The influence of the geometry of deformed steel bars on their bond strength in concrete

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The Authors are to be commended for their choice of a test specimen in which splitting failure of a deformed reinforcing bar in bond is not inhibited by large amounts of confining reinforcement. Previous studies into the influence of lug slope on bond strength^{8,9} used bars with single lugs to give test specimens in which splitting failure did not predominate, and concluded that, for normal bar surface conditions, the angle made by the lug face with the bar axis had little influence where the lug face angle was greater than 45°.

32. Unisteel reinforcement—the type II bar tested by the Authors—was used in an experimental study of the strength of lapped joints in columns carried out at the University of Glasgow.¹⁰ Failure of these laps was accompanied by the formation of mortar wedges on the bearing side of each lug. The length of the wedges at any point varied with the height of the lug at that point, and was approximately 2.5 times the lug height: a much greater value than that found in the tension tests reported in the Paper. Further research to investigate differences in bond action between tension and compression lapped joints therefore appears desirable.

33. From Fig. 1, it appears that the Authors consider that the resultant of the lateral confining force on the bar F_{bst} and the bar pullout force F_b is perpendicular to the failure surface, whether this is concrete/concrete or concrete/steel. This is the case where no shear stresses are present on the failure surface. However, Lutz⁹ has shown that bond is impaired if the frictional properties of the face of the rib are reduced, even if the lug face angle is greater than 45°. Fig. 9 shows that the failure surface angle ϕ will be less than the angle β , where β is $\tan^{-1} F_{bst}/F_{b/2}$, found from the ratio of confining force to pullout force if shear on the failure surface is taken into account.

34. In reference 10 an expression is proposed for the ultimate bond strength of a deformed bar where failure takes place by splitting of the test specimen. The expression is derived from consideration of the strength of the concrete on which the lug bears, failure of which is assumed to be represented by the Coulomb-Mohr failure criteria. The shear stress on the failure surface is due to the internal friction of the concrete, giving shear stresses proportional to the confining force

Fig. 9. Forces on concrete wedge at ultimate load

F_{bst} , and to the cohesion of the concrete, which is independent of F_{bst} . With increasing specific rib areas (i.e. area of engagement of rib on a plane perpendicular to the bar axis/unit length of bar) the contribution of the cohesion of the concrete to ultimate bond strength increases while the contribution of the internal friction of the concrete remains constant. Thus the type I bar tested by the Authors, which has the larger lug area A_{eng} and the smaller rib spacing, may be expected to develop a greater pullout load and a larger value of β than the type II bar. The results presented indicate that the pullout strength and the value of $\tan \beta$ for the type I bars was 12% greater than that for the type II bars. Thus bars with a greater specific rib area produce lower splitting forces in the surrounding concrete at the same bond stress.

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It is interesting to learn of the difference in length of the concrete wedges obtained in the investigation of lapped joints in columns and those obtained in our tests. Further research would seem necessary and desirable to examine the reason for these differences.

36. We agree that in our hypothesis we have assumed the plane of the concrete wedge to be perpendicular to the resultant of the lateral confining force F_{bst} and half the pullout force $F_{b/2}$; this is tantamount to assuming a principal tension/compression type failure. However, neither the polygon of forces in Fig. 9 nor the theory in reference 10 takes into account the frictional properties

of the steel/concrete interface as may be construed by § 33; they simply introduce a rotation of the concrete failure plane according to the concrete failure criterion adopted. The failure itself is conditional only on the bursting force if there is no end bearing.

37. The two-dimensional Coulomb-Mohr failure criterion used in reference 10 is one of many that could be assumed.¹¹ We are of the opinion that most concrete materials specialists would not apply it today even in a normal axisymmetric stress situation, let alone in the small scale complex stress state under consideration. Another difference in the two approaches is that Dr Cairns uses the known bursting force and the defined failure angle given by his failure criterion to calculate the pullout force (bond stress), whereas we use the known bursting and pullout forces to calculate the wedge angle.

References

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