EFFECT OF CREEP OF POLYMERIC FIBRES ON DEFORMATION OF FIBRE CONCRETE BEAM ELEMENTS UNDER THE LONG-TERM LOADING

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Abstract

The paper deals with behaviour of fibre concrete members with polymeric fibres after formation of macro-crack. The polymeric fibres creep under long-term loading. For steel fibres the effect of creep can be neglected. The creep of polymeric fibres after cracking can significantly affect the serviceability limit state design. The paper presents long-term experimental research that shall verify significance of the creep effect on the long-term behaviour of the fibre concrete element with polymeric fibres.

Keywords: fibre reinforced concrete, polymeric fibres, creep, long-term loading

1. Introduction

The main advantage of fibre reinforced concretes compared to common concretes is tensile strength after cracking, toughness and higher ductility both in tension and compression. More pronounced are these properties in tensile zones but effect of ductility is important also in compressed zones of the fibre concrete structure after the limiting strength is reached.

The mostly used fibres for fibre concretes are the steel fibres and synthetic fibres on the polymeric basis. Mechanical properties of these types of fibres are very different. This results also in different characteristics of particular fibre concrete. In both cases the fibres are the main reason of specified advantages.

In tensile zone of structures fibres increase the strength at cracking (CLS – Cracking Limit State) of the cementitious composite. With increase of tensile stresses micro-cracks develop than a macro-crack occurs. In a fibre reinforced concrete element without rebar reinforcement usually one crack is created; elements with rebar reinforcement embody several smaller cracks. The effect of cement matrix is excluded in the macro-crack; the

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tensile forces are transmitted just by fibres (see Fig. 1). This ability of FRC to transmit tensile forces can be considered in the structural design. The tensile strength of FRC after cracking (residual strength) depends on the deformation of the structural member. The value of residual strength is affected by the fibre strength, elastic modulus of the fibre material, geometry and anchoring in the cement matrix.

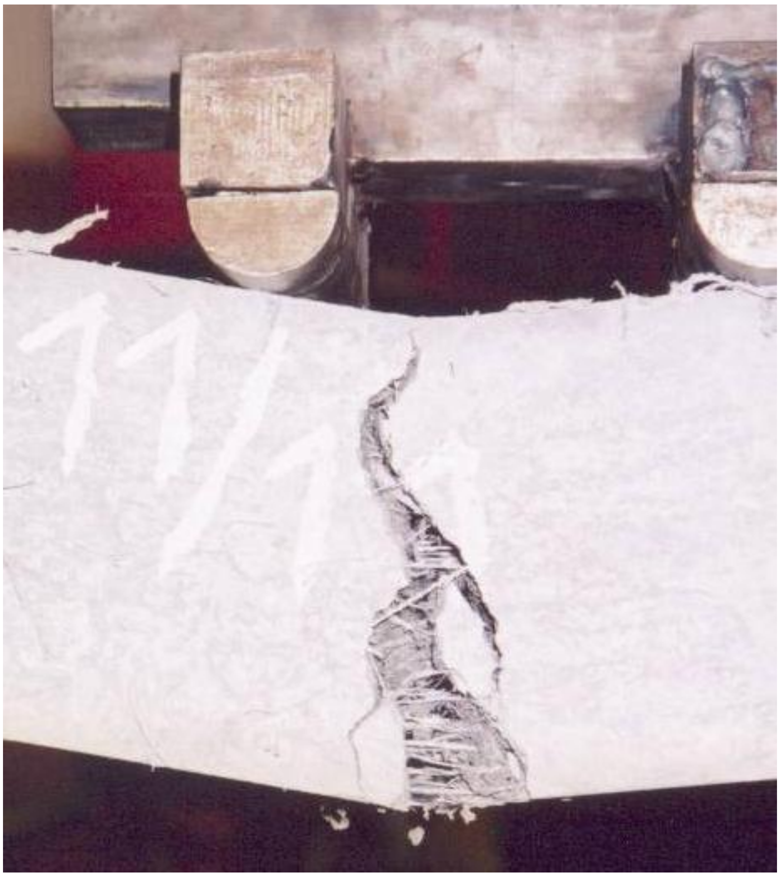

Fig. 1: Bridging of fibres across the macro-crack

Up to macro-cracking a linear behaviour can be assumed for the FRC element. After cracking the behaviour becomes nonlinear. In the structural design a residual strength of FRC can be assumed. Considering of this fact in structural design leads to more economic design but the designer shall be aware of cracking of the element. In the structural element in aggressive environment cracking cannot be accepted with respect to service life of the structure. Macro-cracking can be enabled for FRC structures with polymeric fibres. Cracking in SFRC (Steel Fibre Reinforced Concrete) may lead to corrosion and possible damage of steel fibres.

Another aspect of the FRC behaviour after cracking is long-term loading of bridging fibres. Fibres should have sufficient elastic deformation (prolongation) of fibres. Steel fibres have small deformation as the elastic modulus of steel is high. Polymeric fibres deformation has not been investigated so far. Authors of the paper did not find enough information about polymeric fibres behaviour loaded by long-term tensile stresses. Certificates of producers give information about fibres but not about long-term tensile strain of fibres.

Effect of long-term deformation of fibres cannot be neglected as it may affect behaviour of the FRC structure. The check is performed by determination of effective stiffness of the element and calculation of the deflection assuming linear behaviour. This procedure can be applied also for FRC structures if the width of the crack does not change in time; this condition is met for SFRC. In FRC with polymeric fibres the fibres creep under the long-term loading. The prolongation of fibres causes increase of the crack width and resulting increase of the deflection of the structure. Therefore in the check of the serviceability limit state of the structure with polymeric fibres without rebar reinforcement this effect must be taken into account. Even producers of polypropylene fibres are not able to determine behaviour of the FRC element under long-term loading.

2. New testing methodology

These were reasons that initiated program focused on measurement of polymeric fibres creep at the Faculty of Civil Engineering Department of Concrete and Masonry Structures. The problematic has not been investigated yet so the methodology of testing and measurement of creep of fibres had to be prepared. The experimental program is realised in cooperation with VŠB TU Ostrava where are performed the experiments proposed by Department of Concrete and Masonry Structures from CTU in Prague.

Four samples were manufactured with dimensions 150x150x700 mm (see *Fig. 2*). The samples have the same composition and the same dosage of fibres (9kg/m^3). Fibres of producers FORTA FERO (FF), BENESTEEL (BS), STRUX (D) were used and also waste fibres manufactured by fibrillating of PET bottles (PET). The PET fibres were tested to verify properties of the waste material and find possible utilisation of PET fibres in construction industry. The tests showed that PET fibres are problematic in terms of anchoring of fibres in the cement matrix.

Fig. 2: Picture of the manufactured specimens 150x150x700 mm

The specimens were cut after 28 days to quarters. Thus the resulting dimensions of the specimens are 75x75x700 mm. The cutting was performed to decrease the needed force in the long-time loading.

Fig. 3: Picture of the specimens for experiments 75x75x700

A macro-crack was created in each test specimen before the long-term load is applied. The macro crack was created in a three-point bending test. The load in the three-point bending was applied until the deflection 1.5 ~ 2.5 mm was reached. The decision was adopted because of wide diversity of tensile strengths of particular specimens. This value was determined in previous experiments. The main criteria were sufficient crack width and sufficient load-bearing capacity of the disturbed specimen for the long-term loading.

Fig. 4: Creating of a flexural macro-crack in a three-point bending test

Fig. 5: Control measuring of the crack width after three-point bending test

The specimens are loaded and the deflection is measured by the electronic gauge. After a required 2 mm deflection is reached the flexural test is interrupted and the specimens are equipped for the long-term testing and loaded with the long-term load (see *Fig. 6*).

Fig. 6: Specimens with long-term load

Creating of the crack and loading of specimens was performed in set containing four specimens (each specimen in a set had different type of fibres) FORTA FERO (FF), BENESTEEL (BS), STRUX (D) a PET bottles (PET). Several days elapsed between setting of sets. The picture of the measurement of deflections is in the *Fig. 7* and *8.*

Fig. 7: Measuring of the initial deformation before the long-term loading of the specimen

Fig. 8: Measuring of the increase of deformation

3. Results of measurements

Measurements of deformations are performed periodically and show changes of deflection. The deformation in time is affected by used fibres. Figure 9 depicts diagrams with increasing creep deformation. Each diagram show one set of test specimens.

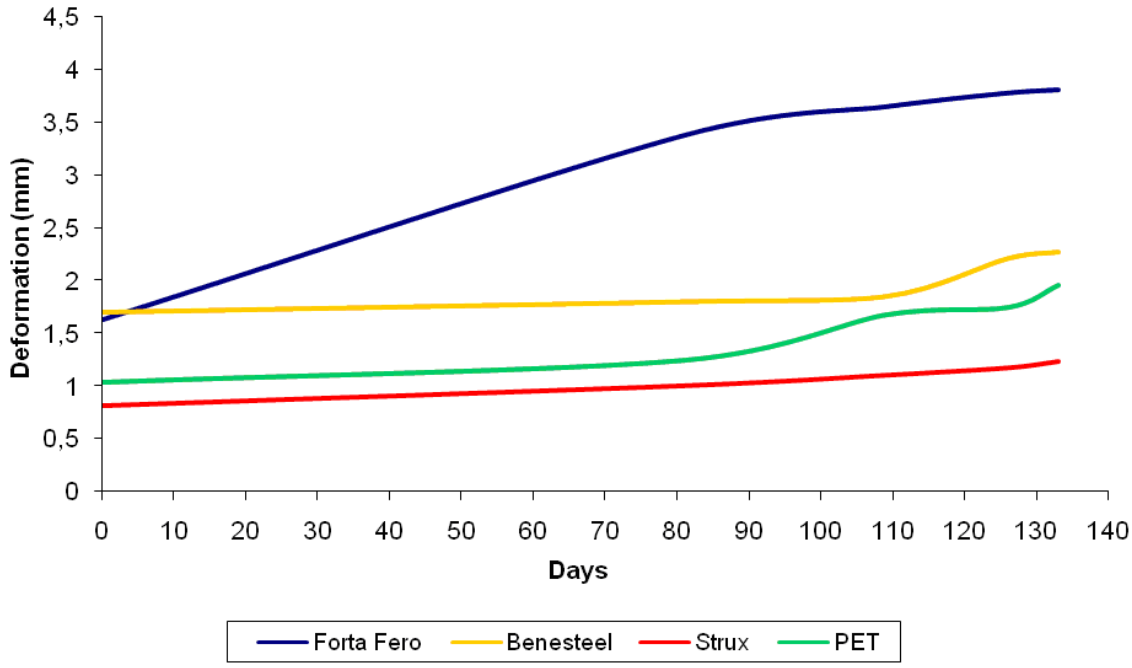

Fig. 9: Deformation – time diagram of creep FRC with polypropylene fibres

4. Conclusions

There have not been stated final conclusions from the experimental program. For the long-term investigations is the 140 days period too short; and no conclusions about particular fibres can be derived from current increase of the deflection. Result values of deformations will be analysis after termination of measurements and subsequently the most suitable polymeric fibres for structural use will be recommended. The current result exhibit that creep deformation of fibre occurs and different types of fibres have different response for the long-term loading.

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