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EXPERIMENTAL ANALYSIS OF STEEL FIBRE-REINFORCED HIGH STRENGTH CONCRETE (M65) WITH PARTIAL REPLACEMENT OF CEMENT BY GGBS

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Abstract : In This Paper Concrete is probably the most extensively used construction material in the world with about six billion tones being produced every year. It is only next to water in terms of per capita consumption. However, environmental sustainability is at stake both in terms of damage caused by the extraction of raw material and being produced every year. It is only next to water in terms of per-capita consumption. However, CO2 emission during cement manufacture. This brought pressures on researchers for the reduction of cement consumption by partial replacement of cement by supplementary materials. These materials called pozzolanas when combined with calcium hydroxide, exhibits cementitious properties. Most commonly used pozzolanas are fly ash, silica fume, metakaolin, ground granulated blast furnace slag (GGBS). This needs to examine the admixtures performance when blended with concrete so as to ensure a reduced life cycle cost. The present paper focuses on investigating characteristics M65 grade concrete with partial replacement of cement with ground granulated blast furnace slag (GGBS) by replacing cement via 15%, 25%, 35%. The cubes, cylinders are tested for compressive strength, split tensile strength. Durability studies with sulphuric acid and hydrochloric acid were also conducted.

Keywords: *GGBS blended concrete, Strength, Steel Fibers, Replacement, Durability.*

I. INTRODUCTION

Concrete is a composite, brittle material utilized in a variety of engineering structures, including foundations, pavements, tunnels, bridges, walls, reservoirs, and dams. Because of these numerous uses, a great deal of research has been conducted to enhance the characteristics of concrete for greater applicability The addition of steel to concrete was one of many attempts to improve its performance These traditional reinforcements are steel reinforcing bars positioned at precise locations inside the structure to resist applied tensile and shear stresses In contrast, the integration of steel fibers is often discontinuous and random in the concrete mixture For concrete mixtures in which the fibers are evenly scattered, they serve a significant role in reducing the incidence of cracks caused by variations in relative humidity and temperature.

The addition of fibers steel, natural, synthetic to the cementitious mixtures improves their mechanical properties Although the role of fire might not always involve an increase in strength, it has a considerable favorable effect on ductility, resilience to dynamic loading, and toughness Concrete reinforcement with fibers is not a substitute for traditional steel reinforcing bars because steel bars and fibers serve distinctive, but both function in improving the concrete performance Steel fiber-reinforced concrete (SFRC) refers to the inclusion of short, discontinuous steel fibers into the matrix of concrete after mixing Water, aggregates, cement, and steel fibers are the primary components of SFRC Depending on the intended uses, SFRC may additionally comprise pozzolana and admixtures As scientists conduct more investigation on the SFRC in response to rising concerns about the brittle nature of concrete, researchers confront knowledge restraints that may inhibit new academic and research partnerships. Hence, it is critical to build and execute a system that allows academics to acquire crucial knowledge from the best reputable sources available.

Concrete:

Concrete, an artificial stone-like mass, is the composite material that is created by mixing binding material (cement or lime) along with the aggregate (sand, gravel, stone, brick chips, etc.), water, admixtures, etc. in specific proportions. The strength and quality are dependent on the mixing proportions.

The formula for producing concrete from its ingredients can be presented in the following equation:
Concrete = Binding Material + Fine and Coarse Aggregates + Water + Admixture

Concrete is a very necessary and useful material for construction work. Once all the ingredients cement, aggregate, and water unit of measurement mixed inside the required proportions, the cement and water begin a reaction with one another to bind themselves into a hardened mass. This hardens the rock-like mass in the concrete. Concrete is powerful, easy to create, and can be formed into varied shapes and sizes. Besides that, it is reasonable, low cost, and instantly mixed. It is designed to allow reliable and high-quality fast-track construction. Structures designed with the concrete unit of measurement are plenty durable and should be designed to face up to earthquakes, hurricanes, typhoons, and tornadoes. This is an incredible advancement.

II. LITERATURE SURVEY

Muhammad Nasir Amin, Waqas Ahmad, Kaffayatullah Khan, Ayaz Ahmad (2022):
This study performed a scient metric-based examination of the literature on steel fibre reinforced concrete (SFRC) to identify its key elements. Typical review papers are limited in their capacity to link distinct segments of the literature in an organized and systematic method. The most challenging aspects of current research are knowledge mapping, cooccurrence, and co-citation. The Scopus search engine was used to search for and obtain the data required to meet the goals of the study. During the data evaluation, the relevant publication sources, keyword assessment, productive authors based on publications and citations, top papers based on citations received, and areas vigorously involved in SFRC studies were recognized. Additionally, the mostly employed keywords by authors in SFRC research include steel fibres, fibre-reinforced concrete, concrete, steel fibre-reinforced concrete, and reinforced concrete. The assessment of authors revealed that 39 authors had published at least 30 articles. Moreover, China, the United States, and India were found to be the most active and participating countries based on publications on SFRC research. This study can assist academics in building collaborative initiatives and communicating new ideas and techniques because of the quantitative and graphical depiction of participating nations and researchers.

Victor Nogueira Lima', Daniel Carlos Taissum Cardoso, Flavio de Andrade Silva (2021):
Recently, fiber-reinforced concrete (FRC) creep behavior has become a much-addressed topic, and the main gap found in the literature is whether cracked FRC is stable in the serviceability limit state. Therefore, this work aims to investigate the creep behavior of steel and polypropylene (PP) FRC by analyzing the growth of the crack opening displacement over time in prismatic specimens subjected to sustained bending. Sustained load tests were also performed on FRC constituents and on the fiber matrix interface in order to evaluate individually their long-term response, and to understand their contribution in bending. Based on a model proposed, the rotation in a plastic hinge located in the crack area could be calculated considering the three mechanisms evaluated fiber pull-out, concrete compression, and shrinkage. It could be concluded that the fiber pull-out mechanism plays a primary role in creep deformation in pre-cracked elements subjected to sustained bending loads.

Dorys C. González, Alvaro Mena (2023):
This study deals with the influence of the fiber concrete mesostructured on the size effect under compressive fatigue loading. For this purpose, three series of cylindrical specimens of steel fiber-reinforced concrete were fabricated. Before fatigue testing, all the cylinders were scanned and the main morphological, orientation, and distribution parameters of the pores and fibers were checked. The images reveal that, near the cylinders' walls, the porosity is lower than that in the cores and is even lower for large sizes. Additionally, larger specimens are more vulnerable to compressive fatigue loading, resulting in a reduction in fatigue life.

Job Thomas and Ananth Ramaswamy (2007):
This paper presents the results from an experimental program and an analytical assessment of the influence of addition of fibers on mechanical properties of concrete. Models derived based on the regression analysis of 60 test data for various mechanical properties of steel fiber-reinforced concrete have been presented. The various strength properties studied are cube and cylinder compressive strength, split tensile strength, modulus of rupture and post cracking performance, modulus of elasticity, Poison's ratio, and strain corresponding to peak compressive stress. The variables considered are grade of concrete, namely, normal strength (35 MPa),

moderately high strength (65 MPa), and high-strength concrete (85 MPa), and the volume fraction of the fiber (V =0.0, 0.5, 1.0, and 1.5%). The strength of steel fiber-reinforced concrete predicted using the proposed models have been compared with the test data from the present study and with various other test data reported in the literature. The proposed model predicted the test data quite accurately. The study indicates that the fiber matrix interaction contributes significantly to enhancement of mechanical properties caused by the introduction of fibers, which is at variance with both existing models and formulations based on the law of mixtures.

M. T. Kazemi, F. Fazileh, and M. A. Ebrahiminezhad (2007):

The most commonly used method of measuring the fracture energy, G, is the method proposed by RILEM TC-50. Although this procedure is widely examined for plain concrete, its applicability to steel-fiber-reinforced concrete (SFRC) needs further evaluation. In this paper, in addition to the RILEM specimen of the three-point bend test, a cylindrical test specimen is also examined. All cylindrical-beam specimens had 300-mm length, with 250-mm span, and 150-mm diameter. The same moulds of standard compression tests were used to cast the SFRC specimens. Steel fibers were crimped and had an average length of 32 mm. Fibbers had an average tensile strength of 600 MPa and the apparent modulus of elasticity of 200 GPa. Results obtained from this study were compared with other experimental results on notched beams. The results of the cylindrical specimens were very close to the results of the beams with rectangular cross section. The effect of the volumetric fraction of fibers in SFRC on the G for three low-percent-volume fractions of steel fibers, 0.5, 1, and 1.5%, was examined. The values of G increased about 11, 15, and 21 times when fiber volume fraction of 0.5, 1, and 1.5% were added to plain concrete, respectively. The cylindrical beams also could be used for the evaluation of existing materials by drilling the structure and obtaining cylindrical cores. By means of linear elastic fracture mechanics analysis it was found that, the minimum depth of initial notch in cylindrical specimen should be greater than 10% of the diameter to ensure geometrical unstable crack growth. Moreover, a new trilinear cohesive law, which predicts both the peak-load and the post peak behaviors more accurately than the bilinear cohesive law, is proposed.

III. METHODOLOGY

3.1 PROCEDURE FOR TESTING THE COMPRESSIVE STRENGTH OF CONCRETE CUBES:

Following are the procedure for testing the Compressive strength of Concrete Cubes:

Apparatus for Concrete Cube Test :

Compression testing machine

- Preparation of Concrete Cube Specimen
  The proportion and material for making these test specimens are from the same concrete used in the field.

- Specimen
  6 cubes of 15 cm × 15 cm ×15 cm size

- Mixing of Concrete for Cube Test
  Mix the concrete either by hand or in a laboratory batch mixer

Hand Mixing

- Mix the cement and fine aggregate on a watertight none-absorbent platform until the mixture is thoroughly blended and is of uniform color.
- Add the coarse aggregate and mix with cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch.
- Add water and mix it until the concrete appears to be homogeneous and of the desired consistency.

Sampling of Cubes for Test :

1. Clean the moulds and apply oil.
2. Fill the concrete in the moulds in layers approximately 5 cm thick.

3. Compact each layer with not less than 35 strokes per layer using a tamping rod (steel bar 16mm diameter and 60cm long, bullet-pointed at lower end).
4. Level the top surface and smoothen it with a trowel.

Curing of Cubes:

The test specimens are stored in moist air for 24 hours and after this period the specimens are marked and removed from the moulds and kept submerged in clear freshwater until taken out prior to the test.

Procedure for Concrete Cube Test :

- Remove the specimen from the water after specified curing time and wipe out excess water from the surface.
- Take the dimension of the specimen to the nearest 0.2m
- Clean the bearing surface of the testing machine
- Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.
- Align the specimen centrally on the base plate of the machine.
- Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
- Apply the load gradually without shock and continuously at the rate of 140 kg/cm^2/minute till the specimen fails
- Record the maximum load and note any unusual features in the type of failure.

Compressive Strength of Concrete at Various Ages:

The strength of concrete increases with age. The table shows the strength of concrete at different ages in comparison with the strength at 28 days after casting.

Compressive Strength of Different Grades of Concrete at 7 and 28 Days :

Age	Strength percent
7 days	65%
28 days	99%

Compressive Strength of Different Grades of Concrete at 7 and 28 Days:

Grade of Concrete	Minimum (N/mm^2) compressive strength at 7 days	Specified characteristics compressive strength at (N/mm^2) 28 days
M15	10	15
M20	13.5	20
M25	17	25
M30	20	30

M35	23.5	35
M40	27	40
M45	30	45
M50	32.5	50
M55	37	55
M60	40.5	60
M65	47	65
M70	50.5	70

3.2 PROCEDURE FOR TESTING THE SPLIT TENSILE STRENGTH OF CONCRETE:

Following are the procedure for testing the Split tensile strength of Concrete
Cylinders:

Apparatus for Split Tensile Strength test of concrete:

Testing Machine:
Testing machine shall meet the following requirements:

- Firstly, it shall conform to the requirements of Test Method C 39/C 39M.
- Secondly, testing machine should be able to apply the load continuously and without shock.
- Thirdly, it should be able to apply loads at a constant rate within the range 0.7 to 1.4 MPa/min (1.2 to 2.4 MPa/min based on IS 5816 1999) splitting tensile stress until the specimen fails.

Plate or Supplementary Bearing Bar:
It is employed when the diameter or the largest dimension of the upper bearing face or the lower bearing block is less than the length of the cylinder to be tested.
Plate width is 50mm
it shall be used in such manner that the load will be applied over the entire length of the specimen.

Bearing Strips:

Two bearing strips are used.

bearing strip size is 3.2 mm thick, 25 mm wide, and of a length equal to, or slightly longer than, that of the specimen

The bearing strips placed between the specimen and both the upper and lower bearing blocks of the testing machine or between the specimen and supplemental bars or plates if needed.

Sampling of Concrete Cylinders Concrete specimen moulds

- It shall be made of steel, and 3 mm thick.
- The mould shall be capable of being opened longitudinally to facilitate the removal of the specimen and is provided with a means of keeping it closed while in use.
- The mean internal diameter of the mould is 15 cm ± 0.2 mm and the height is 30 +/- 0.1 cm.
- The moulds are provided with a metal base plate mould.
- Moulds need to be coated with a thin film of mould oil before use, in order to prevent adhesion of concrete.

Tamping Rod

- Used for manual compaction of concrete specimen
- It shall be a round, straight steel rod with at least the tamping end rounded to a hemispherical tip of the same diameter as the rod.
- Both ends rounded, if preferred.
- Tamping rod diameter is 16 mm and its length is 600 mm.

Concrete pouring and compaction:

1. After the mixture is prepared, it is poured into the oiled mould in layers approximately 5 cm deep.
2. Then, each layer is compacted either by hand or by vibration.
3. For manual compaction, use tamping bar.
4. Distributed bar stroke uniformly in order to compact it properly.
5. Minimum tamping bar stroke for each layer is 30.
6. Penetrate strikes in to the underlying layer

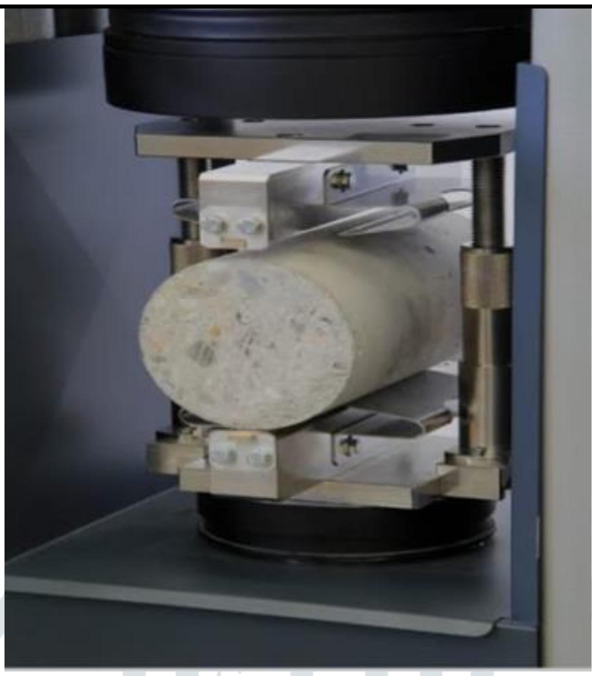
7. Apply the rode for the entire depth of bottom layer
8. complete top layer compaction
9. Lastly, the surface of the concrete should be finished level with the top of the mould, using a trowel and covered with a glass or metal plate to prevent evaporation.

Curing of Specimen:

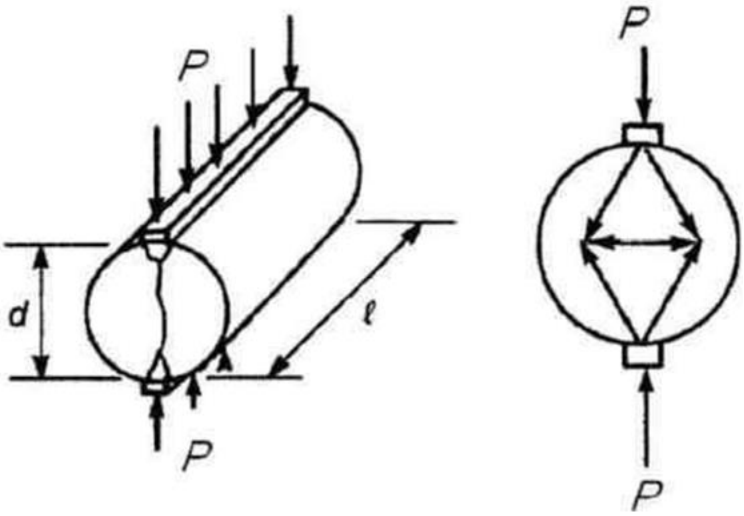
- Casted specimen should be stored in a place at a temperature of 27° +/- 2°C for 24 +/- 0.5 hrs. from the time addition of water to the dry ingredients.
- After that, the specimen should be marked and removed from the mould and immediately submerged in clean fresh water or saturated lime solution and kept there until taken out just prior to the test.
- The water or solution in which the specimens are kept should be renewed every seven days and should be maintained at a temperature of 27° +/- 2°c.
- For design purpose, the specimen cured for 28 days.
- At last, for each reading, three specimens shall be casted and tested. Then, the average tensile strength will be taken.

Procedure of Splitting Tensile Test :

- Initially, take the wet specimen from water after 7, 28 days of curing; or any desired age at which tensile strength to be estimated.
- Then, wipe out water from the surface of specimen
- After that, draw diametrical lines on the two ends of the specimen to ensure that they are on the same axial place.
- Next, record the weight and dimension of the specimen.
- Set the compression testing machine for the required range.
- Place plywood strip on the lower plate and place the specimen.
- Align the specimen so that the lines marked on the ends are vertical and centered over the bottom plate.
- Place the other plywood strip above the specimen.
- Bring down the upper plate so that it just touches the plywood strip.
- Apply the load continuously without shock at a rate within the range 0.7 to
- 1.4 MPa/min (1.2 to 2.4 MPa/min based on IS 5816 1999)
- Finally, note down the breaking load(P)



Calculations:
Calculate the splitting tensile strength of the specimen as follows:
T= 2P/ pi LD
Were,
T = splitting tensile strength, MPa
P: maximum applied load indicated by the testing machine
D: diameter of the specimen, mm
L: length of the specimen, mm



IV. **RESULTS AND DISCUSSION**

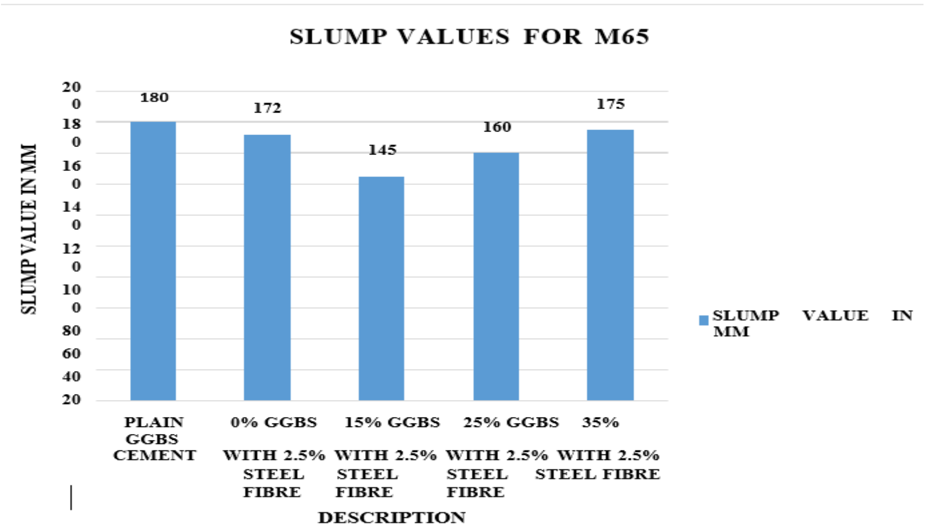
4.1 TESTS FOR WORKABILITY

Concrete slump test or slump cone test is to determine the workability or consistency of concrete mix prepared at the laboratory or the constructionsite during the progress of the work. The slump is carried out as per procedures mentioned in ASTM C143 in the United States, IS: 1199 – 1959 in India and EN 12350-2 in Europe.

Slump Values for M65

Sr.No	Description	Slump
1.	Plain concrete	180

2.	0% ggbs with 2.5% steel fibre	172
3.	15% ggbs with 2.5% steel fibre	145
4.	25% ggbs with 2.5% steel fiber	160
5.	35% ggbs with 2.5% steel fibre	175

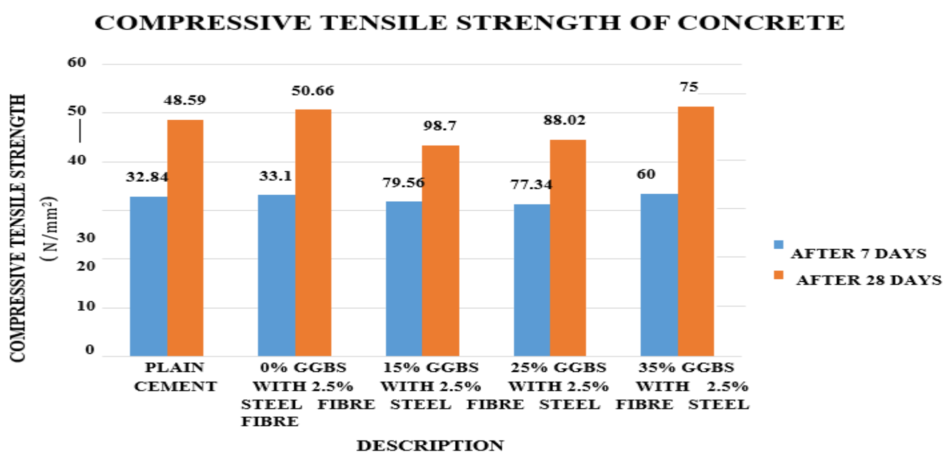


4.2 COMPRESSIVE STRENGTH OF CONCRETE

CTM of 2000 KN capacity was used with load rate of approximately 140 kg/cm /min until failure for Compressive strength test. The test results forcompressive strength are presented in Tables (0%, 15%, 25% and 35% of GGBS concrete) for M65 grades of concrete at room temperature for 7and28 days respectively.

COMPRESSIVE STRENGTH OF CONCRETE

Sr.No	Description	Compressive strength (N/mm2)	
		7 days	28 days
1.	Plain concrete	32.84	48.59
2.	0% ggbs with 2.5% steel fibre	33.10	50.66
3.	15% ggbs with 2.5% steel fibre	79.56	98.77
4.	25% ggbs with 2.5% steel fiber	77.34	88.02
5.	35% ggbs with 2.5% steel fibre	60	75

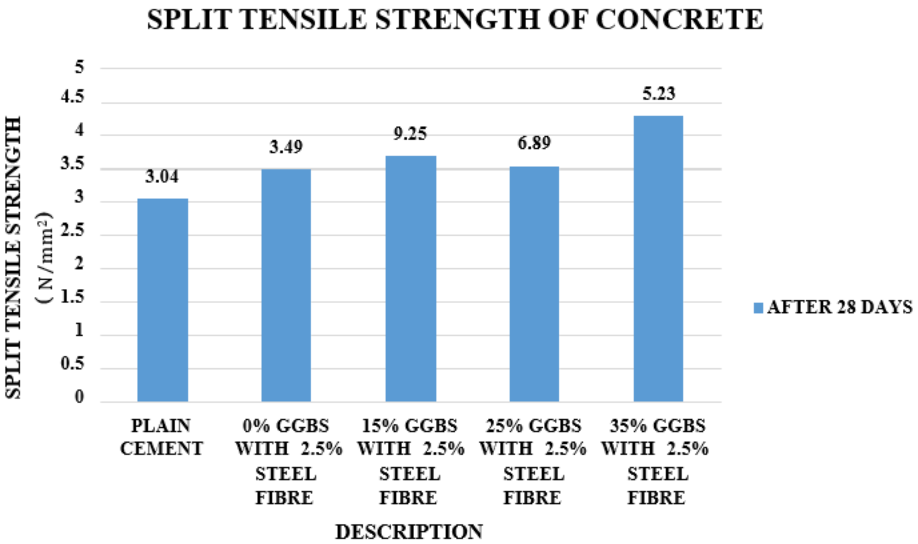


4.3 SPLIT TENSILE STRENGTH OF CONCRETE

For split tensile strength, the load was applied without shock and increasedcontinuously at a nominal rate within the range 1.2 N/mm2 /min to 2.4 N/mm2 /min until failure of the specimen. The test results for split tensilestrength are presented in Table (0%, 15%, 25% and 35% of GGBSconcrete) M65 grades of concrete at room temperature for 28 days respectively.

Split tensile strength of M65 grade concrete

Sr.No.	Description	Split tensile strength (N/mm^2)	
		7 days	28 days
1	Plain Concrete	2.3 N/mm^2	3.04 N/mm^2
2	gbs with 2.5%steel fibre	2.38 N/mm^2	3.49 N/mm^2
3	gbs with 2.5%steel fibre	4.1 N/mm^2	9.25 N/mm^2
4	gbs with 2.5%steel fibre	3.6 N/mm^2	6.89 N/mm^2
5	35% ggbs with 2.5% steel fibre	3.4N/mm^2	5.23N/mm^2



V. CONCLUSION & FUTURE SCOPE

5.1 Conclusion:

This experiment was used to find the optimum possible replacement of cement by GGBS and steel fibre in concrete to produce a better concrete. The followingconclusion are made for GGBS at 35% and 2.5% steel fibre with respect to plain (conventional) concrete.

- It is economical when compared to conventional concrete
- The partial replacement of cement by GGBS not only provides the economy in construction but it also utilization of the GGBS which is generated in huge quantities.
- Workability of concrete increases with the increase in GGBS replacement level.
- The compressive strength of concrete increased when cement is replaced by GGBS. At 35% replacement of cement by GGBS the concrete attained maximum compressive strength.
- The split tensile strength of concrete is increased when cement is replaced with GGBS. At 35% replacement of cement by GGBS the concrete attained maximum split tensile strength.

5.2 Future Scope:

1. Other levels of replacement with GGBS can be researched.
2. Combination of GGBS with different another admixture can be carried out.
3. Studies on replacements levels of high-grade concrete can be carried out.

4. Beams with different shear span to effective depth ratios, varying percentages of tensile reinforcement and varying percentages of GGBS, may be investigated.
5. For use of GGBS concrete as a structural material, it is necessary to investigate the behavior of reinforced GGBS concrete under flexure, shear, torsion and compression.
6. Some tests relating to durability aspects such as water permeability, resistance to penetration of chloride ions, corrosion of steel reinforcement, durability in marine environment etc. need investigation.
7. The study may further be extended to know the behavior of concrete whether it is suitable for pumping purpose or not as present-day technology is involved in ready mix concrete where pumping of concrete is being done to large heights.

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