# Finite element analysis of ultra-high performance concrete beams

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Abstract

Ultra-high performance concrete (UHPC) as a structural material with enormous strength is more and more commonly used in building construction. However, it is still a new material under intensive development with a lot of unresearched topics. In this contribution we consider the problem of bending of beams made of UHPC. Three concrete grades: C40/50, C60/75 and C90/105 were taken into account. In the following abstract only some basic assumptions connected with the investigated material and geometrical parameters of the computational model are presented. The extensive results of finite element analyses completed in the Abaqus environment will be given in a full article and presented at the conference.

*Keywords: ultra high performance concrete, mechanical property, finite element analysis*

## 1. Introduction

From the beginning of building material development engineers have been looking for materials with higher and higher strength. Concrete, which is nowadays the most widely used structural material, has been over last three decades under intensive investigation in many countries with the aim of increasing its strength and providing it with some additional functionalities, finally leading to the concept of ultra-high performance concrete (UHPC) [6, 4].

In the last years structures made of ultra-high performance concrete are very common. The most popular applications of this concrete take place in design of long span girders, bridges and shells.

The compressive strength of this material is much greater than conventional concrete (called also normal strength concrete – NSC) and may reach the value of 250 MPa and more. If ultra-high performance concrete is enriched with steel fibres, its tensile strength of the order of 20–40 MPa [6, 4, 3] makes it possible to design structural elements under bending without using traditional reinforcement. Further possibilities would be provided by using shape memory alloy fibres [5].

What is important, the improvement of compressive and tensile strength of concrete is not the only one advantage of this modern in many aspects material. Structures which are built of conventional concrete have usually almost no ductility. There are studies, where the beneficial influence of additional steel fibres on ductile behaviour of beams was proved.

The great energy absorption capacity, as the next advantage of ultra high performance concrete, is one of the reason why this material could be used in impact-resistance and blast-resistance structures. Nowadays, with this material we can see the perspective of overcoming the brittle nature of conventional concrete.

Due to a very low water-to-binder ratio (w/b) and high fineness admixtures, structures made of ultra-high performance concrete exhibit great durability and adjustment to be subjected to fatigue loads.

The reduction in the weight of a structure made from ultra high performance concrete, which is attributable by mechanical properties of this material, is extraordinary. According to [7] this weight could be twice or even three times smaller than the weight of the structure when made from conventional concrete under the same level of loads.

It stands to reason that ultra-high performance concrete will become the future building material for large-scale field use. At present, the applications of UHPC in building engineering are limited because of its higher initial cost, lack of adequate constitutive laws and widely accepted practical recommendations for designers of structures.

## 2. Numerical analysis

For numerical analysis we have considered a model of a simply supported beam made of the UHPC under four-point bending. The geometrical parameters and localisation of loads are presented in Figs. 1 and 2. The cross-section is rectangular of dimensions 15 x 30 cm. The computational model was prepared in the Abaqus environment and there the finite analysis was carried out [1]. The C3D8R finite element was used. The density of FE mesh is shown in Fig. 3 (the size of one element is 5 x 5 cm). The concrete damage plasticity (CDP) was adapted as the model of concrete.

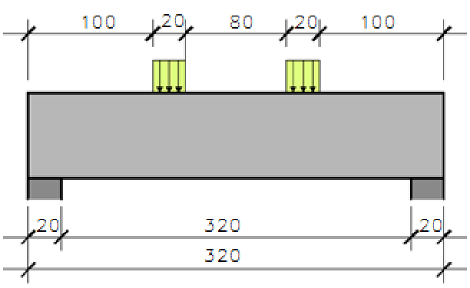


Figure 1: The model of beam considered in analysis

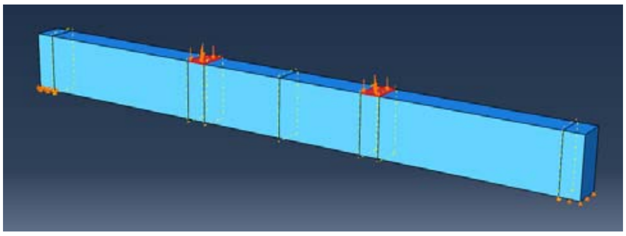

Figure 2: Boundary conditions and loads applied

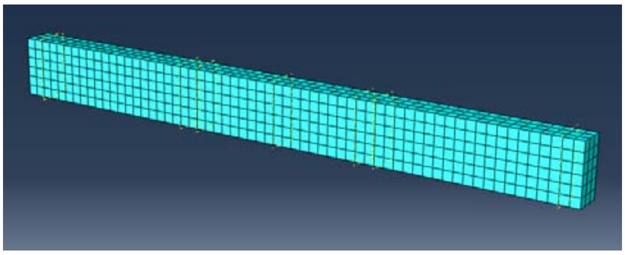

Figure 3: Finite element mesh

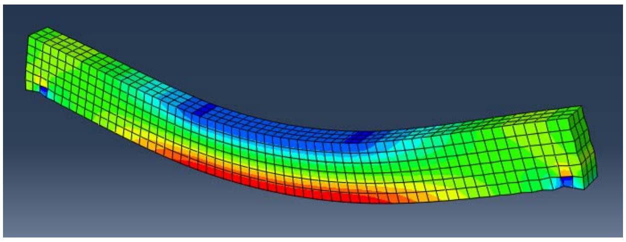

Figure 4: Map of normal stresses

Basic parameters we used for the adapted material model are gathered in Table 1.

Table 1: Materials parameters used in analysis

| | Concrete grade | | |
|---|---|---|---|
| | C40/50 | C60/75 | C90/105 |
| Maximum compressive stress $f_{cm}$ [MPa] | 48 | 68 | 98 |
| Strain at maximum compressive stress $\varepsilon_{c1}$ | 0.00237 | 0.00258 | 0.00283 |
| Plasticity parameter $k$ | 1.71 | 1.48 | 1.27 |

The following relation (1) between the compressive stress and strain was assumed according to [2],

$$\frac{\sigma_c}{f_{cm}} = \frac{k\eta - \eta^2}{1 + (k-2)\eta} \qquad (1)$$

where $\eta = \varepsilon_c/\varepsilon_{c1}$ and a plasticity parameter $k = E_{ci}/E_{c1}$.

The strain at maximum compressive stress was calculated by the formula

$$\varepsilon_{c1} = \frac{1.60\left(\frac{f_{cm}}{10\text{MPa}}\right)^{0.25}}{1000} \qquad (2)$$

Plots of the non-linear stress-strain relationship (1) under formula (2) for the concrete grades of Tab.1 are shown in Fig. 5.

## 3. Conclusion

In this abstract only some basic assumptions of a finite element analysis of ultra-high performance concrete beams were presented. The extensive results will be provided in a full paper and during the conference presentation.

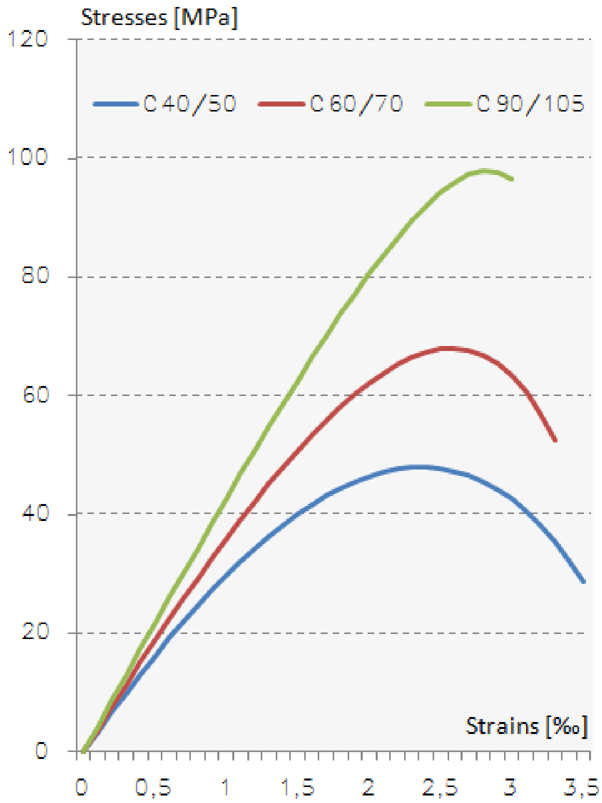


Figure 5: Plot of stress-strain relations for studied concrete grades

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