Study on the physical and mechanical property of ordinary portland cement and fly ash paste
Shaswata Mukherjee¹, Saroj Mandal², Adhikari.U.B³
1- Research Scholar, Department of Civil Engineering, Jadavpur University, Kolkata, India
2- Professor, Department of Civil Engineering, Jadavpur University, Kolkata, W.B, India
3- Ex- Technical Officer, Central Glass and Ceramic Research Institute, Kolkata, India
shaswataa@gmail.com
doi:10.6088/ijcser.0020203000

ABSTRACT
An experimental investigation has been carried out to study the physical and mechanical property of high volume fly ash cement paste. Ordinary portland cement was replaced by 0, 20, 30, 40, 50, 60 and 70 % class F fly ash (by weight). Water-binder ratio in all mixture was kept constant at 0.3. Cube specimens were compacted in table vibrator. As expected bulk density decreases with fly ash increment in the mixture. Apparent porosity and water absorption value increases with replacement of cement by fly ash. Results confirm the decrease in compressive strength at 3, 7 and 28 day with fly ash addition and it is more prominent in case of more than 30% fly ash content mixes. Ultrasonic pulse velocity test results indicate that the quality of the paste deteriorate with increase of fly ash content in the mixture.

Keywords: Fly Ash, OPC, Compressive Strength, Pastes, UPV.

1. Introduction
More than 160 million tonnes of fly ash is being produced by thermal power plant in India (A. K. Jain, 2011). The disposal of fly ash is now a significant concern for the electricity manufacturing plants. Commonly, huge volume of fly ash and bottom ash are now being either ponded or used as land filling to minimize the disposal cost (Bumjoo Kim and Monica Prezzi, 2008). In the year 1985 CANMET first investigate and confirmed that high volume of fly ash has many excellent properties (V.M. Malhotra, 1986). Various standard codes limited the use of quality fly ash up to 35% in cement industry. In India, cement and concrete industry consumes about 40 million tonnes of fly ash. On the other hand, the rising of cement demand can be further resolved by utilizing high volume (more than 50 %) of fly ash in the concrete. This process obviously will be economical as well as reduce greenhouse gas (GHG) emission, minimize waste disposal and health hazards. Thus the use of high volume fly ash in concrete has recently gained popularity as a resource-efficient, durable, cost-effective, sustainable option for ordinary portland cement (OPC) concrete applications (Crouch, L. K et.al. 2007). The aim of this work is to study some physical and mechanical properties such as bulk density, apparent porosity, water absorption and ultrasonic pulse velocity and compressive strength of ordinary portland cement- fly ash pastes (without any aggregate).

2. Materials and Method
2.1 Materials
Ordinary Portland Cement (OPC) having 28 day compressive strength of 54 MPa was used. Typical properties of the OPC used are given in table 1. The fly ash was collected from National Thermal Power Plant, Farakka, West Bengal, India. Chemical composition of both cement and fly ash is shown in table 2. The fly ash contains very less carbon content as indicated by the low value of loss on ignition (LOI). Silica to alumina ratio (SiO2/Al2O3) of the fly ash was ~2.5. The sum total of SiO2, Al2O3 and Fe2O3 equal to 95.74%. Calcium oxide (CaO) content was less than 1%. Hence, as per ASTM C 618-08, it can be classified as class F fly ash. Based on IS: 3812 (Part I)-2003 it can be classified as siliceous pulverized fuel ash. The particle size distribution of fly ash has been given in Figure 1. The fly ash showed a dark gray colour. Normal potable water was used in making the mixture.

Table 1: Typical properties of ordinary portland cement

| FINENESS |  |
| --- | --- |
| Specific Surface (m2/kg) | 312 |
| SETTING TIME (minutes) |  |
| Initial | 180 |
| Final | 290 |
| Normal Consistency (%) | 31.5 |

Table 2: Chemical properties of ordinary portland cement and fly ash

| Chemical composition | SI02 | AI2O3 | Fe2O3 | CaO | MgO | Na2O | K2O | SO4 | LOI* |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| OPC | 18.62% | 4.75% | 3.02% | 61.42% | 3.21% | 1.51% | 1.42% | 2.29% | 3.55% |
| Fly Ash | 64.58% | 25.89% | 5.27% | 0.59% | 0.26% | 0.027% | 0.041% | 0.31% | 2.40% |

*LOI- loss on Ignition

Figure 1: Particle size distribution of Fly ash
2.2 Mix Design and Specimens Preparation

Table 3 represents the mixture proportion of different fly ash-cement pastes. The control mixture without fly ash has been marked as F0 and 20 to 70% OPC have been replaced by fly ash and marked as F20 to F70 respectively. The water-binder ratio was kept constant at 0.3.

Specimens of 50mm cubes were prepared and properly compacted with high frequency vibrating table. Eighteen cubes were cast for each mixture. After 24 hours of casting, the cubes were removed from the mould, and were cured in water at ambient temperature of 25OC till testing. The compressive strength value for a typical mixture at a particular age is based on the average of six cubes.

Table 3: Mixture composition of fly ash-OPC pastes

| Constituents | F0  | F20 | F30 | F40 | F50 | F60 | F70 |
|--------------|-----|-----|-----|-----|-----|-----|-----|
| OPC          | 100 | 80  | 70  | 60  | 50  | 40  | 30  |
| FLY ASH      | 0   | 20  | 30  | 40  | 50  | 60  | 70  |
| W/C Ratio    | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |

2.3 Test procedure

Bulk density, apparent porosity, water absorption and ultrasonic pulse velocity has been measure after 7 day water curing. To determine the bulk density, apparent porosity and water absorption of the fly ash-cement paste specimens, three cubes from each series were dried in hot air oven at 110OC for 24 hours and its weight was taken as dry weight (DW). The specimens were then boiled in water for 2 hours and kept for another 24 hours in the same warm water to penetrate water in the pores. Specimens were then suspended in water with copper wire of 0.5 mm thickness to take the suspended weight (S1 W) as well as soaked weight (S2 W) was also recorded by carefully removing the surface water and the copper wire. The following equations were used to find out the apparent porosity and water absorption of the specimens.

\[
\text{Bulk Density (gm/cc)} = \frac{DW}{S2\ W - S1\ W} \quad (1)
\]

\[
\text{Apparent Porosity (%)} = \frac{S2\ W - DW}{S2\ W - S1\ W} \quad (2)
\]

\[
\text{Water Absorption (%)} = \frac{S2\ W - DW}{DW} \quad (3)
\]

3. Results and Discussions

Figure 2 represent the bulk density of different OPC replaced fly ash paste specimens. It was found that the bulk density of the cement was much higher (1.32 gm/cc) compare to fly ash (0.96 gm/cc). As expected, the bulk density of the specimens decreases with increase of fly ash in the mixture.
Study on the physical and mechanical property of ordinary portland cement and fly ash paste

Shaswata Mukherjee, Saroj Mandal, Adhikari.U.B

International Journal of Civil and Structural Engineering
Volume 2 Issue 3 2012

Figure 2: Bulk Density on OPC replacement

Figure 3 and Figure 4 represent the apparent porosity and water absorption of the specimens. Both the apparent porosity and water absorption value increased with fly ash replacement. This result indicates the poor microstructure with high amount of fly ash pastes.

Figure 3: Apparent porosity on OPC replacement

Figure 4: Water absorption on OPC replacement
Ultrasonic pulse velocity test has been done to assess the quality of paste specimens by method mentioned at IS: 13311 (Part 1) – 1992. It is evident from the UPV test results that all the test specimens fall in “GOOD” category. With fly ash increase the UPV results confirms the deterioration in quality.

Table 4: Ultrasonic Pulse Velocity Test Results of Paste Specimens (Km/Sec)

| Fly Ash Content | 0 % | 20 % | 30 % | 40 % | 50 % | 60 % | 70 % |
|----------------|-----|-----|-----|-----|-----|-----|-----|
| UPV            | 3.78| 3.74| 3.73| 3.68| 3.64| 3.58| 3.55|

The compressive strength was determined using a digital compression testing machine. The maximum load at failure reading was taken and the average compressive strength has been plotted against fly ash content. It is evident that the compressive strength of the specimens decreases with increase of fly ash in the mixture at 3, 7 and 28 day (Figure 5). The drop in compressive strength is prominent when fly ash content in the mix increased above 30%. From the experimental result optimally 60% (max.) fly ash content OPC can be used for some low strength concrete and masonry works. This will directly reduce the cost of construction as well as reduce the green house gas emission.

![Figure 5: Compressive strength of fly ash-cement pastes](image)

4. Conclusion

On the basis of the present study, it may be concluded that, in general use of fly ash in ordinary portland cement decreases the compressive strength up to 28 days. Sharp drop in compressive strength is found for more than 30% fly ash content mixes. As the pozzolanic reaction usually takes time, the strength may get increased over time and some long term study is needed. Bulk density decreased with fly ash addition which may be of good interest for the civil engineer for light weight of the construction. Others physical property such as apparent porosity and water absorption begin to increase with fly ash increment which may harm the durability of high fly ash content concrete. UPV result confirms the poor quality of paste with high fly ash content.
Acknowledgement

The financial assistance to this experimental study received from Department of Science and Technology (DST PURSE SCHEME), Govt. of India, New Delhi.

5. References

1. K. Jain (2011), “Fly ash utilization in Indian Cement Industry: current status and future prospects”, Proceeding of the National Roving Seminar on concrete sustainability through innovative materials and techniques, Kolkata, India, pp 46-51.

2. ASTM C618 - 08a, (2008), standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete, American Society for Testing and Materials, USA

3. Bumjoo Kim, Monica Prezzi (2008), “Compaction characteristics and corrosivity of Indiana class-F fly and bottom ash mixtures”, Construction and Building Materials, 22, pp 694–702.

4. Crouch, L. K., Hewitt, R., Byard, B (2007), “High Volume Fly Ash Concrete”, Proceedings of World of Coal Ash (WOCA), Kentucky, USA, pp 1-14.

5. IS: 3812 (Part I). (2003), Pulverized Fuel Ash - Specification - Part 1: For Use as Pozzolana in Cement, Cement Mortar and Concrete, Bureau of Indian Standards, New Delhi.

6. IS 13311 (Part 1). (1992), nondestructive testing of concrete: Part 1 Ultrasonic pulse velocity, Bureau of Indian Standards, New Delhi.

7. V.M. Malhotra. (1986), “Superplasticized fly ash concrete for structural concrete application”, Concrete International, 8(28), pp 28-31.