



Design File

Mixing Welds and Bolts, Part 1

Practical Ideas for the Design Professional by Duane K. Miller, Sc.D., P.E.

Introduction

There are a variety of circumstances in which the engineer may need to assess the strength of a connection that is composed of both welds and mechanical fasteners. Today, mechanical fasteners are typically bolts, but older structures may include rivets. Such situations may be encountered during the course of rehabilitation, repair or strengthening projects. For new construction, bolts and welds may be combined in connections where the materials being joined are initially secured with bolts, and then welded to gain the full connection strength. As will be seen, calculating the total capacity of the connection is not as simple as totaling the arithmetical sum of the individual components (welds, bolts, and rivets). Such an assumption is unconservative, and the consequences could be disastrous.

Part 1 of this two-part edition of "Design File" will deal with snug-tightened and pretensioned mechanical fasteners combined with welds. Part 2 will address combining welds with slip-critical, high-strength bolted connections.

Some Background on Bolted Connections

Bolted joints are described in the *AISC Specification for Structural Joints Using ASTM A325 or A490 Bolts* (June 23, 2000) as either snug-tightened, pretensioned, or slip-critical (p. 23). A snug-tightened joint has the condition of "tightness that is attained with a few impacts of an impact wrench or the full effort of an ironworker using an ordinary spud wrench to bring the plies into *firm contact*." (p. xi). A pretensioned joint is one in which the bolts have been installed in a manner so that the bolts are under significant tensile load with the plates under compressive load (p. x). Four acceptable methods are listed in Section 8.2: turn-of-

nut, calibrated wrench, twist-off-type tension-control bolts, and direct-tension-indicators. Slip-critical joints have bolts installed just as they would be in a pretensioned joint, but also have "faying surfaces that have been prepared to provide a calculable resistance against slip." (p. xi).

In simple terms, in snug-tightened joints and pretensioned joints, the bolts act as pins. Slip-critical joints work by friction: the pretension forces create clamping forces and the friction between the faying surfaces work together to resist slippage of the joint.

ASTM A325 bolts have a minimum tensile strength of 105–120 ksi (725–830 MPa) depending upon the bolt diameter, while A490 bolts must fall between 150 and 170 ksi (1035–1175 MPa) tensile strength. Riveted joints behave more like snug-tightened joints, but the "pins" in this case are the rivets, and are typically about half the strength of A325 bolts.

When a mechanically fastened joint is loaded in shear, one of two types of behavior is possible. The joint may have the bolts or rivets bear against the sides of the holes in the connected material, concurrently putting the bolt or rivet into shear. The second possible behavior is that friction, introduced by the clamping forces provided by the pretensioned fastener, resists the shear loading. No slippage is expected in this joint, but the possibility exists nonetheless.

Snug-tight joints are acceptable for many applications since minor slippage may not adversely affect the performance of the connection. When there is significant load reversal, pretensioned joints may be required. When joints are subject to fatigue loads with reversal of direction, slip-critical joints are required.

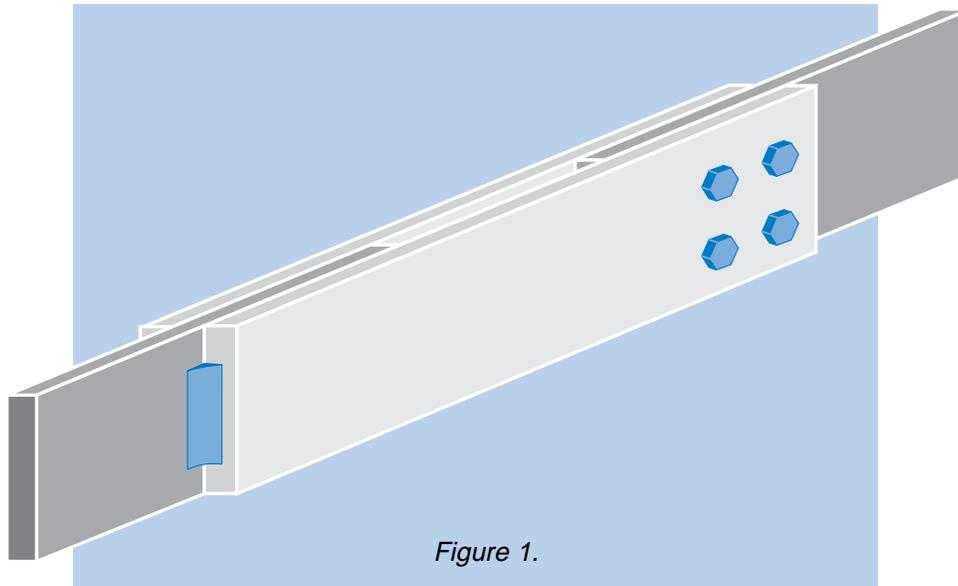


Figure 1.

Thus, an existing bolted connection may have been designed and built to any of these criteria. Riveted joints would be considered the snug-tight type.

Adding Welds to Mechanically Fastened Joints

While a weld may be composed of metal that is capable of demonstrating an elongation of 20% or more in an all-weld-metal tensile specimen, the same metal in a restrained joint may be incapable of delivering any significant deformation prior to fracture, due to the interaction of triaxial stresses. In other words, welded connections are rigid. Welded connections are stiff. Unlike snug-tightened bolted joints that may slip as they are loaded, welds are not expected to stretch and distribute the applied load to any great extent. In most cases, welds and bearing-type mechanical fasteners will not deform equally. The load is transferred through the stiffer part, and therefore the weld will carry virtually all the load, sharing little with the bolts. And that's why caution needs to be taken when welds and bolts and rivets are combined.

Code Provisions

The issue of mixing mechanical fasteners and welds is addressed in the *AWS D1.1:2000 Structural Welding Code—Steel*. Provision 2.6.3 states:

“Welds with Rivets or Bolts. Rivets or bolts used in bearing type connections shall not be considered as sharing the load in combination with welds. Welds, if

used, shall be provided to carry the entire load in the connection. However, connections that are welded to one member and riveted or bolted to the other member are permitted. High-strength bolts properly installed as a slip-critical-type connection prior to welding may be considered as sharing the stress with the welds.”

The first three sentences of this provision address the topic discussed here. The fourth sentence will be addressed in part 2.

When the mechanical fasteners are of the bearing type and a weld is added, the capacity of the bolt is essentially ignored. The weld must be designed to transfer all the load, according to this provision. This is, in essence, the same as the requirement of AISC LRFD-1999, provision J1.9. However, the Canadian standard CAN/CSA-S16.1-M94 also permits the use of the capacity of the mechanical fastener or the bolts alone when this is higher than the capacity of the welds. All three standards are in agreement on this issue: the capacities of the bearing-type mechanical fasteners and the welds cannot be added together.

AWS D1.1, paragraph 2.6.3, goes on to discuss an acceptable situation in the third sentence. Bolts and welds can be combined in the situation where a connection consists of two separate components, as illustrated in Figure 1. On the left is a welded connection, and on the right, a bolted one. This is acceptable. Each part of the overall connection behaves independently, and thus, the Code provides an exception to the principles as contained in the first part of 2.6.3.

The previous provisions are applicable for new construction. For existing structures, D1.1 paragraph 8.3.7, goes on to say:

“Use of Existing Fasteners. When design calculations show rivets or bolts will be overstressed by the new total load, only existing dead load shall be assigned to them. If rivets or bolts are overstressed by dead load alone or are subject to cyclic loading, then sufficient base metal and welding shall be added to support the total load.”

The first sentence permits sharing of loads between mechanical fasteners and welds if the structure is pre-loaded (i.e., any slip has already occurred), but only the dead load can be assigned to the mechanical fastener. Welds must be used to take up all the applied or live load. No such sharing of loads is permitted when the mechanical fasteners are already overloaded. When cyclic loading is involved, no load sharing is permitted.

An Illustration

Consider a lap joint originally connected with snug-tight bolts, as shown in Figure 2a. Additional capacity is being added to the structure, and the connection and the attached members must be increased to provide twice as much strength. Figure 2b illustrates the basic plan to strengthen the members. What should be done to the connection?

Since the new steel is going to be joined to the old with fillet welds, the engineer decides to add some fillet welds to the connection. Since the bolts are still in place, the initial thought is to add only the welds required to transfer the additional capacity of the new steel, expecting 50% of the load to go through the bolts, and 50% through the new welds. Will this be acceptable?

Let's first assume there is no dead load currently applied to the connection. In this case, D1.1 paragraph 2.6.3 applies. In this bearing type connection, the welds and bolts cannot be “considered as sharing the load.” Thus, the specified weld size must be large enough to carry the entire dead and live load. The capacity of the bolts cannot be considered in this example.

Next, let's assume a dead load is applied. Further, let's assume that the existing connection is adequate to transfer the existing dead load. D1.1 paragraph 8.3.7 applies in this case and the new welds are only required to carry the increased dead load and the total live load. The existing dead load can be assigned to the existing mechanical fasteners.

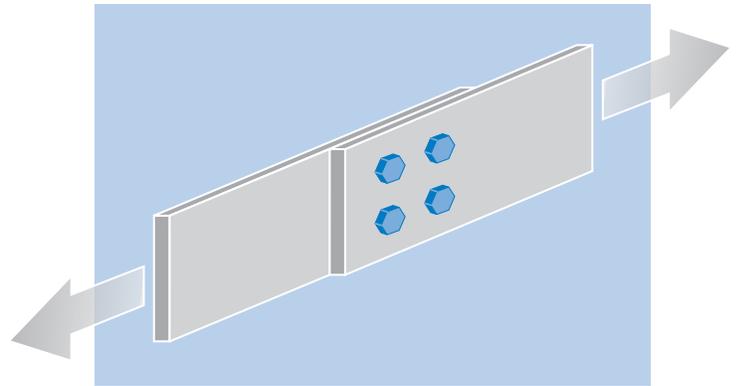


Figure 2a.

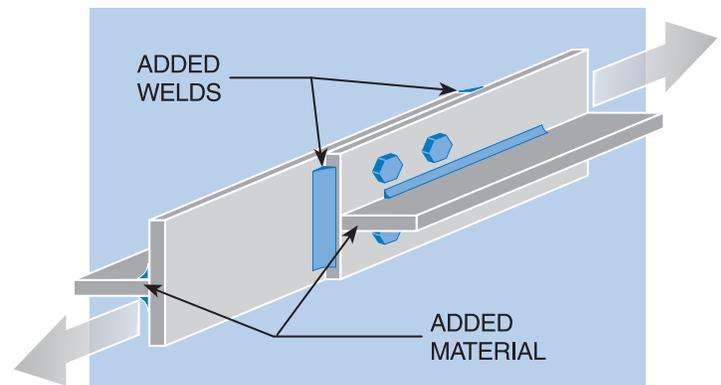


Figure 2b.

Conclusion

In summary, the answer to the question “Is this acceptable?” depends on the loading conditions. In the first case where no dead load was assumed, the answer is “no.” Under the specific conditions of the second scenario, the answer is “yes.” It cannot be concluded that the answer will always be “yes” simply because dead load is applied. The level of dead load, the adequacy of the existing mechanical connection, and the nature of final loading (whether static or cyclic) could change the answer.

All of the above apply to mechanical fasteners of the pin type. Part 2 will deal with high strength, slip-critical bolted connections in combination with welds. The technical aspects of the content of part 2 are currently being evaluated by technical committees. The work of the committees may not be complete in time for the next issue of *Welding Innovation*. Part 2 will be forthcoming just as soon as all the technical information is available. 