Plate Bending and Design Guide One

by Adam Stordahl, PE IES Technical Support, March 2013

Integrated Engineering Software has recently released a new connection tool, VAConnect. VAConnect provides base plate design checks per AISC's Design Guide 1. The following short article provides some commentary on the plate bending provisions of DG1, with the intention of helping engineers better use the new base plate connection program.

AISC's Design Guide One (DG1)[1] provides a procedure for moving from a column reaction and base plate configuration to a resulting concrete bearing stress, anchorage tension demand, and set of plate bending moments. These bending moments are found by modeling the plate as a series of cantilever beams[2]. This simplification of the two-dimensional plate bending problem is inappropriate for some connections.

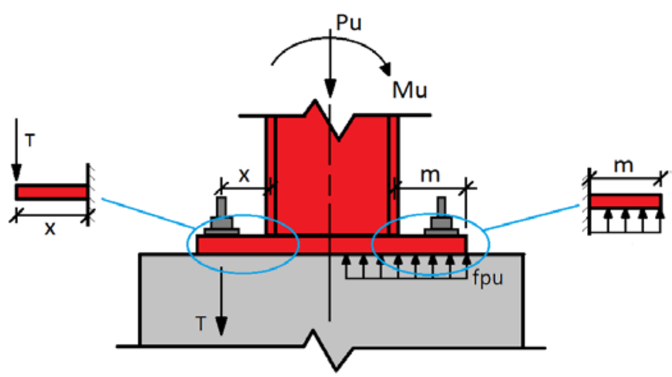

Figure 1: DG1 Base Plate Bending Models

Consider the base plate section, and associated beam models, shown in Figure 1. Also consider the two base plate connections shown in Figure 2. In reality, the tension side of connection A will bend much differently than the tension side of connection B, however, when the tension side moment demand is calculated per DG1 equation 3.4.5 (the point loaded cantilever of Figure 1) both connection A and connection B will generate the same design moment.

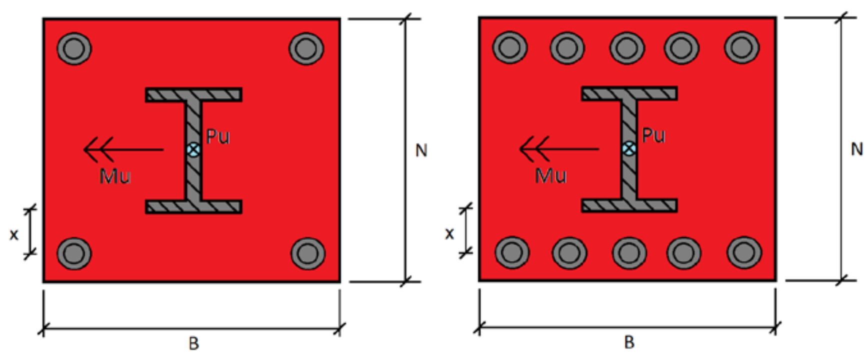

Figure 2: Connection A (left) and Connection B (right)

$$M_u = \frac{T_u * x}{B} \quad \text{(DG1 equation 3.4.5)}$$

[1] Fisher, James M., Ph.D., P.E. and Kloiber, Lawrence A., P.E. *Design Guide 1: Base Plate and Anchor Rod Design*. Second Edition. Chicago, IL: American Institute of Steel Construction, 2010. Print

[2] The only slight variation from this is the "yield-line theory" cantilever considered for I-shape columns under concentric axial forces.

As an example, if x = 4 inches, B = 20 inches, T = 10.0 kips, the design moment calculated by DG1 equation 3.4.5 is 2.0 inch-kips/inch for both connections A and B.

Figures 3-6 show the moment demand when both connections are modeled using the finite element method. In addition to the parameters given earlier, the FEA models assume the plate is 2 inches thick and the column flange is 12 inches wide.

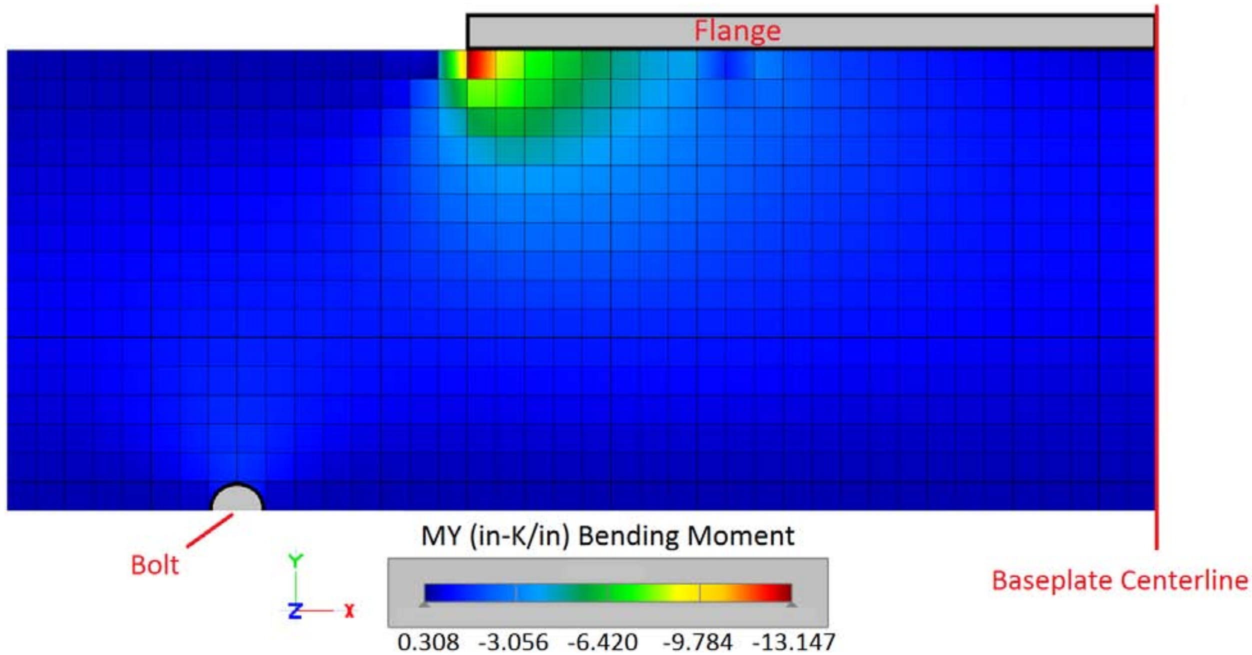

Figure 3: Connection A (two bolts) MY Bending

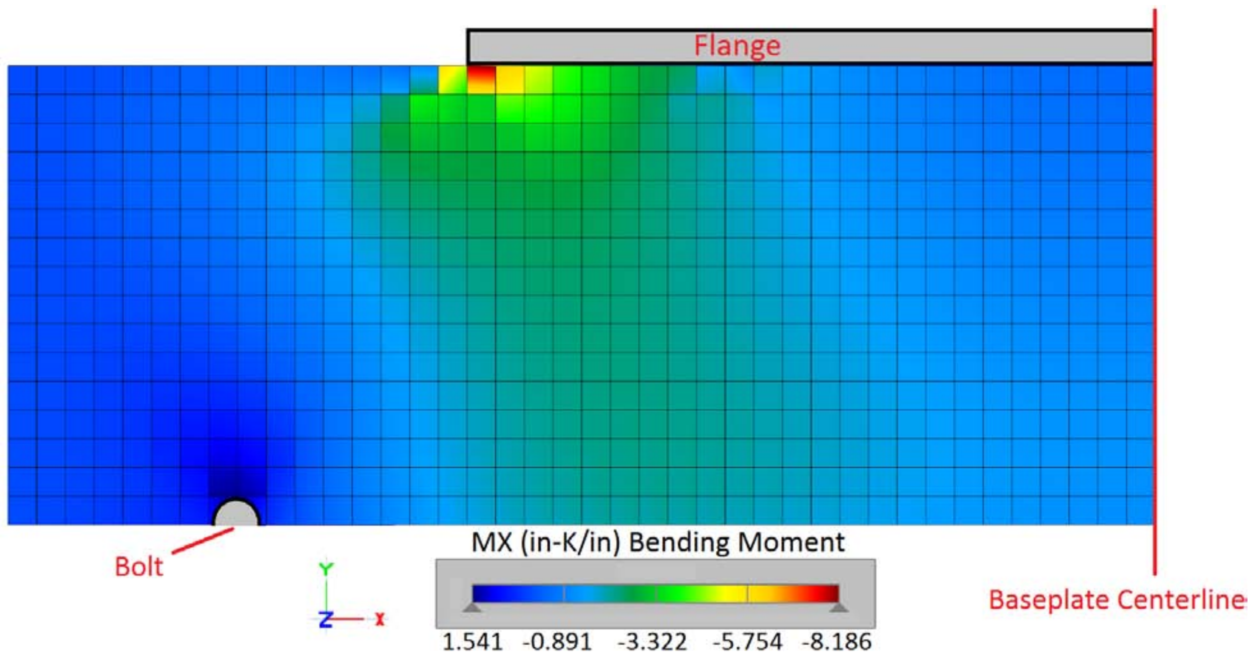

Figure 4: Connection A (two bolts) MX Bending

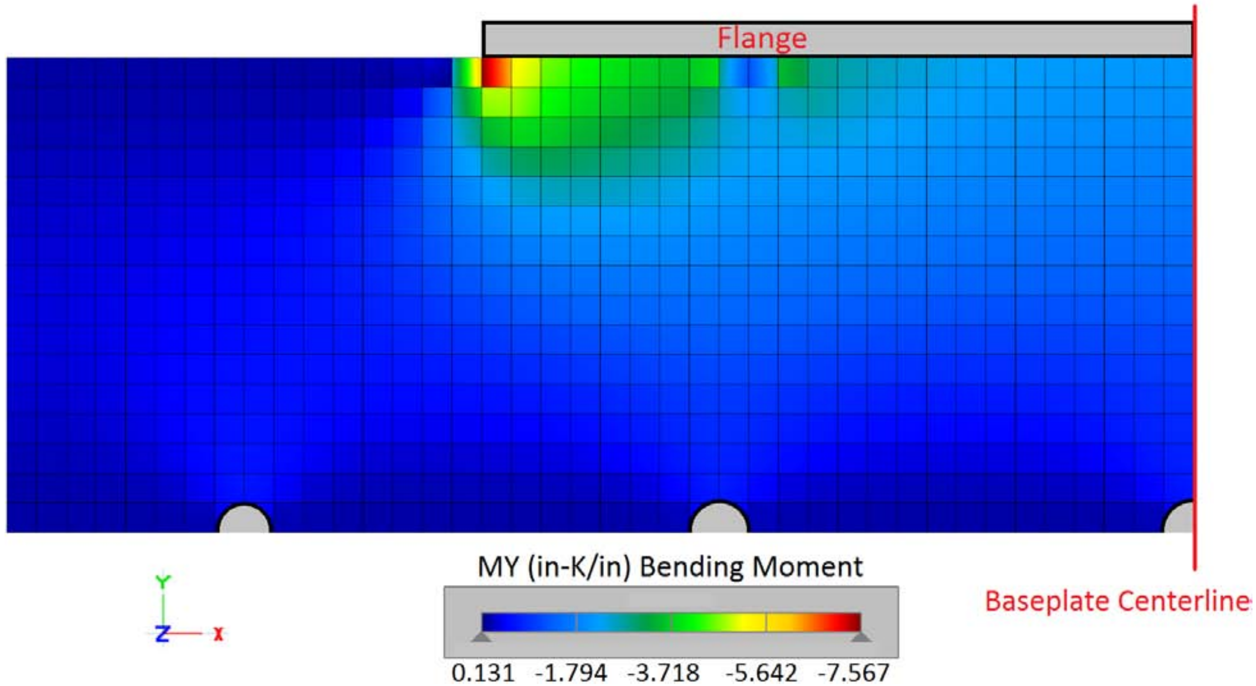

Figure 5: Connection B (five bolts) MY Bending

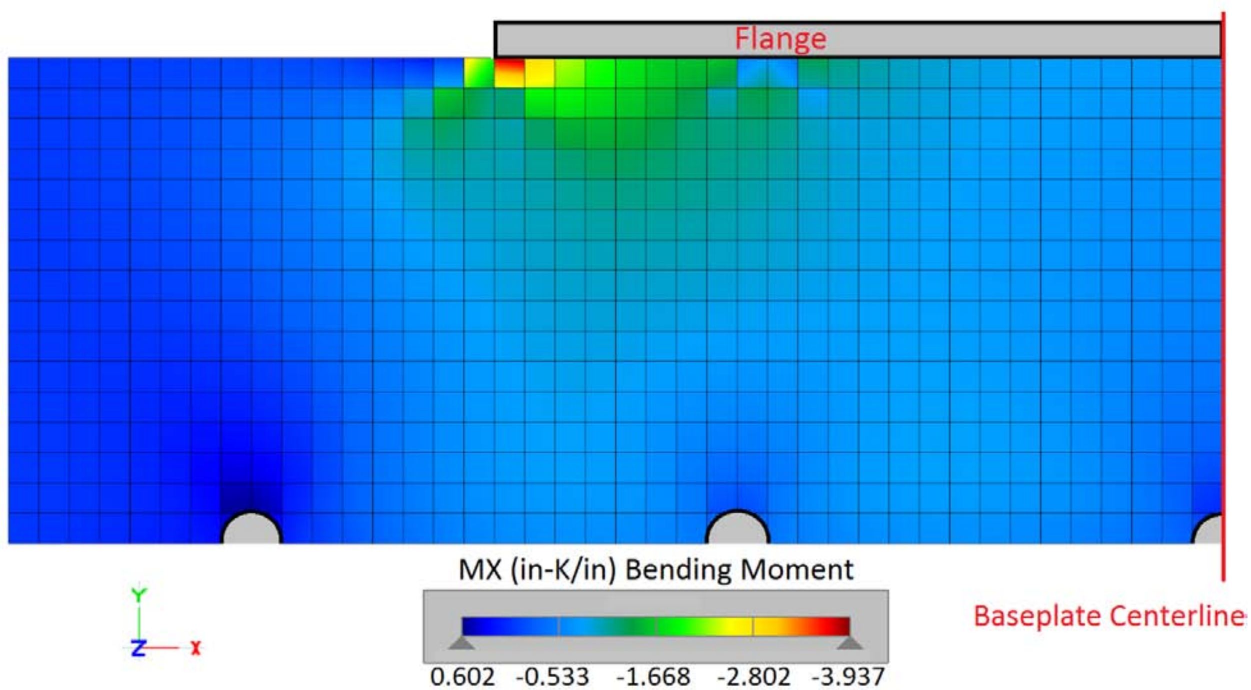

Figure 6: Connection B (five bolts) MX Bending

The finite element analysis results in moments[3][4] much greater than the demand of 2.0 inch-kips/inch predicted by DG1. It is probably not necessary to size the plate's thickness for the maximum moment that occurs over a very small area of the plate near the corner of the column flange; however, even after moving away from this concentration of demand the moments are still much larger.

The moments reported from the finite element analysis are not necessarily the demands that will exist in the real-world base plate. The finite element results do, however, illustrate the effect of considering the two dimensional nature of the problem. Not only does the plate bend in both the Y and X directions, but the moments vary sharply in the X direction, with very large moments at the corner of the column flange. Both of these aspects are lost in the one-dimensional cantilever beam model used by DG1. The FEA analysis also illustrates that (as expected) the tension side of Connection A bends much differently Connection B.

One way to capture some of the differences between the behavior of Connection A and Connection B, while using DG1, is to calculate and effective bending width based on a 45 degree load distribution. The 45 degree distribution is suggested by the design guide in the section dealing with base plates subjected to concentric axial tension (section 3.2). This same concept can be easily extended to the case of base plates subjected to overturning moments. This is the approach used by the base plate program in VAConnect. The effective width adjustment leads to more conservative answers than DG1 equation 3.4.5, but still fails to capture the two-dimensional nature of the problem.

The purpose here is not to suggest that AISC's DG1 is always an inappropriate way to design base plates. The single example problem in this article was purposefully selected to illustrate a weakness in the design guide. The example problem leads to poor DG1 results primarily because the plate is much wider than the column. In other situations the finite element results (which are also not perfect) might be in better agreement with the design guide.

DG1 is a significant simplification of a complicated real-world problem. In order to use this simplified model effectively, it is important to be aware of its underlying assumptions and the potential weakness of those assumptions. Some base plates cannot be reasonably modeled by treating the plate as a cantilever beam[5].

[3] A finer mesh may be needed to find the final moment values if a finite element model is used to determine the design demand. The plots are only meant to illustrate the two dimensional nature of the problem.

[4] The VisualAnalysis 10 models used for this article, and VAConnect Base Plate files for the example problem, can be downloaded here: http://www.iesweb.com/news/2013/DG1AndPlateBending.zip

[5] In the future IES plans to add a finite element analysis option to the base plate program, allowing engineers to more readily analyze base plate connections that fall outside of the scope of DG1.