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Production of Sustainable Concrete Using Class-F Fly as Binary Cementitious Material

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Abstract

Power plants burns huge amount of coal discharging huge sum of fly ash as a scum to the environment. Which leads us to environmental threats in form of waste and hazardous effects. Instead of dumping it to the landfills it has the potential for valuable uses. In this research work feasibility of class-F fly ash is studied and its potential is exploited for the production of sustainable concrete as partial replacement of cement. Four type of concrete mixes containing 5%, 10%, 15% and 20% class-F fly ash as replacement of ordinary Portland cement by weight were prepared and compared with the control mix. These concrete mixes were moist cured and tested at 7, 28 and 90 days to check its compressive and flexural behavior and compared to control mix. Split tensile test on all mixes were performed at 28 and 90 days. Results showed that early age strength of concrete having fly ash is less than strength of concrete without fly ash while later on strength of fly ash concrete increases depicting pozollonic nature of fly ash. Use of fly ash in concrete enhances durability of concrete and reduces the carbon foot prints by reducing use of cement, which is a step towards economical and sustainable construction.

Keywords

Fly ash ... ce, sustainability

1. Introduction

Fly ash is a glass-like material incurred as a by-product in powdered state after combustion of pulverized coal for the production of thermal energy. More than 1.1 billion tons [1] of fly ash were produced in the last decade, and 420 million tons have been recycled in United States. Whereas, locally, all the generated fly ash were dumped in to the landfills. Lighter ash suspends and become part of the atmosphere consequently causes air pollution and respiratory diseases. Fly ash when comes in-contact with water, its lethal matter may leech or dissolve and infiltrate through water. Communities living near or adjacent to the fly ash landfills can face severe damaging effects if came in-contact with it. Although many cases have been reported but no special measures were conducted to encounter it ultimately hundreds of communities have to migrate.

Looking into its characterization the powdered Fly Ash is produced in two classes i.e. Class-C Fly Ash (CC-FA) and Class-F Fly Ash (CF-FA). The cumulative proportioning of Silicon Dioxide (SiO2)

+ Aluminum Oxide (Al2O3) and Iron Oxide (Fe2O3) when surpass 70 percent and reactive calcium oxide is less than 10 percent then chemically the Fly Ash is considered as siliceous CF-FA. On the contrary, when the cumulative proportioning of Silicon Dioxide (SiO2) + Aluminum Oxide (Al2O3) and Fe2O3 is equal or more than 50 percent and calcium oxide is less than 10 percent then chemically the Fly Ash is considered as Calcareous CC-FA [2].

Researchers studied in its physical configuration under microscope and observed that most of the particles of the fly ash originate as solid spheres of glass [3]. Seldom small amount of completely empty and once or twice packed with several tiny spheres may also be present.

In 1965 Mather [4] reported an investigation in which he considered the 60 percent solid volume replacement of cement with CF-FA. For water to (cement + Fly Ash) ratio (W/C + FA) of 0.5 to 0.8, he reported three-day strengths of 4 and 1.5 MPa respectively. The purpose of research was to produce concrete with satisfactory workability and early-age strength, low rise in temperature and high later-age strength. It was observed that concretes with high Fly Ash content requires greater time for initial hardening which is significant in sever weathers for various works. He also reported that the workability of the concretes with high Fly Ash content is far healthier than the control group, decreasing or abolishing the consumption of plasticizers, vibration and total water in the mix. The predominantly spherical shape of the fly ash particles helps to reduce the friction between particles.

In this research programme CF-FA is used as a partial replacement of Portland cement. There are two main significance of replacing fly ash with ordinary Portland cement reducing the toxicity generated by the fly ash in the environment;

To counter the greenhouse gases (GHG) released during the production of cement.

To examine the pozzolanic behavior of the locally acquired fly ash.

2. Research Objective

The primary objective of this research is to determine the optimum mechanical properties of CF-FA concrete. By this we can garner sound statistics corresponding to the optimum dose for the properties of concrete.

3. Experimental Investigation

Following steps has been followed for accomplishment of this research work.

3.1.Materials

The prime material for this investigation is CF-FA [5] and knowing its accurate composition and other properties are of apex importance. Fig. 1 is depicting the chemical composition of the CF-FA. The first bar in left is showing the cumulative percentage of the SiO_2 + Al_2O_3 + Fe_2O_3 which seconds the ASTM CF-FA requirement for its cumulative content. Other parameters are as per the ASTM C 618-1 guidelines.
ASTM Type I Portland cement was used as a cementitious material for every blends. Crushed virgin Limestone coarse aggregate of irregular alignment having mix ratio of 60% - ¾” down to 40 - ½” (60:40) down acquired from Margalla quarry near Islamabad was used in this experimental program. Clean Fine aggregate free from organic contamination was acquired from Lawrencepur. Fig. 2 is illustrating gradation of fine aggregates. No water reducing agents or any other type of admixtures were used in the blend. Analyzed quantity of local tap water was used for preparation of matrix. Other chief properties of all the fine and coarse aggregate are illustrated in Table 1.

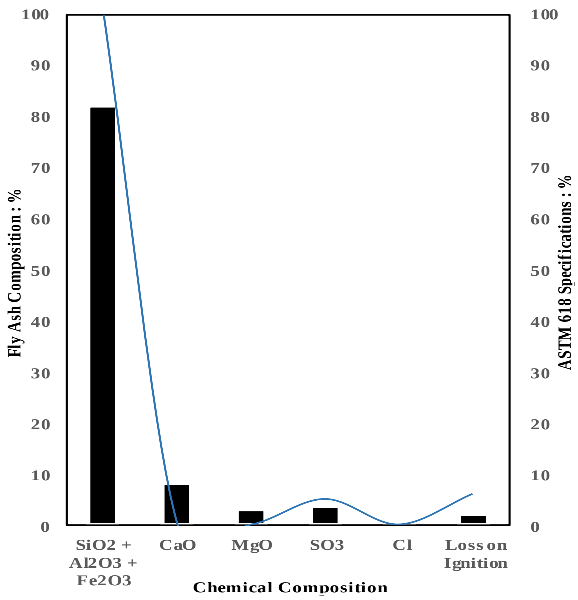

Figure 2: Chemical composition of CF-FA

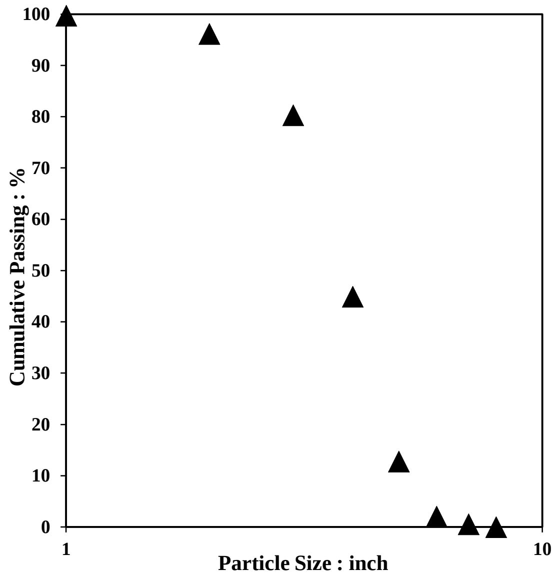

Figure 3: Gradation of Fine Aggregates

Table 3: Properties of Coarse and Fine Aggregates

Properties	Coarse Aggregate	Fine Aggregate
Bulk density (compacted), lb./ft^3	104.84	116.6
Bulk density (loose), lb./ft^3	95.86	102.57
Bulk specific gravity	2.70	2.50
Bulk specific gravity (SSD*)	2.73	2.58
Apparent specific gravity	2.78	2.53
Moisture content, %	0.64	1.24
Water absorption, %	1.02	2.04

3.2. Mix Design

Five proportioned matrix according to ACI Standard 211.1 [4] are designed and each are designated as per their incorporation. Zero incorporation blend is termed as Control mix. Similarly blend having incorporation of 5% is designated as M-5 so on and so forth up to 20%. The adopted W/C and W/(C+CF-FA) ratio was 0.52 which was applied in the preparation of all prototypes.

3.3.Prototypes

For inquiring mechanical properties of CF-FA concrete, 51 cylinders having 6 in. diameter and 12 in. height and 30 prisms having 4 in. x 4 in. cross-sectional area and 20 in. length were casted and cured in water up till the specified time for its testing according to ASTM requirements. For compressive strength test three cylindrical duplication were casted, prepared and tested according to ASTM C 39. Likewise for Flexural strength test three duplication of prisms are prepared and tested according to ASTM C 192. For Split Tensile test three duplication of cylindrical specimens with identical dimensions which was used in compressive strength test were casted, prepared and tested in accordance with the ASTM C 496.

4. Experimental Results and Discussions

Different tests were performed on the prepared prototypes in fresh state as well as in hardened state to determine the properties of concrete when CF-FA is incorporated.

4.1. Slump Test

The investigated values of the slump test are depicted in Fig. 3 is showing a clear increase in the slump value as the incorporation of the CF-FA is increased
Primarily, at 0% incorporation (Control mix) the slump value is 1.5 in. but as incorporation reached to intermediate stage the garner value is 1.8 in. which is relative to the bottom line of the ACI provision pertaining to slump test. At an incorporation of 20% the slump value impinges the ACI guidelines for slump. Therefore, the message is clear from this pattern that as CF-FA content increases, the fluidity of the mixes increases hence this surplus water increases the workability of concrete.

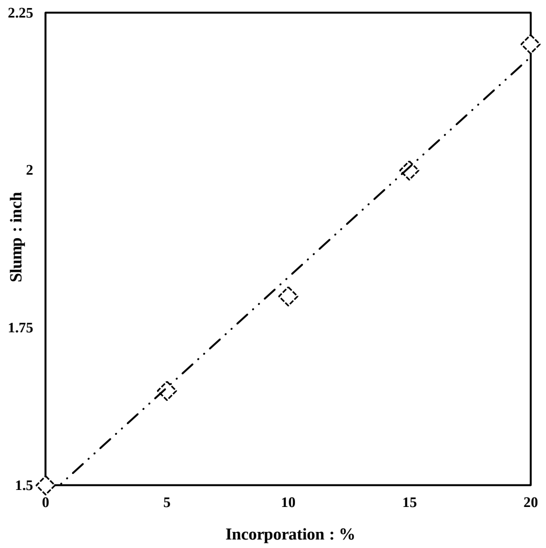

Figure 4: Incorporation ~ Slump

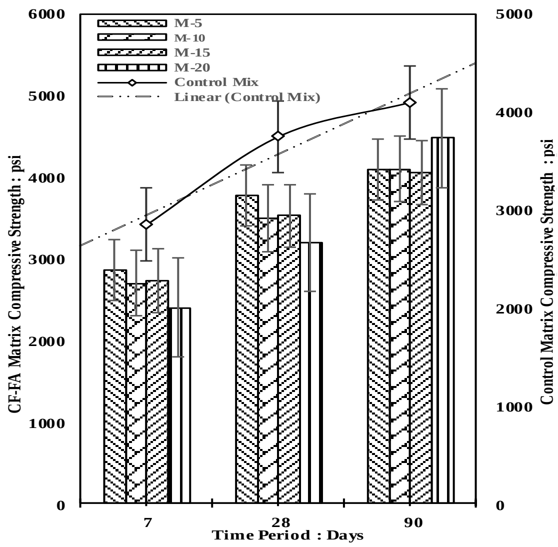

Figure 5: Control mix & incorporated mix Compressive Strength ~ Time period

4.2. Compressive Strength

Compressive strength of concrete (Control or Incorporated) is the major criterion which is needed to be satisfied by any means. Fig. 4 is depicting the relationship between time and incorporation effect on the compressive strength of concrete.

A comparison between control mix compressive strength and CF-FA is done graphically. First bunch of prototypes were tested on the 7th day after the de-molding. It clearly shows that as the incorporation of CF-FA is increasing the compressive strength of the concrete is decreasing. But as the time period is shifted to 28 days, a clear increase in the compressive strength can be observed both in control mix as well as in incorporated mix relative to the former time period, but then again when comparing the 28th day prototypes the greater incorporation content yields lower compressive strength. However, on the 90th day the results mirrored. M-5, M-10, and M-15 approached equal to control mix strength and Maximum incorporation i.e. M-20 yielding a compressive strength of () which is greater than the control mix. This increase in strength is due to the pozzolanic activity of the CF-FA which accelerated after 28 days' time period.

4.3. Flexural Strength

The flexural strength of control mix and CF-FA at different time periods are illustrated in Fig. 5. Approximately identical behavior is observed in this case too when associated with compressive strength. Initially on 7th day the control mix strength and M-20 strength are far apart. In-between a clean declining pattern is recorded. Similarly on the 28th day the M-20 strength became relatively close to the control mix because of the increased time period. Other strengths (M-5, M-10, and M-15) also showed an increasing trend. However, as anticipated from the pozzolanic activity observed in the results of previous section, likewise on the 90th day an encroached increase from the control mix is recorded in the flexural strength at M-20 as well as on M-15 incorporation. M-5 and M10 also showed bottom line pattern with control mix.

4.4. Split Tensile Strength

Fig. 6 is depicting the results of splitting tensile test. Initially on the 28th day a-bit increase is observed at M-10 incorporation matching to control mix. After that a decreasing pattern can be seen at same time period. However, on the 90th day trend is changed and an increasing pattern throughout can be observed. Precisely no significant / noteworthy increase or decrease is observed. Precisely no significant / noteworthy increase or decrease is observed. The incorporated mix strength (median) orbits around the control mix either it is M-5, M-10, M-15 or M-20 on 8th day and also on 90th day.

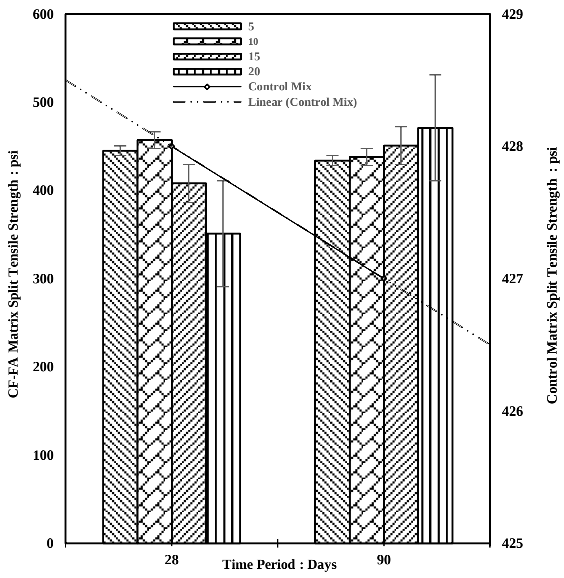

Figure 5: Control mix & Incorporated mix Flexural Strength ~ Time period

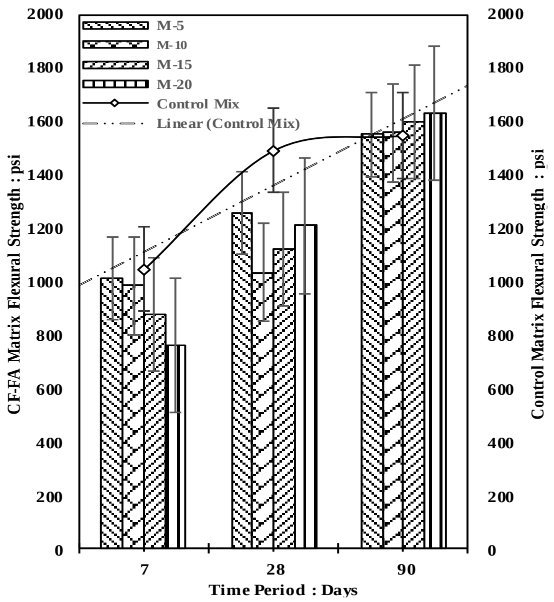

Figure 6: Control mix & Incorporated mix Split Tensile Strength ~ Time period

5. Conclusions

Following are the conclusions that can be drawn from the empirical work conducted in the laboratory:

- The use of CF-FA as an incorporation in the concrete is a significant step towards the sustainable environment.
- The incorporation of well quality fly ash i.e. CF-FA high in fineness and less carbon content penetration acquired locally showed less water requirement by the concrete mix as incorporation increased.

- A decrease of 16% relative to control mix in compressive strength was observed initially on the 7th day after curing in M-20 prototype. After 21 days, 1% increase was recorded relative to former result. On the 90th day, a jump of 10% increase in the strength were garnered.
- An immense downward inclination of 27% relative to control mix at M-20 incorporation was garnered on the 7th day in flexural strength. On the 28th day, 9% increase in the prototypes' flexural strength was recorded. While on 90th day a small increase of 5% was observed.
- A decrease of 18% at M-20 incorporation on the 28th day split tensile strength was observed. However, on 90th day an increase of 10.5% in its strength was garnered.
- All of these statistics are gathered after extensive empirical work. The results and their time periods are suggesting that in those four incorporations the optimum was M-20 at a time period of 90 days.
- Also when considering time period a late pozzolanic activity can be observed. After 28 days, upward inclination in strength either compressive, flexural or split tensile is observed in M-5, M-10, M-15 and M-20 incorporations.

References

[1] William P. Spence and Eva Kultermann., "*Construction Materials, Methods, and Techniques"*. 3rd ed., Editor: Delmar Cengage Learning 2010-01-19., ISBN-13: 9781435481084

[2] P. Kumar Mehta., "*Concrete Microstructure, Properties, and Minerals".* 4th ed., Editor: McGraw Hill Education., ISBN: 9780071797870

[3] ASTM Designation C 618-01., "*Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete"*.

[4] V.S Ramachandran., "*Concrete Admixtures Handbook Properties, Science, and Technology".* 2nd ed., Editor: Standard Publishers Distributor. ISBN: 9780815516545

[5] Kevin Paul Keith., Characterization of the behavior of High Volume Fly Ah Concrete, Auburn Alabama. Pak. J. Engg. & Appl. Sci. Vol. 12, 2011.