Study of Compressive Strength of Concrete with Coal Power Plant Fly Ash as Partial Replacement of Cement and Fine Aggregate

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ABSTACT

This research study comprises of concrete cubes made with OPC (Ordinary Portland Cement) and with different configurations of fly ash by replacing cement and fine aggregate. To achieve the aim of this study, total 81 concrete cubes were cast. Among 81 cubes, 9 cubes were made with normal concrete, 36 cubes were made by replacing 25, 50, 75 and 100% of fine aggregate with fly ash and 36 cubes were made by replacing 10, 25, 50, and 75% of cement with fly ash. The cubes were 6"x6" in cross-section, and the mix design was aimed for 5000 psi. After proper curing of all 81 cubes, they were tested at 3, 7 and 28 days curing age. The cubes were tested in Forney Universal Testing Machine. By analyzing the test results of all the concrete cubes, the following main findings have been drawn.

The compressive strength of concrete cubes made by replacing 100% fine aggregate by fly ash was higher than the concrete cubes made with OPC at all 3, 7 and 28 days curing ages. On the other hand, the compressive strength of concrete cubes made by replacing 10 and 25% cement by fly ash was slightly lower than the concrete cubes made with OPC at all curing ages, whereas, the compressive strength of concrete cubes made by replacing 50 and 75% of cement by fly ash were quite lower than the concrete cubes made with OPC at all curing ages.

Key Words: OPC, Fly Ash, Fine Aggregate, Concrete Cubes.

1. INTRODUCTION

Concrete is a composite material which is being used in variety of structures. More commonly the construction material like aggregates, cement, and steel bars are to be transported from distant places to the site which is quite expensive. Therefore, the aggregates are preferably to be used available in the vicinity.

Fly ash is fine residue material resulting from the combustion of powdered coal in power generation plants. This waste by-product must be effectively disposed to eliminate air, soil, and surface, as well as ground water pollution at added cost to the industry and thus to the society [1-3].

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Fly ash is utilized as partial substitute of Portland Cement and/or fine aggregate, an expensive and energy intensive material. Therefore use of fly ash leads to considerable saving in cost and energy consumption. Utilization of increased volumes of fly ash in concrete will lead to conservation of energy and natural resources. Bulk quantities of some industrial by-products such as fly ash, bottom ash and slag have been used as aggregates for concrete, road embankment as well as sub base construction, but such bulk uses represents low value applications. On the other hand, their use as mineral admixtures in cement and concrete due to their pozzolanic and cementitious properties represents high value applications [4].

Addition of finely ground pozzolanic and cementitious materials like fly ash, can affect the properties of cement mortar/concrete both in fresh and hardened state. In fresh or plastic state, mix proportions, water requirements for specified consistency, setting characteristics, workability, and heat of hydration are some of the properties influenced by mineral admixtures. In the hardened state, the rate of strength development and ultimate strength, permeability, durability against frost attack, sulfate attack, alkali-silica reaction, carbonation, and resistance to thermal cracking are significantly affected with the incorporation of mineral admixtures in cement concrete. Over the years, extensive research has been conducted all over the world to investigate the influence of fly ash on the strength of plain cement concrete. In this study the fly ash produced at Lakhra Coal Power Plant is used as a replacement of cement/fine aggregate, in order to investigate its effects on the strength of concrete.

2. RESEARCH SIGNIFICANCE

2.1 Fly Ash as Wealth Rather Than Waste

With the boom in population and industrial growth, the need for power has increased manifold. It has been observed that the power generation plants running through coal fuel are producing huge amount of ashes, which is being treated as waste. Non utilization of the fly ash will result in the pollution of environment. On the other hand its proper utilization can be a good source of raw material

Researchers have been attempting to convert this waste into the useful material by exploring viable avenues for use of fly ash. It has been reported that this waste stuff is being used as fine aggregate in concrete construction and higher strengths are being achieved [5]. Hence the utilization of fly ash, in those areas where it is cheaply available, would be a feasible step in construction industry rather than transporting standard hill sand from a far distant source.

It is reported that fly ash has cementitious properties; hence fly ash is an inexpensive replacement for various contents of concrete construction [6-13]. When fly ash is employed with portland cement, then hydrated lime combines with the fly ash forming stable cementitious compound which contributes strength. [2,10].

2.2 Advantages/Benefits of Fly Ash Concrete

Fly ash refers to the finely ground material which is added to obtain specific engineering properties of cement mortar and concrete. The other, equally important, objectives of using fly ash in cement concrete include economic benefits and environmentally safe recycling of waste by products. Fly ash is generally finer than Portland Cement and also possesses cementitious propertires. [4].

Fly ash is used in concrete to improve its strength. The various advantages of fly ash in concrete largely depend on mix proportions, mixing procedure and field conditions. Although fly ash creates environmental problems, never the less it improves the quality of concrete. It also lowers the heat of hydration. Fly ash increases strength of concrete, reduces the permeability and corrosion of reinforcing steel, increases sulphate attack resistance and reduces alkali-aggregate reaction [10].

2.3 Properties of Fly Ash used in this Study

Lakhra coal power plant encompasses an area of 250 square kilometers. Fly ash produced through this power plant is very fine powder. The annual production of fly ash from this plant is about 2 million tons, and is deposited as a land fill. It has been reported that dumped fly ash has occupied considerable space of land in the vicinity of power plant which has created environmental problem to the inhabitants who are living in this area. This alarms researchers to consume this land fill fly ash for reduce the issue of environmental and health safety in the vicinity.

The characteristics of fly ash defined by its physical, chemical and mineralogical properties, may vary from source to source. The effective utilization of fly ash in concrete from the specific source requires the study of fly ash as an alternate of common fine aggregate and cement.

3. EXPERIMENTAL PROGRAM

3.1 Materials for Concrete Mixture

The various materials used in concrete mix are given in Table 1.

3.2 Properties of Materials Used in Concrete Mix

3.2.1 Specific Gravity of Fine Aggregate

Standard test procedure as prescribed by ASTM C128-04a was used for this test. In this study specific gravity of fine aggregate was found to be 2.61.

3.2.2 Specific Gravity of Coarse Aggregate

Standard test procedure as prescribed by BS: 812 Part 107: (Draft) and ASTM C 127- 04 was used for this test. In this study the specific gravity of coarse aggregate was found to be 2.66.

3.2.3 Specific Gravity of Fly Ash

The specific gravity test was conducted according to ASTM C 128-04a and the value comes out as 2.54.

3.2.4 Water Absorption of Fine Aggregate

Standard test procedure as described in BS 812: Part 107: (Draft) was used for this test. In this study the water absorption value comes out 1.69%.

3.2.5 Water Absorption of Coarse Aggregate

Standard test procedure as described in BS 812: Part 107: (Draft) was used for this test. The water absorption of coarse aggregate was found to be 1.38%.

3.2.6 Water Absorption of Fly Ash

Standard test procedure as described in BS 812: Part 107: (Draft) was used for this test. The water absorption of Fly ash was found to be 16.92%.

3.2.7 Unit Weight of Fine Aggregate

Standard test procedure as described in BS 812: Part 2: 1975 and ASTM C 29/ C 29M-97 (Reapproved 2003) was used for this test. The unit weight of fine aggregate was found to be 103.47 lb/ft^3.

3.2.8 Unit Weight of Coarse Aggregate

Standard test procedure as described in BS 812: Part 2: 1975 and ASTM C 29/ C 29M-97 (Reapproved 2003) was used for this test. The unit weight of coarse aggregate was found to be 98.48 lb/ft^3.

3.2.9 Unit weight of Fly Ash

Standard test procedure as described in BS 812: Part 2: 1975 and ASTM C 29/ C 29M-97 (Reapproved 2003) was used for this test. The unit weight of Fly ash was found to be 44.52 lb/ft^3.

TABLE 1. MATERIAL USED IN CONCRETE MIX

No.	Material Description	Material Source
1.	Cement	Dada Bhai Cement Factory
2.	Fine Aggregatge	Bolhari sand
3.	Coarse Aggregatge	Petaro crushing plant
4.	Fly ash	Lakhra Power Plant
5.	Water	Tap water available in Concrete laboratory

3.3 Design Method

The British method of concrete mix design, popularly referred to as the "DoE method", was used for design purpose. After having few trials to check the mix design for the required strength of 5000 psi, the ratio was used as:

1 : 1.25 : 2.50 @ 0.39 w/c ratio.

3.3.1 Specimen Details and Test Setup

In this research study total 81 concrete cubes were cast. Among 81 cubes, 9 cubes were made with normal concrete, 36 cubes were made by replacing 25, 50, 75 and 100% of fine aggregate by fly ash and 36 cubes were made by replacing 10, 25, 50, and 75% of cement by fly ash. The cubes were 6x6" in cross-section, and the mix design was aimed for 5000 psi. After proper curing of all 81 cubes, they were tested at 3, 7 and 28 days curing ages. The cubes were tested in Forney Universal Testing Machine.

4. TEST RESULTS AND DISCUSSION

The test results of all the concrete cubes are summarized in Table 2, whereas their graphical presentation is shown in Fig. 1. The compressive strength of concrete cubes made by replacing 100% Fine aggregate by Fly ash was higher than the concrete cubes made by OPC at all 3, 7 and 28 days curing ages as shown in Fig. 1. The compressive strength of concrete cubes made by replacing 75% of Fine aggregate by Fly ash was higher at 3 days but it was slightly lower than the OPC made normal cubes at 7 and 28 days as presented in Fig. 2.

It can be seen that there is increase in strength with the increase in fly ash percentages. This increase in strength due to the replacement of fine aggregate with fly ash is attributed to the pozzolanic action of fly ash.

The compressive strength of concrete cubes made by replacing 10 and 25% cement by Fly ash was slightly lower than the concrete cubes made by OPC at all curing ages. The compressive strengths of concrete cubes made by replacing 50 and 75% of cement by Fly ash were quite lower than the concrete cubes made by OPC at all curing ages as shown in Fig. 3.

Owing to its pozzolanic properties, fly ash is used as a replacement for some of the Portland cement content of concrete. As pozzolan greatly improves the strength and durability of concrete, the use of Fly ash is a key factor in their preservation. In this study test results reveal that the use of Fly ash as a partial replacement of Portland cement can be limited up to 25%.

TABLE 2. COMPARISON OF COMPRESSIVE STRENGTH OF CONCRETE CUBE AT THE AGE OF 3-DAYS, 7-DAYS AND 28-DAYS

No.	Description of Cube	Average Compressive Strength (psi) at the Age of:		
		3-Days	7-Days	28-Days
1.	Cubes made with Normal cement concrete	3241	4594	5129
2.	Cubes made by replacing 25% of Fine Aggregate by Fly ash	3033	4287	4896
3.	Cubes made by replacing 50% of Fine Aggregate Fly ash	3128	4381	4975
4.	Cubes made by replacing 75% of Fine Aggregate by Fly ash	3377	4561	5041
5.	Cubes made by replacing 100% of Fine Aggregate by Fly ash	3608	4614	5197
6.	Cubes made by replacing 10% of Cement by Fly ash	3146	4409	4989
7.	Cubes made by replacing 25% of Cement by Fly ash	2925	4428	5076
8.	Cubes made by replacing 50% of Cement by Fly ash	1872	1931	2283
9.	Cubes made by replacing 75% of Cement by Fly ash	1038	1090	1323

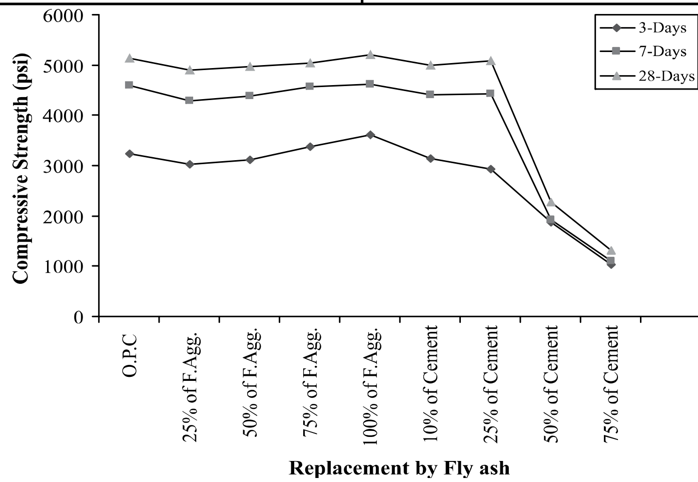

FIG. 1. GRAPHICAL PRESENTATION OF COMPARISON OF COMPRESSIVE STRENGTH OF CONCRETE CUBES AT THE AGE OF 3, 7 AND 28-DAYS

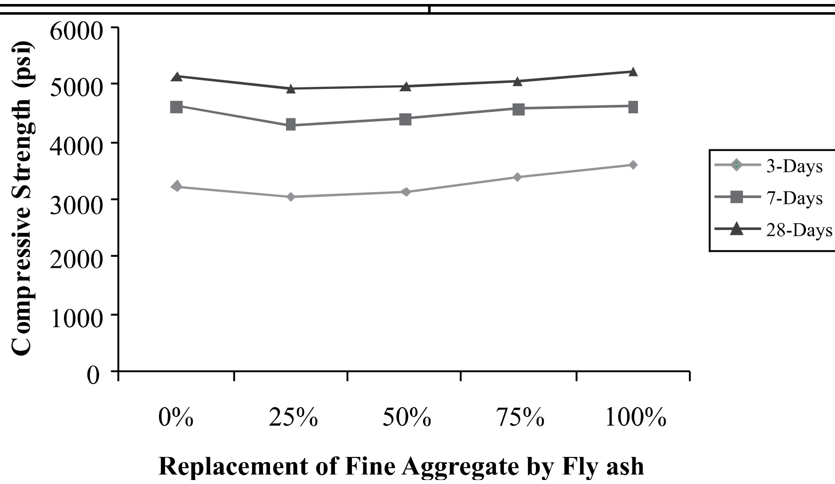

FIG. 2. GRAPHICAL PRESENTATION OF COMPRESSIVE STRENGTH OF CONCRETE CUBES WHILE REPLACING FINE AGGREGATE BY FLY ASH

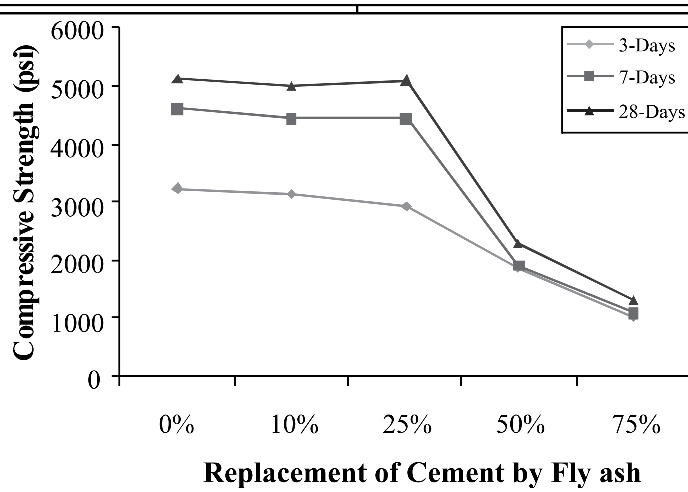

FIG. 3. GRAPHICAL PRESENTATION OF COMPRESSIVE STRENGTH OF CONCRETE CUBES WHILE REPLACING CEMENT BY FLY ASH

5. CONCLUSIONS

By analyzing the test results of all the concrete cubes with OPC concrete and with different configurations of fly ash made concrete by replacing fine aggregate and OPC, the following conclusions have been drawn.

(i) The concrete cubes made by replacing 100% fine aggregate with fly ash provide higher compressive strength than the concrete cubes made by using OPC and common fine aggregate. The above results advocate that fly ash can be used as a substitute of fine aggregate in plain concrete.

(ii) The concrete cubes made by replacing 10 and 25% cement with fly ash provide relatively same compressive strength as compared to concrete cubes made with OPC at 7 and 28 days curing age. This result reveals that the fly ash can be used as an alternate of OPC in plain cement concrete upto 25%.

(iii) This paper emphasizes on the suitability of fly ash to replace the fine aggregate and cement in plain concrete. Further extensive research is required to use fly ash for design and construction of RCC members which may be economical for our construction industry.

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REFRENCES

[1] ASTM C 618-01, "Standard Specifications for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete", Annual Book of ASTM Standards, 2001.

[2] ACI Committee 116, "Cement and Concrete Terminology", ACI 116R-90, American Concrete Institute, pp. 46, Farmington Hills, MI, 1990.

[3] ASTM C618-92(a), "Standard Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as Mineral Admixture in Portland Cement Concrete", American Society for Testing and Materials, Annual Book of ASTM Standards, Volume 4, No. 2, West Conshohocken, Pennsylvania. 1994.

[4] Chandram, V.S.C., “Concrete Admixture Hand Book Properties”, Science, and Technology, 2nd Edition, pp. 657-680, 1996.

[5] Memon, A., "Experimental Study For Utility of Fly Ash of Lakhra Coal Plant as a Structural Concrete Construction Material", M.E. Thesis, Department of Civil Engineering, Mehran University of Engineering & Technology, Jamshoro, Pakistan, 2004.

[6] Sott, A., Thomas, N., and Micheal, D.A., "Evaluation of Fly Ash from Co-Combustion of Coal and Petroleum Coke for use in Concrete"', ACI Materials Journal, Volume 104, No. 1, pp. 62-70, January-February, 2007.

[7] Oner, A., Akyuz, S., and Yildiz, R., "An Experimental Study on Strength Development of Concrete Containing Fly Ash and Optimum Usage of Fly Ash in Concrete", Science Direct Cement and Concrete Research, Volume 35, pp. 1165-1171, 2005.

[8] Wang, K., Mishulovich, A., and Shah, S.P., “Activation and Properies of Cementitios Materials Made with Cement-Kiln Dust and Class Fly Ash", Journal of Materials in Civil Engineering, ASCE, pp. 112-119, January, 2007.

[9] Khan, A.N., Shah, A., and Ali, Q., "Use of Fly Ash as Cementitious Material in Concrete", Research Journal of Engineering and Applied Science, NWFP University of Engineering & Technology Peshawar, Pakistan, Volume 20, No.1, pp.37-45 January-June, 2001.

[10] Amjad, P., "Study of Fly Ash Made Mortar Concrete", M.E. Thesis, Department of Civil Engineering, Mehran University of Engineering & Technology, Jamshoro, Pakistan, 2007.

[11] Memon, F.A., "Experimental Study of Fly ash of Lakhra Coal Power Plant in RCC Beams", M.E. Thesis, Department of Civil Engineering, Mehran University of Engineering & Technology, Jamshoro, Pakistan, 2007.

[12] Atis, C.D., and Karahan, O., "Properties of Steel Fiber Reinforced Fly Ash Concrete", Journal of Construction and Building Materials, Volume 23, pp. 392-399, 2009.

[13] Sahmaran, M., Ismail, O.Y., and Tokyay, M., "Transport and Mechanical Properties of Self Consolidating Concrete with High Volume Fly Ash", Journal of Cement & Concrete Composites, Volume 31, pp. 99-106, 2009.