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Effect of Silica Fume on the Hydration Kinetics of Atbra Cement Pastes Produced in Sudan

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ABSTRACT

Blended cement pastes were prepared with and without super plasticizer using an initial water/cement ratio of 0.30. Hydration kinetics were followed by determining the non-evaporable water and free lime contents at various hydration times, covering the range from 0.5 hour up to 28 days. The results of hydration kinetics indicated three-stages in the hydration reaction; these are the "dormant", the "accelerations" and the diffusion periods. In this study, Atbra Portland cement pastes were prepared with Silica fume as an admixture.
This work is aimed to evaluate the effect of Silica fume on the effect of this admixture on the hydration reaction of cement pastes at different intervals of time (0.5 hours up to 28days).
Keywords: Portland cement, Silica fume, hydration kinetics.

1. INTRODUCTION

Portland cement is a multi component system. The main factors that affect the rate of cement hydration are cement composition, cement fineness, water-to-cement ratio, curing time, and curing temperature when ordinary Portland cement (opc) is mixed with water; a series of chemical reactions begins to take place. The reactions of cement with water proceed at different rates for the various mineral phases and involve both hydrolysis and hydration processes [1].Hydration is a chemical process that, from the anhydrous material through several chemical reactions, leads to the formation of hydrates. This complex process has thermodynamic, kinetics and structural features which depend on both chemical and physical parameters [2].Super plastizers are now widely used in the production of concrete with excellent workability, for easy placement with out reduction in cement content and strength. These admixtures are extremely effective for dispersing cement particles in water. The dispersion mechanism has been described in terms of electrostatic repulsive forces between the cement particles followed by adsorption of charged superplastizer molecules. Several reports have been concerned with the improvement of the strength and development of Portland cement using admixtures [3-5]. Superplastizers have been used to reduce the water of consistency and to improve the workability of cement pastes and consequently concrete, leading to improvement in mechanical properties and resistance towards environmental deterioration, chemical attack and pastes at early stages.

Silica fume: quartz reduced in an electric arc furnace - some SiO2 volatilization and oxidation produces largely glassy SiO2 particles of ≈100 nm diameter.Low density material with 86-95% reactive SiO2 [6].In the present paper, Silica fume was used as additive to the blended cement pastes made with an initial water/cement (w/c) ratio of 0.30 by weight as Reported [7]. The effect of this admixture on the hydration kinetics of hardened cement pastes was clarified.

2. EXPERIMENTAL

Materials used in this investigation are Portland cement produced in Sudan, Atbra , which is designated as At for Atbra cement pastes ,Chemical oxides composition as determined by using x-ray fluorescence and chemical analysis for the Portland cement is shown in table 1.

Table (1): The chemical oxides composition (%) of the sample of ordinary Atbra Portland cement.

Oxides	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3	Ign.loss
Atbra cement	**63. 6**	**21.6**	**4.2**	**3.0**	**2.4**	**2.7**	**1.48**

The specific surface area determined was 2777 m^2/g. Various cement pastes were prepared by mixing with and with-out additive, with water using a w/c ratio of 0.30 by weight mixing was done for 3 minutes continuously and designated by At for cement without additive and, and (SC) for cement with Silica fume.Hydration kinetics was studied by determining the non-evaporable water contents as well as the free lime contents for various cement pastes, after curing for 0.5,1,3, hours and 1,3,7 and 28 days. The details about the methods used for the determination of non-evaporable water and free lime contents were fully described in an earlier paper [8].Non-evaporable water (chemically combined) Wn was determined by heating certain weight of dried sample at1000oC until constant weight.It was calculated on the heated basis and designated as Wn and corrected with respect to free lime content.

Wn (corr) = Wn - (Y x Z), where Y is the free lime content and Z is the ratio of molecular weight of water to CaO (18/56).

Designation:

At = Atbra cement + water.

SC = Atbra cement + silica fume + water

3. RESULTS AND DISCUSSION

Hydration Kinetics

The results of non-evaporable water content (Wn%) and free lime contents(CaO%) for the cement pastes are given in table 2 and 3,and graphically represented as a function of curing in figures 1,2,3,and 4,respectively.

The results of non-evaporable water contents shown in figures 1, 2 indicate a minor increase in the non-evaporable water content from 0.5 hour up to 3 hours of hydration for the neat cement paste (C).During the interval 0.125-1day hydration, there was a marked increase in the rate of hydration followed by a gradual change of the rate of hydration in the later stages up to 3 days. The values of the combined water contents of the cement pastes mixed with 0.3 by (weight of cement) of superplastizer showed the same trend of hydration as that of the neat cement pastes but there was a slight change in the rate of hydration during the first 3 hours.

Results of free lime contents shown in figures 3 and 4 indicate the same changes as in the non-evaporable water contents. Therefore, gradual changes in the free lime contents were observed during the first 3 hours of hydration, followed by a noticeable increase in the free lime contents in the hydration period of 0.125-3 days. Finally the free lime contents indicate a gradual change with increasing hydration age up to 28 day, again, the addition of superplastizer to the blended cement used in this investigation causes minor changes in the rate release of the free lime with age of hydration.

The results of degree of hydration indicated that the addition of 0.3 %(by weight of content) of superplastizer to the blended cement pastes causes a minor retardation of the rate of hydration especially during the first 3 hours.

The results of hydration kinetics, including non-evaporable water contents, free lime contents of these blended cement pastes made with and without superplastizer indicate a minor increase during the early hydration stages from 0.5 hours up to 3 hours (0.125 days). This initial period represents the formation of the initial coating of hydration products on the cement grains with an almost impervious character, this stage is known as "dormant" period [9,10]since it leads to a retardation of the hydration process.

Hydration characteristics of silica fume rereacts relatively fast in the cement system. Pastes require higher water content than silica fume-free ones unless a superplasticiser is added. The silica is consumed in reaction with Ca (OH) lime-rich C-S-H resulting in a paste with lower (or no) Ca $(OH)_2$ and a C-S-H $CaO:SiO_2$ ratio (maybe as low as 1.2) [6].

Table (2): Combined Water (Wn %) (Non –evaporable water) of Atbra (Sudani) Cement Pastes with and without Silica fume

Age of hydration	w/c ratio 0.3 At (Atbra cement with silica fume)	w/c ratio SC (Atbra cement without silica fume)
0.021	0.11	0.4
0.041	0.19	0.45
0.125	0.25	0.49
1.000	1.00	3.11
3.000	3.11	3.70
7.000	3.99	8.60
28.000	5.18	10.23

Table (3): Free lime Content (CaO %) of Atbra (Sudani) Cement Pastes with and without Silica fume.

Age of hydration	w/c ratio 0.3 At (Atbra cement without silica fume)	w/c ratio SC (Atbra cement with silica fume)
0.021	0.33	0.28
0.041	0.38	0.32
0.125	0.44	0.35
1.000	2.57	1.67
3.000	3.16	2.85
7.000	3.82	3.00
28.000	5.68	4.40

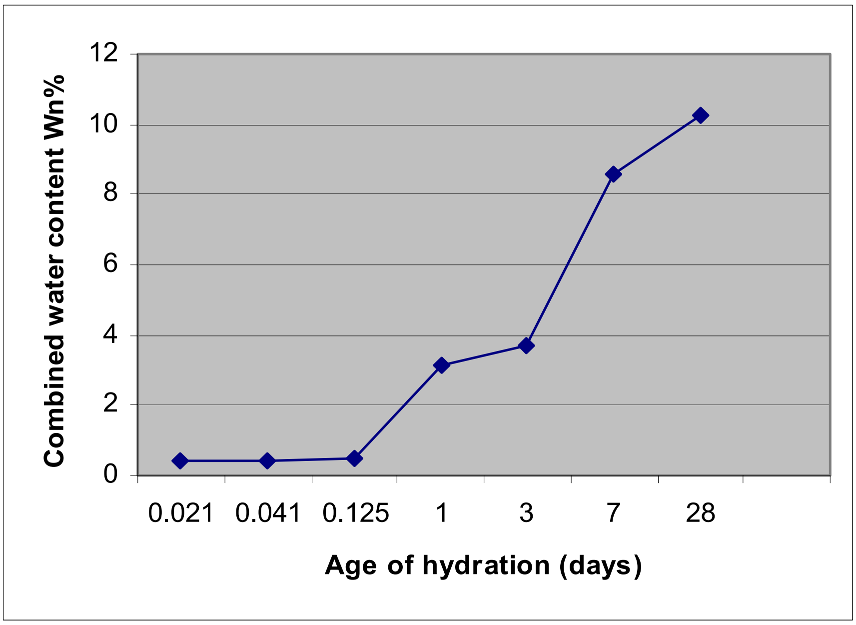

Figure (1): Combined Water (Wn%) (Non –evaporable water) of Atbra (Sudani) Cement Pastes without Silica fume.

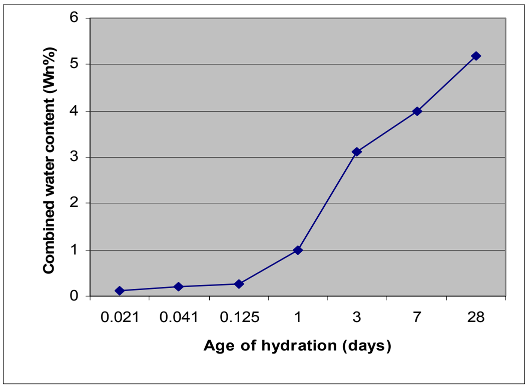

Figure (2): Combined Water (Wn%) (Non –evaporable water) of Atbra (Sudani) Cement Pastes with Silica fume.

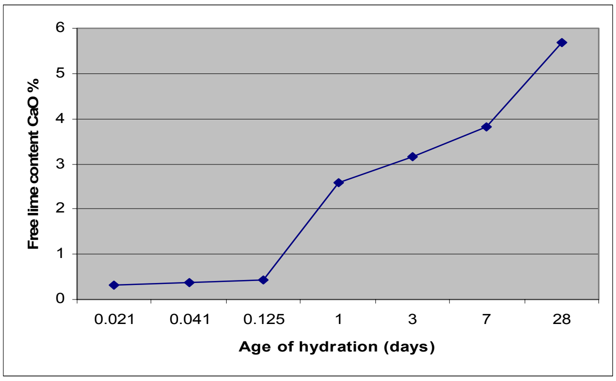

Figure (3): Free lime Content (CaO %) of Atbra (Sudani) Cement Pastes with Out Silica fume.

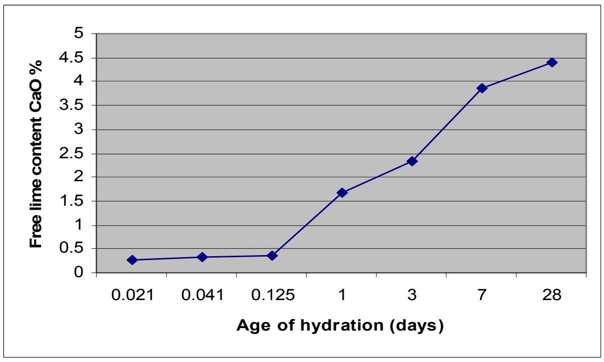

Figure (4): Free lime Content (CaO %) of Atbra (Sudani) Cement Pastes with Silica fume.

In fact, the addition of admixture to the blend cement pastes results in two main opposing effects, which are:

1. A retardation effect on the rate of the hydration of cement which is mainly attributed to the interaction between calcium ions and admixture.
2. A production of a more dense and close textured structure of the resulting

blended cement paste including admixture; and this effect leads to an increase in the rate of hydration of the blended particles through activation by the calcium hydroxide liberated during the early hydration stages of the clinker particles; by this way the Ca+ ions will find a short diffusion-path between clinker and blended grains due to the more packed structure of the paste.

These two effects operate at the same time in opposite directions and lead finally to either an increase or a decrease in the rate of hydration during the early stages.After 3 hours (0.125day) hydration, the initially formed impervious coating hydration products were dispersed and/or crystallized leading to an increased accessibility of water through the hydration coating into the unhydrated parts of the cement grains. this period leads to an increase in the rate of hydration with formation of new inner hydrates, located deeper in the cement grains, which is known as the acceleration period [8,9]; it starts from 0.125 day and ends at about 3 days in the hydration of these blended cement pastes. Finally, the non-evaporable water, water contents, free lime contents again showed a gradual change with curing age up to 28 days of hydration. This can be attributed to the accumulation of larger amounts of hydration products within the originally water-filled spaces (pores) of the hardened pastes.

Consequently, the diffusion of water through the dense hydration products into the remaining unhydrated part of cement grains becomes the rate controlling step; this period is called "diffusion" period [8, 11, 12].

The addition of admixtures (0.3%) by weight of cement to the blended cement in this investigation causes a slight change in the rate of hydration, especially during the final hour's hydration. A compensation effect of two parameters, described earlier in this stage may be noticed during the intermediate state of the hydration process.

4. CONCLUSIONS

To summarize, the addition of silica as an admixture to the blended cement pastes results in two opposing effects, namely, retardation of the rate of hydration through the interaction between Ca 2+ ions and silica as an admixture, and the production of more dense structure of the blended cement pastes, which increases the rate of hydration of the early stages of the clinker particles.

These two effects operate at the same time in opposite directions and eventually lead to either increase or decrease in the rate of hydration during the early stages. A compensation effect of the two parameters may be noticed during the intermediate stages of hydration.

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دراسة تأثير المضافات على عملية الهدرتة
للإسمنت المنتج في السودان – اسمنت عطبرة

فاطمة القادري

قسم الكيمياء - كلية العلوم - جامعة صنعاء

ملخص

حضرت عينات من الاسمنت البورتلاندي المنتج في السودان باستخدام المضاف وبدون المضاف ، والمضاف هو السلكا بخلط الاسمنت الجاف مع الماء بنسبة وزنية 0.3%.

وسميت العجائن المحضرة من اسمنت السودان بدون مضاف At, ومع المضاف sc .

ثم أجريت عملية التادرت لجميع العجائن الاسمنتية لفترات زمنية من نصف ساعة إلي 28 يوما، وعند كل زمن من تفاعل التادرت تم إيقاف تفاعل التادرت لكل عجينة.

وقد أجريت اختبارات حركية تفاعل التادرت حيث تم دراسة حركية التادرت من خلال تقدير محتوي الماء المتحد كيميائيا الماء غير المتطاير وكذلك تقدير محتوي الجير الحر عند الأزمنة المختلفة من تفاعل التادرت .

ومن النتائج التي تم الحصول عليها من هذه الدراسة أمكن استخلاص الاستنتاجات التالية:

1-أوضحت نتائج حركية التادرت أن درجة التادرت تزداد كلما زاد زمن التادرت.

2-عملية التادرت يتم بثلاث مراحل:المرحلة البطيئة ،والمرحلة المحفزة ، المرحلة السريعة.