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A review on the influence of shrinkage reducing admixtures on concrete.

Una revisión sobre la influencia de los aditivos reductores de la retracción en el hormigón.

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ABSTRACT

Shrinkage cracking is a common source of distress in concrete structures. In addition to being unsightly, these cracks serve to accelerate other forms of damage in concrete, thereby shortening the service life of structures. One solution to reduce the potential for shrinkage cracking is to incorporate a shrinkage reducing admixture (SRA) in concrete mixtures. SRAs belong to a special type of organic chemicals (i.e., surfactants) that when mixed in water, reduce the surface tension of the liquid, and thereby reduce the magnitude of capillary stresses and shrinkage strains that occur when concrete is losing moisture. Various studies show that SRAs have proven to reduce drying, autogenous, and plastic shrinkage, which has been summarized in this literature.

Keywords: Shrinkage Reducing Admixtures, Surfactants, Drying shrinkage, Plastic shrinkage, Autogenous shrinkage.

RESUMEN

El agrietamiento por contracción es una fuente común de angustia en las estructuras de hormigón. Además de ser antiestéticas, estas grietas sirven para acelerar otras formas de daño en el hormigón, acortando así la vida útil de las estructuras. Una solución para reducir el potencial de agrietamiento por contracción es incorporar un aditivo reductor de contracción (SRA) en las mezclas de concreto. Los SRA pertenecen a un tipo especial de productos químicos orgánicos (es decir, tensioactivos) que, cuando se mezclan con agua, reducen la tensión

superficial del líquido y, por lo tanto, reducen la magnitud de las tensiones capilares y las deformaciones por contracción que se producen cuando el hormigón pierde humedad. Varios estudios muestran que los SRA han demostrado reducir el encogimiento por secado, autógeno y plástico, lo que se ha resumido en esta literatura.
Palabras clave: Aditivos reductores de la contracción, Tensioactivos, Contracción por secado, Contracción plástica, Contracción autógena.

INTRODUCTION

Concrete volume change is an unavoidable phenomenon, from very early age to long-term behavior. Therefore, concrete structures are vulnerable to self-stresses or shrinkage cracking (Ling et al.,2018). Shrinkage cracking not only cause serious structural defects, but may reduce the serviceability, durability and aesthetics of concrete structure (Liu et al.,2019). It is very necessary and desirable to control and reduce the shrinkage of concrete for the greater service life of the concrete. The coarse or fine saturated lightweight aggregates (LWA) can be used for internal curing. But it is not always easy to find suitable LWA for implementing internal curing. The use of fiber and expansive agents can reduce the risk of cracking due to the reduced shrinkage and increased tensile strength. However, the limitation of this approach has already been recognized, for example: the increased cost, reduced workability of fresh concrete, higher curing conditions and more complex preparation technology. Reducing the tensile stress is one possible way to decrease the cracking risk and it can be undertaken by mitigating the shrinkage evolution with the addition of SRA (Ma et al.,2020). Therefore, in recent years, there has been a growing interest in the use of SRA to produce concrete with reduced shrinkage.

SHRINKAGE REDUCING ADMIXTURES

Shrinkage reducing admixtures are surfactants that reduce the superficial tension of the air-water interface in the dehydrating pore system, as well as the angle of contact of these menisci with the walls of the pore system so that the tensile stresses developed by this apparent drying phenomenon and autogenous shrinkage are decreased significantly.

PRINCIPAL MOLECULES AND DOSAGE OF SRA

SRAs contain various surfactants including (i) Monoalchohols, (ii) Glycols, (iii) Polyoxyalkylene glycol alkyl esters, (iv) Polymeric surfactants, and (v) Amino alcohols. In contrast to other admixtures, the dosages of SRAs are relatively high on the order of 10 times higher than for superplasticizers, except for ultra-high performance concrete.

WORKING MECHANISM OF SRA

SRA is a class of organic chemicals known as surfactants and composed of a head that is covalently bonded to a hydrophobic tail. SRA can be adsorbed on the non-polar interface of SRA, resulting in a decrease of its surface tension. This stems from the electrostatic repulsions between the polar heads of the adjacent surfactant molecules. At a lower concentration, the SRA molecules are present in the form of monomers dissolved in water. However, at a higher concentration, the redundant SRA molecules tend to aggregate and form micelles to reduce the unfavorable contacts between hydrophobic tails and water molecules. In addition, some SRA molecules as a non-ionic surfactant, are adsorbed on the water-solid interface, which causes a reduction in the interfacial energy of cement particles and hydration products, and changes the surface polarity of particles and improves the dispersion of particles. It is due to the hydrogen bonding interactions between the polar units of the SRA which reduce the surface tension of pore solution and interfacial energy to make SRA slow down water absorption and reduce shrinkage.

EFFECT OF SRA ON CONCRETE SHRINKAGE

SRAs are known for their capability to reduce shrinkage. By lowering the surface tension of pore fluid, SRA can reduce the drying shrinkage of concrete by up to 50% (Maia et al.,2012). In addition, SRA was shown to reduce the capillary stresses that are generated by autogenous shrinkage which is extremely beneficial in reducing the risk of shrinkage cracking in concrete elements. In both conventional and high strength concretes, the beneficial influence of the reduction of plastic shrinkage is evident from the results by Mora-ruacho et al. (Mora-ruacho etal.,2009). Several studies also observed a reduction in crack width with the addition of SRAs. Various studies have been carried out to study the influence of SRA on the shrinkage cracking of concrete.

Reduction in drying shrinkage was observed with the addition of SRA by various studies. The observations by Ling et al show that adding 2% Hexylene glycol SRA could reduce the free drying shrinkage by 32%- 44% and restrained drying shrinkage by 4%-17% (Ling et al.,2018). The use of propylene glycol has also proven to reduce drying shrinkage in the study by Passuello et al (Passuello et al.,2009). Mohamadameen et al reported that, with the addition of Butoxyethanol (7.5 l/m^3) and alkyl-ether (0.5–2% of weight of cement), a reduction in drying shrinkage by 18%-42% was observed (Mohamadameen et al.,2014). The study by Rongbing et al also shows similar results. 21.9%- 44.2% reduction in free drying shrinkage was observed by the addition of SRA (Rongbing et al.,2005). It is found that drying shrinkage of cementitious materials is reduced with the increase of SRA content. A greater reduction in shrinkage was observed with higher SRA dosage, in the study by Zhang et al (Zhang et al., 2015). It can be seen that SRA reduces drying shrinkage to different extents even with the same type of cementitious materials. This may be partly be attributed to the different curing conditions.

The excessive plastic shrinkage often causes the crack of concrete, which is a common problem to limit the application of concrete. Hence a lot of research on the plastic shrinkage of concrete containing SRA has been carried out. Shrinkage reducing admixture has taken great interest from researchers due to its effect on reducing shrinkage strain which has important benefits from the point of view of the lower risk of restrained shrinkage cracking (Liu et al.,2019). In both conventional and high strength concretes, the beneficial influence of the reduction of plastic shrinkage is evident from the results by Mora-ruacho et al (Mora-ruacho etal.,2009). SRA improves plastic shrinkage of concrete, which is attributed to the reduction in the evaporation rate and delay of the peak capillary pressure due to the development of menisci in the pores and lower settlement. Significant reduction in shrinkage deformation and crack width was observed with the addition of Polypropylene glycol-based - non-ionic surfactant and wax-based - non-ionic surfactant in the study by Mora-ruacho et al (Mora-ruacho etal.,2009).

The hydration reaction of cement consumes the moisture to dry the interior of capillary pores, which results in autogenous shrinkage of cement materials. A large number of studies have shown that SRA has a good improvement effect on the autogenous shrinkage, which is reduced gradually with the increase of SRA contents. In a study by Zuo et al., low molecular polyether and high molecular polymer were added and a reduction in autogenous shrinkage was observed. 55% reduction was observed with the addition of low molecular polyether type SRA and a reduction by 34% was observed with the addition of high molecular polymer type SRA(Zuo et al.,2017). Reduced deformation induced by autogenous shrinkage was observed in the study by Wehbe et al, with the addition of Hexylene glycol SRA(Wehbe et al.,2017). The study by Rongbing et al also observed a reduction of autogenous shrinkage by 15.3%-48.1% with the addition of a novel shrinkage reducing admixture processed using 2-butoxy ethanol, ethylene oxide, and propylene oxides, potassium hydroxide, ettringite expansive admixture, and Mighty 100 SP (Rongbing et al., 2005). It is seen that SRA can reduce autogenous shrinkage, but the extent of reduction is quite different between the different types of cementitious materials.

EFFECT OF SRA ON OTHER CONCRETE PROPERTIES

The addition of SRAs not only helps to reduce shrinkage, but also affects many other properties and behaviors of concrete, some of them being beneficial and others not (Ma et al.,2020). The addition of SRA will cause a series of changes in the mortar, including pore size distribution, reaction rate, interfacial bond strength, etc. SRA has positive effects on chloride permeability and frost resistance of cement concrete (Ma et al.,2020). SRAs reduce the sorptivity and increase the viscosity of the pore solution, and as a result, the diffusion rate of aggressive ions is reduced, which might be a benefit to improving the corrosion resistance and freeze-thaw performance if concrete. A higher viscosity is likely to enhance the water retention capability and reduce water evaporation, which guarantees the internal relative humidity of the matrix to stabilize the early-age volume change. In addition, SRAs usually provide lower hydration rates at an early age but a slight enhancement to long-term hydration. The addition of SRA also shows an increase in the ultimate degree of hydration (Ma et al.,2020).

APPLICATIONS OF SRA

Shrinkage-reducing admixtures can be used where shrinkage cracking could lead to durability problems or where large numbers of shrinkage joints are undesirable. Where new concrete is used to strengthen or repair structures, shrinkage-reducing admixtures can lower the risk of cracking in what can be a highly restrained environment.

DISADVANTAGES OF SRA

Some chemical admixture used in concrete are incompatible with Shrinkage-reducing admixtures. To integrate the PCE based admixtures and SRA is also a hard nut to crack to the researchers. Also, we have to make sure that the compatibility of SRA with different types of cements used in concrete. Another disadvantage is the dosage of SRA. If we are using higher dosage of SRA, it will lead to an adverse effect in the concrete.

Thus, special care should be taken while adding SRA to concrete mix with other admixtures. Also, the reactions of the shrinkage reducing admixtures with different types of cements.

CONCLUSION

A review covering existing research on shrinkage cracking in cementitious materials was carried out to analyze the influence of the addition of shrinkage reducing admixtures. SRAs have proven to reduce shrinkage in concrete, significantly drying and autogenous shrinkage. They are used at high dosages compared to other concrete admixtures. Reduction in crack width and delay in the crack initiation time is also observed with the incorporation of shrinkage reducing admixtures. Although SRAs are known for their capability to reduce shrinkage, they also affect many other properties and behaviors of concrete, some of them being beneficial and others not.

REFERENCES

Ling Y., Wang K., and Fu C., “Shrinkage behavior of fly ash-based geopolymer pastes with and without shrinkage reducing admixture,” Cem. Concr. Compos., vol. 98, no. October 2018, pp. 74–82, 2019, DOI: 10.1016/j.cemconcomp.2019.02.007.

Liu Y., Yu Z., Lv C., Meng F., and Yang Y., “Preparation of waste cooking oil emulsion as shrinkage reducing admixture and its potential use in high-performance concrete: Effect on shrinkage and mechanical properties," J. Build. Eng., vol. 32, no. October 2019, p. 101488, 2020, DOI: 10.1016/j.jobe.2020.101488.

Ma H., Zhu H., Wu C., Fan J., Yang S., and Hang Z., "Effect of shrinkage reducing admixture on drying shrinkage and durability of alkali- activated coal gangue-slag material," Constr. Build. Mater., no. xxxx, p. 121372, 2020, DOI: 10.1016/j.conbuildmat.2020.121372.

Maia L., Figueiras H., Nunes S., Azenha M., and Figueiras J., "Influence of shrinkage reducing admixtures on distinct SCC mix compositions," Constr. Build. Mater., vol. 35, pp. 304–312, 2012, DOI: 10.1016/j.conbuildmat.2012.02.033.

Mohamadameen A., Alzeebaree R., and Algın Z., "Enhancement of shrinkage behavior of lightweight aggregate concrete by shrinkage reducing admixture and fiber reinforcement," Constr. Build. Mater., vol. 54, pp. 91–98, 2014, DOI: 10.1016/j.conbuildmat.2013.12.041.

Mora-ruacho J., Gettu R., and Aguado A., "Cement and Concrete Research Influence of shrinkage-reducing admixtures on the reduction of plastic shrinkage cracking in concrete," Cem. Concr. Res., vol. 39, no. 3, pp. 141–146, 2009, DOI: 10.1016/j.cemconres.2008.11.011.

Passuello A., Moriconi G., and Shah S. P., "Cement & Concrete Composites Cracking behavior of concrete with shrinkage reducing admixtures and PVA fibers," Cem. Concr. Compos., vol. 31, no. 10, pp. 699–704, 2009, DOI: 10.1016/j.cemconcomp.2009.08.004.

Rajabipour F., Sant G., and Weiss J., "Interactions between shrinkage reducing admixtures (SRA) and cement paste's pore solution," vol. 38, pp. 606–615, 2008, DOI: 10.1016/j.cemconres.2007.12.005.

Rongbing B. and Jian S., "Synthesis and evaluation of shrinkage-reducing admixture for cementitious materials," vol. 35, pp. 445–448, 2005, DOI: 10.1016/j.cemconres.2004.07.009.

Saliba J., Rozière E., Grondin F., and Loukili A., "Cement & Concrete Composites Influence of shrinkage-reducing admixtures on plastic and long-term shrinkage," Cem. Concr. Compos. vol. 33, no. 2, pp. 209–217, 2011, DOI: 10.1016/j.cemconcomp.2010.10.006.

Wehbe Y. and Ghahremaninezhad A., "Combined effect of shrinkage reducing admixtures (SRA) and superabsorbent polymers (SAP) on the autogenous shrinkage, hydration, and properties of cementitious materials," Constr. Build. Mater, vol. 138, pp. 151–162, 2017, DOI: 10.1016/j.conbuildmat.2016.12.206.

Xiaonan W., Wencui Y., Yong G., and Decheng F., "The influence of shrinkage-reducing agent solution properties on shrinkage of cementitious composite using grey correlation analysis," Constr. Build. Mater, vol. 264, p. 120194, 2020, DOI: 10.1016/j.conbuildmat.2020.120194.

Zhang W., Hama Y., and Hyun S., "Drying shrinkage and microstructure characteristics of mortar incorporating ground granulated blast furnace slag and shrinkage reducing admixture," Constr. Build. Mater., vol. 93, pp. 267–277, 2015, DOI: 10.1016/j.conbuildmat.2015.05.103.

Zuo W., Feng P., Zhong P., Tian Q., and Gao N., "Cement and Concrete Research Effects of novel polymer-type shrinkage-reducing admixture on early age autogenous deformation of cement pastes," Cem. Concr. Res., vol. 100, no. August, pp. 413–422, 2017, DOI: 10.1016/j.cemconres.2017.08.007

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