Partial Replacement of Cement With Fly Ash With The Addition of Steel Fibers

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Abstract- *Concrete's structural stability and strength make it the most often utilised building material in the civil engineering sector. Directly releasing garbage into the environment might have negative effects on the environment. The importance of recycling waste has thus been highlighted. To use natural resources more effectively and preserve the environment from waste deposits, waste can be used to create new goods or used as admixtures. The fine powder left over after burning pulverised coal is called fly ash. It is a type of waste material, and in order to make use of it, the fly is combined with steel fibres and added to concrete.*

The dissertation is completed by utilising m25 grade concrete with cement replacing 10%, 20%, and 30% of the fly ash along with the addition of 0.5% and 1% steel fibre to the concrete's total weight. The goal of the study is to determine the ideal replacement and addition rate of steel fiber for achieving the highest compressive strength. There are numerous reuse and recycling options for this industrial by-product, both in the experimental stage and in actual applications.

Keywords- steel fiber, M25 grade concrete, fly ash, cement, aggregate, cube casting

I. INTRODUCTION

Around 80 million tonnes of fly ash are produced annually by thermal power plants in India. Portland pozzolana cement, made by some cement manufacturers over the past few years, uses fly ash as a raw material. It has been discovered that using fly ash in concrete negatively impacts strength characteristics at a young age. By adding fibres, which have been proven highly effective in enhancing the strength characteristics of concrete, one can make up for the early-age strength loss caused by the use of fly ash. Concrete's structural properties, such as static flexural strength, impact strength, tensile strength, ductility, and flexural toughness, are significantly enhanced by the addition of fibres.

Steel fiber reinforced concrete (SFRC) is being used more frequently in construction projects such as flooring, housing, precast, tunneling, heavy-duty paving, and mining due to its durability, toughness, and high-stress resistance. In most cases, the aspect ratios of steel fibers used in concrete mix range from 50 to 100. The range between 0.5% and 2.5% by volume of concrete is the most suitable for concrete mixes. In general, as the concrete formulation and the fiber material type, geometry, distribution, orientation, and concentration vary, so do the characteristics and performance of fiber-reinforced concrete.

Even though there have been many studies on the effects of fiber addition on the mechanical and durability characteristics of concrete, little research has been done on the impacts of fiber addition in concrete with pozzolans.

The goal of the current study is –

- to determine the ideal percentage of steel and fly ash replacement for cement at which the maximum strength can be attained.
- to determine the ideal mix design in terms of the ratios of cement, steel fiber, fly ash, and water.
- to perform a compression test on concrete and to regulate it using an IS specimen measuring 150x150x150 mm.
- to test the compressive strength.
- to offer affordable building materials.
- use proper waste management to protect the environment.

Advantages of Fly Ash

1. Fly ash effectively replaces Portland cement in the concrete mix, which can help to reduce the cost of concrete materials.
2. It satisfies the performance requirements and is an environmentally friendly solution. Additionally, it can help earn LEED points.
3. It provides the building with greater strength over time as its strength increases.
4. Lower bleed channels and decreased permeability are caused by the flash's increased density and long-term strengthening action, which ties up with free lime.

5. The use of fly ash reduces the permeability of concrete, which helps to keep aggressive composites on the surface where the damaging action is kept to a minimum. Additionally, it is very resilient to water, sulphate, and mild acids.

Disadvantages of Fly Ash

1. The fly ash's quality before use is essential. Concrete is frequently negatively affected by low quality.
2. The building may be harmed by the poor quality's increased permeability.
3. While some fly ash produced in power plants is typically compatible with concrete, other types require beneficiation, and a few others cannot be enhanced for use in concrete. Therefore, it is crucial to only use high-quality fly ash to avoid damaging the building's structural integrity.

Advantages of Steel Fibers

1. Concrete reinforced with steel fibers is more resilient to abrasion, impact, and fatigue and has a higher flexural and fatigue strength.
2. Considerable productivity gains may result from the removal of conventional reinforcement and, in some cases, the reduction in section thickness. Steel fibers can result in substantial cost savings, as well as decreased material volume, quicker construction, and lower labor costs.
3. A crack-free stress accommodation occurs throughout the concrete due to the steel fibers' random distribution within it. As a result, microcracks are stopped before they can worsen and affect how well the concrete performs.
4. Steel fibers are a much more cost-effective design option.

Disadvantages of Steel FIbers

1. Steel fibers won't float on a properly finished slab's surface, but rain-damaged slabs will show both aggregate and fibers exposed and will look unsightly while still being structurally sound.
2. Fibers can replace reinforcement in all structural elements (including primary reinforcement), but there will come a point within each element where the cost savings and design economies of the fiber alternative will be reduced.
3. To keep concrete waste to a minimum, strict control must be maintained. Wasted fibres equate to wasted concrete.

Material used

Cement

In concrete, cement serves as a binding substance that thickens when water is applied. It is crucial to the construction industry. The grade of cement used is PPC 53. (JK super cement). The cement that was used was lump-free and brand-new. 3.3 Aggregate: Aggregate is a naturally occurring sand and gravel deposit that also gives concrete structure. Since it makes up between 75% and 80% of the volume of concrete, it has an impact on the material's workability, strength, durability, and economy. Aggregate gives the total composite material strength by serving as reinforcement. Due to its strength, aggregate is often utilised as a base material for highways, railroads, and under foundations.

Coarse aggregate

Coarse aggregate is defined as having a size more than 4.75 mm. The nominal size of the graded coarse aggregate, such as 40mm, 20mm, 16mm, or 12.5mm, is used to characterise it. The largest size that could be used to conveniently make concrete is 80mm. In this investigation, coarse aggregate complies with IS: 383:1970. As coarse aggregate, crushed stone aggregate with a maximum particle size of 12.5 mm and 20 mm was purchased from a nearby quarry. Both the Flakiness Index and the Elongation Index were kept far below 15%. Water absorption and obtained specific gravity are 2.65 and 0.99%, respectively.

Fine Aggregate

Fine aggregate is defined as material that can pass through a 4.75 mm IS filter and contains no more than 5% coarser particles. The primary purpose of fine aggregate is to fill the spaces between larger particles. It also contributes to the mixture's workability and homogeneity. Fine aggregate used in this investigation adheres to IS: 383:1970 and zone III. The obtained specific gravity is 1.27, and the water absorption is 31.57%.

Fly Ash

One of the byproducts of coal combustion, referred to as "pulverized fuel ash" in the UK, is made up of tiny particles that are expelled from the boiler with the flue gasses. Bottom ash is the ash that collects at the bottom of the boiler. Fly ash is typically collected by electrostatic precipitators or other particle filtration equipment in modern coal-fired power plants before the flue gasses reach the chimneys. It is referred to as coal ash along with bottom ash taken out of the boiler. Fly ash has a wide range of constituents depending on the origin and makeup of the coal being burned, but all fly ash contains significant amounts of silicon dioxide (SiO2), both amorphous and crystalline, aluminum oxide (Al2O3), and calcium oxide (CaO), the primary mineral compounds in coal-bearing rock strata.

The constituents can range from trace concentrations (up to hundreds ppm) of one or more of the following elements or substances: arsenic, beryllium, boron, cadmium, chromium, hexavalent chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium, as well as very low concentrations of dioxins and PAH.

Fly ash was typically released into the atmosphere in the past, but current air pollution control requirements provide for its capture before release by installing pollution control equipment. Fly ash is often kept in coal power stations or buried in landfills in the US. About 43% of it is recycled, and it is frequently used as a pozzolan to make hydraulic cement or hydraulic plaster as well as to completely or partially replace Portland cement in the making of concrete. Pozzolans make sure that concrete and plaster set and give concrete additional defense against moisture and chemical attack.

The Resource Conservation and Recovery Act requires that coal fly ash be regulated on the federal level as "non-hazardous" waste, and the EPA announced its final decision in December 2014 after a protracted regulatory process (RCRA). The subtitle D includes a list of coal combustion residuals (CCR's) (rather than under subtitle C dealing with hazardous waste, which was also considered).

Fly or bottom ash may have higher amounts of impurities than coal ash when it is not made from coal, such as when solid waste is burned to provide power in an incinerator (see waste-to-energy facilities). In that situation, the ash that is created is frequently labeled as hazardous waste

Steel fiber

Shotcrete (spray concrete) with steel fiber reinforcement is known as steel fiber-reinforced shotcrete (SFRS). It may be applied more quickly than welded mesh reinforcement and has a better tensile strength than unreinforced shotcrete. It has been used for tunnels a lot.

Water

Water is crucial because it helps cement undergo a chemical reaction. Water must be pure, free of salts, acids, alkalis, and other dangerous substances, as it is utilised for both mixing and curing purposes. Concrete is mixed with potable water.

MIX DESIGN FOR M25 GRADE CONCRETE

Grade to be prepared M25 IS -102699 -: 2000

Target mean strength

fck+ (t) X (s)

Where (fck) = characteristic strength of concrete

25+ 1.65 X 5.3 = 33.745N/mm²

Nominal max size of aggregate (mm)	Water cement per cubic m of conc (kg)
10	208
20	186

Determination of water content

Required water content = 186 + 186 X 3/100

= 191.58 l/m³

Determination of cement content

Cement = 191.58 / 0.48 = 399.125 kg/ m³

Determination of coarse and fine aggregate content

Vfagg= [w + c/sc]+1/i.p .fa/sfa] 1/1000

0.98= [191.58+ 399.125/3.59 + 1/1-0.640 X (fa/2.79) X 1/1000

980= [302.75 + fa/1.0044]

(980-302.75)1.0044 = fa

Fa = 680.2299 kg/m^3

For coarse aggregate
Vcagg = [w+c/sc + 1/p .ca/sca] 1/1000

0.98 = [191.58+399.125/3.59 + 1/0.64. ca/2.66] X 1/1000

(980-302.75) X 1.7024 = ca

Ca = 1152.9504kg/m^3
C/Fa/Ca

399.125/680.2299/1152. 9504

Mix design ratio = 1:1.7:2.8

Cube casting

Size of the cube = 150mm X 150mm X 150mm

Cement required for 3 mould = 4.04 kg

Fine aggregate required for 3 mould = 6.887 kg

Coarse aggregate required for 3 mould = 11.67 kg

4.669 kg for 10 mm aggregate

7 kg for 20 mm aggregate

Compressive force	**Stress in concrete after 28 days**
640 KN	28.44 N/mm^2
630 KN	28 N/mm^2
600 KN	26.66 N/mm^2

Result: Average =27.70 N/mm^2

II. RESULT

Cube casting with replacement of cement with fly ash with addition of steel fibers and test of these cubes will be done after 28 days.

Replacements of 10% fly ash with cement and add 0.5% of steel fibers.

Item	**Quantity**
90% cement	3.63Kg
10% fly ash	0.404Kg
100% sand	6.88Kg
100%aggregate	11.67Kg
0.5% steel fibers	0.112Kg
Water added	3.63 x 0.48 = 1.74lit

Calculation: test after 28 days

Compressive force	**Stress in concrete after 28 days**
650 KN	28.88 N/mm^2
630 KN	28 N/mm^2
620 KN	27.5 N/mm^2

Result: Average = 28.1 N/mm^2

Replacements of 20% fly ash with cement and add 0.5% of steel fibers.

Item	**Quantity**
80% cement	3.23 Kg
20% fly ash	0.808 Kg
100% sand	6.88 Kg
100%aggregate	11.67 Kg
0.5% steel fibers	0.112 Kg
Water added	1.55 lit

Calculation: test after 28 days

Compressive force	Stress in concrete after 28 days
620 KN	27.5 N/mm²
600 KN	26.66 N/mm²
580 KN	26.22 N/mm²

Result: Average = 26.81 N/mm²

Replacements of 30% fly ash with cement and add 0.5% of steel fibers

Item	Quantity
70% cement	2.82 Kg
30% fly ash	1.212 Kg
100% sand	6.88 Kg
100%aggregate	11.67 Kg
0.5% steel fibers	0.112 Kg
Water added	1.35 lit

Calculation: test after 28 days

[1] Compressive force	[2] Stress in concrete after 28 days
[3] 580 KN	[4] 25.77 N/mm²
[5] 500 KN	[6] 23.22 N/mm²
[7] 450 KN	[8] 20 N/mm²

Result: Average =22.98 N/mm²

Replacements of 10% fly ash with cement and add 1% of steel fibers

Item	Quantity
90% cement	4 Kg
10% fly ash	0.44 Kg
100% sand	7.548 Kg
100%aggregate	12.432 Kg
1 % steel fibers	0.2442 Kg
Water added	1.92 lit

Calculation: test after 28 days

Compressive force	Stress in concrete after 28 days
620 KN	27.55 N/mm²
600 kN	26.66 N/mm²
540 KN	24 N/mm²

Result: Average =26.07 N/mm²

Replacements of 20% fly ash with cement and add 1% of steel fibers

Item	Quantity
80% cement	3.75 Kg
20% fly ash	0.8748 Kg
100% sand	7.43742 Kg
100%aggregate	12.25 Kg
1 % steel fibers	0.2442 Kg
Water added	1.68 lit

Calculation: test after 28 days

Compressive force	Stress in concrete after 28 days
580 KN	25.77 N/mm²
560 KN	24.88 N/mm²
550 KN	24.45 N/mm²

Result: Average =25.03N/mm²

Replacements of 30% fly ash with cement and add 1% of steel fibers

Item	**Quantity**
70% cement	3.1 Kg
30% fly ash	1.32 kg
100% sand	7.514 Kg
100%aggregate	12.376 Kg
1 % steel fibers	0.2442 Kg
Water added	1.488 Kg

Calculation: test after 28 days

Compressive force	**Stress in concrete after 28 days**
500 KN	22.22 N/mm²
550 KN	24.44 N/mm²
580 KN	25.78 N/mm²

Result: Average = 24.146 N/mm²

III. CONCLUSIONS

1. It was observed that the water cement ratio dropped as a result of the replacement of cement with fly ash.
2. According to the study, the best outcomes came from replacing 10% of cement with fly ash and 0.5% of steel fibers.
3. A 0.5% steel fiber addition results in greater strength than a 1% addition.
4. For economy and strength, fly ash can substitute cement by 10% when combined with 0.5% steel fibers.

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