Economy in Steel Stiffened Seated Beam Connections

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The current design method for stiffened seated beam connections is conservative for two reasons. First, the connection capacity is calculated based on an elastic analysis of the weld group which does not account for ductility and potential load redistribution in the weld group. Second, the additional strength of the portion of the weld group in tension is not accounted for. This article will explain the assumptions underlying the current design method, illustrate why these assumptions are conservative, and provide alternative design procedures using safe, acceptable engineering methods to deliver a more economical connection.

Stiffened Seated Beam Connection

A stiffened seated beam connection is an alternative to simple shear connections that employ some attachment to the supported beam web (*Figure 1*). In this connection, the beam is supported on a seat attached to a supporting member and reinforced by the addition of a vertical stiffener. The stiffened seat is welded to the support and bolted to the supported beam. Welded stiffened seated connections can be fabricated from two plates or, alternatively, from a WT shape.

The connection is advantageous for several reasons. The seat provides a safe and stable platform for the supported beam during erection. The connection is simple and relatively easy to execute, especially if the field condition limits access to the connection. When uncertain or unreliable field conditions exist, beams can be shipped with additional length and easily cut to fit in the field.

In contrast to these advantages, some fabricators and erectors report that the capacity of the connection is not as strong as alternative connections. Furthermore, as the supported beam reaction increases, the size of the vertical stiffener increases. The additional stiffener length can interfere with architectural requirements and cause coordination issues with other trades.

This article will show that the current design method for evaluating capacity of stiffened seated connections is conservative. The proposed alternative design procedures illustrate two points. First, that there is additional capacity in the connection not accounted for in the current design method. Second, the alternative design procedures can produce smaller, less obtrusive connections than the current design method.

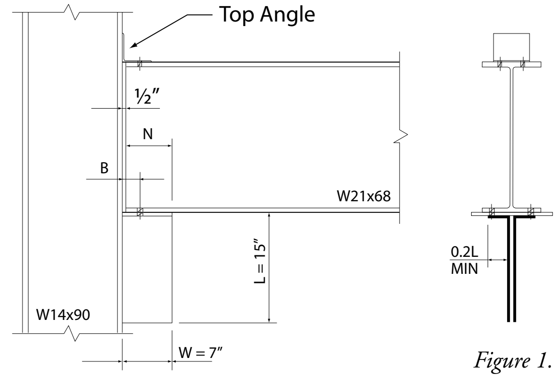

Figure 1.

The available strength of a stiffened seated connection is limited by the capacity of bolts, welds, and connecting elements. The supported beam web must also be checked for local web yielding and web crippling. The limit states associated with the bolts and the connecting elements may be safely omitted for cases which satisfy the requirements of the Stiffened Seated Connections portion of the American Institute of Steel Construction (AISC) *Steel Construction Manual Part 10*. These limits are not the focus of this article, and will not be explicitly considered here.

Current Design Method

The current design method uses a combination of explicit checks and tabulated connection values to determine connection capacity. First, the end reactions and required connection strength are computed. Then the required seat width is calculated based on the limit states of local web yielding and web crippling in the supported member. Finally, the designer selects a stiffener length and a weld size from AISC Table 10-8 *Bolted/Welded Stiffened Seated Connections* which provide adequate capacity. The remaining connection details, such as stiffener thickness and supporting member checks, are prescribed by notes appended to Table 10-8.

The tabulated values typically represent available weld strengths for these connections based on 70 ksi electrodes, but can be adjusted for both 60 ksi and 80 ksi electrode strengths. The available weld strengths are based on an elastic analysis of the weld group connecting the stiffener to the supporting member. The elastic method of analysis for eccentrically loaded weld groups is a simple and conservative method. The simplifying assumptions neglect weld group ductility and potential load redistribution within the weld group. These assumptions may prove overly conservative in some cases. Furthermore, research has shown that fillet weld strength is a function of the angle at which a load is applied to the weld. A transversely loaded fillet weld is 50 percent stronger than a longitudinally loaded weld. A derivation of the expression used to calculate the loads in AISC Table 10-8 is available in *Steel Structures: Design and Behavior* by Salmon and Johnson.

Design Example

A detailed example illustrating the design of a welded/bolted stiffened seated connection is provided on the CD companion to the 13th Edition of the AISC *Steel Construction Manual* (Example II.A-14). The load effects, members, and results of this example will be used here for comparison to the proposed alternative design methods. In this example, a W21x68 beam is connected to a W14x90 column for an R_u equal to 125 kips

Table 1.

Design Method	Expression for Weld Strength	Calculation	ϕR_n (kips/inch)	Percent Increase
Current	1.392D	1.392*5	6.96	-
Alternative 1	$(1 + 0.5\sin^{1.5}\theta)1.392D$	$(1 + 0.5\sin^{1.5}*0.981)1.392*5$	9.60	38%
Alternative 2	ϕCD	0.75*2.78*5	10.43	50%

acting at an eccentricity, e, equal to 5.6 inches. The designed connection capacity is equal to 139 kips using a stiffener length, L, equal to 15 inches attached to the supporting member with a fillet weld size, D, equal to $^5/_{16}$ of an inch. Note that the connection design strength is roughly 10 percent greater than the ultimate demand. The weld available strength, φR_n, is equal to 6.96 kips per inch.

Proposed Alternative Design Method 1

This proposed alternative design method is an adjustment to the elastic analysis of the current design method, which results in significant connection economy at a low computational cost. AISC permits an increase in weld available strength to account for the effect of load angle through the following expression:

$$(1.0 + 0.50 \sin^{1.5} \theta)$$

Where it can be shown that for a stiffened seated connection:

$$\theta = \tan^{-1}(4e/L)$$

The weld available strength, φR_n, adjusted for the effect of load angle is equal to 9.60 kips per inch. This is a 38 percent increase in weld available strength compared to the current design method.

Proposed Alternative Design Method 2

This proposed alternative design method evaluates weld strength using the instantaneous center of rotation method of analysis. The instantaneous center of rotation method for evaluation of eccentrically loaded weld groups is more accurate than the elastic method of analysis. A simplified procedure using tabulated coefficients again results in significant connection economy at a low computational cost. For this example, the horizontal portion of the weld group is conservatively ignored so that tabulated coefficients in Part 8 of the AISC *Steel Construction Manual* can be used. A coefficient value, C, equal to 2.78 is obtained from Table 8-4 for this design example. The weld available strength, φR_n, based on the instantaneous center of rotation method is 10.43 kips per inch. This is a 50 percent increase in weld available strength compared to the current design method.

Comparison and Conclusions

Results from the design example are shown in *Table 1*. Stiffened seated beam connection capacities based on the current design method are conservative. Economy in stiffened seated beam connections is available from two alternative design methods. First, the designer may consider the effect of load angle on the weld group. Second, the designer may elect to use the more accurate instantaneous center of rotation method of analysis. Both alternative methods are shown to provide economy in stiffened seated beam connections with little additional computational effort.

In new design projects, for a given demand, the alternative procedures will provide a more compact connection. A smaller connection provides obvious advantages in material and fabrication costs, architectural considerations, and coordination with other trades. In existing building projects (i.e. – renovation, adaptive reuse), there is additional capacity in the connection. Therefore, additional loading due to renovation/reuse may not require reinforcement of these connections.▪

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