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Effect of Fly ash as a Partial Replacement of Cement on the Compressive Strength of Cement Mortar Using North Sinai Martials

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ABSTRACT:
Mortar is widely used in the construction industry for different purposes. Its compressive strength is the key parameter which is brought under attention. Compressive strength of mortars be contingent upon many influencesfor instance water-cement ratio, fine aggregates size, and different curing conditions. This experimental study was undertaken to investigate the effect of north Sinai sand and fly ash (FA) on compressive strength of mortars under different curing regimes using FA as a partial replacement of cement. A total of 36 cubes of standard size of 7 x 7 x 7 cm were casted in laboratory, out of which 36 cubes each were prepared with 0%, 10%, 20% and 30% FA replacement for cement. Cubes were cured for 3, 7 and 28 days, we observed that the maximum compressive strength was achieved by sample with 10% FA, although 20% FA samples achieved higher compressive strength than the control sample with 0% FA. Also, an additional replacement beyond this value causes reduction in strength.
KEYWORDS*: Portlandcement, flyash, compressive strength.*

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I. INTRODUCTION

In spite of the fact that the Sinai Peninsula is rich in minerals and has a considerable sand deposit[1],there is very little data available about employing it as a cement raw material.

For this reason, our research was applied using North Sinai materials in to take advantages in various projects and infrastructure. The cement industry has begun to expand in recent years and with this expansion and the presence of a large reserve of sand, the research aims to make use of cement and sand in making mixtures and using cement additives to reduce the harmful environmental impact. The production of cement rises the carbon dioxide (CO2) gas emissions represent harmful element for environmental [2, 3]. A dependable cement alternative that reduces the negative environmental effect of cement manufacture. Because of increased urbanization, the creation of different waste materials has expanded[4]. Although with slightly reduced early age performance in comparison to the reference mixture, partial substitution of Portland cement by solid by-products such as pozzolans or supplementary cementitious materials (SCMs) has reasonable importance for structural concrete mixture design and practical application in construction[5]. Pozzolans have been used as a binder in Roman concrete since antiquitywhen they were mixed with slaked lime[6]. FA is a waste product that can cause disposal issues as well as environmental damage due to its ability to pollute air and water on a wide scale [7]. FA is also considered as an environmentally safe substance because its use contributes to the reduction of the cement industry's carbon footprint. [8]. Moreover, based on global coal consumption for electricity generation about 1 Gt/y of fly ashes are generatedwhich the third estimation is used in cement and concrete applications [9-11].Because they do not fulfil the standards for usage in cement or concrete, a portion of these fly ashes are nevertheless landfilled[12-14]. Incorporating this industrial waste as one of the ingredients in product development would help to create a cleaner environment [15]through reducing the amount of fly ash trash disposed of and the amount of cement used in concrete manufacturing. So far, by using FA as a partial cement substitute has resulted in concrete with good mechanical and durability properties[16, 17]. Likewise, the use of

fly ash is limited to up to 20% due to the variety in fly ash properties that are governed by its source and operation at power plants[18]. FA use as a cement replacement material affected concrete workability, compressive strength, and flexural strength [19]. Furthermore,the use of fly ash from 10% to 30% by volume of cement, claimed that the use of fly ash has a negative impact on concrete's compressive strength[20]. Moreover, the use of fly ash in a percentage up to 20% results in increase in tensile strength and density[21]. On the other hand, the evidences of [22-24] illustrated that the using 0%-20% fly ash with increment of 5%which investigatedin 7 and 28-day cured samples showed improvement in terms of strength and durability.

II. MATERIALS AND METHODS

In order to investigate the effect of fly ash as a partial replacement with cement at different percentages 10%, 20% and 30%, the details of material selection, casting of specimens, instrumentation and testing are given below.

2.1 Materials

The cement used was CEM I N52.5 ordinary Portland cement from the Sinai cement factory. The properties of cement were investigated, the specific gravity of cement was 3.14, while the initial and final setting time were 45 and 355minutes respectively thus the chemical and physical properties classify Egyptian Standard Specification. (E.S.S. 4658-1/ 2015) [25].The materials samples were shoed in figure (1)The physical properties and Chemical Specifications of cement are given in table 1 and table 2.

Table (1) physical properties of north Sinai cement

Properties	Cement
Specific gravity	3.14
Water absorption	0.5%
Finesse modulus	2.75

Table (2) : Chemical Specifications of Used Materials

Sample	Si O2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	LOI
Fly ash	53.39	16.07	13.05	6.3	5.48	1.06	1.59	1.71	1.15
Cement	21.64	6.47	1.92	60.53	1.07	2.64	0.13	0.68	1.65

The fine aggregate utilized in the experiment was natural siliceous clean and almost impurity-free sand. It was obtained from El-Arish City in Egypt's North Sinai. It has a maximum nominal size of 0.6 mm, which makes it suitable for casting. Physical properties of the used sand are given in Table (3) and its grading is shown in Table (4) and Fig (2). Sand was sieved over sieve of size 0.6 mm to discard any impurities. Its characteristics satisfy the Egyptian Code (E.S.S 1109/2015)[26]. The drinkable water was used to produce the mortars without band with FA in our study.The percentage of FA which was used as a partial replacement of the cement is 10%, 20% and 30%. In addition, a normal mortar without FA was also casted and tested for comparison of the results as control mix. Thus, in total 9 batches of the specimens were casted and tested during this study.Throughout the study mortar ratio of 1: 3 (Cement: Sand) was considered with fixed water cement ratio of 0.5.

(a) (b) (c)

Figure (1). The materials samples (a) North Sinai sand sample, (b) North Sinai cement sample (c) fly ash sample

Table (3) physical properties of sand

Properties	Cement
Specific gravity	2.5
Initial Setting Time	55 minute
Final Setting Time	355 minute

Table (4) Sieve Analysis Test of Sand

Sieve size (mm)	5	2.5	1.25	0.60	0.30	0.15	pan
Passing (%)	100	100	100	0.62	0.1	0.04	0

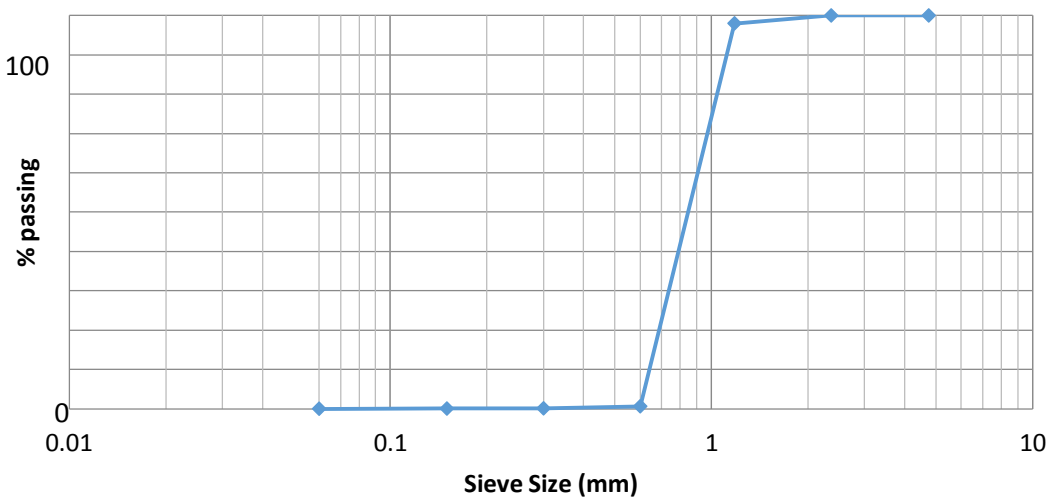

Figure (2). Sieve analysis of North Sinai sand

2.2 Experimental design

The mentioned processes are carried out in a laboratory environment with 22°C temperature and 65 % relative humidity. In the preparation of mortar mixtures for compressive strength experiments, 350 g of cement, 1050 g of standard sand and 175 ml of water are used in each mortar mixture and setting time tests was applied as shown in figure (3),all tests were satisfying according to Egyptian Code and mixed in mortar mixer machine. Prepared mortars are poured into three-segmented rectangular prism moulds of size 7 x 7 x 7 as shown in figure (4). Prepared samples are waited in the laboratory for 24 h. At the end of 24 - h period, the samples are taken out of the moulds and waited in water pools to get cured and prepared for the compressive strength experiments. Compressive strength of each cement mortar is measured at the end of 3, 7, and 28 days.

Figure (3). preparation and testing of specimens in lab

Figure (4). preparation and testing of specimens in lab

III. RESULTS AND DISCUSSION

The results of a total of 36 cubes of standard size of 7 x 7 x 7 cm were casted in laboratory, when cement content were replacement by 0%, 10%, 20% and 30% of fly ash. The results of cubes were cured for 3, 7 and 28 days. The average compressive strength of mortar incorporating fly ash was investigated at different curing ages and in accordance to the guidelines of ASTM C39. The results are tabulated in Tables (5,6,7) and the relation between mixes and compressive strength at different curing ages were illustrated in Figure (5). It can be observed from Table 3 and Figure (5) that at 3 days curing age, the compressive strength for Control Mix-1 was 25.4 MPa.So, when cement content was replaced by 10% fly ash the compressive strength was 27.3 MPa increased about 7.48%. While, Fly ash Mix -20 and Fly ash Mix -30 when cement content was replaced by 20% and 30% fly ash the compressive strength was 21.6 MPa and 19.9 MPa decreased about 14.96% and 21.65% respectively.

However, from Table (4) and Figure (5) that at 7 days curing age, the compressive strength for Control Mix-1 was 36.7 MPa. consequently, when cement content was substituted by 10% fly ash the compressive strength was 39.3 MPa augmented about 7.08%. while, for Fly ash Mix -20 and Fly ash Mix -30, when cement content was substituted by 20% and 30% fly ash the compressive strength was 31.3 MPa and 29.4 MPa reduced about 14.71% and 19.89% respectively. Finally, from table (6) and Figure (5) that at 28 days curing age, the compressive strength for Control Mix-1 was 40.2 MPa.Furthermore, when cement content was replaced by 10% fly ash the compressive strength was 42.3 MPa increased about 5.22 %. While, Fly ash Mix -20 and Fly ash Mix -30, when cement content was substituted by 20% and 30% fly ash the compressive strength was 39.5 MPa and 31.8 MPa that decreased about 1.74% and 20.89% respectively.

Table (5) Compressive strength results of mortars cubes at 3days curing age.

Specimens No.	% fly ash	Average of compressive strength (MPa)	%Strength Difference in Compared to control Mix
Control Mix-1	0	25.4	---
Fly ash Mix -10	10	27.3	+7.48%
Fly ash Mix -20	20	21.6	-14.96%
Fly ash Mix -30	30	19.9	-21.65%

Table (6) Compressive strength results of mortars cubes at 7days curing age.

Specimens No.	% fly ash	Average of compressive strength (MPa)	%Strength Difference in Compared to control Mix
Control Mix-1	0	36.7	---
Fly ash Mix -10	10	39.3	+7.08%
Fly ash Mix -20	20	31.3	-14.71%
Fly ash Mix -30	30	29.4	-19.89%

Table (7) Compressive strength results of mortars cubes at 28days curing age.

Specimens No	% fly ash	Average of compressive strength (MPa)	%Strength Difference in Compared to control Mix
Control Mix-1	0	40.2	---
Fly ash Mix -10	10	42.3	+5.22%
Fly ash Mix -20	20	39.5	-1.74%
Fly ash Mix -30	30	31.8	-20.89%

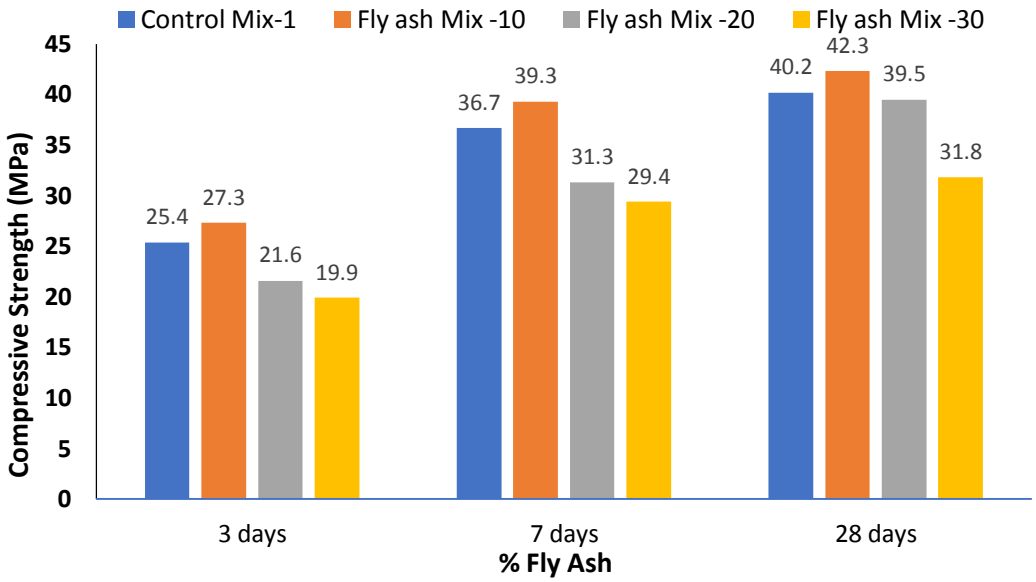

Figure (5) Compressive Strength results of various Mixes

IV. CONCLUSION

In our study, fly ash and north Sinai sand were used in concrete mixesand their effect on the compressive strength of mortar wasstudied. A great potential exists to reduce the concrete industry's contributions to greenhouse gases through reductions in cement consumption. Due to concrete's large consumption and utilization of cement as its one-and-only binder, even small reductions of cement content in concrete could make a significant global impact. Therefore, this experimental work was performed to determine the effect of fly ash as partial cement replacement on the compressive strength of concrete at different curing stages. Based upon the results it can be concluded that fly ash is a supplementary cementitious material, which has the potential to be considered as a partial binder and reduce the cement content. It was found that The highest compressive strength that concrete samples containing 10% fly ash (Fly ash Mix -10) which achieved high early strength compared to control and other samples results different curing ages. but as the curing period increased, the compressive strength developed for all mixes, by increasing the compressive strength at 28 in range 50-60 %. Since the aim of the study was to reduce the cement content in mortar, therefore, it is advisable that concrete incorporating 10% fly ash as cement replacement be used, since mortar achieves increase in strength at different curing ages.

Compliance with ethical standards

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Conflict of interest: Authors declare that they have no conflict of interest.

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