

INSPECTION, ASSESSMENT, AND MONITORING OF RAILROAD ARCH BRIDGES IN SOUTHWESTERN PENNSYLVANIA

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Abstract. *As a result of rail relocation in connection with construction of the Conemaugh Dam and Reservoir in the 1950's, the US Army Corps of Engineers manages a series of five multi-span masonry arch bridges originally built in 1907 for railroad use. At present, the bridges are subject to very light loading from recreational users and occasional maintenance traffic. In their current state, the bridges are partially inundated, and show distinct patterns of damage including longitudinal cracking in the arch barrel, vertical cracking above the piers, bulging of the spandrel walls, and loss of mortar between masonry units. Some previous monitoring and inspection results are available, and a recent thorough inspection and assessment has determined that the most serious longitudinal cracking most probably resulted from previous rail traffic loading, and that this problem is controlled by retrofit transverse ties present in most of the bridges. Further monitoring and maintenance recommendations for the bridges are discussed.*

1 INTRODUCTION

Five sandstone masonry arch bridges spanning the bends of the Conemaugh River were constructed in 1907 by the Western Pennsylvania Division of the Pennsylvania Railroad Company. For purpose of reference, the bridges will be numbered from 1 to 5 based on their geographical location, west to east. The bridges were part of the double-tracked main line of the Conemaugh Division of the Pennsylvania Railroad. In 1953, the construction of a dam changed river water levels and necessitated the relocation of the rail line and the bridges were taken out of rail service. From 1953 to present day, the bridges have been maintained by the United States Army Corps of Engineers (USACE).

Bridge details are given in Table 1.

	Abutment and Pier	No. of Spans	Overall length	Deck type	Deck width
Bridge 1	Spread footing	6	592 ft. (170.7 m)	Asphalt	34 ft. (10.4 m)
Bridge 2	Spread footing	5	440 ft. (170.7 m)	Gravel	34 ft. (10.4 m)
Bridge 3	Spread footing	6	530 ft. (170.7 m)	Gravel	34 ft. (10.4 m)
Bridge 4	Spread footing	7	620 ft. (170.7 m)	Gravel	34 ft. (10.4 m)
Bridge 5	Spread footing	7	620 ft. (170.7 m)	Gravel	34 ft. (10.4 m)

Table 1: Bridge Details

An example of one of the bridges is shown in figure 1.



Figure 1: Bridge 1

A study was commissioned by the USACE in order to evaluate the overall condition of the bridges located in the area of the Conemaugh Dam. Details of the procedures and results corresponding to an inspection performed in 2003 will be provided in the body of the paper. An overview of the recommendations for further study and maintenance of the bridges conclude the findings of this paper.

2 PROCEDURE

2.1 Photo Record and Visual Inspection

Digital photographs were taken of the bridges to give a record of the bridges and their current condition in 2003. This visual inspection was performed from deck, ground, and boat level. An aerial lift was used on bridge 1 to obtain close up photographs of crack gauges installed beneath two of the spans.

2.2 Spandrel wall survey

Survey equipment consisting of a total station and a plumb bob were used to study the alignment of the spandrel wall. A plumb bob was held from deck of the bridge over a pier on its upstream and downstream face. The height of the bridge deck and the distance of the plumb bob from the bottom of the spandrel wall were measured in order to calculate a tilt angle of the wall.

Wall tilt measurements by plumb bob readings were confirmed by sighting the total station along the spandrel wall edge to verify the presence of wall tilt.

2.3 Crack Gauge Readings

6 gauges were installed on the bridges in 1973 to monitor crack growth in the arch barrels. The gauges were unreadable by binoculars due to the small gauge size and mineral deposits from water draining through the cracks. An aerial lift was used to clean and read the gauges but a spotting scope or high powered lens might be needed for future readings.



Figure 2: Crack gauge installed on bridge 1

2.4 Tie rod strain gauge experiment

The purpose of the strain gauge experiment was to determine the presence of residual stresses in the tie-rod. Three strain gauges were applied directly behind the washer and nut of the steel reinforcement system. The strain gauges are applied in a rosette form (circular placement at angles of 0° , 90° , 135°) and a hole is drilled in their center.



Figure 3: Strain gauges applied to tie-rod

As the hole is drilled, stress is relieved at the edge and has to be redistributed in the surrounding area of steel. As the stresses in the bar change, the gauges are strained and results can be recorded to identify levels of residual stress within the bar.

3 RESULTS

3.1 Crack Summary

Three main patterns were seen while inspecting the arch barrels of the bridges. The first and most apparent is that on a majority of the spans, cracks run at a distance approximately one block length inwards from the edge of the wall. This corresponds to the approximate thickness of the spandrel wall of the bridges. A probable cause for cracks in these locations is a separation of the spandrel wall from the arch barrel. Examples are provided in figures 4 and 5 to show this common cracking pattern.



Figure 4: Bridge 3



Figure 5: Bridge 5

The second crack pattern observed occurred at the third points of the arch barrel width. These cracks can be attributed to the location of rail lines on the deck. The bridges were in use as a double line and rails would have been placed approximately $\frac{1}{3}$ of the way across. The weight of the trains would result in a load concentration in the arch barrel at its third point.

The third crack pattern occurs at the midpoint of the arch barrel where transverse bending moments are generally maximum. This pattern is shown in figure 6. Cracking in the middle of the arch barrel is common in masonry bridges during their life span and is shown in figure 7.



Figure 6: Bridge 1, span 2



Figure 7: Bridge 5, span 4

The implications of these crack patterns will be discussed in the report's conclusions.

3.2 Wall Alignment

Plumb bob measurements offered a rough estimation that the spandrel walls were tilting outward at angles of 1.5° and 3° on the upstream and downstream sides, respectively. The

outward tilt of the spandrel walls were confirmed by using a total station to sight along the vertical edges.

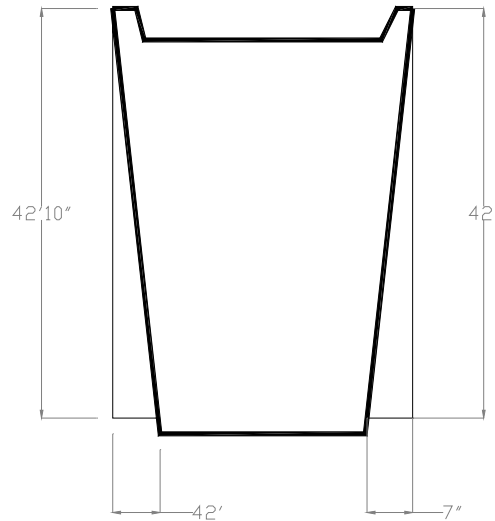


Figure 8: Spandrel wall tilt

3.3 Crack Gauge Readings

Six crack gauges are located on bridge 1. Only 3 of the 6 were accessible by an aerial lift. Readings were obtained from gauges located on spans 1 and 2. Of the inspected gauges, 2 had not moved from on center and the third was judged to be off by approximately 1mm.

3.4 Tie rod strain gauge experiment

Table 2 shows the details of the experimental results in microstrain:

Depth (mm)	Location		
	transverse	longitudinal°	135°
0	+2	+3	+4
1	-105	-1842	0
2	+18	-1399	0
5	+41	-1373	0
6	+45	-1303	0
7.5	+53	-1285	0

Table 2: Strain gauge experiment results

Damage sustained by the 135° gauge during the experiment caused it to give a reading of 0 from the second reading on. Due to this event, actual stress values cannot be calculated. However, the data collected were sufficient to prove the presence of residual stresses in the rod.

Since there are residual stresses in the rod, it is evident that tilt in the spandrel walls is creating a transverse load that is pushing against the steel tie-rod reinforcing system. The strain gauge test validates surveying results that showed that the spandrel walls are leaning out.

4 CONCLUSIONS

Cracks in the arch barrel most likely formed as a result of railroad loading. A majority of these cracks have not grown since the bridges have been removed from rail service. Due to these longitudinal cracks, water drainage carries fill with it and causes the formation of sinkholes on the gravel bridge decks.

Spandrel walls are leaning out as a result of transverse pressures. This can explain the presence of cracking at the first mortar joint in from the arch barrel edge. The spandrel walls are separating from the arch barrel, causing cracks to form.

Tie rods are under constant stress and are most likely preventing spandrel walls from pushing and tilting out.

5 RECOMMENDATIONS

A load-rating study of the bridges is recommended in order to determine whether future vehicular traffic restrictions should be put into place.

The implementation of a drainage scheme for all bridges is necessary to prevent further deterioration.

Sink holes in the road bed of any of the bridges should be refilled and repaired immediately to account for fill loss through arch barrel cracks.