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Research Article

Effect of fly ash on Concrete resistance

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Abstract

This study investigated the effect of fly Ash in percentages (20-70%) of the weight of the cement that the resistance of compression and flow of cement mortar. The experimental work study the reference mix (without the use of additives) to be referenced and compare the results of the rest of the mixes with them. A series of cement mixtures were used in which a fixed percentage of water to cement (0.5 w / cm) and fly ash were used in different proportions and added to different grades. The compressive strength of the cement mortar was calculated at the age of (7, 28 and 56) days. The results of the tests were also checked for the mixtures using fly ash with the reference mixture. The highest compressive strength was found at 30% Fly ash and maintain the flow of the mixture by adding plasticizer up to (1.8)% of the weight of cement.

Keywords: *Cement; Fly ash; compressive strength*

Introduction

Fly ash is a byproduct of thermal and other power plants, with millions of tons annually and just 10-15% is used . The rest is dumped into waste, which leads to the increasing need for large areas of land to land these wastes by increasing their production and production, User. Yazici confirmed that the production of fly ash in Turkey annually is more than 18 million tons, which is more than the rest of the industrial waste in the country. Ahmaruzzaman reported that the current annual global production of fly ash is estimated at about 600 million tons with the accumulation of about 500 million tons of 75-80% of total ash produced. In America between 1985 and 1995, the American Coal Ash Association reported that the amount of fly ash was estimated at 11.3 million tons per year.

Fly ash is defined as a fine powder of spherical glass particles with Pozzolanic properties, consisting mainly of SiO2 and Al2O3.

Fox found that the basic components of fly ash are SiO2 + Al2O3 + CaO. According to ASTM C 618, there are two types of fly ash, Class C fly ash and Class F, class C, based on the ratio of CaO .C Fly ash containing CO is higher than 20% and has characteristics In addition to its characteristics, namely, that with the presence of water it solidifies and increases its resistance over time. Fly ash contains less than 7% CaO and has only Bozolean properties, meaning that it needs to mix with the cement with water so that the silica reacted with the calcium hydroxide produced by the cement lining to obtain the cement properties.

Hawi studied the properties (precipitation, compression, tensile strength, absorption, and density) of different concrete mixtures. Class F fly ash was used as a partial substitute for sand with 15%, 30% and 45% weight substitution ratios, To determine the effect of this replacement on the properties mentioned in ages 7, 14, 28 and 90 days. The results showed a significant positive effect on increasing the compressive strength of the concrete by increasing the sand replacement rate with fly ash and increasing the age of the concrete to reach 48% higher than the compressive strength of the reference mix at 90 days.

The researcher (Rebeiz) studied the possibility of using fly ash as a partial alternative to sand in polymer concrete, It was found that replacing 15% of the weight of sand with fly ash increases the compressive strength of the produced concrete by 30%. Saifali and his group assessed the cost and durability of concrete by replacing part of the cement with fly ash and the results showed that fly ash could be used effectively without causing high costs.

Experiments were conducted by researchers (Kumar and his group) to investigate the geometric properties of concrete to build a solid pavement. The results showed that the use of a mixture of 30% of fly ash and 70% of cement has superior performance. In addition, the use of fly ash reduces the cost of building materials. Figure (1-2) shows compression resistance compared to fly ash ratios.

Researchers (Jayawardane and his group) studied the physical and chemical properties of fly ash that

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used by Tokyo Company in manufacturing Portland Pozzolani Cement, It was found that the cement reduces the emission of carbon dioxide and improve the compression resistance, operability and durability and will be effective in building green buildings.

Classification of Fly Ash

Fox found that the basic components of fly ash are SiO2 + Al2O3 + CaO. According to ASTM C 618, there are two types of fly ash, Class C fly ash and Class F, class C, based on the ratio of CaO .C Fly ash containing CO is higher than 20% and has cement propertiesIn addition to its characteristics Pozzolan ,namely that with the presence of water it solidifies and increases its resistance over time. **F**ly ash class F contains less than 7% CaO and has only Pozzolan properties , wich it need s to mix with cement and water so that the silica in it reacted with the calcium hydroxide produced by the cement hydrate to obtain the cement properties.

Physical Properties of fly ash

Feng and Clark refer to countries that have specific specifications for the use of fly ash in concrete. In the United States, ASTM C 618 is the standard and common standard for fly ash in concrete. Table (1-1) Night Physical and Chemical Properties of Fly Ash by Specification.

Table 1.1 Physical and chemical properties of fly ash

Chemical Requirements	Class F	Class C
$Si0_2+Al_20_3+Fe_20_3$, min. %	70.0	50.0
$S0_3$, max. %	5.0	5.0
Moisture content, max. %	3.0	3.0
Loss of ignition (L.O.I.), max %	6.0	6.0
Available alkalis, as Na_20, max %	1.5	1.5
Physical Requirements	Class F	Class C
Fineness, Amount retained when wet-sieved on 45 µm (No. 325) sieve, max. %	34.0	34.0
Strength Activity Index		
with Portland cement, 7 days, min.% of control	75.0	75.0
with Portland cement, 28 days, min.% of control	75.0	75.0
Water requirements, max.% of control	105	105
Soundness; autoclave expansion or contraction, max. %	0.8	0.8

Mechanism of Fly Ash Type F

The fly ash is in the form of soft metallic granules rich in silica, alumina and calcium hardened in the form of very fine glass balls that do not have cement properties but in the presence of water reacts with calcium hydroxide at normal temperature to give compounds that possess cement properties. In the cement rehydration process, calcium hydroxide is formed by 20% of the weight of the cement, which does not gain concrete resistance, When fly ash is added, it reacts with calcium hydroxide to form a cemented compound (hydrated calcium silicate).

Portland Cement (PC) + Water (H_2O) = Calcium Silicate Hydrate (durable binder) + Hydrated lime (CaOH) (Non durable).

Hydrated lime + Fly ash +Water = Calcium Silicate Hydrate.

Through the equations above we find that fly ash reacts with lime to give the same cement compound resulting from the process of cement hydration.

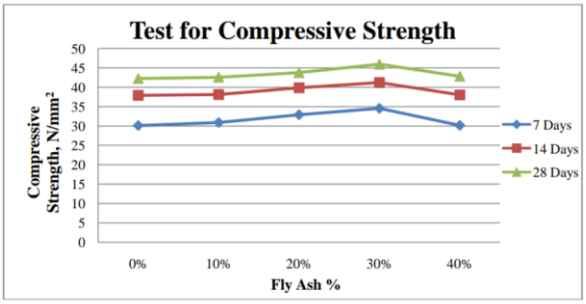

Figure 2.1 Effect of Fuel Ash Ratio on Concrete Compression Resistance

Papadakis found that when different percentages (10-30%) of low-calcium fly ash were used as an alternative to Portland cement in cement mortar, the compressive strength decreased initially, but with age the difference in Resistance with reference mixture begins to fade. Resistance of mixtures (10% and 20% of fly ash) and (30% of fly ash) is higher than that of the reference mixture at the age of six months and one year respectively as shown in Figure (2-2).

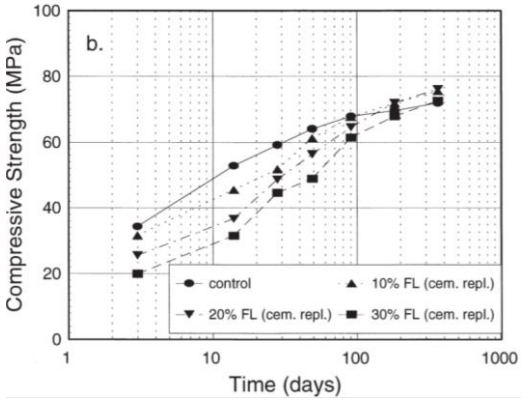

Figure 2.2 Effect of substituting different weight ratios of fly ash on cement resistance on cement mortar compression

The researcher (Hung) studied the properties of concrete mixtures without containers or high volatile ash content (50-80% as a replacement of the weight of cement). The researcher showed that the compressive resistance of 40-60 N / mm2 at the age of 28 days can

be obtained for these mixtures with high fly ash content. He pointed out that the contribution of fly ash is the result of the pozzolan reaction between its silica and alumina content and the hydroxide calcium hydroxide (C3S, C2S) in Portland cement to form calcium silicate and hydrated calcium aluminate. In addition to this chemical effect, fly ash has a physiological effect on resistance by intensifying the microscopic structure of the hardened cement paste due to its high smoothness.

Experimental work

Materials used in research

1-Cement

The normal Portland cement produced by the Kufa Cement Factory, which conforms to the Iraqi Standard No. (5) for the year 1984, was used. The tables (1-3),(2-3) are shown The chemical composition and some physical properties .

Table 3.1 Chemical composition of cement

Oxide	Content	
CaO	62.21	....
SiO_2	20.18	....
Al_2O_3	5.00	....
Fe_2O_3	3.60	....
MgO	2.31	<5.00
SO_3	1.44	<2.80
L.O.I.	3.29	<4.00
Insoluble Residue	1.11	<1.5
Lime Saturation Factor, L.S.F.	0.94	0.66-1.02
(Bogue's equation) main vehicles		
C_3S	57.04	....
C_2S	14.83	....
C_3A	8.60	....
C_4AF	10.95	....

Table 3.2 Physical Properties of Cement

Physical properties	Laboratory results	Standard limit of Iraq1984/5 [14]
Specific surface area (Blaine Method),m^2/kg	283	230≥
Setting time (Vicat Apparatus Initial setting,hr:min Final setting,hr:min	1:50 3:30	00:45≥ ≤10:00
Compressive strength,MPa 3 days 7 days	21.60 31.40	15.00≥ 23.00≥
Soundness (Autoclave Method)	0.15	≤0.8

2- Sand

Sand was used from Al-Akhdar area according to the Iraqi standard No. 45 for the year 1984 within the second gradient area, the specific weight (2.647) and the smoothness coefficient (2.77) and the sulfate ratio (0.34).

Table 3.3 Sieve analysis of fine aggregates used

Requirements of gradient area no.(2) according to Iraqi standard (45)	Combined percentage of passing times	Consolidated percentage of residual material	Sive size (mm)
100	100	0	9.5
100-90	100	0	4.75
-75 100	88	12	2.36
90 -55	65	35	1.18
-35 59	51	49	0.60
30 -8	18	82	0.30
10-0	1	99	0.15

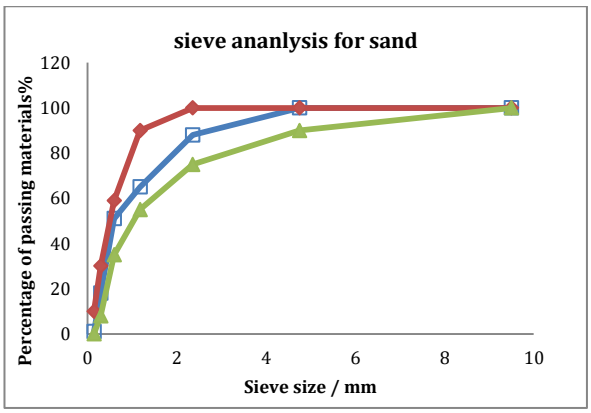

Figure 3.1 Sand sieve analysis

3. Water mixture and treatment

Drinking water (liquefied water) was used in mixing and treating all forms. Fly Ash. The fly ash of Turkish origin F is classified and classified according to ASTM .

Table 3.4 Chemical Analysis and Physical Properties of Fly Ash Class F Used

Specification limits ASTM C618	Oxide content%	Oxides
-----	50.6	SiO_2
-----	9.7	Fe_2O_3
-----	21.9	Al_2O_3
≤70 %	82.2	$SiO_2 + Fe_2O_3 + Al_2O_3$
-----	6.2	CaO
≥ 5 %	4.76	MgO
≥ 5 %	1.4	SO_3
	2.47	K_2O
≥ 1.5 %	0.53	Na_2O
≥ 6 % Loss on Ignition	2.44	LOI
Physical properties		
	2.0	(Specific gravity)
	3226	Smoothness (blain) cm2 / g

Table 3.5 Mixing Rates

Flow **%**	Water / cement ration (w / cm)	Plasticizer (gm)	fly ash (gm)	Fly ash added to the weight of cement materials**%**	Sand (gm)	Cement (gm)	No. Cement mixture
68.7	0.5	**-**	**-**	-	**1375**	**500**	1 (Reference)
69	0.5	0.5	**100**	**20**	**1375**	**400**	**2**
70	0.5	0.8	**150**	**30**	**1375**	**350**	**3**
70	0.5	1.0	**200**	**40**	**1375**	**300**	**4**
70	0.5	1.2	250	50	1375	250	5
71	0.5	1.5	300	60	1375	200	6
72	0.5	1.8	350	70	1375	150	7

Mixtures used

Reference mixture of cement content: sand of 2.75: 1 with water / cement ratio of 0.5(Six mixtures of cement mortar above were prepared with replacement (20, 30, 40, 50, 60, 70)% of the weight of the cement above with change of plasticizer to obtain a steady flow, as shown in Table (3-5)

Mixing method

The cement mortar was mixed according to ASTMC305-99 as follows:

- Weight of cement, sand and fly ash using a delicate balance and mixing manually.

- Half the amount of water is placed inside the mixer and as shown in the table above.

- Put the mixing materials manually inside the mixer and start the mixing process at a slow speed for one minute.

- Add the plasticizer mixed with the remaining water to the mixture.

- Mix the mixture at medium speed for two minutes.

Casting method

According to the American standard ASTMC109 / 109M cubic iron molds with a side length (50) mm were used to prepare nine models for each mixture to measure the compressive strength and age (56,28,7) days.

Pour the models with two layers and stacked each layer using a wooden stacking stick at a rate of 16 strokes per layer to get rid of air spaces inside the concrete well and after leveling the face of the molds covered with nylon for 24 hours to prevent evaporation of water from them.

Processing and ripening

The molds were removed after 24 hours of casting and the samples were then placed in special ripening basins filled with water at laboratory temperature until the time of examination, Fig. 3-2.

Laboratory tests

Operability was checked using a flow test apparatus according to ASTMC1437-07.

1- Flow checking

This test was carried out using the American Standard (ASTMC1437-07) where the mortar was placed in the mold in the form of two layers, each layer 25 mm compacted using an iron stick of 20 strokes and then equal the surface and lift the mold by lifting the plate on the model and lowering it 25 Once in 15 seconds the flow rate of the model is measured as in the following equation:

Cement mortar flow = (B-A) / B × 100%
A: flow rate of the model, mm.
B: the inner diameter of the base of the mold, mm.

2- Compressive resistance check

Compressive strength of cubes (50 * 50) mm as shown in Fig. (3-3a, b, c) was measured by compressive testing device (2000) kN at a speed of (1 kN / s) according to ASTMC109 / C109M-05 7, 28, 56 days Resistance was extracted according to the following equation:

Compressive strength = P/A

Where :

P = load failure (N), A = load-prone area (mm 2)
Note: The average was taken for three models for each age.


Results and discussion

Effect of substitution of fuel ash on operability

Table (4-1) shows the effect of substituting fuel ash on the operability of cement mixtures, where different percentages of plasticizer were used to maintain the flow of cement mortar by 70% where the flow rate of the reference mix was 68.7 and the flow rate increases with increasing the proportion of fuel ash. To keep the mixture flowing 70%, plasticizer was used by up to 1.8 to reduce the mixing water needed to produce a cement mortar of a certain strength and maintain operability. It is noticed from this table that the effect of replacing the fuel ash on the flow of cement mortar is small, as it works in two directions, the first is that its spherical granules work to increase the operability and the second high surface area relative to the surface area of the cement granules, which leads to reduced operability.

Table 4.1 Effect of substitution of fuel ash on operability

Flow %	Plasticizer %	Water / Cement material	Sand (gm)	Cement (gm)	Replacement of fuel ash %	No. Cement mixture
68.7	-	0.5	1375	500	-	1
69	0.5	0.5	1375	400	20	2
70	0.8	0.5	1375	350	30	3
70	1	0.5	1375	300	40	4
70	1.2	0.5	1375	250	50	5
71	1.5	0.5	1375	200	60	6
72	1.8	0.5	1375	150	70	7

Effect of age on the compressive strength of cement mortar

Figure (4-1) and Table (4-2) show the effect of the change in compressive strength by age and the percentage of cement substitutions with fly ash of the reference mix by 20%, 30%, 40%, 50%, 60% and 70%. It is noted that the increase in the compression resistance with age and the increase in the percentage of replacement of cement with fly ash to reach 30% the highest increase in the compression resistance for all ages and resistance less than replacement with more than 30% of the proportion of cement.

Table 4.2 Effect of Age on Compression Resistance of Cement Mortar

56 day	28 day	7 days	Ratios %	Mix number
13.5	12.6	9	0%	1
13.5	11.3	7.2	20%	2
13	11	6.3	30%	3
12	9.8	5.8	40%	4
11.5	8.9	5	50%	5
10.8	7.6	4	60%	6
9.3	6	3.7	70%	7

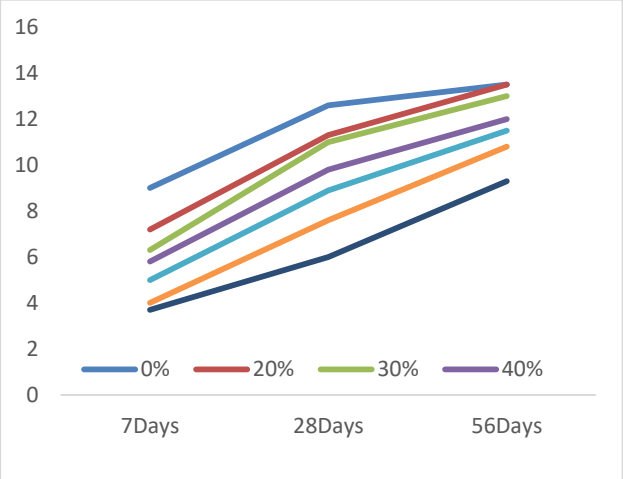

Figure 4.1 Effect of age on compressive strength of cement mortar

Conclusions

This chapter shows the conclusions reached from the laboratory work of this project , as follows:

1-the effect of substituting fuel ash on the flow of cement morter is low .

2-replacement of fuel ash by (20-70)% of the weight of the cement of the cement lead to decrease resistance at early age, but the proportion of this decline is less in advanced ages.

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