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On the necessity of a non-slip mechanism between steel and concrete in the region of a crack*

by Colin B. Brown

Contribution by A. W. Beeby, BSc, MICE and H. P. J. Taylor, BSc, MICE
Cement and Concrete Association : Design Research Department

Having read Dr Brown's interesting attempt to reconcile a bond-slip mechanism for cracking with zero crack width at the bar-concrete interface, we find ourselves perplexed by one particular point. This is the conclusion that in some instances the movement of the concrete surface may be larger than the movement of the bar which is applying the force to the concrete. This offends our feeling of the way in which such a system would behave. A brief inspection of the mathematics does, however, bring to light an inconsistency which may yet save us from the necessity of a serious re-appraisal of these conceptions.

Figure 3a shows the bond stresses acting along the slipped length L^*. These are shown acting in the opposite direction to the applied force F^* at all points. This is again expressed in equation 9, which states that the bond stress is of uniform magnitude and acts in the same direction at all points along the length L^*. Implicit in these assumptions is the further assumption that the direction of motion of the bar relative to the concrete is also the same at all points along L^*. This follows because any reversal in the direction of slip must be accompanied by a reversal in the direction of action of the bond forces, with the impossible result that the steel stresses would increase with distance from the free surface. It follows that the conclusion that the concrete movements are greater than the bar movements, implying a direction of slip such that the steel effectively moves away from the free surface is a result which is incompatible with the initial assumptions. We would therefore suggest that the analysis of the deformation of the concrete must be yielding results which are too large. Perhaps Dr Brown could comment on the likely effect of rectifying this inconsistency upon his conclusions.

We would like to add a few comments on our Research Report (reference 1 of the paper) because there seems to have been some slight misconstruction placed upon what we said. Dr Brown's last sentence reads: "This may mean that the present trend towards ignoring various parameters as insignificant in crack considerations will have to be revised". These parameters were not ignored in our work; the major part of the test programme was taken up with isolating the influence of these variables. These tests showed that, over the range of variables tested, bar type, bar diameter and steel percentage had no significant effect. The no-slip hypothesis was put forward in an attempt to explain why they had no effect. We are aware, of course, that slip may occur in some circumstances and therefore we do not believe that the no-slip hypothesis is the absolute truth—in the same way as Dr Brown, presumably, would not state categorically that there was an absolutely rectangular distribution of bond stresses along a bar—it is an assumption which is possibly not too far from the truth and which leads to an analysis giving significantly better agreement with the experimental facts than does any previous set of assumptions.

It is worth adding here that the reconciliation of slip with the no-slip hypothesis is not so very difficult. It is only necessary to propose that no significant amounts of slip occur at the time at which the cracks form. Once the cracks have formed, slip cannot alter the spacing or width of the cracks because a non-slip mechanism must produce a closer spacing than one in which slip occurs.

Reply by the author

It is a pleasure to respond to the discussion of Mr Beeby and Mr Taylor. They have been partially responsible for an outstanding contribution to the understanding of cracking (reference 1 of the paper). This contribution removes most of the questions about parameter influence from the controversial category.

In this respect their quotation of the last sentence of my paper, without the reference in it to an Editorial in the *Magazine*, does not do their own work justice. Obviously, I have no doubts that Mr Beeby and Mr Taylor gave consideration to the various parameters but the Editorial, based upon their work, may carry weight without the benefit of a reader's understanding.

The concept of reverse slip and hence the anomaly with the slip description of equation 9 is discussed at the end of the paper. This will attenuate the relative movements but not destroy the basis of the argument.

The discussers do not object to the crack shape suggested in Figure 1. This may be attained either by the concrete not cracking in the region of a bar or with cracking and subsequent closing and pressure. The first provides concrete continuity and is not considered in the paper. The second provides concrete continuity and requires that, without the restraint of the concrete on the opposite side of the crack, the concrete moves ahead of the bar. However intuitively disturbing, this is not provided by a complete non-slip mechanism.

As Mr Beeby and Mr Taylor suggest, the paper is not a defence of any particular mechanism. It was written because of the previously mentioned Editorial (reference 8 of the paper) which to me, and maybe to others, overly simplified the problem.