ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Vol 10, Issue 1, January 2023

Effect of Water Reducing Admixture Main and Side Chain Length Variation on the Time-Dependent Slump-Flow Performance of Mixtures with Different C_3A Content

[1] Veysel Kobya*, [2] Kemal Karakuzu, [3] Dr. Ali Mardani

[1] PhD Candidate, Faculty of Civil Engineering Department, Bursa Uludag University, Nilufer-Bursa, Turkey.
[2] PhD Candidate, Bursa Uludag University, Nilufer-Bursa, Turkey.
[3] Associate Professor, Bursa Uludag University, Nilufer-Bursa, Turkey.
Corresponding Author Email: [1] v.kobya@gmail.com, [2] karakuzu.kemal@gmail.com, [3] ali.mardani16@gmail.com

Abstract*— In this study, the effect of the polycarboxylate-based superplasticizer (PCE) main and side chain length variation on the admixture requirement to provide the target slump-flow value (27±2 cm) and the time dependent slump-flow performance of mortar mixtures with different C_3A content was investigated. For this aim, a total of 12 mortar mixtures were prepared by using Portland cement with four different C_3A ratios (2%, 3%, 6%, 9%) and three different main and side chain lengths PCE. According to the results, generally, the PCE requirement for target slump-flow value increased by an increment of the C3A ratio. The admixture requirement for the mixture containing PCE with medium main and side chain length for target slump was 28-41% and 7-12% lower compared to those containing PCE having a long main chain and short side chain and the PCE having a short main chain and long side chain, respectively. On the other hand, time-dependent slump flow performance of mixtures containing PCE having medium main and side chain lengths; compared to those containing long main chain and short side chain and short main chain and long side chain, in the range of 6-22% and 13-30% lower, respectively.

***Index Terms*—C_3A, PCE, main and side chain length, time-depending slump flow.**

I. INTRODUCTION

Polycarboxylate-based water-reducing admixtures (PCE) are used for purposes such as increasing workability in cementitious systems, increasing strength by reducing the water/cement ratio, or decreasing the cost by reducing the amount of cement in the similar water/cement ratio [1,2]. However, in addition to these positive effects, PCE utilization in cementitious systems can sometimes lead to undesirable negative effects which can be expressed as cement-PCE incompatibility [3-6]. In cement-admixture incompatibility, PCE utilization may cause adverse effects such as set retardation, low consistency retention, and increased risk of drying-shrinkage in cementitious systems [6-8].

PCE-based parameters affecting cement-PCE compatibility can be listed as PCE main chain length, side chain number and length, molecular weight, intermolecular bond structure, chemical composition, density, pH, and adding time to the mixture [9-11]. Cement-related parameters affecting the cement-PCE compatibility are the chemical composition of the cement and the amount and structure of its main components (the amount of C_3A and C_4AF and the crystal structure of C_3A), cement fineness and alkali content, and the amount and type of calcium sulfate (gypsum) added to the clinker during cement production [6,12]. It is known that C_3A is one of the most important parameters affecting cement-PCE compatibility. Since the amount of hydrated C_3A and ettringite reduce the amount of water in the mixture until to the setting, it negatively affects the fresh properties of cement paste [13,14]. In this context, the interaction of C_3A and PCE chain properties is vital for cement-PCE compatibility.

In this study, the effect of PCE main and side chain length variation on the PCE requirement to provide the target slump-flow value (27±2 cm) and the time-dependent slump-flow performance of mortar mixtures with different C_3A content was examined.

II. MATERIAL AND METHOD

Within the scope of the study, Portland cement, prepared from the same raw material, has C_3A content in three different ratios and complies with EN 197-1 Standard, was utilized. Some physical, chemical, and mechanical properties of cements are shown in Table I. C_3A ratios were taken into account in the denotation of the cements.

The properties of the synthesized PCEs are shown in Table II. Besides, a schematic drawing of PCEs with different main and side chain lengths is shown in Fig. 1. The method specified by Altun et al. [15] was applied in the synthesis of the PCEs. The denotation of all PCEs was based on the main and side chain lengths. For example, the PCE containing 17 nonionic groups, and a side chain length of 3000 g/mol, was named SP17k-3000.

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Vol 10, Issue 1, January 2023

The mortar mixtures were prepared in accordance with ASTM C109, and CEN standard sand conforming to EN 196-1 was used. In all mixtures, the w/c ratio, sand/cement ratio and slump-flow value were kept constant as 0.485, 2.75 and 27±2 cm, respectively. The denomination of mortar mixtures was performed according to the cement and PCE type. For instance, the mixture containing C2 cement and SP17k-3000 admixture was named as C2SP17k-3000.

The PCE requirement to provide the desired slump-flow value was determined in accordance with ASTM C1437. Besides, time-dependent slump-flow performances of mortar mixtures were measured at every 15 min for 1 hour.

Table I. Chemical, 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 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 II. The properties of PCEs

Properties	**SP17k-3000**	**SP40k-1000**	**SP21k-2400**
Density (g/cm^3)	1.10	1.09	1.08
Mw (Molecular weight-g/mol)	57.000	56.000	56.000
Molar ratio	3:1	3:1	3:1
Main chain length	17k	40k	21k
Side chain length (g/mol)	3000	1000	2400

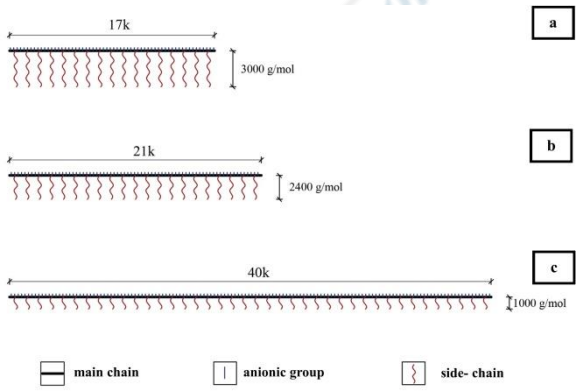

Fig. 1. Schematic drawing of PCEs: **a)** SP17k-3000 **b)** SP21k-2400 **c)** SP40k-1000

III. RESULTS AND DISCUSSION

Time-dependent slump-flow value and relative PCE requirement for target slump-flow value of all mortar mixtures were given in Table III.

Table III. Time-depending test results of mortar mixtures

Mixtures	**Relative PCE ratio (%)**	**Time-dependent slump-flow value (cm)**				
		0 min.	**15 min.**	**30 min.**	**45 min.**	**60 min.**
C2-SP17k-3000	0.3	28	25.2	24	22.7	22
C2-SP21k-2400	0.26	26.8	19.2	18.8	17.6	17.5
C2-SP40k-1000	0.34	27.5	23.5	21.5	21.1	20.7
C3-SP17k-3000	0.32	27.7	24.8	23.6	22.9	22.5
C3-SP21k-2400	0.26	27.8	20.9	19	18	17.7
C3-SP40k-1000	0.36	27.2	22.3	21.6	21.2	21
C6-SP17k-3000	0.32	27.7	24.8	23.6	22.9	22.5
C6-SP21k-2400	0.27	27.9	21	19.1	17.9	17.6
C6-SP40k-1000	0.38	27.4	21	19.8	18.5	18.3
C9-SP17k-3000	0.4	27.5	22.5	20.1	19.4	18.7
C9-SP21k-2400	0.39	28	20.8	18.8	17.3	16.8
C9-SP40k-1000	0.5	27.6	21	19.8	18.4	18.1

Regardless of the PCE type, the PCE requirement for desired slump value increased with the increase in C_3A content in the mixtures. The increase in PCE requirement is more evident in the mixtures prepared with C9 cement.

The PCE requirement of the mixtures containing SP21k-24000 for target slump-flow was 28-41% and 7-12% lower compared to the SP40k-1000 and SP17k-3000. Due to the bridging effect, the PCE requirement was increased as PCE adsorbs more than one cement particle [16-17]. With the increasing PCE requirement, more PCE in the system may increase the possibility of entanglement of polymer main chains. Similarly, the presence of a larger amount of SP17k-3000 in the system to achieve target slump-flow caused the polymer side chains to intertwine decreasing the spreading performance [15,18].

Time-depending slump-flow of the mixture containing SP21k-24000 exhibited lower performance in the range of 6-22% and 13-30% compared to SP40k-1000 and SP17k-3000, respectively. Since the mixtures containing SP40k-1000 and SP17k-3000 PCE requirement for the target slump flow more than SP21k-2400, there is more PCE in the system. The presence of more PCE in the system increases the amount of non-adsorbed PCE and thus the time-dependent slump-flow performance [8,19].

IV. CONCLUSION

In this study, the effect of the PCE's main and side-chain length variation on the PCE requirement for desired slump-flow and the time-dependent slump-flow performance of mortar mixtures having different C_3A content was investigated. The results are listed below:

Regardless of PCE type, increment in C_3A content generally adversely effect on PCE requirement and slump-flow performance of mortar mixtures.

PCE having medium main and side chain length was the best PCE in terms of PCE requirement in all mixtures. On the other hand, time dependent slump-flow performance of mixtures containing PCE having medium main and side chain length was lower than mixtures containing other PCEs.

For further studies, it is recommended to examine the PCE conformations with different chain lengths and their time-dependent adsorption and conformation behavior.

V. ACKNOWLEDGEMENT

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.

REFERENCES

[1] Akman, M. S. (1987). "Beton Katkı Maddelerinin Ana İşlevleri ve Yan Etkileri", İTÜ İnşaat Fakültesi, Malzeme seminerleri, 11 Mayıs, İstanbul, (in Turkish).

[2] Yıldırım, H., Yorulmazel, V., & Ardaç, E. (1996). Süper ve Normal Akışkanlaştırıcı Katkıların Çimento ile Uyuşumu. 4. Ulusal Beton Kongresi, 30-31 Ekim-1 Kasım 1996, İstanbul, ss. 25, 33 (in Turkish).

[3] Schatzmann, M., Fischer, P., Bezzola, G.R. (2003). Rheological behaviour of fine and large particle suspensions. Journal of Hydraulic Engineering, 129(10): 796-803

[4] Schatzmann, M., Bezzola, G.R., Fischer, P., Windhab, E.J., Minor, H.E. (2004). The ball measuring system-a new rheometric tool to determine the flow curve of large particle material. Swiss Group of Rheology Annual Meeting, Poster Session, Lausanne/Switzerland.

[5] Koehler, E.P., Fowler, D.W. (2004). Development of A Portable Rheometer for Fresh Portland Cement Concrete. Aggregates Foundation for Technology, Research and Education (AFTRE), Project No. ICAR-105, August, 306 p.

[6] Mardani-Aghabaglou, A. (2016). Investigation of portland cement and superplasticizer admixture compatibility, Doctoral dissertation, Ege University, İzmir, Turkey.

[7] Bedard, C., & Mailvaganam, N. P. (2005). The Use of Chemical Admixtures in Concrete. Part 1: Admixture-Cement Compatibility. Journal of performance of constructed facilities, 19(4).

[8] Karakuzu, K., Kobya, V., Mardani-Aghabaglou, A., Felekoğlu, B., & Ramyar, K. (2021). Adsorption properties of polycarboxylate ether-based high range water reducing admixture on cementitious systems: A review. Construction and Building Materials, 312, 125366.

[9] Flatt, R. J., & Houst, Y. F. (2001). A simplified view on chemical effects perturbing the action of superplasticizers. Cement and concrete research, 31(8), 1169-1176.

[10] Mardani-Aghabaglou, A., Felekoğlu, B., Ramyar, K. (2017a). Effect of cement C_3A content on properties of cementitious systems containing high range water-reducing admixture, Journal of Materials in Civil Engineering (ASCE), (29), 8.

[11] Mardani-Aghabaglou, A., Son, A. E., Felekoğlu, B., Ramyar, K. (2017b). Effect of cement fineness on properties of cementitious materials containing high range water reducing admixture, Journal of Green Building, 12(1): 142-167.

[12] Roberts, L.R. (1995). Dealing with cement admixture interactions, 23rd Annual Convention of the Institute of Concrete Technology, Telford, UK.

[13] Prince, W.H., Edwards-Lajnef, M., Aïtcin, P.C. (2002). Interaction between ettringite and a polynaphthalene sulfonate superplasticizer in a cementitious paste. Cement and Concrete Research, 32: 79-85.

[14] Rößler, C., Möser, B., & Stark, J. (2007). Influence of superplasticizers on C3A hydration and ettringite growth in cement paste. Finger Institute for building materials science, Bauhaus-University Weimar, (11).

[15] Altun, M. G., Özen, S., & Mardani-Aghabaglou, A. (2020). Effect of side chain length change of polycarboxylate-ether based high range water reducing admixture on properties of self-compacting concrete. Construction and Building Materials, 246, 118427.

[16] Kashani, A., Provis, J. L., Xu, J., Kilcullen, A. R., Qiao, G. G., & van Deventer, J. S. (2014). Effect of molecular architecture of polycarboxylate ethers on plasticizing performance in alkali-activated slag paste. Journal of Materials Science, 49(7), 2761-2772.

[17] Zhang, Q., Shu, X., Yu, X., Yang, Y., & Ran, Q. (2020). Toward the viscosity reducing of cement paste: Optimization of the molecular weight of polycarboxylate superplasticizers. Construction and Building Materials, 242, 117984.

[18] Kai, K., Heng, Y., & Yingbin, W. (2020). Effect of chemical structure on dispersity of polycarboxylate superplasticiser in cement paste. Advances in Cement Research, 32(10), 456-464.

[19] Zhang, Y., & Kong, X. (2015). Correlations of the dispersing capability of NSF and PCE types of superplasticizer and their impacts on cement hydration with the adsorption in fresh cement pastes. Cement and concrete research, 69, 1-9.