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The Effect of Height Replacement Fly Ash on Properties of Mortar

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ABSTRACT

All the time there are lot of tons of cement compositions, including normal Portland cement, are produced around of the world, causing the pollution of atmosphere by greenhouse gas CO_2. For this reason, researchers work to make production more eco-friendly, a laboratory study was aimed to use and evaluate the properties of the mortar mixture made with high dosages of fly ash as a replacement material with cement to reduce the side effect of cement. Cement was used as main binding material for mortar mixture, and fly ash was used as a replacement material at different ratios. Properties of mortars, including density, compressive and flexural strength were evaluated. Cement was replaced with fly ash, replacement dosages on mass basis were 0%, 10%, 20%, 30%, 40%, 50% and 60%. Initially, flexural strength and compressive strength measured at twenty-eight days, and sixty days. The results showed compressive and flexural strengths of mortar were improved with the replacement of fly ash. Fly ash increases at replacement level, 10%, 20%, and 30%, the compressive strength of mortar was increased by 57%, 17% and 6% respectively compared with zero fly ash at 28 days. While at 60days were 25%, 9%, and 13% of replacement level, 10%, 20%, and 30% respectively. At the same time, high percentage fly ash replacement lower strength than normal mortar However, the results shown the mortar with 10% fly ash dosage is the best content for maximum strength.

1. INTRODUCTION

The cement industry across the globe is one of the major polluters by emitting greenhouse gases. As a matter of fact, it generates over a ton of carbon dioxide, and about 2 tons of materials, including fuel and other raw materials, consumed in producing per ton of Portland cement [1-5]. As its use in the construction industry exponentially expands, the production of Portland cement has significantly increased, which elevated CO_2 emission levels [6-9]. Many processes in the cement industry, such as raw material handling, limestone crushing, kiln processing, clinker production and storage, finished cement grinding, and power utilities, produce dust. The thick layer of dust that accumulates on parked cars and highways regularly causes misunderstanding and public uproar among the local population [10]. As a mitigation measure, it has been proposed to use the waste materials in construction as an alternative binder to Portland cement. This type of concrete is made from waste materials including fly ash, silica, and slag cement, allowing it to protect the environment. To preserve the environment for future generations, it is generally crucial to encourage the construction industry to use high-quality concrete that uses less cement, incorporates industrial waste as an additional cementitious material, or uses contemporary cement-free alternatives like geopolymer concrete [10].

According to "ASTM C125", Pozzolan can be define as a "siliceous" or "siliceous and aluminous" ingredient. At the same time, it has little or no cementitious properties. Pozzolan materials will react chemically with calcium hydroxide ($Ca(OH)_2$) at room temperature in the presence of moisture to generate compounds with cementitious qualities. Fly ash, made workability better and as well improve the strength properties therefore, considered to be an effective cementitious component of concrete [11]. At the same time fly ash used in normal and high strength concrete as replacement material with cement. The goal of using fly ash in concrete have high strength are firstly to obtain better durability properties and to reduce heat generation [12]. One of the properties of fly ash is high fineness, this feature will reduce the porosity of concrete and also increase compressive strength of concrete [13].

From thermal power plants, fly ash is produced and formed during the burning of coal, therefor, its cause atmosphere pollution [14]. Fly ash is one type of the mineral additive. In almost all countries of the world, fly ash is used as pozzolanic material with cement [15, 16]. Amorphous silica is the main component of fly ash. In hydrated cement, there are ability to amorphous silica to reacts with $Ca(OH)_2$ which results from react cement with water. That chemical reaction leads to formation of calcium hydrated silicates (gel) and increase the strength of the samples. Beside to different types of concrete, mortar as well has its meant uses in construction field. from long times mortar has been used as a means of adhering concrete blocks or bricks to one another. Moreover, cement mortar used in many different types of constructions such as quick repairs and plastering. There are types of concretes such as foamed concrete, ferrocement, and, shotcrete which have no coarse aggregate in their production and properties, like these materials mainly depend on mortar. Generally, mortar is defined as a mixture of water, cement, and fine aggregate without used coarse aggregate. Although, there are many advantages that can obtain from utilizing fly ash in concrete as well as mortar, however, researches which studied fly ash mortars limited. There are many studies available on the effect of fly ash on concrete properties, but on the other hand, there are no similar studies of the effect of fly ash on mortars. the present work was formulated, to promote the confident use of fly ash in mortar and so increase fly ash usage in mortar [17].

Bendapudi and Saha [18] found there was an improvement in the durability when using fly ash as replacement material with cement, in addition to environment benefits. Cement is considered a relatively expensive material. Therefore, using fly ash led to reducing consumption cement thus cost of construction will be reduced.

Zabihi-Samani et al. [19] conducted a study using cement as the primary material and fly ash as a partial replacement at dosage levels of 0%, 5%, 10%, and 15%. The water-to-binder ratio (w/c) was set at 0.3, 0.4, and 0.5. The objective of their research was to determine the optimal amount of fly ash for producing high-performance concrete.

According to Bahri et al. [20], incorporating 20% landfilled fly ash into mortar resulted in a 12% increase in compressive strength compared to the control mortar. The porosity of mortar significantly influences its compressive strength. When 20% landfilled fly ash was used, the porosity was reduced more effectively than in the control mortar.

In the present study, fly ash was used as a replacement for cement, the primary ingredient, in mortar production. It was added at various replacement levels (ranging from 0% to 60%) to evaluate its effects on the density and strength of the mixtures.

2. EXPERIMENTAL WORK

Through the substitution of fly ash for cement, we made experimental study to evaluate the density, the compressive and tensile strengths of mortars. In this work, fly ash had been used at various percentage levels to investigate the effects of different fly ash dosages on these properties of mortar at various ages of curing.

2.1 Materials

2.1.1 Cement

Portland Cement Standard TASLUJA-BAZIAN which was made in Iraq had been used in our work. Tables 1 and 2 are the two represented the chemical and physical analysis results respectively. According to analysis results in below tables cement conformed to the "Iraqi specification (I.Q.S).

Table 1. Chemical composition and principal compounds of cement

Chemical Composition	Percentage By Weight	Limit of Iraqi Specification I.Q.S No. 5/1984
CaO	61.19	-
SiO_2	21.44	-
Al_2O_3	4.51	-
Fe_2O_3	3.68	-
MgO	2.31	5.0 (max)
SO_3	2.7	2.8 (max)
L.O.I.	2.39	4.0 (max)
I.R.	1.18	1.5 (max)
L.S.F.	0.87	(0.66-1.02)%
C_3S	42.83	-
C_2S	29.4	-
C_3A	5.73	-
C_4AF	11.19	-

Table 2. Physical properties of cement

Physical Properties	Test Result	Limit of I.Q.S 5:1984
Using the "Blaine air permeability" equipment, fineness (m^2/kg)	405	> 230
Soundness with the autoclave technique	Not available	< 0.8 %
Setting time using "Vicat's instrument"		
Initial (minute)	135	> 45 min
Final (hour)	3.25	< 10 hr
Compressive strength for cube (70.7 mm) at		
Three days [MPa]	24.4	>15
Seven days [MPa]	32.3	> 23

2.1.2 Fine aggregate

Natural sand from the Al-Suduor region was imported to Iraq. The findings of the sieve analysis that meet the requirements of the Iraqi Specification (I.Q.S No.45, 1984) are displayed in Table 3.

2.1.3 Water

Water shall be clean and free from organic materials.

2.1.4 Fly ash

In this study class F fly ash was used as a replacement from cement. The extremely fine ash that is created when forced airflow is used to burn powder coal and is frequently expelled with the flue gases. This type of fly ash by product of DCP Company. The fly ash's chemical characteristics were displayed in Table 4 according to ASTM C 618 [21] as outlined in.

Table 3. Fine aggregate grading for this work's use

Sieve Size	Passing %	Iraqi Specification I.Q.S No. 45/1984 for ZONE (2)
9.5	100	100
4.75	91.5	90-100
2.36	80.2	75-100
1.18	60.8	55-90
0.6	38.4	35-59
0.3	22.63	8-30
0.15	1.2	0-10

Table 4. Chemical composition and physical properties for fly ash

Chemical Composition(%)	Fly Ash
SiO_2	33.52
Al_2O_3	17.35
CaO	29.11
Fe_2O_3	5.14
SO_3	2.38
MgO	4.56
Na_2O	0.68
K_2O	0.97
Loss on ignition	0.67
Physical Properties	
Density(g/cm^3)	2.37
Retain on sieve 45μ	12

2.2 Mix proportions

2.2.1 Method for mixture preparation and testing

This study's primary goal was to determine how diverse and high dosages of fly ash, partially substituted with cement, affected the qualities of mortar. We used seven types of substitution of cement by fly ash. Their replacements were 0%, 10%, 20%, 30%, 40%, 50% and 60%. Fresh mortar specimens were cured in the water until test day. The mix design showed in the following (Table 5). In mixing dry materials, namely, fine aggregate, cement and fly ash, were mixed for 1 min. Water was added to the dry materials, and they were mixed for approximately 5 min until a homogeneous mix was obtained. The curing method in the present study is sealed curing of the specimen in water at 28 and 60 days in lab temperature and humidity 50±10%.

Table 5. Mixes as that used in experimental work

Mixed Designation	Cement (g)	Sand (g)	Fly ash (g)	Water (g)
F0	450	1350	0	225
F1	405	1350	45	225
F2	360	1350	90	225
F3	315	1350	135	225
F4	270	1350	180	225
F5	225	1350	225	225
F6	180	1350	270	225

Dry density made according to ASTM C642 [22]. Average of four prismatic specimens have been used, they have dimension (160*40*40mm). After opening from the molds, the specimens were weighed and recorded. The tests for compressive and flexural strength were conducted in accordance with the procedures described in ASTM C349 [23]. Initially, flexural strength and compressive strength were measured at 28 days and 60 days. Flexural test made on three prism specimens, and then compressive strength test was carried out on six broken specimens obtained from the flexural strength test. The compressive strength was carried out using a U-test testing machine with a capacity of 250 kN in compression.

3. RESULTS AND DISCUSSION

From Figure 1 the density of the hardened mortar at 28 days, in both cases (wet and dry) was observed to decrease with an increase in the replacement level for fly ash. But when compared 0% fly ash mortar with 10%, 20% and 30% fly ash mortar we found density of 0% fly ash lower than them that means the density of mortar is enhanced with 10% replacement of fly ash. While other dosages of replacement 50% and 60% found the density was lower than 0% fly ash. That means the amount of water, which absorbed in samples little, maybe because, pores in bodies increased when the amount of fly ash were increased due to consume all the amount of $CA(OH)_2$ while not all amount of fly ash consumed that mean same of fly ash worked as filler material like fine aggregate led to weakness in microstructure of mortar. At the same time there was an increase in density in wet case when compared with a dry density.

Compressive strength results of mixtures produced were represented in Figure 2. Closer observation of Figure 2 showed that the compressive strength of all mixtures increased as with the curing time from 28 days to 60 days, due to continuous hydration reaction. Curing mortar's main purpose is to maintain the mortar's moisture content while it develops strength until the hydration process reduces the amount of water in the pores. Fly ash increases at replacement level, 10%, 20%, and 30%, the compressive strength of mortar was increased by 57%, 17% and 6% compared with zero fly ash at 28 days, while at 60 days were 25%, 9%, and 13% of replacement level, 10%, 20%, and 30% respectively. The increase in compressive strength after twenty-eight days can be explained to the chemical reaction between calcium hydroxide and fly ash. The vitreous coating on the surface of the pozzolanic material particles is dissolved by the ions of Na+ and K+, Al- and Si-, which starts the process. On the surface of the fly ash particles, silica and alumina ions combine with calcium ions in liquid phases to generate hydrates, just like in the pore solution [24-26]. All these reactions lead to forming gel like to that born from react hydrated cement.

Figure 2 also showed that replacement of cement by fly ash with 10% dosage caused a remarkable increase in compressive strengths at all curing times. A closer look at Figure 2 representing compressive strength showed that the strength rate development for mixture was higher before 28 days, however, lower after 28 days. Fly ash replacement with cement resulted with higher early age reaction that mean the rate of reaction was faster with fly ash when compared with mortar contain only cement. At the same time, the strength rate development for mixture was higher with low amount replacement of fly ash until 40%. While mixtures with 50% and 60% replacement give strength lower than the strength of cement mortar. We can explain that, when used big contain from fly ash as a replacement material with cement the amount of $Ca(OH)_2$ (resulted from hydration reaction) are consumed before all the amount of fly ash finish that made fly ash work as a filler material. The substitution of fly ash in mortar resulted in a decrease in the pozzolanic reaction. The incomplete pozzolanic reaction is the cause of this. Higher fly ash volumes result in extra SiO_2, which prevents $Ca(OH)_2$

from melting entirely, preventing the mortar process from finishing its reaction [20].

Flexural strength results of all mixtures were presented in Figure 3. It has been observed from Figure 3 that flexural strength of all mixtures increased as curing time prolonged due to ongoing hydration react. It was also seen that replacement of fly ash with cement result with a remarkable increase in flexural strength at all curing ages. At 28 days of curing, the flexural tensile strength was decreased with increasing fly ash mortar replacement compared to corresponding cement mortar. After sixty days, best tensile strength results about 3MPa were obtained at 30% fly ash mortar. Also, we observed, that replacing of fly ash at 30%, 40% dosages give higher tensile strength of 80% and 81% respectively than reference.

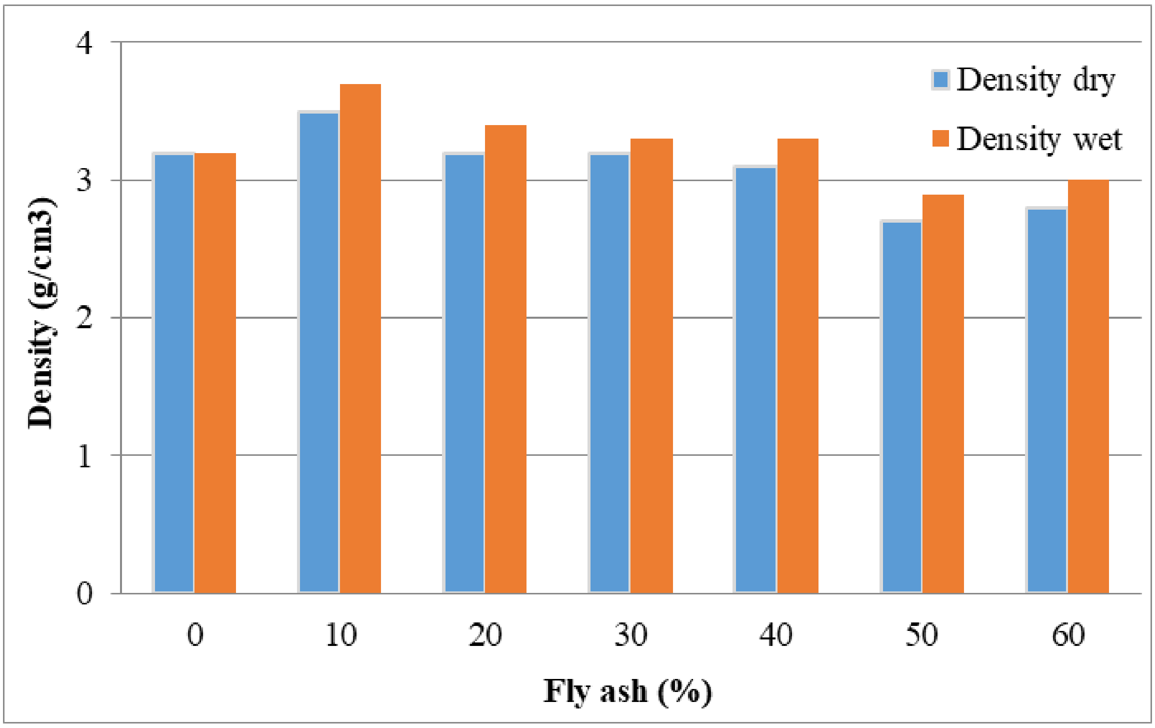

Figure 1. Density of mixtures

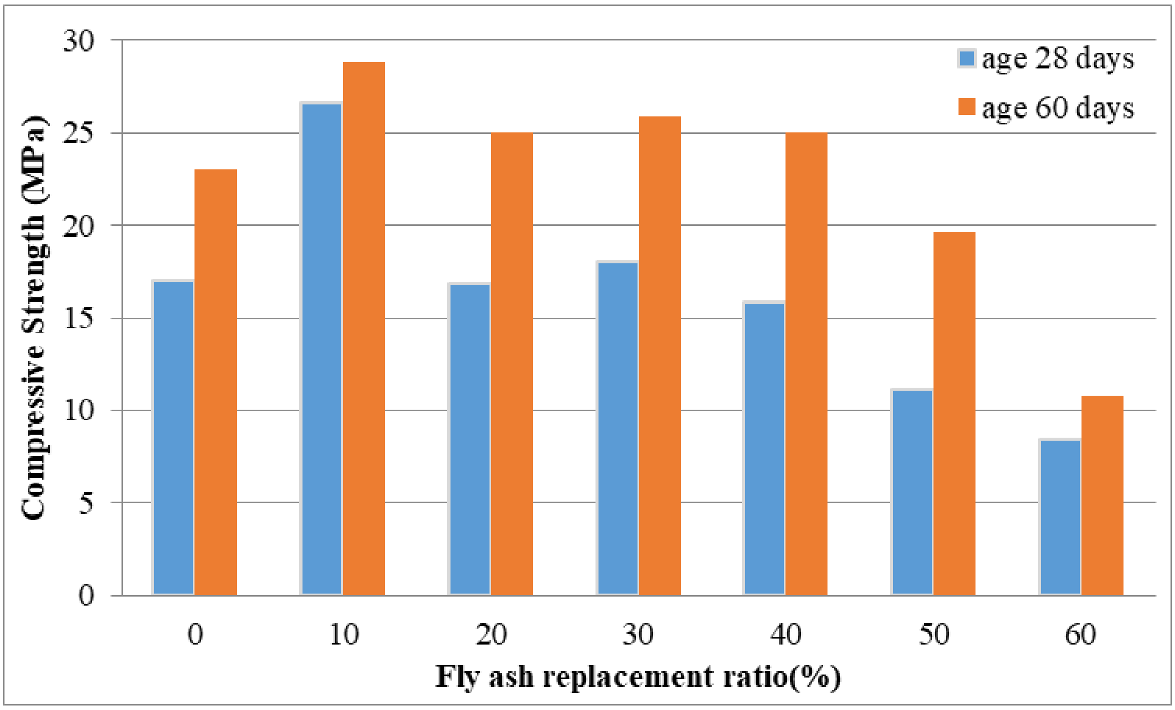

Figure 2. Compressive strength for mixtures

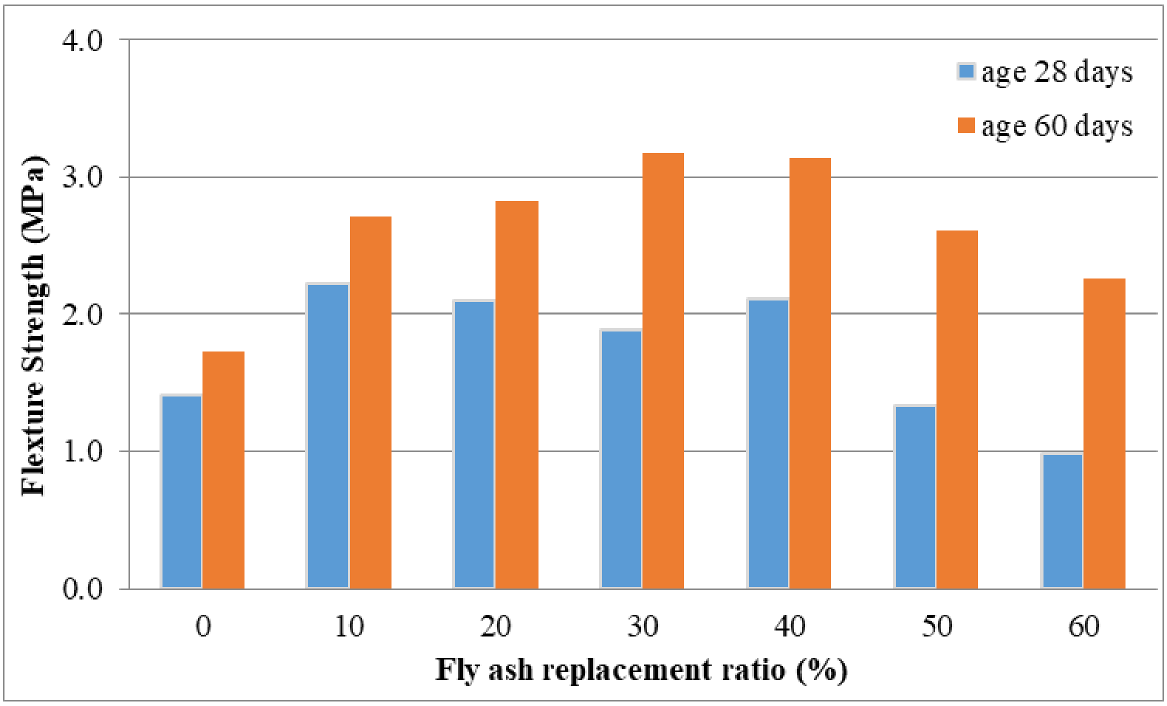

Figure 3. Tensile strength for mixtures

4. CONCLUSION

An investigation has been made of the effects of fly ash as a replacement material at different ratios with cement. Properties of mortars, including density, compressive and flexural strength, were studied. Cement was replaced by fly ash, replacement dosages were 0%, 10%, 20%, 30%, 40%, 50% and 60%. Some concluding observations from the study are given below.

•The use of fly ash reduces cement consumption and thus will have a positive impact on the environment in terms of reducing gas emissions as well as the use of industrial waste.

•Flexural strength and compressive strength measured at 60 days are higher than strength in 28 days because the curing of mortars affects the strength of the mortar.

•Flexural strength and compressive strength were measured at 28 days and 60 days. The results demonstrated that adding fly ash to the mortar improved its compressive and flexural strengths.

•When fly ash was added at replacement level (10%,20%, and 30%) the mortar's compressive strength improved by 57%, 17%, and 6% at 28 days when there was no fly ash added due to enhancement the density of mortar.

•Compressive strength at 60 days were 25%, 9%, and 13% of replacement level, 10%, 20%, and 30% respectively.

•We recommend for future research, investigating the long-term durability like wetting-drying, dry shrinkage, abrasion resistance and heigh temperature resistance.

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