Heavy Duty Riveted Bridge Deck
Fatigue Testing under AASHTO H20 Loading

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Laboratory Fatigue Testing Confirms Long Service Life Expected
Introduction

This paper presents results of on-going fatigue testing conducted at the University of Akron Civil Engineering Labs from 2011 thru 2014. This paper is a continuation of a previously presented paper during the 2010 HMS symposium. It presents results from fatigue cycle testing of Heavy Duty Riveted Bridge Deck Grating under AASHTO H20 loading with a 30% impact factor, while highlighting the significance of the attachment methods and how they are related to fatigue. Fatigue test results are presented for full-scale decks cycled to over 2 million cycles. Deck samples were also tested to higher stresses to establish the fatigue detail of the riveted design. Loading with an actual truck axle and heavy duty tires is presented.

Background and History of Steel Bridge Decks

As discussed in the previous paper presented during the HMS 2010 symposium, history shows the durability of the heavy duty riveted bridge deck. Its proven long life has been observed in many movable bridges around the nation. Some examples include the Veterans Memorial Bridge in Bay City, Michigan (shown directly below), the historic LaSalle Street Bridge in Chicago, IL, and the Robert Moses Causeway Southbound Bridge at Captree State Park in Long Island, New York. Heavy Duty Riveted Grating is a proven open steel bridge deck solution.

Veteran’s Memorial Bridge Bay City, Michigan Riveted Grating installed in 1994. Like new after over 15 years in service.
The LaSalle St Bridge in Chicago, Illinois with Riveted Bridge Deck installed in 1971 is still in good condition after over 37 years in service.

The Robert Moses Parkway Bridge in Long Island, New York with riveted steel deck installed in 1951 was still in service after 56 years.

**Laboratory Testing of Riveted Deck**

During the time period between 2011 and 2014, the University of Akron continued the research and testing program sponsored by Ohio Gratings Inc. that started in 2009. One purpose of the project was to successfully reach 2 million cycles under the AASHTO H20 wheel load with 30% impact factor, while using a bolted method to secure the deck to the supports. In addition, the project investigated the fatigue resistance of the heavy duty riveted bridge deck in order to establish the fatigue behavior, especially in the negative bending moment areas over stringer supports. It was assumed that one reason the riveted decks have performed so well in the field was due to the fact that there are no welds at the top surface where the negative bending puts the top surface in tension. The fact that the rivets are centered below the top surface in a lower stress area is believed to be a major reason for the outstanding performance in the field.
Fatigue Tests:

The fatigue test data on full size deck panels presented here is based on the same Ohio Gratings type 37R5 Lite 5” x ¼” serrated grating with bearing bars of type ASTM A-36 steel that was introduced in the previous paper presented at the HMS 2010 symposium. The stringer spacing was increased from 49” on center to 50” on center. Another difference in relation to the previous test is that this time a bolted attachment method is used. Previously, the deck was attached directly to the supports by using the recommended by AASHTO fillet welding (1-1/2” long, 3/16” staggered) at every support / bearing bar intersection.

In an attempt to perform the testing with loads as close as possible to actual loading conditions, the lab attempted to load the bridge deck grating with an actual truck axle adapted to laboratory equipment for loading. Typical truck tires available are rated for 6,500 lbs. /each thus 13,000 lbs. per set. The axle was equipped with tires of the highest rated tire available which was 9,900 lbs. / tire. This would allow a maximum axle load of 39,600 lbs. which is less than the 41,600 lbs. per H20 with 30% impact.

The idea of continuing the fatigue testing with this load configuration was short lived. As shown in the photos below, once the axle is loaded to 41,600 lbs., the tires are compressed about 2-1/2 inches with sidewalls bulging significantly.  

Unloaded

Loaded to 41,600 lbs.
The excessive compression made the idea of performing the fatigue test with an actual axle and tires impractical. This does point out the fact that the axle load levels used in this testing far exceed those from actual trucks in service.

A spreader beam was then utilized to simulate the axle. Two 10” x 20” steel plates were welded under the spreader beam. These plates were used to provide the AASHTO tire patch for an H20 loading. The plates were placed 72” on center to simulate a design truck axle. High durometer rubber pads were placed under the plates in order for the load to act like a “tire”. Loading was arranged to produce the maximum negative moment over the center support, and was representative of 16 kip wheel load plus 30% impact. A small positive loading ratio, R, was maintained: axle loads varied from 1000 lbs. to 42,600 lbs., producing an effective load range of 41,600 lbs. and thus producing the 20,800 lbs. wheel loads. With the maximum negative moment occurring over the support, the details of interest were the rivet connections between the main bearing bar and adjacent reticuline bars, as well as the attachment of the deck to the supporting structure. In this case, the supporting structure was represented by a series of W 8 x 25 I-beams intended to act like stringers. Three such supports were spaced at 4’ 2” (50 inches) on center.

As previously mentioned, the attachment to the supports was a main focus for this testing. During the previous testing, the welded connection of the deck directly to the supports was shown to be a limiting factor for the fatigue life of the deck. Therefore, for this testing C-shaped steel attachment brackets were shop welded in the grates. The bracket thickness is 3/8”. Each bracket has pre-drilled holes for up to four bolts for attachment to the supports. The brackets are welded in between the 5” x 1/4” bearing bars, at the location of the supports.
Bracket attachment to the grates:

Tensile residual stress fields exist adjacent to a vast majority of weldments, due to the uneven heating and cooling that occurs during the joining process. Often these local residual stresses may be on the order of the yield point of the base metal. Therefore, and as confirmed on the previous test results, welding is not desired at a higher stress area. For this reason, the C-shaped brackets were attached to the bearing bars by applying 1-1/2” long 1/4” fillet welds at each corner of the bracket. The welds were therefore closer to the neutral axis of the bearing bars, and thus subjected to lower stresses during load cycling.

Two individual panels each having a 11’ 5” span x 3’ 0-1/8” width were tested. The panels were side spliced at the panel separation with 5/8” dia bolts and spacers at 15” on center. Initially, the “wheel” loads were placed at the center of the panel width, on one of two panels. The loads were located in order for their centers to be placed 3’ from the center of the middle support. A total of 2 million loading cycles were applied with a frequency of 1 Hz. The maximum recorded strains at the negative bending moment region at the center support were about 550 micro strains measured by a strain gage ¼” from the top of the main bar, translating to approximately 16,000 PSI of bending stress. After the completion of the 2 million cycles, no evidence of any fatigue cracks was observed in the panels. The loads were then moved to the other panel and located adjacent to the panel’s edge, at the side splice separation. The same level of cyclic loading was repeated for 2 million cycles with no evidence of any fatigue cracks.

Following the successful completion of the above two tests, which used the AASHTO H20 16 kip wheel load with a 30% impact factor, the same exact two test configurations were repeated using the same sample panels, but this time having an impact factor of approximately 61%. This overloaded condition translates to an axle load of 51,600 lbs. or wheels loads of 25,800 lbs. Under this excess load, the deck samples were cycled for an additional 630,000 cycles with no sign of fatigue cracks.

Fatigue tests were conducted on a number of different riveted grating types and configurations, some with smaller samples in a setup for higher frequency cycle loading. The objective was to determine the appropriate fatigue design classification for the riveted connection detail. In cases where the grating spans across three or more stringers, negative bending results over an interior support. Repeated loading subjects the riveted connections over the support to cyclic tension. Figure 1 summarizes the results of the fatigue tests. It is clear that specimens evaluated in the laboratory had fatigue strengths in excess of Category C with the vast majority of data points occurring between Categories A and C.
Conclusion:
The laboratory testing confirms that heavy duty riveted bridge deck is very fatigue resistant under heavy truck loading. This type grating can be relied upon to provide decades of service in bridge deck applications.