DISCUSSION

Block Shear Equations Revisited...Again

Paper by HOWARD I. EPSTEIN and LANCE J. ALEKSIEWICZ
(First Quarter, 2008)

Discussion by ROBERT G. DRIVER

The authors provide a historical account of the evolution of block shear equations in the AISC *Specification* (AISC, 2005). The main conclusion of the paper is that the 2005 *Specification* and associated commentary still do not adequately account for a number of common connection configurations, and this observation has merit. The paper cites specific cases that are addressed in the AISC *Specification* commentary and indicates that the information needs to be expanded to clarify where strength reductions are required. Although one can debate the cause and nature of the capacity reduction due to in- and out-of-plane eccentricities (and many have), it comes down largely to semantics that are overshadowed by the fact that methods for accounting for connection efficiency are approximate and that the depiction of the stress distribution in these cases as being linear is in itself an idealization of the actual stress condition in the member. It is desirable from the designer's perspective for these cases to be addressed in a simple way that gives reasonably accurate estimates of capacity, with a resulting reliability index after the resistance factor is applied that is considered acceptable to the profession. Taking a broad and pragmatic view of the block shear research in the literature and the related discussions that have ensued over the past 30 years, it seems clear that the effects of load eccentricity can be addressed effectively by simple factors that are, in essence, equivalent stress factors. This discussion paper addresses two related issues arising from the original paper: (1) the format of the block shear equation itself and (2) the treatment of Tees connected by their flanges only.

It was noted by the authors of the paper that the introduction of the factor U_{bs} to the 2005 AISC block shear equations (using $U_{bs} = 0.5$) results in a least-squares trend line for test-to-predicted ratios (professional factors) of the strength of angles connected through one leg (Figure 3 of the paper) that shows a "marked improvement" over the analogous trend line generated using the 1999 *Specification* equations. What was not highlighted, with respect to this figure, however, is the gross conservatism of the predictions based on the 2005 *Specification* and the associated degree of scatter. For angles and stem-connected Tees in particular, Driver, Grondin and Kulak (2006) determined that the mean test-to-predicted ratio increased from 1.03 to 1.25 when the 1999 AISC *Specification* was replaced with the 2005 edition (using $U_{bs} = 0.5$); this is similar to the results depicted in Figure 3 for the angle tests of Epstein alone (Epstein, 1992). For interpreting whether or not this increase actually represents an improvement, it needs to be emphasized that test-to-predicted ratios greater than 1.0 are not superior to those less than 1.0. (It is the application of load and resistance factors that establish the "safety" of the method.) The measures of primary importance are the proximity of the mean ratio to 1.0, indicating how accurate the model is on average, and the magnitude of the coefficient of variation of the individual ratios, which is a measure of consistency of the accuracy of the design equation over the range of tests considered. These two parameters, when taken together, tend to indicate whether the model reflects the actual behavior sufficiently well. Making use of these principles, observations (Kulak and Grondin, 2001) of highly inconsistent results obtained using existing methods provided the impetus for the development of the unified block shear equation that has been shown to provide improved and more consistent strength predictions for a variety of connection types (Driver et al., 2006).

With regard to the specific case of Tees, the authors are quite correct that the equivalent stress factor recommended by Driver et al. (2006) applies only to stem-connected Tees. However, the unified equation has also been shown (Cai and Driver, 2008) to provide excellent results for flange-connected Tees failing along the alternate block shear path observed by Epstein and Stamberg (2002), although it is acknowledged that these results were not available to the authors of the paper when they prepared their manuscript. Using the test results of Epstein and Stamberg (2002), the

Robert G. Driver is professor, department of civil and environmental engineering, University of Alberta, Edmonton, Alberta, Canada.

unified equation, with no mean stress reduction due to load eccentricity (i.e., equivalent stress factor equal to 1.0), gives a mean test-to-predicted ratio of 1.05 with a coefficient of variation of 0.09, and, using the current resistance factor in the AISC *Specification* (0.75), the reliability index for this connection type is 4.2 (Cai and Driver, 2008). Although the authors have stated that the equivalent stress factor of 0.9 that has been recommended for stem-connected Tees may not provide a large enough reduction if it were applied also to flange-connected Tees, in fact no reduction is required for this case. The cross-sectional shape of the Tee results in an out-of-plane eccentricity of the load with respect to the block that, although indisputably present, is typically relatively small and does not affect the capacity of the member to a degree that would warrant a reduction of the strength for design. However, for some connection configurations where eccentricities are present, reductions are indeed warranted, and recommendations have been made for several common cases (Driver et al., 2006).

REFERENCES

AISC. (2005), *Specification for Structural Steel Buildings,* American Institute of Steel Construction, Chicago, IL.

Cai, Q. and Driver, R.G. (2008), "Performance of the Unified Block Shear Equation for Atypical Failure Paths," *6th International Workshop on Connections in Steel Structures*, Chicago, IL.

Driver, R.G., Grondin, G.Y. and Kulak, G.L. (2006), "Unified Block Shear Equation for Achieving Consistent Reliability," *Journal of Constructional Steel Research*, Vol. 62, No. 3, pp. 210–222.

Epstein, H. (1992), "An Experimental Study of Block Shear Failure of Angles in Tension," *Engineering Journal*, American Institute of Steel Construction, Vol. 29, Second Quarter, pp. 75–84.

Epstein, H.I. and Stamberg, H. (2002), "Block Shear and Net Section Capacities of Structural Tees in Tension: Test Results and Code Implications," *Engineering Journal*, American Institute of Steel Construction, Vol. 39, Fourth Quarter, pp. 228–239.

Kulak, G.L. and Grondin, G.Y. (2001), "AISC LRFD Rules for Block Shear in Bolted Connections—A Review." *Engineering Journal*, American Institute of Steel Construction, Vol. 38, Fourth Quarter, pp. 199–203.