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High Volume Replacement of Cement by Ultra-Fine Fly Ash: Performance of 1:3 and 1:4.5 Mortar

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Abstract - — *Use of super-fine or ultra fine fly ash in mortar and concrete is recent trend. Recently IS allows up to 30% replacement of cement. Ultra-fine fly ash can be used for higher replacement of cement and depending upon the strength properties the structural suitable application can also be further decided. Therefore it can be said that there is a need of research and investigation in this particular area to understand the most beneficial and economical features of the UFFA modified mortar. This study investigates the use of ultra-fine fly ash for high volume (30-50%) replacement of cement to assess the compressive strength of 1:3 and 1:4.5 mortar. Result showed that significant reduction in Ordinary Portland cement can be achieved using UFFA for cement replacement in mortar with higher and same level performance. Maximum increase in compressive strength at the age of 28 days for 1:3 mortar and 1:4.5 mortars was found 40 % and 30 % respectively. After that there is decrease in compressive strength but it is equal to the compressive strength of mortar with 0 % UFFA.*

***Key Words*: Comparative performance, Compressive strength, Ordinary Portland cement, Ultra-fine Fly ash,**

1. INTRODUCTION

Cement both in mortar and concrete, is the most essential element of the infrastructure and has been known as a long-lasting construction material [10, 11]. However, the ecological aspects of cement are now gaining anxiety of researchers, as cement manufacturing is responsible for about 2.5% of total worldwide waste emissions from industrial sources [10]. Using different types of waste materials in construction industry is now a growing trend. Recycling of waste materials is a twofold purpose (a) to minimize the amount of waste to be deposited and (b) to preserve natural resources [12].

Reuse of recycled or waste materials for the construction of civil structures is an issue of great importance in this century. Mixing of mineral admixtures in concrete and mortar improves compressive strength, pore structure and permeability. Some of this materials, known as Pozzolana, which by themselves have no cementitious properties, however, when used with Portland cement reacts to form cementitious materials. Partial replacement of Portland cement in concrete reduces the volume of Portland cement. This reduction in cement volume further reduces the construction cost, energy loss and waste emissions such as carbon dioxide (CO_2) emission. This also, reduces the energy consumption and thus, reduces the rate of global warming [11, 13, and 14].

2. EARLIER INVESTGATION & SCOPE OF THE STUDY

It is widely recognized that most pozzolans when used correctly in concrete increase its durability [9] and Laboratory investigations around the world have shown that when FA particle size is reduced, its performance in concrete is improved [3]. Performance of PFA in concrete is found to be comparable to other highly reactive pozzolans such as silica fume [5, 7] and addition of PFA in concrete has been found to enhance the performance at later age [5, 7]. Investigation reported incorporation of PFA increases the setting time of cement paste and decreased water demand from 30 % to 50 % [1, 2]. Researchers investigated significant improvement in concrete strength and durability without loss in workability with commercially available fly ash [3]. Investigators also reported significant improvement in compressive strength at later age [4, 5]. Researchers reported that addition of UFFA in concrete has been found to enhance the long term performance of concrete in terms of chloride penetration, alkali-silica reactivity and sulfate attack and also significant reduction in both shrinkage and shrinkage cracking potential as compared to concrete containing SF. Due to these advantages UFFA seems to be ideal choice for cement replacement in concrete.

3. OBJECTIVE OF THE STUDY

The objective of this experimental work is to determine the strength characteristics of 1:3 and 1:4.5 mortars with a partial replacement of cement by ultra-fine fly ash 0%, 30%, 40% and 50% concrete

4 EXPERIMENTAL PROGRAMME

The experimental program was designed to find compressive strength of 1:3 and 1:4.5 mortars with different replacement levels of ordinary Portland cement (ultra tech cement 53 grade) with replacement of ultra-fine fly ash. In test series A the specimens were cast with 1:3 mortars with W/C ratio 0.43 for different replacement levels of cement as 0%, 30%, 40% and 50% and test series B the specimens were cast with 1:4.5 mortars with W/C ratio 0.55 for different replacement levels of cement as 0%, 30%, 40% and 50%.

5 MATERIALS AND METHODS

5.1 Ultra-fine fly ash

The fly ash used in the experimentation was obtained from DIRK INDIA PRIVATE LTD. The chemical composition of flyash is shown in the table 1

5.2 Cement

Locally available Ordinary Portland Cement (OPC) 53 grade was used.

5.3 Sand

Locally available Narmada sand (zone-II) was used.

5.4 Water

The water used in the mortar was ordinary tap water from the Bhopal city.

Table 1: Chemical composition of fly ash

Oxides	Percentages
$Si_2O+Al_2O+Fe_2O_2$	70 min
SiO_2	35 min
Reactive silica	20 min
MgO	05 max
SO_3	03 max
Na_2O	1.5 max
Total chlorides	0.05 max

6 TESTING OF CONCRETE CUBES

The compressive strength of mortar speciemen was determined using Compression Testing Machine (CTM). Three samples of each composition were subjected to a compressive strength test, and the average strengths were recorded. The program consists of casting and testing of total of 48 mortar specimens of 70.7 x 70.7 x 70.7 mm size.

7 RESULT AND DISCUSSION

Workability of the mortar good enough and the mortar surface is was found quite homogeneous without air voids in 1:3 mortar. Slightly less workable mortar was observed in case of 1:4.5 mortar. Effect of UFFA replacement on the compressive strength for both martar is shown in table 2 3.

Table 2: Compressive strength of 1:3 mortar prepared with various cement replacement ratio.

Mix	Cement Replacement by UFFA (%)	Compressive Strength	
		07 days (MPa)	28 days (MPa)
M0	0	16	17
M30	30	16	28
M40	40	16.7	30
M50	50	16	17

Table 3: Compressive strength of 1:4.5 mortar prepared with various cement replacement ratio.

Mix	Cement Replacement by UFFA (%)	Compressive Strength	
		07 days (MPa)	28 days (MPa)
M0	0	10.6	12
M30	30	10.6	18.6
M40	40	8.9	16
M50	50	7.5	12

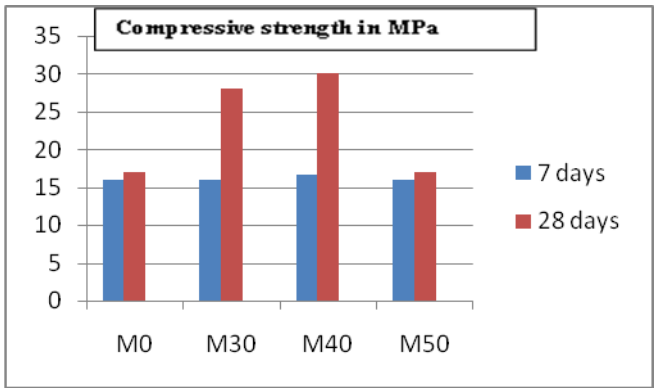

FIGURE 1: Effect of cement replacement by UFFA on Compressive strength of 1:3 mortar

From the bar chart (fig.1) it is clearly understood that as the replacement level increases there is increase in compressive strength at 28 days of curing for both 1:3 mortar and 1:4.5 mortar.

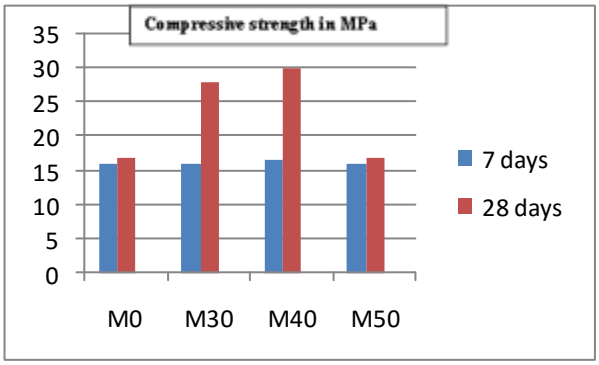

FIGURE 2: Effect of cement replacement by UFFA on Compressive strength of 1:4.5 mortar

In case of 1:3 mortar the maximum compressive strength at the age of 28 days was found at 40 % replacement of cement by UFFA. At 50 % replacement obtained compressive strength was equal to the control mix with 0 % replacement.

In case of 1:4.5 mortar (fig. 2) it was observed that compressive strength at the age of 28 days was much more at 30 % and 40 % replacement than the control mix. Maximum compressive strength was found at 30 % replacement and At 50 % replacement obtained compressive strength was equal to the control mix with 0 % replacement.

3. CONCLUSIONS

Based on the result presented above, the following conclusion can be drawn:

1. Significant reduction in Ordinary Portland Cement can be achieved using UFFA in mortar for cement replacement.

2. Workability of 1:3 mortar during processing was found higher as compared to 1:4.5 mortar.

3. Compressive strength increases as the % of replacement increases. For 1:3 mortar maximum increase in compressive strength at the age of 28 days was found at 40 % replacement of cement by UFFA. Beyond 40 % compressive strength reduces but it was equal to the compressive strength of control mix with 0 % replacement.

4. For 1:4.5 mortar maximum increase in compressive strength at the age of 28 days was found at 30 % replacement of cement by UFFA. Beyond 30 % that compressive strength reduces but it was equal to control mix.

5. At 50 % replacement compressive strength obtained was equal to the compressive strength of control mix for both mortars, it can be said that with proper quality control higher replacement (more than 50 %) can also be achieved.

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