Experimental Study on Partial Replacement of Cement with Flyash and Addition of Steel Fibers

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Abstract: The majority of India's electricity is generated by thermal power plants. Coal is used as a fuel in these thermal power plants to generate electricity. As a byproduct of this procedure, a significant amount of flyash is produced. Flyash is used to partially replace cement in concrete to avoid the need for additional land for its decomposition.
The main goal of this project is to look at how M35 grade cement behaves when mixed 1:1.99:2.32 and mixed with 0.45 water-cement ratio. In this case, flyash class-F replaced 35 percent of the cement, and the steel fiber on the hooked end was used with 1 percent, or 1.5 percent, of the cement's weight. Aspect ratio of steel fiber is 50. The pozzolonic action of flyash and the strong bond formation of steel fiber led to an increase in compressive strength, split-tensile strength, and flexural strength when steel fiber and flyash were added.
The idea of green concrete was developed through the use of flyash in concrete. The flyash-based concrete is affordable and safe for the environment.

Keywords: **Flyash, Steel fibers, Green concrete, Compressive strength, Split-tensile strength, Flexural strength.**

INTRODUCTION

Concrete is a composite building material that is made by mixing aggregate, water, and a binder in equal parts. A chemical interaction between the binder and the water causes this combination to transform into a rock-like substance when it is cast into shapes, demolded, cured, and hardened. Concrete is appropriate for use in practically all civil engineering and architectural structures due to its versatility in use and environmental adaptability. Despite these qualities, concrete nevertheless has a weight that causes issues and challenges during construction, often leading to a high cost for building the underlying parts. The ensuing issues with concrete constructions have been mostly resolved by the introduction of lightweight concrete.

Concrete is the most widely used construction material in the world, especially in developing nations, and there are global issues like the exhaustion of non-renewable mineral resources and the release of greenhouse gases during the manufacture of bond, the main limiting component in concrete. As a result, interest in alternative cementing materials that can be used as partial or aggregate substitutes for conventional Portland cement has increased due to the demand for conservative and more natural friendly cementing solutions. Since the manufacturing of cement requires a lot of energy and contributes approximately 5% of the world's carbon dioxide (CO2) emissions (one tonne of cement creates about one tonne of CO2), numerous efforts have been made to increase the utilisation of cement-replacing materials in the creation of concrete.

In today's society, sustainable development and green construction are prioritised. Thermal power stations produce some tonnes of flyash as a waste product each year. According to estimates, there were 154 million tonnes of flyash available between 2001 and 2012, and between 2017 and 2019, roughly 226 million tonnes of flash will be produced as a coal byproduct. Flyash lacks the cementitious properties necessary to provide strength on its own. However, when there is water present, it combines with free lime from cement and hydrated products (C2S and C3S), which aids in achieving strength and also enhances durability. Due to its extremely fine structure, flyash fills more gaps and provides improved pore structure, improving the strength of the material over time due to decreased permeability.

In India, coal-fired thermal power plants produce 70% of the country's electricity. where the byproduct fly ash is created. Air pollution, water contamination, and in particular a lack of land for the disposal of fly ash are environmental hazards brought on by the use of this coal. The worst conditions for coal disposal are in India. The result of air pollution from coal and lignite used in power plants is light that becomes airborne and poses a health risk. The fact that it causes ozone layer thinning when it enters the atmosphere is crucial in this situation.

The use of flyash in concrete will save construction costs by 25% to 30%. Additionally, it aids in the creation of green concrete, which is defined as concrete that employs waste materials as at least one of its constituents, whose manufacturing method does not harm the environment, and/or which has excellent performance and life cycle sustainability.

- Flyash is frequently used for Embankments, among other things.
- Used as a substance to stabilise soil.
- Fly ash is another ingredient utilised in the creation of flowable fill.
- Used as a mineral filler to fill voids in the asphalt road paving.
- Fly ash is one of the ingredients in geoploymers.
- used in concrete dams with roller compacting.
- Utilised in the production of fly ash bricks.

Steel fibres will assist strengthen the concrete by being added to it. Steel fibres have the advantage of stopping cracks in their tracks by providing adjusting forces at the crack's tips, which delays the cracks' spread throughout the concrete and aids in achieving a progressive failure.

OBJECTIVES

The primary goals of this project were the partial replacement of cement with flyash and the incorporation of steel fibres.

To obtain the various properties of the cement.

To ascertain the hardened concrete's strength qualities, such as compressive strength, split tensile strength, and flexural strength.

The main goal is to understand the characteristics of flyash, how it behaves, and what happens when steel fibres are added to concrete.

LITERATURE REVIEW

Ahmad shah, Er. Sonia (2022) They have carried an experimental investigation on the M_{20} grade concrete with the mix design 1:1.48:2.74 and with the W/C ratio 0.48. In their investigation they obtained the maximum sterngth at the replacement of 10% of the flyash and 1.5% of steel fibers for 28 days for compression. And for split-tensile the strength was achieved at 10% of flyash and 1% of the steel fibers. The addition of flyash helps to increases the workability.

K.Srinivasa Rao et al. (2020) Proved that the optimum dosage of flyash replacement 20%. They have performed experimental investigation on HSC (High Strength Concrete) the maximum strength was achieved at 20% of flyash and 1.2% of steel fibers at 28 days. The crimped steel fibers are used with the aspect ratio 50mm. The flyash based concrete will resists the acid attacks.

Savita, Shwetha (2018) They proved that the additon of the steel fibers will reduce the workability of the concrete. They performed an experimental investigation on the fiber reinforced concrete. The maximum strength was achieved at 0.3% of the steel fibers for compressive strength, for split-tensile and flexural strength it was found to be 0.2% of steel fibers for 7 and 28 days of M_{25} grade concrete.

Samarul Huda, Anwar Ahmad (2017) They proved that the addition of steel fibers will reduce the workability of the concrete. They carried out the experiments on M_{30} grade concerte by making the 10% of steel fibers constant and varying the flyash percentages 10% and 30%. The maximum strength was achieved at 30% of the replacement of flyash.

Sudheer.K.V.Chittilappilly et al. (2016) Carried out investigation work on the flexural strength properties of steel fiber reinforced concrete with the addition of fly ash. The study is carried out for the M_{25} mix. In this investigation steel fibers varied from 0%.0.5%,1%,1.5% of different aspect ratios 20 mm,30 mm and 40 mm and replacement of fly ash varies from 10%,20% and 30%. The test specimens were tested at the interval of 7days and 28 days respectively. It was observed that cement in concrete can be replaced up to 20% to 30% by flyash with the incorporation of steel fibers up to 1.0% to improve its flexural strength of concrete M_{25} and the optimum aspect ratio is found as 40mm.

Adanagouda et al. (2015) Proved that 10% of the flyash is the optimum dosage used for the replacements in the concrete. They also stated that the addition of the steel fibers will reduce the settelment, plastic, water permeability and shrinkage. Tests were performed on the M_{25} grade concrete and there was increase in compressive strength by 26.61%, for split-tensile strength 13% and 9.37% for the flexural strength for 28 days at 1.25% of composite fiber.

MATERIALS AND PROPERTIES

Cement

Argillaceous (clayey) and calcareous (containing lime) materials are combined to form cement, a binding substance that becomes stronger when water is added. Mortar is made of cement and fine aggregate and is used for masonry work, plastering, and other applications. Concrete is created using cement, fine aggregate, and coarse aggregate. We used 53 grade regular portland cement in our project.
The properties of cement are listed in the below table

Table 1 Properties of Cement

Properties	Results
Fineness of cement	94%
Normal consistency or Standard consistency	35%
Initial setting time	30 min
Final setting time	10 hours
Specific gravity	3.07

Fine Aggregate

When the granular material's particles are so small that they can fit through a 4.75mm screen, it is referred to as fine aggregate. Aggregate is the granular material used to make concrete or mortar. The spaces between the coarse aggregate are filled with the fine aggregate. The properties of fine aggregate are listed in the below table

Table 2 Properties of Fine aggregate

Properties	Results
Specific gravity	2.64
Water absorption	1.35%

Coarse Aggregate

Concrete is made with coarse aggregates, which are granular and uneven materials like sand, gravel, or crushed stone. Coarse is typically found in nature and can be obtained by blasting quarries or crushing them manually or with crushers. Coarse aggregate refers to materials that are large enough to be caught by a 4.7mm sieve.
The properties of coarse aggregate are listed in the below table

Table 3 Properties of Coarse aggregate

Properties	Results
Specific gravity	2.6
Water absorption	0.81%

Steel Fibers

A type of metal reinforcement is steel fibre. The term "steel fibre for reinforcing concrete" refers to short, discrete lengths of steel fibres with an aspect ratio (ratio of length to diameter) ranging from about 20 to 100, with various cross-sections, and that are sufficiently small to be distributed randomly in a mixture of unhardened concrete using the customary mixing techniques. Concrete's physical characteristics can be qualitatively altered by adding a particular proportion of steel fibre, considerably enhancing the material's tenacity, durability, and resistance to cracking, impact, fatigue, and bending, among other properties.

Figure 1: Hooked end steel fibers

Flyash

Fly ash, a finely split byproduct of pulverised coal combustion, can be used to improve the strength and workability of concrete while lowering permeability. We employed Class F fly ash in our project.By reducing bleeding, permeability, and cracking with fly ash in concrete, a solid, highly durable concrete that is impervious to sulphate and alkali-aggregate reactions is produced. Additionally, this concrete mix uses less water and tends to resist shrinkage.

The properties of flyash are listed in the below table

Table 4 Properties of Flyash

Properties	Results
Specific gravity	2.62
Fineness	96%

Mix Design

In our experimental work, we used concrete of grade M35 with a mix ratio of 1:1.99:2.32 and a water-cement ratio of 0.45. The proportioning of the concrete mix is done in accordance with IS 10262 (2009): Guidelines for Concrete Mix Design.

METHODOLOGY

The primary goal of the current experiment is to investigate the consequences of using fly ash, a mineral byproduct, to partially substitute cement. Steel fibre is being used as an additional kind of reinforcement in the investigation. Consequently, it is anticipated that steel fibre and fly ash will be used in concrete.

Trial and error is used to select the mix design. Based on the improved slump data, the concrete mix or ratio is adjusted.

Mixing of the concrete is done mechanically.

There are a total of 12 cylinders, 12 cubes, and 12 beams or prisms that are casted. The specimens undergo 7, 14, and 28 days of curing. The specimens are tested when they have finished curing.

Cubes, beams, and cylinders, respectively, were subjected to compression, flexure, and split-tensile testing.

Tests on Fresh Concrete

Fresh concrete's ability to fully compress without bleeding or segregation in the final product is measured by the quantity of practical internal work required. One of the physical characteristics of concrete that influences strength and durability as well as labour costs and final product appearance is workability. When concrete is simply poured and compacted uniformly, that is, without bleeding or segregation, it is considered to be workable. Unworkable concrete requires more work or effort to compact in place, and completed concrete may also have visible honeycombs.

The workability of concrete can be evaluated using one of the three methods below, depending on the water cement ratio in the mix.

- Slump cone test
- Compation factor test
- Vee-bee test

Tests on Hardend Concrete

As the name suggests, hardened concrete has acquired its shape and has served the intended purpose for the designated amount of time; it is no longer plastic. It won't be feasible, meaning that it won't be possible to modify the structure's shape. It is essentially at the "plasticity" stage, where its fluidity has completely disappeared. With time, hardened concrete becomes stronger, thus it's critical to assess the durability and quality of the material. The following tests are conducted on hardened concrete:

1. compressive strength test
2. Split-tensile test
3. Flexural test

Figure 2: Compressive Strenght Test


Figure 3: Split-Tensile Strength Test


Figure 4: Flexural Strength Test

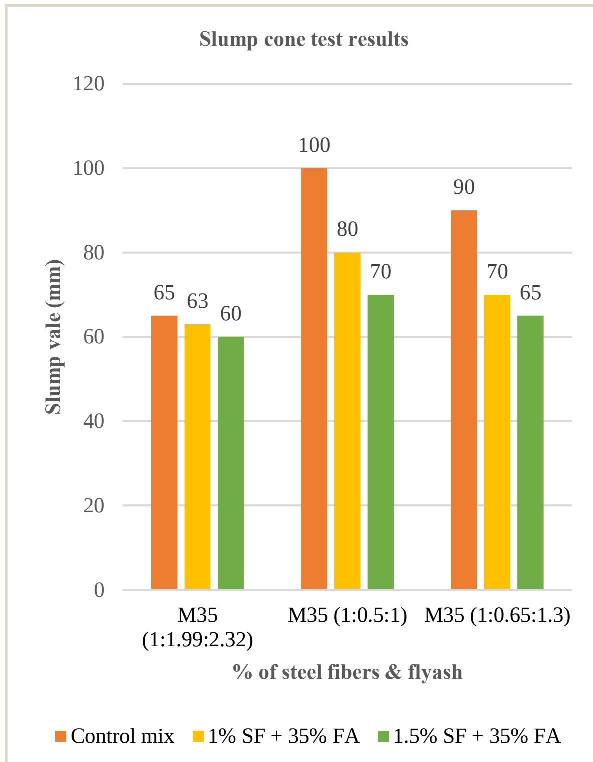
RESULTS AND DISCUSSIONS

Slump cone test

The test was conducted on the fresh concrete before casting of the specimens or moulds. A total 3 different concrete mix ratios are prepared and are tested. The test results obtained for the M35 grade of concrete are listed in the table.

Table 5 Slump cone test resluts

S.No	Grade of concrete	% of flyash	% of steel fibers	Slump value (mm)
1	M35 (1:1.99:2.32)	0	0	65
		35	1	63
		35	1.5	60
2	M35 (1:0.5:1)	0	0	100
		35	1	80
		35	1.5	70
3	M35 (1:0.65:1.3)	0	0	90
		35	1	70
		35	1.5	65

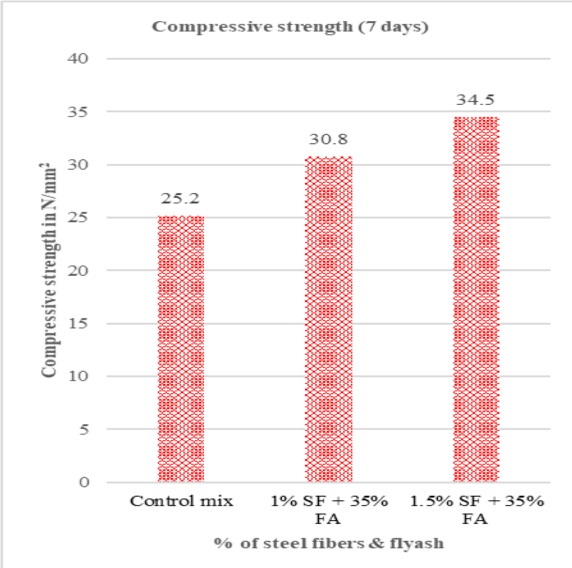


The results of the slump cone test indicating that M35 grade of concrete (1:1.99:2.32) is obtained better than other mix ratios. The workability of the concrete is medium when it is replaced with 35% flyash and 1%, 1.5% of the steel fibers. The increase in percentage of the steel fibers is decreasing the workability of the concrete.

Compressive strength test

Table 6 Compressive strength results (7 days)

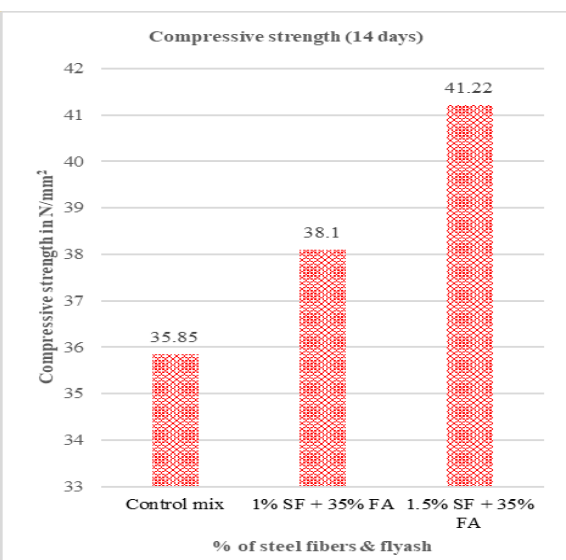
S. No	Grade of concrete	% of flyash	% steel fibers	Compressive strength (N/mm^2)
1	M35 (1:1.99:2.32)	0	0	25.2
2		35	1	30.8
3		35	1.5	34.5



The above graph shows their gradual increase the compressive strength due to increase in steel fiber percentage. The compressive strengths are 25.2 N/mm^2, 30.8 N/mm^2, 34.5 N/mm^2 for control concrete, 35% flyash @ 1% steel fibers, 35% flyash @ 1.5% steel fibers respectively. So the compressive strength was increased by 26.9% at 35% flyash @ 1.5% steel fibers as compared to the control concrete.

Table 7 Compressive strength results (14 days)

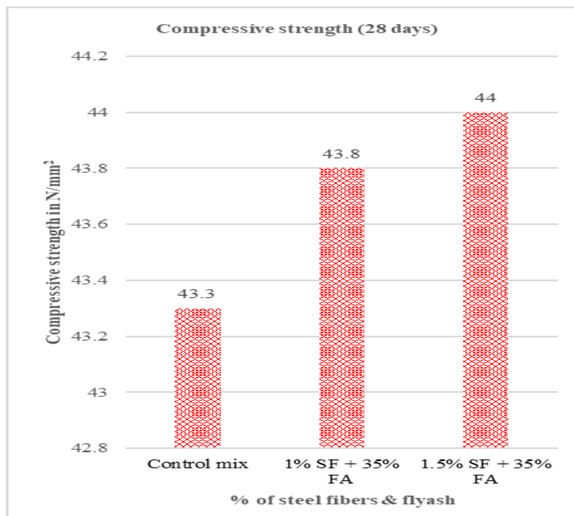
S.No	Grade of concrete	% of flyash	% steel fibers	Compressive strength (N/mm^2)
1	M35 (1:1.99:2.32)	0	0	35.85
2		35	1	38.10
3		35	1.5	41.22



The graph shows that variation of compressive strength for 14 days of curing. The compressive strength for control concrete is 35.85 N/mm^2. The flyash content is made constant as 35% and the steel fibers are varied by 1%, 1.5%. The compressive strength was increased by 13.02% at 1.5% of steel fibers and 35% flyash with respect to the control concrete. For 1%, 1.5% the compressive strength are obtained as 38.1N/mm^2 and 41.22 N/mm^2.

Table 8 Compressive strength results (28 days)

S.No	Grade of concrete	% of flyash	% steel fibers	Compressive strength (N/mm^2)
1	M35 (1:1.99:2.32)	0	0	43.30
2		35	1	43.8
3		35	1.5	44

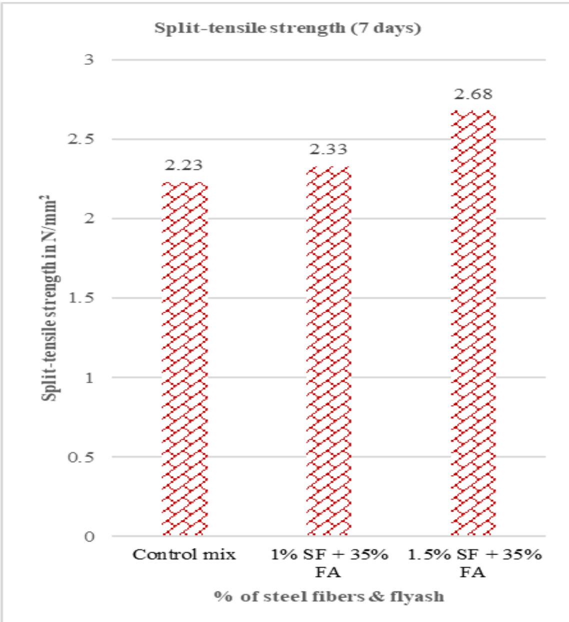


The compressive strength test is performed for 28 days and the results are obtained as 43.3 N/mm^2, 43.8 N/mm^2, 44 N/mm^2 for control concrete and conventional mix 1% , 1.5% respectively. The flyash is made constant as 35% at both 1%, 1.5% of steel fibers. So, the compressive strength was increased by 1.590% for 28 days with respect to the control concrete. The maximum strength was achieved at 28 days at 1.5% steel fibers @ 35% flyash.

Split-Tensile strength test

Table 9 Split-Tensile Strength Results (7 days)

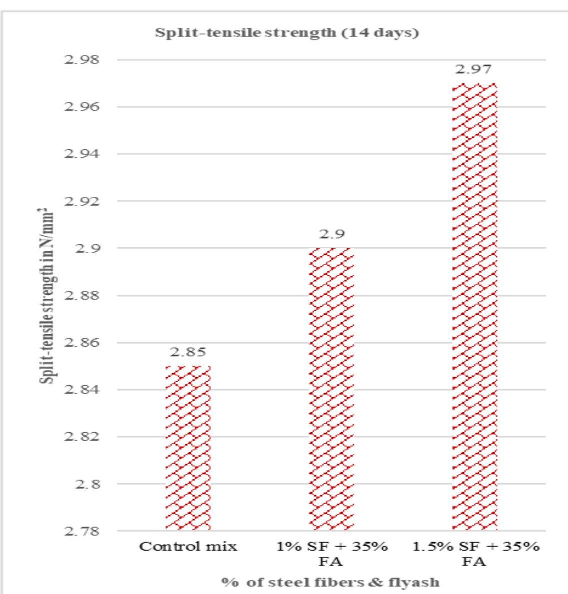
S.No	Grade of concrete	% of flyash	% steel fibers	Split-tensile strength (N/mm^2)
1	M35 (1:1.99:2.32)	0	0	2.23
2		35	1	2.33
3		35	1.5	2.68



The split-tensile strength was obtained for 7 days are 2.23 N/mm^2, 2.33 N/mm^2, 2.68 N/mm^2 for control concrete, conventional mix 1% and 1.5% respectively. The flyash is made constant as 35% in 1%, 1.5% of steel fibers. The strength was increased by 16.79% in conventional concrete as compared to control concrete.

Table 10 Split-Tensile Strength Results (14 days)

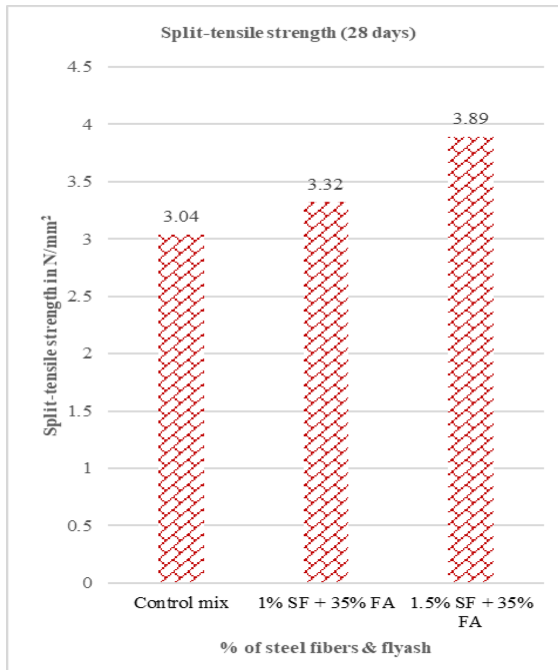
S.No	Grade of concrete	% of flyash	% steel fibers	Split-tensile strength (N/mm^2)
1	M35 (1:1.99:2.32)	0	0	2.85
2		35	1	2.9
3		35	1.5	2.97



The split-tensile strength was obtained for 14 days are 2.85 N/mm^2, 2.9 N/mm^2, 2.97 N/mm^2 for control concrete, conventional mix 1% and 1.5% respectively. The flyash is made constant as 35% in 1%, 1.5% of steel fibers. The strength was increased by 4.04% in conventional concrete as compared to control concrete.

Table 11 Split-Tensile Strength Results (28 days)

S. No	Grade of concrete	% of flyash	% steel fibers	Compressive strength (N/mm^2)
1	M35 (1:1.99:2.32)	0	0	3.04
2		35	1	3.32
3		35	1.5	3.89

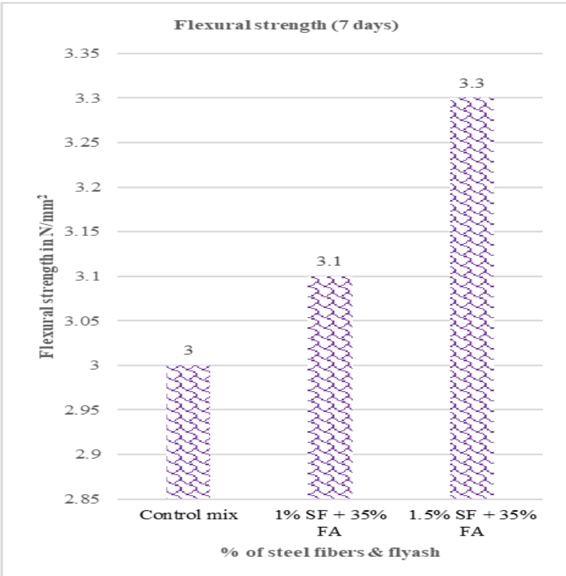


The split-tensile strength was obtained for 28 days are 3.04 N/mm^2, 3.32 N/mm^2, 3.89 N/mm^2 for control concrete, conventional mix 1% and 1.5% respectively. The flyash is made constant as 35% in 1%, 1.5% of steel fibers. The strength was increased by 21.85% in conventional concrete as compared to control concrete.

Flexural Strength Test

Table 12 Flexural Strength Results (7 days)

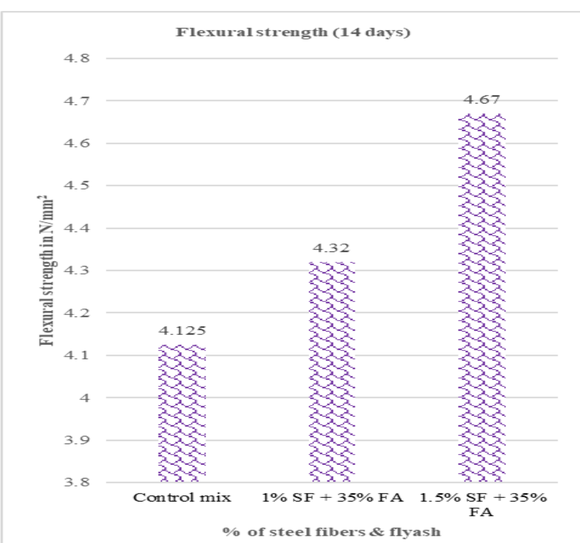
S.No	Grade of concrete	% of flyash	% steel fibers	Flexural strength (N/mm^2)
1	M35 (1:1.99:2.32)	0	0	3
2		35	1	3.1
3		35	1.5	3.3



The flexural strength test was performed for 7 days of curing the specimens and the results are obtained as 3 N/mm², 3.1 N/mm², 3.3 N/mm² for control concrete, conventional concrete 1%, 1.5% with 35% flyash constant. The flexural strength was increased by 9.09% in conventional concrete for 7 days as compared to the control concrete. The maximum strength was achieved at 35% flyash @ 1.5% steel fibers.

Table 13 Flexural Strength Results (14 days)

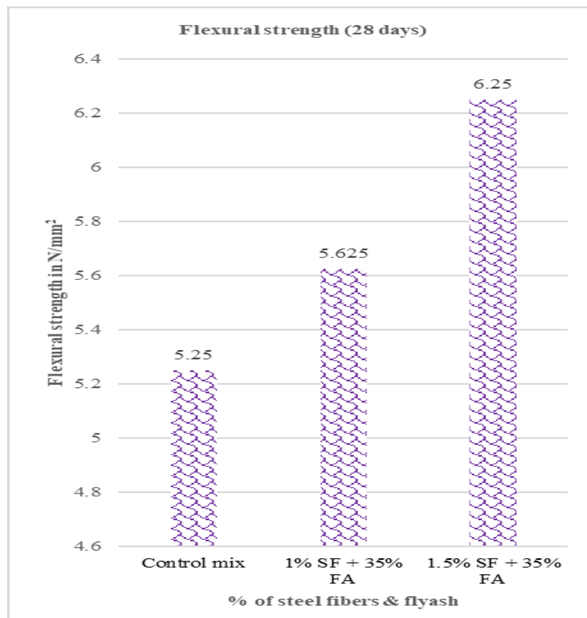
S.No	Grade of concrete	% of flyash	% steel fibers	Flexural strength (N/mm²)
1	M35 (1:1.99:2.32)	0	0	4.125
2		35	1	4.32
3		35	1.5	4.67



The flexural strength test was performed for 14 days of curing the specimens and the results are obtained as 4.125 N/mm², 4.32 N/mm², 4.67 N/mm² for control concrete, conventional concrete 1%, 1.5% with 35% flyash constant. The flexural strength was increased by 11.67% in conventional concrete for 14 days as compared to the control concrete. The maximum strength was achieved at 35% flyash @ 1.5% steel fibers.

Table 14 Flexural Strength Results (28days)

S.No	Grade of concrete	% of flyash	% steel fibers	Flexural strength (N/mm²)
1	M35 (1:1.99:2.32)	0	0	5.25
2		35	1	5.625
3		35	1.5	6.25



The flexural strength test was performed for 28 days of curing the specimens and the results are obtained as 5.25 N/mm², 5.625 N/mm², 6.25 N/mm² for control concrete, conventional concrete 1%, 1.5% with 35% flyash constant. The flexural strength was increased by 16% in conventional concrete for 28 days as compared to the control concrete. The maximum strength was achieved at 35% flyash @ 1.5% steel fibers.

CONCLUSION

The experimental investigation is carried out on the development of green concrete with 35% flyash and steel fibers. The M35 grade of concrete is used for this study. Based on the test results the following conclusions are drawn:

Flyash content increased the workability of the concrete but flyash + steel fibers combination mixes ranges the workability as medium.

There is a better improvement in the compressive strength after addition of the steel fibers to the concrete. The maximum compressive strength was achieved at 28 days for 35% flyash @ 1.5% steel fibers with an increase of 1.590% strength as compared to control mix.

35% flyash @ 1.5% steel fibers gives good tensile strength than other mixes and control mix or control concrete at 28 days with an increase of 21.85%.

There is no strength development for 7 days in flexure. But at 28 days it gave better results. The maximum flexural strength was achieved at 35% flyash @ 1.5% steel fibers with an increase of 16%.

Use of flyash reduces the amount of cement content as well as heat of hydration in a concrete mix. Thus, the construction work with flyash concrete becomes environmentally safe and also economical.

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