CONTROLLING EARLY AGE SHRINKAGE CRACKS WITH STEEL OR SYNTHETIC MACRO FIBRE REINFORCEMENT IN JOINTLESS FLOORS

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Summary

The effect of the use of fibre for controlling early age shrinkage is well-known, although there is no generally accepted method to make calculations on it. One of the biggest advantages could be to increase the dilatations and/or joints distances with the use of the fibres. The effect of the fibre during hardening was measured in our laboratory at different ages and the results were implemented into a time-dependent material model. The crack propagation and crack widths were determined for different floors, where the connection between the concrete and the subgrade was changed. Results show very good effects of both synthetic and steel fibre reinforcement types.

1 Introduction

The use of fibre reinforcement has become an increasingly popular alternative to traditional steel mesh in industrial floors for the control of early age shrinkage. There are however, no generally accepted standards for the design of so-called the jointless floors, only guidelines. One of the most well known guidelines for industrial floors is the British guideline: Technical Report 34 – Concrete Industrial Ground Floors 3rd [5] and 4th [6] edition. This includes the design method for traditional steel bar reinforced, steel or synthetic fibre reinforced or hybrid (steel bar and fibre) reinforced solutions. The 3rd edition of the TR34 (2003) set out a method regarding how to take into account the effect of early age shrinkage, although this method was very conservative and rudimentary. In the 4th edition however, the calculation method of early age shrinkage was totally omitted, and the document limits itself to simply stating that cracks could be avoided if the concrete mix design, curing time and dilatation distances are appropriate and well designed.

2 Laboratory test

2.1 Test specimen

The effect of the fibers at early age had to be measured by laboratory tests. Three points unnotched beam tests were used, becasue making a notch at early age would have been difficult. The load and the middle point deflection were measured. The test was performed by a universal testing machine ZWICK Z150 in the Laboratory of Department of Mechanics, Materials and Structures, Budapest University of Technology and Economics. The speed of the test was 0.2 mm/sec until total failure or 4 mm central deflection.
The concret mix was chosen to imitate the most common industrial floor concrete types, can be seen in Table 1. The added fibre reinforcements used were synthetic and steel with common dosages: at synthetic 2.5 and 5 kg/m^3, whlist for steel 30 kg/m^3. The types of the

fibre reinforcement can be seen in Table 2. The age of the beams were 9, 14, 24 hours and 7 and 28 days, which were indicated in the name of the specimen. The research matrix can be seen in Table 3.

Tab. 1 Concrete mix

Concrete name	Cement type	w/c ratio	Aggregates (kg/m^3)			Admixtures
			0-4	4-8	8-16	
A	CEM-III-A	0,492	722	380	799	Dynamon SR3 1,63

Tab. 2 Fibre reinforcement

Fibre sign/name	Fibre type	Fibre length mm	Dosage kg/m^3	Number of fibres Number/m^3
SY25 Barchip48	Synthetic fibre Surface embossed	48	2,5	150 602
SY50 Barchip48	Synthetic fibre Surface embossed	48	5,0	301 205
ST30 ArmfibR	Steel fibre Hook-end	50	30	93 780

Tab. 3 Research matrix

Name of the specimen	Concrete	Fibre
EAS-A-0-time	A	-
EAS-A-SY25-time	A	SY25
EAS-A-SY50-time	A	SY50
EAS-A-ST30-time	A	ST30

2.2 Results

The results of the different concretes at differnet ages can be seen in Fig. 1. The changes of the material properties show good correlation with the literature [1, 4, 7]. The post-crack performance of the fibres shows differences: the synthetic decreases, while the steel increases. From the tests the elastic modulus (E), the flexural tensile strength (f_t), the ratio of the tensile strength and residual strength (R_{e3}) and the fracture energy (G_f) could be measured.

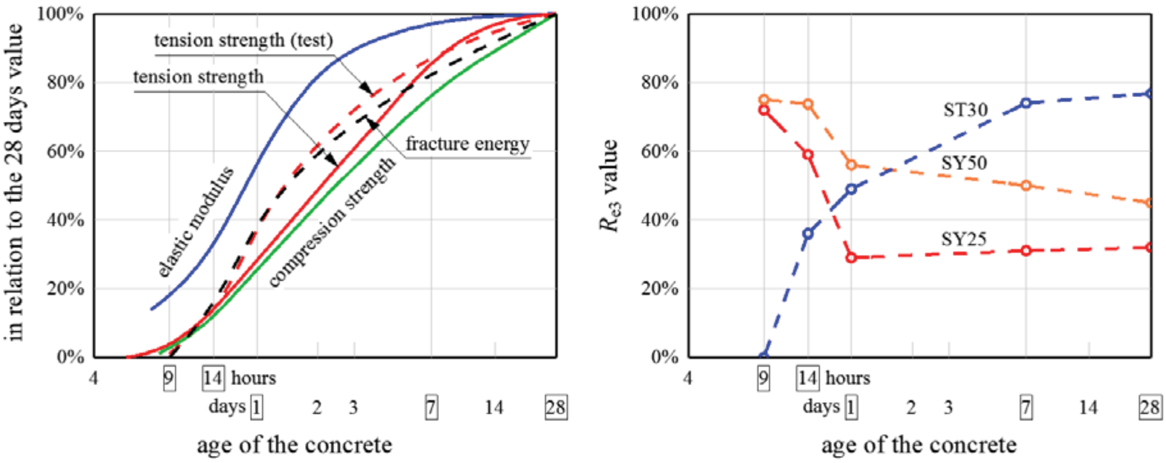

Fig. 1 The increase of the material parameters of the concrete as function of time in relation to the 28 days value [1, 4, 7]. Dashed lines are the results of the present research.

3 Finite Element Analysis

3.1 Material model

Time-dependent material model was used during the analysis, where the results of the tests were used as input parameters. The unknown parameters, such as compression strength, Poisson-number were taken according to literature [1, 4, 7]. Modelling of the FRC was made according to Modified Fracture Energy Method [3]. The numerical calculation was made by ATENA (Cervenka Consulting) FE software.

3.2 Numerical model

A 2D section of the industrial floor was modelled. The thickness was 200 mm. The floor was modelled in symmetry and the full length of the floor was 24 m. The concrete floor was connected to the ground with an interface element. The interface element was determined by its friction, from 0 (no friction) to fix contact. The crack propagation, maximum crack width and deflection was measured during the analysis. The geometry and the parameters of the numerical models can be seen in Fig. 2. The model was loaded with shrinkage according to JSCE [2].

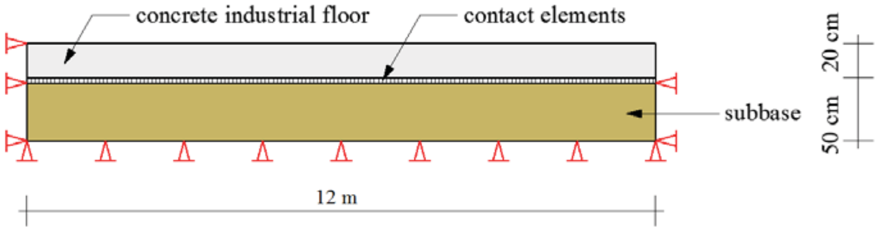

Fig. 2 Geometry and material parameters of the finite element model

4 Results

Results were compared according to the maximum crack width, fibre type/dosage and friction between the floor and the ground (friction of the interface element). The effect of the fibre on the crack width can be clearly seen, but it also need to be mentioned that the friction of the interface element has a great influence on the results. Diagram of this comparison can be seen in Fig. 3.

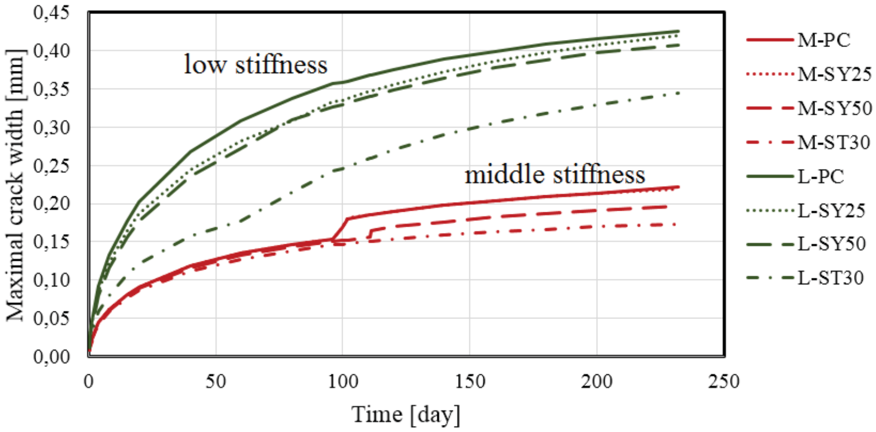

Fig. 3 Comparison of maximum crack widths according to fibre type/dosage and friction

The difference in the crack propagation can be clearly seen in the Fig. 4. The plain concrete has localised cracks while the FRC has more, but smaller cracks. Also the deformation of the edge point is bigger in case of FRC. Although, the added fibre has a positive effect on the crack width, the effect is not significant at this low dosage.

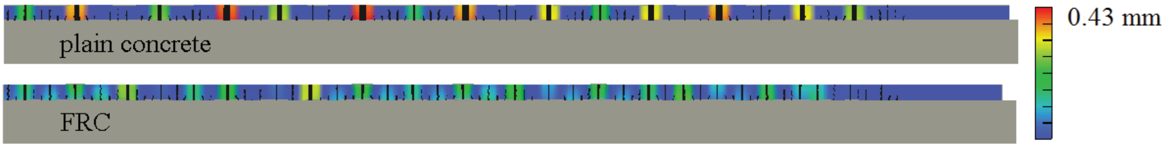

Fig. 4 Crack propagation of plain and FRC

5 Conclusion

The effect of the fibre could be clearly seen in this research on the early age shrinkage of the concrete and the crack propagation of the modelled industrial floor. The crack propagation has been changed by the fibres and it has leaded to smaller cracks. Friction between the concrete and the sub-base is a very important parameter during the modelling and has a significant effect on the final results. On the material model side an important correlation was discovered, namely the residual strength of the FRC is mostly the parameter of the tensile strength of the concrete at early age, but has a different behaviour at synthetic and steel fibres.

References

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