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# HIGH VOLUME FLY ASH CONCRETE SUBJECTED TO SUSTAINED ELEVATED TEMPERATURES

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**Abstract:** The study's goal is to determine the utilization of HVFA concrete at extreme temperatures subjected to 10000C at 1000C intervals for 3 hours. HVFAC's physical and mechanical qualities are investigated. The test programme comprises replacing cement with fly ash 50%, 60%, and 70% from 350°C to 10000°C at 1000°C intervals. Compressive strength, split tensile strength, and weight loss are examples of strength metrics. The colour alter was investigated, and the results showed that as the temperature grew, the strength of the HVFA decreased, and the colour changed from normal to brownish black..

**Key Words:** Normal Concrete, HVFAC, Elevated Temperature.

## 1. Introduction

Concrete is used as construction material and is believed to be the world's second-most-used product. The use of cement is increasing dramatically as the use of concrete increases. The rising scarcity of raw resources, along with the pressing need to safeguard the environment from pollution, has highlighted the need for inventing new construction materials. Reduced production of cement and increased the partial replacement of Portland cement [11]. This major reason is being supplied with high-volume fly ash for cement and concrete. Under the direction of Malhotra, the Canada Centre for Mineral and Energy Technology began work in 1985 to develop HVFA cement and concrete for structural and a variety of other uses. [1,4], HVFA concrete is increasingly being accepted and utilized in a large range of structural applications, including those subjected to high temperatures. Concrete storage, gasification, and liquefaction tanks have applications in the metallurgical, chemical, power, glass, and cement sectors. Other constructions that are subjected to high temperatures include reinforced concrete chimneys with concrete walls, nuclear reactor vessels, aircraft engine test cells, missile launching pads, and turbojet runways In addition, fires occur in ordinary concrete structures in urban industrial regions.[12] These construction materials should be able to withstand extreme temperatures. Although concrete is often regarded as an effective fireproofing material, high temperatures cause considerable damage or even catastrophic collapse. [13] The chemical change of the gel at high temperatures decreases matrix bonding, resulting in concrete strength loss. Because the influence of high temperatures on HVFA concrete has not been studied, there is a need to explore behavior, mechanical properties of HVFA concrete at increasing temperatures [14]. Thus as a result, an attempt was made to improve the use of HVFAC exposed to high temperatures.

## 2. MATERIALS & METHODS

Cement: In the current experiment study cement which is an ordinary Portland having Sp. gravity 3.15 Confirm into IS 12269- 1987 [15] is considered full stop the physical properties of the cement and Chemical Composition is given in the tables 1 and 2

**Table 1: Properties of OPC-53 Grade**

| Material property | Results | Permissible limits: IS 12269 − 1987 |
|---|---|---|
| Specific gravity | 3.15 | 3.12 − 3.19 |
| Fineness | 4% | Less than 11% |
| Normal consistency | 29% | Less than 34% |
| Initial setting time | 45 min | More than 30 min |
| Final setting time | 369 min | Less than 600 min |

**Table 2: Cement Chemical Composition (OPC 53grade)**

| Chemical composition | Percentage |
|---|---|
| Lime CaO | 62 |
| Silica $SiO_2$ | 22 |
| Alumina $Al_2O_3$ | 5 |
| Calcium sulphate $CaSO_4$ | 4 |
| Iron oxide $Fe_2O_3$ | 3 |
| Masgnesia MgO | 2 |
| Sulphur trioxide $S_2O_3$ | 1 |
| Alkalies | 1 |
| **Total** | **100** |

Fine Aggregate: Fine aggregate used locally accessible river sand that conformed to Zone-II of IS 383-1970[16]. The fineness modulus was calculated using the method described in IS 2386(Part I) – 1963 [17].

**Table 3: Fine Aggregate Analysis using Sieves and Physical Properties**

| Description | FA: Fine aggregates: Percentage passing by weight through IS test sieve IS: 383 − 1970 | | | | | | |
|---|---|---|---|---|---|---|---|
| IS Sieve | 10 mm | 4.75 mm | 2.36 mm | 1.18 mm | 600**µ** | 300**µ** | 150**µ** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Zone - I | 100 | 90 − 100 | 60 − 95 | 30 − 70 | 15 − 34 | 5 − 20 | 0 − 10 |
| Zone - II | 100 | 90 − 100 | 75 − 100 | 55 − 90 | 35 − 59 | 8 − 30 | 0 − 10 |
| Zone - III | 100 | 90 − 100 | 85 − 100 | 75−100 | 60 − 79 | 12 − 40 | 15 − 50 |
| Zone - IV | 100 | 95 − 100 | 95 − 100 | 90 − 100 | 80 − 100 | 15 − 50 | 0 − 15 |
| **Results** | **100** | **93.5** | **82** | **54.6** | **39.3** | **20.2** | **4.81** |
| **Remarks** | **Fine aggregates conforms to Zone II** | | | | | | |
| Fineness modulus | 2.89 | | | | | | |
| Specific gravity | 2.54 | | | | | | |
| Bulk density | = 1752 kg/cum | | | | | | |
| Water absorption | 0.01 | | | | | | |

| **Sl.No** | **Properties** | |
|---|---|---|
| 1 | Appearance: | Brown liquid |
| 2 | Specific gravity | At 20°C, the typical value is 1.20. |
| 3 | content of chloride | Chloride content: |
| 4 | Air entrainment | At standard doses, less than 2% more air is typically entrained. |
| 5 | Alkali content | In most cases, less than 72.0 g $Na_2$ O equivalent/litre of admixture. |

. Coarse aggregate: Locally available angular crushed aggregates having size 20 mm and lesser size Conforming to IS 383-197011 with specific gravity 2.63, bulk density 1783 kg/cum & absorption 0.54% are made use the experimental work of study. The sp. gravity of coarse aggregate is calculated. as per code IS: 2386– 1963 [12] Table 1.4 summarizes the findings.

**Table 4: Sieve analysis and coarse aggregate physical characteristics.**

| **IS sieve size in mm** | **Percentage passing of coarse aggregates** | | **Percentage passing of different fractions** | | | **Specifications (IS: 383-1970)** | | |
|---|---|---|---|---|---|---|---|---|
| | **I (20 mm)** | **II (12.5 mm)** | **I 60%** | **II 40%** | **Combined 100%** | **Graded** | **Single sized I** | **Single sized II** |
| 20 | 100 | 100 | 60 | 40 | 100 | 95-100 | 85-100 | -- |
| 12.5 | 0 | 98.5 | 0 | 0 | 0 | -- | -- | 85-100 |
| 10 | 0 | 35.2 | 0 | 29.5 | 29.5 | 25-55 | 0-20 | 0-45 |
| 4.75 | 0 | 8.4 | 0 | 4.1 | 4.1 | 0-10 | 0-5 | 0-10 |
| **Specific gracity = 2.63** | | | | | | | | |
| **Bulk density = 1783 kg/cum** | | | | | | | | |
| **Water Absorption = 0.54%** | | | | | | | | |

Fly Ash: Class F fly ash from Raichur RTP is used Table No.1.5. This fly ash meets the requirements of IS 3812. (part I): 2013 [18].

**Table 5: Properties of Fly ash**

| **Physical Properties** | **Value** |
|---|---|
| Specific gravity | 2.15 |
| Surface area (m/g) | 1.1 |
| Particle Size distribution | 24% |
| Sand fraction | 74% |
| Silt fraction | 2.00% |
| Clay fraction | 2 |
| **Chemical Properties** | **Value** |
| PH | 8.4 |
| TDS (mg/L) | 144 |
| $Sio_2$ (%) | 57 |
| $Al_2O_3$ (%) | 26 |
| CaO (%) | 0.97 |
| MgO (%) | 0.486 |
| $K_2O_3$ (%) | 1.83 |
| $TiO_2$ (%) | 1.55 |
| Loss of ignition (%) | 5.39 |

Super plasticizer: SP-430 super plasticizer was used to achieve substantial water reductions up to 25% without losing workability as in Table No.6.

**Table 6: Properties of Super plasticizer**

**Fig. 1 Casting of Specimens**

Casting and curing of Specimens: Cubes, Cylindrical, cubes are casted for the mix designations C100, C30F70, C40, F60 and C50F50, After 24 hours of casting, the specimens were demoded and cured for 28 days before being temperature tested in the Heath furnace.

**Fire Testing:**

The specimens under study to the required temperature, a custom-built electric furnace had been used. The furnace's max temperature during operation is 1000°C.The heating setup in the furnace complies with ISO: 834-1975[20] standards. The furnace is separated in two portions, one of which may be removed by loosening the screws that hold the two halves together, and it consists of a bed of 110 mm refractory bricks on which the specimens are set. The second component is a heating chamber with electrical heating coils on the sides and top. The whole assembly is enclosed with a heat-resistant coating that prevents heat from escaping from the furnace. The test specimens were treated to temperatures ranging from 35oC to 1000oC at 100°C intervals for 3 hours before cooled to room temperature. Later, the samples were soaked in water for sudden cooling and gradual cooling in air, was tested for a strength in accordance with, IS 516-1959 [21].

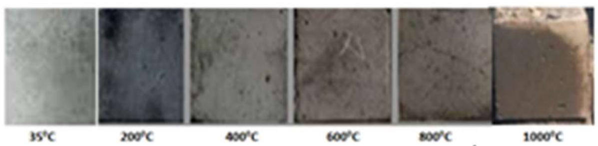


Fig. 2 Colour Change at 350C to 1000°C

Weight Loss: Figure 3 shows the overall % weight Reduction trend. At each temperature, the percentage weight loss reduced steadily as the percentage replacement of fly ash increased. The lower % weight loss in fly ash mixtures may be due to their thick structure as in contrast to standard mixes. It was further found that when the temperature rises, so does the weight loss in all of the mixtures. The greater weight loss at high temperatures might be due to the evaporation of total absorbed and adsorbed water from concrete.

Cracks: Figure 2 shows the fractures seen in normal and fly ash mixes at 600oC. Up to 400oC, there were no apparent fractures in any concrete. Surface fractures were visible at 600oC and became more visible from 800oC to 1000oC, perhaps due to the formation of new interior holes caused by the evaporation of water.

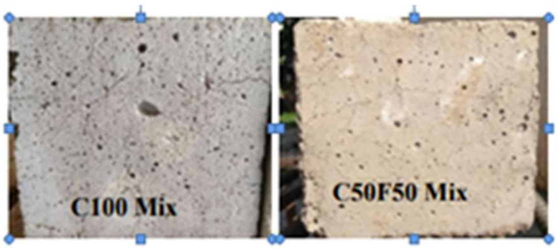


Fig. 3: Cracks observed at 600oC

**Residual compressive strength:**

After exposing cubes to temperatures ranging from 100oC to 1000oC with 100oC intervals, cubes were cooled to room temperature. Residual compressive strengths were determined by testing the cube specimens using a compression testing machine, and the results are shown in table 1.7 to 1.8. Figures 3 and 4 shows the percentage residual compressive strengths of all fly ash mixes after 28 days of exposure to different temperatures. The fly ash mixes had greater percentage residual compressive strengths at all temperatures as compared to regular concrete after 28 days, as shown in Figs. 3 and 4. According to Fig. 3, 4, at 28 days, all concretes gained strength for C50F50 at all temperatures and declined as temperatures increased. The residual compressive strength of the mix C30F70 increased up to 1000oC. C50F50 has a lower percent residual compressive strength between 1000c and 400oC than the other combinations. As a result, it can be inferred that the mix C50F50 performed better at high temperatures than the other mixtures.

**Table 7: Compressive strength test results with 50% cement replacement.**

| TEMP in $^0$C | Compressive strength with gradual cooling (MPa) | Compressive Strength with sudden cooling (MPa) | Residual Percentage decrease in compressive strength (MPa) |
|---|---|---|---|
| 35C | 30.24 | 30.22 | 0.07 |
| 100C | 29.8 | 28.21 | 5.34 |
| 200C | 28.24 | 27.99 | 0.89 |
| 300C | 27.75 | 27.47 | 1.01 |
| 400C | 27.13 | 26.65 | 1.77 |
| 500C | 26.68 | 25.81 | 3.26 |
| 600C | 25.81 | 24.92 | 3.45 |
| 700C | 25.36 | 24.14 | 4.81 |
| 800C | 23.72 | 23.44 | 1.18 |
| 900C | 23.1 | 22.69 | 1.77 |
| 1000C | 19.25 | 19.14 | 0.57 |

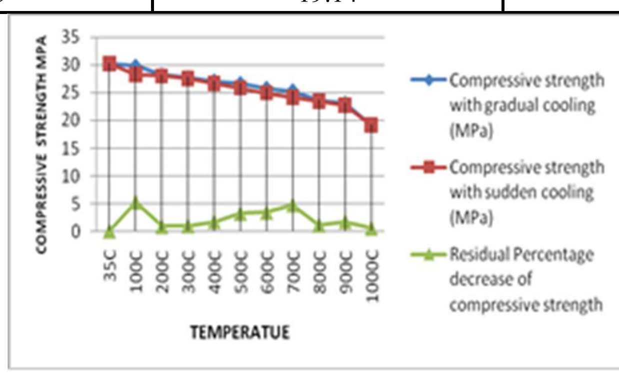


Fig. 4 Variation of compressive strength with 50%, replacement of cement.

**Table-8 : Compressive strength test results of 60%, cement replacement with fly ash.**

| TEMP in $^0$C | Compressive strength with gradual cooling (MPa) | Compressive strength with sudden cooling (MPa) | Residual Percentage decrease in Compressive strength (MPa) |
|---|---|---|---|
| 100C | 28.14 | 27.53 | 2.16 |
| 200C | 27.91 | 27.32 | 2.12 |
| 300C | 26.48 | 25.91 | 2.14 |

| | | | |
|---|---|---|---|
| 400C | 26.06 | 25.76 | 1.14 |
| 500C | 24.87 | 24.43 | 1.79 |
| 600C | 24.56 | 24.12 | 1.81 |
| 700C | 24.12 | 23.68 | 1.84 |
| 800C | 23.68 | 23.38 | 1.25 |
| 900C | 22.93 | 22.34 | 2.57 |
| 1000C | 19.3 | 18.86 | 2.31 |

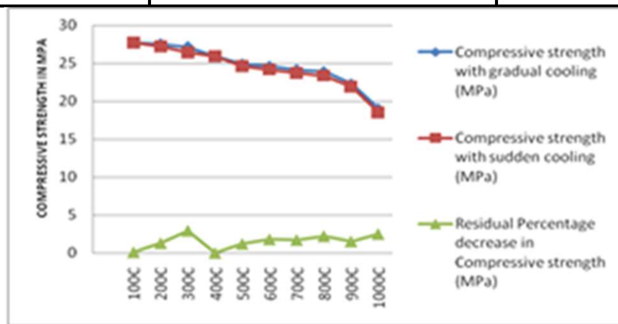


Fig. 5 Variation of Compressive strength with 60%, replacement of cement.

**Table-9: Compressive strength test results of 70%, with fly ash replace cement.**

| TEMP in $^0$C | Compressive strength with gradual cooling (MPa) | Compressive strength with sudden cooling (MPa) | Residual Percentage decrease in Compressive strength (MPa) |
|---|---|---|---|
| 100C | 27.76 | 27.73 | 0.11 |
| 200C | 27.57 | 27.22 | 1.29 |
| 300C | 27.2 | 26.4 | 2.94 |
| 400C | 25.92 | 25.92 | 0.02 |
| 500C | 24.92 | 24.62 | 1.19 |
| 600C | 24.61 | 24.16 | 1.81 |
| 700C | 24.16 | 23.75 | 1.72 |
| 800C | 23.9 | 23.36 | 2.23 |
| 900C | 22.28 | 21.94 | 1.53 |
| 1000C | 19.01 | 18.53 | 2.5 |

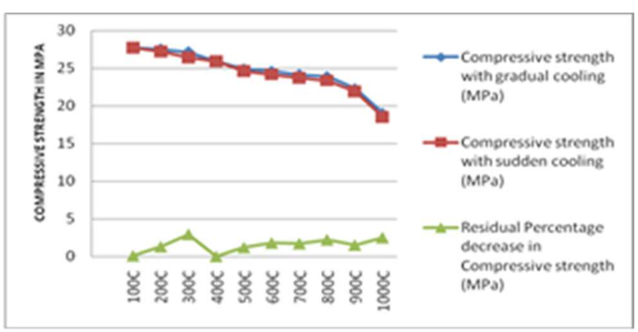


Fig. 5 Variation of Compressive strength with 70%, replacement of cement. Conclusion.

1. The fly ash mixture became orange coloured between 6000C and 10000C, and more fractures were seen at these temperatures.
2. When compared to a typical mix, the low percentage weight loss in fly ash mixtures may be due to the thick structure.
3. In all of the mixes, weight loss increased with increasing temperature. The greater weight loss at high temperatures might be due to the evaporation of total absorbed and adsorbed water from concrete.
4. With the exception of the C50F50 combination, all of the concrete mixes decreased strength up to 1000oC after 28 days.

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