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Processed Fly Ash in the Mortar and Concrete: A Review

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ABSTRACT
Use of fly ash in mortar and concrete is very common now days. Use of processed fly ash is recent. Many studies have been conducted to know PFA performance. These studies show information in this regard. In this paper an effort has been made to review the work already done in the field. The available literature helps the beginner to understand the PFA performance in cement and concrete world and start further research in this particular area.
Keywords –compressive strength, concrete, durability, mortar, processed fly ash

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I. INTRODUCTION

Fly ash is a fine, glass like powder recovered from gases created by coal-fired electric power generation. Fly ash material is solidified while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Fly ash with spherical shape improves the workability of fresh concrete due to the ball bearing effect at low addition of about 5-20 %. Also due to its spherical ball in shape fly ash buoys the aggregate and therefore minimizes the settlement rate of aggregate.

Fly ash generally consists of oxides of silica, alumina and iron. In many countries, fly ash is further processed to reduce the undesirable elements and improve the proportion of amorphous silica [15]. This type of fly ash is known as processed fly ash. Ultrafine fly ash (UFFA) or processed fly ash (PFA) with a mean particle diameter of 1-5 micron is a relatively new pozzolan. UFFA is carefully processed by mechanically separating the ultra fine fraction from the parent fly ash [16].

It is widely recognized that most pozzolans when used correctly in concrete increase its durability [18] and Laboratory investigations around the world have shown that when FA particle size is reduced, its performance in concrete is improved [13]. Performance of PFA in concrete is found to be comparable to other highly reactive pozzolans such as silica fume [15, 17] and addition of PFA in concrete has been found to enhance the performance at later age [15, 17]. Investigation reported incorporation of PFA increases the setting time of cement paste and decreased water demand from 30 % to 50 % [11, 12]. Researchers investigated significant improvement in concrete strength and durability without loss in workability with commercially available fly ash [13]. Investigators also reported significant improvement in compressive strength at later age [14, 15]. 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 PFA seems to be ideal choice for cement replacement in concrete.

II. A BRIEF REVIEW OF THE USE OF FLY ASH IN CEMENT AND CONCRETE

Application of fly ash as admixture to mortar and concrete (whether it is plain cement concrete or self compacting concrete) is very common and many studies have been conducted to evaluate the performance characteristic of the fly ah concrete and mortar [1 to 10]. The brief literature reviews of the latest studies are as follows.

Christy et al. [1] investigated the effect of class-F fly ash for partial replacement of cement and fine aggregate in cement mortar for three different ratios 1:3, 1:4.5 and 1:6. Replacement % was 10, 20, 25 and 30 for 1:3 and 1:4.5 mortars and 10 and 20 for 1:6 mortar. A comparative study was made with the control mix with 0 % for each mortar. Result showed increase in compressive strength for cement replacement for 1:3 and 1:4.5 mortars and for sand replacement to 1:6 mortar.

Satish H. Sathawane et al. [2] conducted experimental study to investigate combined effect rice husk ash and fly ash for cement replacement up to 30 %. The hardened properties of concrete containing RHA and FA in different proportions include compressive strength, flexural strength and split tensile strength. Results were compared with control mix. Result showed that compressive strength increases by 30.15% in compared with targeted strength and reduces by 8.73% compared with control concrete at 28 days, flexural strength increases by 4.57% compared with control concrete at 28 days, split tensile strength decreases by 9.58% compared with control concrete at 28 days, were obtained at combination of 22.5% FA and 7.5% RHA. Partial replacement of FA and RHA reduces the environmental effects, produces economical and eco-friendly concrete.

Neelam Pathak et al. [3] conducted experimental study to investigate the properties of Self-Compacting-Concrete with (class F fly ash ranging from 30% to 50%) and without fly ash. The property investigated were compressive strength, splitting tensile strength, rapid chloride permeability, porosity, and mass loss when exposed to elevated temperatures. The variables included were the temperature effects (20 LC, 100 LC, 200 LC, and 300 LC) using Ordinary Portland Cement. Test results showed little improvement in compressive strength within temperature range of 200–300 LC as com-pared to 20–200 LC but there were little reduction in splitting tensile strength ranging from 20 to 300 LC and with the increase in percentage of fly ash.

Heba A Mohamed [4] conducted experimental study on SCC under three curing conditions (7 and 28 days curing under water and 28days curing in air) with three types of mixes first with different % of fly ash, second with different % of silica fume and third with different % combinations of fly ash and silica fume. The result showed that SCC with 15 % of silica fume shows high compressive strength than those with 30% of fly ash and water cured specimens for 28 days give higher compressive strength.

Yuan Yuan Chen et al. [5] investigated the effect of paste amount on the properties of SCC containing fly ash and slag. Performances of SCC containing fly ash and slag under different water to cementitious material ratio and different cement paste were compared. Concrete designed by DMDAC (Mixture design Algorithm). Result showed that the less the cement paste amount as well as the denser the blended aggregate, the lower the early age compressive strength will be on the contrary, the higher the long- term compressive strength becomes. For good quality concrete the amount of cement paste and water should be minimised for as low as possible to obtain the high ultra-sonic pulse velocity.

Krishna Murthy N et al. [6] designed a simple tool for SCC with high reactive metakaolin and fly ash as an admixture for cement replacement. They provide detailed steps for mix design with 29% of coarse aggregate with three cement replacement ratio 5-20%(by MK), 10-30% (by FA) and different % combination of MK+FA. Authors developed a user friendly mix design tool which is capable of calculating all quantities required in the mix design.

Raharjo. D et al. [7] Optimized the composition of SCC containing fly ash, silica fume and iron slag. Using Optimal Composition SCC were prepared with silica fume (0-20% of fly ash weight) and super plasticizers (0.5 -1.85 of cement weight) and each composition tested by slump cone L-box and V-funnel apparatus to meet the requirements of SCC. Hardened cylindrical specimens were prepared and tested at the age of 3, 7, 14, 28 and 56 days. Authors provide a formula for optimal composition.

Ahmed Ibrahim et al. [8] investigated relationship between high strength self compacting concrete and macroscopic internal structure. They prepared mixes with high volume cement replacement (up to 70%) by slag, fly ash and silica fume. They use a flatbed digital scanner for 2-D digital image of internal structure of HSSCC (high strengths self compacting concrete) cylindrical specimen. Images were analysed by *iPas* software. The result showed good correlation between HSSCC macroscopic structure and compressive strength.

Rafat Siddque et al. [9] predicted the compressive strength of SCC containing bottom ash using Artificial Neural Network. They developed two models with input parameters (material) and output parameters (compressive strength). First (ANN-I) to predict 28 days compressive strength through ANN technique using data taken from literature and second (ANN-II) developed experimentally for SCC containing bottom ash as partial replacement of sand. Result showed that model developed from literature data could be easily extended to the experimental data with some modifications

H. A. F. Dehwah et al. [10] investigated mechanical properties of SCC containing fly ash silica fume and quarry dust powder. Various trial mixes were prepared with fly ash only, quarry dust powder (QDP) only and combination of silica fume and quarry dust powder. Tests were conducted to find compressive strength, split tensile strength, flexural strength and homogeneity by ultra-sonic pulse velocity test. The result showed better performance of SCC incorporating QDP (8-10%) as compared to other two categories of trial mixes.

III. NOTEWORTHY CONTRIBUTIONS IN THE FIELD OF PROCESSED FLY ASH

Very few studies have been carried out on mortar and concrete containing processed fly ash so far [11 to 17]. The brief literature reviews of the latest studies are as follows.

Li Yijin et al. [11] investigated the effect of ultra fine fly ash on the fluidity of cement paste mortar and concrete. Three categories of ultra fine fly ashes were used to replace cement content by 20%, 30 % and 40 %.

Copeland et al. [12] presented experimental study to investigate fresh and hardened properties of high performance concrete containing ultra fine fly ash with different dosages.

Obla et al. [13] presented experimental study to invest gate properties of concrete containing ultra fine fly ash produced by air classification. Durability testing for chloride diffusivity, rapid chloride permeability, alkali-silica reaction (ASR), and sulphate attack was also conducted.

Rajdev et al. [14] conducted a experimental study to compare the performance of concrete produced from portland pozzolana cement and processed fly ash blended ordinary portland cement. Cement replacement percentage were 20, 25 and 30 for M-20 concrete.

C. B Shah et al. [15] conducted pilot study to find the performance of cement mortar at later age by high volume replacement of portland cement with processed fly ash. Compressive strength of standard 70.7 mm mortar cubes were find at the ages of 3,7,28,56 and 90 days. 53 grade of ordinary portland cement were used replace and the percentage replacements were 40, 45, 50 & 55 respectively.

Hossain et al. [16] conducted an experimental study that was performed in order to understand the influence of ultrafine fly ash (UFFA) on the shrinkage cracking of concrete mixtures. The research is focused on comparative performance of concrete containing UFFA with that of concrete containing silica fume (SF). Authors prepared several mortars with varying UFFA and SF content. Free shrinkage strain and splitting tensile strength and residual tensile stress were determined.

Subramanian et al. [17] conducted study focused on influence of ultrafine fly ash on the early age response and the shrinkage cracking potential of concrete. Researchers found performance of UFFA in concrete is to be comparable to other highly reactive pozzolans such as silica fume.

IV. SIGNIFICANT OBSERVATIONS ON PERFORMANCE OF PROCESSED FLY ASH

Li Yijin et al. [11] reported incorporation of ultra fine fly ash increases the setting time of cement paste and decreased water demand and slump loss of concrete. The maximum reduction in water demand was found to be 30 %.

Copeland et al. [12] reported that at a given workability and water content, concrete containing UFFA could be produced with only 50% of the high-range water reducer (HRWR) dosage required for comparable silica fume (SF) concrete. Similar durability measures as SF concrete were observed when a slightly higher dosage of UFFA was used with a small reduction (10%) in water content.

Obla et al. [13] showed same level of performance as **Copeland** et al. [12].

Rajdev et al. indicated that ratio of 7 Day to 28 Day Strength is higher in PFA blended OPC concrete-mix than PPC concrete-mix. Target Mean Strength was found highest in 20% PFA replacement. The most economical concrete-mix design was obtained with 25% PFA replacement.

C. B Shah et al. [15] showed that although the initial strengths were lower than that for only ordinary portland cement, for mix at later age (90 days), the results were close to that of only ordinary portland cement.

Hossain et al. [16] reported that incorporation of UFFA in bridge deck concrete is better because concrete containing UFFA demonstrated significant reduction in both shrinkage and shrinkage cracking potential as compared to concrete containing SF.

Subramanian et al. [17] 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.

V. CONCLUSION

On the basis of study of the research done by various researchers and significant oservation in the field of PFA concrete it can be concluded that PFA is useful for following purposes.

- High volume replacement of cement and sand in concrete.
- Cement replacement combined with other suitable waste admixtures.
- Optimum cement replacement for medium strength, high strength and ultra high strength concrete.
- Strength gain at slower age curing conditions.
- Estimation of reduced construction cost.
- Possibility of achieving Green Construction by these replacements.
- Depending upon above results suitable application for structural concrete

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