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EFFECT OF STORAGE PERIOD IN HOT WEATHER ON THE PROPERTIES OF PORTLAND CEMENT

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Abstract

The aim of this research is to investigate the effect of storage time on the physical properties of ordinary Portland cement in hot weather compared to the normal weather for a specified period (one, two, three, six months and one year). The studied properties were standard consistency, initial and final setting, as well as compressive strength at age 3, 7 and 28 days. The results were compared with the primary results at one-day after production from the factory for the same cement. The results of the research show that by increasing the storage period of the cement compared with both normal and hot weather circumstances increases the negative action on the properties of cement. The proportion of water/cement was increased to obtain the standard consistency and reduce the time of initial and final setting, while after the age of one month it begin to increase up to one year. Compressive strength decreases at all ages of the test 3, 7 and 28 days. It was also found that the effect of hot weather circumstances compared with the normal weather for the same tests and the same ages was marginal. It was also found that by increasing the storage period in normal and hot weather circumstances did not affected the compliance of Portland cement with the requirements of British, Iraqi and Libyan specifications specifically the initial and final setting times. But it fails to meet the requirements of these specifications in the compressive strength test after the age of more than three months.

Keywords: Compressive strength, Final setting time, Hot weather, Initial setting time, Standard consistency.

1. Introduction

Cement is the main effective component of the most important properties of concrete such as the compressive strength durability and volume changes. Although it usually occupies less than 20% of the weight of concrete, it contributes about 50% of the price of materials in the concrete industry. One of the most important problems facing most construction projects is how to manage the process of transporting and storing cement and prepare it for the concrete industry in a timely manner because it is one of the main important building materials on which these construction projects depend. Because it's chemical, physical and mechanical properties are influenced directly by the storage period, circumstances and quality of storage, therefore this directly affects the properties of the manufactured concrete and the quality control procedures.

The cement must be taken care of from the beginning of its transfer from the factory until it is used in the concrete mix at the project site. This requires taking care and taking the practical steps of transporting, unloading, storing and minimizing the storage period. Cement should be stored in weather-tight, properly ventilated structures [1]. However, to reduce the possibility of cement damage it should be stored in weather tight and ventilated places. It is well observed that as the storage period increases there will be the rise of cement lumpiness and blocks and failure in the compressive strength requirements of cement, particularly at early age, an increase in loss on ignition, besides the decrease of specific surface and its effect on the time of initial and final settings [2] as well as the phenomenon of false setting or quick setting [3].

At the time of use, cement should contain no lumps or blocks that cannot break by little pressure between fingers. The removal of hard blocks and lumps by screening does not always retain the quality of cement to the basic level. If there is any doubt, reclaimed cement must be tested to ensure that it meets the requirements and specifications. Also, care should be taken to move the cement to the storage sites to protect it from moisture or contamination with other materials [4]. On the other hand, because cement is exposed to vibrations during the transport process, what is called your storage vibration, which leads to the formation of some balls and blocks, it may delay the cement's integrity and the process of decomposition of water, thus delaying its hardening process and obtaining low early strength. Therefore, the internal surfaces of the cement silo must be soft with a minimum angle of slope at the bottoms 50° for cylindrical silo and 55°-60° angle for rectangular ribbed silos with an air diffuser system that allows for low compressed airflow 0.2-0.4 kg/m^2 intermittently to displace cement blocks that have been firmly anchored in the isolates.

These silos should be cleaned and unloaded at least once per month to prevent the cement caking [1, 5] and that cement stocks in these silos should not exceed 12 m. The sacked cement should not be stored in the form of stack and piles to allow air ventilation. The height of bags should not exceed 14 bags when storing for less than 2 months and 7 bags in case of storage for a longer time, always recommended using the oldest cement first [1]. Compressive strength of concrete at the age of 28-day produced from cement was well stored for 90 days with a reduction of 20%, for six months by 30%, 40% for one year, and 55% for two years while for the compressive strength of concrete at 7-day was lower at higher rates but compressive strength at ages of 6 months and more at a lower rate [2].

Ibrahim studied the certain storage time period on the physical and mechanical properties of Portland cement and comparing this with a test at one day after production from the factory for the same type of cement. The results show that with increasing storage period the water/cement ratio for standard consistency would increase, initial and final setting time decrease, also the compressive strength will decrease at all ages of 3, 7, 28 days [6, 7]. The meagre of research on the effect of the storage period on the properties of Portland cement entails to study the problem of the effect of the storage period in the hot climate on the properties of Portland cement if we know that this atmosphere is prevalent in most countries of the Middle East and the African Sahara of and the Arab Gulf for most of the days of the year [8-10].

Therefore, this research was conducted this research to study the effect of storage time in hot weather of ordinary Portland cement compared to the normal weather for a specified period of time (one, two, three, six months and one year) on the physical properties of Portland cement such as standard consistency, initial and final setting, as well as the compressive strength at 3, 7 and 28 days comparing these results with the initial results of one-day. There is an essential decline in the amount of strength due to ageing. If the condition of cement has been stored in airtight, it provides a predictable strength of up to 3 months. The value of the reduction in strength could be less at the rich mix [11]. Investigations on the clinker pointed that C4AF was the least influenced by storage at high humidity [12]. The influence of the cement storage in fresh and hardened concrete properties was investigated different concrete and mortar types. The investigations show that the impact of the storage conditions is more pronounced for specialized concretes with high sophisticated optimized mixture compositions containing admixtures. Although, the influences also happen for ordinary concrete and could not be neglected [13].

2. Materials and Experimental work

2.1. Materials

2.1.1. Cement

Ordinary Portland cement manufactured in Alfatih cement factory at Derna (Libya) has been used in this investigation. Its chemical composition and physical properties were examined at a one day time according to the British Standard (196-3:2016) [14]. The results are shown in Tables 1 and 2, indicating the compatibility of the cement used for the British Standard (197-1:2011) [15], Iraqi Standard (IQS-5-1984) [16] and the Libyan Standard (LQS-340-1997) [17].

Table 1. Chemical composition of Portland cement.

Oxide	CaO	SiO_2	Al_2O_3	Fe_2O_3	SO_3	MgO	Alkalis	L.O.I	I.R.
Weight (%)	62.4	20.5	5.41	3.11	2.3	3.22	0.76	1.85	0.26
BS 12-1996					<3.0	<5.0		<3.0	<1.5
IQS 5- 1984					<2.8	<5.0		<4.0	<1.5
LQS-340-1997					<3.0	<5.0		<3.0	<1.5

Table 2. Physical properties of Portland cement.

Properties	Results	BS 12-1996	IQS 5-1984	LQS-340-1997
Specific gravity	3.09			
Specific surface area (Blaine) cm^2/gm	3080	>2250	>2300	>2500
w/c for standard consistency %	26			
Soundness (Le Chatelier) mm	2.2	<10	<10	<10
Setting time (Vicat) min				
-Initial	165	>45	>45 <600	>45
-Final	235	<600		<600

2.1.2. Standard sand

Standard sand identical to British Standard (BS 4450: Part6: 1978) was used which passed from an 850 micron sieve, noting that the amount of passing through the 600 micron sieve was less than 10%.

2.1.3. Water

Tap water used form water-supply network system for mixing and curing.

2.2. Experimental testing

The cement was divided after storing it in closed plastic containers into two groups. The first group was stored in the normal laboratory environment, the temperature is (20 ± 2) °C, and a relative humidity is about 20%-35%. While the second group was stored in a special room designed to have a constant temperature of (45 ± 1) °C and relative humidity of 20% (hot weather circumstance). The tests for the two sets of cement were carried out at the normal temperature of the laboratory. Therefore, the cement of the second group of the special room (hot weather circumstances) was taken to the laboratory before the tests for at least 24 hours. The temperature of the test was 20°C.

2.2.1. Physical tests

Examination of the standard consistency, initial and final setting time of the two groups (normal and hot weather) circumstances was carried out using Vicat apparatus according to BS EN 196-3 [13]. after the laboratory storage period for (1, 2, 3, and 6 months; and 1 year) and comparing them with the test of the one day after the production of cement that collected from the factory.

2.2.2. Mechanical tests

BS EN 196-3 [13] was adopted to determine the compressive strength of cement for the two groups after each specified storage period in the laboratory (1, 2, 3, and 6 months; and 1 year) and compare it with the compressive strength after one day age. Cement mortar consisting of cement, standard sand, mixing ratios with a weight ratio of 1: 3 (cement: sand) and a water / cement ratio of 0.4 by weight, was

mixed with a 10 liter capacity pan mixer, then poured into 7.07 cm cubic blocks. These cubes were compacted using a standard vibration machine. After 24 hours of opening the molds, the cubes were processed by submerging them in water continuously until compressive strength tests were administered at the age of 3.7 and 28 days. These tests were compared to the two groups (normal and hot weather circumstance) with a compressive strength test of 3.7 and 28 days old for the same cement one day after production from the plant.

3. Results and Discussion

3.1. Physical properties

Table 3 and Fig. 1, show that the amount of water required to obtain the standard consistency increases with the increase of the storage period of cement in normal and hot weather. There is no obvious difference in effect for the storage temperature on the results of the standard consistency test. From Table 4 and Fig. 2, we notice that the time of initial and final setting time decreases with the increase of cement storage period in the normal and hot weather up to one month, but it starts to increase to reach more than the initial setting time of cement at the age of one day when the storage period of one year in the atmosphere. However, regarding the time of final setting, the increase also begins after one month in the normal and hot conditions to reach more than 235 minutes. Range from two months up to one year showed that there is an increment in the final setting time, the increase in the time of final setting up to 30%. In spite of the increase in the storage period, it was noticed that the cement conforms to the requirements of the British, Iraqi and Libyan standards, where the initial setting time was more than 45 minutes and the final setting time is less than 10 hours. This is due to the increased storage period which increases the formation of some cement balls and blocks that reduce the fines of cement, this reduces the surface area exposed to water interaction, i.e. the lack of chemical activity of coarse grains [3]. This delays the hydration of the cement and its hydrolysis process, thus delaying the initial and the final setting that marks the beginning of the hydration stage of the Portland cement.

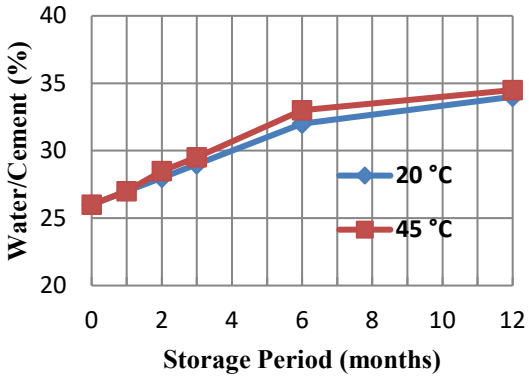

Fig. 1. Effect of storage period temperature on the standard consistency of Portland cement.

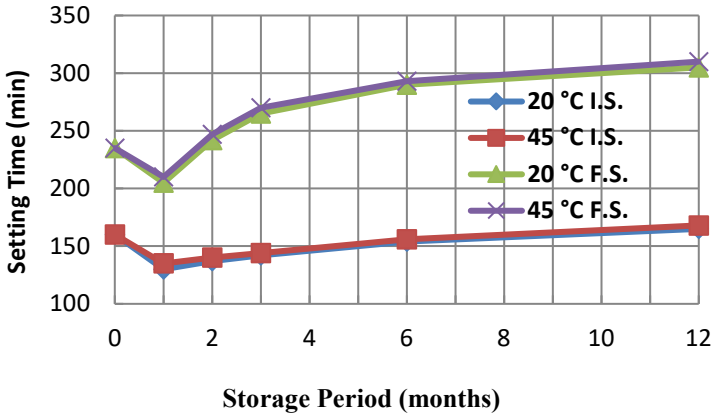

Fig. 2. Effect of storage period temperature on the initial and final setting of Portland cement.

Table 3. Results of standard consistency.

Storage Temperature (°C)	Results of Standard Consistency (%) at Storage Period					
	Day	Month				
	1	1	2	3	6	12
20	26.0	27.0	28.0	29.0	32.0	34.0
45	-	27.0	28.5	29.5	33.0	34.5

Table 4. Results of initial and final setting.

Setting Time	Storage Temperature (°C)	Results of Setting Time (min.) at Storage Period						BS 12-1996 (min.)	IQS 5-1984 (min.)	LQS-340-1997 (min.)
		Day	Month							
		1	1	2	3	6	12			
I.S.	20	160	130	137	142	154	165	>45	>45	>45
	45	-	135	140	144	156	168			
F.S.	20	235	205	242	265	290	305	<600	<600	<600
	45	-	210	247	270	293	310			

I.S.: Initial setting F.S.: Final setting

3.2. Mechanical properties

Table 5 shows the results of the compressive strength test in normal and hot weather circumstances (20 °C and 45 °C) at different ages 3, 7 and 28 days. From the two Figs. 3 and 4, we note that with the increase in the storage period, the compressive strength decreases, and with close proportions, and for all test ages 3, 7 and 28 days, until a storage period of three months, but at the age of six months and more will decrease the compressive strength in early ages less than the later ages as shown in Fig. 4, that shows the relationship between the storage period and the relative compressive strength (compressive strength of cement at a certain storage period relative to its compressive strength at one day's age).

We also note the failure of cement to meet the requirements of the Libyan and British standards after three months and more than storage, which stipulates that the minimum compressive strength should be within 21 to 23 N/mm^2 and 39 to 41 N/mm^2 at the age of 3 and 28 days, respectively, either when comparing the results of the tests with the Iraqi standard.

The storage period can be for a longer period that may extend to more than six months, as it requires that the minimum compression strength be 15 N/mm^2 and 23 N/mm^2 at the age of 3 and 7 days, respectively, as shown in Table 5.

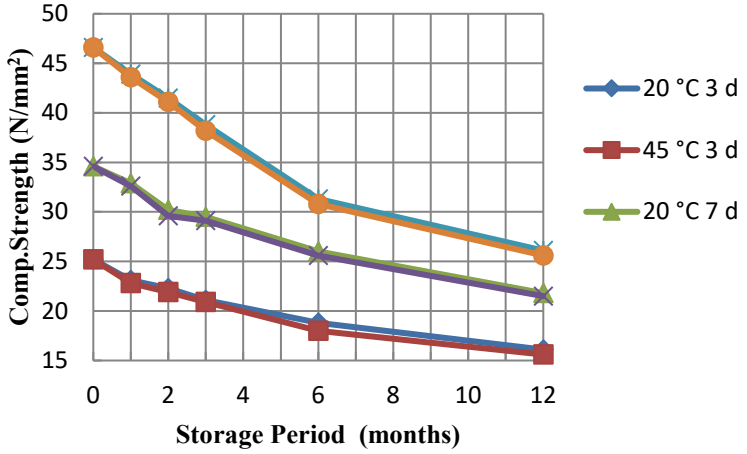

Fig. 3. Effect of storage period temperature on Compressive strength of Portland cement.

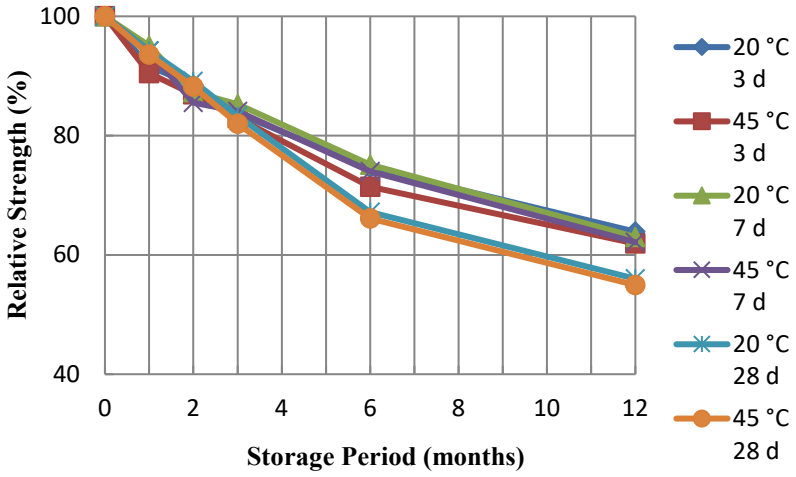

Fig. 4. Effect of storage period temperature on relative strength of Portland.

Table 5. Results of compressive strength.

Age Test (day) Storage Temperature (°C)		Results of Compressive Strength (N/mm^2) at Storage Period						BS 12-1996	IQS 5-1984	LQS-340-1997
		Day	Month							
		1	1	2	3	6	12	N/mm^2		
3	20	25.2	23.1	22.3	21.1	18.8	16.1	>21	>15	>21
	45	-	22.8	21.9	20.9	18.0	15.6			
7	20	34.6	32.9	30.2	29.5	26.0	21.8	-	>23	-
	45	-	32.6	29.6	29.1	25.6	21.5			
28	20	46.6	43.9	41.5	38.8	31.3	26.1	>39	-	>41
	45	-	43.6	41.1	38.2	30.8	25.6			

4. Conclusions

The results of the research can be summarized by the following conclusions, by increase of the storage period of the cement in the normal and hot weather circumstances increases the negative impact on the properties of cement. The proportion of water/cement must be increases to obtain the standard consistency and reduces the time of initial and final settings, while after the age of one month begins to increase up to one year. Compressive strength decreases at all ages of the test 3, 7 and 28 days. The effect of hot weather circumstances compared to the normal weather for the same tests and the same ages are very little. The increasing of the storage period in normal and hot weather circumstances does not affect the compliance of Portland cement with the requirements of British, Iraqi and Libyan specifications in the tests of the initial and final setting time, but it fails to meet the requirements of these specifications in the compressive strength test after the age of more than three months.

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