High Volume Replacement of Cement in Mortar: A Green Mortar

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Abstract— Durability and performance of concrete structures is governed significantly by constituents of concrete mix used. Hence, use of alternative materials in place of cement in concrete to is enormously increased. Use of waste materials as supplementary cementitious materials (SCM) is now a global trend undergoing rapidly. Utilization of waste materials such as blast furnace slag, fly ash, medical waste ash and silica fume, waste glass powder etc. in the construction field, has gained importance because of the shortage of natural resources and various environmental problems caused by storing wastes. 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. 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 mortar. Result showed that significant reduction in Ordinary Portland cement can be achieved using ultra-fine fly ash for cement replacement in mortar with higher and same level performance. Maximum increase in compressive strength at the age of 28 days was found 40 %. After that there is decrease in compressive strength but it is equal to the compressive strength of mortar with 0 % UFFA replacement.

Keywords: Comparative performance, Compressive strength, Ordinary Portland cement, Ultra-fine Fly ash

I. 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 [1, 2]. 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 [1]. 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 [3].

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 (CO2) emission. This also, reduces the energy consumption and thus, reduces the rate of global warming [2, 4, and 5].

Concrete composed by partially replacing cement with industry wastes are termed are green cement. This developed green cement is compared with ordinary Portland cement by many researchers. This "green" material utilizes less natural resource and energy, and generates less CO_2 [6].

II. EARLIER INVESTIGATION & SCOPE OF THE STUDY

Neville and aitcin [7] suggested that high performance concrete is not fundamentally different from the concrete used in the past, although it usually contains fly ash, ground granulated blast furnace slag and silica fume, as well as super plasticizer.

Breitenbiicher [8] discussed that in High Performance Concrete structures, both the increased strength as well as the improved microstructure can be utilized. Both effects are achieved using an optimized concrete technology, namely an extremely low w/c-ratio and the addition of silica fume. In the case of High Performance Concrete, reinforcement can be minimized and/or the dimensions of the structural members can be reduced.

According to Hendriks and Janssen [9] there are several options for the use of recycled materials in constructions. For every option a number of technical and environmental aspects are relevant. This paper describes several models which can be used to take the optimal decision. In general the world-wide used Life Cycle Assessment can be used as a multi-parameter model for the environmental effects.

Mazanec et al.[10] described that shortest necessary mixing time (stabilisation time) was calculated from the evolution of the power applied to the tool during mixing. It was confirmed that high w/c values resulted in short stabilisation times. In addition, the contents of silica fume and quartz flour as well as the type of cement and superplasticizer affected the stabilisation time significantly.

Yeh [11] described a method of optimizing high-performance concrete mix proportioning for a given workability and compressive strength using artificial neural networks and nonlinear programming.

It is widely recognized that most pozzolans when used correctly in concrete increase its durability [13] and Laboratory investigations around the world have shown that when FA particle size is reduced, its performance in concrete is improved [12]. Due to these advantages UFFA seems to be ideal choice for cement replacement in concrete & mortar.

III. OBJECTIVE OF THE STUDY

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

IV. EXPERIMENTAL PROGRAMME

The experimental program was designed to find compressive strength of 1:3 mortar with different replacement levels of ordinary Portland cement (ultra tech cement 53 grade) with

replacement of ultra-fine fly ash. 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%.

V. MATERIALS & METHODS

A. 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

B. Cement

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

C. Sand

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

D. Water

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

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

Table 1: Chemical composition of fly ash

VI. TESTING OF CEMENT CUBES

The compressive strength of mortar specimen 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 24 mortar specimens of 70.7 x 70.7 x 70.7 mm size.

VII. RESULT & DISCUSSION

Workability of the mortar good enough and the mortar surface is was found quite homogeneous without air voids in 1:3 mortar. Effect of UFFA replacement on the compressive strength for mortar is shown in table 2.

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

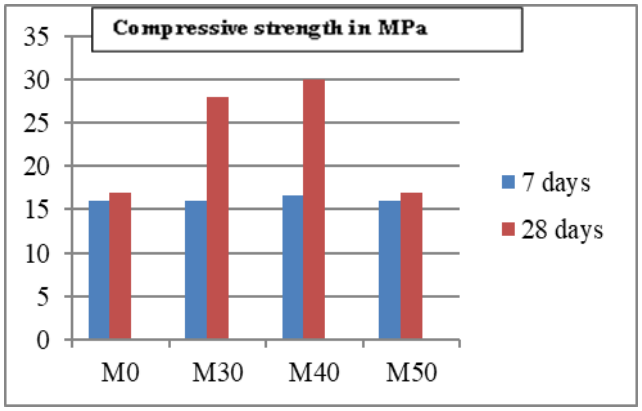

Fig. 1: Effect of cement replacement by UFFA on Compressive strength of 1:3 mortar

From the bar chart (fig.1) it is clearly understood that as the replacement level increases there is increase in compressive strength at later age 28 days. Strength at earlier age (7days) found similar to the mix with 0 % ultra-fine fly ash.

It was observed that 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.

VIII. CONCLUSION

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 the mortar good enough and the mortar surface is was found quite homogeneous without air voids
3) Compressive strength increases as the % of replacement increases. The higher value of compressive strength at the age of 28 days was observed 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) In mortar prepared using 50 % replacement of cement the compressive strength obtained was equal to the compressive strength of control mix. Therefore it can be said that with proper quality control higher replacement (more than 50 %) can also be achieved.

REFERENCES

[1] Amin N. "Use of Bagasse Ash in Concrete and Its Impact on the Strength and Chloride Resistivity "J. OF MAT. IN CIVIL ENGG. , May 2011, P. 717-720
[2] Sujivorakul C., Jaturapitakkul C.and Taotip A." Utilization of Fly Ash, Rice Husk Ash, and Palm Oil Fuel Ash in Glass Fiber–Reinforced Concrete"J. OF MAT. IN CIVIL ENGG. , Sep. 2011, P. 1281 -1288
[3] Zega C. J. and Di Maio A.A." Recycled Concretes Made with Waste Ready-Mix Concrete as Coarse Aggregate "J. OF MAT. IN CIVIL ENGG. , Mar. 2011, P. 281 -286
[4] Vanikar S.N. "THE ADVANCES AND BARRIERS IN APPLICATION OF NEW CONCRETE

TECHNOLOGY", Int. W/S on Sus. Dev. and Con. Tech. , Beijing 2004, P. 25-33

[5] Mehta P.K. "HIGH-PERFORMANCE, HIGH-VOLUME FLYASH CONCRETE FOR SUSTAINABLE DEVELOPMENT", Int. W/S on Sus. Dev. and Con. Tech. , Beijing 2004, P. 3-14

[6] Shah S.P. and Wang K. "DEVELOPMENT OF "GREEN" CEMENT FOR SUSTAINABLE CONCRETE USING CEMENT KILN DUST AND FLY ASH" Int. W/S on Sus. Dev. and Con. Tech. , Beijing 2004, P. 15-23

[7] Adam Neville and Pierre-Claude A tcin "High performance concrete- An overview" Materials and Structures/Mat~riaux et Constructions, Vol. 31, Mars 1998, pp 111-117

[8] Dr.-Ing. R. Breitenbiicher "Developments and applications of high-performance Concrete" Materials and Structures/Materiaux et Constructions, Vol. 31, April 1998, pp 209-215

[9] Ch. F. Hendriks and G. M. T. Janssen "Use of recycled materials in constructions" Materials and Structures" / Matdriaux et Constructions, Vol. 36, November 2003, pp 604-608

[10] O. Mazanec Æ D. Lowke Æ P. Schießl "Mixing of high performance concrete: effect of concrete composition and mixing intensity on mixing time. Materials and Structures (2010) 43:357–365

[11] I-Cheng Yeh, "DESIGN OF HIGH-PERFORMANCE CONCRETE MIXTURE USING NEURAL NETWORKS AND NONLINEAR PROGRAMMING. JOURNAL OF COMPUTING IN CIVIL ENGINEERING / JANUARY 1999

[12] Karthik H. Obla, Russell L. Hill, Michael D. A. Thomas, Surali G. Shashiprakash, and Olga Perebatova, "Properties of Concrete Containing Ultra Fine-Fly Ash", ACI Material Journals Vol 100 Issues 5, pp 426-433, 2003.

[13] "Pozzolanic and Cementitious materials", Ed.V.M. Malhotra and P.K Mehta, Gordon and Preach Publishers, 1996

