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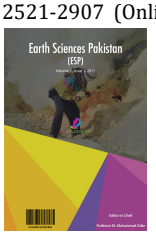

EXPERIMENTAL STUDY ON STRENGTH AND DURABILITY OF CEMENT AND CONCRETE BY PARTIAL REPLACEMENT OF FINE AGGREGATE WITH FLY ASH

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ABSTRACT

Cement is a binding material that is used to bind different aggregate (coarse and fine) through a chemical process known as hydration in the presence of moisture. This research work is planned with the purpose to determine the most appropriate and efficient proportions of admixture i.e. fly ash so as to modify the strength properties of concrete. By adding this admixture strength properties of cement and concrete can be enhanced. Cement be replaced with different percentages levels of Fly ash as 0%, 10%, 20%, 30%, 40% and 50% by weight of cement. To work out the strength properties and the variation pattern due mixing in different proportions of fly ash for different tests such as compressive and tensile strength are planned to be performed after 7, 14, 21 and 28 days curing. These experiments were conducted at Laboratory scale. Addition of fly ash as an admixture in replacement of cement enhanced strength properties of cement and concrete up to a limit. At 10% fly ash cured for 28 days maximum compressive and tensile strength was achieved i.e. 1170 psi and 66 psi respectively. Furthermore, addition of fly ash as cement replacement showed gradual reduction in the strength properties i.e. minimum compressive and tensile strength was found to be for 50% fly ash sample cured for 7 days. As an outcome of this research fly ash is concluded to be an effective replacement of cement for non-loading constructions.

1. INTRODUCTION

Cement and Concrete is widely used in all countries like Pakistan for construction purpose i.e. in building industry because of its advantages like high strength and durability. For constructing road, Buildings, Hospitals, Schools, Colleges, Government Institution etc large quantity of cement is required. Due to increase in demand of cement prices of cement are increasing and also caused shortage of cement. Fly Ash can be used for partial replacement of cement. Fly ash can be used as an admixture in cement and concrete by replacement of fine aggregate (sand) and cement to enhance the binding properties of cement and concrete. Millions of tonnes of Fly Ash is produced in power plant and brick kilns in Pakistan that deteriorate the environment. Fly ash produced in power plant is handled improperly and contained in open surfaces from where minor quantities are used in road construction. When wind is moves particles of fly ashes disperse in atmosphere and disturbs the constituents of atmosphere and causing environmental destruction and air pollution. By use of fly ash we can save sand, cement and consuming industrials waste can be enhanced the binding and mechanical properties of cement and concrete [1].

Fly ash (FA) is the core solid waste emitted mainly from coal power stations. Most vital areas of using fly ash as an alternative reported are: concrete production, road basement material, waste stabilization/solidification, cement clinkers and more recently geopolymer concrete [2-6].

In power generation perspective, FA is a waste material and electricity generation stations are looking for economically advantageous ways to exploit fly ash. However, from construction industry perspective, FA is considered as a supplementary cementitious material (SCM) that is used as a cement replacement in conventional, mass and high performance concrete material [7,8]. Fly ash increases workability, reduces thermal cracking and heat of hydration in concrete at early stage and improves mechanical and durability characteristics of concrete particularly at later ages [9]. In spite of the benefits of incorporating FA in concrete, utilizing 100% of fly ash is not achieved due to several limitations reported [10]. Fly ash can be obtained from sugar mills where sugar cane waste is used for burning. Significant results can be obtained as more durability, greater strength and binding properties by incorporating fly ash in cement [11]. According to environmental protection agency, the use of fly ash in concrete decreases the GHGs emissions equivalent to emissions from 2.5 million cars on road per year [12]. Hence, significant reduction in greenhouse emissions can be achieved by utilization of FA in concrete.

In power plants coal is used, during its combustion fly ashes are produced. Properties of fly ashes depend on chemical composition. For instance Class C of fly ash have higher CaO as compared to Class F of fly ash. Class F of fly ash having constituent silicate, Fe, Al and alkalies. Class F fly ash having solid particles are produced from anthracite [13]. Lime stone and fly ash can be added in concrete separately. By adding these hydrolysis process of concrete was changed. Also increased the durability, mechanical and physical properties of concrete [14]. Fly ash is effective on properties of concrete. Fly ash adding as admixture by partially replacement of cement we can enhance the workability and strength properties of concrete [15].

A researcher has studied effect of admixture on concrete [16]. He added fly ash as an admixture with different percentage as 5% and 10% by partially replacement of fine aggregate and cement to enhance the mechanically properties of cement and concrete. Ordinary Portland cement was used under study because it has greater strength as compared to other type of cement. Water permeability and compressive strength was measured at curing 28 days and concluded that by adding admixture result showed higher compressive strength and low water permeability. Also, a group scientist studied rheological properties, carbonation and compressive strength of concrete by adding fly ash with percentage of 25% and 50% with replacement of fine aggregate [17]. Test result indicate that compressive strength and rheological properties of concrete increased by increasing level of fly ash. Some researcher used bottom ash by replacement of aggregate that obtained from municipal solid waste for concrete masonry units (CMU) [18]. Test result were obtained from concrete by adding MSWBA as aggregate meets ASTM 90 (American Society for Testing and Materials) standard. Next, there also a researcher used dry bottom ash by replacement of fine aggregate in concrete [19]. Six specimens of different proportions of concrete were prepared and fabricated according to ASTM C 11709 (American Society for Testing and Materials for concrete) procedure. Each specimens were tested and concluded that each sample have good strength, stiffness and resistance to wear. In other study stated that United States used coal to generate electricity [20]. From burning of coal almost 80 million tonnes fly ash is produced per year. Fly ash is dumped in landfills but also used for constructional purpose by replacement of cement. By replacing cement resistance to alkali- silica reaction can be improved. And also, Electromagnetic interference shielding effectiveness can also be enhanced.

Some of researcher evaluated the compressive strength and corrosion resistance properties of concrete by mixing fly ash as an admixture with replacement of sand [21]. For this purpose 10%, 20% and 30 % by weight of cement fly ash was used and concluded that compressive strength and corrosion resistance characteristics can be enhanced. In addition, there also a studied the effect of fly ash on tensile and compressive strength of concrete [22]. Fly ash was obtained from lignite coal based power station and added with different percentages 0%, 5%, 10% and 15% by weight of cement. The specimens were cured in 20o C. Compressive and tensile strength were determined at 7, 28, 56, 90, 120 days curing. It was observed that mechanical properties of concrete be enhanced by increasing fitness of fly ash. Two researcher used ordinary Portland cement and partially replaced by difference level of fly ash as 10%, 20%, 30%, 40%, 50% and

and 60% by weight of cement and be cured at different periods at 3, 7, 14, 28, 60 and 90 days [23]. Strength of each sample be determined, and result indicate that strength be enhanced by increasing levels of fly ash. At 40% of fly ash specimens have 14% greater compressive strength and 8% greater tensile strength as compared to ordinary Portland cement.

A studied the workability and mechanical properties of concrete by adding high volume fly ash also called coarse fly ash by replacement of cement [24]. Coarse fly ash shows better result of mechanical properties of concrete.

This research addresses mainly workability of cement concrete by adding fly ash as an admixture and to investigate the effect of fly ash as an admixture on compressive and tensile strength of concrete. Main advantage of adding fly ash in cement is that it reduces the utilization of natural aggregate in concrete, contribute for protection of natural environment and sustainable development. As fly ash are spherical particles that can easily roll over one another and also reduce friction.

2. MATERIAL AND METHODS

2.1 Materials

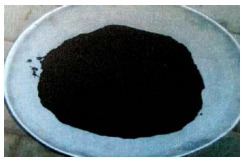
Ordinary Portland cement (OPC) was used for experimental purpose due to locally available in all the countries like Pakistan. Different samples of cement and concrete were prepared for compressive, tensile and workability tests. Fly ash was obtained from thermal power station in Faisalabad. In thermal power station furnace oil was used that produce fly ash have efficient constituent that used to enhance the binding properties of cement and concrete by replacement of cement. Natural sand was used having maximum size 4.75 mm which was also known as fine aggregate. The natural aggregate (gravel) that has 5-20 mm size was said to be coarse aggregate.

(a) Ordinary Portland cement

(b) and

(c) Gravel

(d) Fly ash after drying in oven



(e) Fly ash after Screening

Figure 1: Different Materials being prepared for analysis

2.2 Research Methodology

After collecting materials sieve analysis was performed on cement, sand and fly ash to determine particle size distribution. Total 18 Samples with different proportions of admixture in combination with ordinary Portland cement are prepared. Two tests i.e. compressive and tensile strength are performed to all the samples. Twenty-Four Samples are prepared for compressive strength testing and Twenty-four samples for tensile strength testing with six different percentages of Fly ash as 0%, 10%, 20%, 30%, 40% and 50% replaced by weight of cement and with four different curing time that are 7, 14, 21 and 28 days.

2.3 Experimental Methodology

2.3.1 Sieve analysis

Sieve analysis experiment was performed for cement, sand and fly ash to determine the size. Weight of each sieve measured by using electric balance. Then weight of china dish was measured that is 20 grams. After that weight of dry cement was measured and 100 gram of cement excluding weight of china dish. Then all sieves were placed in ascending order and then place the mechanical shaker firmly. Shaker was shacked for 10 minutes. Sieve stack was removed from shaker carefully and again weight of each sieve was recorded, and weight of cement retained in each sieve was measured. The percentages of retained mass in each sieve was measured. Also, the mass retained in bottom pan was measured that is the fine aggregates.

2.3.1.1 Sieve analysis of cement

Mass of cement taken =100gram

Table 1: Sieve analysis of cement

Sieve No.	Diameter (mm)	Mass of empty sieve (g)	Mass of sieve + Mass of cement retained (g)	Mass of cement retained (g)	Percentage Retained	Percentage Passed
1	4.75	422.6	422.6	0	0	100
2	2.80	388.1	388.1	0	0	100
3	1.70	380.1	380.1	0	0	100
4	1.00	350.8	350.8	0	0	100
5	0.60	321.5	321.5	0	0	100
6	0.355	299.7	299.7	0	0	100
7	0.212	285.5	308.3	22.8	22.8	77.2
8	0.075	267.8	313.1	45.3	45.3	31.9
Pan	----	269	299.9	30.9	30.9	00

2.3.1.2 Sieve analysis of cement

Mass of container =20-gram, Mass of sand taken =90 gram

Table 2: Sieve analysis of cement

Sieve No.	Diameter (mm)	Mass of empty sieve (g)	Mass of sieve + Mass of cement retained (g)	Mass of cement retained (g)	Percentage Retained	Percentage Passed
1	4.75	422.6	422.6	0	0	100
2	2.80	388.1	388.1	0	0	100
3	1.70	380.1	380.1	0	0	100
4	1.00	350.8	350.8	0	0	100
5	0.60	321.5	322.1	0.6	0.6	99.4
6	0.355	299.7	308.9	9.2	9.2	90.2
7	0.212	285.5	338.8	53.3	53.3	36.9
8	0.075	267.8	300.7	32.9	32.9	4
Pan	----	269	299.1	30.1	30.1	00

2.3.1.2 Sieve analysis of Fly ash

Mass of fly ash = 90g

Table 3: Sieve analysis of fly ash

Sieve No.	Diameter (mm)	Mass of empty sieve (g)	Mass of sieve + Mass of cement retained (g)	Mass of cement retained (g)	Percentage Retained	Percentage Passed
1	4.75	422.6	422.6	0	0	100
2	2.80	388.1	388.1	0	0	100
3	1.70	380.1	380.1	0	0	100
4	1.00	350.8	359.8	9	10	90
5	0.60	321.5	337.9	16.4	18.22	71.78
6	0.355	299.7	314.6	14.9	16.55	55.23
7	0.212	285.5	301.2	15.7	17.44	37.79
8	0.075	267.8	293.1	25.3	28.11	9.68
Pan	----	269	276.1	7.1	7.88	00

After sieve analysis the grain size of fly ash is found to be 1mm. sieve analysis for cement, sand and gravel showed that size of cement is 0.212mm, sand is 0.6mm and that of fly ash is 1mm. Through sieve analysis of fly ash impurities can be removed and fine particles of fly ash play important role to enhance the strength properties of cement and concrete.

2.3.2 Tensile strength

For measuring of tensile strength different samples of cement and sand were prepared in shape of briquettes with ratio 1:2 in which 1 part of cement and 2 parts of sand is used. For preparing sample die is used. First 3 samples were prepared as a trial in which exact weight of sand and cement is measured which required for one sample. After trailing it was concluded that for preparing of sample in die 80gram of sand and 40 grams of cement is used. Total 24 samples were prepared to determine the tensile strength. Six different sample was prepared, and each sample was cured 7, 14, 21 and 28 days. Fly ash is added as an admixture with

different percentages as 0%, 10%, 20%, 30%, 40%and 50% by weight of cement.

Table 4: All samples prepared for testing tensile strength

Percentage of Fly ash used	After 7 days curing time	After 14 days curing time	After 21 days curing time	After 28 days curing time	Weight of Cement Used (g)	Weight of Fly ash Used (g)
0 %	Sample 1	Sample 7	Sample 13	Sample 19	40	0
10 %	Sample 2	Sample 8	Sample 14	Sample 20	36	4
20 %	Sample 3	Sample 9	Sample 15	Sample 21	32	8
30 %	Sample 4	Sample 10	Sample 16	Sample 22	28	12
40 %	Sample 5	Sample 11	Sample 17	Sample 23	24	16
50 %	Sample 6	Sample 12	Sample 18	Sample 24	20	20

After completion of curing period of each sample then each sample be dry for 24 hours after drying tensile strength be measured of each sample with help cement testing machine-6601 with a maximum load capacity of 1100 pounds.

Figure 2: Cement Testing Machine-6601

2.3.3 Compressive strength

For measuring compressive strength concrete testing machine was used. Concrete samples consist mixture of cement, sand, gravel and water. Samples for testing compressive strength were prepared in cylindrical shape having 6-in diameter and 12-in length. 1600g cement, 3200g sand and 6400g of concrete was used for one mould. The standard ratio cement: sand: gravel was taken as 1:2:4. Six samples with different levels of Fly ash as 0%, 10%, 20%, 30%, 40% and 50% replaced by weight of cement were prepared with curing time 7, 14, 21 and 28 days.

Table 5: All samples prepared for testing tensile strength

Percentage of Fly ash used	After 7 days curing time	After 14 days curing time	After 21 days curing time	After 28 days curing time	Weight of Cement Used (g)	Weight of Fly ash Used (g)
0 %	Sample 1	Sample 7	Sample 13	Sample 19	1600	0
10 %	Sample 2	Sample 8	Sample 14	Sample 20	1440	160
20 %	Sample 3	Sample 9	Sample 15	Sample 21	1280	320
30 %	Sample 4	Sample 10	Sample 16	Sample 22	1120	480
40 %	Sample 5	Sample 11	Sample 17	Sample 23	960	640
50 %	Sample 6	Sample 12	Sample 18	Sample 24	800	800

(a)

(b)

(c)

(d)

Figure 3: Samples prepared for Compressive Strength test (a) Cured for 7 days (b) Cured for 14 days (c) Cured for 21 days (d) Cured for28 days

After completion of curing days i.e. 7, 14, 21 and 28 days then compressive strength of each sample were determined by using concrete testing machine.

Figure 4: Concrete Testing machine

3. RESULTS AND DISCUSSION

3.1 Tensile strength

Tensile strength was measured of briquettes by using cement testing machine. Results of each samples with different percentages of fly ash is described in table

Table 6: Tensile strength of briquettes

Percentage of Fly ash used	Samples cured for 7 days		Samples cured for 14 days		Samples cured for 21 days		Samples cured for 28 days	
---	Sample No.	Tensile Strength	Sample No.	Tensile Strength	Sample No.	Tensile Strength	Sample No.	Tensile Strength
0 %	1	54	7	57	13	59	19	63
10 %	2	56	8	59	14	62	20	66
20 %	3	52	9	56	15	58	21	62
30 %	4	51	10	55	16	57	22	60
40 %	5	49	11	54	17	56	23	59
50 %	6	47	12	52	18	53	24	56

Tensile strength was determined of briquettes in which cement content were replaced by fly ash with different percentage as 0%, 10%, 20%, 30%, 40% and 50% by weight of cement and cured for 7, 14, 21, and 28 days, result are presented in Figure 5. The tensile strength is found to be increasing as the curing period is increasing. curing period have significant effect on tensile strength at 28 days curing maximum strength is obtained as compared to 7 days curing for all percentages of fly ash because in the presence of water cement gain more strength. For control concrete strength were attained 54 psi while curing at 28 days 16% strength increased than 7

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days curing. Similarly, by adding 10% fly ash by weight of cement 56psi strength achieved at 7 days curing while 16.5% strength increased at curing 28 days. At 20% fly ash strength was increased 19% from curing 7 to 28 days. At 30% fly ash strength were 51 psi at curing 7 days while 18% strength was improved at 28 days by adding 40% fly ash by weight of cement. By adding 50% fly ash strength were obtained 47 psi at curing 7 days while at 28 days curing 56 psi were obtained which was 19% of 7 days curing. So, from above discussion it is concluded that tensile strength can be enhanced by increasing curing days reason is that briquettes were flooded with water 3 to 4 times a day because gravel were not used in briquettes that can be dipped under water for whole curing period which caused enhanced the strength that's why there is little increase in strength by increasing curing period. The addition of fly ash with 10% has significant effect on tensile strength for curing 7, 14, 21 and 28 days. By adding 10% of fly ash strength were 56 psi which is 3% of controlled briquettes at curing 7 days. Similarly, tensile strength increased as 3.5%, 5% and 4.7% than controlled briquettes by adding 10% fly ash and be cured for 14, 21, and 28 days respectively. The result clearly indicate that tensile strength dropped due to increasing percentages cement replacement from 20 to 50% of fly ash. The present study results indicate that the optimum percentage of fly ash to be used is 10%. All other percentages of fly ash affect adversely the tensile strength as shown in figure 5. A study also has determined tensile strength similar trend has been observed as described above [25].

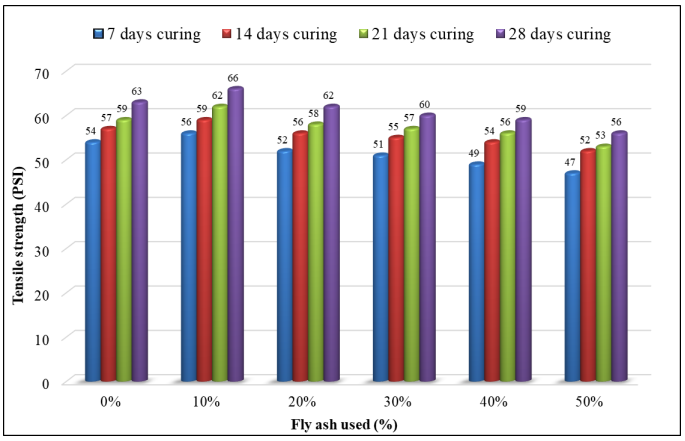

Figure 5: Tensile strength of briquettes

3.2 Compressive strength

Compressive strength of concrete was measured with help of concrete testing machine of different samples with different percentages of fly ash. Results are presented in table 7.

Table 7: Compressive strength of blocks

Percentage of Fly ash used	Samples cured for 7 days		Samples cured for 14 days		Samples cured for 21 days		Samples cured for 28 days	
---	Sample No.	Tensile Strength	Sample No.	Tensile Strength	Sample No.	Tensile Strength	Sample No.	Tensile Strength
0 %	1	624	7	780	13	936	19	1092
10 %	2	702	8	858	14	960	20	1170
20 %	3	546	9	680	15	802	21	880
30 %	4	468	10	546	16	678	22	810
40 %	5	437	11	468	17	663	23	750
50 %	6	351	12	390	18	624	24	690

Compressive strength test was performed for different samples of concrete and the results are summarized in table 7. total six samples were prepared in which cement content were replaced by fly ash with different percentage as 0%, 10%, 20%, 30%, 40% and 50% by weight of cement and cured for 7, 14, 21 and 28 days. The addition of fly ash with 10% in concrete has significant effect on the 7, 14, 21 and 28 days curing. The 7 days compressive strength of the sample that has 10% fly ash was 12% of the control concrete. While at 14 days curing was 10% of the control concrete. At 21 days curing strength was 2% and at 28 days curing was 7% of the control concrete. By adding 20% to 50% fly ash compressive strength adversely affected mean decreased by adding more than 10% of fly ash. At 20% fly ash 12.5% strength decrease than control concrete for curing 7 days while for 14 days curing strength decreases 12.5% of control cement and at 21 days curing 14% strength decreased than control cement. Similarly, trend is shown for 28 days curing where 19% strength be decreased. At 30% fly ash 25% strength was decreased for 7 days curing while for curing 14 days 30% strength be decreased. At 30% fly ash 25% strength was decreased for 7 days curing while for curing 14 days 30% strength be decreased than control concrete. For curing 21 and 28 days strength decreased 27.5 % and 25% respectively than control cement. By adding 40% fly ash by weight of cement strength decreased for 7 and 14 days curing 29% and 40% respectively than control cement. While at 21 and 28 days curing strength decreased than control concrete as 29% and 31% respectively. By adding 50% fly ash strength decreased than control concrete as 43%, 50%,33% and 36% for curing 7, 14,21 and 28 days respectively. It is concluded that the chemical composition at 10% fly ash must be investigated to address its effect on hydration process. The fly ash effect on the compressive strength is investigated by replacing the cement content by 20%, 30%, 40%, and 50% decreased the compressive strength compared to the control concrete. It is recommended to limit of replacement of fly ash to be 10% by weight of cement. the compressive strength is found to be decreased as the percentage of fly ash increasing more than 10% for the results at 7, 14, 21 and 28 days curing as well. The present study results are in agreement with the findings from previous studies which stated that pozzolanic reaction at room temperature is slow, thus a longer curing period is needed to observe its positive effects. Results also indicate that optimum percentage of fly ash to be used is 10% by weight of cement all other percentage of fly ash affect adversely the compressive strength as presented in figure 6. Another research conducted gives similar trend for compressive strength variation has been observed as presented in table 7 [25].

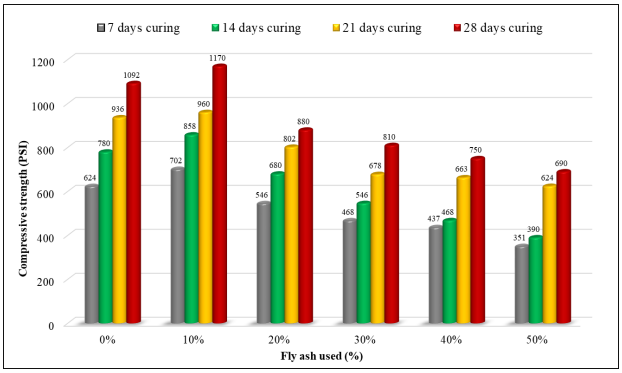

Figure 6: Compressive strength of blocks

4. CONCLUSIONS

Study conducted showed that tensile and compressive strength increases with increasing curing time. For different percentages of fly ash compressive and tensile strength trend varied. Maximum compressive strength observed for 10% of fly ash sample cured for 28 days as 1,170 psi, while minimum compressive strength was obtained for 50% fly ash sample cured for 7 days as 351 psi. Similar trend was found in case of tensile strength. Particle size of fly ash have a major role for getting maximum compressive and tensile strength after 28 days.

5. RECOMMENDATIONS

Fly ash should be taken from coal based power plant instead of furnace oil power plant because fly ash from coal based power plant has high carbon content as compared to that of furnace oil based plant, so more strength can be attained with greater carbon content. To enhance the strength properties of concrete modification in composition of fly ash is recommended. Fly ash free from impurities is to be used. Fly ash in concrete as replacement of cement can be used only for non-load bearings places, e.g. in developing landscaping, constructing jogging tracks and pavements in parks.

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