Experimental Behaviour of Glass Fiber in Mechanical Properties of Slag Concrete

Er. Tophan Tripathy[1] , Prof.(Dr).Gopal Charan Behera[2]

#Asst. Prof, Civil Engineering Department, GIET, Baniatangi, Bbsr-751013, Odisha, India

Prof. & Head, Civil Engineering Department, GEC, BBSR-756113, Odisha, India

Abstract--Literature shows increase in slag percentage in place of NCA enhances the compressive strength while increase in tensile strength is not substantial. As use of slag has increased the compressive strength to a substantial amount, the civil engineers are in a need to pace their research for enhancement of tensile strength. In normal strength and high strength concrete use of steel fiber with natural coarse aggregate has increased tensile strength to a higher amount. So, the same can be used for enhancement of tensile strength for concrete with slag. Till now no such work is carried out for improvement of tensile strength as well as compressive strength with addition of glass fiber with slag as coarse aggregate. In this study an attempt has been taken to measure fresh properties of concrete as well as the effect of addition of glass fiber on mechanical properties of slag concrete.

Keywords — *Slag, Glass fiber, Concrete Mix, Compressive Strength, Split tensile Strength and flexural Strength..*

I. Introduction

Whenever we look into the major problems on earth, population is the greatest headache, which cannot be avoided. In order to fulfil Human basic needs for a shelter, more and more constructions are required. On the other hand the population is increasing in a geometric progression manner. So, more waste products are evolved. In 2009, construction, demolition waste (C&DW) and waste from iron industries generated in Europe, the United States, and Japan have been reported to about 510, 317, and 77 million tons per year, respectively, but the waste recovered is 30, 82, and 80%, respectively (World Business Council for Sustainable Development 2009). On the other hand, C&DW in Thailand is about 10 million tons per year, and it cannot be recovered (World Business Council for Sustainable Development 2009). If this waste could be recycled as an aggregate for use in concrete production, the amount of landfill required for disposal sites would be reduced, which would help to conserve natural resources. Hence, in the present day, society needs the use of waste products as construction material with preservation of natural diminishing materials. The present society urgently needs the preservation of Natural Coarse Aggregate (NCA). As per a survey, conducted by Ensafe. Inc: a single ferroalloy industry produces 220,000 tons of slag per year. It will require a huge area of land for dumping. Hence, slag can be used as a construction material being success in all compaction tests. That's why the slag which is a waste product can be used for preparation of concrete. Earlier researchers have found the use of Slag is beneficial for improvement of compressive strength, but it is found that the tensile strength is not improving much more. So, there is a need of inclusion of some material which can improve the tensile strength of concrete. Literature shows inclusion of fibers can enhance the tensile strength of concrete. So tensile strength of concrete can be increase by adding glass fiber.

II. Objective

The strength of the concrete depends on the properties of its constituent materials along with their volumetric fraction, water cement ratio, admixture added, curing methodology and degree of control. For the optimum use of slag as a coarse aggregate for making of concrete & increasing the tensile strength by adding glass fiber.

III.SCOPE

To achieve the objective in the stipulated time only M25 grade of concrete with ferroalloys slag as coarse aggregate was designed and its strength with addition of glass fiber as reinforcement with an increment of 1 kg/m^3 was verified.

To achieve the above mentioned objective the total work is divided into two phases. In the first phase a mix design was prepared for M25 and it was casted and tested. Cubes, cylinders and prisms are casted to determine the compressive strength, spilt tensile strength and flexural strength respectively with slag as coarse aggregate as well as glass fibre as reinforcement with an increment of 1 kg/m^3. In the second phase of the work, test results were analyzed and compared with the theoretical values obtained from different codes. The strength of the concrete depends on the properties of its constituent materials along with their volumetric fraction, water cement ratio, admixture added, curing methodology and degree of control. For the optimum use of slag as a coarse aggregate for making of concrete & increasing the tensile strength by adding glass fiber .

IV. MATERIALS AND THEIR PROPERTIES

The common materials used for making concrete is as follows

1 Cement
2 Fine aggregate (sand)
3 Slag as Coarse aggregate
4 Glass fibre

1. Cement

The cement is the commonly used binding material in concrete. The cement primarily consists of the silicates and aluminates of lime and clay. This mixture is ground, blended, fused in a kiln at a temperature nearly equal to 1400˚C and a product clinker is obtained. The clinker is cooled and ground to get cement. Some of the cements classified according to BIS are listed below.

Type	PPC CEMENT
Brand	ULTRATECH
Specific Gravity	3.15
Initial Setting Time	95 mins
Final Setting Time	11 hr 07 mins
Compressive Strength	53 N/mm^2

2. Fine Aggregate

According to the IS code IS: 383-1970 fine aggregate are the materials passing through an IS sieve of 4.75 mm gauge. The fine aggregate acts as the filler material in making concrete. The most important function of the fine aggregate is to provide workability and uniformity in the mixture. The fine aggregate mixed with cement paste to hold the coarse aggregate particles in suspension. In this program sand is used as the fine aggregate. The properties of the sand used in the experimental program are listed below.

ZONE	II
Bulk density	0.56
Water Absorption	1%
Specific Gravity	2.55

3. Slag as Course Aggregate

According to IS: 383-1970 coarse aggregates are the materials which retained in the 4.75 mm sieve. As it covers nearly equal to 60% space in concrete its properties greatly influence the behaviour of concrete. For which it is necessary that the aggregate should have good strength, durability and weather resistance, their surface free from impurities like silt, loam etc which may weaken the bond.

In our experimental program ferroalloys slag is used as coarse aggregate instead of Natural coarse aggregates. Slag is the waste product of the ferroalloys plant. It is first obtained in the molten state and then after hardening the material is crushed to obtain slag. Some useful properties of the slag are listed below. Fig:1 shows a photograph of slag to be mixed.

PROPERTIES	Values
Specific Gravity	3.49
Impact Value	6.1 %
Crushing Value	35.5 %
Water Absorption	0.4%

4. Glass Fibre

Glass fibre is a material consisting of numerous extremely fine fibers of glass**.** Glass fibre is commonly used as an insulating material. It is also used as a reinforcing agent for many polymer products; to form a very strong and light fibre-reinforced polymer (FRP) composite material called glass-reinforced plastic (GRP), popularly known as "fibreglass". Glass fibre has roughly comparable properties to other fibers such as polymers and carbon fibre. Although not as strong or as rigid as carbon fibre, it is much cheaper and significantly less brittle. Fig:2 shows the appearance of glass fibre.

4.1 Physical properties

- Low thermal conductivity
- Will not burn or smolder
- Will not stretch or shrink
- High strength to weight ratio
- Resistant to sparks and welding spatter
- High dielectric strength/low constants
- Resistant to chemical

To achieve the objective in the stipulated time only M25 grade of concrete with ferroalloys slag as coarse aggregate was designed and its strength with addition of glass fiber as reinforcement with an increment of 1 kg/m^3 was verified.

4.2 Chemical Properties

Silicon Dioxide	52-56% min
Calcium Oxide	16-25% Max
Aluminium Oxide	10-12%
Magnesium Oxide	8-12%
Boron Oxide	0-6%
Sodium Oxide	0-1%
Potassium Oxide	0-1%

Fig: 1. Slag to be used in mix

Fig: 2. Glass fibre

V. EXPERIMENTAL PROGRAMME

The experimental programme includes the following steps

1. Batching
2. Preparation of concrete mould
3. Preparation of concrete
4. Tests on fresh concrete
   - 4.1 Slump test
   - 4.2 Compaction factor test
5. Preparation of sample
6. Striping
7. Curing
8. Tests on hardened concrete
   - 8.1 Compressive strength
   - 8.2 Spilt tensile strength
   - 8.3 Flexural strength

1. Batching

In this part of experimental program the calculated quantities of material as per the mix design are weighed and kept separately for preparation of concrete. The required quantities of the material for each mix are listed below. The designation of the mix is done by the combination of alphabet with numerical. The alphabets represent the mix is designed for a characteristic strength of 25 MPa and the numeric shows the amount of glass fibre added in kg/m^3 in a particular mix. The designation MIX-2 is meant for design of concrete for characteristic strength of 25 MPa with 2 kg of glass fibre in 1m^3 of concrete. Total four castings were done as listed in Table-1.

2. Preparation of concrete mould

In this stage of experiment program the concrete mould was cleaned properly and the screws are tightened properly to make sure that no slurry will escape through the joint. After tightening the moulds are oiled properly for easy striping of the specimen. The apparatus for the testing of the fresh concrete is also oiled properly.

3. Preparation of concrete

Among the batched materials sand was thrown into the mixture machine with cement and rotated for few minutes. After through mixing the slag followed by glass fibre were thrown into rotating drum. Then the whole material is thoroughly mixed and water was added to the mix for making concrete. After through mixing the concrete was taken out from the rotating drum and the drum was again made ready for another session.

4. Tests on fresh concrete

In the experiment program the workability tests are conducted on the fresh concrete suddenly after taken out from the rotating drum. Workability is the measure of ease of mixing, transporting, placing, compacting the concrete. Workability affects the degree of compaction of concrete. The following two tests are conducted in each and every batch.

4.1 Slump test
4.2 Compaction factor test

4.1 Slump test

This method of test specifies the procedure to be adopted, either in the laboratory or during the progress of work in the field, for determining, by the slump test, the consistency of concrete where the nominal maximum size of the aggregate does not exceed 38 mm. in this method the slump is measured by withdrawing the slump cone filled with concrete in three layers with tamping of 25 blows in each layer. The arrangement for slump test is shown in fig:3 .The results of slump values for various mixes is reported on Table-2 and fig:3 shows the arrangement of slump test.

4.2 Compaction factor test

The test is more precise and sensitive than slump test and is particularly useful for concrete mixes for very low workability as are normally used when concrete is to be compacted by vibration. Such concrete may consistently fail to slump. This test is designed primarily for use in laboratory but if circumstances permit it may also be used in the field. In this test the concrete is first partially compacted with the help of compacting factor apparatus and then fully compacted with the help of vibrator and the corresponding weight is observed. The ratio of these two is known as compaction factor. The arrangement for compaction factor test is shown in fig: 4. The results of compaction factors for various mix is reported on Table-2.

5. Preparation of sample

In this process the concrete is placed in the moulds; such as cube, cylinders and prism prepared for various tests. Proper care should be taken to remove the entrapped air by using table vibrator or needle vibrator. The concrete specimen with proper compaction attains maximum strength. The concrete should be placed in three layers and proper compaction is done after filling each layer. The top surface should be leveled properly. The mixing of materials is shown in fig: 5.

6. Striping

The fresh concrete is left to set for 24 hours. Then the concrete specimens are designated as discussed earlier with permanent markers. Specimens are removed from the moulds. During the period of striping proper care should be taken to prevent the crushing of concrete on edges.

7. Curing

Curing is the process by which the loss of moisture from the specimen is prevented. It is very much important to maintain the moisture content when the concrete is gaining strength. Lack of curing may lead to development of cracks and reduction of strength. The stripped specimens are cured in a curing tank under room temperature for 28 days. After 28 days of curing, white washing was done for marking of crack pattern. Then concrete specimens taken for testing on harden concrete.

8. Tests on hardened concrete

To determine the properties of the hardened concrete the following tests should be done on the specified specimen. The tests are

8.1 Compressive strength
8.2 Spilt tensile strength
8.3 Flexural strength

8.1 Compressive strength

Compressive strength is defined as the measure of maximum resistance of concrete to axial loading. The cube used for compressive strength is of size 150mm X 150mm X 150mm. there are three specimens are taken for this test. The specimen made clean, dry and placed in between the plates of compression testing machine as shown in figure. The load was applied at the rate of 14 N/mm^2. The maximum load at failure which the cube fails is observed and recorded. The arrangement for compressive strength test is shown in fig: 6 and crushing pattern of cube during compression is shown in fig: 7. The results are shown in tabular form in the Table-3.

8.2 Spilt tensile strength

The concrete is very strong in compression and weak in tension. This test is used to determine the brittle nature of concrete. The size of the specimen is 150 mm diameter and 300 mm height. The test arrangement is shown in figure. The testing specimens should clean, dry and placed in compression testing machine along the length. The force is applied and increased continuously. The arrangement for spilt tensile test is shown in fig:8 and failure is shown by fig: 9. The maximum load at failure is observed and shown in Table-3.

8.3 Flexural strength

This test is conducted to measure the resistance of concrete in bending. The concrete is loaded by two point loads, for which required markings are done. The middle third part is loaded with pure bending. The arrangement of the test is shown in figure. The arrangement for flexural strength test is shown in fig: 10. The load is applied and the load at failure is observed and shown in the Table-3.

To achieve the objective in the stipulated time only M25 grade of concrete with ferroalloys slag as coarse aggregate was designed and its strength with addition of glass fiber as reinforcement with an increment of 1 kg/m^3 was verified.

Table-1: Details of castings

Designation of mix Material	MIX-0 (0 kg/m^3 glass fibre)	MIX-1 (1 kg/m^3 glass fibre)	MIX-2 (2 kg/m^3 glass fibre)	MIX-3 (3 kg/m^3 glass fibre)
Cement (In Kg)	34	34	34	34
Sand (In Kg)	48.746	48.76	48.76	48.76
2.36mm	4.876	4.876	4.876	4.876
1.18 mm	14.626	14.626	14.626	14.626
600 µ	12.184	12.184	12.184	12.184
300 µ	12.184	12.184	12.184	12.184
150 µ	4.876	4.876	4.876	4.876
Slag (In Kg)	138.38	138.38	138.38	138.38
20-12.5 mm	83.028	83.028	83.028	83.028
12.5-4.75 mm	55.352	55.352	55.352	55.352
Glass fibre(In gm)	-	86.47	172.94	259.41
Water (In Kg)	17	17	17	17

Table-2: Test results of fresh concrete

Percentage	**Slump (mm)**	**Compaction Factor**
MIX-0	0	0.9
MIX-1	1	0.9
MIX-2	1	0.9
MIX-3	2	0.9

Fig: 3. Slump test

Fig: 4. Compaction factor apparatus

Fig: 5. Mixing of ingredients

Fig: 6. Arrangement for compressive strength test

Fig: 7. Crushing pattern of cube

Fig: 9. Failure during split tensile test

Fig: 8. Arrangement for split tensile strength

Fig: 10. Arrangement for flexural test.

Table-3: Test Results of Hardened Concrete

MIX	Avg. Weight of cubes (Kg)	Avg. Weight of cylinder (Kg)	Avg. Weight of prism (Kg)	Compressive Strength (N/mm^2) 28 days	Split Tensile Strength (N/mm^2)	Flexural Strength (N/mm^2)
MIX-0	8.95	13.562	12.993	37.33	3.40	5.13
MIX-1	9.13	13.612	13.282	43.24	3.50	5.50
MIX-2	9.17	13.585	13.231	45.89	3.82	6.13
MIX-3	9.19	13.727	13.346	50.90	4.34	6.49

VI. INTERPRETATION OF TEST RESULTS

The test results obtained are shown in the table-3 and compared with values obtained from various codes. The test results such as weight, compressive strength, spilt tensile strength and flexural strength with different quantity of glass fibre are discussed below.

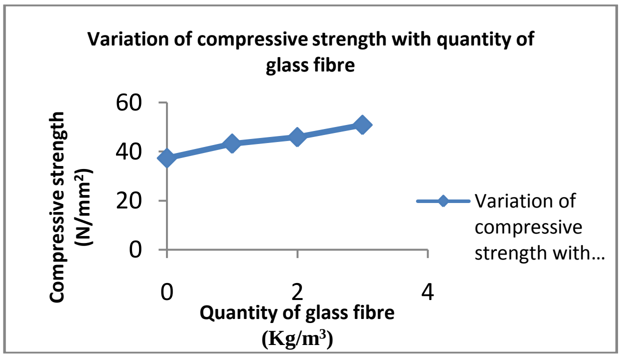
1. Weight

The weight of the specimen depends on specific gravity of its constituent materials .The materials having high specific gravity sustains more compressive load. To verify the effect of weight of the specimen on strength parameters, individual weight of cubes, cylinders, prisms were taken. The values are tabulated in Table-3. The average weight of specimen prepared with MIX-0, MIX-1, MIX-2, and MIX-3 was found to be 8.95 Kg, 9.13 Kg, 9.17 Kg and 9.19 Kg for cubes, 13.562, 13.612, 13.585, 13.727 for cylinders and 12.993, 13.282, 13.231, 13.346 for prism respectively. From the values it is clear that the increase in weight is not marginal. So when the glass fibre is added with slag concrete it may not increase the dead load of the structure marginally.

2. Compressive strength

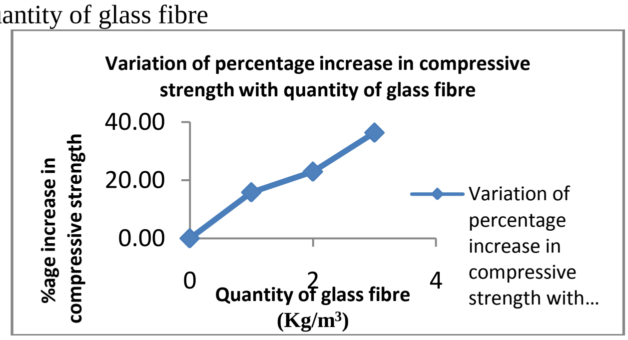
Compressive strength is an important property of harden concrete which influences other mechanical properties of concrete. Compressive strength of concrete specimen prepared with MIX-0, MIX-1, MIX-2, and MIX-3 was found to be 37.33 MPa, 43.24 MPa, 45.89 MPa, and 50.90 MPa respectively. A graph is plotted between the compressive strength and quantity of glass fibre is shown in Fig: 11. Graph shows the increase in compressive strength with increasing in quantity of glass fibre.

FIG: 11. Compressive strength vs. quantity of glass fibre



Percentage increase in compressive strengths of MIX-0 to MIX-3 along with quantity of glass fibre is plotted in the Fig:12. The percentage increase in strength was found to be increased and the variation was found to be gradual till MIX-1. After that the rate of variation decreases slightly followed by a greater rate. In this investigation it is observed that the compressive strength increases with increase in quantity of glass fibre. This may be possible due to presence of glass fibre, which gives an extra binding force internally. So the glass fibre along with slag can be used for design of compression members.

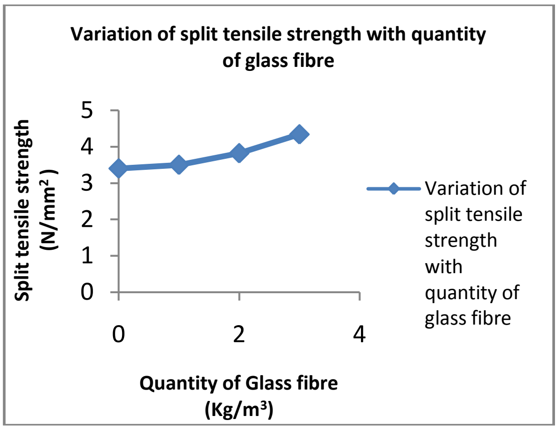
FIG: 12. %age increase in comp. Stress vs. quantity of glass fibre



3. Split tensile strength

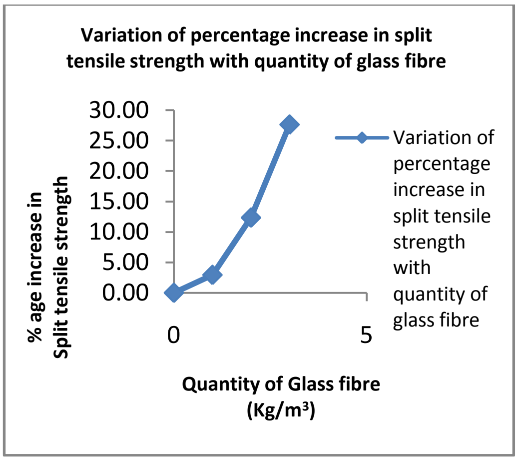
The split tensile strength of concrete specimen with only slag and without glass fibre (MIX-0) and slag having 3Kg/m^3 glass fiber (MIX-100) was found to be 3.40 MPa and 4.34 MPa respectively. The increase in the spilt tensile strength is considerable. The split tensile strength of specimen prepared with MIX-1, MIX-2 and MIX-3 was found to be 3.50 MPa, 3.82 MPa and 4.34 MPa respectively. These values are plotted in the in fig:13. It may be clearly observed that the split tensile strength increases with a low rate initially, but with increase in glass fibre strength increases.

FIG:13. Split tensile strength vs. quantity of glass fibre



The percentage increase in spilt tensile strength is calculated and plotted vs. quantity of glass fibre in fig: 14. Here it is found that initially the variation is marginal. But with increase in quantity of glass fibre, it increases rapidly. This may be due to internal bonding of glass fibre and concrete.

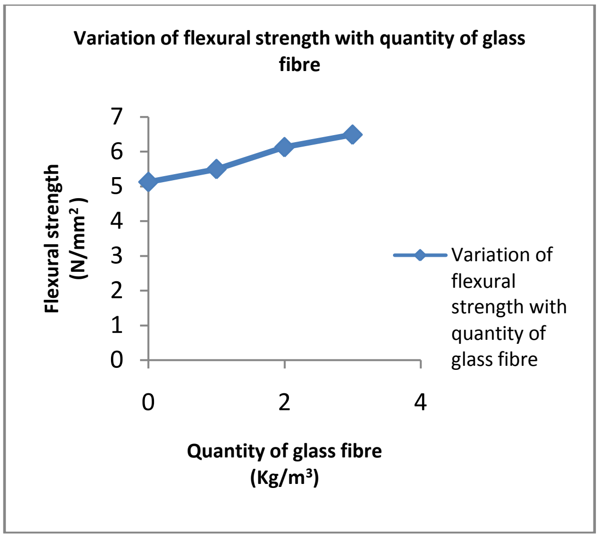
FIG: 14. %age increase in split tensile strength vs quantity of glass fibre



4. Flexural strength

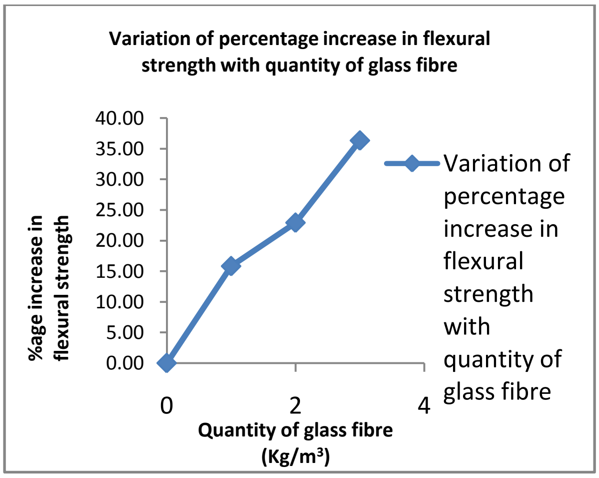
Flexural strength of concrete specimen prepared with MIX-0, MIX-1, MIX-2 and MIX-3 was found to be 5.13 MPa, 5.50 MPa, 6.13 MPa and 6.49 MPa respectively plotted against quantity of glass fibre shown in fig:15. From the graph it is observed that the strength varies gradually with increasing quantity of glass fibre.

FIG: 15. Flexural strength vs. quantity of glass fibre.



The percentage increase in flexural strength is plotted in the Fig:16. In this investigation the percentage change in flexural strength is found to be increasing with increasing in the quantity of glass fibre. An undesirable decrease in rate on the third reading may be due to faulty workmanship.

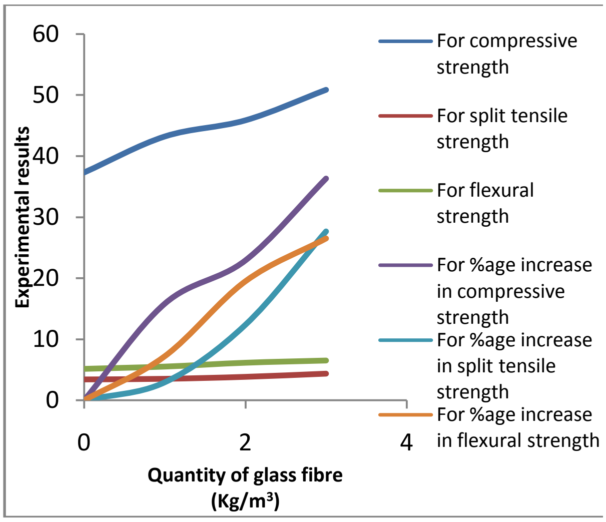
FIG: 16. %age increase in flexural strength vs. quantity of glass fibre



5. Summarisation of the test data

All the data of the experiment are plotted against quantity of glass fibre. From the curves it can be noticed that the parameters like compressive strength, split tensile strength, flexural strength as well as their percentage increase value overly increases with quantity of glass fibre shown in fig: 17.

FIG:17. Summarisation of the test data



VII. CONCLUSION

From the investigation throughout the experiment we concluded that

1. The workability increases with increase in the percentage of glass fiber.

2. The change in weight of specimen with increased quantity of glass fiber is marginal. Hence it rarely affects the dead load of the structure.

3. Compressive strength increases with increase in quantity of glass fiber, so it is better to design compression members with it along with slag.

4. The split tensile strength increases with increase in the quantity of glass fiber, which can be regarded as a good sign from the durability point of view.

5. The flexural strength increases with increase in the quantity of glass fiber.

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