properties are described below.

2.3.1 Cement

Ordinary Portland cement of 43 grade were used, as per code IS 8112 (1989). The normal consistency and initial setting time of cement was 30% and 30 minutes respectively.

Table 1.1 Physical Properties of Cement

Physical Properties	Observed Values
Grading Type	OPC 53 grade
Fineness Modulus	1.8%
Specific Gravity	3.15
Initial Setting Time	165Min
Final Setting Time	456Min

2.3.2 GGBS

Ground-granulated blast-furnace slag (**GGBS** or GGBFS) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder.

Table 1.2 Physical Properties of GGBS

Physical Properties	Observed Values
Grading Zone	Zone – II
Fineness Modulus	3.08
Specific Gravity	2.66
Water Absorption	1.13%

2.3.3 Fly ash

Fly ash is a byproduct from burning pulverized coal in electric power generating plants. During combustion, mineral impurities in the coal (clay, feldspar, quartz, and shale) fuse in suspension and float out of the combustion chamber with the exhaust gases. As the fused material rises, it cools and solidifies into spherical glassy particles called fly ash. Fly ash is collected from the exhaust gases by electrostatic precipitators or bag filters.

Table 1.3 Physical Properties of Flyash

Physical Properties	Observed Values
Color	White
Specific Gravity	2.18
Shape	Spherical
Bulk density(g/cm-3)	1.5

2.3.4 Fine Aggregate

River sand (Coarse sand) was used as fine aggregate. Zone – II sand has been used in this experimental study. The test procedures as mentioned in IS-383 (1970) were followed to determine the physical properties of fine aggregate are shown in Table 3.4.

Table 1.4 Physical Properties of Fine Aggregates

Physical Properties	Observed Values
Fineness Modulus	8%
Specific Gravity	2.56
Initial Setting Time	55Min
Final Setting Time	9Hours

2.3.5 Coarse Aggregate

The coarse aggregate used here with having maximum size is 20mm. We used the IS 383:1970 to find out the proportion of mix of coarse aggregate, with 45% 12.5mm size and 55% 20mm. The physical properties of coarse aggregate as tabulated in Table 3.5.

Table 1.5 Physical Properties of Coarse Aggregates

Physical Properties	Observed Values
Fineness Modulus	2.71%
Specific Gravity	2.75
Water Absorption	0.56%

2.3.6 Glass Fiber

Glass fiber also called fiberglass. It is material made from extremely fine fibers of glass Fiber is a lightweight, extremely strong, and robust material. Although strength properties are somewhat lower than carbon fiber and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed using molding processes. It has remarkable physical and mechanical assets. GFRC properties are dependent on the quality of materials and accuracy of production method. In most of the glass fibers the content of glass fibers differ from 3 to 7 percent by weight however, when the fiber ratio goes up density declines. Glass is the oldest, and most familiar, performance fiber. Fibers have been manufactured from glass since the 1930s. The specifications of these fibers are presented in Table 1.6and the image of the Glass Fiber is shown in Figure 1

The Glass fibers are the most common of all reinforcing fibers for polymeric matrix composites (PMC). The principal advantages of glass fibers are low cost, high tensile strength, high chemical resistance and excellent insulating properties.

Figure 1 Glass Fiber

Table 1.6 Physical Properties of Glass Fiber

Physical Properties	Values
Type	Alkali resistant glass fiber
Density	2.60
Elastic Modulus (Gpa)	74Gpa
Tensile Strength (Mpa)	3500Mpa
Length (mm)	13mm

2.3.7 Water

As per recommendation of IS: 456 (2000), the water to be used for mixing and curing of concrete should be free from deleterious materials. Therefore potable water was used in the present study in all operations demanding control over water quality.

3. EXPERIEMENTAL PROCEDURES AND TEST

3.1 Slump Test

Fresh concrete when unsupported will flow to the sides and sinking in height will take place. This vertical settlement is known as slump. The workability (ease of mixing, transporting, placing and compaction) of concrete depends on wetness of concrete (consistency) i.e., water content as well as proportions of fine aggregate to coarse aggregate and aggregate to cement ratio. The slump test which is a field test is only an approximate measure of consistency defining ranges of consistency for most practical works. This test is performed by filling fresh concrete in the mould and measure the settlement i.e., slump.

3.2 Hardened Concrete Properties

3.2.1 Compression Test On Concrete Cubes The determination of the compressive strength of concrete is very important because the compressive strength is the criterion of its quality. Other strength is generally prescribed in terms of compressive strength. The strength is expressed in N/mm2 . This method is applicable to the making of preliminary compression tests to ascertain the suitability of the available materials or to determine suitable mix proportions. The concrete to be tested should not have the nominal maximum size of aggregate more than 20mm test specimens are either 15cm cubes or 15cm diameter used. At least three specimens should be made available for testing. Where every cylinder is used for compressive strength results the cube strength can be calculated as under. Minimum cylinder compressive strength = 0.8 x compressive strength cube (15cm x 15 cm x 15cm) The concrete specimens are generally tested at ages 7 days,14days,28days.

3.2.2 Split Tensile Test On Cylinder Concrete is strong in compression but weak in tension. Tension stresses are likely to develop in concrete due to drying shrinkage, rusting of reinforcement, temperature gradient etc. In concrete road slab this tensile stresses are developed due to wheel loaded and volume changes in concrete are available to determine this. Split test is one of the indirect methods available to find out the tensile strength.

3.2.3 Flexural Test On Beams It is the ability of a beam or slab to resist failure in bending. It is measured by loading un-reinforced 6x6 inch concrete beams with a span three times the depth (usually 18 in.). The flexural strength is expressed as "Modulus of Rupture" (MR) in psi. Flexural MR is about 12 to 20 percent of compressive strength.

3.2.4 Acid Attack Test: The concrete cube specimens of various concrete mixtures of size 150 mm were cast and after 28 days of water curing, the specimens were removed from the curing tank and allowed to dry for one day. The weights of concrete cube specimen were taken. The acid attack test on concrete cube was conducted by immersing the cubes in the acid water for 28days after 28 days of curing. Hydrochloric acid (HCL) with pH of about 2 at 5% weight of water was added to water in which the concrete cubes were stored. The pH was maintained throughout the period of 28 days. After 28 days of immersion, the concrete cubes were taken out of acid water. Then, the specimens were tested for compressive strength. The resistance of concrete to acid attack was found by the % loss of weight of specimen and the % loss of compressive strength on immersing concrete cubes in acid water.

3.2.5 Sulphate Attack Test The resistance of concrete to sulphate attacks was studied by determining the loss of compressive strength or variation in compressive strength of concrete cubes immersed in sulphate water having 5% of sodium sulphate (Na2SO4) and 5% of magnesium sulphate (MgSO4) by weight of water and those which are not immersed in sulphate water. The concrete cubes of 150mm size after 28days of water curing and dried for one day were immersed in 5% Na2 SO4 and 5% MgSO4 added water. The concentration of sulphate water was maintained throughout the period. After 28days immersion period, the concrete cubes were removed from the sulphate waters and after wiping out the water and girt from the surface of cubes tested for compressive strength following the procedure prescribed in IS: 516- 1959. This type of accelerated test of finding out the loss of compressive strength for assessing sulphate resistance of concrete Mehta and Burrows (2001). Figure 5 represents the Percentage loss in strength of M40 due to Sulphate respectively

4. RSULTS & DISCUSSION

4.1 RESULTS

The result of the investigations carried out for the selection of proper materials to arrive at the optimum mix proportions and the results of fresh and hardened properties of ordinary plain concrete with or without glass fibre are given below

4.2 MIX PROPORTIONS

Table 4.1(a) mix proportions

Ingredients	unit	MIX 0	MIX 1	MIX 2	MIX 3	MIX 4	MIX 5	MIX 6
Water	Lit/m³	192	192	192	192	192	192	192
Cement	Kg/m³	427	341	298	255	341	298	255
Fine aggregate	Kg/m³	661	654	650	650	654	650	650
Coarse aggregate	Kg/m³	1164	1150	1143	1143	1150	1143	1143
Water cement ratio	By mass	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Fly ash	Kg/m³	-	43	43	43	43	43	43
GGBS	Kg/m³	-	43	86	129	43	86	129
Glass fibre	Weight of Cement	0% of cement	0.5% of cement	0.5% of cement	0.5% of cement	1.0% of cement	1.0% of cement	1.0% of cement

Table 4.1(b) mix Design

Mix	%Glass fibre	%fly ash	%GGBS
M	0	0	0
M1	0.5	10	10
M2	0.5	10	20
M3	0.5	10	30
M4	1.0	10	10
M5	1.0	10	20
M6	1.0	10	30

4.3 SLUMP TEST

Slump Test Results are tabulated in Table 5.1 and shown in Figure 5.1

Table 4.2 Slump flow Test

Mix	M	M1	M2	M3	M4	M5	M6
Slump Test(mm)	100	90	85	80	80	70	65

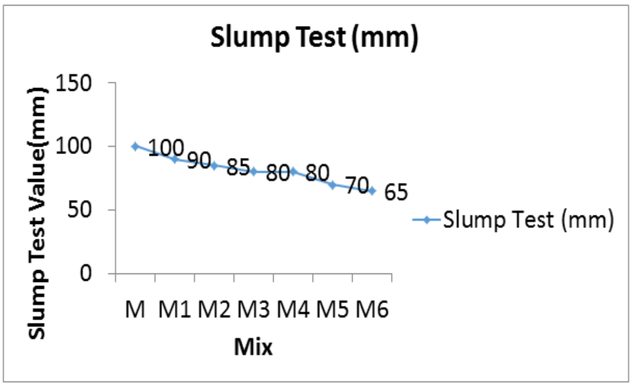

Figure 2 various mixes of slump test

4.4 COMPRESSIVE STRENGTH TEST RESULTS

Compressive strength of the Cubes was conducted for the curing period of 7, 14 & 28 days of strength and the Results are tabulated in Table 5.2 and shown in Figure 5.2

Table 4.3 compressive strength Test Results

Mix	Glass Fibre	Fly ash	GGBS	Compressive Strength		
				7 Days (N/mm²)	14 Days (N/mm²)	28 Days (N/mm²)
M	0.0%	-	-	28.67	40.84	47.28
M1	0.5%	10%	10%	32.93	41.73	49.80
M2	0.5%	10%	20%	34.58	43.86	50.86
M3	0.5%	10%	30%	33.20	42.35	48.46
M4	1.0%	10%	10%	33.60	42.91	51.26
M5	1.0%	10%	20%	34.93	44.62	52.85
M6	1.0%	10%	30%	32.40	41.40	46.77

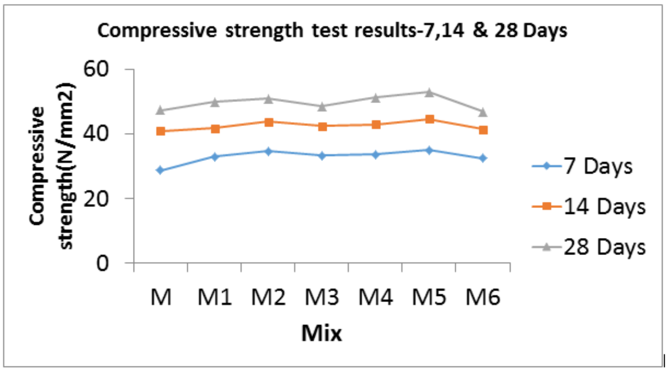

Figure 3 Compressive Strength of Cubes with varying % of Glass Fiber (0%, 0.5%, 1.00%) & fly ash (10%), GGBS (10%,20%,30%) at different curing periods (7 days, 14 days & 28 days)

4.5 Split Tensile Strength Test Results

Split Tensile strength of the Cylinders was conducted for the curing period of 7, 14 & 28 days of strength and the Results are tabulated in Table 4.4

Table 4.4 Split Tensile Strength Results of Cylinders

Mix	Glass Fiber	Fly ash	GGBS	Split Tensile Strength					
				7 Days (N/mm²)	Increases In(%)	14 Days (N/mm²)	Increases In(%)	28 Days (N/mm²)	Increases In(%)
M	0.0%	-	-	2.83		3.43		3.94	
M1	0.5%	10%	10%	2.86	1.04	3.61	4.98	4.56	13.59
M2	0.5%	10%	20%	3.12	9.29	3.77	9.01	5.18	23.93
M3	0.5%	10%	30%	3.06	7.52	3.70	7.29	4.71	16.34
M4	1.0%	10%	10%	2.93	3.41	3.72	7.79	4.77	17.40
M5	**1.0%**	**10%**	**20%**	**3.18**	**11.07**	**3.88**	**11.59**	**5.60**	**29.64**
M6	1.0%	10%	30%	3.09	8.41	3.76	8.77	5.06	22.13

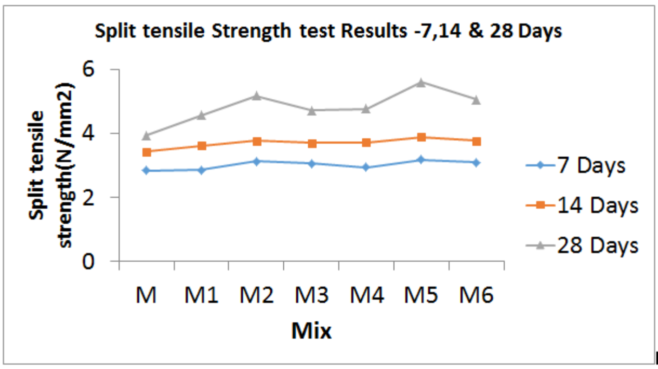

Figure 4 Split Tensile Strength of Cylinders with varying % of Glass Fiber (0%, 0.5%, 1.00%) & fly ash (10%), GGBS (10%,20%,30%) at different curing periods (7 days, 14 days & 28 days)

4.6 Flexural Strength of Beams

Flexural strength of the Beams was conducted for the curing period of 7, 14 & 28 days of strength and the Results are tabulated in Table 4.5 and shown in Figure 5

Table 4.5 Flexural Strength Results of Beams

Mix	Glass Fiber	Fly ash	GGBS	Flexural Strength			
				14 Days (N/mm²)	Increases In(%)	28 Days	Increases In(%)
M	0.0%	-	-	4.48		5.23	
M1	0.5%	10%	10%	4.58	2.18	5.36	2.42
M2	0.5%	10%	20%	4.90	8.57	5.64	7.27
M3	0.5%	10%	30%	4.76	5.88	5.55	5.76
M4	1.0%	10%	10%	4.74	5.48	5.63	7.10
M5	**1.0%**	**10%**	**20%**	**5.02**	**10.76**	**5.86**	**10.75**
M6	1.0%	10%	30%	4.88	8.19	5.69	8.08

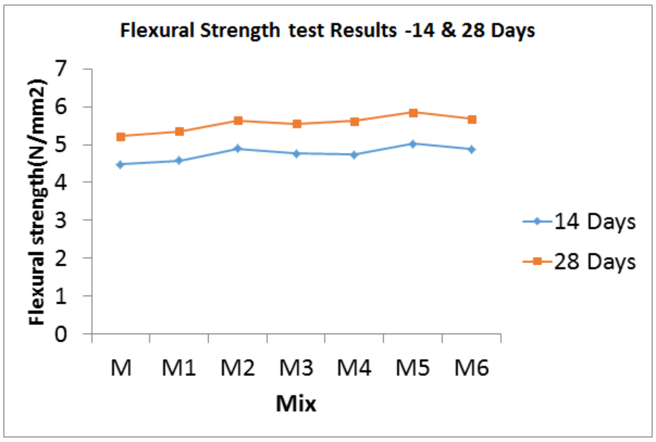

Figure 5 Flexural Strength of Beams with varying % of Glass Fiber (0%, 0.5%, 1.00%) & fly ash (10%), GGBS (10%,20%,30%) at different curing periods (7 days, 14 days & 28 days)

4.7 Acid Resistance Test

The concrete cube specimens of various concrete mixtures of size 150 mm were cast and after 28 days of water curing, the specimens were removed from the curing tank and allowed to dry for one day. The results are given in table 4.6 and Figure 6.

Table 4.6 Acid resistance Test Results

Mix	M	M1	M2	M3	M4	M5	M6
Wt.Loss (Kg)	0.062	0.148	0.105	0.111	0.083	0.133	0.143
Comp.St(N/mm2)	41.64	46.71	47.46	42.04	45.24	46.97	43.33

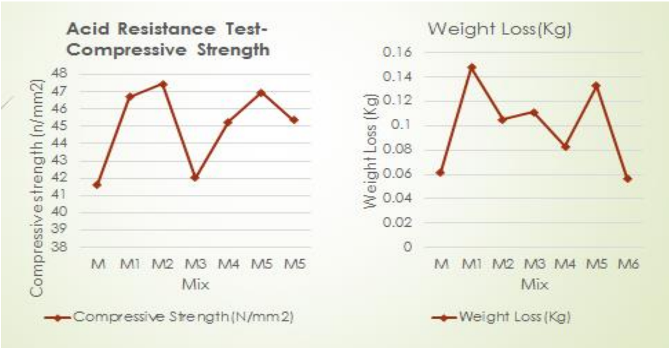

Figure 6 Acid resistance test with varying % of Glass Fiber

4.8 Sulphate Resistance Test

The resistance of concrete to sulphate attacks was studied by determining the loss of compressive strength or variation in compressive strength of concrete cubes immersed in sulphate water having 5% of sodium sulphate (Na_2SO_4) and 5% of magnesium sulphate ($MgSO_4$) by weight of water and those which are not immersed in sulphate water. The results are given in table 4.7 and Figure 7.

Table 4.7 Sulphate resistance Test Results

Mix	M	M1	M2	M3	M4	M5	M6
Wt.Loss (Kg)	0.036	0.018	0.032	0.051	0.036	0.038	0.057
Comp.St(N/mm2)	46.17	47.60	48.53	46.35	49.24	49.64	45.37

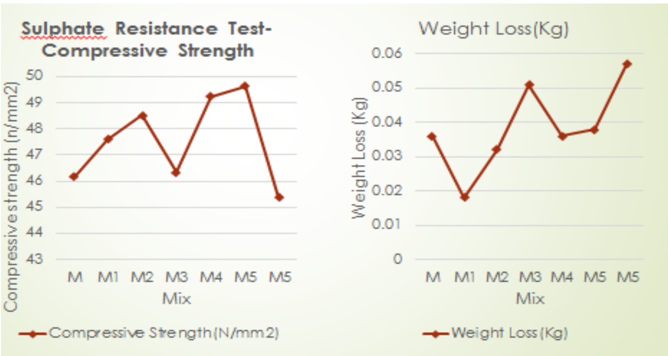

Figure 7 sulphate resistance test with varying % of Glass Fiber

4. Conclusion

The following conclusions are made from the present investigations

1. Compressive strength in concrete enhances up to 1% of glass fibre and then decreases gradually. Split tensile strength of concrete increases with per cent increase in glass fibre up to 1%, 20% GGBS with 10% fly ash. Beyond 1%, 20% GGBS with 10% fly ash there is a decrease in strength of concrete.
2. Replacing the cement with GGBS, fly ash and glass fiber in concrete is one of the best solutions available to the problem of environmental impacts.
3. Split and flexural strength concrete increases with percent increases in GGBS, and glass fiber. Beyond certain limit decreases strength of concrete.
4. Acid and Sulphate resistance test were investigated, Gradually Compressive strength and Weight loss are increased compared to the M40 grade concrete.
5. The investigation M40 concrete, different percentage of fiber, GGBs and fly ash concrete performances are better than normal concrete. When the % fiber, %GGBS increases at the time the compressive, split tensile strength and Durability also increased.

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