ARPN Journal of Engineering and Applied Sciences



# EXPERIMENTAL STUDY OF ULTRA FINE PARTICLES IN MECHANICAL AND DURABILITY PROPERTIES OF FLY ASH CEMENT COMPOSITE MORTAR

L. Krishnaraj, Madhusudhan N. and P. T. Ravichandran
Department of Civil Engineering, SRM University, Kattankulathur3, Tamil Nadu, India
E-Mail: krishnarajcivil@gmail.com

**ABSTRACT**

The paper deals with the impact of Alccofine on the strength, durability and characterization of ball milled fly ash based cement mortar. The cement is partially replaced by fly ash in the form of Raw Fly Ash (RFA) and Ultrafine Fly Ash (UFFA). The basic properties of materials were studied. The results showing that RFA mortar samples are showing more normal consistency of 38% than the UFFA samples at 28%. The mechanical strength development of the fly ash mortar with influence of AF are investigated. The OPC was replaced with 50% of RFA and UFFA reduced 30% and 10% of strength comparing with control mortar. The 10% of AF additionin both RFA and UFFA mortar gained better split tensile strength than the control mortar. The water absorption of mortars casted with 0.40 show very low water absorption than the mortars casted with 0.55. Above 24% water absorption is decreased by replacing cement with fly ash and alccofine. Fly ash mortar blended with AF shows better mechanical and durability properties. The microstructural properties of the specimens were analyzed using Scanning Electron Microscope (FESEM) analysis. Overall the SEM analysis posited that due to the impact of alccofine and the fineness of fly ash facilitated the ball milled fly ash based mortar shows better characteristics of controlled cement mortar.

**Keywords:** alccofine, ultra fine fly ash, ball milling, microstructural analysis, compressive strength, durability study.

## 1. INTRODUCTION

Growing concern on the global warming has reached the epitome in recent years. The Greenhouse gases (GHG) emission has been the contemporary issue in all the developed as well as the developing nations. Cement industry plays an important role in the emission of greenhouse gases (GHG) since production of one ton cement emits almost one ton of carbon dioxide. Therefore a mitigate measure has to be developed in order to combat the consequences. One such measure is to replace the cement partially by Secondary cementitious products such as Fly ash, Silica fume, rice husk ash, Ground Granulated Blast furnace slag. Among all the available SCM's Fly ash, a byproduct of thermal power plant, has gained the predominant position in cement replacement practices. It is observed that incorporating fly ash has a significant increase in the strength and also exhibits lower shrinkage deformations [1].

However, the usage of fly ash has been restricted due to lack of comprehension in the characteristics of fly ash. Studies have reported that the addition of ultra-fine fly ash showed better results in fluidity, thus performing for good workability [2]. Therefore the scope for research on the varied forms of fly ash is to be carried out. Ball milling has been adopted in several studies to understand the benefits of finer fly ash [3]. Some research has shown that the fineness of fly ash mainly increases the strength characteristic of mortar [4, 5]. In addition the performance characteristics can also be increased by utilization of finer fly ash [6]. However the shortcoming for the judicious use of finer fly ash was the workability characteristics and necessary additives should be incorporated to overcome adverse effects [7]. To overcome the defect, in some studies chemical admixtures has been used to improve the workability of mortar [8]. It was observed that effect of chemical admixture had a substantial elevation in the workability and strength of fly ash cement mortars [9]. It was observed in a research that incorporating alccofine increases the self-compatibility characteristics of mortar [10]. In this paper, the effects of Alccofine incorporated fly ash cement mortar on the mechanical, durability and microstructural properties were examined.

## 2. EXPERIMENTAL PROGRAM

### 2.1 Materials

In this study Ordinary Portland cement of 43 grade (OPC 43) of Ultratech brand confirming to IS 8112 was used. Distilled water having the pH value as 7 was used for mortar preparation and casting of specimens. For the curing of specimens normal potable water mixed with lime powder was used. The class C Raw Fly ash (RFA) obtained from Neyveli Lignite Corporation, Neyveli, Tamil Nadu was taken to make ultra-fine fly ash. The RFA was grinded for 5 hours to reduce its size into ultrafine particles, and ultra-fine fly ash is produced. Conforming to IS 650, three different grade of standard Ennore sand has been used as the fine aggregate for preparing standard mortar samples. All the particles of standard sand fall within the size range of 2mm to 90mm. Each grade of sand was taken equally for the mix.

### 2.2 Chemical admixtures details

Alccofine is replaced at 5% and 10% which is manufactured through granulation of slag obtained. The Physical and chemical composition of Alccofine is given in the Table 1 and 2.

ARPN Journal of Engineering and Applied Sciences



**Table-1.** Physical composition of Alccofine.

| **Fineness** ($cm^2/gm$) | **Specific gravity** | **Bulk density** ($kg/m^3$) | **Particle size distribution** | | |
|---|---|---|---|---|---|
| | | | **D10** | **D50** | **D90** |
| 800 | 3.11 | 700-900 | 1 | 5 | 9 |

**Table-2.** Chemical composition of Alccofine.

| **Cao** | **So$_3$** | **$SiO_2$** | **$Al_2O_3$** | **$Fe_2O_3$** | **MgO** | **Cl** |
|---|---|---|---|---|---|---|
| 61-64% | 2-2.4% | 21-23% | 5-5.6% | 3.8-4.4% | 0.8-1.4% | 0.03-0.05% |

In addition to alccofine, superplasticizer Conplast SP 340 which was based on sulphonated naphthalene (SNF) polymers was used in the percentage of 1% to 1.3%.

**2.3 Mortar mix proportions**

Along with the control mortar six more mix combinations were investigated. In those, three mix combinations for RFA mortar and remaining three for UFFA mortar. The same mix combinations were also casted with low water cement ratio by adding super plasticizer in to it. So in total 14 mix combinations were investigated in this project. In this study Mix design that adopted was confirming to IS 10262-2009. The adopted mix ratio for the mortar mix was 1:3. The water binding ratio adopted for mix combinations without super plasticizers was 0.55 and 0.4 for the mix with super plasticizer.

**2.4 Specimen preparation**

The preliminary tests were conducted to determine the water to binder ratio. Firstly, normal consistency for cement was carried out in accordance to IS 4031-Part 4, and the water requirement for the mortar was identified. Secondly, with the identified consistency the water to binder ratio for the cement mortar was optimized using flow table test. The cement mortars prepared with RFA and UFFA at 1:3 ratio along with chemical admixtures such as alccofine and superplasticizer were subjected to flow table test. The flow table test was performed conforming to IS 5512, and the water to binder ratio was found to be workable at 0.55 with the aid of superplasticizer at 1%.

The specimen was subjected to compressive strength testing in lieu with IS 4031-Part 6 for all the mixtures. The cubes were observed for the durability test such as the water absorption test. To determine tensile strength of cement mortar, the specimens made were in accordance to IS 1586: 1999 for all the different mix proportions. After 24 hours, specimens were de-molded and immersed in the water tank for curing up to the testing age. Compression strength and split tensile strength were determined at $7^{th}$, $14^{th}$, 28th, $56^{th}$ and $120^{th}$ day. The microstructural properties of the specimens were analyzed using scanning electron microscope (FESEM) test.

**3. RESULTS AND DISCUSSIONS**

**3.1 Basic properties**

The degree of wetness exhibited by a freshly mixed mortar is the consistency of that mortar. Fineness is one of the major factors affecting the normal consistency. The results showing that RFA mortar samples are showing more normal consistency of 38% than the UFFA samples at 28%. 10% replacement of fly ash with the AF shows the maximum consistency. This is due to the high reactive ability of the Alccofine. Flow table tests are carried out in accordance to IS 5512 to determine the workability of the fresh mortar. It is also noticeable that the flow table value rapidly increases after 0.55w/c ratio. If the w/c ratio reaches 0.6 the flow table value crosses 110mm. Hence for AF mortars also W/C is taken as 0.55 and casted.By trial and error method the amount of super plasticizer to be added to maintain the flow of samples are determined. The w/c ratio set as constant (0.4). For RFA samples it took 1.3% of SPL to reach the same workability that we got in 0.575 w/c ratio. For all other samples 1% addition of SPL was enough to reach same workability of 0.55 w/c.

ARPN Journal of Engineering and Applied Sciences



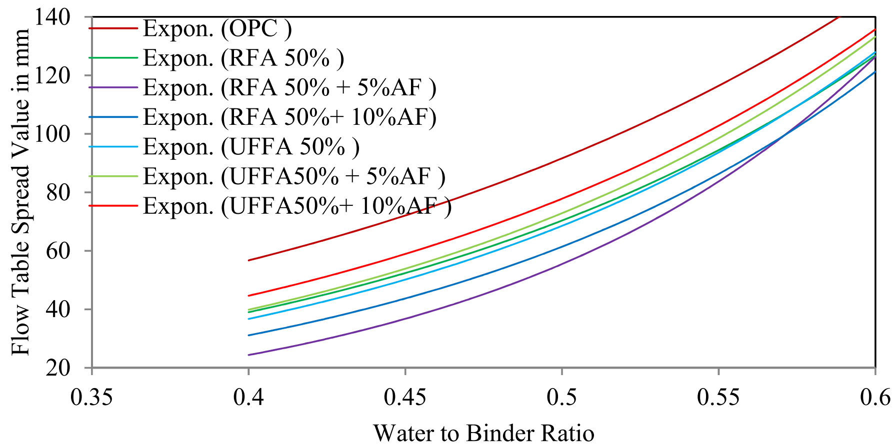


**Figure-1.** Flow table spread value of AF blended fly ash mortar samples.

### 3.2 Compressive strength test of composite mortar samples

Compressive strength test are done in 7th day, 14thday, 28thday, 56th day and 120th day of curing. For RFA mortar the water binder ratio is taken as 0.575. 50% replacement of cement with fly ash reduced 30% compressive strength in RFA mortar and 10% strength in UFFA mortar. It is observed that 5% UFFA replaced with AF in UFFA mortar improves the compressive strength and reaches almost the strength of control mortar and 10% fly ash is replaced with AF exhibited more strength than control mortar. By reducing the w/c ratio from 0.5 to 0.4, the compressive strength increased. This is mainly due to the reduction of voids in the mortar. The excess amount of water in the mortar will escape after the casting, this allow generating small voids inside the mortar. If the water content is low, the chance for void generation is less and hence the strength got increased. Figure-2 and Figure-3 shows the graphical representation of compressive strength test result of samples with and without super plasticizer respectively. From the graph it is noticeable that, the compressive strength of AF blended UFFA mortar compressive strength is almost that of control mortar and mortar with SPL also the strength is better, which is due to low water-cement ratio.

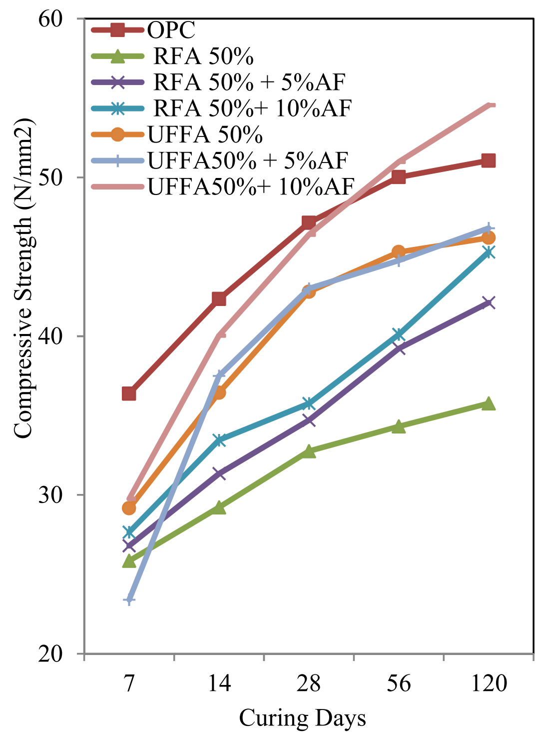


**Figure-2.** Compressive strength results of AF blended Fly ash mortar without SPL.

ARPN Journal of Engineering and Applied Sciences



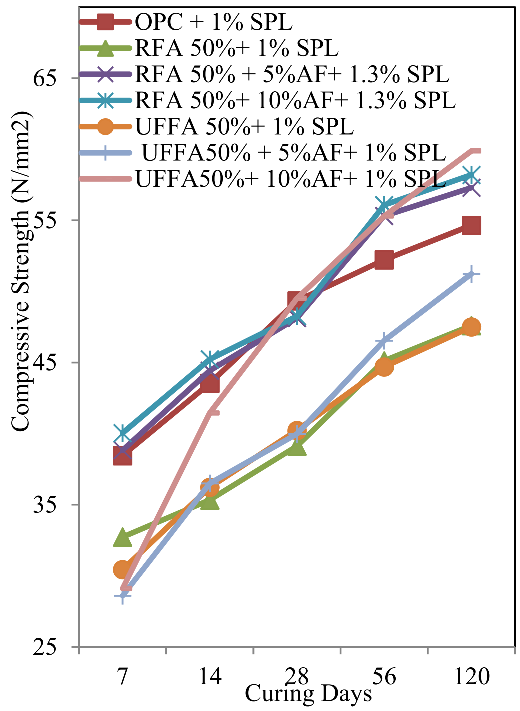


**Figure-3.** Compressive strength results of AF blended Fly ash mortar with SPL.

**3.3 Split tensile strength test**

The Split Tensile strength test is done in 14th day, 28th day, 56th day and 120th day of curing. For RFA mortar the water binder ratio is taken as 0.575. 50% replacement of cement with fly ash reduced 5% split tensile strength in RFA mortar and 2% strength in UFFA mortar. However the strength increased when 5% and 10% AF was added to the mortar which was as good as control mortar. Water content was reduced with the aid of 1% superplasticizer and flow was also maintained. By reducing the w/c ratio from 0.50 to 0.40, the split tensile strength increased which is mainly due to void reduction in the mortar. Figure-4 and Figure-5 shows the graphical representation of split tensile strength test result of samples with and without super plasticizer respectively. From the graph, 50% RFA replaced mortar shows the poor split tensile strength among all mortar. And mortar with 0.40 w/b ratio, RFA samples shows little better split tensile strength.

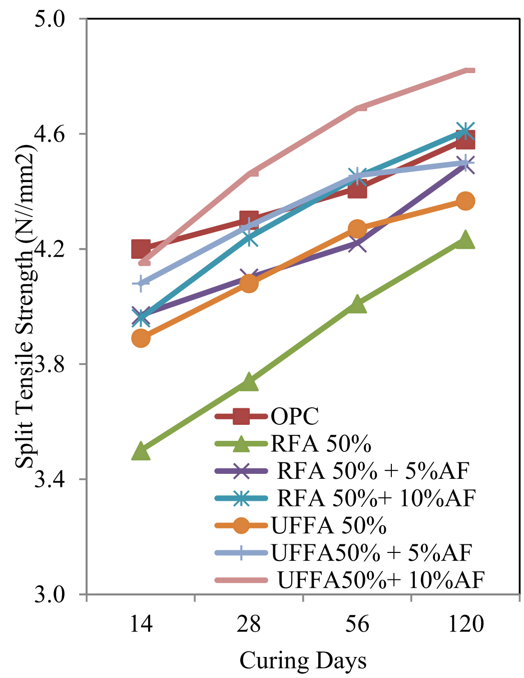


**Figure-4.** Split tensile strength test results of AF blended Fly ash mortar without SPL.

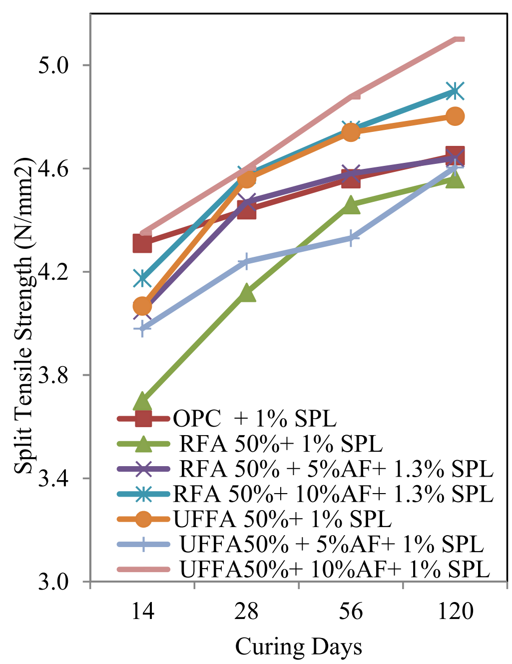


**Figure-5.** Split tensile strength test results of AF blended Fly ash mortar with SPL.

**3.4 Water absorption test**

Cubes of 50 x 50 x 50mm size are casted for all mortar samples to determine the percentage of water absorbed. Water absorption increases when the void ratio in the mortar increases. Water absorption affects the durability of the mortar. If the water absorbed by the

ARPN Journal of Engineering and Applied Sciences



mortar is high then the durability of the mortar is low. The dampness in the mortar leads to reduction in strength of the mortar. The water absorption of each mortar samples is determined in this test.

It is observed that fly ash mortar shows lower water absorption than control mortar. This is due to the finer particles in the fly ash mortar is high. And due to the same the void ratio in the fly ash mortar is less, compared to the control mortar. AF is finer than RFA and UFFA hence 5% and 10% replacement of the fly ash with AF reduce the void ratio and decreases the water absorption. It is noticeable that the UFFA mortar is showing low water absorption than the RFA mortar. It is due to finer particles anticipated in the UFFA mortar. Figure-6 is the graphical representation of percentage of water absorption in each mortar specimens.

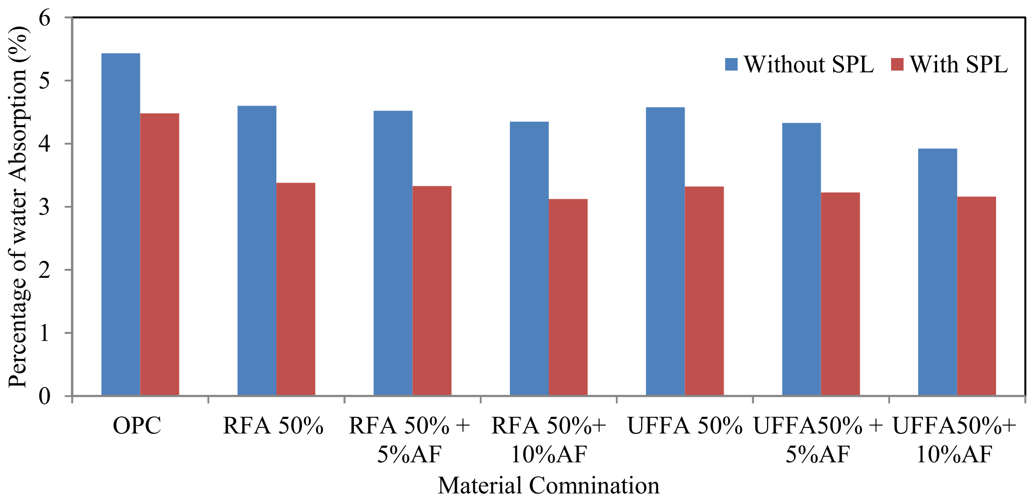


**Figure-6.** Comparison of water absorption between 0.55 w/b mortar and 0.4 w/b ratio mortar.

From the Figure-6 it is observed that the water absorption of mortars casted with 0.40 (with 1% spl) show very low water absorption than the mortars casted with 0.55. When the mortar have excess amount of water content, these excess amount of water will escape from the mortar after casting. This space will remain as void in the mortar and the mortar will absorb the water and allow the water to occupy in those voids. This will increase the dampness of mortar and hence the durability will get decreased. Above 24% water absorption is decreased by replacing cement with AF blended Fly ash.

**3.5 Chemical resistance test**

Chemical Resistance of the mortar is one of the important aspects to be studied under the durability property of mortar. 50 x 50 x 50 mm sized cubes are casted for this test and immersed in $HNO_3$, HCl and $H_2SO_4$ solution. The physical appearance, weight change and compressive strength are analyzed shown in Figure-7. After 28 day of curing the cubes are dried and then immersed in $HNO_3$, HCl and $H_2SO_4$ solution for next 28 days. Then the cubes are taken from the solution and dried in room temperature and the tested for compression. It is observed that control mortar is showing very good resistance in $HNO_3$ and HCl solutions. But control mortars 49% strength is decreased after immersing in $H_2SO_4$ solution. At the same time AF blended UFFA mortar immersed in $H_2SO_4$ solution are showing better acid resistance than the control mortar.

ARPN Journal of Engineering and Applied Sciences




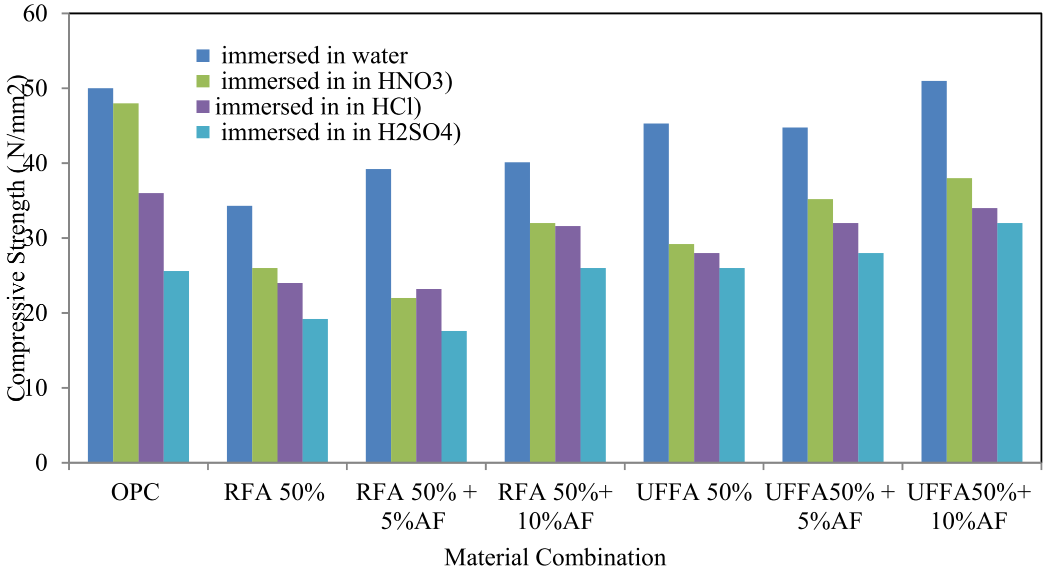


**Figure-7.** 56th day compressive strength of normally cured mortar specimen and acid immersed mortar specimens (0.55 w/b ratio).

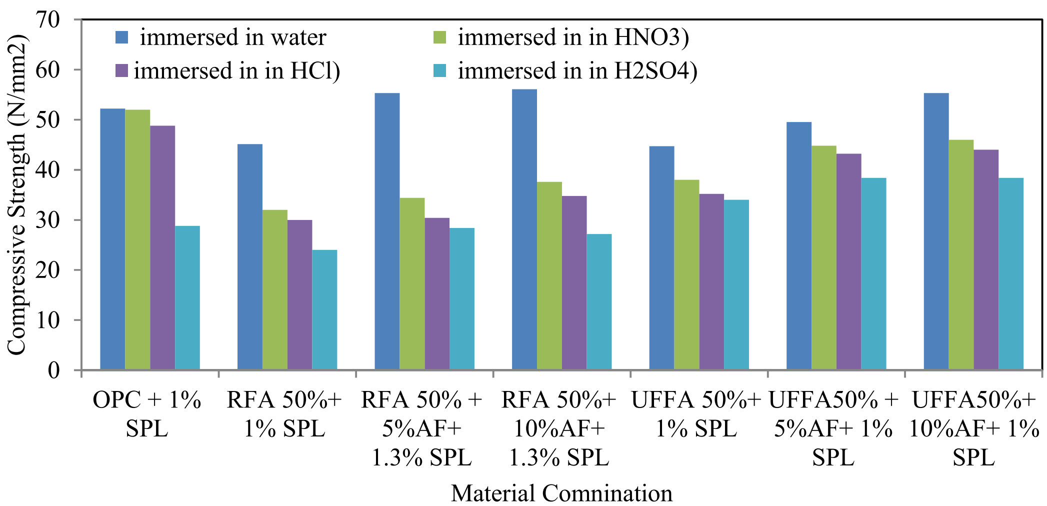


**Figure-8.** 56th day compressive strength of normally cured mortar specimen and acid immersed mortar specimens (0.40 w/b ratio + 1% SPL).

It is noticeable that mortar casted with 0.40 w/b ratios shows very good acid resistance to all the acid solutions. This is because of the low void presence in the mortar casted with 0.40 w/b ratio. 10% AF blended UFFA mortar shows better acid resistance than the control mortart is observed that AF blended fly ash mortars have less percentage in weight loss than the control mortar when the specimens are immersed in $H_2SO_4$. The percentage weight loss in mortars casted with 0.55 w/b ratio and 0.40 w/b ratio is illustrated in Figure-9 and Figure-10.

ARPN Journal of Engineering and Applied Sciences



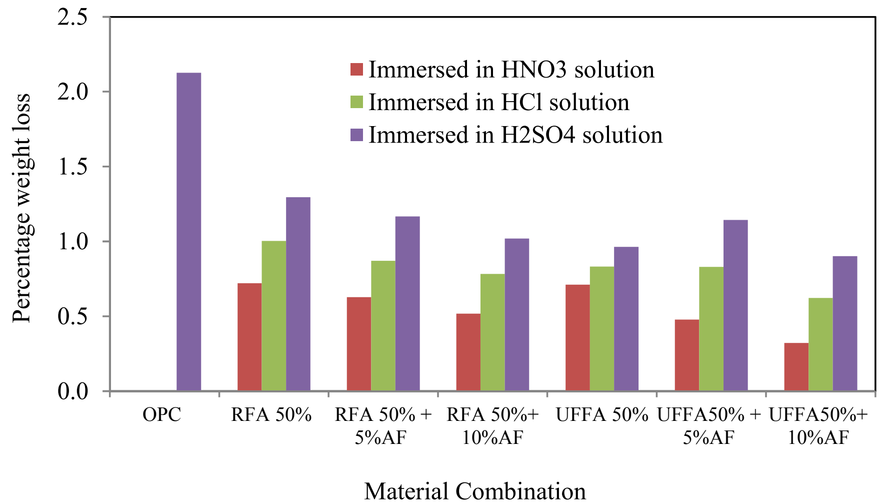


**Figure-9.** Weight loss of AF blended Fly Ash mortar samples immersed in acid solutions (Mortar casted with 0.55 w/b ratio).

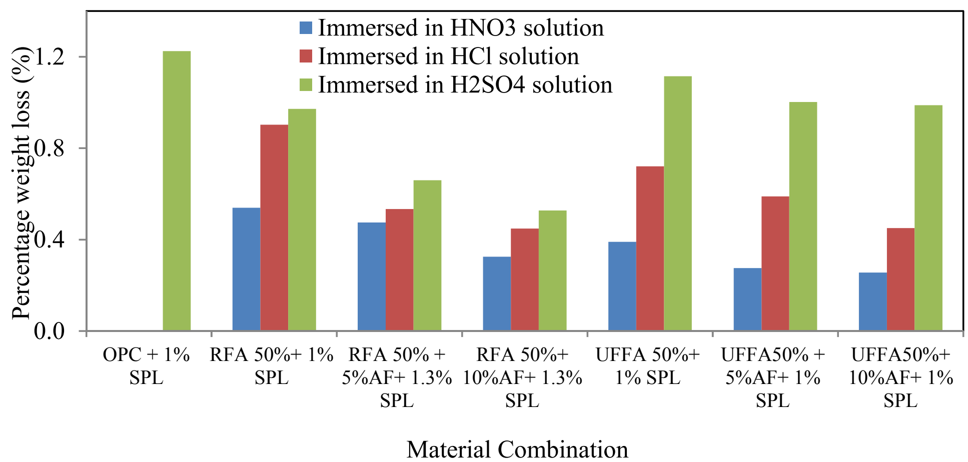


**Figure-10.** Weight loss of AF blended Fly Ash mortar samples immersed in acid solutions (Mortar casted with 0.40 w/b ratio).

From the Figure-9 and Figure-10 it is noticeable that the percentage weight in loss of mortar specimens casted with 0.40 w/b ratio is lower than the percentage weight in loss of mortar specimens casted with 0.50 w/b ratio. It is observed that AF blended fly ash mortar is not losing large weight comparing to other mortar specimens immersed in the acid solutions.

### 3.5 Microstructural analysis

#### 3.5.1 Scanning Electron Microscopy (FSEM) test

SEM was conducted to analyze the microstructure of the various mortar specimens. The shape of the particles involved is analyzed by FSEM.

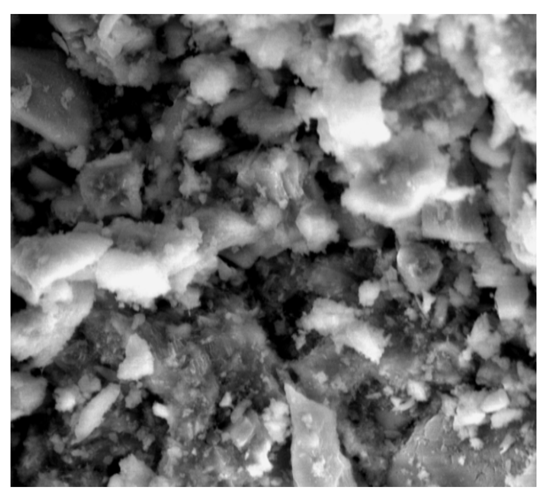

**Figure-11(a).** SEM micrograph of OPC mortar at 28 days.

VOL. 12, NO. 7, APRIL 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences



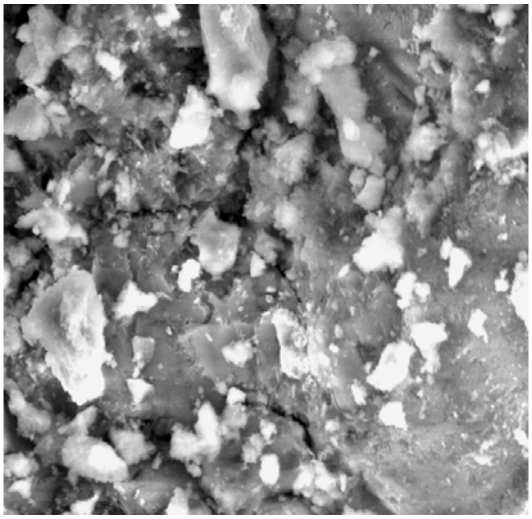

**Figure-11(b).** SEM micrograph of 50% UFFA and 10% AF with SPL mortar at 28 days.

Figure-7(a) and 7(b) shows the SEM micrographs of OPC with 20µm and 10µm magnitudes. Figure-8(c) and 8(d) shows the SEM images of UFFA samples with 20µm and 15µm magnitudes, showed the best compressive strength among all. The OPC mortar sample images posit regular and spherical shape of the particles. But the UFFA sample shows the non-spherical shape of particles compared with OPC mortar that is the reason why OPC mortar had more workability than the UFFA mortar. From the SEM images it was clear that UFFA mortar had finer particles than control mortar. Hence they have more reactive surface area than the control mortar and UFFA mortar. And that was the reason why AF blended UFFA mortar exhibited better compressive strength than any other mortar samples.

## 4. CONCLUSIONS

The study dealt with the replacement of cement by fly ash with the aid of alccofine at different replacement percentages. The mortar specimens with 5 wt% and 10 wt% of alccofine was observed to have improved strength and performance characteristics compared to controlled mortar specimens. The conclusions for the improvement recorded are as follows:

a) Adoption of lower w/b ratio will enhance the mechanical and durability properties of the mortar. 50% replacement of cement with RFA reduces the strength upto 42% in cement mortar and 50% replacement of cement with UFFA reduced the strength upto 10% in Cement mortar.
b) Usage of super-plasticizers is effective in maintaining the flow of mortar, thus reducing the w/b ratio. Control mortars have poor acid resistance, while fly ash mortar shows better resistance to the acids.
c) Normal consistency is more for the fly ash mortars. The reason is, fly ash mortars have more reactive surface area and the water demand is high, this increases the consistency of the mortar pastes. Water absorption decreases according to the percentage increase in AF addition.
d) The replacement with UFFA is very effective than the replacement with RFA, this is mainly because the UFFA is more finer than RFA, thus it provides large reactive surface area than the RFA and the voids in the UFFA mortar is lesser than voids in the RFA mortar.
e) 50% replacement of the cement will reduce the consumption of cement in large margin. High percentage replacement of cement with fly ash in cement mortar is relevant. Blending of fly ash with AF will increase the strength and durability properties mortar

## REFERENCES

IoannaPapayianni, Eleftherios K, Anasstasiou. 2009. An investigation of the behavior of raw calcareous fly ash in mortar mixtures. World of Coal Ash (WOCA) conference.

Li Yijin, Zhou Shiqiong, Yin Jian, and GaoYingli. The Effect of Fly Ash on the Fluidity of Cement Paste, Mortar, and Concrete. Central South University, PRC. International Workshop on Sustainable Development and Concrete Technology.

Akshata G. Patil and S. Anandhan. Ball Milling of Class-F Indian Fly Ash Obtained from a Thermal Power Station.

Steve W. M. Supit, Faiz U. A. Shaikh, Prabir K. Sarker. 2014. Effect of ultrafine fly ash on mechanical properties of high volume fly ash mortar. Construction and Building Materials. 51: 278-286.

Slanicka, S. Influence of Fly Ash Fineness on the Strength of Concrete. Cement and Concrete Research, V.21, 1991, pp. 285-296.

P. Chindaprasit. 2004. Influence of fly ash fineness on strength, drying shrinkage and sulfate resistance of blended cement mortar. Cement and Concrte Research. 34: 1087-1092.

ShunsukeHanehara, Kazuo Yamada.1999. Interaction between cement and chemical admixture from the point of cement hydration, absorption behavior of admixture, and paste rheology. Cement and Concrete Research. 29(8): 1159-1165.

F. Puertas and T. Vazquez. 2001. Early Hydration cement effect of admixtures superplasticizers. Materiales de Construcción. 51(262).

Siddharth p upadhyay, m.a.jamnu. 2014. Effect on compressive strength of high performance concrete incorporating alccofine and fly ash. Journal of International Academic Research for Multidisciplinary Impact Factor 1.393, ISSN: 2320-5083, 2(2).

VOL. 12, NO. 7, APRIL 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences



Suresh Thokchom, Partha Ghoshand Somnath Ghosh. 2009. Effect of water absorption, porosity and sorptivity on durability of Geopolymer mortars. ARPN Journal of Engineering and Applied Sciences. 4(7).

Caijun Shi and Robert L. Day. 1994. Acceleration of the reactivity of Fly Ash by chemical activation, 1995, Cement and Concrete Research. 25(1): 15 21.

En-Hua Yang, Yingzi Yang and Victor C. Li. 2006. Use of high volumes of fly ash to improve ECC Mechanical properties and Material greenness, 2007, ACI Materials Journal.

Liu Baoju, XieYoujun, Zhou Shiqiong, Yuan Qianlain. 2000. Influence of ultrafine flyash composite on the fluidity and compressive strength of concrete. Cement and concrete Research. 30: 1489-1493.

C Freeda Christy and D Tensing. 2010. Effect of class-F fly ash as partial replacement with cement and fine aggregate in mortar. Indian Journal of Engineering & Materials Sciences. 17: 140-144.

Hasan Biricika, Nihal Sarier. 2013. Comparative Study of the Characteristics of Nano Silica, Silica Fume and Fly Ash Incorporated Cement Mortars. Materials Research.

Li Yijin, Zhou Shiqiong, Yin Jian, and Gao Yingli. The effect of fly ash on the fluidity of cement paste, mortar, and concrete. Central South University, PRC.

Abhijitsinh Parmar, Dhaval M. Patel, DronChaudhari, Harpalsinh Raol. 2014. Effect of Alccofine and Fly Ash Addition on the Durability of High Performance Concrete. International Journal of Engineering Research & Technology (IJERT). 3(1), IJERT, ISSN: 2278-0181.

Mehta P. K. 1985. Influence of Fly Ash Characteristics on the Strength of Portland-Fly Ash Mixture. Cement and Concrete Research. 15: 669-674.