Effect Of Notches In The Flange

After a bridge collapse, a finite element analysis was performed to determine the effects of notch cuts in the flange of steel plate girders

By M. Ala Saadeghvaziri, Ph.D., P.E.

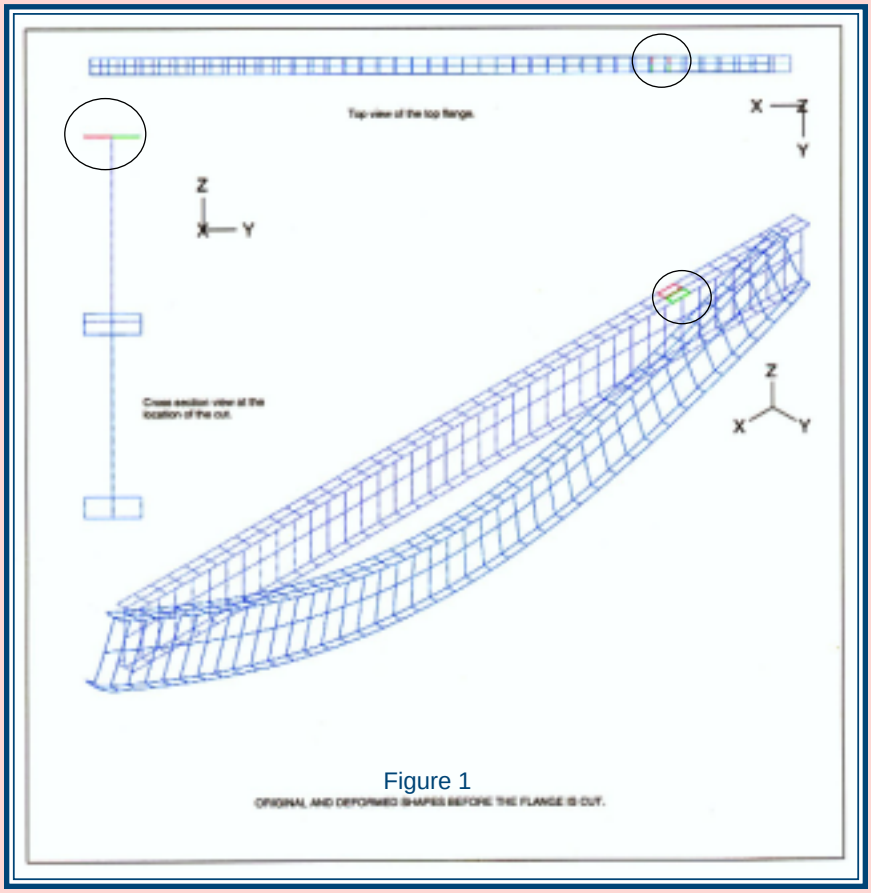

Figure 1
ORIGINAL AND DEFORMED SHAPES BEFORE THE FLANGE IS CUT.

On April 16, 1996, a 50-ton facia girder buckled and fell during a bridge reconstruction project on State Route 581 near Harrisburg, PA, killing one motorist and injuring a worker. The disaster occurred as workers were disassembling the westbound lane of the structure. They had already removed the deck and most of the floor beams, and were finishing installation of lift hooks in the girder, which was 130' long and 9' deep, according to reports in the April 29 issue of *ENR*.

According to an internal investigation by the Pennsylvania Department of Transportation (*ENR* May 20), in preparation to removal, workers cut 5"- to 6"-wide notches in the top flange of the girder. PennDOT had instead expected 2½"-by-4" "window holes". In addition the contractor failed to brace the girder against the abutment. "Cutting notches into the top flange [was] the critical error...the beam was severely compromised," according to Bradley L. Mallory, State Transportation Secretary.

In response to this report, a finite element analysis was performed to determine the effect of a notch cut in a flange.

The analysis was performed on a simply supported 100'-span plate girder made up of ⅜"x92" web plate and two 2¼"x28" flange plates. A uniformly distributed load of 42 lb./in. was applied. The analysis included three stages:

- no cut in the flange;
- half of the top flange cut at a section about 18' from the right support ($1/6^{th}$ of span); and
- the entire flange is removed for the section of part b.

The length of the notch was 30" and the size of the notch was

selected arbitrarily to simplify modeling (30" corresponds to one element size). The analysis was performed using ADINA (from ADINA R&D, Inc., Watertown, PA) and its element death/birth option. That is, the analysis included three time steps where at step one all elements are active, at step two a 30"-long element corresponding to half of the top flange become inactive, and finally, in the third step the element corresponding the other half of the top flange becomes inactive. Isoparametric shell elements (with 16 nodes) were employed to model the girder.

Figure 1 shows the original and deformed shapes before the cut in the flange were made, where displacements are symmetric with respect to the web plane. Note that the elements being removed (notches in the flange) are shown in red and green on the original mesh. Shown in Figure 2 are various views of the deformed and original shapes of the model after half of the flange is cut. The out-of-plane deformation of the girder due to lack of symmetry resulting from a cut in half of the flange is very significant. This can be observed by comparing Y-displacement to Z-displacement of the model by considering the cross section view of the girder as shown in Figure 2. The value of Y-displacement is more than half of the Z-displacement at the location of the cut. This result indicates that in a situation like this it is important to provide lateral support at the location of the cut too. Figure 3 shows similar views after removal of the entire flange (over a 30" length) where the displacements are again symmetric with respect to the plane of the web.

Contours of flexural stresses for all three stages are shown in Figure 4. Note that lack of symmetry in flexural stress through the height of the cross section (for case a) is due to the fact that the reactions are not located at the neutral axis of the girder. Cutting half of the top flange

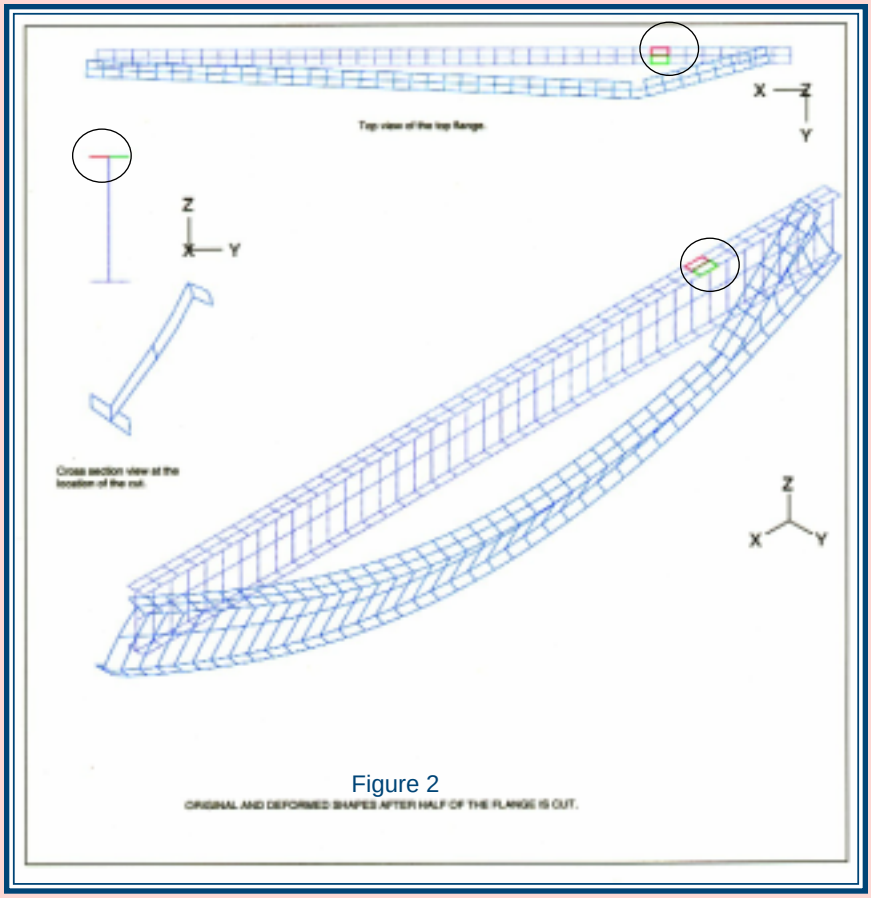

Figure 2
ORIGINAL AND DEFORMED SHAPES AFTER HALF OF THE FLANGE IS CUT.

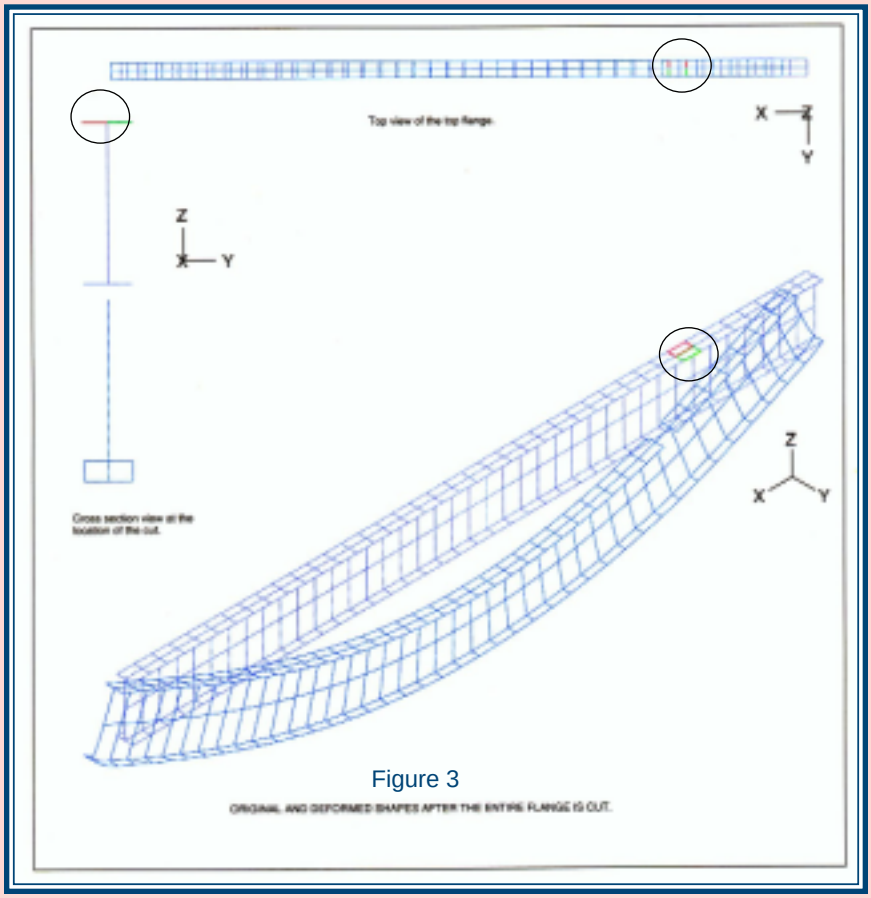

Figure 3
ORIGINAL AND DEFORMED SHAPES AFTER THE ENTIRE FLANGE IS CUT.

increases the maximum compressive stress from -3 ksi to -5.4 ksi. Removal of the entire flange (over a 30" length) increases the maximum compressive stress to -13.75 ksi. For all cases the stresses are well below the yield stress of steel.

Therefore, initial instability due to lack of symmetry during removal procedures and not necessarily the size of the notch appears to be the more important cause of possible problems. As previously mentioned, providing lateral supports at the location of flange cuts should be considered in addition to bracing at other locations as needed.

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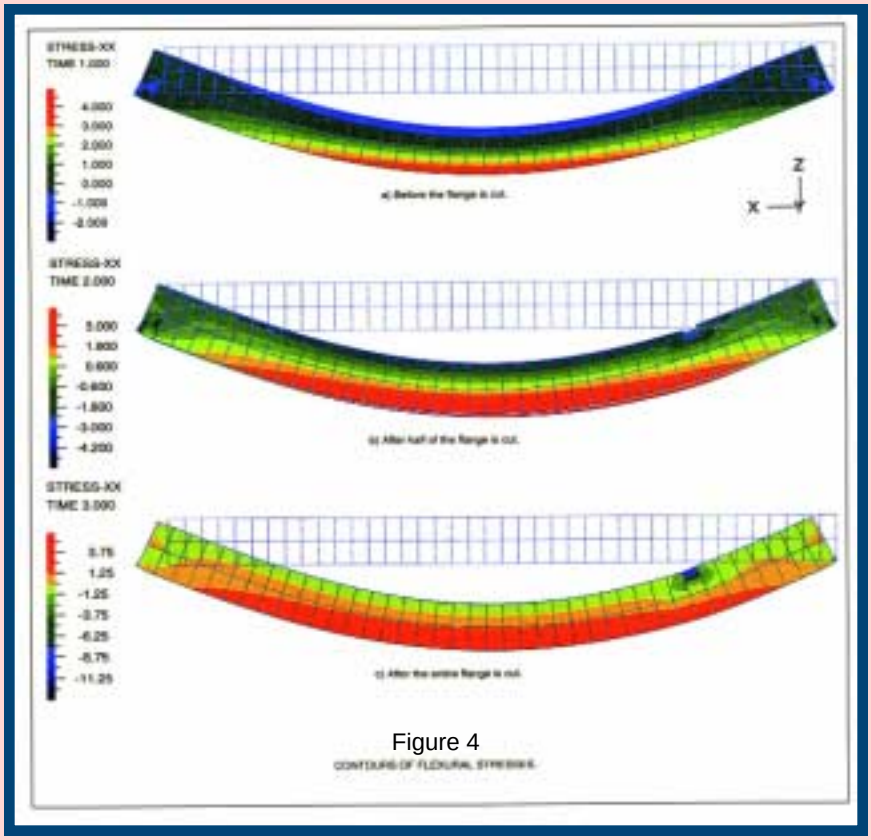

Figure 4