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Influence of cement grinding fineness on mortar properties

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Abstract

Used in the construction of buildings, bridges, castles, factories, hydroelectric plants and other structures, cement has been an essential element in the development of the modern world. It is used in these structures in various forms such as concrete and mortar. This study aims to evaluate the effect of cement fineness on mortar properties. The initial setting time of different sizes such as 90µm, 63µm 40µm, called A, B and C were 151, 133 and 115 respectively. During the production of mortars with these different sizes, it was shown that within two days of age, the compressive strength for A, B and C samples were 16.65, 19.45 and 23.1 MPa respectively. These values reached 50.25, 55.05 and 57.9 MPa after 28 days for the same samples. On the other hand, after two days, the flexural strength reached 3.25, 3.86 and 4.49 MPa for A, B and C respectively, while it was 6.98, 7.02 and 7.22 MPa.

Keywords: Cement; Mortar; Fineness; setting time; Compressive strength; Flexural strength

1. Introduction

The cement industry, which is used in the production of various infrastructure and construction projects (building structures, bridges, highways, water conservation projects and other vital infrastructure), plays a crucial role in the global economy [1, 2]. The World Cement Association estimates that cement production will reach 8.2 billion tonnes by 2030 [1]. Cement has become an essential element in the production of mortar [2] and concrete [3]. Given these hydraulic binder properties, its strength and adaptability, the fineness of the cement plays a predominant role in the bonding between the grains of concrete or mortar [4, 5]. A large national survey evaluated the impact of a number of researchers who found that changing the fineness of cement has a significant effect on key properties of cement and concrete, such as setting time, consistency, and compressive and flexural strength for cement and concrete respectively [6, 4]. Several empirical and industrial scale studies have been carried out to improve the durability, chemical effectiveness of cement, quality of additives and especially the fineness of cement grinding [7]. Studies have reported that the fineness of cement has a significant effect on the hydration rate and, in particular, on the strength rate. The finer the cement, the greater the hydration surface area, resulting in faster strength development [8]. The fineness of the

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cement can have a significant effect on the properties of the mortar. Finer cement particles typically result in better workability, increased strength and reduced permeability in the mortar. The fineness of the cement can have a significant effect on the properties of the mortar. Finer cement particles typically result in better workability, increased strength and reduced permeability in the mortar. The increased surface area of finer particles promotes better hydration, resulting in stronger inter-particle bonds and improved overall mortar performance. However, too fine a cement can also lead to problems such as rapid setting times and potential difficulties in achieving the desired consistency. It's important to find a balance in cement fineness to optimise mortar properties for specific applications. Increasing the fineness of the cement also increases the drying shrinkage of the concrete. Grinding fineness appears to be a critical parameter in controlling these mortar properties. Consequently, it is important to select the required cement particle size for better performance in terms of mortar and concrete properties [9, 10, 11, 12]. In their study, it was shown that both particle size and size distribution seem to have a great influence on the properties of concrete [13, 12]. A similar study showed that cement fineness has slight chemical effects on the properties of the cement, resulting in rapid setting and reduced compressive strength [14]. The fineness of the cement can generally be determined by adjusting the granulometry of the cement, with a size of less than 80 µm considered ideal for better results. This can also be achieved by relying on the grinding time of the cement; the longer the grinding time, the greater the fineness of the cement [15, 16]. Few attempts have been made in the literature to investigate the effect of cement grinding time on the properties of mortar or concrete. Most studies have been carried out on the effect of grinding time of additives on the properties of cement, and almost all studies have reported a positive effect on the properties of concrete or mortar. The aim of this study is to investigate the effect of cement fineness on mortar properties. The study involves the use of commercial cement (blank) and the preparation of empirical cements that differ from it in terms of grinding time and method. These different cements were used to prepare mortars for mechanical tests such as compressive strength and flexural strength, and since cement fineness plays an important role in grain consolidation, the setting time of each material was also studied.

2. Materials and Methods

2.1. Materials composition and properties

In this study, commercial clinker (20 kg) from the Hadjar Soud cement plant (Skikda-Algeria) was used to design an experimental cement that would enable several parameters affecting the fineness of grind of the cement on the properties of the mortar to be investigated. Other constituents such as gypsum and slag were also used in the manufacturing of empirical cement. The samples were analysed by XRF and the results are presented in Table 1.

Table 1 XRF analysis results of materials

Compound	Clinker	Gypsum	Blank	Slag	
	Value (%)			Compound	Value (%)
CaO	65.95	28.12	60.16	CaO	42.04
Al_2O_3	5.64	1.50	5.72	Al_2O_3	7.9
Fe_2O_3	3.43	0.78	3.30	Fe_2O_3	3.07
SiO_2	21.7	6.61	24.66	SiO_2	36.88
MgO	0.93	1.24	0.69	MgO	4.77
Na_2O	0.26	-	0.30	K_2O	0.55
K_2O	0,78	0.24	0.50	SO_3	0.35
Cl^-	0.03	0.01	0.032		
SO_3	0.26	40.90	2.7		
LOI	0.92	19.50	1.80		
Total	99.90	98.90		Total	95.56

The prepared cement (10 kg) is a mixture of clinker (75%), slag (18%) and gypsum (5%), which was ground to the appropriate fineness in a ball mill for 5 hours at the Civil Engineering Department of Badji University (Annaba-Algeria).

Six kilograms of the prepared cement were used to produce three other types of cement (A, B and C), differing in fineness only by the amount of time spent regrinding in the cement factory's vibratory shredder. The plant's commercial cement was also used to prepare the different samples for the physical-mechanical tests (strength, consistency and swelling shrinkage) in order to make an objective comparison. Blaine and sieve residue measurements were used to assess the effect of cement fineness. Using the air permeability apparatus and the standard ASTM C204 test procedure (ASTM C204-17, 2017), the Blaine measurement was carried out and three sieves (40 µm, 63 µm and 90 µm) were used to determine the particle size. The test consists of taking 20g from each sample and sieving it using a mechanical device "Alpine". The results of the sample analysis and the Blaine measurement are given in Table 2.

Table 2 Technical properties of different cements

Cement	Grinding time	Mill type	SSB as function of air permeability time		Weight of oversize of different sieves (g)		
			s	cm² /g	90 µm	63 µm	40 µm
A	5 h	Ball mill	63	3630	0.74	2.39	5.06
B	+ 2 min from the first grinding	Vibro-shredder (cement plant)	93	4667	0.1	0.91	3.66
C	+ 3 min from the first grinding	Vibro-shredder (cement plant)	135	5220	0.07	0.63	3.40
Blank	Not defined	Industrial ball mill	200	3419	2.5 (200 µm)		19.35 (45 µm)

2.2. Mortar preparation and setting times

Table 3 Mechanical test results for cements (Blank, A, B and C)

Cements	Setting time (min)		Compressive strength (MPa)			Flexural strength (MPa)		
	Initial	Final	2-day	7-day	28-day	2-days	7-day	28-day
Blank	145	250	15.80	33.8	46.5	3.62	5.72	7.04
A	151	210	16.65	35.65	50.25	3.25	5.91	6.98
B	133	184	19.45	39	55.05	3.86	6.56	7.02
C	115	145	23.10	44.3	57.90	4.49	6.61	7.22

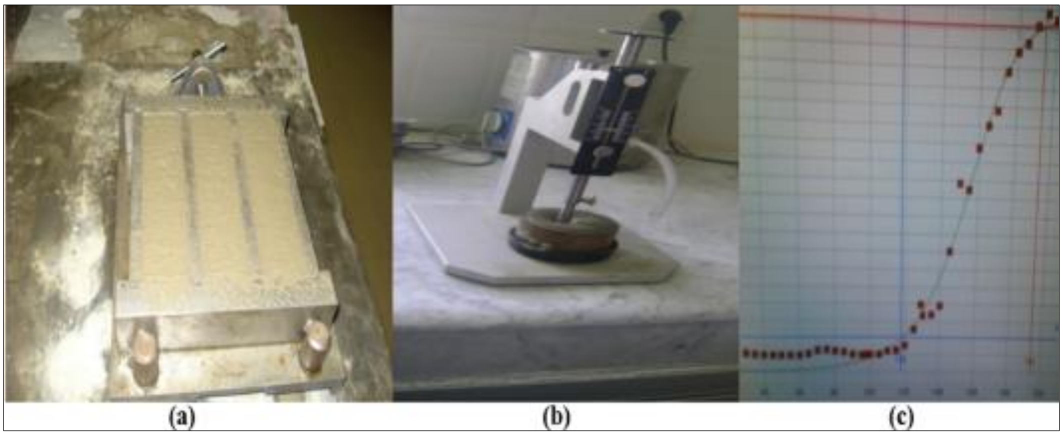

Figure 1 a) Mortar filled mould, b) Vicat apparatus, and c) Mortar setting time curve

The mortars used in the physical-mechanical tests were mixed and cast using a standard mortar prism of 4 cm × 4 cm × 16 cm and a water/binder dilution of 0.5, in accordance with BS/EN 196-1:2005. The prepared mortars (24 hours after preparation) were demoulded and placed in a water tank to set at room temperature (Figure 1.a). These mortars were subjected to short and long term flexural and compressive strength tests using the Toni Technik Press universal testing machine at a loading rate of 120 kN/min. The setting time, which is one of the qualitative characteristics of the cement, was determined by the standard method using a Vicat needle apparatus (Figure 1.b). The setting times (initial and final) (Figure 1.c) and the results of the compressive strength and flexural strength tests are given in Table 3.

3. Results and discussion

3.1. Effect of fineness on mortar setting time

Figure 2, which shows the setting progress of the different cements, clearly shows that the setting time decreases with increasing cement fineness. For example, it can be seen that the setting time started at 145 minutes for commercial cement (blank control) and 151 minutes for cement A, whereas this value was recorded at 20 and 30 minutes less for cements B and C respectively. The detailed analysis of these data seems to conclude that the fineness of the material has a significant influence on the beginning and end of setting. A decreasing gap between the beginning and the end of setting can vary depending on the fineness, it was 105 minutes for the blank cement, 59, 51 and 30 minutes for the cements A and B and C respectively. This can be explained by the fact that the fine grains agglomerate more quickly to form extremely strong bonds, which accelerates setting. Ehikhuenmen et al [12] found similar results, in their study 3 different cement finenesses (150 µm - 75 µm, 75 µm - 45 µm and 45 µm - 0 µm) were used to prepare the mortars to investigate the setting times of each particle size range. The results showed that the setting times decreased progressively as the cement fineness increased (175 minutes (initial setting time) for sizes 150 µm - 75 µm, an initial setting time of 140 minutes for finer sizes 45 µm - 0 µm).

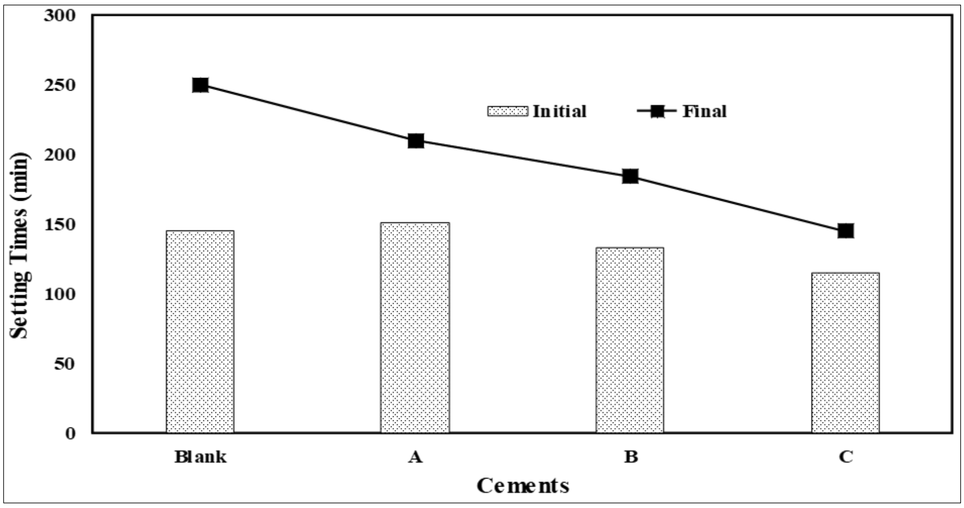

Figure 2 Effect of setting time on cement type

3.2. Effect of compressive strength on mortar

The compressive strength evolution of the different tests is shown in Figure 3 above. In general, it can be seen that the fineness of the cement affects both the short and long term mechanical strength. The average compressive strength at 2 days was 15.7 MPa for the blank cement, whereas it increased by a factor of 3 to 7 for the other cements (A, B and C). The medium and long term resistance was 33-46 MPa for the blank cement, while an improvement of 5-10 was observed for the experimental cements. In their study, Puangprakhon and Bunthai [17] indicated that mortars made with finer cement particles had higher compressive strength than mortars made from control cement.

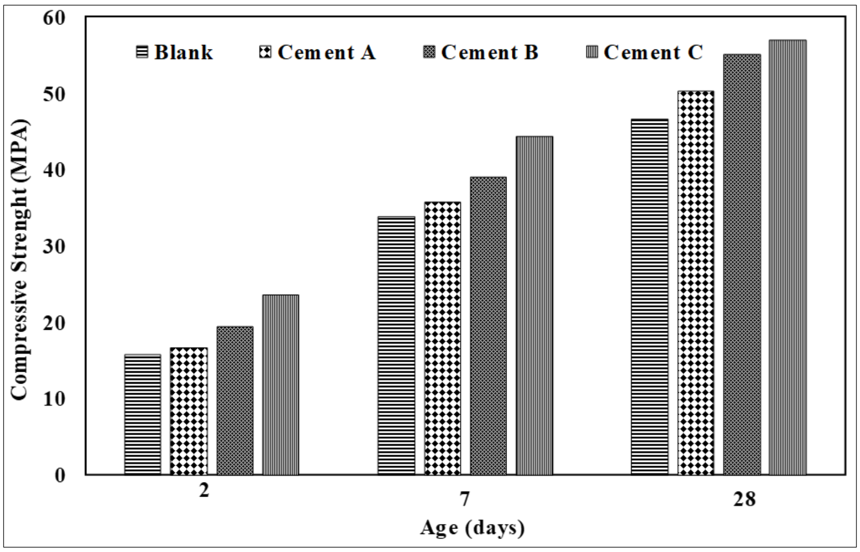

Figure 3 Effect of age on compressive strength of different mortars

3.3. Effect flexural strength on the mortar

The results of the flexural strength tests carried out on different mortars are shown in Figure 4. The flexural strength of all samples, regardless of age, is generally increased by the effect of cement fineness. Around the middle age this tendency seems to be more pronounced. The flexural strength was 3.25 MPa for the blank cement, which seems to be influenced by the fineness of the cement, as this value increased from 0.5 to 1.2 MPa for cements A and C, respectively. After seven days, cements B and C showed the highest resistance (7 MPa), while the resistance of the control sample was 5.72 MPa. It should be noted that at 28 days, no variation in strength was observed for any cements.

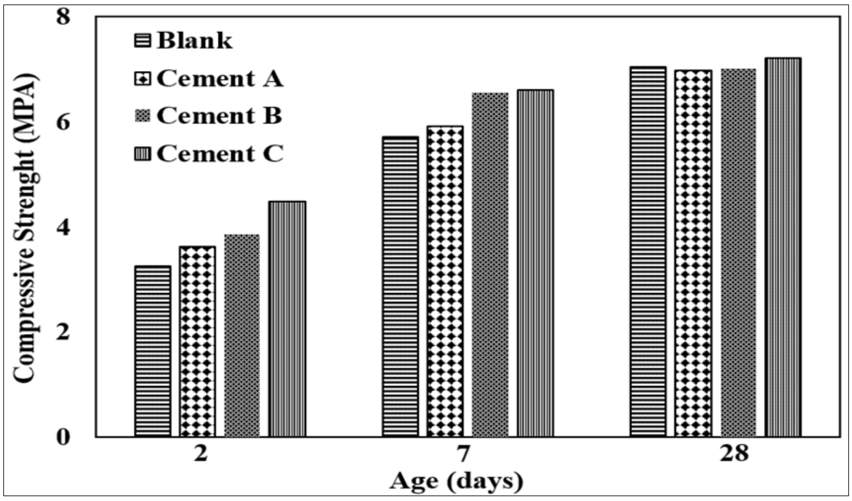

Figure 4 Effect flexural strength by the age for different mortar

4. Conclusions

This study investigated the composition of the materials used in the production of cement, such as clinker, gypsum and slag. A cement of three different sizes was produced. Comparative studies were carried out to investigate the effect of different physical properties on the mortar produced with these different sizes.

Firstly, it was found that the setting time decreased as the cement fineness increased. In addition, cement fineness affects both short and long term mechanical strength, such as compressive strength and flexural strength.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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