The Making of "Iron Bridge" Road in Pike County, Indiana:

William T. Washer, the Smith Bridge Company, and Bridge #150

by

James L. Cooper

-unless otherwise noted, photos courtesy of http://www.HistoricBridges.org/

With special thanks for the assistance of James A. Barker

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As was their practice, the Pike County Board of Commissioners authorized two of its members – Patrick McNabb and Herman Henke – to build a bridge across the Patoka River on the Surphur Springs and Augusta Road in June 1875. Within a month, the board adopted plans and specifications drawn up by A. H. Miller for "the Iron Arch Bridge No. 1, Smith Bridge Company, Toledo, Ohio."[1]

On the 5th of September, the board received construction proposals for the bridge "at or near SW of NE quarter of Section 2, Township 2 South, Range 7 West." The commissioners promptly awarded a construction contract to W. T. Washer of Troy, Perry County, for the stonework at $6.75 per perch[2] "upon which is to be placed Smith Patent Wrought Iron Open Arched Bridge at $22 per [lineal] foot."[3] The County Auditor then transcribed detailed specifications for the substructure and superstructure along with the Articles of Agreement with Washer into the "Commissioners Record."[4]

The specifications for the bridge show quite a bit of collaboration between the parties. "The rock to be used in the building and construction of the work aforesaid [i.e., abutments and wing-walls] shall not be less than twelve inches in thickness, to be well jointed, and the face of the abutments and wing-walls are to be dressed the same as rocks are dressed on the Postlelhwait Mill Bridge on Patoka River in Dubois County". Washer is generally credited with constructing the referenced Postlewaite Covered Bridge in 1872.[5] Furthermore, the commissioners acknowledged in the Articles of Agreement that the specifications for the superstructure were "submitted by the said W. T. Washer."[6]

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[1] In September, Miller was paid $15 for his specifications for the "Patoka River Bridge." Pike County, "Commissioners Record," J: 252, 255, 277.

[2] A "perch" is 1.5 feet wide by one foot high by 16.5 feet long, equaling 24.75 cubic feet.

[3] Robert Smith only had one iron bridge patent to his name: #339,492 was granted in 1886, more than a decade after Pike #150 was built, and dealt with improved ways of forming the "eyes" at the ends of eye-bars. Smith did not receive a patent, at least in his own name, dealing with any sort of arch or bowstring truss bridge. There was, furthermore, no reference to a patent in the Smith Bridge Company specifications for the Patoka River bowstring.

[4] Pike County, "Commissioners Record," J: 279, 281-286. Copies of the specifications and Agreement can be found Appendix A..

[5] George Gould, *Indiana Covered Bridges Thru the Years* (Indianapolis, 1977), 31-32, 50; Wayne M. Weber, *Covered Bridges in Indiana* (Midland, Michigan, 1977), 63.

[6] Pike County, "Commissioners Record," J: 285.

Construction of the iron bridge was to be completed by January 1876. In December 1875, Washer received a partial payment of $1,000 for work on the Patoka River Bridge. In March 1876, he received another partial payment of $120 plus $2,943.50 as the "balance [of] compensation for building an Iron Bridge across Patoka River per contract."[7]

The bowstring soon became a notable Marion township monument. In June 1877, for example, when residents petitioned for a change in the road carrying the bridge, they had already informally renamed the Sulphur Springs and Augusta road as "the Iron Bridge and Augusta road."[8] The commissioners also kept a close watch on the bowstring. In August 1889, they ordered the Marion township trustee to give notice to the parties who built a dam across the Patoka River "at the iron bridge in said township" to remove same or suit would be brought by the county "so that the dam will not damage said bridge or its abutments."[9]

The significance of the Patoka River iron bridge extends well beyond nineteenth-century Pike County, Indiana. The county's consulting engineers were correct to consider this "a unique structure of historical importance."[10] The bridge was also determined “SELECT” in the statewide historic bridge inventory.[11]

This is the only surviving example of the Smith Bridge Company’s “Open-Arch” Bridge design in Indiana and possibly in the United States. It was, furthermore, built by William T. Washer, “a celebrated contractor and bridge-builder” across southwest Indiana and north central to northwest Kentucky in the last half of the nineteenth century.[12] The Patoka River Bridge reveals ways in which both its designer and its builder each shifted efficiently and collaboratively between timber and iron as bridge materials and with production and erection increasingly mechanized and specialized concentrating on bridges

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[7] Pike County, “Commissioners Record,” J: 347, 377, 385.

[8] The petitioners were quite specific about the location of the road: beginning in S2/T2S/R7W and heading south into S11 and then west to Patoka township. Pike County, “Commissioners Record,” K: 48, 56-57.

[9] Pike County, “Commissioners Record,” O: 418.

[10] United Consulting Engineers, Inc., *Bridge Reinspection Report for Pike County, Indiana* (Indianapolis, 1980).

[11] Mead & Hunt, *Indiana Historic Bridge Inventory: List of Select and Non-Select Bridges* (December 2010), 4: 3-34.

[12] Interstate Publishing Co., *History of Daviess County, Kentucky* (Chicago, 1883), 435-436.

Robert W. Smith and the Smith Bridge Company

Bridge-building in the Midwest in the second half of the nineteenth century incorporated design, fabrication, and construction-erection in a very competitive process. From the start, Smith relied on efficiency in design and production to generate least-expensive bids.[13] As a young carpenter, he and his brother set up a woodworking machine shop and lumberyard in Tippecanoe City, Ohio, and reportedly invented a system of self-supporting roof trusses for barns. When he focused on bridge work, Smith designed and secured a patent (1867) for a double-intersection Warren truss in timber and two years later (1869) for roofing and lateral bracing systems.[14] Smith's timber truss design was not frozen in his patents. Indeed, he continued to develop his design into what some analysts have categorized as four types of Smith trusses.[15]

Robert W. Smith
-photo courtesy of Miriam Wood

First organized as the R. W. Smith & Company partnership, the business moved in 1867 to Toledo, Ohio, where better rail transportation was available both for supplies of timber and iron and for shipment of pre-fabricated superstructures. In Toledo, it was formally incorporated as the Smith Bridge Company.[16] While many bridge designers and fabricators concentrated exclusively on the more traditional timber-truss patterns, others opened for business as exclusively iron designers and fabricators. The Smith Bridge

[13] Mark Brown & Matthew Reckard, "Cataract Bridge: Historical Background" (J. A. Barker Engineering, Inc., 2001, rev 2002); Matthew Reckard, P.E., "Smith Trusses: Bringing Covered Bridges into the Industrial Age" (J. A. Barker Engineering, Inc.).

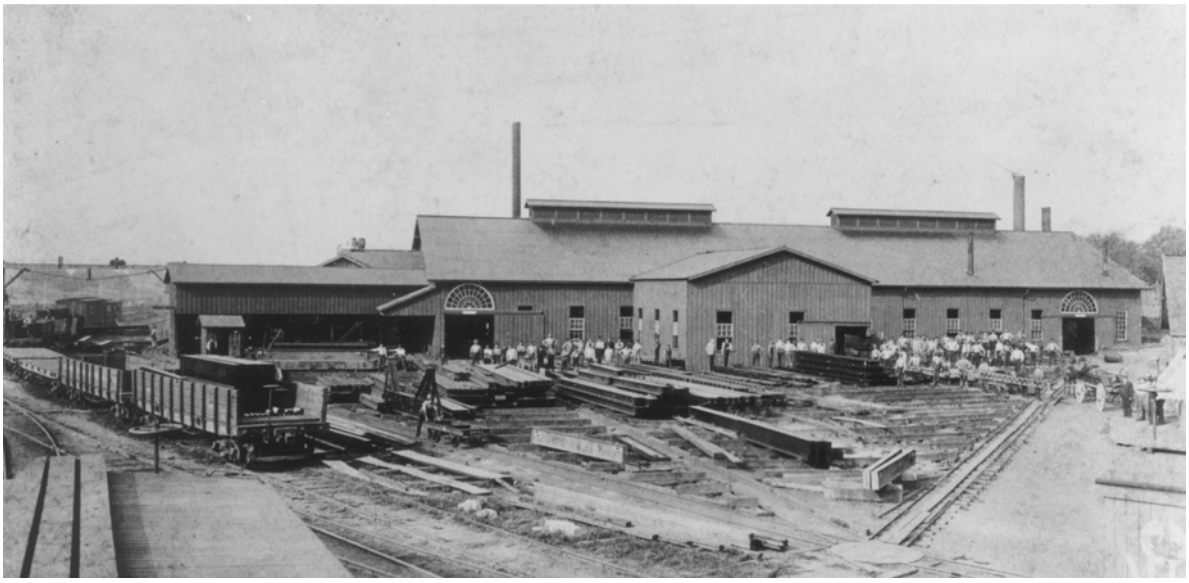
[14] Robert W. Smith, "Improvement in Bridges," U.S. Patent No. 66,900 (July 16, 1867); "Improved Bridge," U.S. Patent No. 97,714 (December 7, 1869).

[15] Ray E. Wilson, "The Smith Patented Truss," *Indiana Covered Bridge Society Newsletter*, April 1966: 1, 3, 4; Ray E. Wilson, "The Story of the Smith Truss," *Covered Bridge Topics* (National Society for the Preservation of Covered Bridges), April 1967: 2, 3, 5; Ray E. Wilson, "More on Smith Truss Bridges," *Indiana Covered Bridge Society Newsletter,* January 1972: 2.

[16] Robert W. Smith sold out to a group of investors in 1890 who reorganized the operation into the Toledo Bridge Company. Toledo Bridge sold out in 1901 to J. P. Morgan and were incorporated into the American Bridge Company.

Company of Toledo and the Massillon Bridge Company of Massillon, Ohio, on the other hand, worked in both timber and iron. Smith started in iron fabrication by 1870.[17]

Much of Robert Smith's success in both timber and iron was due to his inventiveness in industrial machinery, including "a gaining-machine, which does the work of 15 men", "a process for making a steel eye-bar", a "rotary saw, for making the joints of bridge-chords", "and a multiple punch, by which six pieces of iron can be punched at one operation."[18]



Smith Bridge Company factory, Toledo, Ohio.
-photo courtesy of Miriam Wood

The Pike County Patoka River Bridge provides a relatively rare opportunity to detail some of the ways in which Robert W. Smith and his associates explored their way from efficient timber to efficient iron design and fabrication.

Smith's Wrought-Iron, Open-Arch Bridge, No. 1

The Patoka River bowstring was to have a clear span of 90-feet and be 93-feet "full" with a 14-foot roadway built "in accordance with accompanying plans and following specifications":

[17] The author's extensive but nonetheless incomplete research notes shows the Smith Bridge Company engaged in 26 bridge contracts in Indiana, of which 15 were for timber-trusses and 11 for iron.

[18] Clark Waggoner, ed., *History of Toledo and Lucas County, Ohio (*Munsell & Co., New York, 1888), 786-787.

Arched Top Chord

The chords were to be constructed "in straight sections of panel length, and when joined together, the ends of the sections will form a true segment of a circle." Each section was to consist of two pieces of 7-inch channel bar "placed edgewise" and 10-inches apart with flanges outward. By creating an arch from short, straight sections of rolled iron rather than heating and bending sections, Smith followed the straight-section principle he applied to his timber design. In both cases, it simplified construction without sacrificing strength.

The arched-chord channels were to be held apart and in line "by continuous trussing, consisting of a flat bar of iron ½ by 2.5 inches, placed edgewise between the channel bars, bent into zigzag shape and riveted firmly at its angles to the respective channel bar alternately." The ends of the sections were to be planed "to a perfect surface at angles corresponding to the radii of the arch, and when placed in position form tight perfect joints which are secured by plates firmly riveted."[19]

[19]Pike County, "Commissioners Record," J: 283.

The “continuous trussing” did require a fair amount of metal heating and bending, but was probably simpler to fabricate than a multitude of separate lacing bars and would require fewer rivets per foot of chord. It was also likely quicker and cheaper to install, although it may be a bit less strong.

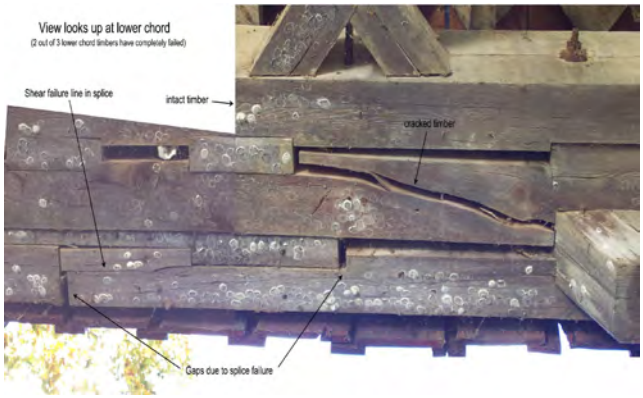
Lower Chord

Each lower chord consisted of two runs of “flat bars of iron 5/8 by 4-inch.” “At all splices the ends of all the links are enlarged to receive pin holes and have [the] same sectional area of iron as elsewhere.” Round iron pins of 2-inch diameter join the four “links” of lower-chord eye-bar runs.[20]

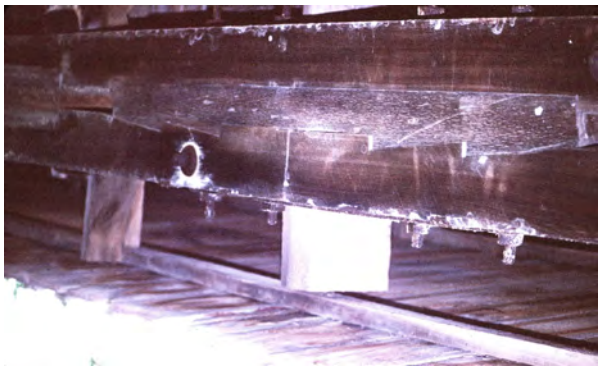
That pinning does not occur at panel points nor include truss web members is unique among Indiana’s metal-truss superstructures. Smith may have carried over the practice of “splicing” lower-chord members between rather than in panel points from timber-truss design where sections of a run were typically connected with blocks or fish-plates.

[20] In 1886 – more than a decade after the Patoka River Bridge was constructed – Robert W. Smith did receive a U.S. patent (#339,492) for manufacturing eyes for steel eye-bars by working wrought iron into the eyes. Here again Smith was concerned with efficiency and with the newer material, steel.

Below are two examples of intra-panel splices in timber trusses. To the left can be seen Smith's use of spice blocks to connect a lower-chord run on the Cataract Bridge in Owen County. To the right illustrates J. J. Daniels' use of fish-plates for the same function in the West Union Bridge in Parke County. Both employ intra-panel joints. Also note Smith's search for efficiency in the simplicity of his splice blocks compared with Daniels' more elaborate fish-plates.



Cataract Bridge under restoration in 2004
-photo courtesy of Barker Engineering



West Union Bridge, Parke County

The specifications for the Patoka River Bridge do not describe the point of bearing where the top and lower chords meet. At span-end, the lower chord plates have been shaped as round and threaded rods which pass through a cast-iron plate placed at the end of the top-chord channels. The rods are then bolted for adjustment to keep the top chord's designed circumference true.

Posts

The specifications called for 2.5-inch “Star iron with thread cut on each end.”

The lower end passes between the pairs of lower-chord eye-bars and through a cast-iron shoe where secured by adjustable “jam nuts above and below.” *[below, left]*

The upper end passes though a “cast block placed between the channel bars of the arch with jam nuts above and below.” *[to right]*

Diagonal or Tie Rods

Round iron rods supplied the truss diagonals. Their dimensions varied by location. The specifications called for "the upper ends" to be "looped round upper end of posts." The "lower ends" were to pass between the pairs of lower-chord eye-bars, "through cast shoe beneath and adjusted and secured by threat and nut." *[lower left]* In practice, the upper ends of the diagonal rods were also threaded, passed through cast blocks, and were secured with nuts. *[lower right]*

"Brace Beams" and Lateral Bracing

A pair of "overhead girders" form "brace beam[s]" running perpendicular to the roadway and riding on the lower chord adjacent to lower panel points 4 and 6. The "brace beams" extend beyond the trusses to anchor sway braces. According to the specifications, the girders consist "of two parallel flat bars of iron [½ by 3 inches], held apart and in line by continuous zigzag trussing [3/8 by 2 inches] riveted at its angles to each side alternately."

A sway or “diagonal brace” of “Star iron” extends from each outer end of a “brace beam,” through which the Star’s threaded lower end is bolted *[below, left]* “up to the arch” where the Star iron end has been forge-welded into an eye and bent to enter a post and, through the post, the upper panel point’s cast-iron block *[below, right]*.

Round 3/4-inch iron rods with threaded ends originally supplied lateral bracing. The rods extended diagonally between the lower panel points of the trusses, passed through the cast-iron blocks there, and were secured with nuts.

Floor Joists

“To be of oak 3 by 10 inches laid on [the lower] chords 2-feet apart.”

Flooring

“To be of oak lumber 2 1/4-inches thick and laid diagonally.”

From the bracing through the joists and the flooring, the specifications made no reference to floor-beams – members typically found on metal-truss superstructures. In metal-truss structures floor-beams provided some lateral stability and supported runs of stringers which in turn helped to carry the roadway above. Smith’s “overhead girders” or “brace beams” did add some lateral stability but had nothing directly to do with supporting the roadway. Instead, the oak floor joists which ran perpendicular to the roadway at 2-foot spacing picked up the floor-beam function in deck support – much as found in Smith’s and in many other timber-truss bridges. Thus the Smith Bridge Company’s “Wrought-Iron, Open-Arch Bridge” design was transitional in that it

incorporated a number of elements it regularly employed in timber-truss design as well.[21]

Capacity of Bridge

"Per W. T. Washer," the Smith Bridge Company "warranted" this Wrought-Iron, Open Arch Bridge "to sustain a test of 1,800 lbs. per lineal foot, exclusive of its own weight, without subjecting the iron to a greater strain than 1/5 of its ultimate strength."[22]

The cast and wrought iron in the structure was "to be thoroughly painted with two coats of mineral paint and linseed oil."

William T. Washer

Although Washer was a well-known bridge-builder in southwestern Indiana and in north-central and northwest Kentucky in the last quarter of the nineteenth century, his reputation rather quickly faded from view after his death in 1901. He has been best remembered in covered bridge circles. But even the dean of Hoosier covered bridge history, George Gould, reported that "little is known about William T. Washer, except for the covered bridges he built in southwestern Indiana." "He built at least 20 covered bridges which, I believe, included the eight in Evansville over Pigeon creek."[23] Gould was, however, sure of Washer's paternity for only nine of the 20 bridges he noted.[24]

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[21] The Massillon Bridge Company, the other Ohio designer-fabricator who also build in timber and iron, also carried over some elements of its timber design into its iron bowstring. Joseph Davenport's patented "Wrought Iron, Howe Truss Arch" has some of the same elements as Smith's "Open-Arch."

[22] For a contemporary assessment of the Smith Bridge Company's warranted strength, see emailed letter of James A. Barker to James L. Cooper, 26 August 2013 (Appendix B).

[23] George E. Gould, *Indiana Covered Bridges Thru the Years* (Indianapolis, 1977), 18.

[24] Gould's list of structures attributed to Washer:

Perry-Spencer Co. line: Huffman Mills & Shoals
Posey Co.: Grafton, Solitude, New Harmony
Pike Co.: Pikeville & Winslow (?)*
Dubois Co.: Kessner's (?) & Postlewaite (?)**
Gibson Co.: Old Red, Moore & Wheeling
Vanderburgh Co.: eight in Evansville (?)

*Indeed, H. J. Dare, not Washer, secured the construction contract for the Winslow Bridge in September 1877. Pike County, "Commissioners Record," K: 119-126.

**References in the Specifications cited above rather confirm Washer's construction in this case.

Like Robert W. Smith, Washer began his career as a carpenter and soon moved into bridge-building. Both understood the benefits of efficiency for successful contracting in the second half of the nineteenth century. Smith focused on design and fabrication. Washer, on the other hand, concentrated on contracting – *i.e.*, on the building of bridge substructures and the erection of superstructures – and depended on others for their design and fabrication. In this increased specialization of function, Washer moved ahead of most nineteenth-century builders of timber bridges and towards twentieth-century practice.

Born in June 1829, William T. Washer by age twenty worked as a carpenter in Troy township of Perry County, Indiana, and quickly became a community leader. When Troy was reincorporated in 1859, Washer was named trustee. In the same year, he became an officer at the founding of the local masonic lodge.[25]

As the bridge under consideration illustrates, Washer did not always work in timber. That the Smith wrought-iron bowstring was erected within a year or two of the three Smith timber-truss superstructures Washer is credited with erecting in Gibson County is more than coincidence. Washer's relationship with the Smith Bridge Company during the second half of the 1870s was, indeed, close. He allied himself with Smith's design and productive efficiencies in fabrication.

Washer's versatility, extended marketplace, and relationship with the Smith Bridge Company were also noted in passing in two court cases that reached the U. S. Supreme Court.[26] Washer received a contract from Bullitt County, Kentucky, to build a stone arch bridge over Pond Creek on the Jefferson County line in July 1878, and he went to court to secure pay for the construction.[27] According to the court decisions, the Smith Bridge Company reportedly supplied materials valued at $340.75 for the Pond Creek Bridge.

Washer did a fair amount of bridge masonry along with the erection of superstructures. His name can be found along with date (1874) on a nameplate on the stone abutments of the Dry Run Bridge on Wyandotte Avenue in Crawford County. He is also known to have received contracts for stone work in Vanderburgh County.[28] Son Edward, who

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[25] Troy Township, Perry County, Indiana, 1850 federal census, 367b; Thomas J. De La Hunt, *History of Perry County, Indiana* (W. K. Stewart Co., Indianapolis, 1916), 113, 120.

[26] Washer v. Bullitt County, 110 U.S. 558 (1884); Bullitt County v. Washer, 130 U.S. 142 (1889). Both cases concerned the same bridge.

[27] Bullitt County is located south of Louisville towards the center of the state.

[28] Vanderburgh County, "Commissioners Record," D-1: 307, 312-314,

rose to virtual partnership in the family business, was designated in the 1880 federal census as a “stone mason.”[29]

Washer was by no means tied exclusively to the Smith Bridge Company. In the 1890's after Smith sold his company, and it was transformed into the Toledo Bridge Company, “W. T. Washer & Son of Troy, Indiana” switched his informal partnership to the Indiana Bridge Company. He signed 21 contracts for metal bridge superstructures and parts with Muncie metal designers and fabricators. These included from 1892 through 1898 a couple of through-truss structures, a number of ponies, a “cantilever leg,” some “beam girders,” and a few sets of metal caissons.[30]

Not surprisingly, Washer had expanded the definition of his work from “carpenter” to “bridge-builder” by the time the1900 census-taker arrived on the family doorstep.[31] Still, we know only a piece of what this builder constructed. His work in Kentucky remains largely unknown, and his erection of timber, stone, and metal bridges in Indiana only partly documented. Fortunately, Pike County Bridge #150 remains as a testament to the invention and fabrication of the Smith Bridge Company, the craftsmanship of William T. Washer, and the efficiencies of each in and through their specialization.

Recommendations

Pike County Bridge #150 has survived due to the repairs and rehabilitations undertaken over the years by the county authorities. In December 1908, for example, the commissioners decided to refloor "The Iron Bridge" over the Patoka River near Survant. John Survant received a contract to lay new oak joists (12-inches wide by 2-inches thick by 16-feet long) on centers 12-inches apart.[32]

The major rehabilitation occurred in 1978 when the original stone abutments were encased in concrete, some rolled steel stringers added, and more external sway braces welded on. The county also built a timber structure above steel beams seated on raised abutment ledges. Placed inside and somewhat above the old iron superstructure, the new one reduced the roadway to a width of 10 feet and 2 inches.

Not surprisingly, Pike County finds Bridge #150 an issue for contemporary traffic and wishes to replace it for vehicular use. The best preservation alternative would be to remove the whole assemblage from the Patoka River, recycle the 1978 additions, repair

[29]Troy Township, Perry County, Indiana, 1880 federal census, 67a.

[30]Contracts 730, 1838, 2004, 2012, 2178, 2310, 2310 1/3, 2310 ½, 2311, 2331, 2359, 2519, 2520, 2526, 2983, 3028, 2028 1/4, 3028 ½, 3109, 3110, 3110 ½, “Client Index,” Indiana Bridge Company (Drawings Archives, School of Architecture, Ball State University).

[31]Troy Township, Perry County, Indiana, 1900 federal census, 5b.

[32]Pike County, "Commissioners Record," T: 159-161.

the original cast and wrought iron, relocate the superstructure to an appropriate pedestrian trail location, and rebuild the timber deck and roadway to the original specifications. As James Barker has suggested, the old superstructure restored to original strength should meet AASHTO standards for pedestrian loading (see Appendix B). And, without modern add-ons, the superstructure will fully display the special and rare Smith Bridge Company design, originally erected by the once highly respected builder, William T. Washer.

Appendix A

Proceedings of Hon. Board of Commissioners of Pike County Indiana when convened in Special Session on Tuesday the 21st day of September, 1875. Present the Honorable J. J. Bowman, Patrick M Kobb and Herman Kuhe Commissioners and Amel J. Patterson County Auditor.

And now the Board order the following to be entered of Record to-wit:

Specifications of Abutments

For a bridge to be erected across Patoka River at or near the S W qr of the N E qr of Sec. 2 in Town Two South of Range Seven West, on the line of the New Sulphur Springs & Augusta Road when the same crosses the River aforesaid in the County of Pike in the State of Indiana, to-wit:

There are to be erected two abutments, one there on Each side of the River and at the place aforesaid, said abutments to be five by fourteen and one half feet on the top, and to taper one inch to the foot from the base to the top on the front and Ends, the height there of to be directed and determined by the Superintendent of said Bridge.

There are also to be erected four curved wing walls, one of which is to be built and carried up at Each end and with the abutments aforesaid which are to be three feet thick on the top and covered with Caps of Stone six inches thick, not less than one foot wide and three feet long, all to have the same taper as the abutments, the length there of to be directed by the Superintendent aforesaid. The Contractor

to sink the foundation for the above work a sufficient depth so as to secure a good and solid foundation, and if necessary, the same to be underlaid with two layers of White Oak timber one foot Square croping each other with an extension or projection of six inches at the base of the abutments,

The rock to be used in the building and construction of the work aforesaid shall not be less than twelve inches in thickness, to be well jointed and the face of the abutments and wing walls are to be dressed the same as rocks are dressed on the Postlethwait Mill Bridge on Patoka River in Dubois County and State of Indiana; and it is further provided that there are to be binders in every second layer or tier of rocks not over three feet apart and

not less than three feet in length with not less than one foot top alternating from front to rear and the fills to be large rock of the same thickness as the front layers, all of the above Stone work to be laid in good mortar made of pure lime and clean sand well mixed.

The height of the abutments and height and length of the wing walls are to be directed and determined by the Superintendent and the said abutments to be ninety feet apart in the clear at the top when Completed.

All of the above work to be done and performed in a good substantial and workmanlike manner and to be warranted by the Contractor in a good and sufficient Bond in double the amount of the contract price for the term of twelve months from the time the work shall be received or accepted by the Board of Commissioners of Pike County and State of Indiana, or their agents.

All the above matters and things set forth herein are to be done and performed by the contractor and the work to be completed on or before the 10th day of December, 1875.

The Contract for the construction of the above work to be let out by the perch, and the Board of Commission aforesaid reserve the right to reject any and all bids if they see proper.

The above work to be paid for at the times and in the manner following, Viz: Forth the Contract price to be paid in County Orders after the Contractor shall have given Bond as required by the terms of the Contract and the remaining three fourths in County Orders when the bridge is Completed and received.

And it is understood that all necessary Earth work in filling the abutments to the level of the Bridge is to be included in the contract and done and performed by the Contractor, and that ten feet at each end of the bridge be covered with small broken Stone the full width of said bridge, at least eight inches deep over Top of Stone necessary to the erection of said Bridge to be well grouted with good lime mortar and the ~~Contractor~~ to furnish all the material necessary for

Said work. Adopted July the 21st, 1875

G. J. Bowman
Patrick McStabb } Comrs.
Herman Hemke

Specifications for Smith's Macright Iron, Open-Arch Bridge, Which we propose to build for Pike Co. Ind.

To consist of one span 90 feet in clear and 93 feet full with one Roadway 14 feet in clear. To be built in accordance with accompanying plans and following specifications, viz:

Arches

To be constructed in straight Sections of panel length, and when joined together, the ends of the Sections will form a true segment of a circle. the Sections are to each consist of two pieces of (7") inch Channell bars placed edgewise or vertically, and 10 inches apart with flanges outward and are held apart and in line by continuous Bracing, Consisting of a flat bar of iron ½ by 2½ inches, placed edgewise between the channel bars bent into zig zag shape and riveted firmly at its angles to the respective channel bars alternately. The ends of the sections are planed to a perfect Surface at angles corresponding to the radii of the arch, and when placed in position form tight perfect joints which are secured by plates firmly riveted.

Chords

To be links of flat bars of iron ⅞ by 4 inch at all Splices the ends of all the links are enlarged to receive pin holes and heave same Sectional area of iron as elsewhere, and with not less than two links in each chord. The ends of links (at splices) to be connected with turned iron pins 2 inches diameter, turned to a perfect surface so as to secure a uniform bearing.

Posts

To be 2½ inch star iron with thread cut on each end. The lower end passes between the chord links and through the Cast iron shoe beneath and are adjusted and secured by jam nuts above and below. the upper end passes through the Cast block placed between the channell bars of the arch

with jam nuts above and below.

Diagonal or Tie Rods

To be of round iron. varying in size as per dimensions shown on plan: the upper ends are looped around upper end of posts. lower end passes between chord links and through cast shoe beneath and are adjusted and secured by thread and nut.

Lateral Bracing

Overhead girders are constructed of two parallel flat bars of iron. held apart and in line by continuous zizzaag trussing. rivetted at its angles to each side alternately. The brace beam will be constructed in the same manner as the overhead grider. the parallel bars to be ½ by 3 zigzag bar ⅜ by 2. they will extend outside of chords on each side sufficiently to form a base. and from the ends of which a diagonal brace of 2 Star iron will reach up to the arch. Lateral Rods. both upper and lower. to be of round iron ¾ inches diameter with one set of overhead griders Turned.

Floor Joist

To be of oak 3 by 10 inches laid on chords 2 ft apart.

Flooring

To be of Oak lumber 2¼ inches thick. and laid diagonally.

Capacity of Bridge.

Warranted to sustain a test of 1800 lbs. per lineal foot. exclusive of its own weight. without subjecting the iron to a greater strain than ½ of its ultimate strength.

The whole to be finished complete in a neat and workmanlike manner. with all joints and bearings perfect. All materials to be of the best quality and the whole structure. except joist and flooring to be thoroughly painted with two coats of mineral Paint and linseed oil.

Respectfully Submitted
Smith Bridge Co
Per W. L. Masher

Articles of Agreement,

This Agreement made and entered into on this the day of September A.D. 1875. by and between A. J. Bateman. Patrick McNabb and Herman Henke Commissioners of Pike County in the State of Indiana of the first part and W. J. Washer of the County of Perry in the State of Indiana of the Second part Witnesseth. That the said Commissioners. Party of the first part. have this day awarded to the said W. J. Washer party of the second part the contract for building the new Bridge across Patoka River where the Sulphur Springs and Augusta Road intersects with said River in Marion Township in the County and State aforesaid.

The said Commissioners, party of the first part, agree and bind themselves to pay to the said W. J. Washer, party of the second part, one fourth the contract price for building said Bridge (the Stone work and Structure thereupon) when he shall have given bond for the faithful and workmanlike performance of the work, according to the Specifications for the Stone work of said Bridge gotten up by Henry A. Miller and adopted by the Commissioners aforesaid at their Special Session July the 21st, 1875. and Erect upon the Stone work when Completed "Smiths Wrought Iron Open Arch Bridge" according to the Specifications for said Iron work submitted by the said W. J. Washer, party of the second part, to the said Commissioners, party of the first part, on the 10th day of September, 1875, and adopted by said Commissioners the day following. (Sept. 11th 1875)

And the said Commissioners, party of the first part, agree and bind themselves to pay said W. J. Washer, party of the second part, the remaining three fourths of the contract price for building said Bridge when the same is completed in all things according to the Specifications adopted and required by the Superintendent of said work,

And the said W. J. Washer, party of the second part agrees and binds himself to do all the work mentioned and required to be done by the Specifications for the Stone work, including timber foundations upon which the Stone work is to be erected, ~~driving piles~~, ~~excavations~~ ~~filling~~ etc excavations filling etc and receive therefor the Sum of Six Dollars and Seventy five Cents per cubic perch for the Stone work in full Compensation therefor, and the said W. J. Washer, party of the Second, said further agrees and binds himself to erect upon the Stone abutments when completed "Smith's Wrought Iron, Open Arch Bridge" for the sum of Twenty two Dollars per foot, all of which is to be done in a good workmanlike order,

And it is made a part of this Contract that the County Auditor issue to W. J. Washer orders on the Treasurer of Pike County when he shall have given bond for the faithful performance of this Contract, for one fourth the Contract price for building said Bridge and Orders on the Treasurer aforesaid for the remaining three fourths of the Contract price, when the work shall have been completed and received and the said W. J. Washer agrees to receive said in payment for building said Bridge, the Stone work to be completed on or before the 10th day of December, 1875, and the Bridge thereon on or before the 10th day of January, 1876.

Appendix B

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Jim,

I will attempt to translate to modern roadway loading as requested. May get a bit technical, so you may need to simplify for your audience, but you will have this as backup.

Background

Standard roadway loadings are used with certain general analysis methods, with the *combination* defining a general approach to structural design. Knowing one without the other is like having half of a treasure map. In the US, the AASHTO guidelines are generally used to define both roadway loadings and analysis methods, and the combination (after having been constant for half a century) has changed twice in the past 15 years. For comparison with 19th century loadings, the standard AASHTO "H" loadings are appropriate. Also, the "allowable stress" method is reasonable and easy to compare. Allowable stress method has been used since the 1850's and was the AASHTO anointed method until ten or fifteen years ago, so is reasonably current.

Starting around 1995, "load factor method" was an acceptable alternative to "allowable stress" method, but used the same AASHTO "H" loadings. Starting around 2004, "load and resistance factor" method became AASHTO's recommended method, and it uses a different roadway loading. For bridges designed before 2004, INDOT lets you design using "load factor" method. The new analysis methods were calibrated to give roughly similar results, in terms of load ratings, as the older allowable stress method, so the latter should be adequate for this exercise.

Roadway Loading: AASHTO requires you to design for two alternate load applications. For this exercise I will assume an AASHTO 20-ton design load, corresponding to a "LOAD LIMIT 20 TONS" sign on road. The first design case is a single semi trailer truck having 3 axles. The front two total 20 tons, and the third axle (supporting rear end of trailer) weighs 16 tons. The second design case approximates (says AASHTO) a train of lesser-weight trucks closely following each other. This is a uniform load of 640 pounds per foot along the road per traffic lane, plus a concentrated load of 18^{K} for bending moment or 26^{K} for shear. For this exercise, just use the larger. One "^{K}" = 1,000 pounds. See attached page from AASHTO. You must multiply these loads by an impact factor varying with bridge length. For an 88-foot span it is about 1.24.

Analysis Method: Allowable stress method is pretty simple in concept. It is assumed you know the material stress (e.g., psi) at which each part of your structure yields (in common parlance,

"fails"). Your design technique is to specify large enough members so that the combination of the structure's self-weight (dead load) and design roadway loading (live load plus impact) stresses the weakest member to no more than a specified allowable stress that is less than the yielding stress. For wrought iron and steel, the allowable stress in tension and compression has been generally set by AASHTO as 55% of the yielding stress. This 55% assumes some abuse by irresponsible truckers, so emergency vehicles of known weight are allowed to pass at higher percentages – but that's irrelevant here. Also, for compression members, the designer must account for lower yielding stresses due to buckling. And buckling depends on unsupported length and stiffness of the compression member's cross section. So that part gets complicated, structurally. It's not just a question of how much cross section area a member has. And the arch is a pure compression member.

Rough Conversion of Pike 150's Design Specification

The design strength of the Pike 150 arch is going to be less than the iron's yield stress because of buckling. And it will be much less because the pitiful star-iron lateral braces don't give much lateral support. The crossed diagonals give the arch marginally adequate lateral support in the vertical direction, but the star iron outriggers are poor support in the transverse horizontal direction. They may be marginally adequate if everything is perfect. But today's vehicles are heavier than 1870 vehicles and move much faster = greater potential impact energy ($e= m\underline{v^2}$) and in both longitudinal and transverse horizontal directions. Vehicle impacts happen.

I am going to estimate that the arch would buckle when the arch iron is stressed to about 1/3 of its test strength. To be a bit less conservative and make the math easier, I will say, at 36% of yield stress.

Now, you say the bridge was designed to sustain its own weight (dead load) plus 1,800 lbs per foot live load without exceeding 20% of its perfect "ultimate strength". That happens to be 55% of my reduced, guesstimated buckling stress (20% / 36% = 55%), and that exactly equals the modern allowable stress design goal.

But, how does the 1,800 design live load correlate with modern AASHTO "H" loading? Let's compare with the AASHTO H-20 design loading. The trouble is that both load alternatives described above (called "truck" loading and "lane" loading) contain concentrated loads. These must somehow be converted to" equivalent" uniform loadings[1]. There are no guidelines for this. One must make "reasonable" assumptions.

The AASHTO semi trailer has a wheelbase between 28 feet and 44 feet, whatever produces the greatest load in structure. In reality, few 72,000 pound trucks are this short. So, spreading out

[1] In 1870 wagons weren't so heavy, and a herd of cows was probably the heaviest loading on bridges. So using a uniform load per foot was a reasonable design criteria – then.

the concentrated axle loads over 50 feet, *and assuming this extends the full 88-foot length of bridge* seems reasonably conservative.[2] For this single-lane bridge, doing so would give an "equivalent" uniform load of 72^K x 1.24 impact / 50' = **1,780 lbs per foot** .

Similarly, the 26k concentrated load of the "lane" loading case might reasonably be spread out over, say, 30 feet. That would add 26^K x 1.24 impact / 30' = 1075 lbs per ft to the 640 x 1.24 = 795 lbs per ft uniform load for that case, making a total uniform load of **1,870 lbs per foot**. This is slightly higher than the truck loading value, making "lane" loading the controlling case.

So:
If the Pike County Bridge 150 arch-truss was truly designed to carry its own weight plus 1,800 pounds per foot at 20% of its material's yielding stress, the above logic suggests that it should be strong enough to carry a modern day load rating of 20 tons x 1800 / 1870 = 19 tons.

I would personally feel more comfortable thinking in terms of a posted **15 ton load rating**, provided that

(1) the rigorous analysis of all parts of the repaired arch-truss primary truss supports it.
(2) the lateral bracing is strengthened to handle likely impacts from vehicles, trees, floods, etc.
(3) the floor system is designed for it.
(4) a stronger bridge railing is provided to protect the arch-truss from vehicle impacts.

Pedestrian Loading: The pedestrian design loading is set by AASHTO at 85 pounds per square foot for a bridge such as Pike 150. Multiplied times the 10.3-foot deck width, this is only 880 pounds per foot along bridge, much less than the 1,800 pounds per foot you found to be the specified design loading. A rigorous analysis, including the effects of partial-span loadings, should be part of a proper rehabilitation design project.

James Barker
August 26, 2013

[2] This is done to provide an estimate of the strength of the arch-truss. Actual project design would involve a rigorous mathematical analysis of the arch-truss. And the floor system would be designed to carry actual axle forces.