INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY
ISSN: 2454-132X
Impact factor: 4.295
(Volume 4, Issue 2)
Available online at: www.ijariit.com

An experimental investigation of mechanical properties of concrete due to the effect of fiber and fly ash

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ABSTRACT

The high cost of conventional construction materials is an existing factor affecting housing system around the world. This has necessitated research work into alternative materials in the construction field. The aim of this paper is to study the properties of fibers reinforced concrete produced from steel fibers and fly ash. As different dosages of cement were replaced by fly ash and steel fiber, additive material was added. Fibers have been used in concrete as reinforcement and strengthening component under tension. The various strength such as compressive strength, flexural strength and split tensile strength was experimentally noted for each sample, the fly ash was replaced 5, 10, 15 and 20% cement content respectively. The sample was cured for 7, 14 and 28 days respectively. The aspect of soaking was also considered. The results obtained indicate noticeable improvement in strength with the inclusion of fibers and cement.

Keywords*:* *Fly ash, fibre, curing period, soaking, split tensile strength.*

1. INTRODUCTION

Fly ash is a by-product of the combustion of pulverized coal in electric power generation power 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 materials solidify into spherical glassy particles called fly ash [1]. The fly ash is collected from the exhaust gases by electrostatic precipitators or bag filters. The chemical makeup of fly ash is primarily silicate glass containing silica alumina iron and calcium. Colour generally ranges from dark grey to yellowish tan for fly ash used for concrete. It addition it has a pozzolanic property [2]. Fly ash has been considered as a "Pollution Industrial Waste". The majority of thermal power plants 84% are run by coal. In addition to the reduced dead weight, the lower modulus of elasticity and adequate ductility of light weight concrete may be advantageous in the sesmic design of structures.

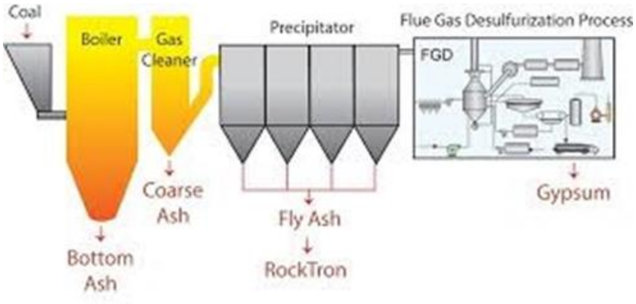
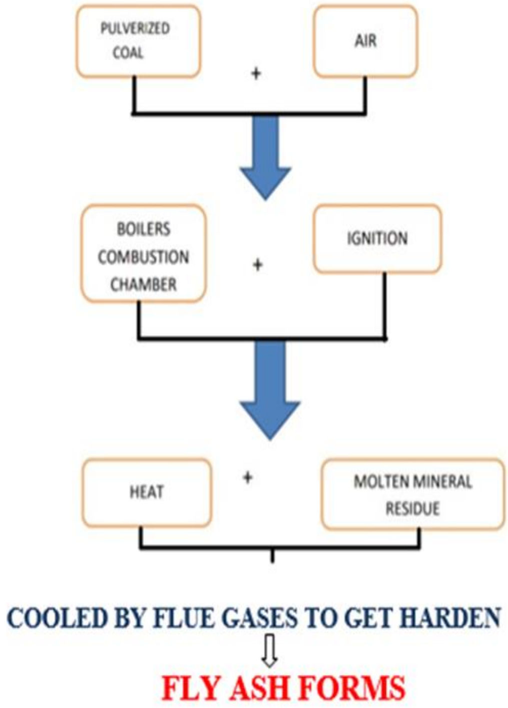


Fig.1. Collection of fly ash from exhaust gases by the electronic precipitator



1.1. CLASSIFICATION OF FLY ASH

According to ASTM fly ash is classified into two types such as:

(1) Class C
(2) Class F

Class C Fly ash-

Fly ash produced from burning of younger lignite or sub-bituminous coal in addition to having pozzolanic properties also has some self-cementing properties [3]. In the presence of water class c fly, ash gets stronger over time. It contains more than 20% lime (CaO). It doesn't require activator alkali and sulphate (So_4) contents and generally higher in class c fly ash.

Class F Fly ash-

The curing of harder, older anthracite, and litmunious coal typically produces class F fly ash. This fly ash is also pozzolanic in nature and contains less than 7% lime (CaO) possessing pozzolanic properties, the glassy silica, and alumina of class fly ash requires a cementing agent such as Portland cement, quicklime or hydrated lime mixed water to react and produce cementitous compounds [4]. Adding a chemical activator such as sodium silicate (water glass) to a class F ash can form a geopolymer.

1.3. CONSEQUENCES OF FLY ASH

ENVIRONMENTAL ASPECT: As we know that pollution is a resource which mankind has not utilized yet. The same way fly ash is an ingredient part for a human which has to be given privilege. [3]
Fly ash when remained exposed to the environment will be a nutshell hard to break. But if utilized can be a milestone for success.

At present 70% of power generation in the country is accommodated by coal. There is need for new innovative ideas {i.e. utilization of fly ash} for reducing impacts on the environment.

COST CONSIDERATION**:** The 70% of power generation by thermal power plants produces fly ash in abundant form, therefore the cost of dry fly ash available at the power plants are very cheap. There is a need to process out the dry available fly ash and create a way for the beginners to make them handle fly ash as a new resource for study and investigation.

1.4. FALLACIOUSNESS IN PREVIOUS PROPOSED PROVISIONS

In general, the studies till now have proven a way towards enhancing of performance, strength, durability and light weight characteristics in a broader fashion but have dwindled in approach towards mechanical properties of fly ash [5].

GEOPOLYMERS- fine and heat resisting coating and adhesives [4].

Our study will lay out a new light weight concrete which will not only possess the strength and high-performance properties but will become a trendy material in terms of aesthetics and cost [6].

2. SPECIMEN PREPARATION

The purpose of this research is to identify factors that contribute to strength gain in the composite specimen. This section summarizes the procedures and materials used in performing the investigation. The composition of the fly ash is as follows:

COMPONENT	BITUMINOUS	SUBTIMUNIOUS	LIGNITE
SiO_2 (%)	20-60	40-60	15-45
Al_2O_3 (%)	5-35	20-30	20-25
Fe_2O_3 (%)	10-40	4-10	4-15
CaO (%)	1-12	5-30	15-40
LOI (%)	0-15	0-3	0-5

Table 2.1 shows the normal range of chemical composition of fly ash produced from different coal types

Variability of the chemical and the physical properties of fly ash depend upon several factors such as coal type and source type, type of boiler condition, condition during combustion, type of emission control device, storage, and handling methods. Variations in any of these factors affect the characteristics of fly ash and its engineering properties.

2.1. STEEL FIBER

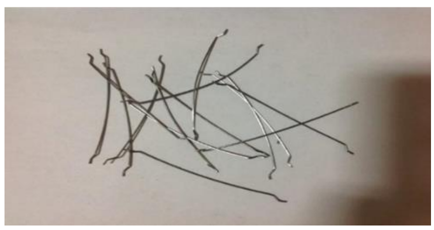


Fig.2. Steel Fiber

2.2.1. Effect of Fibers Utilized with Concrete

Fibres are generally utilized in concrete to manage the plastic shrink cracking and drying shrink cracking. They also lessen the permeability of concrete and therefore reduce the flow of water. Some types of fibers create greater impact, abrasion and shatter resistance in the concrete [7]. Usually, fibers do not raise the flexural concrete strength. The fibers are bonded to the material, and allow the fiber reinforced concrete to withstand considerable stresses during the post-cracking stage. The actual effort of the fibers is to increase the concrete toughness.

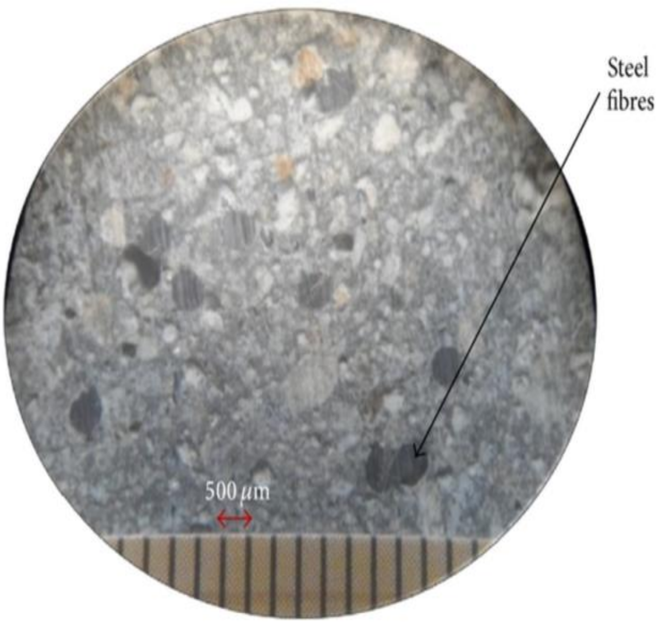


Fig.3. Microscopic view of 25% of fly ash with 1.5% of steel fiber concrete

2.2.2Properties of Concrete Improved by Steel Fibers

Below are some properties that the use of steel fibers can significantly improve[8]:

- Flexural Strength: Flexural bending strength can be increased by up to 3 times more compared to conventional concrete.
- Fatigue Resistance: Almost 1 1/2 times increase in fatigue strength.
- Impact Resistance: Greater resistance to damage in case of a heavy impact.
- Permeability: The material is less porous.
- Abrasion Resistance: More effective composition against abrasion and spalling.
- Shrinkage: Shrinkage cracks can be eliminated.

2.2 MATERIALS USED

Following materials were used in the experimental program-

(i) Type-1 Portland cement
(ii) Specific gravity=3.14
(iii) Fine aggregate, river sand that passed through 4.75mm sieve
(iv) Coarse aggregate
(v) Fly ash
(vi) Steel fiber
Length= 40mm
Diameter= 0.3m

The water reducing admixture, naphthalene formaldehyde sulfonate (sikament) was reduced in all mixing in the experimental work. Lime powder was used to improve the presence of alkali in fly ash. Normal tap water was used for mixing the concrete throughout the experimental work. It was ensured that all these materials execute with respective material standards or properties.

In present study, the concrete mixture was prepared by hand mixing. The procedure was mixing the fibre-reinforced concrete involved the following-

- The gravel and sand were placed and dry mixed.
- The cement and fibre were spread and dry mixed.
- The mixing water (60%) was added and mixed for approx. 2 min.
- The remaining mixing water (40%) was added and mixed.
- Finally the freshly mixed fibre reinforced concrete was cast into specimens mould and vibrated simultaneously to remove any air remained entrapped. After casting, each of the specimens was allowed to stand for 24 hour in laboratory before demoulding. All the specimens was cured in water tank curing.

2.3 TESTS AND METHODS

2.3.1- COMPRESSIVE STRENGTH TEST

The compressive strength test was carried out in accordance with AUSTRALIAN STANDARD [9] using MTS machine with a loading capacity of 1000KN and a loading rate of 20+-2MPa/min. Three cylindrical specimens were tested for compressive strength at the time period of 3 days, 7 days, 14 days, 28 days and 56 days after casting.

Fig.4.Crack pattern at ultimate failure load of cylindrical specimen

Fig. 5. Compressive strength testing Machine

2.3.2- TENSILE STRENGTH TEST

The indirect tensile strength test was carried out in accordance with AUSTRALIAN STANDARD [10] using MTS machine with a loading capacity of 1000KN and a loading rate of 1+-0.1MPa/min provided with indirect tensile strength test strength at the time period of 28 days after casting. The indirect tensile strength of the specimen was calculated using-

$$T=\frac{2000P}{3.14LD} \qquad \text{----(i)}$$

Where,

T= indirect tensile strength (MPa)
P= maximum applied force
L= Length (mm)
D= Diameter (mm)

Fig.6.Tensile strength test on the cylindrical specimen

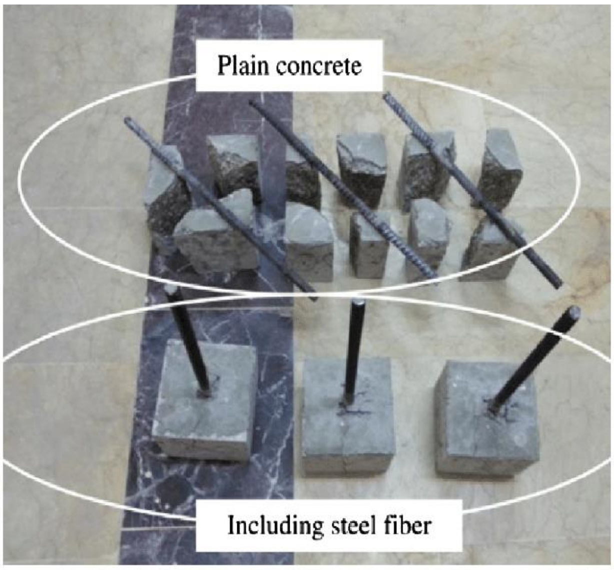


Fig.7. Change of Failure mode from spitting to pull-out failure in steel fiber reinforced cold-bonded fly ash aggregate

Fig.8.Split tensile test

2.3.3 FLEXURAL STRENGTH TEST: FOUR POINT BENDING TEST

The modulus of rupture development of concrete test was carried out in accordance with the AUSTRALIAN STANDARD [11] using hydraulic MTS testing machine having a loading capacity of 1000KN. Three beam specimens were tested for flexural strength until the maximum load is reached after 28 days of casting [12].
The modulus of rupture of the specimen was calculated by using-

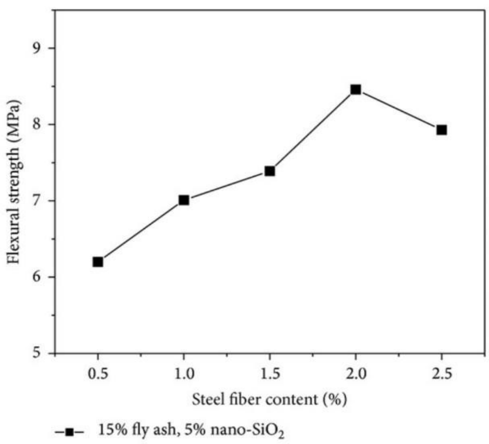
$$fr_p=\frac{PL(1000)}{BD^2} \qquad \text{----(ii)}$$

Where,

Fr_p= modulus of rupture (MPa)
P= maximum applied force (KN)
L= span length (mm)
B= average width of the specimen at a section of failure (mm)
D= average depth of specimen at section of failure (mm)

Fig.9. Flexural strength setup before testing

Fig.10. Testing apparatus of flexural toughness [13]



Graph- Effect of steel fiber content on flexural strength

3. CONCLUSION

Substitution of cement by fly ash by 10% and addition of 1% steel fibers results in higher compressive strength further addition of more than 1% steel fibers will bring down the compressive strength. Addition of 1% steel fibres results in higher tensile strength and use of more than 1% steel fibres will bring down the compressive strength. Based on the compressive and tensile strength it can be concluded that the optimum percentage of steel fibre to be added.

4. RESULT AND DISCUSSION

Based on limited experimental investigation concerning the compressive strength, tensile strength, flexural strength and the density of specimen, the following conclusion are drawn:-

- Compressive strength increases on the addition of steel fibre in fly ash and split tensile strength increases but remains less as compared to compressive strength.
- Use of fly ash in concrete can save the coal and thermal power plant disposal and produce a ‘greener’ concrete for construction.
- The cost analysis also indicates that per cent cement reduction decreases cost of concrete with increasing strength of concrete.
- Behaviour under creep and shrinkage.

This investigation concludes that fly ash with steel fibre or any other fibrous material such as plastic fibre can be innovative substitution for cementitious construction.

5. ACKNOWLEDGMENT

We take this opportunity our sincere thanks and deep gratitude to all those people who extended their whole hearted co-operation and helped us in completing this paper successfully.

We would like to thank **Prof. (Dr.) Monica Mehrotra**, Director, Babu Banarasi Das Engineering College, Lucknow who has given us her immense support and encouragement.

We would like to thank **Prof. B.S. Srivastava**, Head of Department, Mechanical Engineering, Babu Banarasi Das Engineering College, and Lucknow who has given us his time and guidance and encouragement to successfully complete the work.

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