# SHRINKAGE OF STEEL AND POLYPROPYLENE FIBRE REINFORCED HIGH PERFORMANCE CONCRETE

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## Introduction

By adding steel or other fibres, which can act as fibrous reinforcement, the properties of high performance concrete can be improved [1]. Swamy and Stavrides [2] have asserted that the shrinkage of a composite containing 1% by volume of fibres is up to about 20% less than that of a comparable plain concrete. According to Barr and Baden [3], the optimum steel fibre content for the reduction of composite shrinkage is 1%. Contrary to Swamy and Stavrides [2], Myers et al. [4] maintain that polypropylene fibres have a very small influence on composite shrinkage. Koveler et al. [5] have stated that the presence of polypropylene fibres results in a considerable decrease in the plastic shrinkage of fibre reinforced concrete. With regard to the total shrinkage, they stated that the effect of polypropylene fibre reinforcement is virtually insignificant up to a content of 0.2% by volume.
The results of the authors' own laboratory investigations into the shrinkage of polypropylene and steel fibre reinforced high performance concrete, with volumetric fibre content of 0.75% have been analysed in this paper. During the laboratory investigations the autogenous as well as the total shrinkage of fibre reinforced high performance concrete was measured. In order to compare the shrinkage of fibre reinforced concretes with that of a comparable concrete without fibres, the shrinkage of such a comparable concrete, without fibres, was also included in the measurements.

## Experimental details

*Laboratory Investigations*
Measurements of the shrinkage of composites on prism-shaped test specimens (10×10×40 cm) were performed. The total shrinkage of the fibre reinforced concrete was measured on the test specimens, which were exposed to an environment with a constant relative humidity of 70±3% and a temperature of 22±3°C in a climatic chamber. Electronic measurements of autogenous shrinkage were carried out on sealed specimens, from the moment when they were cast, whereas the total shrinkage of the unsealed specimens was measured by an inset displacement transducer.

*Preparation of the Composites and Specimens*
The fibre reinforced concrete specimens were prepared from washed crushed limestone aggregate, with a maximum nominal grain size of 16 mm, and the addition of fine silica sand. The binder consisted of cement type CEM II/A-S 42.5R (360 kg/m$^3$) and silica fume (40 kg/m$^3$). To ensure appropriate workability, a naphthalene type superplasticizer was used. For all fibre contents, the effect of longer ($l$= 30mm) and shorter ($l$= 16mm) steel fibres and polypropylene fibres ($l$= 12mm) on the shrinkage of fibre reinforced concrete, at a water-to-binder ratio of fresh concrete mixtures of 0.36, was investigated.

Table 1 Mix proportions and properties of the composites.

| Mix | M1 | M4 | M7 | M10 |
|---|---|---|---|---|
| Fine aggregate 0-4 [kg/m$^3$] | 1133 | 1126 | 1126 | 1126 |
| Coarse aggregate 8-16 [kg/m$^3$] | 755 | 750 | 750 | 750 |
| Fibres | - | (V1) | (V2) | (P) |
| [%] by volume | - | 0.75 | 0.75 | 0.75 |
| Flow [cm] | 55 | 43 | 46 | 41 |
| Density [kg/m$^3$] | 2436 | 2452 | 2420 | 2383 |
| $f_{cm,28days}$ [MPa] | 68.9 | 86.6 | 85.5 | 78.2 |

Legend: (P) polypropylene fibres ($l$= 12mm)
(V1) shorter steel fibres IRI 50/16 ($l$= 16mm)
(V2) longer steel fibres IRI 50/30 ($l$= 30mm)

## Results and Discussion

Measurements of composites with a fibre content of 0.25%, 0.50% and 0.75% by volume of polypropylene fibres, and shorter and longer steel fibres, were performed. In this short paper only the results of composite shrinkage with a volumetric fibre content of 0.75% are presented, in Figures 1, 2, 3 and 4.

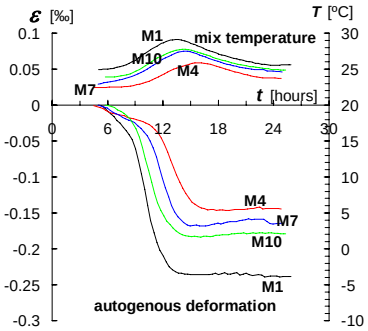


Fig. 1 Early autogenous shrinkage of the investigated composites.

From Figure 1, which shows autogenous shrinkage of a typical composite, it can be seen that the shrinkage of the composite containing shorter steel fibres is the least of all the investigated concretes, and amounts to about 40% less than the shrinkage of the comparable concrete without fibres, and about 13% less than the shrinkage of the composite with an equal content of longer steel

fibres. The shrinkage of the composite with a content of 0.75% of polypropylene fibres was, 24 hours after mixing, 25% less than the shrinkage of the comparable concrete without fibres, and about 7% greater than the shrinkage of fibre reinforced concrete with the same content of longer steel fibres IRI 50/30.

After 28 days, and up until about 80 days after the preparation of the test specimens, the autogenous shrinkage of the composite with a 0.75% content of polypropylene fibres differed from that of a composite with an equal content of shorter and longer steel fibres by 8% at the most. The shrinkage of composites with the same content of polypropylene, or shorter or longer steel fibres, was, 14 days after mixing, approximately 16% less than the shrinkage of high-performance concrete without fibres, and finally approximately 11% less (Fig. 2).

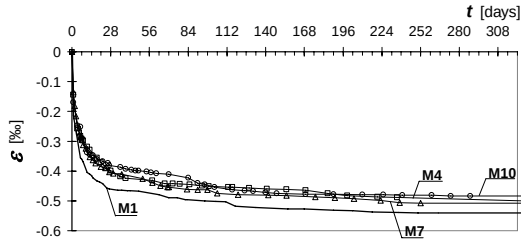


Fig. 2 Development over time of the autogenous shrinkage of the investigated composites.

From Figure 3 it can be seen that the total shrinkage of the composite was the least in the case of a content of 0.75% of polypropylene fibres, which was, 14 days after mixing, 36% less than that of a comparable concrete without fibres, whereas on the 322nd day after mixing it was 30 % less. The shrinkage of the composite with a 0.75% content of shorter steel fibres was, in general, 8% less than the shrinkage of the composite with the same content of longer steel fibres, and approximately 8% greater than the shrinkage of the composite with the same content of polypropylene fibres. The largest shrinkage, of all the composites, was measured in the case of the composite with a 0.75% content of longer steel fibres. It amounted to 22% on the 14th day after mixing, and 19% on the 322nd day, compared to the shrinkage of the comparable concrete without fibres.

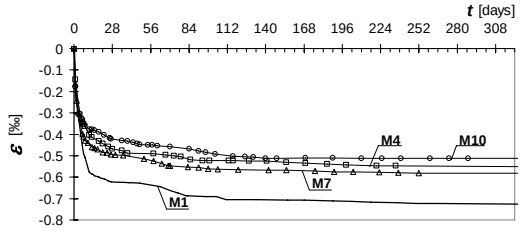


Fig. 3 Development over time of total shrinkage of investigated composites.

From Figure 4 it can be seen that drying shrinkage of the composite with a content of 0.75% of polypropylene fibres was the least of all the fibre reinforced concretes, and is, in general, 80% less than the shrinkage of the comparable concrete without fibres. The drying shrinkage of the composite with the same content of shorter steel fibres was 36% less than that of the composite with the same content of longer steel fibres, and 66% greater than the shrinkage of the composite with the same content of polypropylene fibres. The greatest drying shrinkage of the fibre reinforced concrete was determined in the case of the composite with a content of 0.75% of longer steel fibres, and was in general approximately 52% less than the shrinkage of concrete without fibres.

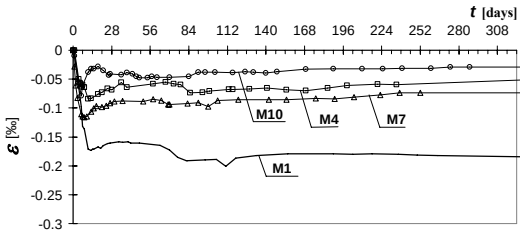


Fig. 4 Development over time of the drying shrinkage of the investigated composites.

## Conclusions

The total, autogenous and drying shrinkage of high performance concrete reinforced by polypropylene or steel fibres is lower than that of comparable high performance concrete without fibres. The reduction in shrinkage depends primarily on the volumetric content of the fibres used.

From the results of the experimental investigations it can be seen that the steel fibres are more effective in reducing the early autogenous shrinkage, whereas the polypropylene fibres are more effective in reducing the drying shrinkage of the composite.

Based on the results of the experimental investigations, it can be concluded that shorter steel fibres, with a content of 0.75% of fibres, are more effective in reducing the early autogenous shrinkage of high performance steel fibre reinforced composites than longer ones.

The casting of steel fibre reinforced concretes generally requires a longer period of vibration than is necessary in the case of comparable concrete without fibres.

## References


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