

## UNIAXIAL TENSION: NONLINEAR MODELLING AND EXPERIMENT ASPECTS

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*The paper shows possibilities of nonlinear fracture mechanics simulation to capture results of uniaxial tension experiments and discuss problematic aspects of modelling. The aim is to give a better insight into uniaxial tension behavior, such as the formation of fracture process zone, the influence of load eccentricity and heterogeneity of concrete.*

### Introduction

The aim of this paper is to show possibilities of nonlinear fracture mechanics simulation to capture uniaxial tension experiments and to discuss problematic aspects of FEM modeling. Software ATENA [2] is used for this purpose.

### Experiment

The prismatic specimen of 100x100x400 mm with notches (the depth 7 mm and thickness 3 mm) on all four side faces is subjected to uniaxial tensile force. Fig.1 shows the experimental set-up with gear system to

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eliminate both secondary flexure and the flexure caused by load eccentricity.

### **Computational model**

Several 3D computational models were developed and tested using ATENA 3D. Note, that the node incompatibility in notched specimen is effectively solved by master-slave approach. The secondary flexure case was modeled by one tensile force and hinged support; crack patterns are shown in Fig. 2. In order to model a heterogeneity of real material and thus to speed up the secondary flexure phenomena occurrence, the initiation and propagation of fracture process zone, a weaker material was considered along one side of the notch. The material was simply weakened by smaller tensile strength and fracture energy of concrete.

### **Numerical results**

#### *Eliminating secondary flexure modelling*

This alternative is easier from computation point of view and resulted in a good agreement of the trend, Fig. 3. Some disagreements can be observed in both pre-peak and post-peak regions. Let us emphasize that the average material parameters from more experiments were used here in a straightforward way without any modification.

The stress concentration factor near the notch tip was calculated for these cases, the 3D calculation resulted in the starting value of the factor 4, Fig. 4. Strong stress concentration occurs only in the elastic range and diminishes when notched section becomes softened.

#### *Leaving secondary flexure modelling*

Virtual simulation of this case is more difficult. Imperfections should be considered in order to model random fracture process zone propagation and the speed-up of its initiation. Two main reasons for secondary flexure occurrence are usually mentioned in literature: the eccentricity of uniaxial tensile loading and the heterogeneity of material.

#### *Material heterogeneity influence*

In a simplified way the heterogeneity of real material can be modeled by a weaker part of material along one side of the notch in order to speed up the secondary flexure phenomena occurrence, the initiation and propagation of fracture process zone. The material was simply weakened by smaller tensile strength and fracture energy of concrete, e.g. to 70, 90, 99.5 % of their initial value. This simple procedure really resulted in

satisfactory simulation of secondary flexure, weakening to 99.5 % provided the best results, Fig. 5.

### **Conclusion**

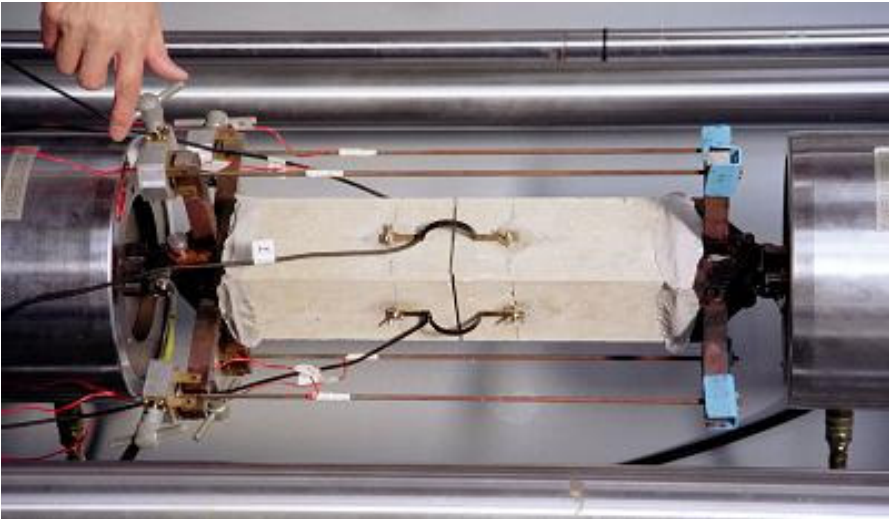
Nonlinear 3D modeling of uniaxial tension test of concrete could capture the experimental I-d diagram including post-peak branch rather well. The agreement was good for the case of eliminating secondary flexure. Modeling of leaving secondary flexure was more difficult, but the trend has been captured. For this case the modeling of material imperfection is necessary, the paper discuss the role of eccentricity of loading and the material heterogeneity influence in a simplified way.

### **Acknowledgements**

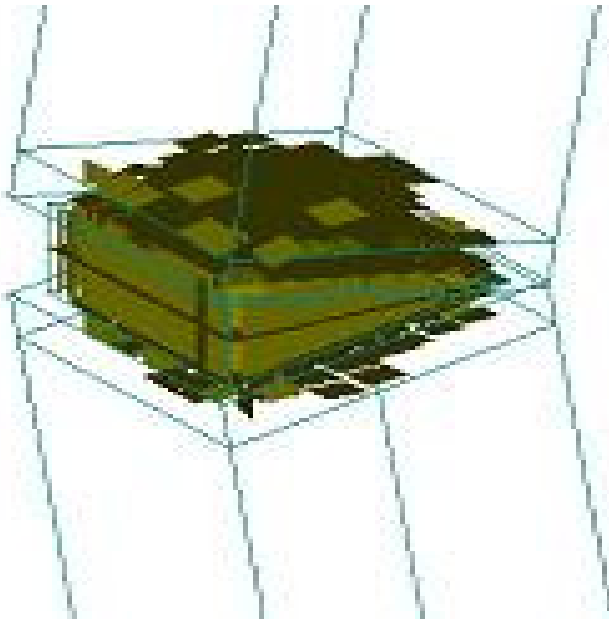
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### **References**

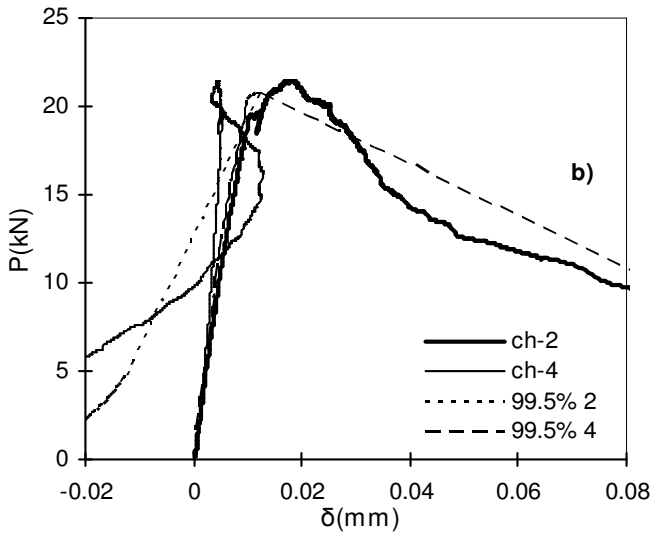
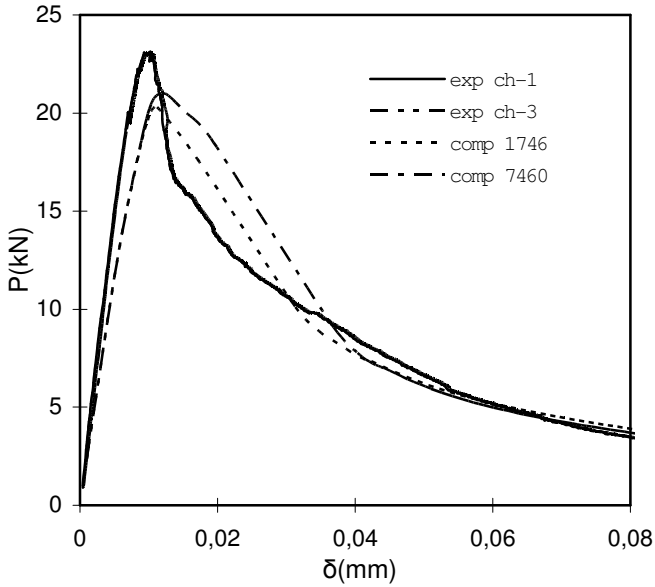
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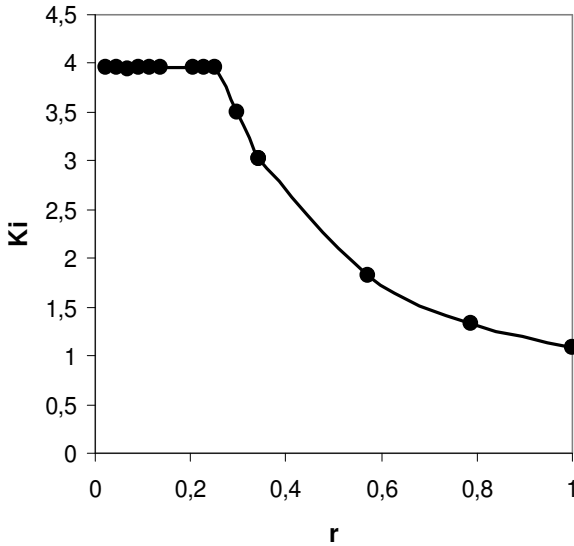
**Fig. 1 Experimental set-up**



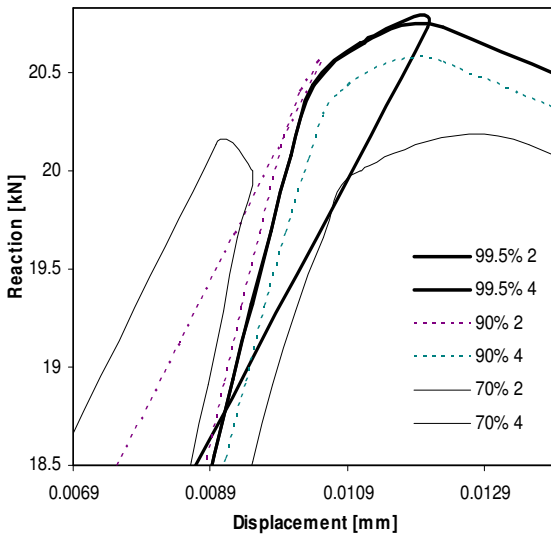
**Fig. 2 Crack patterns during the secondary flexure**



**Fig. 3 Experimental and simulated I-d curves: eliminating and leaving(b) secondary flexure**



**Fig. 4 Stress concentration factor vs. uniaxial force level ratio**



**Fig. 5 The detail around the peak for different virtual weakening of material**