# Sensibility of Tension Model on the Structural Behavior of UHPFRC

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## 1. Introduction

Finite element (FE) code in combination with an appropriate material model may serve as a suitable tool to analyze the structural performance of ultra high performance fiber reinforced concrete (UHPFRC). However, the available constitutive models derived from the small-size specimens do not necessarily provide the correct post-cracking relation for the use in the simulation of structural members. One of the main reasons for possible errors is a deviation in preferred orientation and distribution between the fiber reinforcement in small-size specimens and the fiber reinforcement in structures. This variation may be captured by the suitable tension model in the analysis[1)]. A sensibility analysis is conducted to evaluate the effect of the tension model on the predicted beam behavior. The comparisons between the numerical and the experimental results are also shown to validate the FE simulation.

## 2. Methods and materials

Data of an I-shaped beam made from reactive powder concrete with 200N/mm$^2$ compressive strength and 12N/mm$^2$ tensile strength, which is one of the UHPFRC, is used for the validation of calculated results in this paper[2)]. The details of its dimensions, arrangement of reinforcing steel and loading condition are shown in **Fig.1**. The properties of steel fiber used are given in **Table 1**. In the present study, a 3D nonlinear FE code CAMUI developing at the Hokkaido University was used[3)]. In this analysis, 20 node iso-parametric solid elements, with 8 Gauss's points were adopted. The 3D elasto-plastic and fracture model[3)] was used for the concrete model before cracking. When the crack occurs, constitutive models were applied in the directions parallel and normal to the crack plane. To consider the effect of fiber, the tension softening model reported by Fukuura et al.[2)] is adapted to a stress-strain relationship of fiber reinforced concrete in the direction normal to crack (**Fig.2**). A sensibility analysis of tension model is conducted with varying a shape of model into 3 types (**Fig.2**). The fracture energy of all models is kept constant. The ascending part of the Vecchio & Collins model[3)] was applied for the 2D concrete compression model in a plane parallel to the crack. After peak stress, the effect of crack on compression-softening is considered by the linear descending line defined by the compressive fracture energy[1)]. Shear transfer stresses were calculated using model proposed by Li & Maekawa[3)]. However, the use of high performance concrete having very high concrete compressive strength induced a smooth crack surface. As a result, the stress transfer equation is simplified by multiplying the shear transfer envelop by a reduction coefficient $A$[1)] ($A$ = 0.25 for this paper).

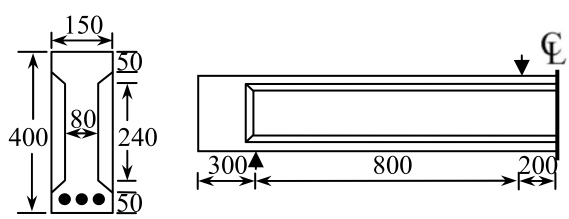


**Fig.1** Detail of specimen BRC4[2)]

**Table 1** Properties of steel fiber

| Volume ($V_f$) | Tensile strength ($f_t$) | Diameter ($\phi$) | length ($l$) |
|---|---|---|---|
| 2% | 2700MPa | 0.2mm | 15mm |

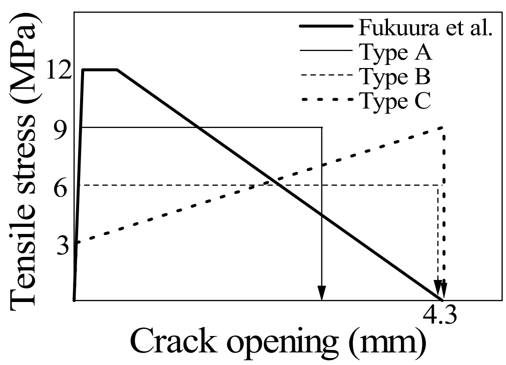


**Fig.2** Variation of tension model

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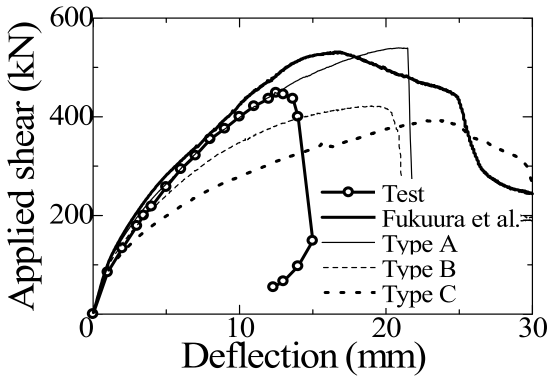


**Fig.3** Sensibility of tension models

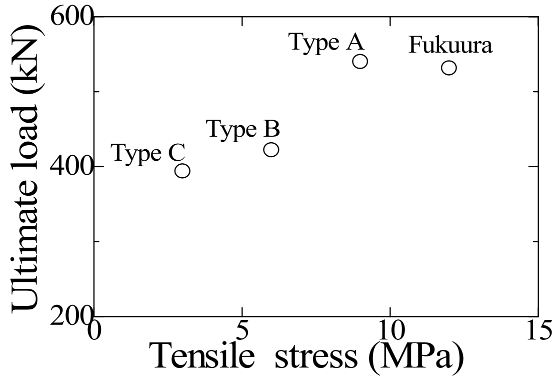


**Fig.4** Comparison of ultimate load

**3. Results and discussion**

**Fig.3** shows the load-deflection curves of experimental and FE results with varying the shape of tension models for specimen BRC4. It can be observed that the calculated ultimate load is changed with the variation of the shape of tension model (**Fig.4**). The overestimation of predicted ultimate load with proposed model is not reasonable because the effect of steel fiber still did not consider in compression model and tension stiffening model for UHPFRC with steel reinforcing bars. Consequently, the more rational predicted ultimate load should be lower than that of experimental result. It can be seen that the calculated stiffness become closer to the test result when “Type A” tension model is applied. Despite having lower tensile strength, the predicted ultimate load with “Type A” model is higher comparing with model by Fukuura et al. (**Fig.4**). This indicates the importance of post-peak relationship of tension model on the total response of beam. A large reduction of predicted ultimate load is found when “Type B” tension model with a half of tensile strength but constant fracture energy is applied. The ultimate load is quite close to that of the test but the stiffness is different. “Type C” tension model is an attempt to virtually represent the tensile stress-strain of pseudostrain hardening cementitious composites such as ECC (Engineered Cementitious Composite)[4]. The big assumption here is the compressive strength of this simulated ECC-like material is 200N/mm$^2$ (much higher than available ECC). It can be observed that there is a small change of predicted ultimate load comparing with result from “Type B” tension model but a larger amount of ductility can be observed from the ECC-like tension model (Type C). It can be said that the tensile strength and post-peak behavior of tension model have to be considered together in order to get the suitable model for the analysis.

**4. Conclusion**

Tension model plays a very important role on the simulation of structural behavior of UHPFRC member. Not only tensile strength but also post-peak behavior of model has an effect on the overall ultimate capacity and ductility of member.

**References**

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