EJENS
European Journal of Engineering and Natural Sciences
e-ISSN : 2458-8156

Effect of Water-Reducing Admixture Main Chain Length Change on Consistency Retention Performance of Mortar Mixtures Having Different C_3A Content

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Abstract

In this study, the effect of the PCE main chain length variation on the admixture demand to provide the desired slump value (27±2 cm) and the consistency retention performance of mortar mixtures having different C_3A content was investigated. For this purpose, a total of 12 mortar mixtures were prepared by using CEM I 42.5R type cement having four different C_3A content (2%, 3%, 6%, 9%) and using PCEs having three different main chain lengths (27000 g/mol, 55500 g/mol, 78000 g/mol). According to the results, irrespective of the PCE type, the PCE requirement increased by an increment of the C_3A ratio. This behavior was more pronounced in the mixture containing the cement having the highest C_3A ratio (9%). Compared to the mixture containing PCE having medium main chain length, the admixture demand to provide desired slump value of the mixture containing PCEs having short and long main chains was obtained at 3.9-4.5 and 4.7-6.5 times higher, respectively. The shortness of the PCE's main chain reduces the adsorption and electrostatic effect of the admixture. The poor performance of the PCE having a long main chain may be due to the bridging effect and the intertwining of the long polymers. PCE having a medium main chain showed almost %21 lower consistency retention performance than the others. This is due to the greater admixture requirement to achieve target flow value in the mixtures containing admixture with short and long main chains compared to admixtures with medium chains.

Key words

C_3A, consistency retention performance, main chain length, PCE, PCE requirement

1. INTRODUCTION

Polycarboxylate-based water-reducing admixtures (PCE) consist of the main chain having carboxylic groups and comb-like side chains with polyethylene groups terminated by hydroxyl or methyl. The chain properties of PCEs are one of the most important parameters affecting their dispersing performance [1-5]. Electrostatic repulsion results from the anionic monomers that are adsorbed on the surface of the cement grains due to the negatively charged main chain. Therefore, cement particle agglomeration is avoided. Furthermore, because of steric hindrance, non-ionic polyethylene glycol (PEG) side chains repulse cement granules physically, increasing fluidity [6,7]. While adsorption is determined by the number of free carboxylate groups (COO-), steric hindrance is determined by the adsorbed polymer's side chain characteristics [8-10].

The number of carboxylate groups on the main chain increment as the PCE main chain length increases. Consequently, an increment in adsorption is expected. On the other hand, PCE's efficiency is reduced by a bridging effect caused by long main chains or larger polymer molecules. Because of the bridging effect, cement particles flocculate, decreasing the workability (fluidity) of mixtures. The bridging effect occurs when a PCE molecule attaches to more than one cement particle [11,12].

C_3A content of cement is one of the most important parameters affecting PCE efficiency because C_3A is the most reactive component of cement. Its high reactivity has a significant impact on PCE's performance. Furthermore, negatively charged PCE molecules have a strong attraction to the positively charged surface of C_3A and its hydration products (calcium sulfoaluminate hydrates) [2]. Rapid hydration and hence low rheological performance (high yield stress and apparent viscosity) are provided by high C_3A cement paste. Besides, a high C_3A amount causes low consistency retention performance and high PCE requirement [13,14]

In this study, the effect of the PCE main chain length change on the PCE requirement and the consistency retention performance of mortar mixtures having different C_3A content was investigated.

2. MATERIALS AND METHODS

Within the scope of the study, CEMI 42.5R type Portland cement having four different C_3A content, in accordance with the EN 197-1, was utilized. Cements and PCEs are nominated as their C_3A contents and molecular weights (Table 1). Standard CEN sand in accordance with EN 196-1 was utilized as aggregate. The specific gravity and water absorption rate of the sand are 2.72 and 0.7%, respectively.

Table 1. Cements and PCEs nomination

Cement and PCE nomination	C_3A content (%)	Molecular weight (g/mol)
C2	2.13	-
C3	3.60	-
C6	6.82	-
C9	9.05	-
PCE27k	-	27000
PCE55k	-	55500
PCE78k	-	78000

All mortar mixtures were prepared in accordance with ASTM C109 and the w/c ratio, sand/cement ratio and slump value were kept constant as 0.485, 2.75 and 27±2 cm, respectively. The PCE requirement to provide the desired slump value was determined in accordance with ASTM C1437. Besides, consistency retention performances were measured at every 15 min for 1 hour.

Mixtures are nominated based on the cement used and admixture. For instance, the mixture containing C2 cement and PCE27k admixture is named as C2PCE27k.

3. RESULT AND DISCUSSION

Time-dependent slump-flow value and relative PCE requirement for desired slump value of all mortar mixtures are given in Table 2.

As it seen from Table 2, regardless of the PCE type, the PCE requirement increased with the increment in cement C_3A content. The increase in the PCE requirement is more evident in the mixtures prepared with C9 cement. Similar results were found in previous studies regarding the negative effects of C_3A on the fresh properties of cementitious systems [13,15-16].

Table 2. Time-dependent slump performance of mixtures

	Time-dependent slump value (cm)

Mixtures	Relative PCE ratio (%)	0 min.	15 min.	30 min.	45 min.	60 min.
C2-PCE27k	100	27	24.5	23.5	22	21.6
C2-PCE55k	20.3	26.8	19.2	18.8	17.6	17.5
C2-PCE78k	116.4	26.9	24.1	23	22.6	22.2
C3-PCE27k	100	26.9	24.1	22.5	22	20.9
C3-PCE55k	20	27.8	20.9	19	18	17.7
C3-PCE78k	116.9	26.6	23.7	22.8	21.7	21.2
C6-PCE27k	100	27	23.6	22.5	21.7	20.5
C6-PCE55k	20	27.9	21	19.1	17.9	17.6
C6-PCE78k	122.2	26.5	23.4	21.7	20.9	20.5
C9-PCE27k	100	26.9	22.3	21.5	20.4	19.1
C9-PCE55k	21.4	28	20.8	18.8	17.3	16.8
C9-PCE78k	127.5	27.4	22.5	21	20.5	18.9

The PCE requirement for desired slump value of PCE27k and PCE 78k were obtained 3.9-4.5 and 4.7-6.5 times higher than that of the PCE 55k, respectively. It was attributed to the PCE having a short main chain (PCE 27k) resulting in a decrease in adsorption and electrostatic repulsion [6]. For the PCE having long main chain (PCE 78k), it may occur due to the bridging effect and the intertwining of the polymers. Cement particles flocculate and consequently workability (fluidity) of the mixtures reduce due to bridging effect.

PCE55k showed almost %21 lower consistency retention performance than PCE27k and PCE78k. This was attributed to the fact that the PCE requirements for the target slump value of PCE having short and long main chain were much higher than for the PCE having medium main chain length (PCE55k). As a result, the non-adsorbed part of PCE27k and PCE78k may higher than PCE55k. As it is known, the non-adsorbed part of PCE determines fluidity properties such as time-dependent consistency retention behavior [12,14].

4. CONCLUSION

In this study, the effect of the main chain length on the PCE requirement and the consistency retention performance of cementitious systems having different C_3A content was examined. The results are listed below:

- PCE having medium main chain length (55000 g/mol) outperformed the PCE having short main chain length (27000 g/mol) and long main chain length (78000 g/mol) in terms of PCE requirement for desired slump value.
- PCE having long main chain length was the worst PCE in terms of slump-flow performance and PCE requirement.
- PCE having short and long main chain length showed higher performance than PCE having medium main chain length in terms of consistency retention due to their use in high dosages.

In conclusion, it was determined that PCE with medium main chain length was the most suitable admixture in all mixtures having different C_3A ratio.

ACKNOWLEDGMENT

The authors gratefully acknowledge the support of the Bursa Uludag University Science and Technology Centre (BAP) under grant numbers FDK -2022/804 and the Scientific and Technological Research Council of Turkey (TUBITAK) (Grant No: 219 M425). The first author acknowledges the scholarships provided by the TUBITAK 2211A during his doctoral studies. In addition, the first and second authors acknowledge the scholarship provided by Turkish Council of Higher Education (YÖK 100/2000 Program) during their PhD studies

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

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