

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

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## ABSTRACT

Concrete pavements are widely used by pavement engineers due to their advantages over flexible pavements such as longer 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 negligible effect on workability. Also, the use of SRA caused about 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 occurrence of first crack. Finally, no certain relationship was observed between the usage of SRA and variations of the skid resistance of concrete pavements.

## KEYWORDS

Concrete pavement, Drying shrinkage, Tensile stress, Shrinkage cracks, Shrinkage reducing admixture

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## 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 exposed to environmental conditions, shrinkage cracks are happened that are more critical than other design parameters [4].

Shrinkage reducing admixture is a material which is used in concrete in order 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<sup>1</sup>(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 durability properties of HPC<sup>2</sup>. They realized that use of SRA increases slump, improves durability properties of concrete and decreases free and restrained shrinkage. In addition, using SRA results a reduction in mechanical properties. Qiao et al. [11] focused on the effect of different dosage 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 were concluded if shrinkage controls in concrete pavements. Different effect of SRAs that produce in different company on mechanical and durability properties was a challenge to use them in concrete pavements in order to control shrinkage. In this study, the effect of shrinkage reducing admixture on the behavior of concrete used in concrete pavements was investigated.

## Materials and Methods

Type II Portland cement produced by Tehran cement factory was used in this study with density of 3130 kg/m<sup>3</sup>.

Furthermore, 3 types of aggregates used in this study: gravel 9.5-19 mm, gravel 6-12 mm and sand 0-6 mm. the

proportion of each types were 20%, 25% and 55% of total weight of aggregate respectively. In addition, the chemical properties of Shrinkage reducing admixture and superplasticizer are shown in table 1:

**Table 1: chemical properties of SRA & superplasticizer**

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

The mix composition was expanded based on national method for concrete mix design [12] with two W/C of 0.35 & 0.4 and the amount of cement and SRA were 400kg/m<sup>3</sup> and 2% by weight of cement, respectively. Table 2 shows four concrete mix composition examined in this study:

**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 <sup>3</sup> )	2372	2363	2344	2334
Slump (mm)	68	72	65	70

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

## Results and discussion

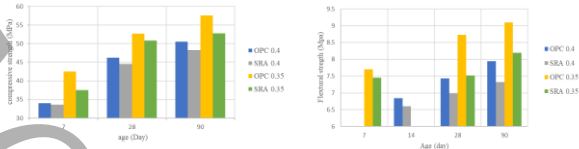
Results of fresh properties of concrete represented in table 2, too. It shows that using SRA has no important effect on the behavior of concrete at early ages. Also, w/c has a minor effect on workability of concrete.

Results of compressive and flexural strengths are shown in figure 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].

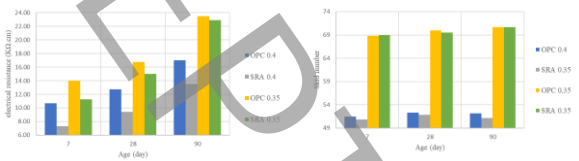
<sup>1</sup> Shrinkage reducing admixture

<sup>2</sup> High performance concrete



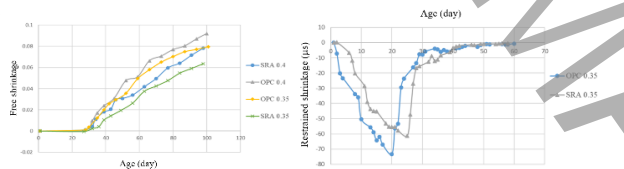
**Figure 1: Compressive (left) and Flexural (Right) Strength**

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



**Figure 2: electrical (left) and skid (Right) resistance**

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



**Figure 3: Free (left) and restrained (Right) shrinkage**

## 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, following remarks can be made:

- The use of SRA had a negligible effect on fresh properties of concrete (Slump & density)
- 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 delay in cement hydration.
- Electrical resistance of concrete decreased about 20%, when SRA was used in concrete. It might be caused by increasing ion dosage of concrete and delaying in cement hydration.
- There was no certain effect between SRA usage and variation of skid resistance.

- Free and restrained shrinkage reduced about 12 & 20 percent respectively by using SRA. In addition, age of 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.

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