UTILISATION OF MODEL SIMULATION IN OPTIMISATION OF FIBRECONCRETE FOR STRUCTURAL ELEMENTS

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Abstract

A research project inquiring feasibility of fibreconcrete precast element is being developed. In the paper three members – structural element, concrete precast pipe and a non-bearing member are discussed, usefulness of the fibreconcrete exploitation and possibilities of modelling and simulations in the analysis, decision-making process and considerations of fibreconcrete benefits and choose of a convenient fibreconcrete in a particular member.

Keywords: Fibreconcrete; pre-cast member; simulation; finite element method.

1 Introduction

Fibre-reinforced concrete is a contribution to the range of structural materials. Benefit of fibres in fibre-reinforced concrete is in improvement of the performance of fibre-reinforced concrete in comparison with the plain concrete but also in application in reinforced concrete and prestressed concrete members. In cooperation with industrial sphere possibilities of use of fibreconcrete in pre-cast elements are inquired into. Exploitation of fibreconcrete shall bring benefits and savings which lies in decrease of conventional reinforcement or reducing of thickness of elements, better crack control and thus enhancement of durability.

Several industrial manufacturers have accepted an offer of cooperation with the department of concrete and masonry structures in application of fibreconcrete in structural elements. The aim of the joint work is finding out members, where use of fibres will be a contribution, determination of a convenient type of fibreconcrete and verification of manufacturability of the fibreconcrete element.

The primary task of the industrial plants is manufacturing and earnings. It was impossible to restrain production by excessive number of experiments. On the other hand there is necessity of finding a fibreconcrete suitable for a particular element from a large number of different fibreconcretes available and to meet desired properties and achieve required behaviour of the pre-cast member. Therefore possibilities of simulation of the behaviour and acting of the fibreconcrete element by mean of FEM analysis were examined.

Possibilities of simulation will be presented for three types of fibreconcrete members differing in behaviour and purpose of the element.

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2 Fibreconcrete beam with conventional bar reinforcement

The main goals of the fibreconcrete beams research were to prove the benefits of fibreconcrete in the structural element behaviour and to verify possibilities of material modelling in FEM analysis.

Since an unlimited number of fibreconcretes with different properties may be designed and produced a simple procedure for determination of fibreconcrete material parameters for FEM structural analysis had to be proposed. A routine exploiting results of simple laboratory test and inverse analysis has been experienced at our department. Basic laboratory specimens are tested; cubes in compression and splitting tensile test and prisms in a four-point flexural test. The flexural test is modelled in a FEM program, where compressive strength and tensile strength from cube testing are the inputs for the first run of finite element analysis. FE analysis is performed for several times and input material parameters are varied until a satisfactory coincidence of load-deflection (L-d) curve measured and L-d curve calculated by means of FE analysis is reached. This way of material parameters fitting is called inverse analysis. Material properties obtained in inverse analysis are used in further analysis of a member made of investigated fibreconcrete.

To confirm correctness of proposed procedure the validity of material model from inverse analysis was checked in a research described below.

2.1 Possibilities of numerical simulation of the structural element

Two sets of beams were prepared and tested in a flexural laboratory test. Setup of the test is depicted in the fig.1. Dimensions and load scheme of the beam for the case study were selected for the reason of separation of various parameters on structural behaviour in bending. One set of polypropylene fibreconcrete beams with longitudinal steel bar reinforcement and a comparative set of beams from common concrete reinforced with identical steel bar reinforcements were prepared.

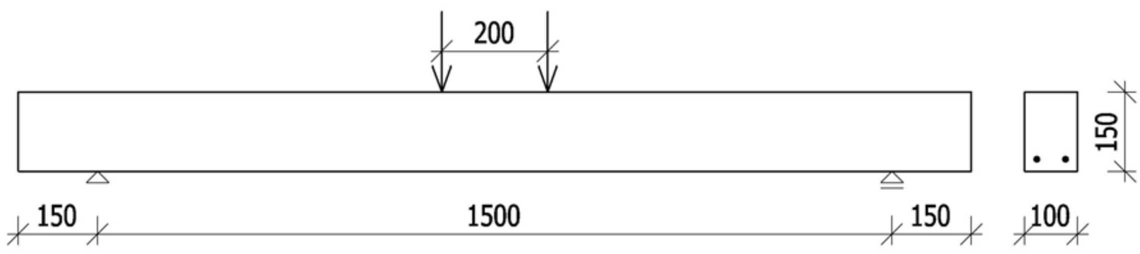

Fig. 1 Sketch of the laboratory loading setup

Comparing of results of bending test of reinforced concrete and reinforced fibre concrete beams from experiment proved benefits of fibre concrete; fibreconcrete beams have higher load-bearing capacity (fig. 3), non-brittle mode of failure and more favourable layout of cracking.

In the process of verification the main task was a simulation of a prescribed test using acquired material relation. The result of numerical modelling is load–deflection relation, which is compared with measurements. Fig. 4 shows an output from the program for the tested beam. Material properties confirmed by the inverse analysis were used for FE analysis of a fibre concrete beam with conventional reinforcement.

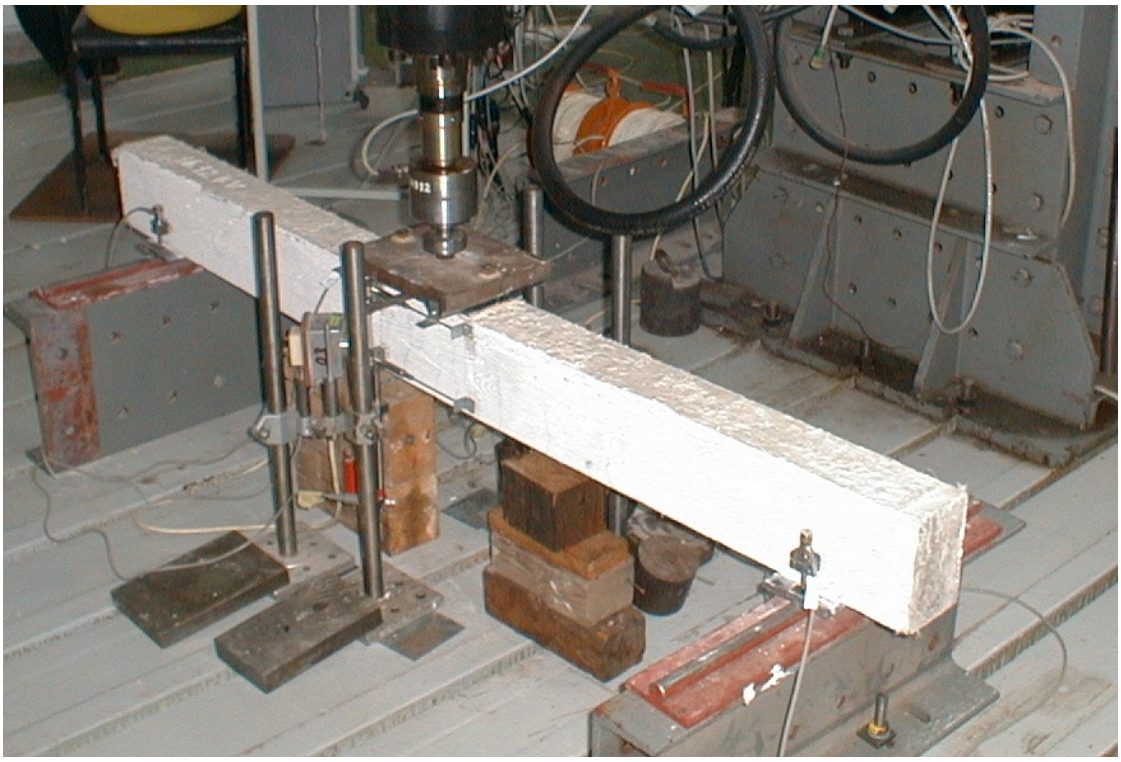

Fig. 2 Loading of the beam in the laboratory

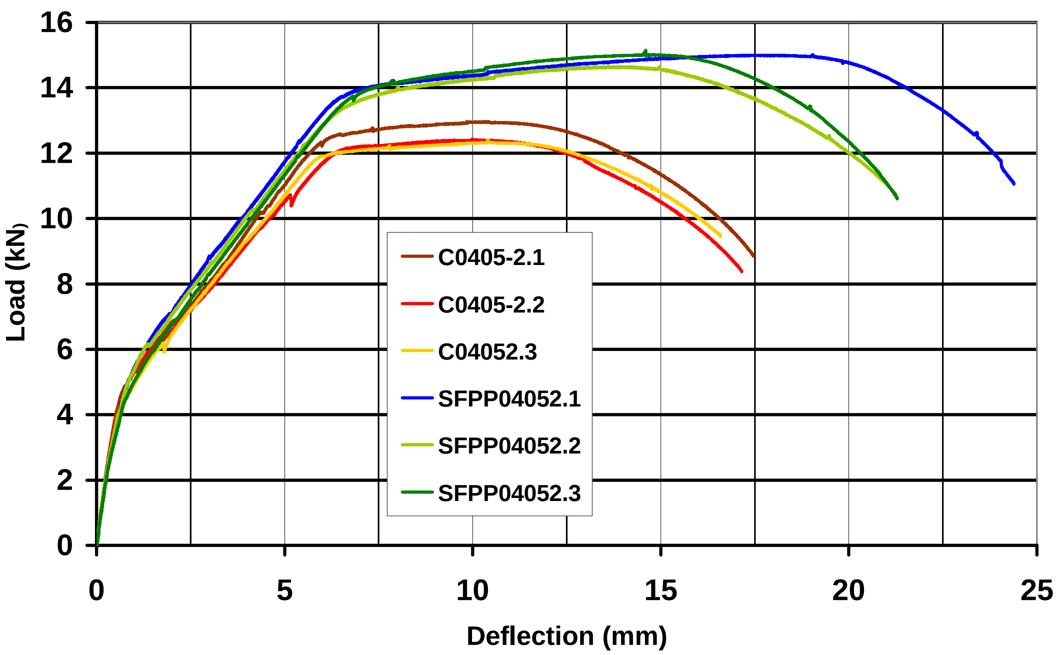

Fig. 3 Load –deflection curves for concrete beams (C) and fibre concrete beams (SFPP)

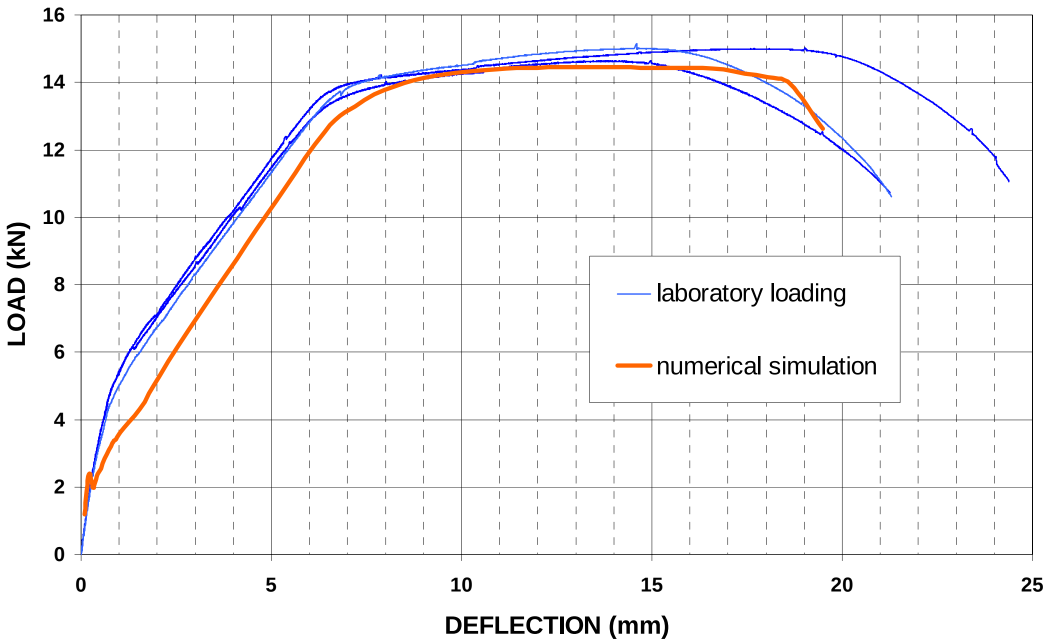

Fig. 4 Comparison of load –deflection curves of fibreconcrete beams (laboratory loading) and ATENA simulation

The experiments and analysis confirmed that numerical simulation relates to real behaviour of fibreconcrete member and may replace some real experiments.

3 Sewer pipes

Sewer pipes are made in two forms: one from plain concrete, second from reinforced concrete. Pipes made from plain concrete have satisfactory load-bearing capacity, but after the first crack is formed a brittle failure of the pipe follows. Reinforcement which consists of main spiral reinforcement (10 505) and secondary longitudinal reinforcement (10 216) avoids brittle failure of the pipe, but anyway after forming of the first crack the use of the pipe is restricted on account of wide cracks and lost of watertight of the sewer pipe. Fibreconcrete may solve both problems mentioned; fibreconcrete members fail in a non-brittle mode and cracks have more favourable lay-out and may satisfy demands on water-tightness. To prove the suppositions, an experiment with three types of fibres was performed. There were made pipes with diameter 600 mm from two different types of steel fibres and polypropylene fibres and comparative pipes from plain concrete and reinforced concrete. In the experiment the load was applied on the top of the pipe and load at first crack and ultimate load was measured. The experiments showed that pipes from fibreconcrete withstand higher loads until first crack occurs than pipes from plain concrete. Pipes with polypropylene fibres have roughly the same load at first crack as pipes from reinforced concrete (with conventional bar reinforcement). Pipes with fibres have even higher cracking-load than reinforced concrete pipes.

Fig. 5 Testing of the sewer pipe

The increase of the cracking-load and ultimate load is not necessary from the point of view of the service of sewer pipes. Hence in subsequent steps of the development, an analysis is performed to determine either thinner wall of the pipe or fibreconcrete with lower strength. Possibilities of decreasing of the pipe wall thickness are calculated in a simple routine assuming that the material will remain same as in performed experiments, as the suitability of the material was proved. On the other hand there is an opposite way where dimensions of the pipe will remain same and a fibreconcrete with new properties is sought. In this case collaboration with technologist and further verification of designed fibreconcrete mixture is necessary.

Choose which of these ways would be chosen is a matter of multi-criterion analysis considering economical aspects and possibilities of the manufacture.

4 Bridge cornice

Cornice is not a load-bearing part of the bridge; nevertheless it can be subjected to substantial strain, salts treatment and atmospheric effects. Cracking due to volumetric changes must be prevented for this element. Because of aesthetic requirements on cornice, to provide bond of anchors and prevent corrosion and pull-out of anchoring elements. Fibreconcrete may be a contribution to better service, behaviour and durability of the element. Other problem that may be solved by use of fibreconcrete is cracking and failure during transport and resulting fall of the element and injure of pedestrians and damage of passing vehicles.

After preliminary analysis of the stress state of the element (fig. 6) where the elastic stresses were determined, a suitable fibreconcrete was chosen. With respect to demands on durability of the cornice and risk of corrosion SSFRC with polypropylene fibres was pointed out for the testing of workability of the fibreconcrete mixture in the precast-plat devices and manufacturability of the cornice. The manufacturability of the cornice has been verified in a pilot plant and the made cornice was used in a bridge build-up.

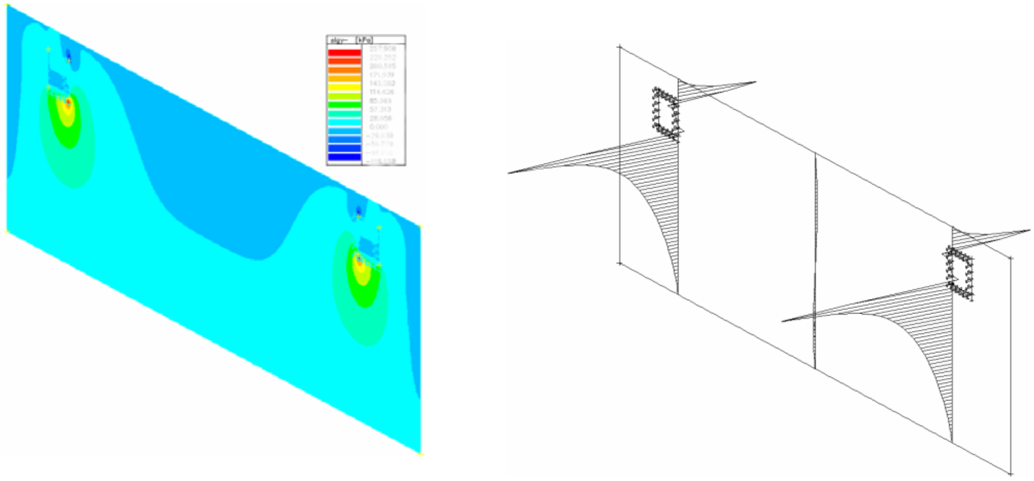

Fig. 6 Stress state from the preliminary analysis of the cornice

Nowadays in a model simulation possibilities of reduction of conventional reinforcement are investigated.

5 Conclusions

Proper choice of material plays an important role in good design of fibreconcrete member. The numerical simulation may become a strong tool in the analysis; it may reduce the need of laboratory experiments and shall help in the decision-making process which fibreconcrete (if any) is suitable for use in a particular structure.

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