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Possibilities to Control Concrete Shrinkage by Means of Chemical Admixtures

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Abstract. The main object of the present paper is to describe the possibilities to control shrinkage of concrete by means of chemical admixtures. In an introductory part, also a general overview on the state of knowledge in the field of concrete shrinkage is given. The actual experience indicates that the control of concrete shrinkage with the traditional plasticisers and superplasticisers is quite limited, despite the water reduction obtained at same concrete consistency. A decrease in concrete shrinkage in the order of 30% is, however, possible by the addition of special shrinkage-reducing admixtures. The use of sulfoaluminate-based expansive admixture allows in principle to compensate completely the shrinkage of concrete. An effective means to improve the shrinkage compensating effect is the combination of the expansive admixture with a shrinkage-reducing admixture.

1. Introduction

Shrinkage, which is defined as the reduction in the outer volume without the influence of an external force, is one of the critical properties of concrete. As the concrete is usually under restraint (*e.g.*, by the foundation or the reinforcing steel), the shrinkage may lead to crack formation and affect its serviceability (see *Fig. 1*). The actual knowledge about the mechanisms and control of shrinkage and cracking is still not always on a sufficient level. In practice, it remains sometimes difficult to cope with all the problems arising in this respect.

The main object of the present paper is to describe the progress in the field of chemical admixtures with regard to the control of shrinkage and cracking of concrete. For the better understanding, a general overview on concrete shrinkage will be given in a first part of the paper.

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2. Overview on Concrete Shrinkage

2.1. *Types of Shrinkage and Significance*

Shrinkage of concrete is due to changes in the water balance within the pore system of the concrete. According to the time of occurrence and the origin of these changes in the water balance, different types of shrinkage can be distinguished [2]. The most important ones are the plastic shrinkage (fresh concrete) and the drying shrinkage (hardened concrete).

The *plastic shrinkage* is essentially a physical process, which presents itself when the concrete surface is drying after placing and compacting. This drying leads to capillary forces, which result in a higher compaction degree of the concrete and thus in a reduction of the volume. Cracking due to plastic shrinkage can usually be avoided by proper curing of the concrete. The concrete composition influences plastic shrinkage insofar that a water-rich concrete, with a high water retention capacity, is more susceptible to this type of shrinkage.

Drying shrinkage is defined as the volume reduction of concrete due to the water loss after hardening. This shrinkage is nearly exclusively provoked by the properties of the hardened cement paste, which is characterised by a very high internal surface. Drying shrinkage of the concrete has the greatest practical significance among the different types of shrinkage and can not be avoided. The main factors influencing drying shrinkage and possibilities to control it will be discussed in the following chapters.

The other types of shrinkage, apart from the above-mentioned, are the *chemical* and *carbonation shrinkage*. They have usually only little practical significance.

2.2. *Main Factors Affecting Drying Shrinkage of Concrete*

The main factors affecting the drying shrinkage of concrete can be grouped as follows:
- humidity conditions of the environment
- shape and size of the structural element
- composition of concrete
- characteristics of concrete components.

The shrinkage potential will obviously depend on the *humidity of the environment*, since it controls the water loss from the hardened concrete; the amount of shrinkage increases if the ambient humidity is reduced.

The *shape and size of the structural element* is also directly related to the magnitude of drying shrinkage; with decreasing volume/surface ratio, the shrinkage will increase. That means that thin structural members and structures with a large exposed surface (*e.g.*, slabs and walls) will always have a higher shrinkage and be more prone to cracking.

With respect to *concrete composition*, the water content is generally a good indicator of the order of drying shrinkage to be expected. *Fig. 2* indicates that the drying shrinkage increases linearly with the wa-

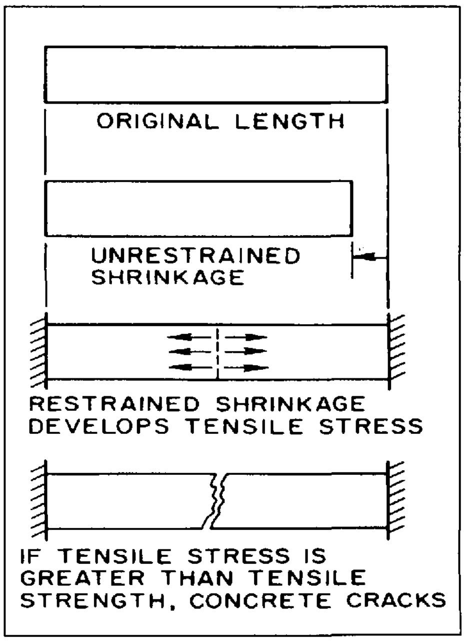

Fig. 1. *Cracking of concrete due to shrinkage under restraint* [1]

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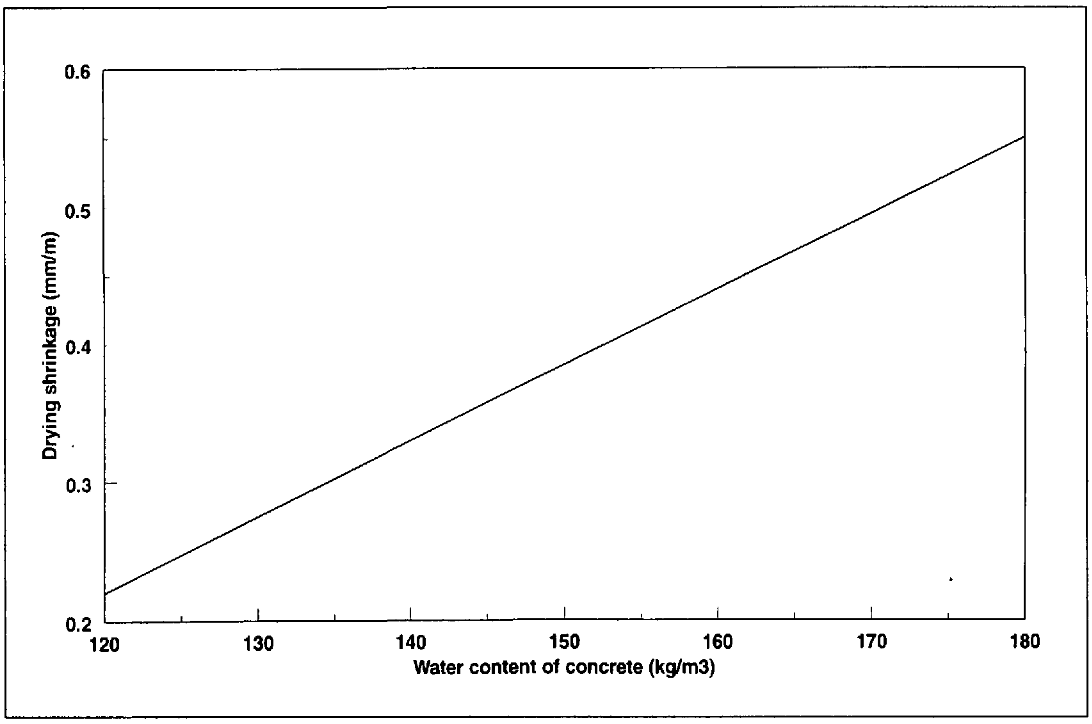

Fig. 2. *Typical effect of water content of concrete on drying shrinkage* [1]

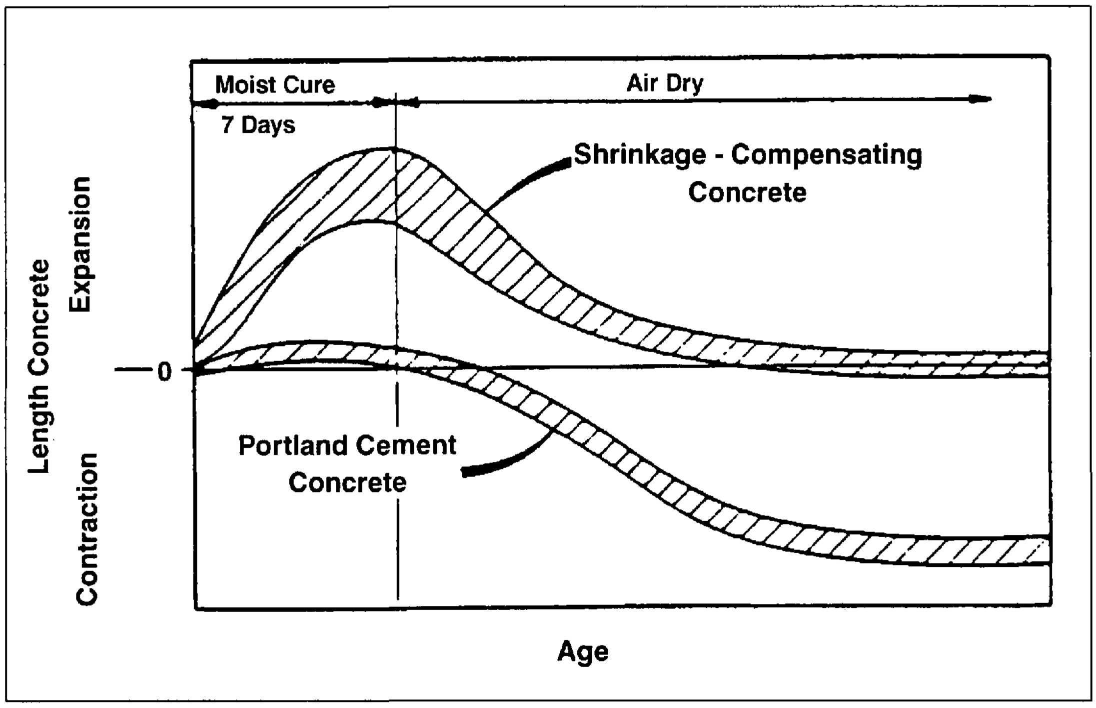

Fig. 3. *Typical length-change characteristics of shrinkage compensating and Portland cement concrete* [3]

ter content of concrete. The cement content is not believed to be a primary factor for shrinkage (at constant consistency).

The drying shrinkage of concrete may increase with the fineness and the aluminate and alkali content of the Portland cement, whereas it may be reduced at higher alite contents. Essential for minimum shrinkage is an optimised gypsum content. Mineral additives in the cement will affect the shrinkage only to the extent that they affect the concrete water requirement.

For given mix proportions, the type of aggregate used may have a considerable influence on the drying shrinkage of concrete. A higher modulus of elasticity of the aggregate will result in a lower shrinkage. On the other hand, the clay content and the water absorption properties of the aggregate will affect the shrinkage behaviour of concrete.

Chemical admixtures like plasticisers/superplasticisers, set retarders and air entrainers have virtually no influence on shrinkage, whereas certain accelerators can affect it negatively. There are, however, specific chemical admixtures available which allow to reduce the drying shrinkage of concrete (see also *Chapt. 3*).

2.3. *Control of Cracking of Concrete Due to Drying Shrinkage*

The measures adopted for the control of cracking due to drying shrinkage comprise the reduction of the cracking tendency of the concrete or the application of expansive admixtures to compensate the concrete shrinkage. The provisions made in the design of the concrete structures to avoid shrinkage cracking comprise the use of adequate and properly positioned reinforcement and the use of control joints.

The cracking tendency of concrete can generally be reduced by the decrease of the shrinkage itself. In accordance with the influencing factors described in the previous chapter, the principal ways to achieve least shrinkage of concrete are:

- optimisation of concrete mix composition (minimisation of water content)
- selection of cement with low C_3A and alkali and high C_3S content, optimum gypsum dosage and not too high fineness
- use of aggregate of high modulus of elasticity, low absorption and free of clay.

The possibilities to minimise drying shrinkage with chemical admixtures are elucidated in *Chapt. 3*.

The use of expansive admixtures to compensate shrinkage may be an effective means to avoid shrinkage cracking. The basic concept of shrinkage compensation is to increase the concrete volume before the commencement of shrinkage, so that the concrete will attain after the shrinkage process the original volume (see *Fig. 3*). The use of the expansive admixture does accordingly not prevent the development of shrinkage; the early expansion just balances the subsequent normal shrinkage.

There exist several types of expansive admixtures, which can be used in shrinkage-compensating concrete. The most common type is based on calcium sulfoaluminate ($4CaO{\cdot}3Al_2O{\cdot}3\ SO_3$) due to its favourable expansion characteristics. This type of admixture will also be discussed in the next chapter.

3. Control of Drying Shrinkage of Concrete by Means of Chemical Admixtures

3.1. *Use of Plasticisers/Superplasticisers*

The commercially used plasticisers and superplasticisers do generally not influence noticeably the drying shrinkage, despite the water reduction obtained at same concrete consistency [4–6]. Test results of *'Holderbank'* in *Fig. 4* illustrate that the shrinkage is virtually not improved with conventional superplasticiser despite the substantial water reduction achieved.

The use of plasticisers and conventional superplasticisers in concrete is therefore no guarantee that the concrete shrinkage will be reduced. The only way to know

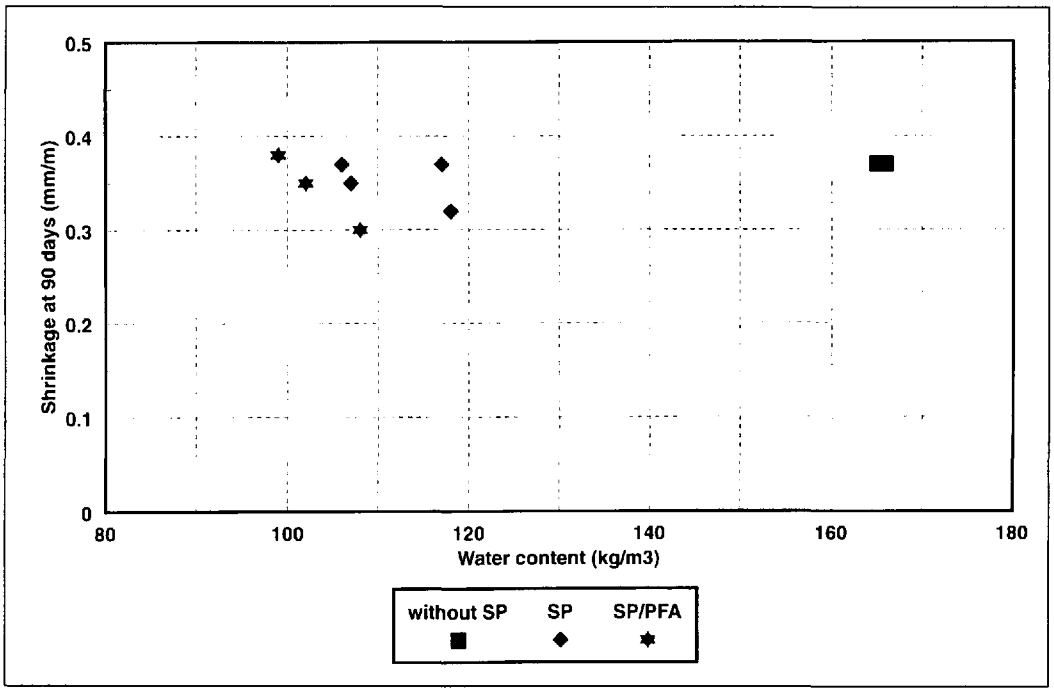

Fig. 4. *Drying shrinkage of concrete mixtures made of Portland cement, superplasticiser* (SP) *and fly ash* (PFA) *as a function of the water content of concrete*

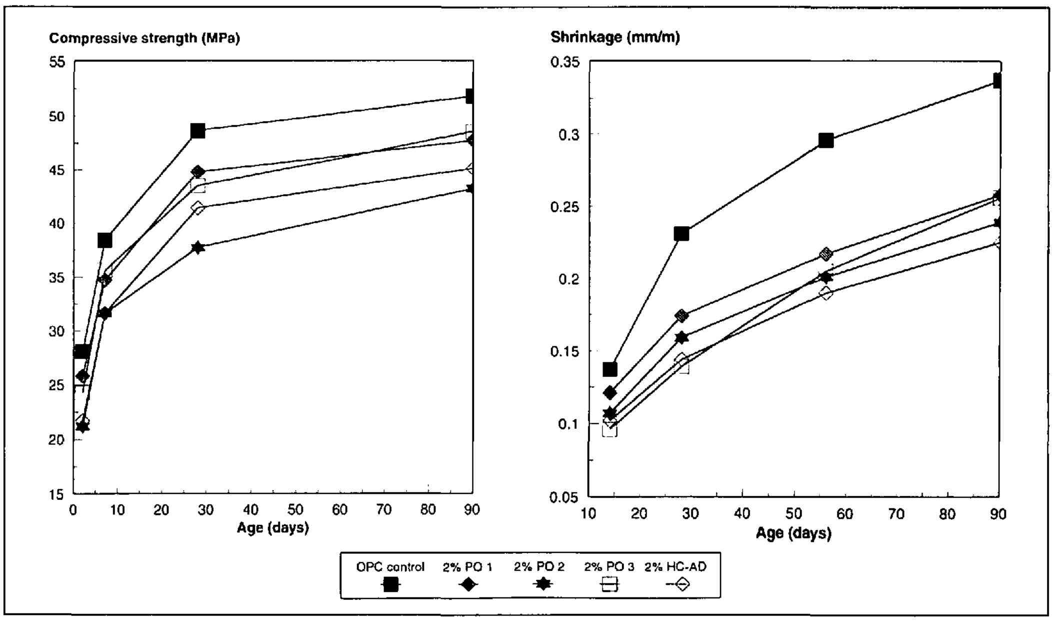

Fig. 5. *Strength and shrinkage of ordinary Portland cement* (OPC) *concrete containing shrinkage-reducing admixtures Polyol* (PO) *1 to 3 and HC-AD* (Eucocomp 100)

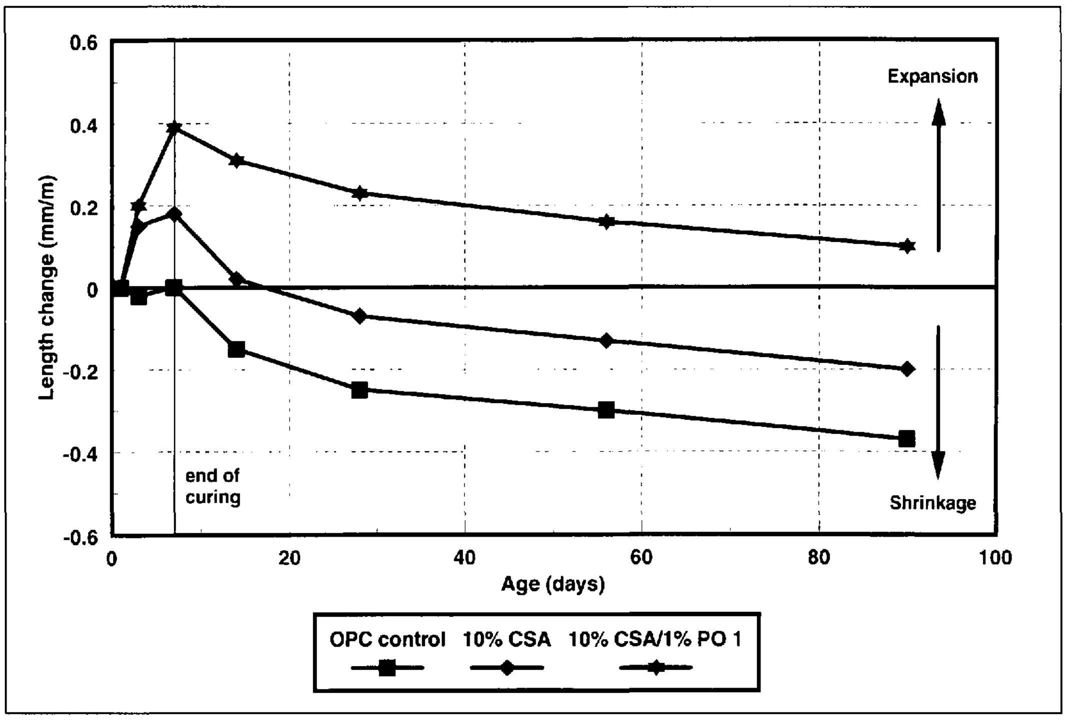

Fig. 6. *Development of expansion/shrinkage of ordinary Portland cement* (OPC) *concrete with expansive admixture CSA and shrinkage-reducing admixture Polyol* (PO) *1*

if such admixtures will result in lower shrinkage is to test them on the corresponding concrete mixes.

3.2. *Use of Shrinkage-Reducing Admixtures*

Several chemical admixtures designed for the purpose of drying shrinkage are available in the market. The positive effect of these admixtures, which are usually based on polyalcohol compounds, can be explained by the weakening of the capillary tensions or by the improvement of the water retention properties of the concrete.

The actual reduction in the final drying shrinkage with the mentioned admixtures lies in the order of 30%. A drawback for their use is still the decrease in concrete strength, in particular at early age. *Fig. 5* presents some practical results obtained at '*Holderbank*' on concrete mixes with 2% of different shrinkage-reducing admixtures compared to a control mix without admixtures.

3.3. *Use of Sulfoaluminate-Based Expansive Admixture*

Cracking of concrete due to drying shrinkage can in principle be totally eliminated through shrinkage compensation by means of the use of sulfoaluminate-based expansive admixture. The main controlling factor to achieve adequate expansion is the admixture dosage, which has to be optimised for each concrete mix design.

The most interesting results from the point of view of shrinkage compensation are obtained with a combination of expansive and shrinkage-reducing admixtures. By the combination, it is possible to multiply the expansive effect and to compensate more effectively the concrete shrinkage (see test results of '*Holderbank*' in *Fig. 6*). A critical point is, however, the reduction in early strength of concrete.

4. Conclusions

Among the different types of concrete shrinkage, drying shrinkage of the hardened concrete has the greatest practical significance in connection with crack formation. The principal measures to reduce the drying shrinkage and cracking tendency of concrete are, besides the provisions in the design of the concrete structure, the optimisation of the concrete mix design (minimisation of water content) and the proper selection of cement and aggregate.

Despite the possible water reduction with plasticisers and superplasticisers at same concrete consistency, there is generally no positive effect on the drying shrinkage of concrete. Accordingly, a lower water content achieved by means of such admixtures will not guarantee a reduction in the drying shrinkage of the concrete.

A reduction in the amount of drying shrinkage of concrete and thus in the cracking tendency is possible by the addition of special shrinkage-reducing admixtures. Typical shrinkage reductions achieved by these admixtures are in the order of 30%.

The use of sulfoaluminate-based expansive admixtures for shrinkage compensation allows in principle to avoid completely cracking of concrete due to drying shrinkage. An effective means to improve the shrinkage compensating effect is the combination of the expansive admixture with a shrinkage-reducing admixture.

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[1] ACI Committee 224, 'Control of Cracking in Concrete Structures', ACI Report 224R-90.
[2] P.-C. Aïtcin *et al.*, 'Integrated View of Shrinkage Deformation', *Concrete International*, **1997**, September, p. 35.
[3] ACI Committee 223, 'Standard Practice for the Use of Shrinkage Compensating Concrete', ACI Report 223-290.
[4] V.S. Ramachandran, 'Concrete Admixtures Handbook – Properties, Science and Technology', 2nd edn., Noyes Publications, 1995.
[5] J.J. Brooks, A. Neville, 'Creep and Shrinkage of Concrete as Affected by Admixtures and Cement Replacement Materials', ACI Publication SP 135, 1992, pp. 19–36.
[6] D. Whiting, 'Effects of High Range Water Reducers on Some Properties of Fresh and Hardened Concrete', Research and Development Bulletin RD 061.01 T, Portland Cement Association, 1979.