V－324 Computational Model for Stress Transfer across Reinforced Concrete Interfaces

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Introduction

The shear transfer ability of a crack plane, subjected to in-plane forces, might make a vital contribution to the ultimate load capacity of RC structures. It is therefore necessary to study in detail the internal mechanisms of shear transfer across a single crack, subjected to in-plane shear loading, to enable a more accurate modelling of shear stiffness and shear capacity.

The two principle mechanisms of shear forces to be transmitted across a RC crack with reinforcement normal to the crack plane are either through the interaction between the rough surfaces of the crack, called '*aggregate interlock*', and through the shear resisted by the reinforcement, termed as '*dowel action*'. Both these mechanisms are mobilized by the same system of general forces that exist at the crack plane and are related to the same crack pattern. It is the purpose of this report to propose a unified model for RC interface stress transfer, subjected to in-plane shear forces, in which the aggregate interlock and the dowel action are treated together by the combination of a generic model for embedded bars and a modified model for aggregate interlock.

Stress Transfer across RC Interface

The stress transfer across RC interfaces can be predicted by combining a model for embedded bar behavior, under generalized displacement, with a plain concrete aggregate interlock model. The deformational and mechanical characteristics of a RC interface are shown in Fig. 1. The equilibrium of normal and transverse forces, separately verified constitutive relations and the compatibility of displacements, between steel and concrete at the interface, are given below.

$$\textit{Equilibrium}: \ \sigma_c^{/} = \rho_s \overline{\sigma_s} \ ; \ \tau_t = \tau_c + \tau_d \quad (\textit{where} \ \tau_d = \rho_s \tau_s) \tag{1}$$

$$\textit{Constitutive relations}: \ \sigma_c^{/} = \sigma_c^{/}(f_c^{/}, \delta, \overline{\omega}(S)) \ ; \ \overline{\sigma_s} = \overline{\sigma_s}(\overline{\varepsilon_s}(S), \delta_b, f_c^{/}, D)$$
$$\tau_c = \tau_c(f_c^{/}, \delta, \overline{\omega}(S)) \ ; \ \tau_s = \tau_s(\delta_b, D) \tag{2}$$

$$\textit{Compatiblity}: \ \delta_b = \delta / 2 \ ; \ \omega_b = 2S \ ; \ \omega_s = c\,\omega_b \ ; \ \overline{\omega} = (c+3)\,\omega_b / 4 \tag{3}$$

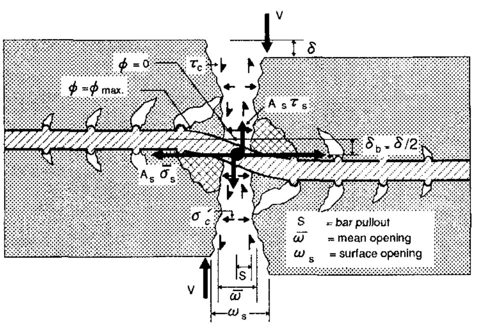

Figure 1: Deformational and mechanical characteristics of a RC interface

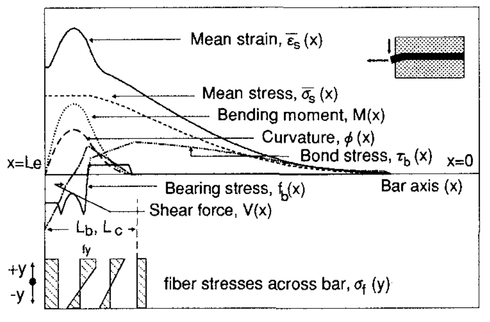

Figure 2: Spatial distribution profiles of parameters in embedded bar model

The model for the embedded bar, subjected to any generalized displacement path, i.e. pure axial pullout, pure transverse shear displacement or generic coupling of both, has already been verified [3]. Typical spatial distribution profiles of parameters, from the model, are shown in Fig. 2.

For aggregate interlock, a stress transfer model for plain concrete [1] is used. However in order to consider the effect of the bar axial and shear stresses at the interface on the surrounding concrete, an idealization of a deteriorated concrete area around the bar is made, which is incapable of transferring stresses, due to crushing and splitting. It is expressed as a function of the mean axial and shear stress of the bar at the interface and shown graphically in Fig. 3.

With these formulations, shear transferred by both aggregate interlock and dowel action can be predicted in an unified manner.

Verification of Stress Transfer Model

The ultimate mean axial stress in the bar at the interface, attained in accordance with the displacement path defined by equilibrium and compatibility requirements of the interface, determines the shear capacity of the interface. Under a coupled displacement path of axial pullout and transverse shear displacement, the axial stiffness and strength of the bar are reduced compared to bar performance under pure pullout condition [3]. Prediction of total shear stresses transferred, τ_t, along with the associated displacement path, (δ, ω_s), with test results for a typical specimen under pure shear loading are shown in Fig. 4, along with the individual contributions from concrete, τ_c, and steel, τ_d. Satisfactory predictions for shear capacity obtained for a wide range of RC rough crack shear transfer test results [2,4], as shown in Fig. 5, indicate the accuracy and versatility of the model. From numerical simulation carried out to study the effect of varying reinforcement ratio, ρ_s, the variation of τ_c, τ_d and the mean axial stress in the bar, $\overline{\sigma}_s$, can be observed. The rate of increase of τ_c with ρ_s decreases, whereas the rate of increase of τ_d with ρ_s increases, with the increase of ρ_s; $\overline{\sigma}_s$ decreases uniformly with the increase in ρ_s, as shown in Fig. 6.

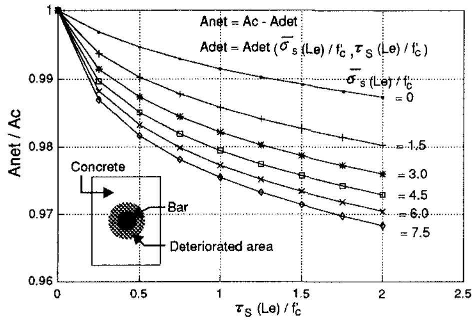

Figure 3: Variation of deteriorated concrete area with bar stresses at interface

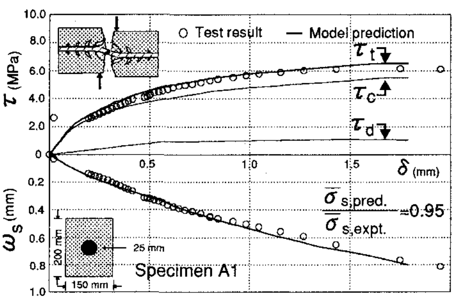

Figure 4: Shear transferred vs. associated interface displacement paths.

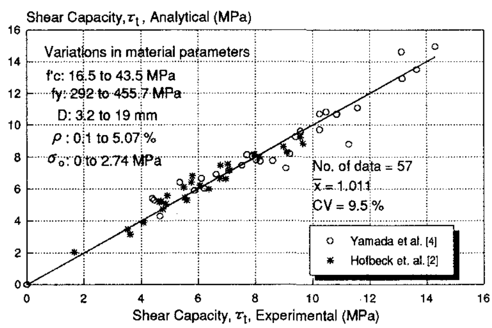

Figure 5: Comparison of predicted and test shear capacities, from literature.

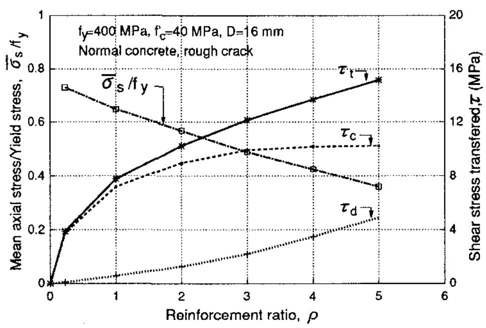

Figure 6: Shear transfer and confining stresses vs. reinforcement ratio

Conclusions

RC interface stress transfer can be predicted by combining a generic model of an embedded bar with a modified aggregate interlock model, and shear transferred by both concrete and steel can be dealt in an unified manner. The ultimate mean axial stress attained by the embedded reinforcement, under a coupled displacement path, determines the shear capacity of the interface.

References

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