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Determination of Setting Times of Mortar Mixtures Prepared with Cement Having Different C_3A Ratios

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Abstract: The duration of concrete transportation to the construction site, its workability and formwork removal time are significantly affected by the setting time of cement. Therefore, it is of great importance to know the initial and final setting times of concrete mixtures in construction applications. According to the literature survey, the setting time of cementitious systems is generally determined on cement paste mixture by the Vicat test. However, it was understood that a limited number of studies were carried out on the determination of the setting time using concrete mixtures. In this study, the effect of cement C_3A ratio variation on the initial and final setting times of cementitious systems was determined using mortar mixtures. For this purpose, mortar mixtures were prepared by using cement having four different C_3A content (2%, 3%, 6% and 9%). The ratios of water/cement and sand/cement as well as slump-flow values were kept constant as 0.485, 2.75 and 27±2 cm, respectively. In order to provide the desired flowability, polycarboxylate ether-based water-reducing admixture (PCE) was used. The initial and final setting times of the mortar mixtures were determined using a concrete penetrometer equipment. According to the results, PCE demand to provide the target slump-flow value increased by increasing the cement C_3A content. In addition, the setting time values reduction was observed with the increase of cement C_3A content. It was determined that the results obtained are compatible with the literature.

Keywords: Setting time, C_3A, Penetrometer, PCE requirement

Introduction

The term setting of cementitious systems is meant to transition cement-based materials from a flowable to a hardened state (Mindess et al, 2002; Hong et al, 2020; Kaya, 2022). It is of great importance to know the initial and final setting times of concrete mixtures in construction applications in terms of the duration of concrete transportation to the construction site, its workability and formwork removal time. However, the setting times of the mixtures can be obtained differently from each other due to the various methods used in practice. This situation can cause serious adverse effects on the properties of cementitious systems. situation can cause (Mindess et al, 2002; Durgun et al, 2022; Lee & Hover, 2016).

The fresh-properties of cementitious systems depend on many physical and chemical parameters. The rate of hydration and workability of the cementitious system are significantly affected by some factors such as the chemical composition of cement, especially its C_3A content and fineness as well as the gypsum type and amount added to its clinker during the manufacturing process (Zingg et al, 2009; Karakuzu et al, 2021; Kobya et al, 2022). C_3A is the most reactive component of cement (Mehta & Monteiro, 2006; Karakuzu et al, 2022). The

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formation of needle-like ettringite as a result of the C_3A reaction consumes some of the free water in the solution and adversely affects the fresh state properties of cementitious systems (Luke & Aitcin, 1990). Therefore, low C_3A content in cementitious systems is preferred in terms of fresh-state properties (Aitcin, 2004; Gawlicki et al, 2010).

The rapid hydration of C_3A seriously affects the setting time of the mixtures. In this context, the C_3A content of cement is one of the important parameters to be considered in terms of setting time and workability properties. The setting time of cement is usually measured with the Vicat test. It was understood that there is detailed information in the literature on this subject. However, it was determined that there is a lack of information in the literature about the determination of the setting time of mixtures using penetrometer apparatus. In this study, the effect of different C_3A ratios on the setting time of mortar mixtures was investigated. For this purpose, mortar mixtures were prepared using cement with 4 different C_3A ratios produced from the same raw material. A penetrometer was used to determine the initial and final setting times of the mixtures.

Materials and Method

Materials

In this study, CEMI 42.5R type cement having 4 different C_3A ratios and conforming to EN 197-1 was used. The chemical composition, as well as physical and mechanical properties of cement provided by their manufacturer is shown in Table 1. The designation of the cement was concluded according to its C_3A ratio. Some properties of the polycarboxylate based water reducing admixture (PCE) used in the preparation of the mortar mixtures are shown in Table 2. The CEN sand in accordance with EN 196-1 was used in the preparation of mortar mixtures.

Table 1. Chemical composition as well as physical and mechanical properties of cements

		Cement type			
Chemical Properties	Unit	C2	C3	C6	C9
C_3A	%	2.1	3.6	6.8	9.05
C_3S	%	58.9	47.6	52.9	48.42
C_2S	%	9.8	20.2	16.7	21.25
C_4AF	%	16.8	16.1	12.5	10.07
Physical and mechanical properties					
Specific gravity		3.21	3.20	3.17	3.1
Specific surface area	cm^2/g	3786	3754	3659	4259
28-day compressive strength	MPa	48.5	48.4	51.0	50.7

Table 2. Some properties of PCE

Type	Solid content (%)	Density (g/cm^3)	pH 25°C	Chloride content (%)	Alkali ratio, Na_2O (%)
Polycarboxylate based	40	1.070	2-5	<0.1	<10

Method

The mortar mixtures were prepared in accordance with ASTM C109. In all of the mortar mixtures, the water/cement ratio, sand/cement ratio and target slump-flow values were kept constant as 0.485, 2.75 and 270±20 mm, respectively. Hobart mixer was used to prepare the mixtures homogeneously. Slump-flow value of mortar mixtures was determined in accordance with ASTM C1437.

The initial and final setting times of the mortar mixtures were determined using a penetrometer device in accordance with ASTM C403. For each cement type, the mortar mixture in which the target slump-flow (27±2 cm) values were provided by using different ratios of PCE was prepared. The prepared mixtures were filled into 150 mm cube molds and recorded the time at which initial contact was made between cement and mixing water. When the penetration needle of the penetrometer device with a bearing-area of 16 mm^2 penetrates 25 mm into the specimen, the resistance value was determined as the first penetration resistance. From this measurement, the penetration test was repeated at 30-minute intervals. The time during which the penetration resistance of 3.5 MPa was determined was obtained as the initial setting time, and the time during which the penetration resistance of 27.6 MPa was determined as the final setting time. The average of three specimen measurements was taken to determine the initial and final setting times. The penetrometer device and the experiment for determining the setting times are shown in Figure 1 and Figure 2, respectively.

Figure 1. Penetrometer device

Figure 2. Determination of the initial and final setting times of specimens with penetrometer

Results and Discussion

The PCE requirements and slump-flow values of the mortar mixtures are shown in Table 3. For C3, C6 and C9-cement containing mortar mixtures, the PCE requirement to provide desired slump-flow value increased by 2%, 4% and 52%, respectively, compared to the mortar mixtures prepared with C2 cement. Due to the high reactivity of C_3A, the formation of ettringite in large quantities causes the reduction of free water in the solution, thus negatively affecting the flow performance of the mixture (Mardani-Aghabaglou et al, 2017). Therefore, the increase in the C_3A ratio of cement led to an increase in the PCE requirement for the target slump-flow value of the mixtures.

Table 3. PCE requirement and slump-flow value of the mixtures

	PCE requirement (%)*	Slump-flow value (cm)
C2	0.260	26.0
C3	0.265	27.8
C6	0.270	27.9
C9	0.395	26.9

*by weight of cement

The penetration resistance values and the initial - final setting times of the mortar mixtures are shown in Figure 3. Compared to the mortar mixtures prepared with the C2 cement, the initial setting times of the C3, C6 and C9 cement-containing mixtures decreased by 6%, 8% and 9%, respectively, with the increase in the C_3A content. It was observed that there was a decrease in the final setting times of 2%, 4% and 8%, respectively. As can be seen from the results, the increase in C_3A content led to a decrease in the setting times of the mortar mixtures. In addition, the reduction in initial setting times is slightly greater than in final setting times. This is due to the fact that C_3A component is the most reactive component in cement, as stated before. Therefore, the increase in C_3A content was more effective on the initial setting time.

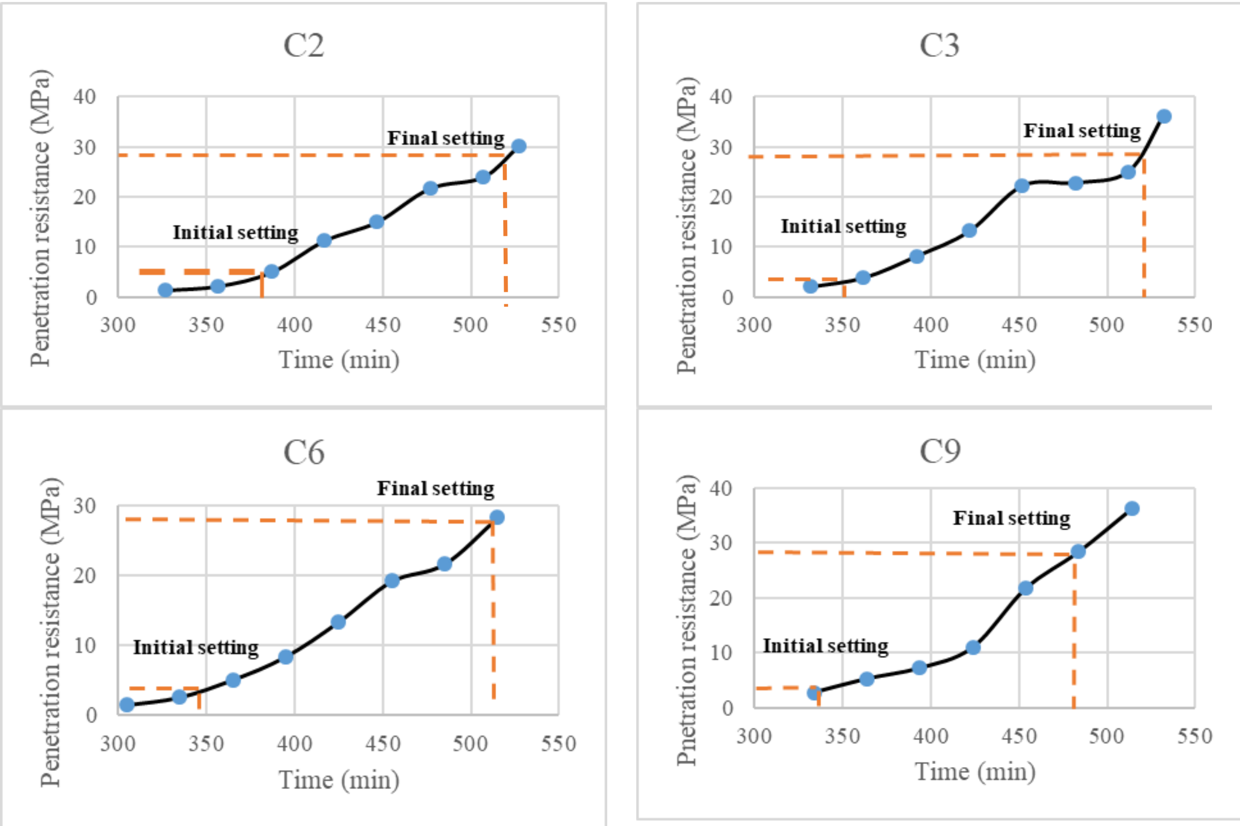

Figure 3. Penetration resistance and initial - final setting times values of the mixtures

Conclusion

The results obtained in this study, in which the initial and final setting times of mortar mixtures prepared with cements with different C_3A content were determined by penetrometer, are as follows:

• The PCE requirement to provide the desired slump-flow value in the mortar mixtures decreased by the reduction of cement C_3A content.

• The increase in C_3A content resulted in a reduction of the setting time of mortar mixtures. This effect was more pronounced for the initial setting time. It was thought that the C_3A content are more affected by elapsed time.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Acknowledgements and Notes

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