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Full Length Research Paper

Effect of the physical parameters on the quality of Ordinary Portland cement of Jordan

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This study discusses different physical parameters of the Ordinary Portland cement (OPC) that is produced and available in Jordan, and their comparison with Jordan standard specifications which include Blaine, compressive strength at different ages, consistency, setting time and expansion. All the results are presented to provide both quantitative and qualitative notion of several locally produced ordinary Portland cement. However, most of the constituents that were determined experimentally were within the range of the standard values. The possible reasons for variation in physical parameters and their consequences have been discussed. It has been found that Alrajihi cement has the best quality in all the samples studied with reference to their physical parameters.

Key words: Ordinary Portland Cement, physical parameters, Jordan cement.

INTRODUCTION

Cement industry is considered as a strategic industry, because it is directly related to the work of construction and reconstruction. It uses hydraulic cement as the association of mortar or concrete components. It is with this industry that a simple comparison can be made with the major industries, which depend on the availability of raw materials that are necessary for such comparison. There are five cement plants in Jordan: Alrajihi cement, Ashamalia cement, Arabia cement company and La farge Group which has two cement plants, one in Fuheis (Fuhese cement) and the other in Ashaedia (Ashaedia cement). All these cement plants produce ordinary Portland cement (OPC).

The basic mixture that the cement industry consists mostly of is clay and limestone, which is heated at a temperature sufficient to cause a reaction between them for the production of calcium silicate (Iffet and Emek, 2003; Noor ul-Amin, 2010; Strydom and Potgieter, 1999).

The use of poor quality cement in structural and constructional works may cause loss of durability and properties. So, quality assurance of OPC has become an important and critical factor. The cement, which is used in construction works, must have certain qualities in order for it to play its part actively, otherwise it will create a number of problems. When these properties lie within a certain spiced range of standards, the engineer is confident that the cement performance will be quite satisfactory. Moreover, based on these properties, it is possible to compare the quality of cement from different sources. A number of tests are performed in the laboratories of cement industries to ensure that the cement complies with the desired quality and meets the requirement of the relevant standards (Miller and Conway, 2003; Noor ul-Amin, 2010). There are several brands of OPC available in the local market of Jordan, whose chemical ingredients are the same, but variations in their physical parameters occur due to the variation in the amount of chemical constituencies.This study aims at investigating the physical parameters of OPC and comparing it with Jordan standard specification.

Basic chemistry of Portland Cement

The raw material of cement consists of a mixture of limestone, clay (Argel) of shale, silica, iron oxide and alumina (Miller and Conway, 2003; Noor ul-Amin, 2010; Bensted, 1980; Strydom and Potgieter, 1999; Amin et al., 2009), and is customized with two additional articles by circumstance and the nature of each plant, namely sand and iron which are the so-called corrective materials.

Limestone is essentially a $CaCO_3$ calcium carbonate, but a valuable nature reserve due to the impurities like the SiO_2, Al_2O_3, Na_2O_3, Fe_2O_3, CaO, Na_2O_3 and Fe_2O_3.

Sand consists of the head of CaO and iron consists mainly of Fe_2O_3. Installation cement, which is another term for chemical composition, consists of cement from four oxides namely SiO_2, Al_2O_3, CaO and Fe_2O_3. The primary source of CaO is limestone and it becomes very high in temperatures from $CaCO_3$ to CaO. Moreover, it will be seen later that the primary source of $Al2O_3$, SiO_2 and Fe_2O_3 is clay, sand and iron, respectively (Noor ul-Amin, 2010). The addition of these raw materials and the specific intervention of grinding these raw materials massively in a mill until the degree of softness is reached is called raw milling. This did not take place in mills that contain chemical reactions, but only grinding of raw materials and the use-fulness of this grinding (which are all particles of the interactions) increased the surface area of the granules equipped to enter into the chemical reactions. The percentages of valuable raw materials are almost around 75% of the stone, 20% of the clay, 3% of the sand and 2% of the iron. These percentages vary depending on the results and analysis. Heating the raw material and flattening it for it to enter into the oven and transfering the $CaCO_3$ to CaO is converted in accordance with the following formula:

$CaCO_3$ CaO + CO_2

When the temperature of 950°C interacts with the four oxides, it shows an interference on the raw material in the oven. The inside oven combines the four component oxides of the so-called phases of clinker C_3S, C_2S, C_3A and C_4AF. These four articles were called a clinker, because a raw material, in a valuable cement industry, can issue a clinker or enters the next stage of cement processing. It should be noted that the four phases stand for the following: C stands for CaO, A for $Al2_2O_3$, S for SiO_2 and F for Fe_2O_3, while their temperatures at 1450 C are at the end of the furnace when the flame is up (Bye, 1999).

Experimental study

Cement samples were collected from local market of the five cement plants namely; Alrajihi Cement, Ashamalia Cement, Arabia Cement Company, Fuheis Cement and Ashaedia Cement, and were stored in polyethylene bags and carried to the laboratory for study. For each brand of cement, three samples were collected from different stores with different dates and each sample was about 1 kg. All tests were conducted according to the Jordanian standard.

Determination of compressive strength

For studying the effect of compressive strength of the blanded mortar, mixes were prepared by adopting a cementitious sand ratio of 1:3. The blends were sufficienlty mixed in dry and wet condition for four minutes, and were cast into mould of 40 mm × 40 mm × 40 mm using a vibrating machine with normal speed 1200 r/min for 120 s in order to get compact cubes. The temperature of the mixing room was kept at 20 ± 2°C and relative humidity of 65%. The molded samples were placed in the moist curing chamber for 24 h at a temperature of 20 ± 1°C and relative humidity of 90%. After 24 h, the specimens were stripped from their moulds and were placed in water curing tank having a temperature of 20 ± 1°C until testing. A Toni tecknik compressive strength machine with a load range of 0 to 300 KN and a loading rate of 24 KN/sec was used for the compressive strength. The compressive strength of the specimens was measured according to Jordan standard specification "JS. 30-1, 2005" after 3, 7 and 28 days from the mixing date (JS, Specification for Portland cement, 2005). For each age, three specimens of every mixture were tested and the mean value of these measurements was reported.

Determination of standard consistence and setting time

The standard consistence of cement was determined by Vicat apparatus. About 400 g cement and a measured quantity to water were mixed vigorously on impervious surface by means of two trawls for 240 s. The mould was filled immediately with the cement paste and the surface of cement was smoothed in the mould. The plunger was lowered to touch the surface of the cement paste and was allowed to sink in the surface.

The same procedure was performed with different paste containing different amounts of water and the amount of water was noted for which the plunger remained at about 5 mm in the bottom of the mould. The cement paste, which was already used for standard consistence, was used for the study of setting time. The setting time was determined at 20°C and 65% relative humidity.

Determination of expansion

About 100 g of the cement was mixed with sufficient quantity of water to give a standard consistence. The mould was placed on a glass plate and filled with cement paste, keeping the split closed. The second glass plate was placed on the mould and a small weight was placed on it. The whole apparatus was immersed in water at a temperature of 20°C and left for 24 h. The mould was removed from the water, and the distance separating (expansion) the indicator points was measured.

RESULTS AND DISSUSSION

The compressive strength of all the studied samples at 3, 7 and 28 days of hydration time is shown in Figure 1. It is obvious from the figure that minimum compressive strength after three days of hydration is that of Fuheis cement (14.3 N/mm^2), while maximum is that of Alrajihi cement (27.8 N/mm^2), and the minimum limit is 15 N/mm^2 according to Jordan standard specifications.

The minimum compressive strength after seven days was observed in Fuheis cement (20.8 N/mm^2), while the maximum was observed in Ashamalia cement (35.8 N/mm^2). However, the lower limit of compressive strength at seven days (24 N/mm^2) was observed according to Jordan standard specification. Similarly, the lowest value of compressive strength at twenty eight days was found to be 35.79 N/mm^2 for Ashaedia cement and the highest as 45.96 N/mm^2 for Alrajihi cement, which should not be less than 34.5 N/mm^2 according to Jordan standard specification. These results in Table 1 show that the studied samples have compressive strengths at all ages within the limits.

The proper lime content is limited due to the lower early

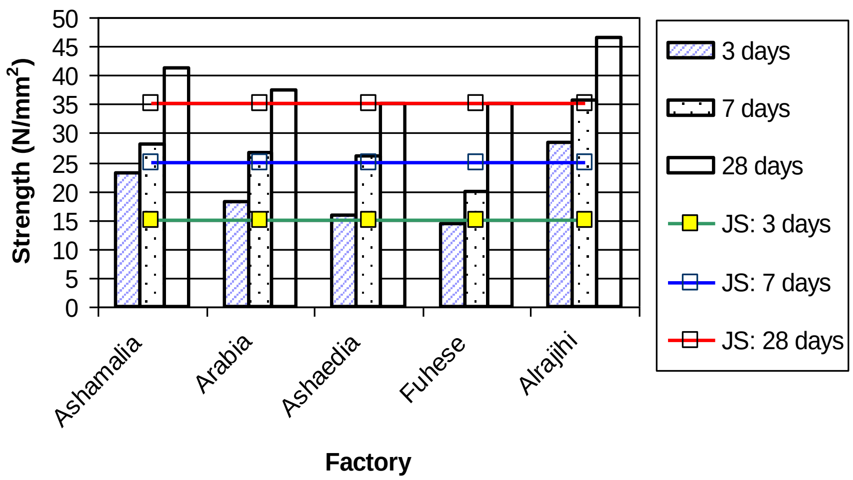

Figure 1. Compressive strength of different brands of cements.

Table 1. Physical properties of different brands of cement.

Physical test	Standard	Ashamalia	Arabia	Ashaedia	Fuhese	Alrajihi
Compressive strength (N/mm^2)						
3 days	15	22.8	17.9	16.3	14.3	27.8
7 days	25	28.2	26.5	25.9	20.8	35.8
28 days	35	41.1	36.7	35.2	35.1	45.96
ConsIstency (%)	28	28.2	27.8	27.5	26.1	30.02
Fineness, Blaine (cm^2/g)	2250	3183	3080	3117	2565	2989
Setting time (min)						
Initial	45	135	168	155	165	145
Final	600	235	290	245	245	235
Soudness (expansion) (mm)	10	1.75	1.55	1.98	1.88	1.65

strength prouced when the lime content of OPC is too low, and unsoundness when it is too high (Paraskeva et al., 2007; Antiohos et al., 2007). High lime content is associated with early strength, whereas slightly lower content of lime favors ultimate strength which develops gradually over a long period of time. In order to increase the strength, it is necessary to raise the lime content or the grinded raw material, or both, but higher temperatures are required to burn the high lime mixtures.

Figure 2 shows consistency of all the studied cement samples. It is obvious from the figure that Fuheis cement has a normal consistency of 26.10%, while Alrajihi showed 30.02% and the minimum limit according to Jordan standard (JS) specification is 28.00%. From the present investigation, it is clear that only Ashamalia and Alrajihi cement have consistency within the permissible range, while all other cements have lower values of normal consistency.

The setting time for all the studied cement samples and their comparison with Jordan standard specification is shown in Table 1. When comparing the values in Table 1, one can observe that Ashamalia cement has the lowest (135 and 235 min) and Arabia cement has the highest (168 and 290 min) initial and final setting time respect-tively, while according to Jordan standard specification, the lower limit of initial setting time is 45 min and the upper limit is 600 min.

The setting time of the cement when spaced out by other parameters may also be closely related with the lime content in clinker and cement. If the lime content is kept fixed, and the silica is too high, which may be accompanied by a decrease in alumina and ferric oxide, the temperature of burning will be raised automatically and the special influence of the high lime will be lost. If

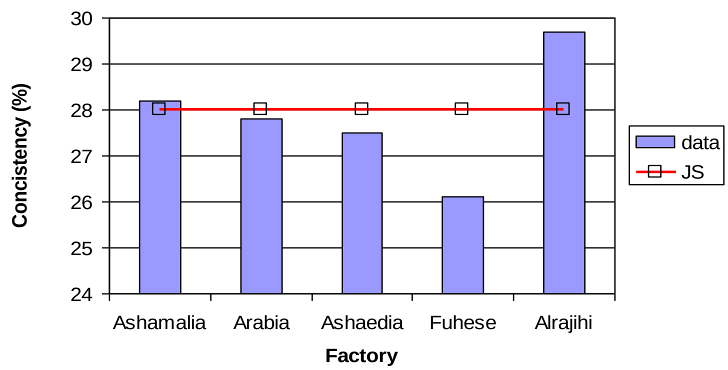

Figure 2. Consistency of different brands of cements.

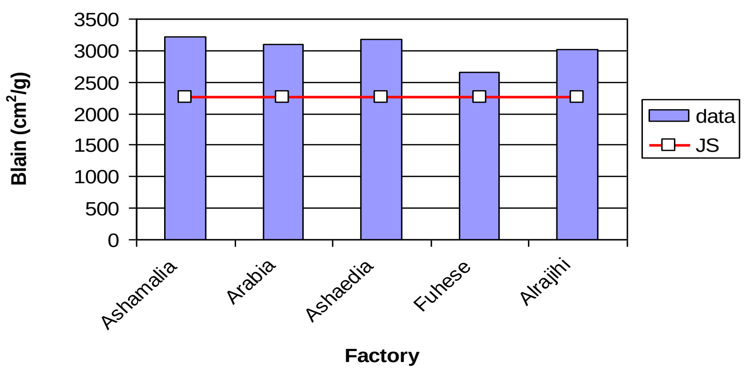

Figure 3. Blaine (fineness) of different brands of cement.

the lime content is too low, which means an increase in the alumina and ferric oxide, the cement may become quickly-set and may contain a larger amount of alumina compounds, which appear to be of little value for their cementing qualities. Rapid setting is undesirable, and is not permitted by the standard specifications, because the cement is set up so rapidly that it cannot be properly worked in the forms before staining occurs (Noor ul-Amin, 2010; Bye, 1999).

Another factor that affects the setting time of the cement is the amount of sulphuric anhydride. High content of SO_3 increases the setting time (Paraskeva et al., 2007). It is clear from Table 1 that all the cement produced in the Jordan have the setting times within the limits of standard specification. Table 1 also shows soundness (expansion) observed for all cement samples. The maximum expansion was observed in Ashedia (1.98 mm) and the minimum in Arabia cement (1.55 mm), while the upper limit of Le-chatelier expansion according to Jordan standard specification was 10 mm. However, it is concluded that all the cement samples have the expansion values within the permissible limits.

The expansion of cement from other factors is closely related with magnesia contents, especially at later ages (Pandey and Shukla, 1980). If magnesia goes above 2%, it appears in the clinker as free MgO (periclase). Periclase reacts with water to form $Mg(OH)_2$, and this is the slowest reaction among all other hardening reactions. Since $Mg(OH)_2$ occupies a larger volume than MgO and is formed on the same spot where the periclase particle is located, it can split apart the binding of the hardened cement paste, resulting in expansion cracks commonly known as magnesia expansion (Antiohos et al., 2008; Hewlett, 1997). Apart from the pericalse free lime, it may cause expansion and cracking of the mortar or concrete.

Figure 3 shows the fineness of Blaine for all the studied cement samples. The observed Blaine was 3183, 3080, 3117, 2565, and 2989 cm^2/g for Ashamalia, Arabia, Ashaedia, Fuhese and Arajihi cement respectively, while it should not be less than 2250 cm^2/g according to Jordan standard specification. It is not difficult to deduce from the argument that cement samples have fineness in accordance to Jordan standard specification.

The possible reaons for the variations in physical parameters may be attributed to the variation in the chemical compostion of the raw mixture, non homogeneity of the material, poor burning of kiln feed in the kiln, variation in retention time in the kiln, grain size of the cement, etc

(Sebbahiet al., 1997).

Conclusion

The physical parameters of almost all the cement samples were found in accordance with the permissible range of Jordan standard specifications. However, some minor deviations were found in some of the samples which may be due to different reasons, as the samples were collected from the market. The ideal range of physical parameters of Portland cement is the problem of the research chemist. But out of the experience of observant operatives and the formulation of experimentally demonstrated principles by engineers and chemists, certain rather than definite limitations in the feasible composition of a cement have been established. Within those limits, experience has shown that the mixture behaves satisfactorily in the kilns and produced good cement. On the other hand, outside those limits, experience has shown that trouble in burning may result or that the cement may be of inferior quality.

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