Effect the Local Fly Ash on Cement Mortar Properties

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Abstract

It is good to disposal the byproducts of bricks factories because of pollution of the environment. But the big challenge is to use these byproducts while imposing the properties of construction material and keeping pace with materials technology progress. So, in this study a byproduct (fly ash) of Al Aslaah bricks factories in the south Iraq is used to evaluate the effects for physical properties of the Portland cement mortar. Mortar cubes of 7cm were cast with fly ash partial replacement of cement weight (5%, 10%,15% and 20%) and compared against standard cement mortars cubes. The investigations involved the compressive strength, setting time, heat of hydration and density. While the results illustrate that the increasing of fly ash replacement percentage has significant increase in initial and final setting time and reduces the early and peak temperature of hydration. Also the density got proportionally less values with increasing the fay ash replacement. However, at early ages, 3days the compressive strength values were declined for all the fly ash percentages, but the situation changed for percentage 5% and 10% fly ash replacement at later age and the compressive strength were passed the standard cement mortar values at age 28days.

Keywords: Fly Ash, Bricks Factories, Compressive Strength, Setting Time, Heat of Hydration, Density.

الخلاصة

من المفيد التخلص من النواتج العرضية لمعامل الطابوق لتفادي التلوث البيئي، لكن التحدي الكبير هو استخدام هذة النواتج العرضية وأستغلالها في تحسين مواصفات المواد الانشائية للبناء لمواكبة التطور الحاصل في تصنيع هذه المواد. هذه الدراسة البحثية تتناول احد النواتج العرضية للطابوق المحلي وهو الرماد المتتطاير لمعامل انتاج طابوق الاصلاح الواقعه في مدينة الناصرية في جنوب العراق.تم استخدام النواتج هذه المعامل المحلية لتقييم تأثيرها على مواصفات ملاط الاسمنت وذلك بعد استبدال نسبة وزنية من الاسمنت بهذة المادة.ان نسب الاستبدال اخذت كالتالي 5%،10%،15%،و 20% من وزن الاسمنت. وتم مقارنة النتأئج مع ملاط الاسمنت القياسي. ان عملة التحقق البحثية شملت ،مقاومة الانضغاط،زمن التجمد،حرارة الاماهة والكثافة.حيث أن النتأئج اوضحت ان زيادة نسبة استبدال الرماد المتطاير في ملاط الاسمنت يزيد زمن التجمد الابتدائي بصور مميزة وكذلك يزيد زمن التجمد النهائي.ومن جهة اخرى يقلل حرارة الاماهة المبكره والقصوى.أيضا الكثافة تظهر تناقص متناسب بزيادة نسبة الاستبدال للرماد المتطاير.في حين مقاومة الانضغاط في العمر المبكر ،3أيام، أظهرت انخفاض عن قيمة الملاط القياسي لجميع نسب الاستبدال لرماد المتطاير، ولكن المقاومة في العمر المتأخر ،28 يوم، أظهرت زيادة ملحوظة لبعض النسب من الملاط القياسي وهما النسبتان 5% و 10% والنسبة التي أظهرت اعلى مقاومة أنضغاط هي 10%.

الكلمات المفتاحية: الرماد المتطاير، معامل الطابوق، مقاومة الأنضغاط، زمن التجمد، حرارة الاماهة، الكثافة.

1. Introduction

Many experimental studies have been conducted on investigating of concrete mortar properties over the years. One of the most important kinds of experimental work is mineral admixtures. This includes adding materials having chemical effect on concrete mortar paste. Often times this process is implemented by percentage replacement of cement weight of concrete or cement mortar. Using fly ash replacement is very common of environmental benefits and it saves the cement requirements of strength and allows preserving the raw materials of manufacturing of cement [Wankhede and Fulari, 2014]. Some of these research studies are as the following.

(Malhotra, 1990), Investigated the effect of Canadian fly ashes on the properties of concrete. The samples of concrete were tested to evaluate compressive strength, creep, strain and resistance to chloride on penetration at various ages up to one year.

(Bouzouboa *et.al.,* 2004), at can met Canada, has conducted experiments to evaluate the mechanical properties of concrete that contains high volume fly ash cements. Moreover, cement mortar blended with high fly ash has been investigated to evaluate the physical properties.

(Li Yijin *et.al.,* 2009), conducted a study to demonstrate that using ultra-fine fly ash (UFA) in cement mortar or concrete can improve their fluidity. On the other hand, using coarse fly ash can't reduce water. Therefore, the added fly ash plays a role in determining the properties of cement mortar and concrete.

(Sarath *et.al.,* 2011), noticed that the importance of using the partial replacement of fly ash in cement for improving the long-term durability of concrete and environment benefits. Moreover, the local fly ash that is used in this research is wasted .Cement is considered a relatively expensive material. Then using fly ash to compensate some of cement percentage would be cost effective.

(Izhar and Jamker ,2012),conducted a study with variable replacement ratio namely 0%,5%,10% and 15% of cement weight with fly ash. The water to cementitious material ratio (w/c) has also been taken in varying way as 0.3, 0.4 and 0.5. The effect of these parameters has been studied on fresh and hardened properties of concrete. The main aim of the research was to determine the required proportion of fly ash based concrete.

(Sherzad Hakkari, 2015), has investigated the effect of different type of mineral admixture on heat of hydration and late strength. Many types have been considered such as fly ash, silica fume, pozzolan, ruce-husk ash (RHA), ground granulated blast-furnace slag (GGBFS) and cutting stone and tile waste (CSTW). The results showed that pozzolans reduce the heat of hydration and increase both later strength and durability.

2. Objective of the study

The properties of cement mortar depend mainly on two factors (Shetty, 2011)

1- Properties of the ingredients of mortar.

2-The relative proportion of the ingredients.

When the admixtures are considered, the chemical composition of mortar would be gaining complexity. Therefore, these mortars should be experimentally studied and investigated the effect on mortar properties. In this research, fly ash partial replacement of cement weight could be used. Consequently, the following properties could be investigated.

a- Setting time.
b- Compressive strength.
c- Heat of hydration.
d- Density.

The main objectives of this research are:-

- Enhancing strength and durability.
- Make use of disposal material, reduce cost and enhance environmental benefits.

3. Materials

3.1. Sources of Materials

In addition to the conventional ingredient of mortar, cement, sand and water the local fly ash would be added to mortar.

a- Cement: Portland cement type I is used in this research study. is locally manufactured and commonly in construction projects. It is manufactured to consent with Iraqi standards of materials.

b- Sand: local fine aggregate is used. The fine aggregate is brought from Zubair quarries. These quarries have very good quality and relatively unexpressive.

c- Water: The reverse osmosis water that is treated locally is used in mixing process. This water type is commonly used in mixing and drinking in Basrah, the location of conducting the research.

d- Fly ash: There are so many bricks factories in the south of Iraq. The process of, manufacturing brick would deposit fly ash that is wasted. Al-Aslaah factories, in Nassiria, are producing a lot of demand of bricks. Therefore, it would be practical to choose their fly ash as a subject of the study. The batching of fly ash was from these factories after taking the permit from the owners.

3.2. Specification of materials.

The specifications of mixing materials are as the following:-

a- Cement: The cement type is I that is called ordinary Portland cement. It's specific gravity is (3.14) and Blaine fineness is (4400) cm^2/g.

b- Sand: Local fine aggregate. It was washed and dried. It is passing 850 µm sieve and not more than 10% passing 600 µm.

c- Water: Water has a pivotal effect on concrete (mortar) properties. In this research clean potable water was used.

d- Fly ash: It's specific gravity is (2.21) and Blaine fineness is ($2950cm^3/g$) .Fig. (1). Shown the fly ash using in this research.

Fig. (1) Fly ash used in this research.

4. Experimental program

The experimental work was done according to Guide No. (98/1990) and Iraqi standard specification(No.5/1984) with mortar cubes of 70mm size, to replace 0%,5%,10%,15% and 20% cement with fly ash. The mixing was implemented by a mechanical mixer. A vibrating table was also used to compact the mortar in molds as demonstrated in Fig (2). The samples were carefully placed and covered to maintain to moisture for 24hours. After that, the samples were cured by putting them in potable water basin until the day of test.

Fig. (2) 70mm mortar cubes used in this research.

The proportion of materials was taken according to Guide No (98/1990) and Iraqi standard specificationNo.5/1984 and as the following

a- Binder is one part (200 g) for one sample, 3 specimens.
b- Sand is three parts (600 g) for one sample.
c- Water is 0.4 of binder weight (80 ml) for one sample.
d- Fly ash is taken as a percent of the binder weight. This percent is taking from 0% to 20% by 5% increase in each mix.

5. Results and Discussion

5.1. Setting times:

The initial and final setting times of standard cement mortar and based fly ash mortars have been measured. For the standard cement mortar, the initial and final setting times were 170 and 260 min, respectively. The based fly ash mortars gave longer setting time in terms of initial and final setting times. The results showed that the more the percentage of fly ash replacement is the longer setting times. However, all the setting times were within the limited specification of Iraqi standards that are not less than 45min. for the initial setting time and not more than 600min.for the final setting time. Table (1) shows the initial and final setting times of standard cement mortar and based fly ash mortars. Moreover, the results showed that the replacement of fly ash has more effect on initial setting times than final setting times. For example, the increase of initial setting time of 5% fly ash replacement mortar was 7% while the increase of final setting time for same mortar was 1%. Since the increase of initial setting time was within the standard limits, increasing the initial setting time is beneficial to from the finishing well and takes the required time to perform the adjusting if it is required.

Table (1), the setting time for mortar based fly ash

No.	Specimen's fly percentage	Initial setting time (min)	Final setting time (min)
1	0	170	260
2	5	182	262
3	10	184	263
4	15	190	266
5	20	193	271

5.2. Compressive strength:

The compressive strength values of standard cement and based fly ash mortars are presented in table (2). The percentage of fly ash replacement was varied from 0% to 20% cement weight by 5% each sample. At the age of 3 days, the compressive strengths of all based fly ash mortars were less than the standard mortar's. The average compressive strength of standard mortar at age of 3days was 25.5 MPa. Whereas the average compressive strength values of 5%, 10%, 15% and 20% were 23.5, 24, 21.6 and 19.9 MPa respectively. However, none of the average compressive strengths of based fly ash mortars was lower than the limit of Iraqi standard specification, which is 15MPa at age of 3 days.

The results of testing at age 7 days showed that there was slight increase in average compressive strength of 5% and 10% replacement of fly ash mortars,37.8, 38.7MPa respectively, while the standard mortar gave an average compressive strength of 36.7MPa.The 15% and 20% replacement of fly ash mortar gave average compressive strengths 30.4 and 28.3MPa respectively which are less than the average compressive strength of standard mortar. It is also noticed that there is no value lower than the limit of Iraqi standard specification which is 23MPa. The samples were also tested at age of 28days.The highest average of compressive strength was corresponding to 10% replacement of fly ash mortar which is 43.1MPa. The 5% replacement of fly ash mortar was the second highest of average compressive strength that is 41.1MPa while the standard mortar gave an average strength of 39.7MPa. Both 15%and 20% replacement of fly ash mortars gave average compressive strengths of 36.7 and 32.7MPa respectively. It can be concluded from the results that the compressive strength development of based fly ash mortar depends upon two major parameters that are the percentage of fly ash replacement and the age. It is clear that the compressive strength develops at the late age. Fig (3) shows the average compressive strength values of different percentages of fly ash replacement mortar test in different ages.

Table. (2) Compressive strength values of standard cement and based fly ash mortars, (A) age of specimens 3days, (B) age of specimens 7days and (C) age of specimens 28days.

(A)

Specimens No.	% of fly ash	Compressive strength (MPa)	Average of compressive strength (MPa)
1	0	24.1	25.53
2		25.9	
3		26.6	
4	5	23.2	23.5
5		24.5	
6		22.8	
7	10	24.2	24.27
8		23.9	
9		24.7	
10	15	21.7	21.6
11		22.3	
12		20.8	
13	20	20.6	19.9
14		21.8	
15		17.3	

(B)

Specimens No.	% of fly ash	Compressive strength (MPa)	Average of compressive strength (MPa)
1	0	38.1	36.7
2		35.4	
3		36.6	
4	5	38.7	37.77
5		39.6	
6		35.0	
7	10	39.1	38.67
8		38.7	
9		38.7	
10	15	28.8	30.32
11		29.7	
12		32.6	
13	20	28.9	28.3
14		27.3	
15		28.7	

(C)

Specimens No.	% of fly ash	Compressive strength (MPa)	Average of compressive strength (MPa)
1	0	40.7	39.7
2		39.6	
3		38.8	
4	5	40.1	41.07
5		41.9	
6		41.2	
7	10	43.7	43.07
8		41.3	
9		44.2	
10	15	38.1	36.67
11		35.2	
12		36.7	
13	20	31.9	32.75
14		33.1	
15		33.2	

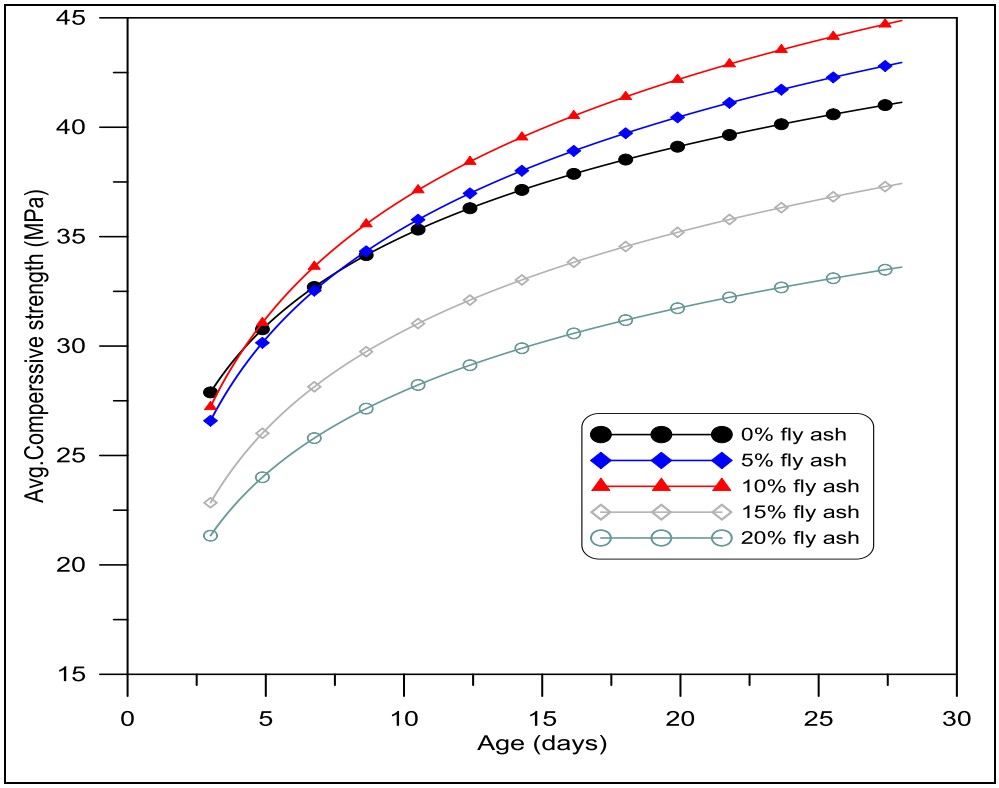

Fig. (3) Compressive strength of mortars with difference fly ash percentage.

5.3. Heat of hydration:

Heat of hydration temperatures of standard mortar and based fly ash mortars were measured in time intervals of two hours up to 24hours. Table (3) shows the initial and peak temperature of hydration. Time to reach the peak temperature for each replacement percentage of fly ash has also been recorded. The results show that there is a decrease in initial temperature of hydration when the fly ash is added to the mortar. This decrease becomes more when the percentage of replacement of fly ash is increased. The standard mortar initial temperature is 34 (^{0}C) while the 5%,10%,15% and 20% replacement of fly ash mortar initial temperatures are 33,32,32 and 30(^{0}C) respectively. Peak temperature of standard mortar is 41(^{0}C) while the 5%,10%,15% and 20% replacement fly ash mortar give peak temperatures of 39,38,37 and 36(^{0}C) respectively. Therefore, the fly ash mortar adding reduces the peak temperature of mortar. The more percentage replacement of fly ash gives the lower peak temperature of mortar. Moreover, the results show that the elapsed time to reach peak temperature increases when fly ash is added. The elapsed time reach peak temperature of standard mortar is 18hours while 5%,10%,15% and 20% replacement of fly ash mortars are 19,20,20 and 21 hours respectively. It is clear that fly ash replacement enhances mortar by reducing heat of hydration. The development of heat of hydration of standard mortar and based fly ash mortars can be shown in Fig.(4).

Table (3) Initial and maximum hydration temperature for replacement percentage of fly ash

Fly ash percentage (%)	0	5	10	15	20
Initial hydration temperature (^{0}C)	34	33	32	32	30
Maximum hydration temperature (^{0}C)	41	39	38	37	36
Time ago mixing to maximum hydration temperature (hr)	18	19	20	20	21

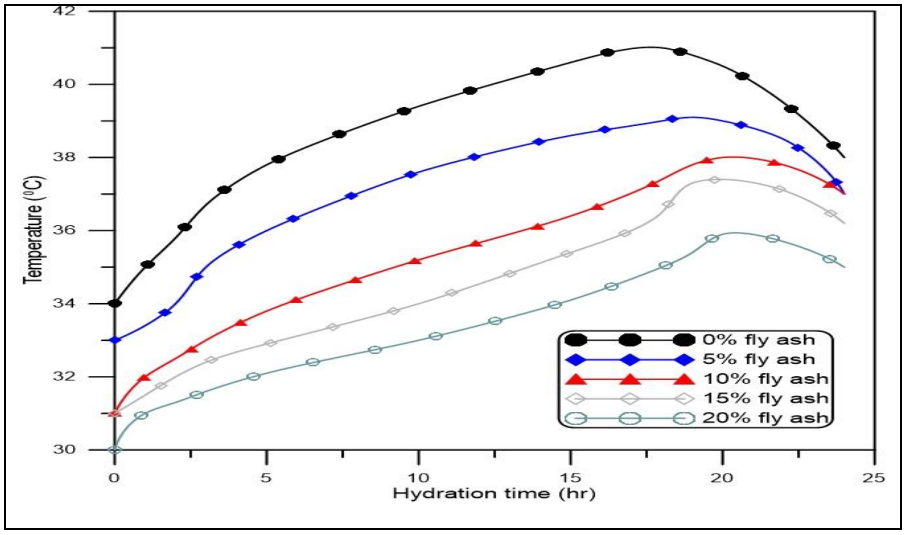

Fig.(4) Developing of heat hydration for mortar through 24hours

5.4. Density:

Changes of density for standard mortar and based fly ash mortars were measured by using Archimedes principle. The age of testing is taken of 8days after preparation. Fig.(5) shows the average changes of density in standard mortar and based fly ash mortars. The density of standard mortar is 2.42g/cm^3 while the based fly ash mortars are 2.4,2.39,2.35 and 2.29g/cm^3 respectively. It is clear that the based fly ash mortars give less density values. They become lighter when fly ash replacement increases since, the specific of gravity of fly ash is less than specific of gravity of cement.

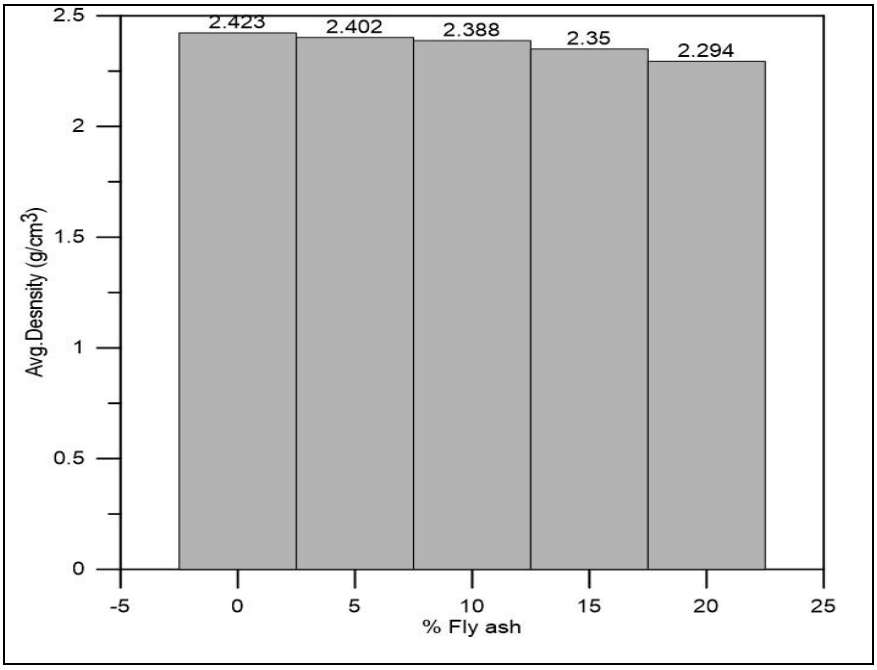

Fig.(5) Density for based mortars and fly ash mortars changes.

6. Conclusion.

In this research study, the following points can be concluded.

1- Adding fly ash to cement mortar would increase the setting times. The more the percentage of fly ash replacement is longer setting time. For example, 5% replacement fly ash gives an initial of setting time of 170min. While 20% replacements fly ash gives an initial setting time of 193min. Since the setting times of based fly ash mortar within the standard limits, the increase would be beneficial to give more time to adjusting and casting neat finishing.

2-Adding fly ash to mortar would decrease compressive strength in the early ages. It is noticed that the late ages the compressive strength increase for certain percentage replacements of fly ash, 5% and 10%. This increase is obvious at age of 28days and 10% replacement of fly as gives the highest average of compressive strength which is 43.07MPa.

3- Based fly ash mortars would emit less heat of hydration. In return, the climate in Iraq, especially in the south, is relatively and extremely hot. Therefore, reducing the heat of hydration would reduce the cracks and shrinkage.

4- After investigating the changes of density values. It turns out that the based fly ash mortars are lighter than the standard mortar. That would reduce the loads that are applied to the structures.

5- To sum up, that based fly ash mortars improve the mechanical properties of mortar and cost-effective because it is inexpensive in comparison to cement. Moreover, making use of the brick industrial disposal would make it ecofriendly.

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