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FRACTURE MECHANICS OF MULTIPLE FIBRE SYSTEMS IN CEMENT-BASED MATERIALS

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ABSTRACT

A fracture mechanical model for the fibre bridging in a cement-based material reinforced with straight discontinious fibres is presented. The fibre/matrix interactions are modelled by a 3 parameter shear-slip relation combining the interfacial debonding and the interfacial friction. From this, the model predicts that the influence of the interfacial debonding on the fibre bridging curve is significant if the fibres are stiff, if the aspect ratio is small or if the fibre length is small.

Key words: Fibre bridging, Interfacial friction, Interfacial debonding, Fracture mechanics.

Conventionally, only one fibre type is used in order to ensure a satisfactory mechanical behaviour of a fibre reinforced concrete. However, the geometry and the material parameters of the fibres have a significant influence on the mechanical behaviour. Therefore it may be expected that a more optimal design can be obtained by adding more than one fibre type into the cement-based material. Therefore, the purpose of the project reported here is to set up models for the mechanical behaviour of multiple fibre systems. In that respect the knowledge of the fibre/matrix interactions and their influence on the fibre bridging for the individual fibre types is essential.

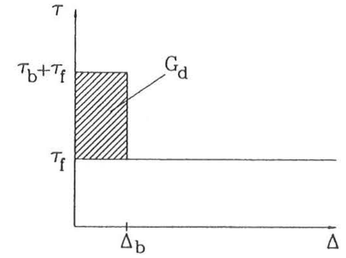

Figure 1: *Assumed shear-slip relation for the fibre/matrix interface*

For straight fibres, the fibre/matrix interactions are believed to be caused mainly by interfacial debonding and interfacial friction. The deformations due to interfacial debonding will be concentrated in thin layers around the fibres. Therefore, it seems natural to model the interfacial debonding by fracture mechanics. Traditionally, linear elastic fracture mechanics has been used. However, pull-out tests carried out by Al-shannag [1] have indicated that non-linear fracture mechanics should be used, i.e. the interfacial debonding should be modelled by a shear-slip relation. Therefore, the interfacial debonding and the interfacial friction cannot easily be distinguished. Al-Shannag [1] proposes that the two components could be combined as shown in figure 1. The friction is modelled by a constant stress τ_f and the debonding by a constant stress τ_b until the debonding slip Δ_b is reached, $\tau_b\Delta_b$ defining the debonding energy G_d.

Based on the above shear-slip relation a procedure for calculating the fibre bridging curve has been set up (A homogeneous fibre distribution is assumed and possible fibre ruptures and snubbing effects are disregarded). By normalizing the fibre bridging stress with $\sigma^* = 1/2V_f\tau_fL_F/d_f$ and the crack width with $w^* = (\tau_fL_f^2)/(d_fE_f)$, the fibre bridging curve at small crack widths can approximately be expressed as a function of the two non-dimensional quantities, $\tau^* = \tau_b/\tau_f$ and $B_d = (d_f/L_f)(G_dE_f)/(\tau_f^2L_f)$. V_f is the fibre volume fraction, L_f is the fibre length, d_f is the fibre diameter and E_f is the elastic modulus of the fibre.

In figure 2 normalized fibre bridging curves at small crack widths are shown for the case of pure friction ($\tau_b = 0$) and for varying values of τ^* and B_d. The influence of τ^* and B_d is shown as the difference from the fibre bridging curve for pure friction. Hereby, it follows that the influence from τ_b is significant for large values of B_d. Therefore, in the case of stiff fibres (large E_f), a small aspect ratio (large d_f/L_f) or small fibre lengths it must be essential to consider the interfacial debonding. Otherwise, it seems reasonable only to consider the interfacial friction.

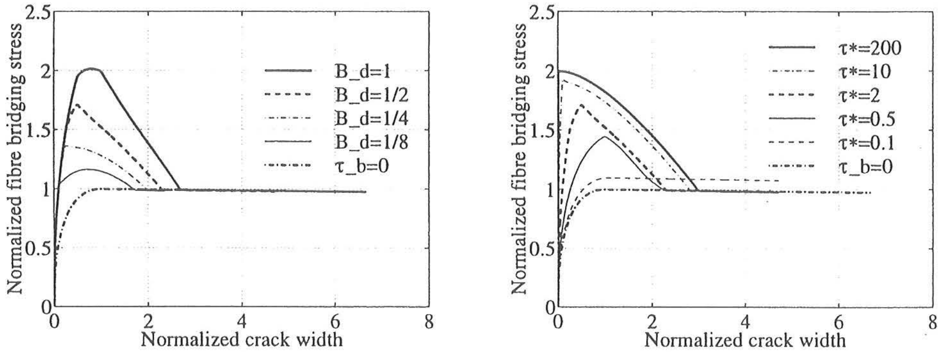

Figure 2: *Normalized fibre bridging curves for left:* $\tau^* = 2$ *and varying values of* B_d*, and right:* $B_d = 1/2$ *and varying values of* τ^**.*

REFERENCE

[1] Mohammad Jamal Al-Shannag: "*Tensile behaviour of fiber reinforced DSP*". Ph.D.-dissertation, The University of Michigan, 1995.