Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 53(7) (2021) 641-644
DOI: 10.22060/ceej.2020.17542.6600

The Effect of Shrinkage Reducing Admixture on the Behavior of Concrete used in Concrete Pavements

M. Gholami[1], F. Moghadas Nejad[1*] , A. A. Ramezanianpour[1], A. M. Ramezanianpour[2]

[1] Department of Civil & Environmental Engineering, Amirkabir University of Technology, Tehran, Iran
[2] Department of Civil Engineering, University of Tehran, Tehran, Iran

ABSTRACT: Concrete pavements are widely used by pavement engineers due to their advantages over flexible pavements such as long lifetime, good performance and durability, etc. However, concrete pavements represent some drawbacks such as shrinkage that increases the tensile stress in concrete, which may lead to cracking, warping, etc. Drying shrinkage is the most important type of shrinkage in concrete pavements. To prevent or reduce the amount of cracking, shrinkage reducing admixture (SRA) can be used. This admixture controls shrinkage by reducing water surface tensile in capillary tubes. In this study, the effect of shrinkage reducing admixture on the behavior of concrete used in concrete pavements was investigated. Slump, compressive strength, third-point flexural strength, electrical resistance, skid resistance, free shrinkage, and restrained shrinkage by ring test were performed. Two water-cement ratios of 0.35 & 0.4 were used for mix design and the percentage of shrinkage reducing admixture used in mixtures was 2% by weight of cement. The results showed that the use of SRA had a negligible effect on workability. Also, the use of SRA caused about a 10% reduction in compressive and flexural strength and electrical resistance. Furthermore, a reduction of 10% and 20% was observed in free and restrained shrinkages, respectively, followed by a 40% reduction in crack width and more than one-week delay in the occurrence of the first crack. Finally, no certain relationship was observed between the usage of SRA and variations of the skid resistance of concrete pavements.

Review History:

Received: Dec. 19, 2019
Revised: Feb. 25, 2020
Accepted: Feb. 27, 2020
Available Online: Apr. 03, 2020

Keywords:

Concrete pavement
Drying shrinkage
Tensile stress
Shrinkage cracks
Shrinkage reducing admixture

1. INTRODUCTION

Because of higher lifetime, performance, and durability, concrete pavements are widely used over asphalt concrete on transportation infrastructure [1]. However, concrete pavements show some terrible properties like Shrinkage – Volumetric loss of concrete due to water evaporation[2] – and warping that occurs because of drying shrinkage [3] in some cases. Also, these pavements have large surfaces, so when they are exposed to environmental conditions, shrinkage cracks have happened that are more critical than other design parameters [4].

Shrinkage reducing admixture is a material that is used in concrete to decrease shrinkage cracks without any volumetric change of concrete (expansion) [5]. It controls shrinkage by reducing capillary tension [6].

Kim & Lee [7] used several contents of SRA[1](1 to 5 percent) in latex modified concrete and observed that the use of SRA had no significant effect on fresh properties of concrete, but it increased the compressive and flexural strengths. Chen *et al.* [8] found using SRA affords a delay in cement hydration and initial setting time. Deboodt *et al.* [9] Showed that the use of SRA causes a reduction in compressive and flexural strengths and modulus of elasticity. Also, they mentioned that SRA helps concrete against shrinkage and its cracks. Hatami *et al.* [10] investigated the effect of SRA on the durability properties of HPC[2]. They realized that the use of SRA increases slump improves durability properties of concrete and decreases free and restrained shrinkage. In addition, using SRA results in a reduction in mechanical properties. Qiao *et al.* [11] focused on the effect of different dosages of SRA on ions migration in concrete containing 400kg cement and *w*/*c*=0.4 and reported that it had a good effect on ions migration for relative humidity between 40 & 80 percent.

Increasing the length of concrete slabs and rate of implementation of them was concluded if shrinkage controls in concrete pavements. Different effects of SRAs that produce in the different companies on mechanical and durability properties was a challenge to use them in concrete pavements to control shrinkage. In this study, the effect of shrinkage reducing admixture on the behavior of concrete used in concrete pavements was investigated.

1 Shrinkage reducing admixture

2 High performance concrete

*Corresponding author's email: moghadas@aut.ac.ir

Copyrights for this article are retained by the author(s) with publishing rights granted to Amirkabir University Press. The content of this article is subject to the terms and conditions of the Creative Commons Attribution 4.0 International (CC-BY-NC 4.0) License. For more information, please visit https://www.creativecommons.org/licenses/by-nc/4.0/legalcode.

Table 1. Chemical properties of SRA & superplasticizer

name	density (gr/cm^3)	nature	% active material
SRA	0.96	Polypropylene glycol, non-ionic	90%
superplasticizer	1.05	Polycarboxylate, non-ionic	35%

2. MATERIALS AND METHODS

Type II Portland cement produced by the Tehran cement factory was used in this study with a density of 3130 kg/m^3.

Furthermore, 3 types of aggregates were used in this study: gravel 9.5-19 mm, gravel 6-12 mm, and sand 0-6 mm. the proportion of each type were 20%, 25%, and 55% of the total weight of aggregate, respectively. In addition, the chemical properties of Shrinkage reducing admixture and superplasticizer are shown in Table 1.

The mix composition was expanded based on a national method for concrete mix design [12] with two *w/c* of 0.35 & 0.4, and the amount of cement and SRA were 400 kg/m^3 and 2% by weight of cement, respectively. Table 2 shows four concrete mix compositions examined in this study.

Also, slump, compressive strength, flexural strength with center-point loading, electrical resistance, skid resistance, free shrinkage, and restrained shrinkage were performed as an experimental program.

3. RESULTS AND DISCUSSION

The results of fresh properties of concrete are also represented in Table 2. It shows that using SRA has no important effect on the behavior of concrete at early ages.

Table 2. Concrete mix Composition (per cubic meter)

Name	OPC 0.35	SRA 0.35	OPC 0.4	SRA 0.4
w/c	0.35	0.35	0.4	0.4
Cement (kg)	400	400	400	400
Gravel 9.5-19 (kg)	375.6	375.6	365.3	365.3
Gravel 6-12 (kg)	469.5	469.5	456.6	456.6
Sand 0-6 (kg)	1032.8	1032.8	1004.6	1004.6
Water (kg)	140	140	160	160
Superplasticizer (kg)	2	2	1.6	1.6
SRA (kg)	0	8	0	8
Density (kg/m^3)	2372	2363	2344	2334
Slump (mm)	68	72	65	70

Also, *w/c* has a minor effect on the workability of concrete.

Results of compressive and flexural strengths are shown in Fig. 1. Water cement ratio has an inverse relationship with mechanical properties. It might be because of reducing matrix and non-reacting water and increasing aggregate.

Also, SRA caused a reduction in compressive and flexural strengths. Delay in cement hydration was concluded by using SRA and decreasing the mechanical properties [8, 9].

Fig. 2 represents the results of electrical and skid resistance. It is observed that electrical resistance decreases when SRA is used in concrete. That's because of delaying in cement hydration [8, 9] and the increasing dosage of ions in concrete [13]. Also, there is no certain relationship between skid resistance and SRA usage.

Fig. 3 shows the effect of SRA on the behavior of free and restrained shrinkage (restrained shrinkage was tested on concrete with *w/c*=0.35). SRA can mainly reduce free shrinkage (length change) of concrete and the ring's strain of

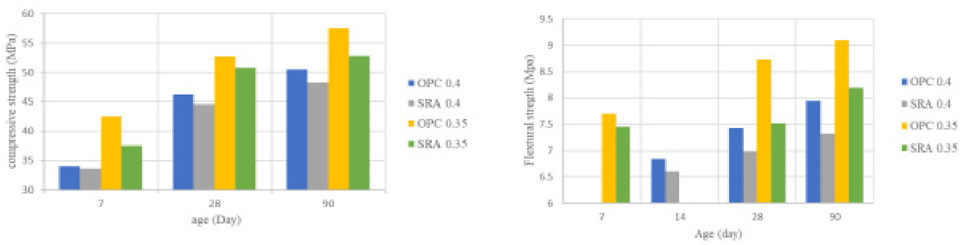

Fig. 1. Compressive (left) and Flexural (Right) Strength

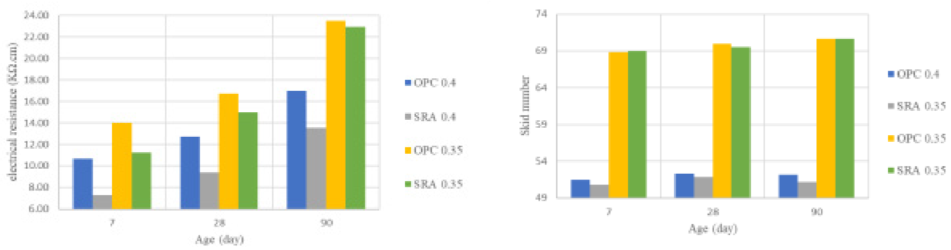

Fig. 2. Electrical (left) and skid (Right) resistance

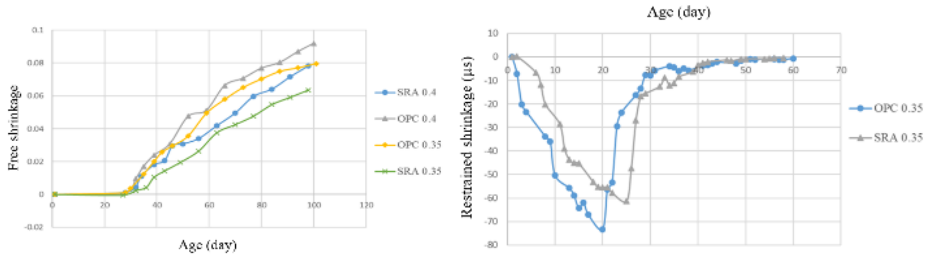

Fig. 3. Free (left) and restrained (Right) shrinkage

restrained shrinkage. Furthermore, this admixture increases the age of the first crack in the concrete and decreases the crack width and number of cracks. It may happen because SRA reduces the capillary tension of water, rate of evaporation, surface tension, and initial concrete temperature [6, 14].

4. CONCLUSION

This research tried to find the effect of SRA on the mechanical and durability behavior of concrete used in pavements. From the observed results, the following remarks can be made:

Ø The use of SRA had a negligible effect on the fresh properties of concrete (Slump & density).

Ø This admixture had a negative effect on compressive and flexural strengths of concrete and reduced these mechanical properties up to 10 & 15%, respectively. It might be due to a delay in cement hydration.

Ø The electrical resistance of concrete decreased about 20 % when SRA was used in concrete. It might be caused by increasing the ion dosage of concrete and delaying cement hydration.

Ø There was no certain effect between SRA usage and variation of skid resistance.

Ø Free and restrained shrinkage reduced about 12 & 20 percent, respectively, by using SRA. In addition, the age of the first crack appeared 8 days later, and crack width decreased more than 40% which shows SRA had a desirable effect on controlling shrinkage and its cracks.

REFERENCES

[1] R.A. Embacher, M.B. Snyder, Life-cycle cost comparison of asphalt and concrete pavements on low-volume roads; case study comparisons, Transportation research record, 1749(1) (2001) 28-37.

[2] D. Mostofinejad, Reinforced Concrete Structure, Arkan-e Danesh publication, Volume 1 (2017).

[3] J.M. Ruiz, R.O. Rasmussen, G.K. Chang, J.C. Dick, P.K. Nelson, Computer-based guidelines for concrete pavements, volume II: design and construction guidelines and HIPERPAVE II user's manual, Federal Highway Administration, FHWA–HRT–04–122 (2005).

[4] J. Zhang, V.C. Li, Influences of fibers on drying shrinkage of fiber-reinforced cementitious composite, Journal of engineering mechanics, 127(1) (2001) 37-44.

[5] Committee of concrete chemical additives, Iran concrete Institute, the application of chemical additives in concrete, Yazda publication, (2014).

[6] P.K. Mehta, P.J. Monteiro, Concrete microstructure, properties and materials, third ed., McGraw-hill, 2017.

[7] B.J. Lee, Y.Y. Kim, Durability of latex modified concrete mixed with a shrinkage reducing agent for bridge deck pavement, International Journal of Concrete Structures and Materials, 12(1) (2018) 23.

[8] S. Chen, H. Zhao, Y. Chen, D. Huang, Y. Chen, X. Chen, Experimental study on interior relative humidity development in early-age concrete mixed with shrinkage-reducing and expansive admixtures, Construction and Building Materials, 232 (2020) 117204.

[9] T. Deboodt, T. Fu, J.H. Ideker, Evaluation of FLWA and SRAs on autogenous deformation and long-term drying shrinkage of high performance concrete, Construction and Building Materials, 119 (2016) 53-60.

[10] B. Hatami, A.M. Ramezanianpour, A.S. Daryan, Investigation on the Effect of Shrinkage Reducing Admixtures on Shrinkage and Durability of High-Performance Concrete, Journal of Testing and Evaluation, 46(1) (2017) 141-150.

[11] C. Qiao, W. Ni, J. Weiss, Transport due to diffusion, drying, and wicking in concrete containing a shrinkage-reducing admixture, Journal of Materials in Civil Engineering, 29(9) (2017) 04017146.

[12] Building and housing research center, The national Method for concrete mix design, BHRC Publication, No. S-479 (2008).

[13] W. Zuo, P. Feng, P. Zhong, Q. Tian, J. Liu, W. She, Effects of a novel polymer-type shrinkage-reducing admixture on early age microstructure evolution and transport properties of cement pastes, Cement and Concrete Composites, 95 (2019) 33-41.

[14] [14] M.J. Rosen, J.T. Kunjappu, Surfactants, and Interfacial Phenomena, John Wiley & Sons, Inc., Hoboken, New Jersey, (2012).

HOW TO CITE THIS ARTICLE

M. Gholami, F. Moghadas Nejad, A.A. Ramezanianpour, A.M. Ramezanianpour, The Effect of Shrinkage Reducing Admixture on the Behavior of Concrete used in Concrete Pavements, Amirkabir J. Civil Eng., 53(7) (2021) 641-644.

DOI: 10.22060/ceej.2020.17542.6600