The load ratings of through truss railroad bridges are often controlled by the low ratings of the floorbeam hangers. These low ratings are solely the result of the provisions of the AREMA Manual Chapter 15, in which not only are hangers to be rated for the axial load of the floorbeam, and the bending caused by the floorbeam deflection, but allowable stresses in tension are reduced to 14 ksi when rivets are used in hanger end connections. After some research into the background of the required stress reduction, it was decided that the AREMA Manual would permit an increase in allowable rating stresses if the rivets in the hanger connection were to be removed and replaced with high strength bolts.

Accordingly, the Union Pacific Railroad embarked on a so-called “Truss Hanger Rivet Replacement Program” in the summer of 1998, to replace the rivets with HS bolts on many of their through truss structures. That program continues today, and has been very successful in terms of ease of change-out, and the moderate cost of the benefit achieved.

1 Manager Structural Projects, Union Pacific Railroad, 1416 Dodge Street, Omaha Nebraska 68179

2 Principal, Modjeski and Masters, Inc., 1055 St. Charles Avenue, Suite 400, New Orleans, Louisiana 70130
INTRODUCTION

In recent years, the Union Pacific Railroad has developed a need to pass heavy loads across many of their through truss bridges on a regular day-to-day basis, but many of these trusses have a relatively low rating. The overall truss load ratings are often controlled by the low ratings of the floorbeam hangers.

It is apparent that the low ratings of the floorbeam hangers are sometimes solely a result of the provisions of the AREMA Manual Chapter 15, in which not only are hangers to be designed (and rated) for the axial load of the floorbeam and the bending caused by floorbeam deflection, but allowable stresses in tension are reduced to 14 ksi (from 19.8 ksi) when rivets are used in hanger end connections. Some have wondered whether these manual provisions were justified, and whether some relief could be found.

BACKGROUND RESEARCH

Accordingly, an effort was undertaken by Modjeski and Masters on behalf of the Union Pacific Railroad to research the background of the manual provisions to determine what effects were being recognized and guarded against by the Manual provisions.

1) **Inclusion of Floorbeam Bending in Hanger Load**

This provision first shows in the 1925 AREA Specifications for Steel Railway Bridges under the provisions for Combined Stresses, Article 46. The sentence is: “members subject to both axial and bending stresses (including bending due to floorbeam deflections) shall be so proportioned that...”.

While the 1935 AREA Manual had dropped the parenthetical phrase in the above quote, it was put back in the 1957 AREA Manual. But sometime between then and now, the specific mention of “bending due to floorbeam deflection” was removed from the Manual. However, there is no question that such bending does exist and that it should be included in the loads applied to floorbeam hangers, both for design and for rating. Thus, no relief can be found on the basis of omitting floorbeam bending effects.
2) **Reduction of Allowable Stress for Riveted Hanger End Connection**

The reduction to an allowable stress of 14 ksi for hangers with riveted end connections was added to the Manual in 1961 or 1962, as the result of an extensive research and testing effort which had begun in 1947. That effort was under the auspices of Subcommittee 4 of the AREA Committee 15, which Subcommittee was headed initially by C. H. Sandberg, and which had among its members Nathan Newmark and Frank Masters. The research was conducted at Purdue University by Professor L. T. Wyly and others, and it is documented in AREA Bulletins published in Volumes 50, 51, 53, 54, 56, 57, 61, 62, and 63 between 1949 and 1963.

The research considered a total of 170 hanger failures on 83 spans of 50 bridges. Ninety-one failures were in riveted truss spans, with 82 in thru trusses, and 9 in deck trusses. Of the 82 in thru-trusses, 79 failed in the net section through the line of the lowest rivets connecting the members to the top chord gussets, while only 3 failed at the point of greatest computed bending stress just above the floorbeam connection.

The Subcommittee believed this pattern of failures was essentially a fatigue problem, in which the lower rivets of the top hanger connections had slipped slightly and were in bearing on the sides of the hole, thus adding a further stress raiser to the inherent stress concentration due to the hole itself. After further testing of full-size joints, they concluded that replacement of the lower 2 lines of rivets in the upper hanger-to-gusset connection with high-strength bolts would generally protect existing structures against fatigue failures of this sort.

The Subcommittee also found that floorbeam hangers made up of two units (say two channels) connected by widely separated tie plates or batten plates, did not perform satisfactorily. Because of shear lag effects, the inside unit carried significantly more of the load, and this caused severe racking effects on the hanger. Conversely, the Subcommittee found that continuous and unbroken lacing appeared to satisfactorily tie the main components of the hanger together into a unit.

In pin-connected trusses, there had been 79 failures reported, of which 54 were through the re-entrant cuts at the copes of the flanges at the upper connection. The Committee found the re-entrant cuts caused stress concentration factors of 5 or more and proposed a procedure for mitigating the stress concentration on existing bridges by burning and grinding out the re-entrant cut.

In 1960, the Subcommittee published recommended revisions to the AREA Manual, Chapter 15, to cover the following revisions regarding floorbeam hangers:

- Reducing allowable tension in floorbeam hangers with riveted end connections to 14 ksi while allowing 18 ksi for bolted end connections in 33 ksi yield material.
- Prohibiting coping or notching of the main material.
- Prohibiting forked ends.
- Requiring solid webs or continuous lacing.
- Controlling drifting so as not to enlarge holes or distort metal.
These provisions were adopted in 1961, and they remain in the Manual in the same or slightly modified form to this day. The 14 ksi allowable for riveted end connections remains unchanged, but the allowable for bolted end connections has been increased to 19.8 ksi for A36 material.

In 1962, the Subcommittee, by then chaired by E. T. Franzen, and with such names as L. S. Beedle, E. S. Birkenwald, G. K. Gillan, J. M. Hayes, and W. H. Munse added to its roster, made a recommendation for a Manual change to Part 7 of Chapter 15 dealing with Methods of Strengthening Existing Trusses. The change proposed language as follows:

"The use of high strength bolts at the top connections of the floorbeam hangers to replace all rivets should also be considered to improve the load transfer to the gusset plates."

This language remains in the Manual to this day in slightly modified form in Article 7.2.4.1f).

PROPOSED REMEDY FOR LOW HANGER RATINGS

As a result of this review of past research, it was decided that the general remedy for the relatively low hanger ratings lay in the replacement of rivets with high-strength bolts in the upper hanger connection.

With the connection made with high strength bolts, the increase in rating of the hanger, if it is of 33 ksi yield point steel, should be at least 29%. \( \frac{18,150}{14,000} = 1.296 \) This would mean that a current rating of E49 would increase to at least E63 (which happens to be enough to carry 315 coal cars). If the hanger is of 30 ksi yield point steel, the increase in rating should be at least 18%. In fact, if the dead load is figured in at say 1.6 ksi, the increase in rating for 33 ksi yield material would be \( \frac{18,150 - 1,600}{14,000 - 1,600} \), or about 1.335, and for 30 ksi material would be \( \frac{16,500 - 1,600}{14,000 - 1,600} \), or about 1.20.

Thus, if all other members of a truss had previously rated OK for the loads to be passed, but only the hangers were deficient, then the controlling rating of the entire truss might be significantly increased by the simple and relatively inexpensive replacement of rivets with HS bolts in the upper hanger end connections. This, of course, pre-supposes that the body of the hanger is OK, and there are no other defects that would reduce the ratings.

If the 20% rating increase achievable by this procedure for unknown strength material, assumed to be 30 ksi material, were not enough, then a coupon can be taken and the actual yield point determined by a load test. One test of one standard coupon cut from the outstanding channel leg at the low end of the outside lower connection on one of the mid-panel hangers would be sufficient. The test might cost $300 to $500, and probably should be a routine part of the procedure.
TRUSS HANGER CONNECTIONS
RIVET REPLACEMENT WITH A-325 TYPE 3 BOLTS

INSPECT HANGER AND CONNECTION PLATES
VISIBLE CRACKS FOUND?

Y N

UNDER TRAFFIC
WORK WINDOW

REPLACE ONE RIVET WITH ONE BOLT AT A TIME
REPLACE NO MORE THAN ONE VERTICAL ROW OF RIVETS ON ONE SIDE AT A TIME

RIVET REMOVAL
1. MECHANICALLY CHIP OFF HEAD
2. DRIVE OUT SHANK WITH PUNCH
3. MEASURE EXISTING HOLE SIZE

REAM ALL CONNECTION HOLES
USE SHARP, FLUTED, TAPERED REAMER
EXISTING: 13/16 ø REAM TO 15/16 ø (FOR 7/8 ø BOLT)
15/16 ø REAM TO 1 1/16 ø (FOR 1 ø BOLT)

CHECK REAMED HOLE FOR CRACKS AND SCORING
(USE DYE PENETRANT)
CRACK OR SCORING FOUND?

Y N

CRACK PRESENT
SCORED
INSTALL A-325 BOLT
HARDENED WASHER UNDER HEAD AND NUT
(BEVELED WASHER ON SLOPED FACE)

TIGHTEN BOLT
TURN-OF-NUT METHOD
SNUG TIGHT PLUS 1/3 TURN

BOLT TORQUE CHECK
USE SKIDMORE-WILHELM CAL. DEVICE TO DETERMINE JOB TORQUE
7/8 ø BOLTS = 39,000 # TENSION
1 ø BOLTS = 51,000 # TENSION
CHECK WITH CALIBRATED TORQUE WRENCH

RECORD HOLE LOCATION, CRACK LENGTH, ORIENTATION, HANGER OR CONN PL., JT NUMBER
RECORD HOLE AND SCORE LOCATION, DEPTH, HANGER OR CONN PL., JT NUMBER

CALL FOR INSTRUCTIONS
SUBMIT RECORD TO RAILROAD
The procedure would include reaming the rivet holes to remove micro-cracked metal generally caused by hole punching, and it would seem prudent that so long as this were to be done, the replacement H.S. bolt ought to be one size greater diameter. This would allow for removal of all of the presumably micro-cracked metal in the old hole, and the larger bolt would generally strengthen the connection. After reaming, the holes would be dye penetrant tested to see that no cracks remain.

ADOPTED TRUSS HANGER RIVET REPLACEMENT PROGRAM

The Union Pacific Railroad adopted the recommendation of their consultant, and in the summer of 1998, initiated the so-called “Truss Hanger Rivet Replacement Program”.

A Flow Diagram of the rivet-to-bolt replacement procedure is presented here.

The procedure includes an initial inspection for visible cracks (in which case, special procedures may be required), and restrictions on rivet removal, depending on whether the replacement must be done under traffic, or whether a work window of track outage time can be assigned. The rivets are removed by mechanical means only, with no torching or lancing methods permitted. After rivet removal, the rivet hole is measured for size, and reamed to the next larger bolt size, i.e. a 15/16" diameter hole for a 7/8" rivet would be reamed to 1-1/16" diameter for a 1" bolt.

Many rivet holes in older bridges were made by punching, and the process of punching a hole causes deformation of the steel plate around the hole, and possible micro-cracking of the hole wall surface. Reaming to the next larger hole size removes the possibly micro-cracked material, and this, combined with the compression field caused by the clamping effect of the HS bolt, greatly reduces the potential for fatigue crack development. Before inserting the replacement bolt, the reamed hole was dye-penetrant tested to check for hole wall cracks. In order to achieve good clamping, and to overcome possible surface imperfections in the member plates, hardened washers were required under both the head and the nut of the new HS bolts.

RESULTS OBTAINED

Phase One of this program was to replace rivets with H.S. bolts at 31 bridges, consisting of 52 truss spans with 274 floorbeam hangers. The work was done by contract forces consisting of two crews of six to seven men each. One crew worked in the northeastern portion of the railroad in the states of Nebraska, Iowa, and Illinois, while a second crew began in the southeast (Texas and Louisiana), and progressed north through Oklahoma and Missouri. The work began in May 1998, and was completed in six months. The project was completed ahead of schedule and well under budget. Overall, the project went very smoothly. Cracks were found in the bottom rivet row of four hangers, each at different bridge locations. In addition, notable corrosion was found at the interface between the hanger members and connection plates at one other bridge. In each case, steel plate was added to the connection to structurally bypass the area of the defect.
The project resulted in an average cost of $3,900 per hanger, or $20,400 per span. On average, each crew completed work on 1.2 hangers per day, or 1.2 spans per week. In comparison, recent hanger member replacement projects have resulted in an average cost of $35,000 per hanger, and have required one week to replace one or possibly two hangers. In addition, considerable falsework, staging, and track-time is required to replace a hanger and is not necessary for the rivet replacement work. The rivet replacement work was done with a one-man “spider” basket that was suspended from a beam secured to the top chords of the truss span. The men could tie the basket off on the outside of the truss to clear trains with minimal disruption to traffic or to work.

Had this program been completed by the hanger member replacement method, the resulting cost would have been roughly $9.6 million instead of $1.1 million by the rivet replacement method.

It should be pointed out that the rivet replacement logic is not necessarily a long-term solution for the span, as a portion of the hanger’s useful life is still consumed due to fatigue. As the useful life of a hanger is fully consumed, assuming the remaining members are in adequate condition, the hanger member should be replaced to further extend the life of the span. For those hangers that have sufficient remaining life and will eventually be replaced to extend the life of the span, the rivet replacement is not a wasted effort. First, as previously discussed, an immediate rating increase can be gained for much less money and effort than replacing the member, and the remaining useful life of the hanger can be utilized while running heavier traffic. Second, rivet removal is a preparatory step in replacing a hanger. If in the future a hanger needs to be replaced, the rivets will have already been removed at the upper connection.

Phase One of the hanger rivet replacement program had a very positive impact on heavy load capabilities of the Union Pacific system. Fourteen of the thirty-one bridges worked on contributed to increasing the allowable gross weight of over 1,000 mainline track miles. A second phase of this program is underway in 1999 that will use company forces to work on 10 bridges, consisting of 19 spans with 88 floorbeam hangers. The Phase Two work will contribute to increasing the allowable gross weight of approximately 650 miles of track. A third phase of this work is anticipated sometime in the near future, once bridge rating data is compiled for the former Southern Pacific system.

CONCLUSIONS

The Union Pacific Truss Hanger Rivet Replacement Program has become an unqualified success, and a relatively inexpensive method of increasing the load rating of bridges with riveted truss hangers. This program has made a positive impact on the heavy load carrying capabilities of a number of lines, and has done so with minimal traffic interruptions.