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# High Volume Fly Ash Mixed Green Concrete For Civil Engineering Purposes

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**Abstract**

Concrete is the most common material used in the construction of civil engineering structures and the global demand for concrete is significantly increased due to infrastructure growth worldwide. The production of Portland cement which is the main ingredient of concrete is not only costly but energy intensive. It consumes approximately 7.8 GJ (Gigajoule) of energy per ton of cement production and also cement production process results in the emission of large amount of $CO_2$, a greenhouse gas. To overcome these problems, there is need to find some replacement to some extent. Nowadays there is a solution to some extent and the solution is known as “Green” concrete. By the use of green concrete, it is possible to reduce the $CO_2$ emission in atmosphere towards eco-friendly construction technique. There is a much potential industrial waste product that has the potential to replace cement in concrete, however, fly ash is the industrial waste material that is discussed in depth in this particular paper. In this study, the potential use of siliceous/class F fly ash from power plant Kolaghat as a partial replacement of cement was studied. Firstly concrete mixes M30 is designed with two water-cement ratio 0.42 and 0.40 as per the Indian standard code (IS-10262:2009) by adding 25% of fly ash (Siliceous/Class-F) as a partial replacement of cement, without using any chemical admixture. Three concrete cubes of size 150 mm x 150 mm x 150 mm are cast for water-cement ratio 0.42 (Mix-A) and three concrete cubes of size 150 mm x 150mm x 150 mm are cast for water-cement ratio 0.40 (Mix-B) and tested for compressive strength at 28 days, 56 days and 90 days curing for all mixes. Based on the results high volume fly ash-based green concrete was made using siliceous fly ash. Concrete mixes M20 is designed with water-cement ratio 0.42 by adding 50% of fly ash (Siliceous/Class-F) as a partial replacement of cement, without using any chemical admixture. Six concrete cubes of size 150 mm x 150 mm x 150 mm are cast for water-cement ratio 0.42 (Mix-C) and tested for compressive strength at 28 days, 56 days and 90 days curing for all mixes. The analysis of result shows the promising values with respect to compressive strength as well as workability. Thus, green concrete may be used as a partial replacement of cement by means of fly ash as it is cheaper, because it uses waste products, saving energy consumption in the production. The result also shows that at initial stages strength gain is less for fly ash mixed green concrete and the strength is higher at later ages. Over and above all high volume fly ash mixed green concrete has greater strength and durability than the normal concrete.

**Keywords:** Concrete, Eco-Friendly Concrete, Fly Ash, High Volume Fly Ash (HVFA), Eco-Friendly Construction Material, Partial Replacement of Cement, Green Concrete, Compressive Strength.

## Introduction

Green concrete is a concept of using eco-friendly materials in concrete, to make the system more sustainable. It can be defined as the concrete with material as a partial or complete replacement for cement or fine or coarse aggregates. The substitution material can be of waste or residual product in the manufacturing process. The substituted materials could be a waste material that remains unused, that may be harmful (material that contains radioactive elements). By the use of green concrete, it is possible to reduce the $CO_2$ emission in atmosphere towards eco-friendly construction technique. There are many industrial waste products that have the potential to replace cement in concrete, however, fly ash is the industrial waste material that is discussed in depth in this paper. Fly ash produced from the burning of pulverized coal in a coal-fired boiler is a fine-grained, powdery particulate material that is carried off in the flue gas and usually collected from the flue gas by means of electrostatic precipitators, or mechanical collection devices such as cyclones. Fly ash is the notorious waste product of coal-based electricity generating thermal power plants, known for its ill effects on agricultural land, surface and sub-surface water pollution, soil and air pollution and diseases to mankind. Fly ash is also known to be a good pozzolanic material and has been used to increase the ultimate compressive strength and workability of fresh concrete. This paper summarizes the various efforts underway to improve the environmental friendliness of concrete by using HVFA as the partial replacement of cement without using any chemical admixture. High volume fly ash constitutes about 50% fly ash, a lower water content, low cement content and a low water-cement ratio. Use of HVFA in concrete is gaining significance and is considered as a sustainable option for many concrete constructions. HVFA concrete has lower strength at early ages but at a later age, HVFA concrete shows a continuous increase in strength properties. Significantly both the crack width and drying shrinkage reduce and thus contribute to the long-term durability of concrete. HVFA concrete exhibits comparable costs, increased strengths and enhanced durability.

## Related Work

Previous studies reveals that the addition of fly ash mixed green concrete resulted in great profits such as reducing in heat of hydration, minimization of inherent alkali-aggregate reaction, significant reduction of steel corrosion, improvement in durability of concrete, decrease in cost etc. [1, 2, 3, 4, 5, 6,7]. In extension, it enhances the environment by contributing towards the reduction of greenhouse gases. The objective of this investigation is to study the effect of high volume of fly ash in the fresh and hardened properties of concrete.

## Fly ash as cementitious material

Fly ash is a very fine powder and tends to travel far in the air. When not properly disposed of, it is known to pollute air and water and causes respiratory problems when inhaled. When it settles on leaves and crops in fields around the power plant, it lowers the yield. When pulverized coal is burnt to generate heat, the residue contains 80% fly ash and 20% bottom ash. Fly ash produced in Indian power stations are light to mid-grey in color and have the appearance of cement powder. Use of fly ash concrete in place of PCC will not only enable substantial savings in the consumption of cement and energy but also provide economy. The use of fly ash has a number of advantages. It is theoretically possible to replace 100% of Portland cement by fly ash, but replacement levels above 80% generally require a chemical activator. Studies have found that the optimum replacement level is around 30%. Moreover, fly ash can improve certain properties of concrete, such as durability. Because it generates less heat of hydration, it is particularly well suited for mass concrete applications. The use of fly ash in concrete in optimum proportion has many technical benefits and improves concrete performance in both fresh and hardened state. Fly ash used in concrete improves the workability of plastic concrete and the strength and durability of hardened concrete. Generally, fly ash benefits concrete by reducing the mixing water requirement and improving the paste flow behavior.

**Benefits of using high volume fly ash in concrete**

Advantages of using fly ash in concrete include the followings:

- ✓ High volume fly ash in the concrete mix efficiently replaces Portland cement that in turn can aid in making big savings in concrete material prices.
- ✓ It is also an environmentally-friendly solution, which meets the performance specifications. It can also contribute to LEED points.
- ✓ It improves the strength over time and thus, it offers greater strength to the structure.
- ✓ Increased density and also the long-term strengthening the action of flash that ties up with free lime and thus, results in lower bleed channels and also decreases the permeability.
- ✓ The reduced permeability of concrete by using fly ash also aids to keep aggressive composites on the surface where the damaging action is reduced. It is also highly resistant to attack by mild acid, water and sulphate.
- ✓ It effectively combines with alkalis from cement, which thereby prevents the destructive expansion.
- ✓ It is also helpful in reducing the heat of hydration.
- ✓ The pozzolanic reaction in between lime and fly ash will significantly generate less heat and thus, prevents thermal cracking.
- ✓ It chemically and effectively binds salts and free lime, which can create efflorescence. The lower permeability of fly ash concrete can efficiently reduce the effects of efflorescence.
- ✓ HVFA concrete is more sustainable concrete compared to conventional concrete as it reduces the usage of cement and also reduces environmental pollution.
- ✓ HVFA concrete performs well at a later stage than at an early age.
- ✓ Low water-cement ratio and adequate curing are essential for strength gain.
- ✓ The long-term permeability of HVFAC is very low.
- ✓ HVFA concrete is effective in controlling temperature effects in mass concrete applications.
- ✓ HVFA concrete can be safely used in Concrete in Pavements for economic and ecological benefits.
- ✓ Fly ash contents of up to 50% may be suitable for most elements provided the early-age strength requirements of the project can be met and provided that adequate moist-curing can be ensured.

## Experimental Program

In this study, the potential use of siliceous fly ash from power plant Kolaghat as a partial replacement of cement was studied. The experimental program designed to investigate the influence of various parameters on the concrete compressive strength and it consisted of two phases.

### Phase 1:

Firstly concrete mixes M30 is designed with two water-cement ratio 0.42 and 0.40 as per the Indian standard code (IS-10262:2009) by adding 25% of fly ash (Siliceous/Class-F) as a partial replacement of cement, without using any chemical admixture. Three concrete cubes of size 150 mm x 150 mm x 150 mm are cast for water-cement ratio 0.42 (Mix-A) and three concrete cubes of size 150 mm x 150 mm x 150 mm are cast for water-cement ratio 0.40 (Mix-B) and tested for compressive strength at 28 days, 56 days and 90 days curing for all mixes.

### Phase 2:

Based on the results of the first phase, in the second phase, high volume fly ash mixed (50 % as the partial replacement of cement) green concrete was made using siliceous fly ash. For this phase, concrete mixes M20 is designed with water-cement ratio 0.42 by adding 50% of fly ash (Siliceous/Class-F) as a partial replacement of cement, without using any chemical admixture. Six concrete cubes of size 150 mm x 150mm x 150 mm are cast for water-cement ratio 0.42 (Mix-C) and tested for compressive strength at 28 days, 56 days and 90 days curing for all mixes.

## Materials used

**1. Cement:** In the present study, 43 grade Ordinary Portland Cement (OPC) with a specific gravity of 3.12 was used throughout the investigation. The cement satisfies the requirement of IS-8112.

**2. Fine aggregate:** The natural river sand available in the local market which passes through 4.75 mm IS sieve and conforming to zone I of IS 383 is used. Specific gravity and fineness modulus of sand used are 2.62 and 2.73 respectively.

**3. Coarse aggregate:** The crushed coarse aggregate of 20 mm maximum size as well as 12 mm size are obtained from the local crushing plant, is used in the present study. The specific gravity of the coarse aggregate used is 2.65.

**4. Water:** Water is an important ingredient of concrete as it actively participated in a chemical reaction with cement, clean potable water which is available on our college campus is used.

**5. Fly ash:** In the present investigation work, siliceous fly ash used is obtained from Kolaghat power station in India with a specific gravity of 2.03 as per IS:1727. Fly ash meeting specifications of IS: 3812 & IS: 456.

## Mix proportioning

### Phase 1: Mix design

In this phase, M30 grade mix is designed based on the guidelines given by IS: 10262-2009. Mix design is done using two water-cement ratio 0.42 (MIX-A) and 0.40 (MIX-B).

**Mix-A:** For water-cement ratio = 0.42,

**A-1 Stipulation for proportioning:**

| | | |
|---|---|---|
| **a.** Grade design | : | M30 |
| **b.** Type of cement | : | OPC 43 grade |
| **c.** Types of mineral admixture | : | Fly ash |
| **d.** Maximum nominal size of aggregate | : | 20 mm |
| **e.** Minimum cement content | : | 320 $kg/m^3$ |
| **f.** Maximum water cement ratio | : | 0.45 |
| **g.** Workability | : | 25 - 50 mm (slump) |
| **h.** Exposure condition | : | Severe (for rcc) |
| **i.** Degree of supervision | : | Good |
| **j.** Type of aggregate | : | Crushed angular aggregate |
| **k.** Chemical admixture type | : | Nil |

**A-2 Test data for materials:**

| | | |
|---|---|---|
| **a.** Cement used | : | OPC 43 grade |
| **b.** Specific gravity of cement | : | 3.12 |
| **c.** Fly ash | : | Conforming to IS: 3812 |
| **d.** Specific gravity of fly ash | : | 2.03 |
| **e.** Chemical admixture | : | Nil |
| **f.** Specific gravity of | : | |
| 1. Coarse aggregate | : | 2.65 |
| 2. Fine aggregate | : | 2.62 |
| **g.** Water absorption | : | |
| 1. Coarse aggregate | : | 0.82 % |
| 2. Fine aggregate | : | 0.8 % |
| **h.** Free (surface) moisture | : | |
| 1. Coarse aggregate | : | Nil (absorbed moisture nil) |
| 2. Fine aggregate | : | Nil |
| **i.** Sieve analysis: | | |
| 1. Coarse aggregate | : | Conforming to table 2 IS: 383 |
| 2. Fine aggregate | : | Zone 1 of table 4 IS: 383 |

**B. Target strength for mix proportioning:**

$$f'_{ck} = f_{ck} + 1.65\, s$$

Where, $f'_{ck}$ = target average compressive strength at 28 days,

$f_{ck}$= characteristics compressive strength at 28 days, and

s = standard deviation = 5 $N/mm^2$

Therefore, target strength ($f'_{ck}$) = 30 + 1.65 X 5= 38.25 $N/mm^2$

**C. Selection of water-cement ratio:**

From Table 5 of IS 456, maximum water-cement ratio =0.45.

Based on experience, adopt water-cement ratio as 0.42.

0.42 < 0.45, hence O.K.

**D. Selection of water content:**

From Table 2, maximum water content for 20 mm aggregate = 186 litre (for 25 to 50 mm slump range).

**E. Calculation of cement and fly ash content:**

Water-cement ratio = 0.42

Cementations material (cement+ fly ash) content = 186/0.42 = 442.85 $kg/m^3$

From table 5 of IS 456, minimum cement content for 'severe' exposure conditions = 320 $kg/m^3$

442.85 $kg/m^3$> 320 $kg/m^3$, hence O.K.

Now, to proportion a mix containing fly ash the following steps are suggested:

a. Decide the percentage fly ash to be used based on project requirement and quality of materials

b. In certain situations increased in cementations material content may be warranted. The decision on increased in cementations material content and its percentage may be based on experience and trial.



Note: This example is with an increase of 10 % cementations material content.

| | |
|---|---|
| Cementations material content | = 442.85 X 1.10 = 487.13 $kg/m^3$ |
| Water content | = 186 $kg/m^3$ |
| So, water-cement ratio | = 186/487.13 = 0.381 |
| Fly ash @ 25% of total cementations material content | = 487.13 X 25% = 121.78 $kg/m^3$ |
| Cement (OPC) | = 487.13 - 121.78 = 365.35 $kg/m^3$ |

**F. Proportion of volume of coarse aggregate and fine aggregate content:**

From Table 3, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate for water-cement ratio of 0.50-0.60. In the present case water-cement ratio is 0.42. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.08, the proportion of volume of coarse aggregate is increased by 0.016 (at the rate of -/+ 0.01 for every +/- 0.05 change in water-cement ratio). Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.42 is 0.616.

| | |
|---|---|
| Therefore, volume of coarse aggregate | = 0.616 |
| Volume of fine aggregate | = 1 - 0.616 = 0.384 |

**G. Mix calculations**

The mix calculations per unit volume of concrete shall be as follows:

**a.** Volume of concrete = 1 $m^3$

**b.** Volume of cement = Mass of cement / (1000 X specific gravity of cement)

= 365.35 / (3.12 x 1000) = 0.117 $m^3$

**c.** Volume of fly ash = Mass of fly ash / (1000 X specific gravity of fly ash)

= 121.78 / (2.03 X 1000) = 0.059 $m^3$

**d.** Volume of water = Mass of water / (1000 x specific gravity of water)

= 186 / (1000 X 1) = 0.186 $m^3$

**e.** Volume of all in aggregate = [a - (b + c + d)]

= [1- (0.117 + 0.059+0.186)]

= 0.638 $m^3$

**f.** Mass of coarse aggregate = e X volume of coarse aggregate X specific gravity of coarse aggregate X 1000

= 0.638 X 0.616 X 2.65 X 1000 = 1041.471 kg

**g.** Mass of fine aggregate = e X volume of fine aggregate X specific gravity of fine aggregate X 1000

= 0.638 X 0.384 X 2.62 X 1000 = 641.879 kg

**H. Mix proportions:**

| | |
|---|---|
| Cement | = 365.35 kg/$m^3$ |
| Water | = 186 kg/$m^3$ |
| Fly ash | = 121.78 kg/$m^3$ |
| Fine aggregate | = 641.879 kg/$m^3$ |
| Coarse aggregate | = 1041.471 kg/$m^3$ |
| Water cement ratio | = 0.381 |

So the final ratio (C: F: FA: CA) is 0.75:0.25:1.317:2.137

Note: C = Cement, F = Fly ash, FA = Fine aggregate, CA = Coarse aggregate.

**Mix-B:** Similarly for water-cement ratio = 0.40,

**Mix proportions:**

| | |
|---|---|
| Cement | = 383.62 kg/$m^3$ |
| Water | = 186 kg/$m^3$ |
| Fly ash | = 127.88 kg/$m^3$ |
| Fine aggregate | = 625.435 kg/$m^3$ |
| Coarse aggregate | = 1032.132 kg/$m^3$ |
| Water cement ratio | = 0.363 |

So the final ratio (C: F: FA: CA) is 0.75:0.25:1.223:2.017

**Phase 2: Mix design**

In this phase, M20 grade mix is designed based on the guidelines given by IS 10262-2009. Mix design is done using water-cement ratio 0.42 (MIX-C).

**Mix-C:** For water-cement ratio = 0.42,

**A-1. Stipulation for proportioning:**

| | | |
|---|---|---|
| **a.** Grade design | : | M20 |
| **b.** Type of cement | : | OPC 43 grade |
| **c.** Types of mineral admixture | : | Fly ash |
| **d.** Maximum nominal size of aggregate | : | 20 mm |
| **e.** Minimum cement content | : | 300 kg/m$^3$ |
| **f.** Maximum water cement ratio | : | 0.55 |
| **g.** Workability | : | 0 mm (True slump) |
| **h.** Exposure condition | : | Mild (for rcc) |
| **i.** Degree of supervision | : | Good |
| **j.** Type of aggregate | : | Crushed angular aggregate |
| **k.** Chemical admixture type | : | Nil |

**A-2. Test data for materials:**

| | | |
|---|---|---|
| **a.** Cement used | : | OPC 43 grade |
| **b.** Specific gravity of cement | : | 3.12 |
| **c.** Fly ash | : | Conforming to IS: 3812 |
| **d.** Specific gravity of fly ash | : | 2.03 |
| **e.** Chemical admixture | : | Nil |
| **f.** Specific gravity of: | | |
| 1. Coarse aggregate | : | 2.65 |
| 2. Fine aggregate | : | 2.62 |
| **g.** Water absorption: | | |
| 1. Coarse aggregate | : | 0.82 % |
| 2. Fine aggregate | : | 0.8 % |
| **h.** Free (surface) moisture: | | |
| 1. Coarse aggregate | : | Nil (absorbed moisture nil) |
| 2. Fine aggregate | : | Nil |
| **i.** Sieve analysis: | | |
| 1. Coarse aggregate | : | Conforming to table2 IS:383 |
| 2. Fine aggregate | : | Zone 1 of table 4 IS: 383 |

**B. Target Strength for mix proportioning:**

$$f'_{ck} = f_{ck} + 1.65\ s$$

Where, $f'_{ck}$ = target average compressive strength at 28 days,

$f_{ck}$= characteristics compressive strength at 28 days, and

s = standard deviation = 5 N/mm$^2$

Therefore, target strength ($f'_{ck}$) = 20 + 1.65 X 5= 28.25 N/mm$^2$

**C. Selection of water-cement ratio:**

From Table 5 of IS 456, maximum water-cement ratio = 0.55.

Based on experience, adopt water-cement ratio as 0.42.

0.42 < 0.55, hence O.K.

**D. Selection of water content:**

From Table 2, maximum water content for 20 mm aggregate = 186 litre (for 25 to 50 mm slump range).

**E. Calculation of cement and fly ash content:**

Water-cement ratio = 0.42
Cementations material (cement+ fly ash) content = 186/0.42 = 442.857 kg/$m^3$
From table 5 of IS 456, minimum cement content for 'severe' exposure conditions = 320 kg/$m^3$
442.857 kg/$m^3$> 320 kg/$m^3$, hence O.K.

Now, to proportion a mix containing fly ash the following steps are suggested:

c. Decide the percentage fly ash to be used based on project requirement and quality of materials

d. In certain situations increased in cementations material content may be warranted. The decision on increased in cementations material content and its percentage may be based on experience and trial.

Note: This example is with an increase of 10 % cementations material content.

| | |
|---|---|
| Cementations material content | = 442.857 X 1.10 = 487.142 kg/$m^3$ |
| Water content | = 186 kg/$m^3$ |
| So, water-cement ratio | = 186/487.142 = 0.381 |
| Fly ash @ 50% of total cementations material content | = 487.142 X 50 % = 243.571 kg/$m^3$ |
| Cement (OPC) | = 487.142 – 243.571 = 243.571 kg/$m^3$ |



**F. Proportion of volume of coarse aggregate and fine aggregate content:**

From Table 3, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate for water-cement ratio of 0.50-0.60. In the present case water-cement ratio is 0.42. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.08, the proportion of volume of coarse aggregate is increased by 0.016 (at the rate of -/+ 0.01 for every +/- 0.05 change in water-cement ratio). Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.42 is 0.616.

| | |
|---|---|
| Therefore, volume of coarse aggregate | = 0.616 |
| Volume of fine aggregate | = 1 - 0.616 = 0.384 |

**G. Mix calculations**

The mix calculations per unit volume of concrete shall be as follows:

| | | |
|---|---|---|
| **a.** | Volume of concrete | = 1 $m^3$ |
| **b.** | Volume of cement | = Mass of cement/ (1000X specific gravity of cement) |
| | | = 243.571 / (3.12 x 1000) = 0.078 $m^3$ |
| **c.** | Volume of fly ash | = Mass of fly ash/ (1000 X specific gravity of fly ash) |

= 243.571 / (2.03 X 1000) = 0.119 $m^3$

**d.** Volume of water = Mass of water/ (1000x specific gravity of water)

= 186 / (1000 X 1) = 0.186 $m^3$

**e.** Volume of all in aggregate = [a - (b + c + d)]

= [1- (0.078 + 0.119 + 0.186)]

= 0.617 $m^3$

**f.** Mass of coarse aggregate = e X volume of coarse aggregate X specific gravity of coarse aggregate X 1000

= 0.617 X 0.616 X 2.65 X 1000 = 1007.19 kg

**g.** Mass of fine aggregate = e X volume of fine aggregate X specific gravity of fine aggregate X 1000

= 0.617 X 0.384 X 2.62 X 1000 = 620.75 kg

**H. Mix proportions:**

Cement = 243.571 kg/$m^3$

Fly ash = 243.571 kg/$m^3$

Water = 186 kg/$m^3$

Fine aggregate = 620.75 kg/$m^3$

Coarse aggregate = 1007.19 kg/$m^3$

Water cement ratio = 0.381

So the final ratio is 0.50:0.50:1.274:2.06

**Casting:** Standard cast iron Cubes of dimensions 150mm X 150mm X 150mm are used to cast the specimens for compression test. The side plates of the mould where sufficiently stiff to eliminate spreading and warping. Before the concrete was placed in the mould, all the joints were checked thoroughly for any leakage. A thin film of grease was applied to cover the joints between the halves of the mould at the bottom surface of the mould and its base plate in order to ensure that no water escapes.

**Curing:** After casting, the specimens are stored in the laboratory at room temperature for 24 hours. After these periods the specimens are removed from the moulds and immediately submerged in clean, fresh water of curing tank and specimens are cured for 28, 56 and 90 days in the present investigation work.

**Strength:**Of the various strengths of concrete, the determination of compression has received a large amount of attention because the concrete is primarily meant to withstand compressive stresses. Generally cubes are used to determine the compressive strength. In the present investigation, the size of concrete moulds 150 X 150 X 150 mm are used. In the compressive test, the cube while cleaned to wipe of the surface water, is placed with the cast faces in contact with the planes of the testing machine, i.e. the position of the cube then tested is at right angles to that as cast. The specimens were removed from the moulds and submerged in clean fresh water until just prior to testing. The temperature of water in which the cubes were submerged was maintained at $27^{O}$ C+/- $2^{O}$ C and 90% relative humidity for 24 hours. The specimens were cured for 28, 56, and 90 days.

**Tests of concrete cubes with fly ash:** Compressive strength tests were carried out on cubes of 150 mm size using a compression testing machine of 2000 KN capacity as per IS 516:1959. The casted cubes are to be tested for 28 days, 56 days, and 90 days.

## Result and Discussion

The 28, 56 and 90 days compressive strength tests were carried out for phase-1 and phase-2 mixes and presented in table 1 and table 2.

**Table 1**: Compressive test results of phase-1 mixes at various stages of curing (25% Flyash)

| **Age of testing (Days)** | **Compressive strength of concrete cubes in N/mm$^2$** | |
|---|---|---|
| | **MIX-A** | **MIX-B** |
| 28 | 15.56 | 16 |
| 56 | 22.32 | 22.72 |
| 90 | 30.22 | 32 |

**Table 2:** Compressive test results of phase-2 mixes at various stages of curing (50% Flyash)

| **Age of testing (Days)** | **Compressive strength of concrete cubes in N/mm$^2$** |
|---|---|
| | **MIX-C** |
| 28 | 16 |
| 56 | 22 |
| 90 | 26.97 |



The analysis of result shows the promising values with respect to compressive strength as well as workability.Test result shows the advantages of using HVFA mixed green concrete far outweigh the disadvantages. The most important benefit is reduced permeability to water and aggressive chemicals. Properly cured concrete made with fly ash creates a denser product because the size of the pores is reduced. This increases strength and reduces permeability. The result also shows that at initial stages strength gain is less for HVFA mixed green concrete and the strength is higher at later ages. Over and above all green concrete has greater strength and durability than the normal concrete.

## Limitations of HVFA mixed concrete

There are also some limitations of using fly ash that should be considered. The quality of fly ash to be utilized is very vital. Poor quality often has a negative impact on the concrete. The poor quality can increase the permeability and thus damaging the building. Some fly ash, those are produced in power plant is usually compatible with concrete, while some other needs to be beneficiated, and few other types cannot actually be improved for use in concrete. Thus, it is very much vital to use only high-quality fly ash to prevent negative effects on the structure. Some of the shortcomings of HVFA concrete are

- Extended setting times.
- Slow development of strength.
- Low early age strength.
- Delay in Construction.

- Difficult to use in cold weather concreting.
- Low resistance to deicer-salt scaling and carbonation.

## Conclusion and future work

HVFA mixed green concrete has manifold advantages over the conventional concrete. Since it uses the recycled aggregates and materials, it reduces the extra load in landfills and mitigates the wastage of aggregates. Thus, the net $CO_2$ emissions are reduced. Since a huge quantity of cement is used in concrete in mass concrete construction and the cost of fly ash is negligible as compared to that of the cement, the use of HVFA concrete brings about a substantial saving in cement consumption and overall construction cost. HVFA mixed green concrete may be used in general RCC structures including road pavements, dam construction etc. without any risk of steel corrosion. The fly ash is an industrial waste and great hazard for our environment. The designers of concrete structures, therefore, must incorporate the use of fly ash in their structural concrete.The reuse of materials also contributes intensively to economy. Since the waste materials like aggregates from a nearby area and fly ash from a nearby power plant are not much expensive and also transport costs are minimal. It helps in recycling industry wastes. It reduces the consumption of cement overall and has better workability, greater strength and durability than normal concrete.By using this concept we can save environment and can give this environment to our next generation. If we don't control the broadly use of materials, water and energy and environmental degradation, we will suffer for this act by our own risk. If we don't stop this so, there will be a huge deficiency by the environment and the world will not stable and may be destroyed. Thus, it may be concluded that the HVFA mixed green concrete is a futuristic material for construction industry.



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