

## International Journal of Innovative Research in Science, Engineering and Technology

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# Use of Fly Ash as Partial Replacement of Cement in Concrete Subjected to Elevated Temperatures

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**ABSTRACT:** This paper presents the effect of addition of fly ash (0-30%) in concrete. Fly ash is a waste material having pozzolanic nature obtained from thermal power plant. Fly ash is added to the concrete in varying percentages, ranging from 0 to 30%. The compressive strength and ultrasonic pulse velocity (UPV) were measured at ambient temperature and at elevated temperature of 200 °C, 400 °C and 800 °C. The exposure of cube specimens to elevated temperatures is maintained for 2 hours. The highest compressive strength at ambient temperature is observed with F15 concrete. At all the targeted elevated temperatures the highest compressive strength is observed with F15 concrete. At ambient temperature, at all the replacement levels of fly ash in concrete, the UPV values of concrete cube specimens exhibited excellent quality. At exposure temperature of 200 °C, the concrete cube specimens exhibited good quality of concrete in accordance with IS 13311 (Part 1): 1992.

**KEYWORDS:** Fly ash, compressive strength, ultrasonic pulse velocity, elevated temperatures

### I. INTRODUCTION

Fly ash is a waste material having pozzolanic nature obtained after the combustion of pulverized coal in electric power generating plants. It is collected from the exhaust gases by electrostatic precipitators. Fly ash particles are generally spherical in shape and diameter ranges from less than 1  $\mu\text{m}$  - 150  $\mu\text{m}$ . It is generally finer than Portland cement. The chemical composition of fly ash is determined by the types and relative amounts of fire-retardant material in the coal used. The main chemical components present in fly ash are silicon dioxide ( $\text{SiO}_2$ ), Aluminum oxide ( $\text{Al}_2\text{O}_3$ ), Ferric oxide ( $\text{Fe}_2\text{O}_3$ ), Calcium oxide ( $\text{CaO}$ ). Fly ash is widely used in producing cement and concrete because of its fineness and pozzolanic nature and sometimes self-cementitious nature. As per ASTM C 618(1993) fly ash is categorized into the following categories namely class C which is produced from lignite of sub-bituminous coals and class F produced from bituminous coals.

In total coal ash the percentage of fly ash present is 75 – 85% remaining ash is termed as bottom ash or boiler slag. Fly ash produced from various power plants is not equally pozzolanic and it is not always suitable for use as mineral admixture in concrete. The major disadvantage of fly ash is its disposal in land fields creating environmental burden.

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## II. MATERIALS AND METHODS

**Cement:** Ordinary Portland cement 53 grade (OPC) is adopted throughout the experimental investigation. The properties are given in Table I.

**Sand:** Krishna sand which is available locally is used in the experimental investigation. The specific gravity and fineness modulus of sand are 2.57 and 2.46 having zone II as per IS 383:2016<sup>[1]</sup>.

**Coarse Aggregate:** Crushed granite passing through 20 mm and retained on 10 mm sieve. Specific gravity of coarse aggregate is 2.7 and fineness modulus 8.83.

**Water:** Potable tap water available from R.V.R & J.C College of Engineering was used for mixing and curing of concrete specimens.

**Fly ash:** Fly ash which is used for the present experimental study is collected from Narla Tata Rao Thermal Power Station near Vijayawada. The fly ash collected is shown in Fig. 1



Fig. 1: Fly ash collected from the power plant

### Experimental tests

The mix proportion arrived for M35 concrete as per IS 10262:2009<sup>[2]</sup> is 1:1.45:2.45 with water cement ratio of 0.42. OPC is replaced with fly ash by 0% (F0), 5% (F5), 15% (F15) and 30% (F30) by weight. The compressive strength and ultrasonic pulse velocity were measured at ambient temperature and at elevated temperature of 200 °C, 400°C and 800 °C. The exposure of cube specimens to elevated temperatures is maintained for 2 hours. Code books used in present experimental study are shown in Table II.

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Table I: Physical properties of cement

S.No	Property	Value
1.	Specific Gravity	3.13
2.	Setting Time	92 min
	Initial Setting Time	195 min
	Final Setting Time	
3.	Compressive Strength	
	7 Days	29.23 MPa
	28 Days	41.62 MPa

Table II: Standard references considered for the experimental study

S. No	Property	Reference
1.	Mix(M35)	IS 10262:2009 <sup>[2]</sup>
2.	Compressive Strength	IS 516:1959 <sup>[3]</sup>
3.	UPV values	IS 13311(part-1): 1992 <sup>[4]</sup>

## Experimental Procedures

Compressive strength test is conducted on concrete cubes of size 100 mm x 100 mm x 100 mm at 28 days of curing age at ambient temperature. The targeted temperatures considered are 200 °C, 400 °C and 800 °C. After 28 days of water curing of concrete cube specimens, the specimens are kept air dried for 2 days and then kept in an electric furnace at targeted temperatures for 2 hours of duration. The cubes after subjected to targeted temperatures are then kept undisturbed in the laboratory for 24 hours and then the compressive strength and ultrasonic pulse velocity (UPV) are measured. The UPV values of concrete cube specimens are measured at ambient temperature and at elevated temperatures. The UPV testing on concrete cube specimens is conducted in accordance to IS 13311 (part-1):1992<sup>[4]</sup>. Table III shows the quality assessment of concrete in accordance with IS 13311 (Part-1): 1992<sup>[4]</sup>. Fig. 2 shows the testing of concrete cube specimens using UPV equipment.

Table III: Quality of concrete as a function of UPV

Pulse Velocity from probe	Designation of quality of concrete
>4.5	Excellent
4.5-3.5	Good
3.0-3.5	Medium
<3.0	Doubtful

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Fig. 2: UPV test Apparatus and concrete specimens

### III. RESULTS AND DISCUSSIONS

#### Compressive Strength:

The compressive strengths of concrete cube specimens at ambient temperature and at elevated temperatures are shown in Table IV. The compressive strength results of F5, F15 and F30 are increased by 101.56%, 106.06% and 100.08% respectively. At 200 °C exposure temperature, the compressive strength of F0, F5, F15 and F30 are 89.61%, 87.12%, 87.26% and 84.22% when compared with 28 days compressive strength at ambient temperature. At 400 °C exposure temperature, the compressive strength of F0, F5, F15 and F30 are 78.54%, 75.04%, 71.426% and 70.26% when compared with 28 days compressive strength at ambient temperature. At 800 °C exposure temperature, the compressive strength of F0, F5, F15 and F30 are 24.14%, 22.24%, 23.53% and 19.61% when compared with 28 days compressive strength at ambient temperature which is shown in Fig. 3. The cubes exposed to 400 °C and 800 °C are shown in Fig. 4.

Table IV: Compressive Strength of concrete subjected to elevated temperatures

Mix designation	Compressive strength (MPa)			
	At 28 days	At 200 °C	At 400 °C	At 800 °C
F0	46.51	41.68	36.53	11.23
F5	47.24	41.18	35.45	10.51
F15	49.33	43.05	35.25	11.61
F30	46.55	39.2	32.71	9.13

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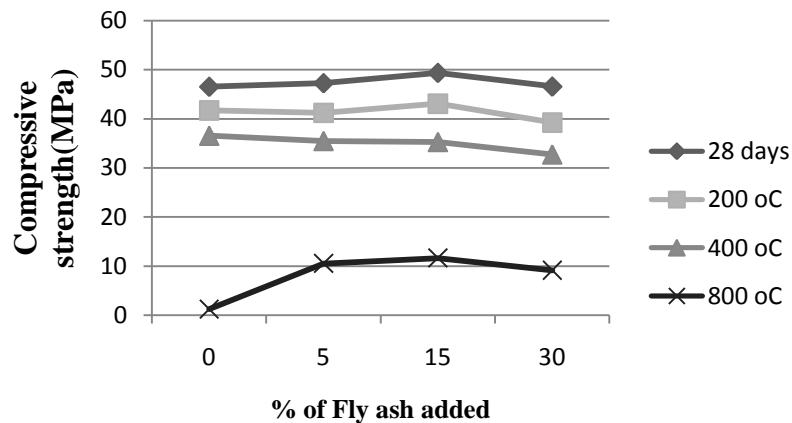


Fig. 3: Compressive strength vs. % fly ash added

### Ultrasonic Pulse Velocity:

The UPV values of concrete cube specimens at ambient temperature and at elevated temperatures are shown in Table V. The UPV test results of F5, F15 and F30 are decreased by 101.99%, 104.18% and 104.38% respectively. At 200 °C exposure temperature, the UPV values of F0, F5, F15 and F30 are 90.03%, 88.08%, 86.23% and 84.35% when compared with 28 days UPV values at ambient temperature. At 400 °C exposure temperature, the UPV values of F0, F5, F15 and F30 are 22.71%, 20.91%, 18.73% when compared with 28 days UPV at ambient temperature. Fig. 5 shows the UPV values of concrete cube specimens after exposure to elevated temperatures using fly ash as partial replacement of cement. A good relationship between UPV values and compressive strength of concrete is observed with a  $R^2$  value of 0.9546 and is shown in Fig. 6.



Fig. 4: Cube specimens after subjected to 400 °C and 800 °C

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Table V: UPV values and quality of concrete as per IS 13311(Part 1): 1992

Mix designation	Ultrasonic Pulse Velocity (Km/s)			
	@ 28 days	@ 200 °C	@ 400 °C	@ 800 °C
F0	5.02 (E)	4.52 (E)	3.29 (M)	1.14 (D)
F5	5.12 (E)	4.51 (E)	3.14 (M)	1.05 (D)
F15	5.23 (E)	4.51 (E)	2.92 (D)	0.98 (D)
F30	5.24 (E)	4.42 (G)	2.74 (D)	E.S

E: Excellent; G:Good; M: Medium; D:Doubtful; E.S: Explosive spalling

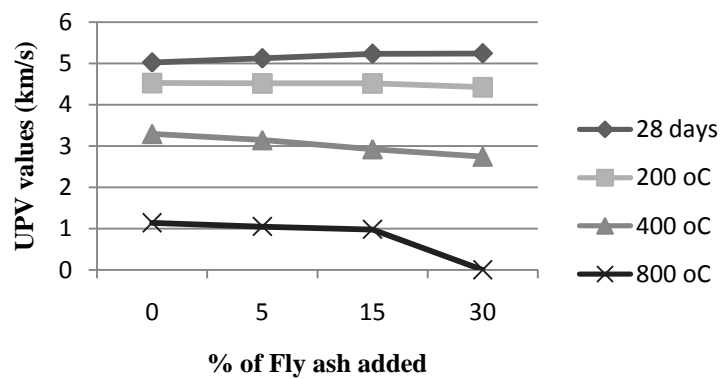


Fig. 5: UPV values vs. % fly ash added

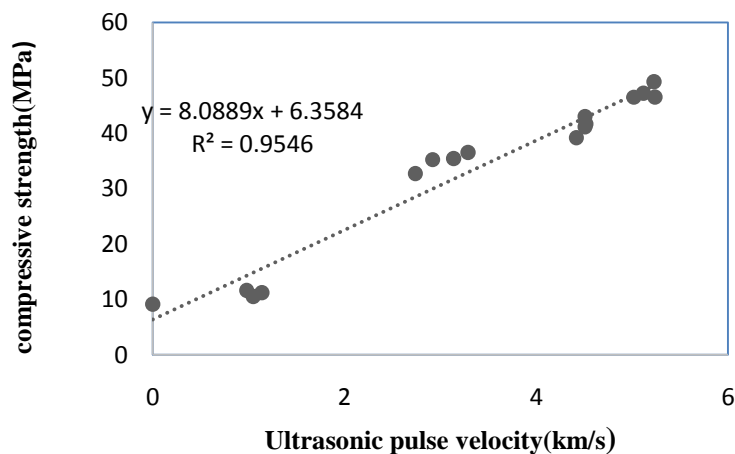


Fig. 6: Compressive strength vs. Ultrasonic pulse velocity

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## IV. CONCLUSION

The highest compressive strength at ambient temperature is observed with F15 concrete. At all the targeted elevated temperatures the highest compressive strength is observed with F15 concrete. The highest compressive strength achieved for F15 concrete could be due to the filling capability and pozzolanic nature of fly ash used as partial replacement of cement. The decrease in the compressive strength of F30 concrete at elevated temperatures could be due to the increase in the pozzolanic material and decrease in the cement content. At ambient temperature, at all the replacement levels of fly ash in concrete, the UPV values of concrete cube specimens exhibited excellent quality. At exposure temperature of 200 °C, the concrete cube specimens exhibited good quality of concrete in accordance with IS 13311 (Part 1): 1992.

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