Consider Overall Structural Performance When Specifying Fatigue Details

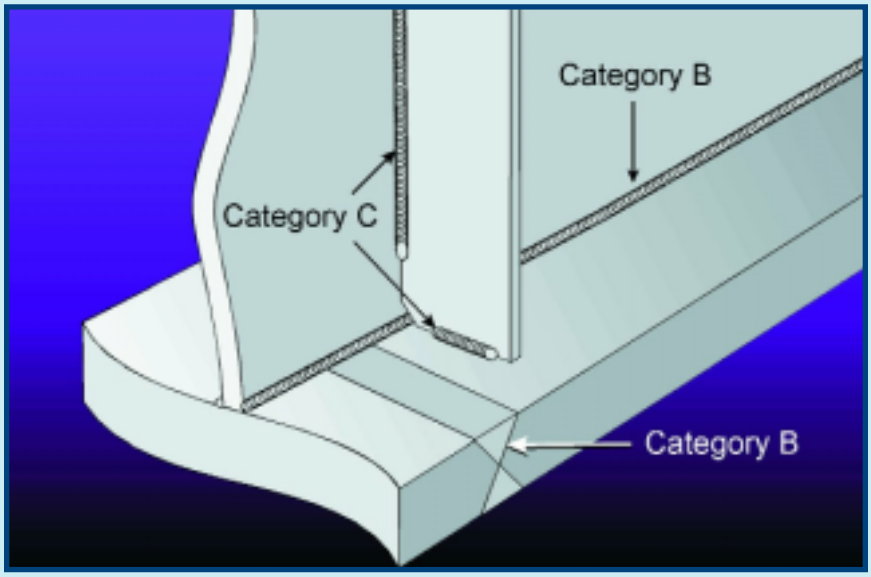

Figure 1

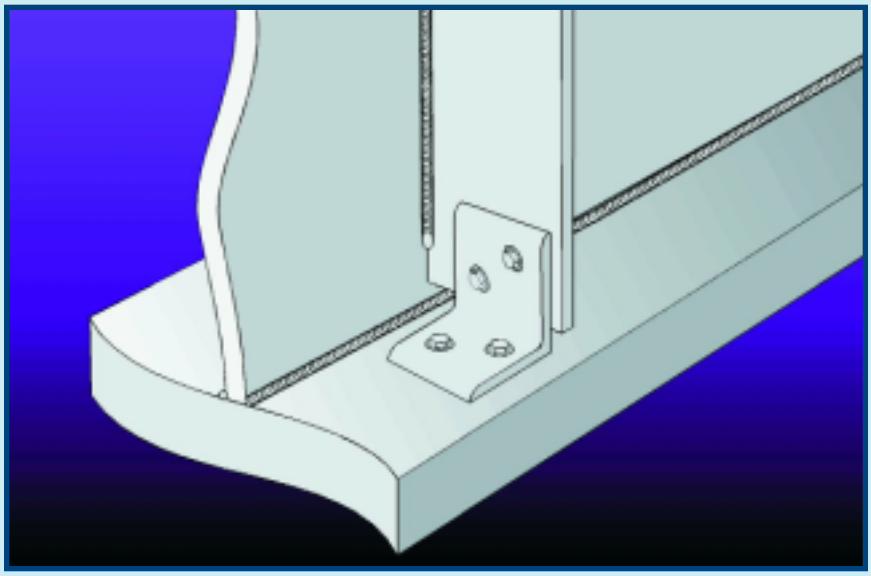

Figure 2

By Duane K. Miller, P.E.

This is the first in a series of articles focusing on welding and the practicing engineer

THE DESIGN OF STRUCTURES SUBJECT TO MOVING LOADS WILL BE GOVERNED BY strength, permanent deformations, deflections, or fatigue limitations. All of these limitations are controlled by the geometric section properties, or material properties. The fatigue strength of the structure is also controlled by the structural details and connections. The performance of various types of connections and attachments has been categorized into groupings that have been assigned alphabetic designations. Category A is the reference group which includes unwelded rolled sections. This group has the highest allowable stress range for a given number of cycles. Categories B through F group various connections with progressively diminishing stress ranges. Thus, a Category B detail has a greater allowable fatigue stress range than a Category D detail, etc.

Too often, engineers will strive to eliminate "bad" details and increase the allowable stress range without examining the overall impact of this "improvement" on the performance and cost of the structure. For example, for the web to flange connections on plate girders, a continuous fillet weld has a fatigue category rating of B, whereas a partial penetration groove weld

has a slightly lower rating of B' However, it is extremely rare that either Category B or B' will control; that is, other design factors generally will be more restrictive than the presence of these fatigue details. It would be undesirable, therefore, for a designer to specify the use of fillet welds in an application where partial penetration groove welds would constitute a more economical approach, just because of the slightly better fatigue performance of the Category B detail. (Note: the validity of the new Category B' grouping has been questioned by several knowledgeable engineers. Specifically, it may be based upon processes and joint details that are not commonly applied to fabrication based upon American standards.)

Cost Vs. Performance

Current specifications properly require the attachment of transverse connection plates to the flanges of bridge girders (see AASHTO 10.20.1). This is to avoid the unacceptable out-of-plane movement that can result in fatigue cracking. Stiffeners used as diaphragm or cross-frame connection plates are routinely welded to the compression flange, but any of three options may be employed for fastening to the tension flange. If performance is unchanged, preference generally is given to the lower cost option.

The stiffener can be welded to the tension flange. This is a Category C detail and is illustrated in **Figure 1**. Notice that the web to flange connection is a Category B detail, and the full Penetration butt splice, ground flush and inspected, is also a Category B detail. When the stiffener is welded to the flange, the overall allowable stress range is reduced. Notice also that the stiffener to web weld is also a Category C connection. The stress range experienced at this point, however, is slightly lower due to the closer proximity of the weld termination to the neutral axis.

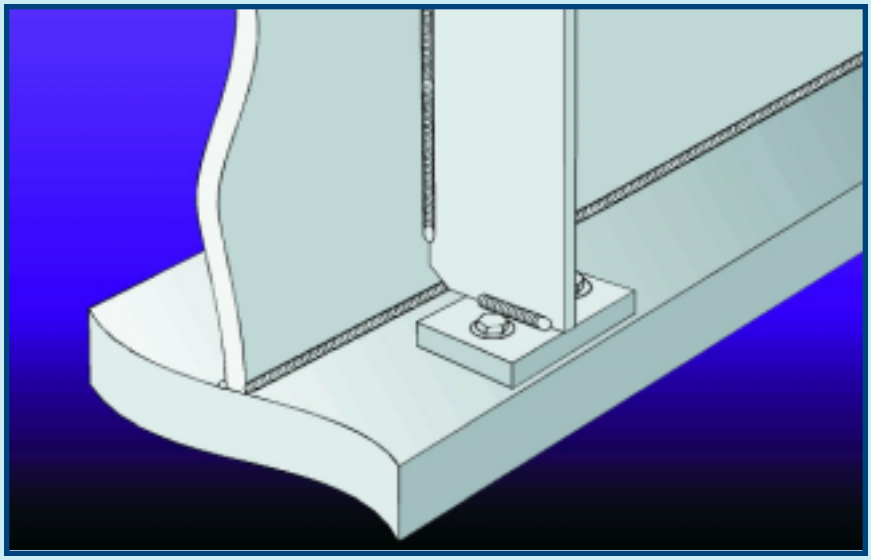

Figure 3

In order to avoid the Category C detail as it relates to the flange, many designers have opted for alternate connections. One approach is to bolt a structural angle to both the web and flange as illustrated in **Figure 2**. An alternative is to initially bolt a pad to the flange and then weld the stiffener to the pad. This is illustrated in Figure 3. Both of these are examples of Category B details as they relate to the flange. Obviously, both of them necessitate bolting and additional material. They may also impose severe work flow and material handling problems upon the fabrication shop. Cleaning and painting the area under the bolted connection of the third option generally interrupts the normal flow of materials in a typical shop. All of these issues add to the cost of these alternative types of connections.

The essential question is whether performance will be the same with any of the three connections. Granted, the welded detail has a lower fatigue allowable. Without additional information, however, it is impossible to determine which approach is better because serviceability of the structure may not be limited due to the presence of the Category C detail on the flange. The fatigue life may already be limited by the stiffener to web Category C detail.

A Category C detail, such as a welded shear stud, may constitute the controlling variable in other portions of the structure. Finally, deflection or strength may control and fatigue would not be the limiting factor. Therefore, the engineer should evaluate the overall limitations of the structure's performance and determine whether these details impose any undesirable implications for the structure's performance. If they do not, the more economical details characteristic of the lower allowable fatigue stress range can reduce the overall cost of the structure.

CASE STUDY

In an effort to take a conservative overall approach to a dynamic structure, an engineer had initially specified the connection detailed in **Figure 3** to be employed throughout the structure. However, upon closer examination, it was determined that the detail was only required in the high stress regions of the flange. Therefore, the lower cost welded connection of the flange was employed where permissible, and the bolted connection was utilized where necessary. The cost comparison chart above illustrates the savings achieved by use of the welded flange connection.

Cost Comparison

Type of Connection	*$ Costs*
Bolted Angle	
Labor:	
Cut & punch clip angle	
Punch holes in stiffener	
Drill holes in flange	
Clean & paint clip angle	
Bolt clip angle in place	$78.00
Materials:	
Angle, bolts	$10.00
Total for Bolted Angle	**$88.00**
Welded Pad Assembly	
Labor:	
Cut plate	
Grind and paint faying surfaces	
Drill holes - plate & flange	
Install bolts	
Weld auxiliary plate to stiffener	$60.00
Materials:	
Plate, bolts, filler metal	9.00
Total for Welded Pad Assembly	**$69.00**
Welded To Flange	
Labor:	
Weld to flange	$5.00
Material:	
Filler metal	1.00
Total for Welded to Flange Connection	**$6.00**

In each instance where the directly welded connection was permissible, a savings of $63.00 per connection was realized.

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