Center for Infrastructure Engineering Studies

Investigation of Cause of Cracked Stringer on the Blanchette Bridge

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16. Abstract
The Blanchette Bridge carries Interstate 70 across the Missouri River, connecting St. Louis and St. Charles counties in eastern Missouri. The westbound bridge was constructed in 1958. In 1979, the original reinforced concrete roadway deck on the bridge was replaced with a steel grid deck system, welded to supporting girders and stringers.

In 1999 and 2005, cracks were discovered in stringers on the bridge approach spans. The members cracked in a counter-intuitive fashion—from top to bottom at midspan between supports, where positive bending would be expected. The stringers were repaired with bolted splices. The Missouri Department of Transportation (MoDOT) worked with UMR to investigate the cause of these cracks.

The investigative effort included site visits, review of bridge documents, preliminary fatigue analyses, review of material property information, detailed analyses, and field testing.

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I-70 Twin Bridges

Blanchette Bridge during the redecking project on the westbound structure (in background)

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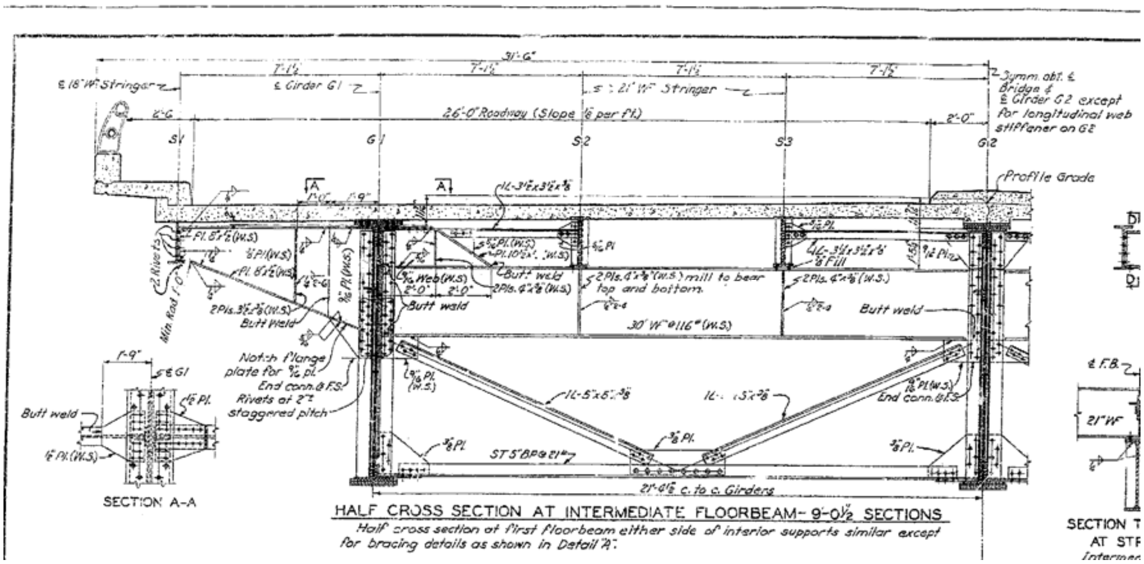


Typical superstructure section through approach spans showing original cast-in-place concrete deck.


Cracked stringer found during 2005 inspection (prior to repair).

The general construction sequence of the redecking project was as follows:

1. Removal of the existing concrete deck.
2. Attachment of shim plates to top of plate girders and stringers. Shims in the negative moment areas of the plate girders were bolted to the top flange angles. Shims on stringers were field welded to the top flanges.
3. Placement of grid deck.
4. Field welding of grid deck to top of shims.
5. Placement of wearing surface on grid deck.

Steel shims were needed on top of the plate girders and stringers to allow the steel grid deck to be set at the correct elevation and bear fully on the girders and stringers. The grid deck transverse bars were welded to these shims.

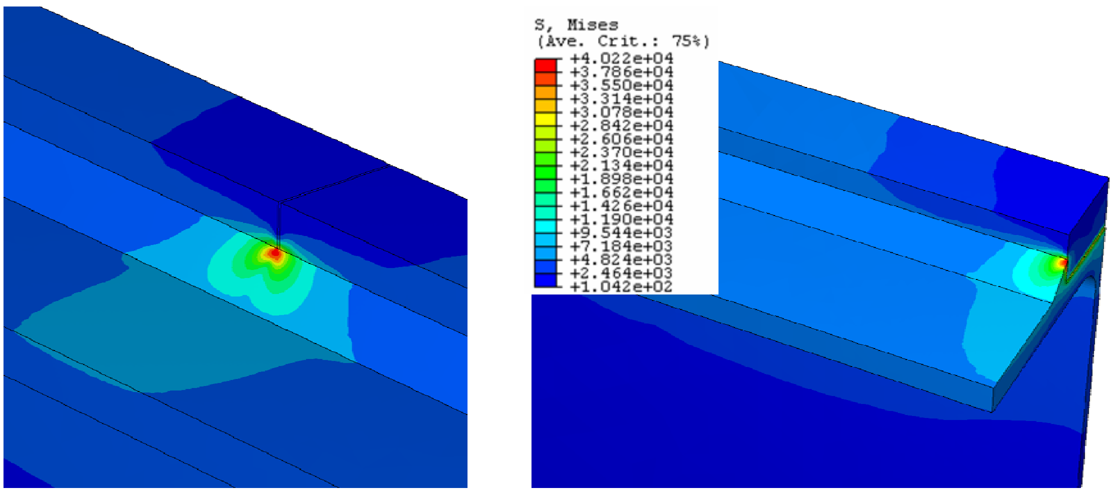
Shim plate and weld detail on stringer top flange.

The treatment of the fillet welds connecting the shim plate to the stringer top flange is a significant detail. Field inspection of the open butt joints in the shim plates showed that the fillet welds frequently were run across the gap between the shims. Field observations also show that the fillet welds are typically 3/8” to 1/2” in size, compared to the 1/4” size shown in the project drawings. The design drawings did not include a detail showing how the fillet weld should be treated at the butt joints in the shim plates.

Another important factor relates to the fit of the grid deck to the structure. The installation notes for the grid deck state that it is essential for the bearing bars of the grid deck to be in full contact with the stringer flanges prior to welding. The grid deck is a relatively stiff element. Two deck panels are used to cross the bridge deck width. Each deck panel would be supported by an exterior stringer, the exterior plate girder, two interior stringers, and the center plate girder. Any variations in the relative top elevations of these elements will cause a “misfit” or gap between the bottom of the grid deck and the top of the shim material at one or more of the support locations. Misfits could also be caused by variations in the depth of the grid deck (tolerances of +/- 1/16” are shown for the bearing bar depth on the shop drawing). Grid decks are welded, and distortion from these misfits can occur. This distortion would result in the deck warping, so the affected panel would no longer be planar, thereby providing an additional source for misfits.

Discussions with one of the contractor's project engineers revealed that a number of these misfits occurred during the construction and that the typical solution to the problem was parking a piece of construction equipment on the panel, forcing it to seat itself on all of the shim plates for welding. Apparently this "fix" was not a common occurrence, but was not rare, either.

An approximate assessment of the fatigue life of the weld detail showed that if bending effects caused a net tensile stress at the shim plate butt joint, fatigue could cause cracking of the weld and stringer. A finite element analysis showed very high stress concentration at the butt joint, which can be seen in the graphical stress analysis results shown below.



Graphical rendering of stress analysis results at given negative bending moment.
*Sample contours of (a) Von Mises stress (in psi) at shim plate butt-joint and (b) thru-notch section view.
Note stress concentration at weld tip at notch location in red.

Analysis of the grid deck-stringer interaction showed that the stiffness of the grid deck would carry more load to the plate girders than a simple analysis using a "tributary area" approach would. This factor, combined with the reduction in dead load due to replacement of the original concrete deck with the grid deck, would reduce the dead load moment in the stringers and could allow net tensile stresses at the butt joint locations under service load.

Field measurements of stringer stresses were taken over a several week period. These measurements showed that negative bending in the stringers occurred under live load. In addition, negative bending was caused in the stringers by thermal deformations in the grid deck due to day-night temperature cycling.

Strain gage installation.

The following conclusions were reached on the cause of the cracked stringers:

1. The stringer cracking occurred at details that had very high stress concentration factors due to open shim butt joints with fillet welds crossing the joint.
2. Fatigue of the fillet welds due to traffic loading led to cracking of the weld material.
3. High negative bending stresses in the stringer resulted in cracking through most of the section after the weld crack propagated into the stringer.
4. The high negative bending stresses result from construction or temperature forces, or some combination of those, in addition to the effects of continuity on the stringer force distribution.
5. The redundancy and strength of the grid deck and stringers prevented serious distress or failure in the bridge deck.

The detail that led to the cracking was due to decisions made during the design and construction phases of the redecking project. A better understanding of the impact of replacing the original concrete deck with a grid deck, along with specific direction to the welders on how to terminate the shim plate fillet weld could have prevented this detail from occurring.