conference preview

THE SPLICE IS RIGHT

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Sixteen tips for fostering collaboration when it comes to splices.

THE UNSUNG HERO in connection design is the splice. However, when the splice is right, the price is right. Getting it right means meeting engineering, fabrication, transport and erection requirements. It also means paying special attention when the field splice is all welded or fulfills an architecturally exposed structural steel (AESS) role. Following are sixteen tips to initiate discussion between the architect, engineer, fabricator and erector on splices.

1. Design for the required forces. The actual required weld or bolts at the splice should be determined based on the required forces. When designing splices with moment, the minimum axial load in the column may be used to offset the tension force from the moment. AISC Design Guide 1: *Base Plate and Anchor Rod Design Section 3.4* "Design Procedure for a Large Moment Base" is a good reference for connections with moment and axial load.

2. Avoid overusing complete joint penetration (CJP) welds, especially at field welded column tension splices. When welded connections are to be used, and if properly sized partial joint penetration (PJP) welds are suitable to transfer the applied forces, there are advantages in using PJP welds in lieu of CJP welds. In addition to lowering the cost of welding due to less weld volume and testing requirements, PJP welds are typically detailed with no gap, allowing for some direct bearing at the flanges. CJP welds are typically detailed with a root opening, requiring more robust erection aids to temporarily hold the column in place before the welding is complete. Note: Avoid CJP joints at tension splices.

3. For gravity splices, select members such as W14 sections for clean column lines. AISC's *Manual* gives various gravity column splice details that may be used for typical conditions. These details are more historic in nature and do not require further calculations. However, they are not necessarily applicable for non-typical gravity splices or tension splices but are still a good lower bound for these connections. W14 columns are preferred for clean column splices and to facilitate framing connections. The advantage of W14s is that the inside-flange-to-inside-flange dimension of all W14 columns (W14×43 and greater) is equal and thus provides full-contact bearing at the thinner column flange. If temporary wind conditions are to be checked, ASCE 7/ ASCE 37: *Design Loads on Structures during Construction* can be used to determine the temporary wind forces.

4. Consider end-plate connections for compression members other than columns. When splicing compression members such as truss web members or truss chords, consider end-plate connections to take advantage of the compressive force in the member. When compression splices for members other than columns are finished to bear, AISC's *Specification* Section J1.4.2 allows the splices to be proportioned for either 1) a tension force = 50% of the required compression force or 2) the moment and shear resulting from a transverse load applied to at the splice location equal to 2% of the required compressive strength of the member. The minimum of these forces may be used and the forces act exclusively from other forces at the splice.





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5. Weld multi-member joints in the shop and introduce a simple splice away from the joint. Ideally, a splice is introduced at a location where a connection is already naturally occurring. However, if three or more members intersect at one location, it is often more feasible to weld the joint or node in the shop for a better control of the geometry and assembly. In such a case, stubs will project away from the joint and often practical end-plate bolted connections will be used for compression splices and overlapping plates for tension splices.

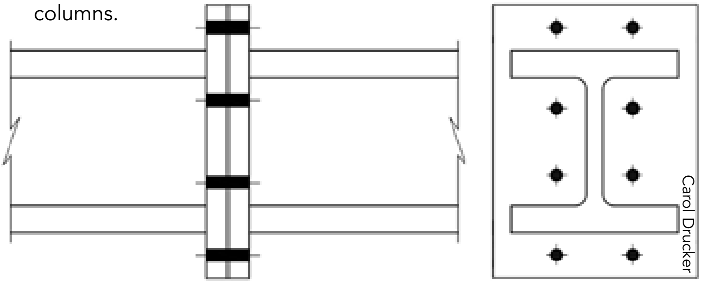
6. Trial fit splices with complex geometries in or near the shop. The consequences of a splice, or several coordinated splices, not fitting in the field generally justify a trial fit-up in the fabricator's shop or yard. This trial fit-up can be part of the specifications for the project, but often the fabricator will initiate the procedure to mitigate risk. Other factors affecting fit-up are loading conditions and camber requirements.

7. Select splice location to optimize the handling of the components. Overhead crane capacity in the shop, size and weight limitations during transport and crane access on-site can all impact on the ideal location of splices. A collaborative effort is needed to determine the optimum location, which may be a stick-built construction, a modular approach, segments of an otherwise continuous component, nodes separated from other components or frames or a combination thereof. In some situations, it is necessary to reduce the weight of the components by using high-strength steel and compact sections or by field welding the splice.

8. When evaluating a column splice for erection purposes, an essential consideration is safety. OSHA 1926 Subpart R – "Safety Standard for Steel Erection" has some specific requirements to consider for column splices. 1926.756 "Beams and columns Paragraph (d) Column Splices" states: "Each column splice shall be designed to resist a minimum eccentric gravity load of 300 lb (136 kg) located 18 in. (46 cm) from the extreme outer face of the column in each direction at the top of the column shaft." This is a part of the regulations to account for a 200-lb (91-kg) ironworker wearing a tool belt that can weigh 70 lb (32 kg) standing on a spud wrench in a hole at the top of the column, creating a moment at the splice joint.

9. The column splice should be conservatively located 5 ft (1.5m) above the beam for better access. In addition, Subpart R 1926.756 (e)(1) states: "The perimeter columns extend a minimum of 48 in. (122 cm) above the finished floor to permit installation of perimeter safety cables prior to erection of the next tier, except where constructability does not allow." 1926.756 (e)(2) states: "The perimeter columns have holes or other devices in or attached to perimeter columns at 42 to 45 in. (107-114 cm) above the finished floor and the midpoint between the finished floor and the top cable to permit installation of perimeter safety cables required by § 1926.760(a)(2), except where constructability does not allow." However, the 4-ft (1.2-m) column extension limit is sometimes not enough since it can cause an interference between the splice plates and the holes for the safety cable. For constructability reasons, it is recommended that the column splice be conservatively located at 5 ft (1.5 m) above the top of the beam.

▼ Tip 4 – Consider end-plate connections for compression members other than columns.

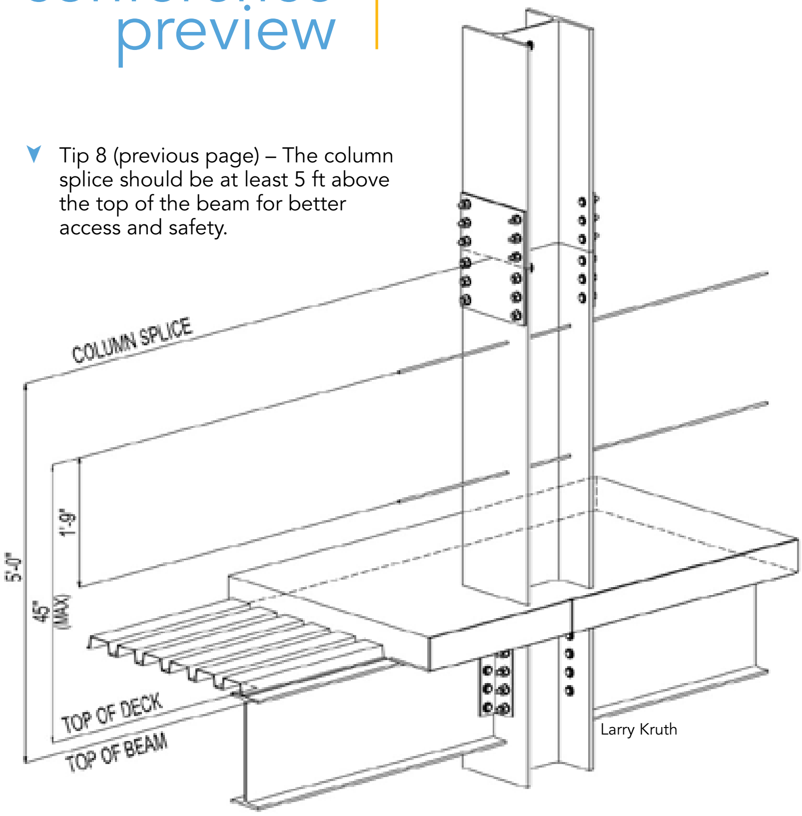


▲ Splice design requires strategy and collaboration as it has the potential to greatly impact fabrication, erection time and cost. Getting the splice right matters.

▼ Tip 3 – Provide a clean column line at the splice.
Tip 12 – Take into account splice alignment and temporary support during field welding.

▼ Tip 6 – Weld complex nodes in the shop and bolt on-site as much as possible. The joint shown in contact bearing was machine finished. All field joints were bolted.
All shop welds were CJP.
Tip 7 – Select a splice location to optimize the handling of the components. High-strength steel was used to make the node lighter in this 2-story-tall transfer truss at the bottom of a 50-story building.

Tip 8 (previous page) – The column splice should be at least 5 ft above the top of the beam for better access and safety.



10. For welded splices, make it direct. The ideal welded splice is direct: shape-to-shape or tube-to-tube. No gussets, knife edges, flanges or lapped plates; a directly welded splice made with groove welds (complete or partial, depending on the loading conditions) makes the splice right. Direct-welded connections fulfill architect Louis Henry Sullivan's objective of "form ever follows function" in an economical and efficient manner. Field welding can be used to reduce the weight of the splice to satisfy specific loading requirements or aesthetic criteria.

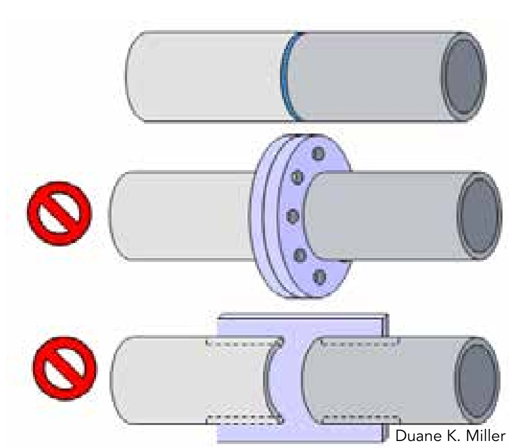
11. Optimize the details such as backing, access holes and tabs. "The devil is in the details" and welded splices are no different. Such details include backing, weld access holes and weld tabs. Left-in-place steel backing must not introduce stress concentrations. Properly sized and prepared weld access holes can be used to reduce constraint in welded splices. Weld tabs enable quality welding but may impact performance of the splice in service. Certainly, left-in-place weld tabs detract from the appearance of splices.

12. The splice must be spliced; field-welded connections require special attention. Splices may be easily designed and detailed, but eventually splices must be spliced (i.e., fabricated and erected). For field-welded connections, the "splicing system" must consider splice alignment, temporary support, access for welding (including out-of-position welding) and when required, post-welding inspection. Collaboration between the architect, engineer, fabricator and erector is required to develop innovative "splicing systems" to make these seemingly simple splices in a cost effective and reliable manner.

13. Leave welded splices in the as-welded condition. A properly made weld will have a visually pleasing appearance. Spatter and other small imperfections can be removed by localized grinding or chipping. However, complete removal of the weld reinforcement (crown) usually detracts from the aesthetics of the welded splice. Costly grinding operations usually create surfaces that are visually different than the as-received base metal condition, attracting more attention to the splice. Time and effort should be directed to making the initial weld correctly, along with a desirable appearance, as compared to a focus on removing all signs that the splice was made by welding.

14. Consider the distance to view when deciding on the splice detail on AESS members. As with all AESS, it is critical to consider the distance to view (greater or less than 20 ft—6 m) when deciding on the detailing and level of remediation required. When the installed steel has connections that are very close to view, it may be appropriate to fully remediate (grind) reinforcement from butt-welded connections. However, the same treatment for connections that are over 20 ft (6 m) away is typically unjustified and simply adds cost to the project.

15. Make the connections between large AESS members appear inconspicuous. The majority of connections used in AESS tend to enhance or make a design detail out of the act of connecting the steel. However, the reverse is normally the case when larger aggregated members require splicing, usually as a result of transportation and lifting limitations. The object here is to make the connections between the members appear unapparent.



Tip 10 – When AESS requires a clean line, make it direct.

Tips 14, 15 and 16 – When AESS is close to view, reduce the visual impact of the splices as much as possible.

16. For reduced visibility of large splices, consider hidden or discreet connections. If the intention is to simply make the splices appear less visible, given either the level of exposure of the AESS or budgetary restrictions, there are two other very effective cost-saving options:

- **Hidden connections:** To join HSS members, bolted connections can be hidden beneath specially designed cover plates that are shaped to match the form of the primary attaching members. Plates are attached to each end of the joining members.
- **Discreet connections:** Here, the bolted connection between the tubular members leaves the bolts visible, but the connection is designed in such a way as to reduce their visual impact and retain the trim visual lines of the joining members.

A splice is not an afterthought. A splice location and its design require careful consideration early in the process as well as collaboration between the architect, engineer, fabricator and erector. When the splice is right, all parties—including the client and the end user—benefit. ■

This article is a preview of Session N87 "The Splice is Right" at NASCC: The Steel Conference, taking place April 13-15 in Orlando. Learn more about the conference at www.aisc.org/nascc.