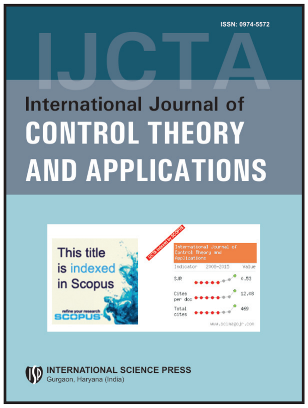

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Impact of Ball Milled Fly Ash Nano Particles on the Strength and Microstructural Characteristics of Cement Composite Mortars

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Abstract: The substitution of Ordinary Portland Cement in concrete utilizing the high volume of secondary cementitious materials, for example, fly ash can have ecological and also financially favorable circumstances, by reduction of greenhouses gasses from the production of cement, alteration of waste materials from landfill, decrease the natural assets required to the production of cement. By considering all factors, the application of top-down nanotechnology for changing over the micro scale level particle into ultrafine particles with the utilization of ball mill grinding process. This paper reports the experimental study carried out to investigate the effect of Alccofine (AF) blended with Raw Fly Ash (RFA) and Ultra-Fine Fly Ash (UFFA) mortar to enhance the strength of the blended cement mortar. 50% of OPC is replaced from cement mortar by RFA and UFFA sample with addition to that Alccofine is blended with Fly ash in 5% and 10% by weight basis. The Mechanical and Microstructural properties of OPC replaced by RFA and UFFA sample mortar specimens were studied.

The Class C raw fly ash is carried out for 2 hours ball mill grinding to obtain Ultra-Fine Fly Ash which is having 80% the particle at less 1-5 micron level. Alccofine is the byproduct obtained from silicon industries. Influence of AF not only enhances the strength, but also improves the durability of the mortar. The strength development of OPC replaced with 50% of UFFA and 10% of AF mortar was improved 6% higher in compressive strength compare to the control specimens. The addition of UFFA particle and AF improves strength performance and microstructural behavior improvement clearly evident from the microstructural test results. The Blended OPC mortar with UFFA and AF mortars can effectively utilized in mortar plastering application and manufacturing of precast elements and also used as a economical point of view in construction industry.

Keywords: Ultra Fine Fly Ash, Ball Milling, SEM, EDX, Microstructural Analysis, Compressive Strength.

1. INTRODUCTION

The green house gas level increasing in the atmosphere and the subsequent effects on temperature change in the environment impact are possibly try to identify the capability of the world to encourage current situations of practices. The harmful gases results in an drastically increased temperature for the environmental impact. The cement industry is considered to be one of the most energy consuming industries, which is also responsible for approximately 6-7% of the global man-made CO_2 emissions annually [1, 2]. Thus calling for a retrospective measure to limit the transcending cement utilization in construction industry. As a result extensive research has been carried out to replace cement partially by supplementary cementing materials (SCMs) since, these materials possess the properties of cement.

Supplementary cementing materials such as Fly ash, Silica fume, and Rice husk ash are widely used as the replacement for cement. Contemporarily, Fly ash has gained rapid usage among all the SCMs. Fly ash possess pozzolanic activity due to the presence of $SiO_2$and Al_2O_3. Fly ash has been extensively used as partial replacement since increased compressive strength is achieved [3, 4]. However, a report says that the compressive strength of fly ash based cement mortar did not show substantial improvement [5]. Hence further studies is being carried out on the different forms of fly ash. A finer fly ash is obtained by ball milling method is utilized in studies to comprehend the effects of finer fly ash. In some studies it is found that the strength gain incorporating fly ash is enhanced by reducing the fly ash particle size [6-8]. In addition the performance characteristics can also be increased by utilization of finer fly ash. 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. Chemical admixtures are used in various research to enhance the workability of cement mortars [9,10]. It was observed that effect of chemical admixture had a substantial increase in the workability and strength of fly ash based mortars. It is recorded in a study that the introduction of alccofine elevates the self-compatibility attributes such as resistance towards segregation, filling and passing ability as well [11, 12].

This paper presents the comprehensive solution for the effective utilization of fly ash in cement composites with the aid of strength enhancer. And also to keep the strength and microstructural performance characteristics intact when cement is replaced by the fly ash and alccofine.

2. MATERIALS AND METHODOLOGY

2.1. Materials

In this study Ordinary Portland cement of 43 grade (OPC) of confirming to IS : 8112 was used. The specific gravity of the cement was found to be 3.15. 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 saturated lime water was used. The class C Raw Fly ash (RFA) obtained from Neyveli Lignite Corporation, Neyveli, Tamil Nadu was taken to grind ultra-fine fly ash (UFFA). The RFA was grinded for 2 hours to reduce its size into ultrafine particles to obtain the UFFA samples. Three different grade of standard Ennore sand has been used as the fine aggregate for preparing standard mortar samples Conforming to IS 650. Alccofine (AF) is a specially ball mill processed material which high fineness value, based on slag of high glass content with high reactivity grinded and obtained by the procedure of controlled granulation [13]. The fineness of AF if 800 cm^2/gm, specific gravity is 3.11. 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%.

2.2. Sample Preparation and Testing

The effect of finer particle in basic properties, mechanical properties and microstructural properties of materials were studied. The OPC control sample was replaced with 50% of RFA and UFFA sample with addition of 5, 10% of AF sample were compared with and with out super plasticizer. 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. The samples were studied using IS 10262:2009, IS4031:Part-4 and IS 1586:

1999.The specimens were casted and after 24 hours the specimens are de-molded and immersed in the water tank for curing upto the testing age. Compression strength and split tensile strength were determined at 7th, 14th, 28th, 56th and 120th day. The microstructural properties of the specimens were analyzed using scanning electron microscope (FESEM) and the chemical composition was analyzed using energy dispersive X-ray spectroscopy (EDX) test. The particle phase identified using X-ray diffraction analysis (XRD) [14].

3. RESULTS AND DISCUSSIONS

3.1. Particle Size Reduction Analysis

The particle size analyzer (PSA) test was studied to determine the particle size reduction during the ball milling process. The laboratory 2kg volume of ball mill was used to grind the fly ash particle at 1:10 powder to balls ratio up to 2 hours grinding in constant speed. The OPC sample, RFA, ball milled UFFA sample and AF sample particle size were analyzed and shown in Figure 1. From the results it is clear that the particle reduction was improved by ball milling process. The fineness of sample can be arranged as AF > UFFA > RFA > OPC particles.

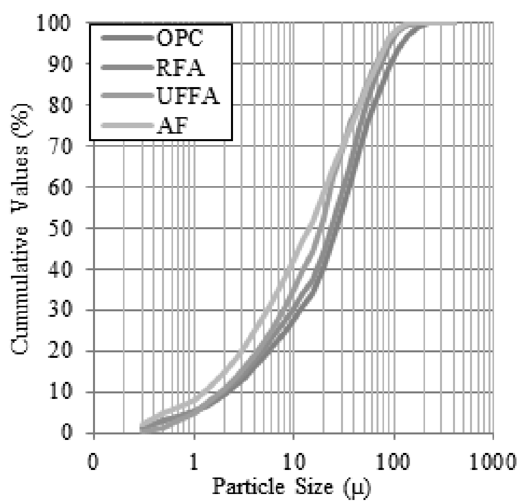

Figure 1: particle size analyzer of materials

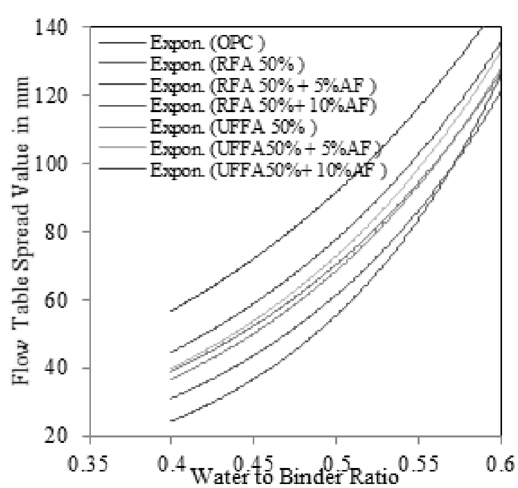

Figure 2: Flow table value of different mortars

3.2. Fresh Mortar Properties

The degree of wetness exhibited by a freshly mixed mortar is the consistency of that mortar. The results showing that RFA mortar samples are showing more normal consistency of 38% than the UFFA samples at 28%. It is observed that when we replace the RFA and UFFA with AF the consistency is getting increased. Similar result were found in initial setting time and final setting time. Flow table tests are carried out in accordance to IS 5512 to determine the workability of the fresh mortar. The AF blended with RFA and UFFA mortar flow table spread values are given in Figure 2. When coming to the fly ash mortars with AF, the samples have more workability. But still the flow table value comes around the 0.55 value. So it was easy to conclude the w/c ratio as 0.55 in fly ash mortars. In RFA mortars the flow table value reaches around 110 only at a w/c ratio of 0.575, hence for those samples w/c ratio is taken as 0.575. 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 [15].

To attain more strength the water cement ratio should be reduced. But if water cement ratio decreases the flow will decrease and it will affect the ease of casting. To maintain the flow, super plasticizers are added. 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. The particle size is very small and round in shape, because the particles are getting finer and the reaction increases and hence the consistency and workability also getting changes.

3.3. Material Characterization Techniques

The X ray diffraction (XRD) analysis was conducted to study the phase characteristics of OPC, RFA, UFFA and AF particles which is indicated as S1, S2, S3, S4 and S5 respectively pattern are shown in Figure 3. From the XRD pattern it clear that the highest peak at 26.5° which is quartz phase. The peaks corresponding to the calcium hydrate (CaH) indicate at 2 theta values 42.5° and 50.5° of OPC, RFA, UFFA and AF samples. The peaks corresponding to the calcium silicate (CaS) indicate at 2 theta value 61.3° and 68.4° of OPC, RFA, UFFA and AF samples. Form the pattern identification for different materials combination were compared and inferred that

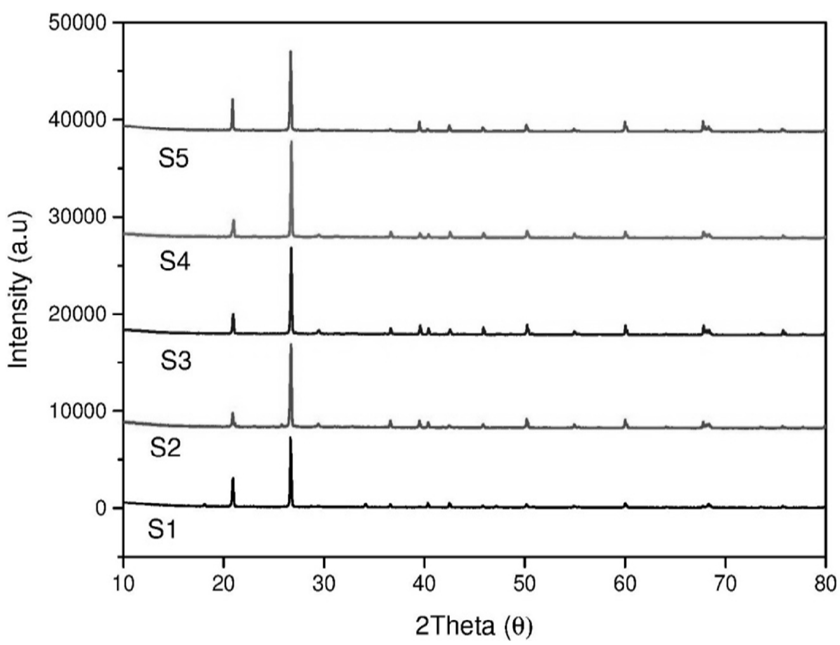

Figure 3: XRD patterns of Materials

there is no change in chemical composition and phase characters [16]. This is the reason for strength improvement which is evident form the compressive strength test results.

3.4. Compressive Strength Test of Composite Mortar Samples

The compressive strength test are done in 7, 14, 28, 56 and 120 days of curing of blended RFA and UFFA in addition to the AF with and with out SPL test results are shown in Figure 4 & 5. 50% replacement of cement with fly ash reduced 30% compressive strength in RFA mortar and 10% strength in UFFA mortar. When 5% fly ash is replaced with AF the strength is gained in both RFA and UFFA mortar. AF addition failed to yield increased strength. It is observed that 5% UFFA replaced with AF in UFFA mortar improves the compressive strength and reaches almost the strength of control mortar. When 10% fly ash is replaced with AF, both the RFA and UFFA mortar gains better compressive strength than the control mortar. By reducing the w/c ratio from 0.55 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. To maintain the flow 1% super plasticizer is added in the mortar. From the graph it is noticeable that, the compressive strength of AF blended UFFA mortar only have a compressive strength more or near the control mortar. When it comes in to mortar with SPL, RFA samples are also showing better or near compressive strength of control mortar. This is due to difference in water cement ratio used in the casting of RFA and UFFA mortar. For RFA mortar samples 0.575 w/c ratio is adopted, at the same time for all other samples 0.5 w/c is used [14, 17].

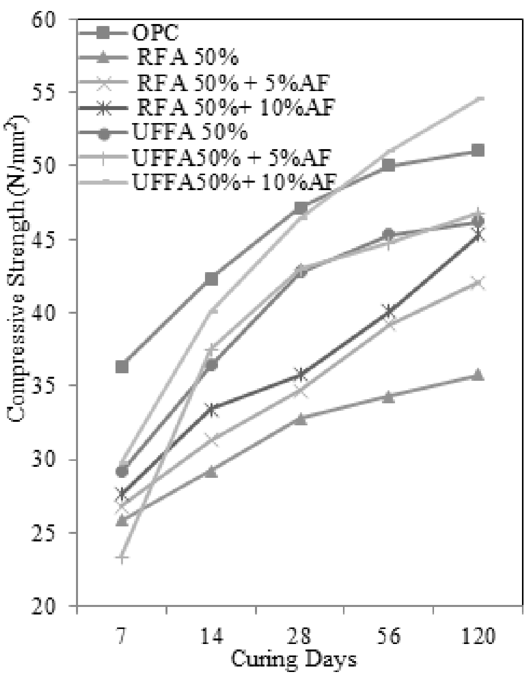

Figure 4: Compressive strength results of AF blended Fly ash mortar without SPL

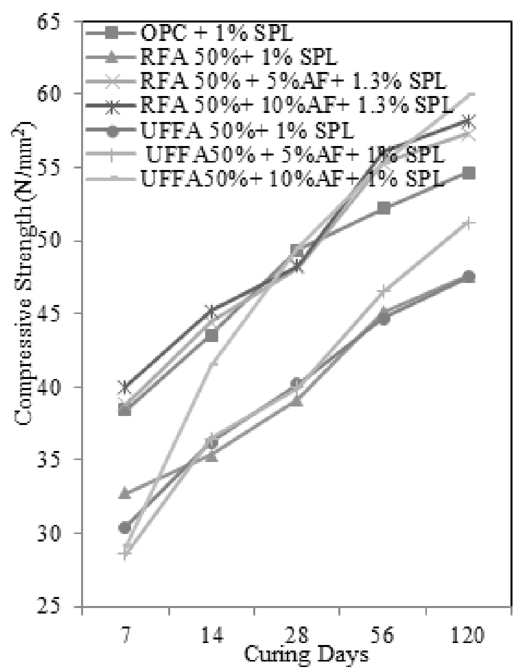

Figure 5: Compressive strength results of AF blended Fly ash mortar with SPL

3.5. Microstructural Analysis

The Scanning Electron Microscopy (SEM) was conducted to analyze the microstructure and shape of the particles of the various mortar specimens.

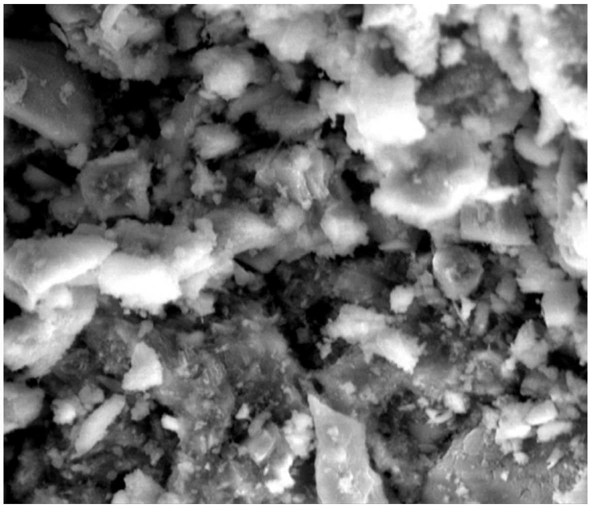

Figure 6: (a) SEM micrograph of OPC mortar

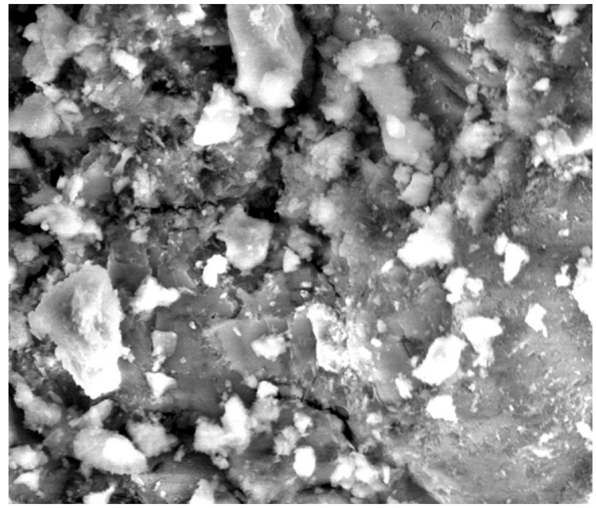

Figure 6: (b) SEM micrograph of RFA 50% mortar

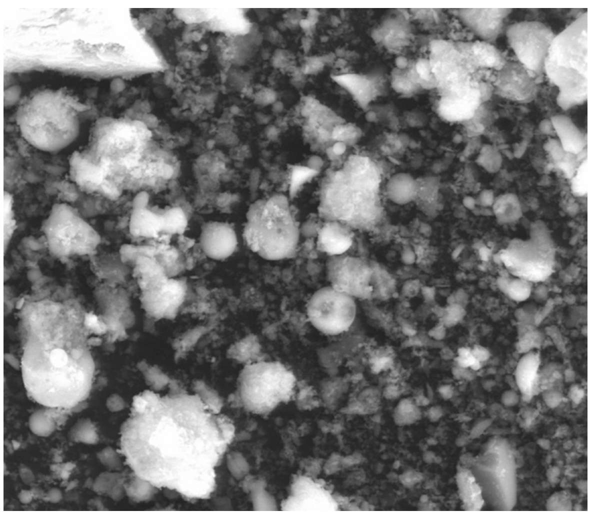

Figure 6: (c) SEM micrograph of UFFA 50% mortar

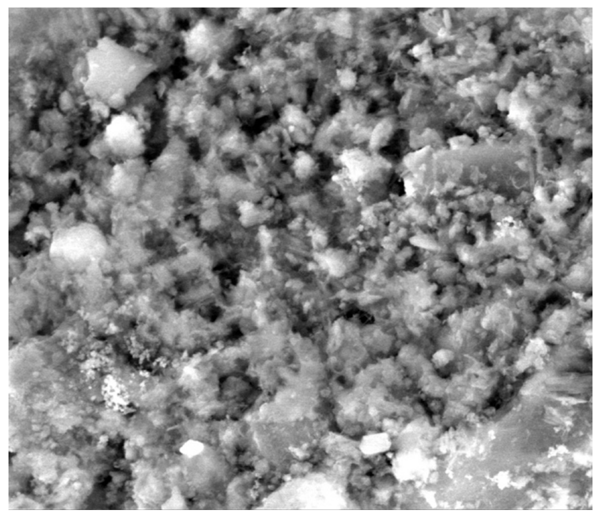

Figure 6: (d) SEM micrograph of UFFA50% and 10% AF blended mortar

The Figure 6(a), (b), (c), (d) shows the SEM micrographs of OPC sample, RFA 50% replacement of sample, UFFA 50% of replacement of sample and UFFA 50% with 10%AF sample with 20 µm magnitudes at 28 days curing periods. From the SEM images, the OPC mortar sample images shows irregular and non spherical shape of the particles. But the UFFA sample shows the 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 UFFA mortar having more reactive surface area than the control mortar. And that was the reason why AF blended UFFA mortar exhibited better compressive strength than other mortar specimens [8, 11, 17].

Energy-Dispersive X-ray Spectroscopy (EDX) analysis of OPC mortar, UFFA mortar, RFA mortar were shown in Figure 7(a), (b) and (c) respectively. It was observed that Silica content is more in OPC mortar and that might be the reason that OPC mortar is showing decent mechanical strength properties. Calcium content is high in UFFA mortar, about 33.3% and was less in RFA mortar. That was the reason why UFFA mortar shows better mechanical strength than the RFA mortar [18].

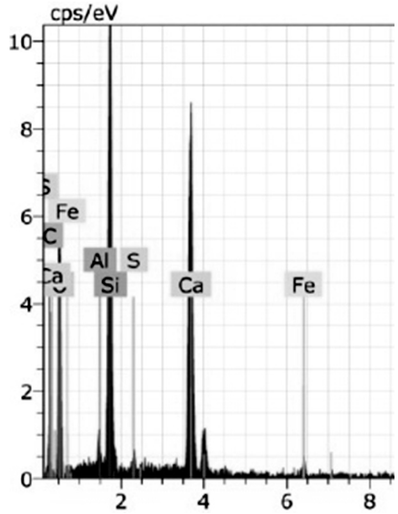

Figure 7: (a) EDX of OPC Mortar

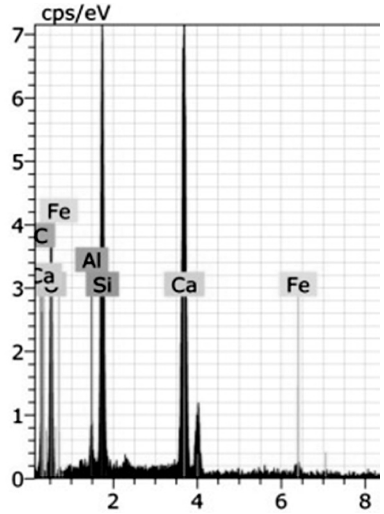

Figure 7: (b) EDX of RFA Mortar

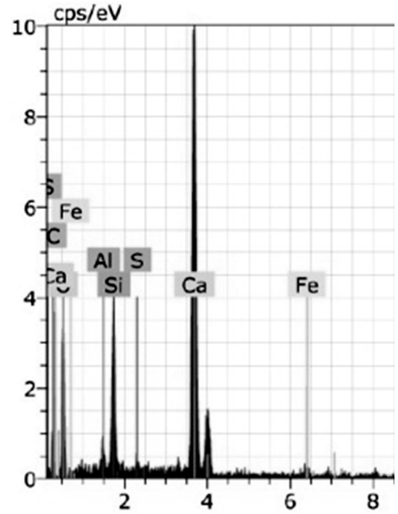

Figure 7: (c) EDX of UFFA mortar

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% and 10% of alccofine (by weight) was observed in strength improvement and performance characteristics while compared with controlled mortar specimens. The conclusions for the improvement recorded are as follows

The compressive strength attained in the AF blended mortar specimen was significantly more than the specimens of RFA and UFFA alone. 50% replacement of cement with RFA reduces the strength up to 42% in cement mortar and 50% replacement of cement with UFFA reduced the strength up to 10% in Cement mortar.

Replacement of cement with RFA and UFFA reduce the workability of the mortar. This is due to the increase in reactive surface area in fly ash mortar and due to the angular particle shape of the fly ash mortar. Usage of super-plasticizers is effective in maintaining the flow of mortar, thus reducing the w/b ratio.

Normal consistency is more for the fly ash mortars. The reason is, fly ash mortar 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.

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.

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.

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