OPERATING CHARACTERISTICS OF CEMENT COMPOSITES WITH HYBRID NON-METALLIC FIBRE REINFORCEMENT

Josef Knězek[1], René Čechmánek[1]

Abstract

Structural applications of cement composites with non-metallic fibre reinforcement. Key factors of production technology of cement composites with dispersed fibre reinforcement. Load operating characteristics – cement composite response. Questions of fibre composite weathering aging. Possibilities and limits of production of cement composites with dispersed hybrid fibre reinforcement. Observations from present experiments.

Keywords: non-metallic fibres, hybrid fibre reinforcement.

1 Introduction

Until recently for Europe dominant non-metallic fibres for reinforcement of composite matrix based on Portland cement – alkali-resistant glass fibres (AR-fibres) in form of strands with defined length have opened new possibilities in formation of building and broken shell constructions. Initial production technology with parallel spraying of cement-sand mortar and AR-fibres was supplemented with premix technology – wet mixing of fibre cement mixture and subsequent casting into moulds. Limited level of AR-fibres alkali-resistance was gradually suppressed by superior surface treatment of AR-fibres, adjustment of cement matrix alkalinity and application of acrylate dispersions. If these measures are not applied in our building experience, then it is necessary to take note of the time development of composite mechanical properties in the way that is schematically shown on Fig. 1. Lower machine-technical requirements and apparent simplicity of premix technology go along with restriction of AR-fibre strand length, where even lowering of „tex“ of initial strands is not enough for elimination of initial slenderness of fibres applied with spraying technology. Final composite from spraying technology is characterized by 2D-arrangement of AR-fibres, but in premix technology – also in dependence on final product geometry - there is also a strong tendency to 3D-arrangement of AR-fibres. Mentioned phenomena influence immediately mechanical properties. On Fig. 1 shown operating characteristics of flexural stress/relative deformation has in fact strong statistical character, which is in case of premix technology influenced by mixing equipment, initial mixture composition and keeping of technological regimes. In recent years implemented spraying technology of wet mixture premix can support 2D-orientation of AR-fibres. To what extent the used fibres are dispersed uniformly in final composite – concerning both amount and orientation of fibres – so much the presumptions for „uniform level“ of mechanical properties are formed, independently of the non-metallic fibre type. It can be noted, that current quality experience is characterized by flexural strength variation coefficient not exceeding 15%.

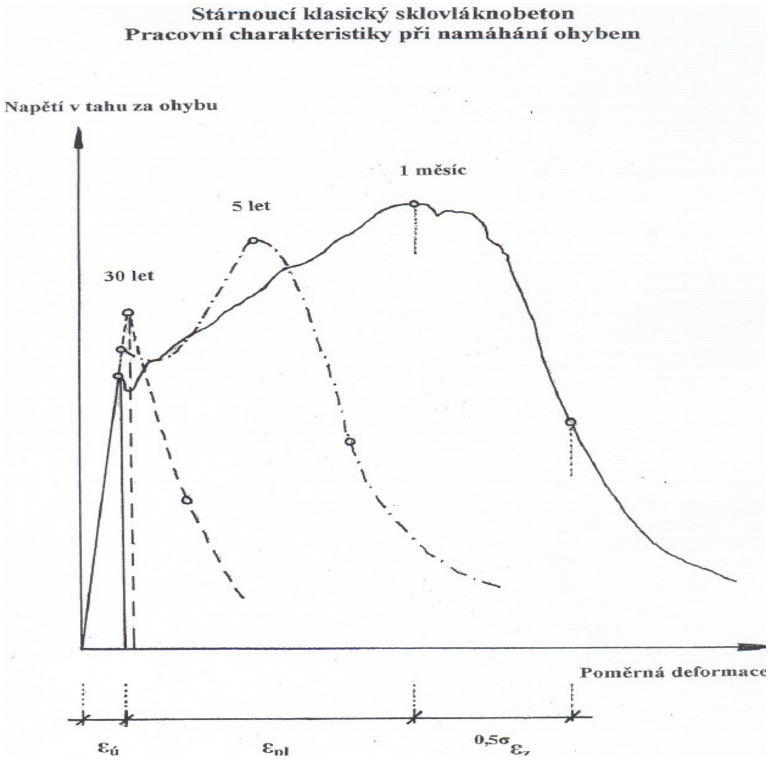

Fig. 1 Operating characteristics of glass fibre reinforced concrete made by spraying technology during weathering aging

Continual progress in premix technologies has brought new solutions in recent years. One of them, which is known as Ductal is characterized by suppression of coarse grained components, optimization of grading composition and adequate deformation behaviour of final composite with dispersed fibre reinforcement when managing the mixing process. Operating characteristics of this ultra-high quality concrete with high deformation capacity at bending strength exceeding 40 MPa and compressive strength 200 MPa is shown on Fig. 2. Other type of cement composite with high deformation capacity at tensile strain is composite commonly referred to as HPFRCC (High Performance Fibre Reinforced Cement Composites). It uses in addition to the high ductility of used fibres (generally PVA-fibres) also specific deformation properties of cement matrix with extremely fine grained filling components, whose operating characteristics is shown schematically on Fig. 3. In both cases utilization of fine grained matrices is typical. The problem of fibre cohesion with the matrix is solved specifically, which guarantees the ability to eliminate big elongation of used fibres through numerous cracks system. Schematic comparison of operating characteristics at tensile strain in case of cement mortar, fibre reinforced concrete and HPFRCC is shown on Fig. 4.

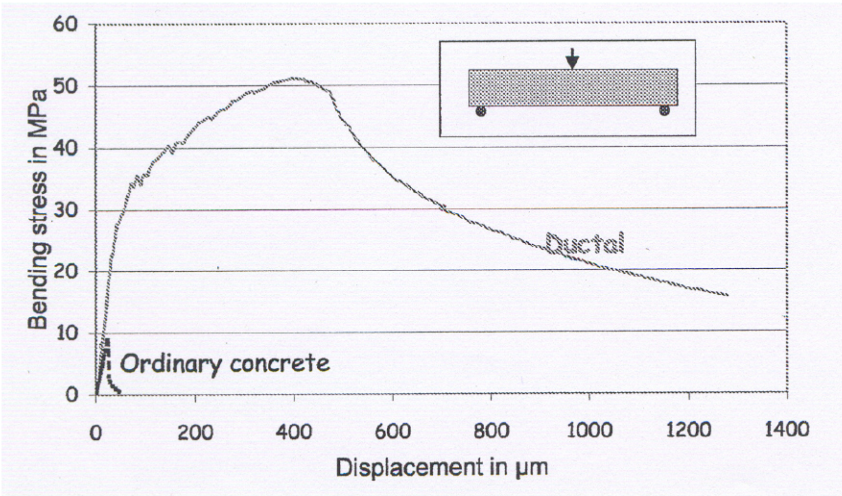

Fig. 2 Operating characteristics of Ductal composite at flexural strain

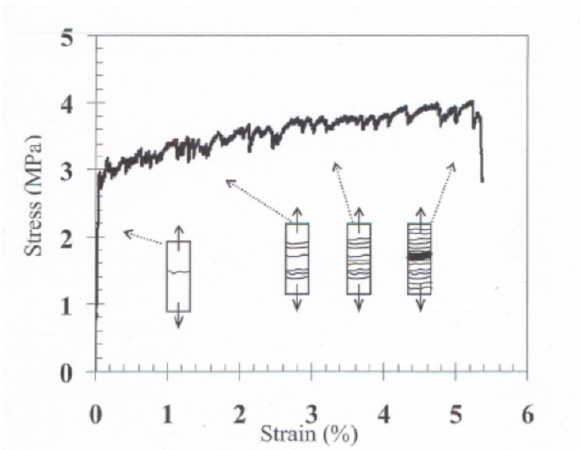

Fig. 3 Operating characteristics of HPFRCC at tensile strain

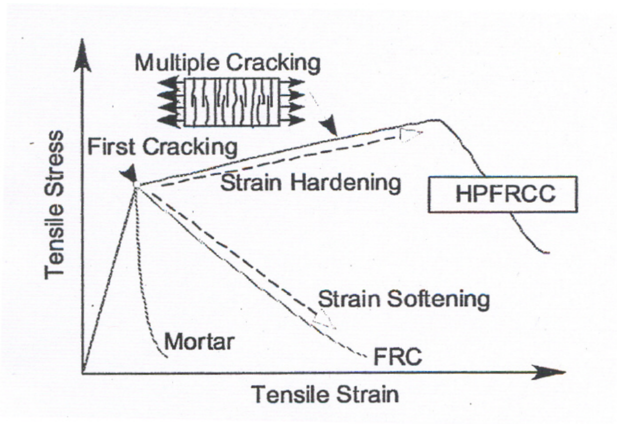

Fig. 4 **C**omparison of cement mortar, FRC and HPFRCC operating characteristics at tensile strain

2 Cement composites with hybrid fibre reinforcement

Utilization of fibre reinforcement in cement composite composition is not purposeless and has its unsubstitutable function in final composite structure (or should have, once it is dosed into mixture and its effective dispersion in final composite volume is suggested). At parallel use of two or more fibre types of specific properties it is necessary to technically meet expectations of their potential benefits. From our present experience technically acceptable results were obtained at meeting the workability conditions of initial production mixture. Relatively simple objective was for example the composition of cement composite designed for technical applications at higher temperatures, permanently not exceeding 500°C, where hybrid fibre reinforcement was formed by fibre mineral wollastonite ($L_{f.max}$ = 3 mm) and carbon fibres (L_f = 10 mm). For cement composites having building purposes the impulse for utilization of hybrid fibre reinforcement can be demands on toughness adjustment at impact strain, but also economic aspects. The fundamental problem of cement composites with hybrid fibre reinforcement is processing technology managing of wet fibre mixture – "homogenization". (Potentially suitable suspension technologies of hybrid fibre reinforcement processing are specific case, which cannot be implemented out of specialized manufacturing companies). From our experience can be concluded, that at wet mixing it is possible to determine empirically the acceptable fraction of the "second" fibre in view of workability, if we from another reasons have to keep the fraction of the "first" fibre, with length ratio at least 1 : 3. Longer fibre should not exceed 20 – 30 mm in dependence on flexural stiffness, especially in cases of sheet constructions with thickness less than 20 mm made from cement composite. It is necessary to minimize the dimensions of matrix structural particles.

3 Influence of wet fibre mixture mixing method on composite operating characteristics at flexural strain

Problem complexity of wet fibre cement mixture homogenization evokes the question, which technically available mixing method is more suitable. If it is possible to prove exact the statistically significant difference between different mixing methods – it means as statistically significant – when we admit the real situation in stochastic character of structural components arrangement.

Results of realized homogenization experiment with standard wet glass fibre reinforced concrete mixture are shown on Fig. 5 and Fig. 6, where mortar mixer JM 125 and OMNI MIXER 10EV were used. Processed data of specimen sets were statistically processed and the zone determining the occurrence probability of mean values P = 90% is marked with a dashed line.

Mixing technology in JM 125 was adopted from common production, mixing parameters in OM 10EV are preliminary for the present, for the final implementation they should be optimized.

Comparison of basic physical-mechanical parameters of composites made by different mixing methods shows, that homogenization in OM 10EV will be able to provide generally superior structure arrangement in final composite. At practically identical bulk density (and porosity level) OM 10EV provides in the area of elastic behaviour higher cooperation of fibre reinforcement with the matrix. After start of cracks at strain over proportional limit, the effectivity of identical glass fibre quantity is higher.

Table 1. Comparison of glass fibre reinforced concrete properties

Homogenization method	Number of specimens	Bulk density/v% kg m^{-3}	Proportional limit/v% MPa	Bending strength/v% MPa	Modulus of elasticity/v% GPa
JM 125	16	2022/3,9	12,0/12,0	14,9/15,4	21,3/12,7
OM 10EV	14	2027/3,6	15,0/3,0	16,7/15,6	26,4/9,8

Note: v% = variation coefficient in %

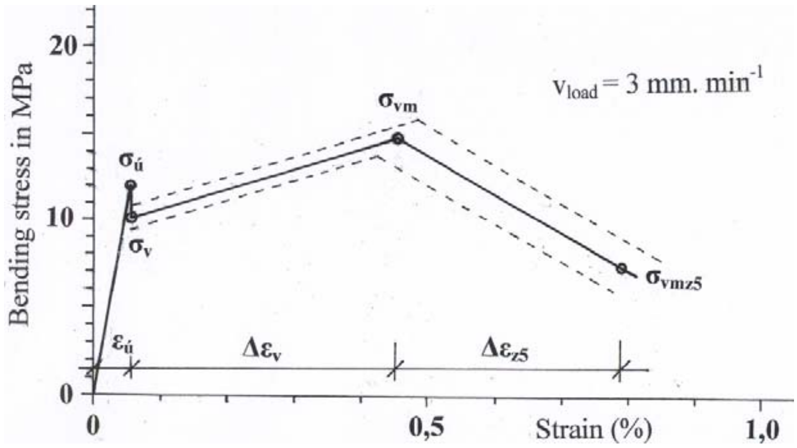

Fig. 5 Operating characteristics of standard glass fibre reinforced concrete at flexure, wet mixture homogenization in JM 125.

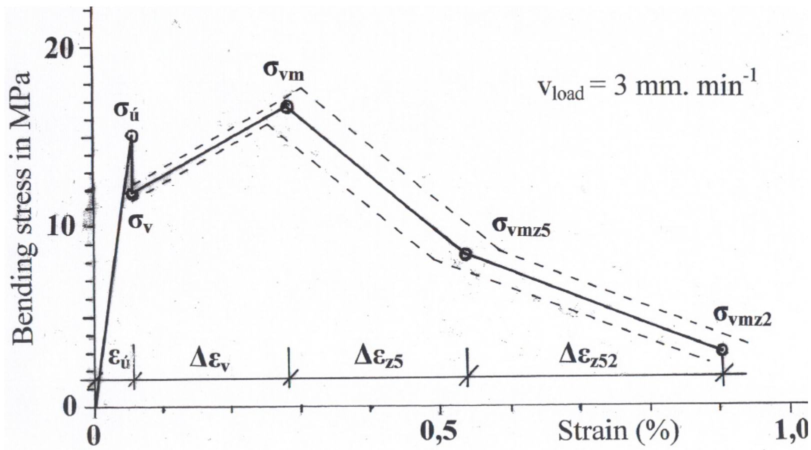

Fig. 6 Operating characteristics of standard glass fibre reinforced concrete at flexure, wet mixture homogenization in OM 10EV

Operating characteristics of cement composite with dispersed reinforcement formed by Kuralon RECS 100 fibres, whose production mixture was homogenized in OM 10EV mixer like glass fibre reinforced concrete mentioned in Table 1, is shown on Fig. 7.

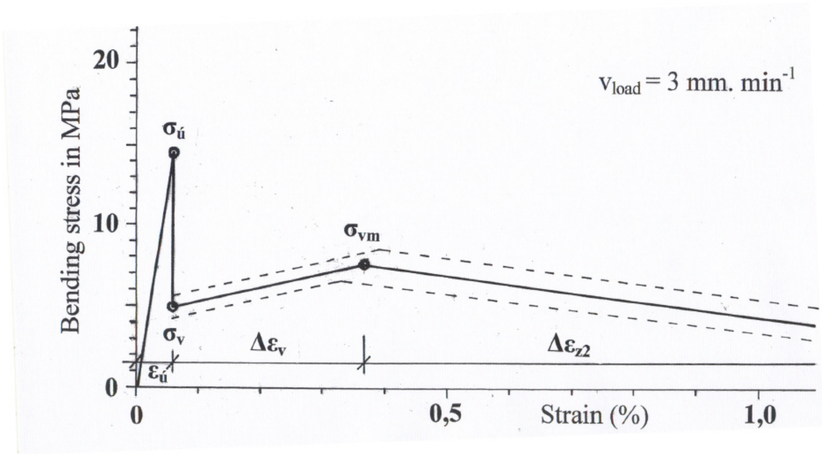

Fig. 7 Operating characteristics of cement composite with Kuralon RECS 100 fibres

4 Conclusions

Cement composites with dispersed fibre reinforcement represent a complex structural system, whose technically effective description is necessary to build on statistic base. Building applications in form of thin sheet constructions can be in their physical-mechanical properties significantly influenced by both quantity and orientation of reinforcing fibres. In these cases the utilization of selected procedures of fracture mechanics can be problematic and it is necessary to define the operating characteristics of deformation strain at real thickness of future building construction. Fibre composite homogenity is more complex problem in case of more fibre types utilization. Research of cement composites with hybrid fibre reinforcement continues, the results will be published continuously.

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