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# Flow behavior and strength for fly ash blended cement paste and mortar

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**Abstract**

In this study, compressive strength and flow behavior of fly ash incorporated cement paste and mortar were investigated. For this purpose, four water to binder ratios ($w/(c+f)$) such as 0.25, 0.35, 0.45 and 0.55 with three curing ages and five wide range of fly ash replacement levels ($f/c$ ratio) namely 0, 0.1, 0.2, 0.3 and 0.4 were introduced in the experimental scheme. The workability of the mixture was ensured through Marsh cone and flow table tests for fly ash blended cement paste and mortar, respectively. The test result showed that compressive strength increases with age as expected in all cases and an empirical relationship for compressive strength of blended cement paste and mortar with mix factors such as $w/(c+f)$ ratio, $f/c$ ratio and age is also proposed. The estimated compressive strength versus $w/(c+f)$ ratio curves for different curing ages and $f/c$ ratios resembles the nature of Abrams' strength versus $w/c$ ratio curves.


*Keywords:* Paste; Mortar; Fly ash; Workability; Strength

## 1. Introduction

A large number of researches have been directed towards the utilization of pozzolana materials. For the construction industry, the development and use of blended cements become a common practice in these days. Pozzolana from power plant residue such as fly ash are receiving more attention now since their uses generally improve the properties of the blended cement concrete, the cost and the reduction of negative environmental effects (Chindaprasirt and Rukzon, 2008). Fly ash improves the properties of concrete or cement paste due to the pozzolanic reaction and its role as a micro-filler. It is often thought that the first function (pozzolanic reaction) is most important. The hydration reaction depends on curing period so that, in many specifications, it is noted that fly ash–cement concrete needs a longer curing period than conventional concrete (Termkhajornkit et al., 2006).

The main implications of the partial replacement of cement by fly ash in cement paste and mortar are micro-structure improvement, pore filling effect and better packing characteristics of the mix. The workability of the blended cement paste and mortar is greatly modified due to the incorporation of finer Pozzolana materials such as fly ash, silica fume, etc. This addition depends both on the quality of fly ash and the stipulated requirements of

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strength and durability. Presently, fly ash and cement contents in a mix are determined by laboratory trials. The first requirement to be met is usually the workability of the mixture, which is controlled by the water–cementi tious-material ratio. To decide upon the extent to which fly ash can be used at the lowest possible water–cementi tious-material ratios, different workability tests are conducted to optimize the proportion of fly ash (Joshi and Nagaraj, 1990).

The workability of the cementitious product has been attained by some compatible water reducing admixtures like super-plasticizers. In addition to this, the cement super-plasticizer compatibility is affected by the following parameters related to the cement: chemical and phase composition, especially $C_3A$ content, alkali content, amount and type of calcium sulphate (dihydrate, bassanite, anhydrite), cement fineness and free lime content. Taking into account the properties of a super-plasticizer, the following factors are of great importance: its chemical nature and average molecular weight, super-plasticizer degree of sulphonation, admixture dosage and addition method (Grabiec and Piasta, 2004). The determination of the optimum dosage of super-plasticizer for blended paste and mortar is generally carried out by different methods such as Marsh cone test, flow table test and mini slump cone test.

According to the authors, the strength of cement paste can be estimated from the information of $w/c$ ratio, age and fineness of cement (Kondraivendhan and Bhattacharjee, 2010). Same thing is extended to cement fly ash paste and mortar as well (Kondraivendhan and Bhattacharjee, 2013). The hydration products of fly ash reduce the pore size, in this way more strength and durable concrete are obtained (Kocak and Nas, 2014). By the utilization of fly ash it is not only minimizing the carbon foot print but also sustainable development can be achieved (Wang and Shuang, 2011; Imbabi et al., 2012). It is also observed that the degree of hydration of paste and mortar has been improved by better particle size distribution and finer particle sizes of fly ash (Zhao et al., 2015).

In this study, the experimental compressive strength for fly ash blended cement paste and mortar specimens is investigated and the foremost workability requirement is also carried out by Marsh cone test and flow table test for fly ash blended cement paste and mortar, respectively. The compressive strength is determined experimentally and a relationship for compressive strength with mix parameters is developed for fly ash blended cement paste and mortar specimens as well. The estimated compressive strength of fly ash blended cement paste and mortar is plotted against $w/(c+f)$ ratio for various curing ages and $f/c$ ratios.

## 2. Experimental investigation

The main objective of this experimental investigation is to study the strength and workability for fly ash blended cement paste and mortar. The experimental factors and their levels have been chosen accordingly as follows;

### 2.1. Materials

#### 2.1.1. Cement

To investigate upon the response of strength improvement and workability, one grade of cement as defined in Indian Standard (IS) was used namely ordinary Portland cement OPC 43 grade conforming to IS: 8112:1989 (2005) and ASTM Type 1 specifications. The mean particle diameter of cement is 17 μm which is determined by laser based Time of Transition method using Ankersmid CIS-50 particle size analyser. The physical and chemical composition of cement is given in Tables 1 and 2.

#### 2.1.2. Sand

Natural river sand owing to their rounded shape was used in this work as it ensures better packing characteristics than the crushed sand. Locally available two types of river sand having the fineness modulus values of 2.66 and 2.08 were mixed in the proportion of 70% and 30% respectively so as to obtain packing density value of 0.61. The grading of sand satisfies the Indian standard IS: 383-1970 (2002) and is given in Table 3.

Table 1
Physical properties of ordinary Portland cement.

| Characteristics | Results obtained | Requirement as per IS: 8112-1989 |
|---|---|---|
| Normal consistency (%) | 29.00 | |
| Initial setting time (min) | 115.00 | Min 30 |
| Final setting time (min) | 165.00 | Max 600 |
| Specific gravity | 3.15 | |
| Blaine's fineness ($m^2$/kg) | 335.00 | Min 225 |
| Soundness (mm) | 1.00 | Max 10 |
| *Compressive strength (MPa)* | | |
| 3 days | 34.00 | Min 23 |
| 7 days | 42.00 | Min 33 |
| 28 days | 51.50 | Min 43 |

Table 2
Chemical properties of ordinary Portland cement.

| Oxide composition | (wt%) |
|---|---|
| CaO | 59.98 |
| $SiO_2$ | 21.18 |
| $Al_2O_3$ | 5.36 |
| $Fe_2O_3$ | 3.48 |
| MgO | 2.05 |
| $SO_3$ | 2.8 |
| $Na_2O$ | 0.36 |
| $K_2O$ | 0.69 |
| LOI | 2.67 |
| Insoluble residue | 2.32 |
| Free lime | 1.06 |