AD 380
What height of shear stud should be used in Eurocode 4?

The answer to this question is not as obvious as it may sound. BS EN1994 1 1[1] is not itself consistent, because in the list of notation it defines h_{sc} as the 'overall nominal height' of a stud connector, but elsewhere the same variable is defined as simply 'the overall height'. Moreover, a stud that is for example 105 mm long when manufactured would typically have "length after welding" (LAW) of 100 mm when welded directly to a beam flange, or 95 mm when welded through decking. It would generally be described as a nominal 100 mm stud.

This advisory desk note provides guidance on the height/length to be used in design calculations, noting that this is interim advice and may change after a program of tests/analysis has been completed.

BS EN1994 1 1, clause 6.6.5.8(1) which deals with detailing clearly states that the 'nominal height' of a connector should extend not less than 2d (where d is the stud diameter) above the top of the decking. Only one variable is used to define decking height, and it may be assumed to be the height to the top of the shoulder in this case, i.e. excluding any small stiffening ribs in the crest of the decking. A nominal 100 mm stud, of 19 mm diameter, may therefore be used with 60 mm decking (this is a combination that has been shown through many push tests and frequent practice to 'work'). Note that if LAW of 95 mm was to be applied, this detailing check would fail. The code correctly clarifies that the "nominal length" should be used because a pass/fail detailing check should not rely on dimensions that may vary slightly on-site.

Stud resistance values are also a function of h_{sc}, in terms of the solid slab resistance P_{Rd} (clause 6.6.3.1(1)) and the reduction factors k_l (clause 6.6.4.1(2)) and k_t (clause 6.6.4.2(1)) used to allow for the presence of decking. SCI's current advice is that LAW should be used, because although the code itself is not clear, in the ICE Designers' Guide to Eurocode 4[2], Prof. Roger Johnson uses the LAW in his examples. This is authoritative guidance.

However, the correct answer as to whether "nominal" or LAW should be used in the various formulae affecting stud resistance depends on what was used by the researchers/code writers when deriving the various empirical formulae. If a designer uses the same value he is simply reversing the analysis that was used to derive the equation so should get the right answer. SCI is currently carrying out testing and analysis that should lead to revised resistances, and for ease of use by designers we will consider using the "nominal height" for all checks.

One final point for designers to be aware of is that studs come in standard lengths (of which 100 and 125 mm are the most common). A designer may consider increasing the length of a stud to (potentially) increase resistance, but only standard lengths should be specified.

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1. BS EN 1994-1-1:2004 (Incorporating corrigendum April 2009)
   Eurocode 4: Design of composite steel and concrete structures
   Part 1-1: General rules and rules for buildings
2. Designers Guide to Eurocode 4: Design of Composite Steel and Concrete Structures, EN 1994-1-1, Second edition, Roger P Johnson, Published, 2012

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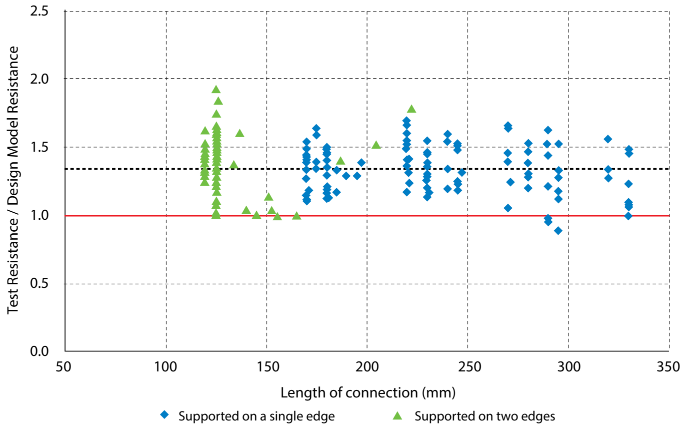

Figure 10: Comparison between resistance obtained by FE analysis and the resistance predicted by the new design model

resistances for nearly all of the connection designs included in the study.

Typical connections are conservative by a factor of 20-30%. A number of cases are considerably more conservative, but these tend to be 'edge cases', such as extremely wide connections with thin plates, where the widths of the yield lines are limited.

Conclusion

A large study has been undertaken to investigate the behaviour of lapped gusset plate connections, using Finite Element analysis. The modelling has shown that the eccentricity of the two plates does generate a moment that must be accounted for in design.

New rules have been developed that allow design of a wide range of different connection designs. These rules are described in the revised BCSA/SCI Green Book [6], to be published imminently.

1 Design of structural steel hollow section connections; Volume 1: Design Models
Australian Institute of Steel Construction, 1996

2 Hollow structural sections connections manual
American Institute of Steel Construction, 2010

3 CISC Technical Memorandum No 5 Ultimate compressive capacity of a L brace connection detail
CISC, 2002

4 Eccentric cleats in compression and columns in moment-resisting connections.
Heavy Engineering Research Association Report R4-142:2009
HERA, 2009

5 Khoo, X. E, Perera, M, Albermani, F.
Design of eccentrically connected cleat plates in connections
International Journal of Advanced Steel Construction, Volume 6, Issue 2
The Hong Kong Institute of Steel Construction, 2010

6 Joints in steel construction: Simple joints to Eurocode 3 (P358)
SCI and BCSA, 2014