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Investigation on the performance of different cement brands commonly used in Libya

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Abstract

The quality of cement is one of the important factors related to the strength and durability of structural concrete. Large quantities of cement are used in building and construction works in Libya. However, no comparative study has been made to investigate the mechanical and physical properties of the cement brands. Consistently, fineness, soundness, setting time and compressive strength of each of the cement brands were determined according to EN and ASTM standards. All brands of cement tested have normal and acceptable consistencies. The soundness and fineness values for all the brands tested fall below the maximum allowable value of 10 mm and 10% respectively. Cement brands with more setting time (both initial and final) show lower compressive strength. However, based on the results of compressive strength, all the cement could be acceptable for normal construction works where strength is paramount cement BE could be given preference.

Keywords: Cement brands, compressive strength, physical properties, cement paste, cement mortar.

1. Introduction

Construction works in Libya start-up to growth to replace or repair damaged building as well as a significant number of infrastructure works after a civil war. As a result, the Libyan market is facing a major challenge due to an increase in cement demand. To overcome this challenge, several brands of local and exported cement are used today.
The quality of cement is an important requirement and has to be taken into account to ensure the durability and quality of the construction project. Variation of cement quality may occur due to change in the properties of raw material, kiln temperatures, as well as fineness upon grinding (Olonade et al., 2015).
With so many *different cement* products on the global market, the evaluation of physical and chemical properties of cement is important to use the suitable grade and type before commencing any construction work. Failure of concrete structures is usually attributed to incorrect selection of material amongst other factors (Bhamere, 2016; Thomas & Ban, 1990).
Portland cement is considered to be one of the most conventional as well as one of the most commonly used binders in making concrete structure. A typical Portland cement clinker is produced by mixing limestone, clay, sand and iron oxide and heating them at elevated temperatures in rotary kilns. Once the clinker has sufficiently cooled a small amount of gypsum is added in order to control the setting time (Almabrok, 2014).
Portland cement is composed of four basic chemical compounds. These includes tricalcium silicate (C3S), dicalcium silicate (C2S),tricalcium aluminate(C3A), tetracalcium luminoferrite (C4AF). Among these components silicates plays a crucial role in the strength gaining. C3S easily reacts with water, results in more heat of hydration and responsible for early strength development, whereas, C2S react slowly, produces less heat of hydration and responsible for later strength development (Bhamere, 2016).
Cement quality can be different from producer to producer due to vary in raw materials properties or manufacturing process. These changes can significantly affect the properties of mortar or concrete with using different cements (Olonade, et al., 2015). The main properties expected of cement in construction, are permanency of structure, strength and rate of setting suitable to demand of the work at hand (Duggal, 2008). Large quantities of cements are used in building and construction works in Libya. However, most of the construction industries rely on the experience, availability and cost in selecting the brand of cement to be used in their projects. So, quality control has become an important and critical factor of cement production (Elbagermia et al., 2014).

No enough investigations are available in the literature regarding the performance of cements in Libyan market when use in structural concretes. The aim of this work was to investigate the mechanical and physical properties of some selected brands of cement available in the Libyan market; compare the results with standards to determine conformity and to compare the results among the brands.

2 METHODS AND MATERIALS

2.1 Materials

Four different brands of cement ratifying the criteria of CEM I (El BorgeZliten, Al Borge Egypt, Helwan Egypt, and Dernah)were collected from the Libyan market and labelled as BL, BE, HE and DC respectively. After collection, each cement bag was kept in an air-tight plastic bag to avoid surface contamination and unwanted hydration with the moisture present in the air.
The fine aggregate used was locally available silica sand collected from Awjilah town and called Awjilah sand with an absorption capacity of 0.20%, specific gravity of 2.60.The particle size distribution of Awjilah sand by sieving method (ASTM C 136, 2001) is illustrated in Figure 1. The water source used was of drinking water standard (pH 7.4;2.29 μS/cm).

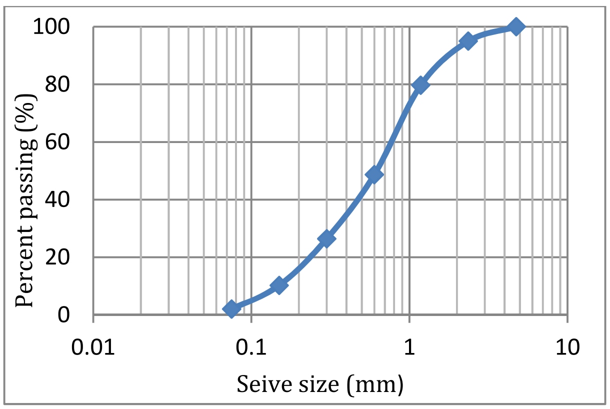

Figure1: Particle size distributions (sieving method) of Awjilah sand.

2.2 Testing procedures

2.2.1 Cement paste

2.2.1.1 Fineness Test

A 50g of each brand of cement was weighed approximately to the nearest 0.01g and then sieved through 150μm sieve. The Weight of cement retained on the sieve was measured and the percentage of weight retained with respect to initial weight was determined. This procedure was in line with the provision of ASTM C184 (1994).

2.2.1.2 Standard consistence, setting times and soundness tests.

The standard batch consisting of 650 g of cement for each sample with sufficient water to give a paste of normal consistency in accordance with the procedure described in ASTM C187 (1998) was carried out. The soundness of the cement paste made from each sample was conducted, following the procedure highlighted in EN 196-3 (2016). Setting times (initial and final) of paste made from each of the samples were investigated as prescribed by ASTM C191 (2008).

2.2.2 Cement mortar

2.2.2.1 Mix proportions

The composition of the mortar was in accordance with ASTM C270 (2014) with the mix proportions being 1 part of cement and 3 parts of sand (by mass) at a fixed water/cement ratio (w/c) of 0.50. Each mortar batch comprised cement (450 g), fine aggregate (1350 g), water (225 g).

3.2.2.2 Mixing, casting and curing of test samples

The mixing process followed the procedure outlined in ASTM C305 (2014) using the Hobart mixer (model N-50 G) mixer where all laboratory work was conducted at 22 ± 2 C°. The moulds containing consolidated mortar were sealed in zip lock plastic bags to prevent moisture loss and stored in a moist atmosphere for 24 hours. Once the samples were stripped from their respective mould, demoulding took place thereafter and triplicate mortar specimens having 50 x 50 x 50 mm dimensions were placed into a curing tank filled with lime saturated water ASTM C511 (2003) for up to 28 days at a temperature of 22 ± 0.5°C.

2.2.2.3 Workability and compressive strength

The workability tests were performed only for the mortars, due to the excessive fluidity of the cement pastes. Compressive strength tests are also not carried on neat cement paste due to difficulty in moulding as well as excessive shrinkage and subsequent cracking of neat cement paste. Flow was determined by the spread diameter on a hand driven flow table in accordance with ASTM C1437 (2007)

Compressive strength of mortar was tested at the age of 3, 7 and 28 days using an ADR –Auto V2.0 250/25 compression testing machine (Figure 2) with a maximum capacity of 250 kN following the listed procedures of the test method ASTM C109/C109M, 2013. Vertical load at a rate of 0.99 kN.s^{-1} was exerted on the specimens and records were taken of the maximum load indicated by the testing machine (load at failure).

Figure 2: ADR-Auto compression testing machine

3 RESULTS AND DISCUSSION

3.3 Standard consistence, fineness, soundness and settings times of samples

Table 1 summarizes the results of tests on the standard consistence, fineness, soundness and setting times of the cement types studied.

Table 1: Setting times and physical properties of the selected cement brands

Properties	Cement Brand			
	DC	BE	HE	BL
Standard consistency (%)	27	28	26	27
Fineness (%)	4.4	4	5.8	5.1
Soundness (mm)	0.5	1.5	2	1.5
Setting Times				
Initial (min)	134	130	146	140
Final (min)	280	276	290	285

It can be seen that the consistency (water demand ratio)of all cement types varied from 26% to 28%. This satisfies the ASTM standard requirements (22% to 30% by weight of dry cement) for normal consistency of cement paste. Consistency increases with increase in fineness of cement. Finer cement offers a greater surface
area and would be expected to take more water during the hydration process (Olonade, et al., 2015).This performance is in agreement with the corresponding fineness and consistencies values shown in Table 1. In addition, from the results obtained, it can be seen that the fineness of all cement types varied from 4% to 5.8%. These values are below the value of 10% specified in the standards for Portland cement.
As for the soundness, the results suggested that all the cement types had expansion between 0.5 – 2 mm. Thus, all cement types satisfy the EN-196-3 (2016) requirement which specifies an expansion not more than 10 mm for Portland cement. This shows all the brands of cement tested have the least tendency to crack if used during construction(Anejo et al., 2014).

Setting behavior is another most important property of cement, which is greatly influenced by clinker reactivity and by cement fineness(Graeme, 2003). The setting times of the cement types, shown in Table 1, suggested that HE cement would likely have a delay in the initial setting by about **16** minutes when compared with that of BE cement. A similar trend was observed in case of final setting, while other cement types fell in the range of 134 – 140 and 280 – 285 minutes for initial and final setting times, respectively. Generally, the changes noticed in setting times of cement can be attributed to changes in their fineness and clinker composition(Olonade, et al., 2015).

3.4 Workability and compressive strength

The flow of all mortar mixes were found to vary in between 72% to 79% which is suitable for proper consolidation of the sample by hand. This result indicated that the studied cement types have no significant effect on flow (Figure 3).

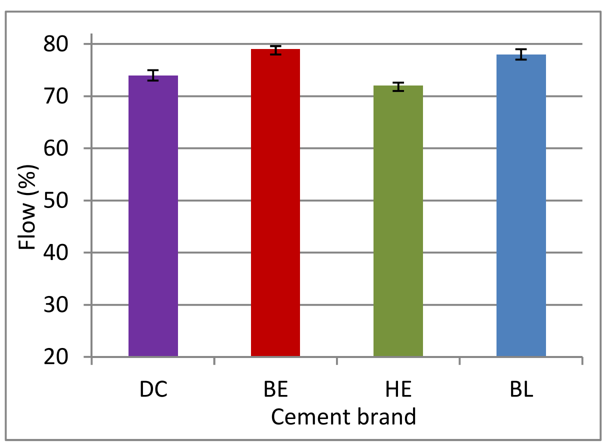

Figure 3: Effect of cement brands on flow of mortar mixes (Error bars equal average ± standard deviation)

The variation of compressive strength at 3, 7 and 28 days for cement mortar made with different brands of cement is shown in Figure 4.

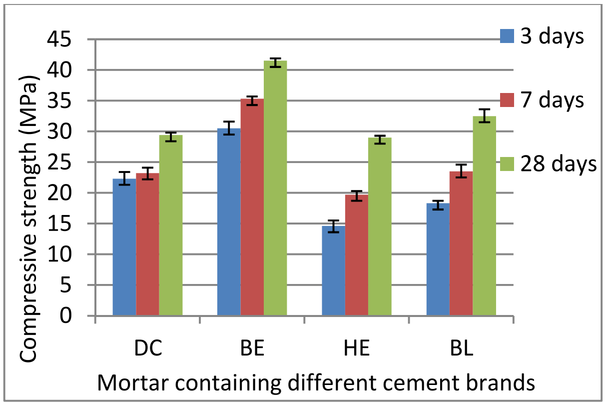

Figure 4: Variation of Compressive strength with age (Error bars equal average ± standard deviation)

It can be seen that the 3 days test result showed mortar containing BE cement had the highest compressive strength followed by DC then BL and finally HE cement. Their 3 days strengths were 30.5, 22.3, 18.3 and 14.6 MPa respectively. Almost the same trend was noticed with the 7 days result. Mortar made with BE cement produced the highest compressive strength (35.3 MPa) among the others whereas mortar prepared with BL, DC and HL cement had a compressive strength of 23.5, 23.2 and 19.7 MPa respectively.

The behaviour of 28 days compressive strength of cement mortar made with BE was quite different from the others. Cement mortar made with BE cement brand showed the highest compressive strength of 41.5 MPa whereas the cement mortar contained DC, HE and BL had a compressive strength of 29.4, 29.0 and 32.5 MPa respectively. The better performance of the mortar made with BE cement, in term of strength, could be partly attributed to its mineral composition and fineness(Hugjian et al., 2014; Naceri & Benia, 2006).
The compressive strength continued to increase with age in all cement mortars up to the 28 days irrespectively of the brand of cement types (Figure 4).This continual increase in strength with curing age indicates that cement hydration occurs in all mixes but to a varying extent. The continuous increase of the compressive strengths of the cement mortar with time can be explained by the hydration reaction that is a never-ending process (Elena & Lucia, 2011).Formation of CSH gel during the hydration reaction considers the main source of strength development(Almabrok, 2014).It is also seen that about 79, 85, 68 and 72%of the 28-day strength was attained at the early age of **7** days for mortar containing DC, BE, HE and BL cement brands respectively. The compressive strength goes on increasing rapidly in the early stage and slow in later days(Shetty, 2006).

In general, the results showed that the longer time of setting (both initial and final) will lead to a decrease in compressive strength. Correlations between the setting time and compressive strength of cement mortar can be used to predict the strength of cement from the setting time data that can be quickly determined in the laboratory(Mohammed et al., 2012).
Furthermore, it can be noticed that the relation between the cement fineness and compressive strength of all mortar mixes is an inverse relationship (Figures 6). Mortars made with finer cement showed higher compressive strength. More cement fineness increases the rate of hydration and thus accelerates strength development especially at the early ages(Aghabaglon et al., 2017; Al-Swaidani et al., 2016)

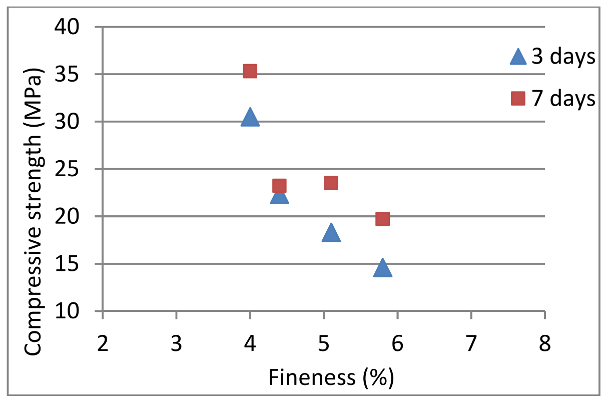

Figure 5: Relationship between fineness and compressive strength

CONCLUSION

In Libya, the demand for cement is increased due to the huge construction projects to replace or repair damaging building and infrastructure works after a civil war. To meet the demand for cement, several brands of local and exported cement are used today with lack of quality control. A comparative study to investigate fineness, consistencies, soundness, setting times and compressive strength of different cement brands commonly used in Libya was undertaken. In this study, all the cement brands tested exhibited mechanical and physical properties that meet the requirements of the appropriate ASTM and EN standards. These make them suitable for use in construction where no particular properties are required.

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