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Research paper



Influence of a Retarding Admixture on the Behavior of Mortars Made from Different Types of Cement

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Abstract

The effect of retarding admixture on the fresh and hardened behaviour of different types of cement mortars and pastes when using a retarding admixture was investigated in this study. The types of cement used are; White cement (WhC), Ordinary Portland cement (OPC) and Sulphate Resistant Portland cement (SRC). Different cement mortar and paste mixes were cast, for this purpose, with and without the admixture. Initial and final setting times, compressive strength, length change, absorption and density for these mixes were examined at the curing ages of 3,7,28,45 days. The results showed that the addition of retarding admixture delayed the setting time significantly of WhC paste. The retarding admixture has a positive effect on the compressive strength of the mortar specimens for all types of cement used. regarding the length change test, the admixture was found to reduce the initial expansion for all types of cement at all ages. The results also showed an increase in the density and decrease in water absorption, especially at the later ages for all types of cement. Among all cement types used, WhC was noticeably the most affected type by using the retarding admixture compared to other types of cement used.

Keywords: *Cement type; Compressive strength; length change; Retarding admixture; Setting time.*

1. Introduction

Several attempts were conducted to improve concrete properties . This was through the addition of materials or combinations of several materials during the mixing to add new characteristics to meet the requirements of using concrete. One of these materials is the chemical admixtures such as superplasticizers, water reducers, accelerators and retarders. These admixtures are added to concrete or mortar to reduce the water content in a mixture, accelerate the early strength gain or to slow the setting rate while retaining the flowing properties of a concrete mixture. Retarding admixture is defined in ACI 116R as "an admixture that causes a decrease in the rate of hydration of the hydraulic cement and lengthens the time of setting" [1]. The mechanism of the retarders is based on slowing down the growth of $Ca(OH)_2$ by modifying the crystal growth or morphology [2]. This occurred through the adsorption of the retarder components by the cement particles and forming a protective skin which interns slow the speed of the hydration of cement components [2].
The retarding admixture is preferable to be used in mass concrete to slow down the heat of hydration. This type of admixture is also used in hot weather to prevent the formation of a cold joint caused by shortening the setting time of cement-based materials at high temperature [3]. In addition to the advantages mentioned above, it was observed that the use of this type of admixture contributes to reducing the water to cement ratio through their disported action and effective distribution of water during the hydration process. This, in turn, increases the strength of the cement paste materials with high density and low permeability while maintaining a good workability.
The retarding admixtures sources are from the materials based on hydroxy-carboxylic acids and their salts, lignosulfonic acids and their salts, phosphates, sugar and their derivatives, and inorganic salts [4]. Many factors affecting the action of the retarding admixtures during the hydration process such as; retarder type, the dosage of the retarder, the temperature degree during the addition of the admixture to the mix, and cement type [2, 5, 6].
An observation by Abalaka [7] recorded a flash set and a reduction in the compressive strength when 0.2-1% (by wt. of cement) of sugar content was used. The results also revealed that using up to 0.06% of sugar results in delaying the initial setting time by 94 minutes and increasing the strength by up to 11.84% at 3 days of water curing when 0.05% sugar content was used. This is in agreement with results recorded by many researchers dealt with using sager as a setting retarder as reported in [2, 8].
The effect of the type and the overdose of retarding admixtures on the microstructural and some mechanical properties of cement mortars was investigated by Ozturk and Baradan [9]. Four types of retarding admixture were used in their study; two of them are lignin based modified polymer, the other two are modified phosphate based and naphthalene sulphonate based admixtures. The results revealed that mortars having naphthalene sulphonate based admixture possess a higher strength compared to mortars incorporating the other type of admixtures. The overdose of the admixture results in lower strength. This can possibly be attributed to the excessive delay in the formation of hydration components which causes more porous in the microstructure of the cement mortars. Alsadey [3] obtained similar results in his investigation regarding the effect of overdosing the retarders on the properties of the concrete mixes. In his study, a reduction in the compressive strength was recorded when using a dosage above the optimum dosage (i.e. the dosage which gives higher strength). However, adding this type of admixture to below the optimum enhancing the concrete properties.
As stated earlier, retarding admixtures are used in a hot climate to remedy the effect of high temperature on the setting time of the ce-

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ment-based materials. Khan and Ullah [6] studied the effect of curing temperature and curing condition on the setting time of cement pastes made from two types of pozzolanic cement and one from high early strength cement (type III). The results, for all types of cement paste, indicated that high temperatures and low relative humidity can cause a significant reduction in both the initial and final setting times. They attributed the results to the effect of these factors on the rate of hydration of cement and accelerate the formation of rigid cement paste within a shorter time. Alshimasi et. al. [10] found that the retarding admixture performed adequately at 20°C, however, its efficiency was significantly hindered when the temperature raised beyond the ambient.

As can be seen that the effect of admixture types, dosages and the curing temperature were well investigated, however, the effect of the cement types was rarely investigated in the literature.

Because each type of cement has a different chemical composition from one to another, the effect of retarding admixture may vary according the cement type. For this purpose, the authors decided to conduct this study. The main objective of our study is to investigate the effect of retarding admixture on some mechanical and physical properties of cement mortars and pastes manufactured from commonly used cement types (Ordinary Portland Cement OPC, Sulphate Resistance Portland Cement SRPC and White Cement WhC). These properties are; setting time, density, absorption, compressive strength and length change. The type and the dosage of retarding admixture were kept constant for all mixes. The experimental work was conducted at an ambient temperature ranging from 20-25 ° C.

2. Experimental work

2.1. Materials and mix preparation

Three types of cement were used in this study; Type I (OPC), Type V (SRPC) and white cement (WhC) conforming to ASTM C150 [11]. Their chemical and physical properties were illustrated in Table 1. Natural sand was used to cast the cement mortar with and without admixture. The Lignosulphonate based retarder admixture, commercially known as RHEOBUILD® 600, with a specific gravity of 1.16 at 250C was adopted to investigate its effect on the properties of these types of cement.

The mix proportions adopted in the experimental work were (1: 3) (cement: sand), by volume, for all mixes including the plain mixtures which considered as the reference mixes (has no admixture). W/C ratio of the reference mixes was 0.50 and for mixes with retarder was (0.4). First, the mortar dry components were mixed manually on a solid, clean and non-porous surface (flat iron containers). The retarder admixture was blended with water and then added to the dry materials gradually with well stirring until a homogeneous mixture was achieved. The dosage of the retarder admixture was 1.2% by wt. of cement following the recommendation by the manufacturing company. The mixtures were, then, cast into the moulds. After 24 hours of casting, the specimens were demoulded and placed in a water tank until the testing age of (3, 7, 28 and 45 days).

2.2. Testing methods

2.2.1. Setting time test

The initial setting time is the time from adding the water to the cement to the time at which the cement paste starting losing its plasticity. The final setting time is recorded from the time when the water was added to the cement to the time at which the cement paste loses all its plasticity and start to gain strength. Vicat approach was used to determine the initial and final setting time tests following the ASTM C191 method [12]. The test was conducted for all types of cement used with and without admixture. The consistency test was conducted first to find the suitable w/c for the reference mixes in accordance with ASTM 187 [13]. The equivalent dosage of the retarder was kept constant and the w/c was changed until the same consistency was achieved. The test was performed under laboratory temperature ranging from 20-25 ° C.

Table 1: Chemical compositions of cements

Oxide composition	Oxide content %		
	OPC	SRPC	WHC
CaO	62.11	54	58.265
SiO_2	22.02	19.2	19.4
Al_2O_3	5.27	3.8	6.5
Fe_2O_3	3.4	4.8	1.8
MgO	2.71	2.1	1.4
SO_3	2.41	0.274	0.412
Free CaO	1.46	0.244	1.4
L.O.I	1.47	1.53	1.55
I.R	0.29	0.31	0.27
L.S.F	0.86	1.58	0.91
C_3S	45.17	40.48	36.64
C_2S	29.13	23.87	27.97
C_3A	7.97	1.77	13.88
C_4AF	10.35	14.61	5.47

2.2.2. Compressive strength and density tests

The compressive strength test was carried out according to BS EN 12390-3:2002 requirements [14]. A total of 72 cubic samples (24 per cement type) with dimensions of (70 * 70 * 70 mm) were used to perform this test. Half of the prepared samples were cast without using admixture and the other half was mixed with admixture. For the compressive strength test, three cubes were tested for each curing age (3, 7, 28 and 45 days). The average of the results of these three cubes was recorded as the compressive strength value at a specified age. The cubes were weighted before testing to determine the unit weight.

2.2.3. Length change test

The length change test was performed according to ASTM C157 [15] which measured the relative change, either increase or decrease, in the original length of the specimens. Three samples were cast for each mixture to perform this test. The dimensions of the prisms used were 25 * 25 * 300 mm. After de-moulding, the first reading was recorded using the dial gauge with accuracy equal to (0.001 mm). The specimens were, then, placed in the water tank until the day of the test. The second reading was recorded on the day of the test and the change in length was calculated. The laboratory temperature during the test of all mixes was ranged from 20-25 ° C. The results recorded in Table 2 are the ratio between the difference in reading for two different ages to the original sample length multiply by 100%.

2.2.4. Absorption test

ASTM C642 [16] Water Absorption test was conducted to investigate the effect of admixture on water penetration ability inside the mortar. Three mortar cubes (70 * 70 * 70 mm) was used to perform this test. The cubes were immersed in a water tank until the day of the test, and weighed, after they were taken out of the tank in the saturated dry surface. The cubes were, then, oven dried with 110 ° C for 24 hours and were weighed again. The weight difference as a percentage of the original weight was registered as absorption value.

3. Results and discussions

3.1. Setting time

Setting time is a term refers to the stiffening of the cement paste, i.e. transformation from a fluid state to a rigid state. The setting takes place in the cement paste due to a selective hydration of C_3A and C_3S and generates relatively high heat. Thus, it can be expected that

the performance of different cement types can vary from one to another according to the chemical compositions (C_3A and C_3S) of the cement.

Table 2 shows the results of the initial and final setting time of the three types of cement, for plain mixes and mixes with retarding admixture. The addition of retarder to the cement paste led to delaying the initial setting time by 65%, 15%, and 78% and final setting time by 43%, 43% and 13% for OPC, SRC and WhC respectively compared to cement paste without admixture.

WhC has faster setting time among the cement types used in this study. This behaviour seems to be due to the higher content of C_3A which reacts rapidly with water during the hydration, forming calcium aluminate hydrate and relatively high heat of hydration, which interns speed the setting of the paste [2]. Adding retarder admixture delay the direct hydration of C_3A which leads to slowing down the initial setting time especially for WhC mortar. SRC has a higher setting time due to the larger particle size than other types (retaining percentage on sieve 175 µm is higher) which means smaller surface area than the others.as well as SRC has less C_3A content than the others. Mardani et. al. [17] based on experimental study results, found that increasing the cement fineness and C_3A content accelerated the setting time of cement paste and increase the effectiveness of the admixture, consequently improve the fresh state properties.

Table 2: Results of the setting time

Cement type	Initial setting time (min)		Final setting time (min)		Finance (sieve 170µm) %
	Without adm	With adm	Without adm	With adm	
OPC	85	140	200	285	0.60
SRPC	130	150	210	300	1.30
WHC	45	80	195	220	0.64

3.2. Density and absorption

The results obtained from the tests of density and absorption of the three types of cement mortars are given in Table 3. It can be seen that the density increased significantly with curing age. At the age of 45 days, the percentage of that increase in the density of plain mortars were (4.63, 7 and 4.97%) for WhC, RPC and OPC respectively compared with that of 3 days. Moreover, adding the retarding admixture increased the density by (9.5, 12 and 5.3%) for WhC, RPC and OPC respectively. The absorption of the mortars decreased by (41, 48, and 13%) and (71, 74, and 65%) for WhC, RPC and OPC for plain mortars and after adding the admixture to the mixes respectively. The effect of retarding admixture on increasing the density and decreasing the absorption was significant for all types of cement. As stated in Section 1, due to the action of the admixture, the w/c was reduced and this has a positive effect on minimizing the size and number of voids in the structure of the cement paste which in turn increases the density and reduces the penetration of water.

3.3. Compressive strength

The results illustrated in Figure 1 show that there is an increase in compressive strength in the presence of the admixture for all types of cement and in all ages. The increase in compressive strength was 151, 141, 96.6, 74.7% at 3, 7, 28, 45 days respectively for mortar with WhC. For OPC, there was also a gain in the compressive strength by (92.9, 80.6, 133.7 and 110%) at (3, 7, 28, 45) days respectively. The results obtained when SRC was used is similar The gain in strength increased with increasing the curing age by (32, 56, 79, 65%) at age of (3, 7, 28, 45) days, respectively.

It can be concluded that the addition of the retarding admixture has a positive effect on the compressive strength of the cement mortar for all types of cement used. This might have attributed to its high

Table 3: Results of the density and absorption of cement mortars
*Mortar without retarder **Mortar with retarder

Mix designation	Density (kg/m3)				Absorption %			
	3 days	7 days	28 days	45 days	3 days	7 days	28 days	45 days
OPC- 0*	2210	2250	2270	2320	5.87	5.42	5.35	5.11
SRPC-0	2140	2190	2210	2290	6.0	6.11	3.43	3.1
WHC-0	2160	2170	2195	2260	6.97	6.12	4.1	3.6
OPC- **	2160	2260	2340	2420	5.2	4.8	2.88	1.7
SRPC-r	2250	2280	2290	2370	4.7	4.1	1.6	1.2
WHC-r	2200	2210	2340	2410	5.2	3.43	1.8	1.5

efficiency to reduce the water content in the concrete mixture which results in increasing the compressive strength. The effect of the retarder on WhC mortar strength was more significant. This behaviour is due to the action of this type of admixture on inhibits the rapid hydration of the higher C_3A content in this type of cement which affects positively the strength at early ages of the cement mortar. The increase in mortar strength after adding retarding admixture to the mixes in its optimum dosage was reported in many recently published types of research in the same field [3, 7, 9, 18].

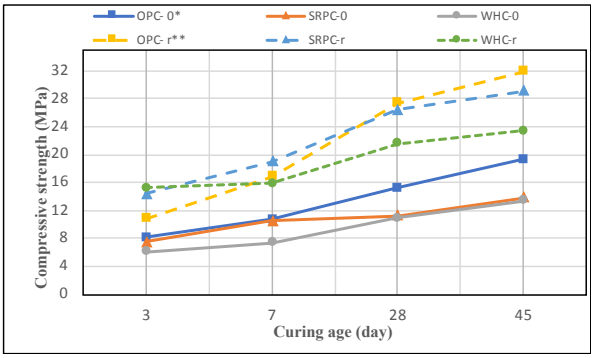


Fig.1: Compressive strength results versus curing age

3.4. Length change

Figure 2 shows the length change results versus curing age for plain mortars and that with retarding admixture. The results recorded at (3, 7, 28, 45) days indicated that the initial expansion was occurred first then followed by a contraction in all mixes. This due to the formation of the ettringite at the early age of the hydration. This early expansion is predominant in all plain mixes and especially in WhC mortar which showed higher expansion due to the higher C_3A content as stated earlier. When retarding admixture was used, the expansion was overshadowed by shrinkage. As the initial stiffening of cement paste increases, shrinkage increases at a constant rate. The results were in agreement with the results obtained by Gowda [19] who studied the effect of using different types of retarding admixture on the linear shrinkage of OPC mortar.

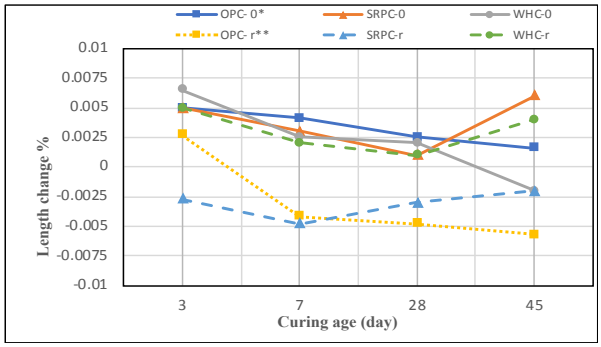


Fig. 2: Length change results versus curing age

4. Conclusions

From the results reviewed in the previous section, the following remarks can be addressed;

1. The setting time of the cement paste was noticeably affected by adding retarding admixture to the mix for all types of cement used. WhC paste was the most affected type due to the higher C3A content.
2. The retarding admixture acted as water reducing admixture and results in an increase in the density due to decreasing the voids content and reduction in the absorption of water for all mixes.
3. Using retarding admixtures, the expansion was lower than that of plain paste. The lower expansion is due to the increased period of time spent in the plastic stage.
4. For all cement mortars, the compressive strength increased when using retarding admixture compared to the plain mixes without admixture.
5. The effect of the retarding admixture on the fresh and hardened properties of WhC mortar was more significant compared to another type of cement.

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