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FORT MADISON BRIDGE
(Atchison, Topeka & Santa Fe Railroad Bridge)
Iowa Bridges Recording Project
Spanning Mississippi River
at U.S. Highway 61
Fort Madison
Lee County
Iowa

HAER No. IA-62

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HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
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HISTORIC AMERICAN ENGINEERING RECORD

FORT MADISON BRIDGE
(Atchison, Topeka & Santa Fe Railroad Bridge)

HAER No. IA-62

Location:	Spanning the Mississippi River and linking U.S. Highway 61 with Illinois Route 9; Fort Madison, Lee County, Iowa/ Hancock County, Illinois UTM: 15.644040.4490680 USGS: Fort Madison, Iowa quadrangle (7.5 minute series, 1964; photorevised 1975)
Date of Construction:	1927
Designers:	A.F. Robinson, Santa Fe Railroad
Builders:	American Bridge Company, New York (superstructure); Union Bridge and Construction Company, Kansas City, Missouri (substructure)
Fabricator:	American Bridge Company, New York
Present Owner:	Burlington Northern Railroad
Present Use:	Roadway/railway bridge
Significance:	This bridge is a major river span and had, at the time of its construction, the longest and heaviest electrified swing span on the Mississippi River. The bridge superstructure was built by American Bridge Company, one of the largest bridge companies in American history.
Historian:	Robert W. Jackson, August 1995
Project Information:	This document was prepared as part of the Iowa Historic Bridges Recording Project performed during the summer of 1995 by the Historic American Engineering Record (HAER). The project was sponsored by the Iowa Department of Transportation (IDOT). Preliminary research on this bridge was performed by Clayton B. Fraser of Fraserdesign, Loveland, CO.

In 1927, the Atchison, Topeka & Santa Fe Railroad completed construction of a new combination double-track railroad and two-lane highway bridge at Fort Madison, Iowa, which featured the longest and heaviest swing span ever built on the Mississippi River. The primary purpose of the bridge was to replace the single track combination railroad and roadway bridge built at Ft. Madison in 1887, which no longer had adequate load carrying capacity.[1]

A charter for a bridge at Ft. Madison was first obtained in 1872 for a proposed railroad from Peoria, Illinois. The bridge was not built, however, and on March 3, 1887, Congress authorized the Santa Fe Railroad to build a combined railroad and wagon bridge at the same approximate location stipulated in the original charter. Before the selection of Fort Madison as a point of construction had been announced, the cities of Keokuk, Iowa and Fort Madison carried on a spirited competition for the honor of hosting the new bridge, with both cities expecting to benefit from the jobs and increased business that would accompany a new rail line. Unknown to the citizens of Keokuk, who already had one Mississippi River railroad bridge, the Santa Fe officials had ruled out another Keokuk crossing as impractical long before the decision was announced.[2]

Work on the first Fort Madison Bridge commenced in the same month that authorization was granted, and the structure was essentially completed on December 7, 1887, at an initial cost of over $580,000. The bridge was built by the Mississippi River Railroad & Toll Bridge Company, owned by the Santa Fe Railroad.[3] The contract for the superstructure went to Union Bridge Company of New York, and the contact for the substructure went to Sooysmith & Son of New York. Noted bridge engineer Octave Chanute served as chief engineer and W.W. Curtiss was resident engineer. The bridge had an overall length of 2,963', consisting of eight spans and an east approach of about 350 yards. Commencing at the east

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[1]"Santa Fe Builds New Bridge Over Mississippi River," Railway Age 83 (9 July 1927), 47-53. Unless otherwise noted, the information contained in this report regarding the design and construction of the 1927 Fort Madison bridge is taken directly from this article.

[2]Glen D. Bradley, The Story of the Santa Fe (Boston: Gorham Publishing, 1920), 265; L.L. Waters, Street Trails To Santa Fe (Lawrence, KS: University of Kansas Press, 1950), 86.

[3]James Marshall, Santa Fe: The Railroad That Built An Empire (New York: Random House, 1945), 205.

approach, there were two approximately 150′ spans, then a draw span 400′-6" long, then a span 274′-6" long, then four spans 237′-6" long, and then a trestle approach composed of seventy-four 14′ spans.[4]

By the mid-1920s, the increased size and weight of locomotives and rolling stock had necessitated the construction of a new bridge at Fort Madison. Building a new structure at this location would have the further advantage of providing double tracks, thereby eliminating a stretch of single track introduced in the line by the old crossing. The new bridge was designed in the office of A.F. Robinson, bridge engineer, Atchison, Topeka & Santa Fe System, under his direct supervision. H.W. Wagner, chief engineer, Atchison, Topeka & Santa Fe, eastern lines, and his assistants, were in charge of the construction work, with R. A. Van Nes serving as assistant engineer in the field. The substructure was built under contract by the Union Bridge and Construction Company of Kansas City, Missouri (a different company than that firm involved in construction of the 1887 bridge). The superstructure was designed and built by the American Bridge Company, New York. Work began in April 1925, and completed in July 1927 at a total cost of approximately $5.5 million.[5]

The American Bridge Company, an amalgamation of about twenty-five competing firms representing approximately fifty percent of the nation′s fabricating capacity, was organized by J.P. Morgan and Company in April 1900. Less than a year later most of its stock was acquired by United States Steel Corporation, a creation of Andrew Carnegie. Other companies were subsequently added to the corporation, and the firm was by far the most dominant bridge construction company in American when contracted to build the superstructure of the new Fort Madison Bridge. The work of this corporation has been fairly well documented and is known to virtually all bridge historians.[6]

In contrast, the Union Bridge and Construction Company, called by J.A.L. Waddell in 1916 "one of the best known bridge building companies of America," has been largely forgotten. The firm

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[4]F.B. Maltby, "The Mississippi River Bridges: Historical and Descriptive Sketch of the Bridges over the Mississippi River," Journal of the Western Society of Engineers 8 (August 1903), 474.

[5]Railway Age, 47, 53.

[6]Victor Darnell, A Directory of American Bridge-Building Companies: 1840-1900 (Washington: Society for Industrial Archeology, 1984), 85-86.

erected the swing bridge over the Atchafalaya River in Louisiana for the Southern Pacific Railroad in 1911, and contracted for the substructure work on the Plattsmouth highway bridge over the Missouri River the year after completion of the Fort Madison Bridge. Apparently the company had some expertise in erecting bridge substructures in deep, swiftly flowing rivers. The officers in 1916 were L.S. Stewart, president, and H.K. Seltzer, vice-president.[7]

The new Fort Madison Bridge constructed by these companies was placed in a location which permitted a better grade and alignment of the approaches than did the old bridge built in 1887. The location of the new bridge was studied extensively before a definite position was determined, with the final placement and alignment dictated mainly by the limitations of geography and existing rail alignment. On the Illinois side the line of the Santa Fe Railroad lies upstream from the crossing in a parallel position to the river, while on the Iowa side the railroad lies close to the river bank for a considerable distance downstream. The old bridge was constructed at right angles to the river channel, thus reducing the overall length but also creating curves of about ninety degrees central angle in the alignment of each approach. Owing to the close proximity of the west bank of the river and the river channel, it was necessary to place the west approach on a ten degree curve. In order to reduce the angle of the approach alignments, the new bridge was placed upstream from the old structure on a skew of sixty-five degrees with the direction of the channel, thereby reducing the total curvature by about fifty degrees of central angle and reducing the rate of curvature of the west approach to five degrees. When the swing span is closed it makes connection with the shore sections at an oblique angle, which is essential if there is to be no overtravel, which could cause considerable damage to the bridge.[8]

The main river crossing consists, from east to west, of four fixed through truss spans of 270'-6" and a draw span with two equal arms of 265'-10", the distance being measured center to center of piers. The east approach consists of nine spans of

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[7]J.A.L. Waddell, Bridge Engineering 2 (New York: John Wiley & Sons, 1916), 1072, 1513; Office of the Chief of Engineers, United States Army, List of Bridges over the Navigable Waters of the United States, 1927 (Washington: Government Printing Office, 1928), 18-19.

[8]Railway Age, 47; "An Electrically Operated, Skew Type Swing Bridge," Engineering World 30:6 (Chicago: International Trade Press, 1927), 360.

girders 100′-6" center to center of piers and the west approach of nine spans of girders 80′-6" and one span 102′-4" center to center of piers. The bridge links Iowa Route 2 with Illinois Route 9 above the tracks on the swing span and truss structures and beside the tracks on separate girder structures adjacent to the railroad approach spans. The first girder span at each end of the truss spans is skewed so as to shift the roadway directly over the centerline of the tracks as the roadway enters the truss spans, resulting in an abrupt discontinuity in roadway alignment. At the Iowa bridgehead the approach roadway is awkward due to a steeply rising grade and reverse-curve alignment. The Illinois approach roadway is relatively straight and rises on a more gentle grade. A double-deck configuration is maintained throughout the length of the truss spans. The highway level carries a minimum roadway width of twenty feet and has a bituminous surface on a Portland cement concrete slab. The maximum vertical roadway clearance to low bridge steel is 14′-6". The roadway design load is an H-20 equivalent live load with a 32,000-pound single axle. The highway portion of the bridge is operated on a toll basis.[9]

There are a total of twenty-five spans supported by two concrete abutments and twenty-four concrete piers. The piers are numbered 1 through 24 from east to west and the abutments are designated as the east and west abutments. Piers 1 through 8, 17 through 24, and the two abutments are supported on timber piles. Piers 9 through 16 are supported on caissons. The east abutments and the first eight piers are founded on sand and silt. Piers 9 through 12 are founded on coarse sand. The remaining piers are founded on hard blue clay. The pivot pier, Pier 14, is a circular design. Piers 1 through 8 and 17 through 24 are nine-sided piers. The roadway is supported by one-half of the pier and the railroad tracks are supported by the other half. All piers are set square with the center line of the bridge with the exception of the two rest piers for the draw span which conform to the skew of the river channel.[10]

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[9]Howard, Needles, Tammen & Bergendoff and Wilbur Smith & Associates, "Mississippi River Toll Bridge: Bridge Location, Revenue and Traffic Studies at Fort Madison, Iowa" (Kansas City: Howard, Needles, Tammen & Bergendoff, 1968), iv. A Report Prepared by Howard, Needles, Tammen & Bergendoff and Wilbur Smith & Associates for the Iowa Department of Transportation, Ames, Iowa.

[10]Collins Engineers, "Substructure and Channel Bottom Investigation of Railroad Bridge No. 231.4 over the Mississippi River at Fort Madison, Iowa" (Chicago: Collins Engineers, 1989), 2, a report prepared by Collins Engineers for the Atchison, Topeka & Santa Fe Railway Company, contained in the files of the Iowa

Cores of the river bed at the proposed site of the new bridge showed that bed rock existed at an elevation 165' below low water level and was overlaid with a thick stratum of sand, gravel and clay. There was, therefore, no possibility of economically carrying the pier footings to rock. The river piers were accordingly founded on the over-burden at a depth of 62 to 72 feet below low water while the piers for the approach spans are on pile foundations. All of the piers are of concrete, with shafts having side and downstream end batters of 1" to the foot and a batter of 2" on the upstream end, except that the shaft of the pivot pier is a true cylinder. None of the piers have coping, belt courses, rustication or other embellishments. They are reinforced with grids of 3/4" eyebars spaced 18" at center, both vertically and horizontally at a depth of 6" from all faces except under each bearing shoe where the spacing is 9". The shafts are doweled to the footings by 5' lengths of 75-lb. and 85-lb. rail, spaced 2" center to center, both longitudinally and transversely. The intermediate piers under the fixed spans have shafts 10'-6" wide by 42'-4" long and have caissons 22' wide by 68' long. The pivot pier is 47' in diameter with a caisson 52' square.

With the exception of the swing span, the entire railroad deck was originally built with a creosote timber ballast floor. On the fixed truss spans this consisted of 4" x 10" planks supported on a stringer system consisting of four main stringers under each track with a jack stringer between the tracks and between each track and the adjacent truss. Continuity of the deck at the ends of panels was carried out by enclosing the top flanges of the floor beams (which project above the stringers) with a bed of bituminous putty that completely filled the channel-shaped space between adjoining timbers above the tops of stringers.

The original highway deck was made of reinforced concrete topped with a 3/4" thickness of Johns-Manville's standard asphalt bridge road surfacer. The concrete slab was supported on steel stringers, of which four were of a special built-up box section designed to support rails for two street car tracks depressed in the pavement, while one on the center line of the bridge and three next to each truss were of 15" I-beams. The floor beams and stringers of the upper deck were protected by smoke shields 36" wide centered over each track. These were made of 3/8" steel plates curved concave downward for ready drainage. Bolted connections of the plates to the floor were designed to facilitate ready renewal.

Department of Transportation, Ames, Iowa.

The most important feature of the Fort Madison Bridge is certainly the swing span. Chanute's use of a swing, or draw, span for the bridge built in 1887 was in keeping with the practice of other Mississippi River bridge designers who had long favored this type of movable bridge as a means of providing for riverboat traffic. Draw spans operate by swinging horizontally around a vertical axis on a pivot pier located approximately in the middle of the river channel. By the mid-1920s, however, the demands of riverborn commerce for ever-increasing widths of waterway openings, and the growing weight of rolling stock, had imposed the necessity of building longer and stronger movable spans. This meant that the loads to be swung were much greater than they had formerly been, thus requiring heavier machinery and more powerful power units.

In choosing the design of a new movable bridge for the Fort Madison location, the Santa Fe Railroad could have selected a vertical-lift or bascule bridge, types that generally offered several advantages over the swing-span bridge. According to bridge historian David Plowden, builders of these types, particularly the bascule, denigrated the swing bridge in their advertising by playing up the fact that the draw span itself took up part of the channel. Because the swing bridge must rotate on a large pivotal pier in the approximate center of the navigation channel, it also divides the channel into two smaller halves. In addition, the swing span must rotate a full ninety degrees to allow ships to pass, and then rotate back to a closed position. This can be a very time consuming activity, especially with large, heavy spans. On the Fort Madison Bridge, each opening cycle takes about fifteen minutes.[11]

The bascule bridge, the earliest of all movable types, was deemed by noted bridge engineer J.A.L. Waddell to be either equal or slightly superior to the swing span, except in those cases where the bridge deck is very close to the water, thus necessitating a well or wells for receiving the counterweighted end or ends of the bascule.[12] That was exactly the situation faced by the Santa Fe Railroad in the design of the new Fort Madison Bridge. The Mississippi River at Fort Madison lies within the limits of the slack water above the Keokuk power dam which is located about twenty-three miles downstream from the proposed point of crossing. Consequently, low water level in 1925 was about 10' higher before the dam was built, thereby reducing the headroom between low water and the superstructure of the old bridge. To

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[11]David Plowden, Bridges: The Spans of North America (New York: Viking Press, 1974), 187; Howard, Needles, Tammen & Bergendoff, iv.

[12]Waddell, 1208.

avoid increasing the grade of the approaches, and to economize on the sub-surface masonry, it was desirable to keep the track grade on the new bridge as low as possible. The plans approved by the War Department provided for a clearance of 10' over the high water level guaranteed by the water power company that operated the Keokuk dam, thus making it possible to restrict the grade on the approaches to 0.4 percent.[13]

The vertical-lift bridge, which eventually replaced the swing-span bridge as the preferred type, was another alternative to the swing bridge. It was generally less expensive to build, simpler to operate, and less demanding of power than the swing span. It was also, according to Waddell, generally more economical than the bascule type. The greatest hinderance to its adoption for early twentieth-century bridges was probably the opposition stemming from owners of bascule patents.[14] From a functional standpoint, however, it was a very attractive option. Why, then, did the railroad not chose this design over a swing span? There can be no definite answer to this question without further research, but one possible answer is implied by a comparison of types made by Waddell.

In Bridge Engineering (1916), Waddell writes that when the swing span type is pitted against either the bascule or vertical lift type of movable bridge, "the first point to determine is what proportionate length of single opening is equivalent to the two openings afforded by the rotating draw. This is a matter of personal opinion, and even in one man's mind it might vary materially for different cases." For Waddell, a single clear opening twenty-five per cent greater than either of the clear openings afforded by the swing type would give equally good or better facilities for navigation. However, as Waddell notes,

> Neither the author nor the designer of the bridge under consideration has anything to say about deciding this point, because the court of last appeal is always the War Department. If that department deems that the clear opening or openings suggested by the designer be insufficient, it has no hesitation whatsoever in saying so and compelling the petitioner for approval to increase the said clear opening or openings as much as its engineers consider advisable.[15]

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[13]Railway Age, 47.

[14]Waddell, 746.

[15]Ibid, 1208.

The new Fort Madison Bridge was designed at a time when it could still be said that the swing span was the standard type of movable bridge in use, particularly for long-span bridges.[16] On the Mississippi River the type had long been dominant, and was that type with which both the Santa Fe Railroad and the War Department had the most experience. Therefore, it seems reasonable to assume that the swing-span option was chosen because it was proven, familiar, and technologically feasible.[17]

Whatever the rational behind the design decision, there were aspects of movable bridge operation that had to be addressed in the design of the new Fort Madison Bridge. One such aspect had to do with the selection of power units and machinery to operate the swing span. The power unit of a moveable span is a standby unit which may be unused for long periods of time, but must also be ready for use on very short notice. For this reason the steam engine used for earlier swing-span bridges, which depended for its operation on a boiler that was always kept under pressure, was very inefficient.[18] For example, the South Halsted Street Bridge in Chicago, designed by Waddell and built in 1892, could not be operated efficiently until its steam engines were replaced by electric motors in 1907. This was in keeping with Waddell's original specifications, which called for the use of two sixty-five horsepower motors.[19]

As originally designed, the turning machinery of the Fort Madison Bridge was distinctive in that the four driving pinions were in no way connected with each other by pinions. Each pinion had an individual set of reducing gears and was driven by four independent motors. Each motor was a General Electric 75 hp., 440-volt, 3-phase, 25-cycle, mill type equipped with a solenoid brake. All of the motors were supplied with electric current from the same power line, and the load was equalized so that the force required at the rack was equally distributed between the four. The end lift and bridge lock at each end of the span was operated by two 50 hp. General Electric, 440-volt motors; one motor normally operating the machinery, the other drifting, but so arranged in the control that either of the motors may be made operative by means of a double-throw switch. The solenoid brakes

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[16] "The Maintenance of Movable Bridges," Railway Engineering and Maintenance 23:6 (Chicago: Simmons-Boardman Publishing, June 1927), 230.

[17] Maltby, 419; Plowden, 187.

[18] Railway Engineering and Maintenance, 230.

[19] Waddell, 721.

on these motors were so arranged that both could be operative regardless of which motor was working.

Development of a practical design for a swing span of the length and weight imposed in the Fort Madison Bridge presented conditions not encountered in bridges of ordinary proportions and necessarily involved departures from normal practice. Investigation of a center bearing design for a swinging reaction of 10,000,000 lbs. and a closed reaction of 15,000,000 lbs. on the center pier developed prohibitive proportions and led to the adoption of a combination center and rim bearing design in which one-third of the load is carried on the center and two-thirds on the drum. According to Railway Age, the practical evolution of this idea, under the conditions imposed in this case, gave rise to a method of load distribution which not only possesses a commendable simplicity but also embodies some unique details.

The load distribution system consists of eight loading girders spanning transversely between the two trusses and sixteen radial girders which, at their outer ends, frame into a drum girder 42′ in diameter, and at their inner ends rest on top of a disc-type center bearing. The primary problem involved was to distribute the load from the trusses to the loading girders and from the loading girders to the radial girders so that each radial girder would receive 1/16 of the total load, with the further requirement that the point of application of this load would be such that one-third would be carried to the center and the remaining two-thirds would be carried to the drum.

Another distinctive feature of the design is the manner in which the load is transferred from the loading girders to the radial girders. The radial girders are connected in pairs at a point 14′-4" from the center or approximately the outer third point by steel loading or diaphragm castings which frame into the webs of the adjoining girders and on top of each of these castings is a bearing casting having a spherical top surface of 1′-5 3/4" radius. Also, at two points in the length of each pair of loading girders, so located as to come directly over the eight bearing castings mentioned above, the loading girders are connected by similar diaphragm or loading castings with a concave spherical surface at the bottom with a 1′-6" radius that fits over the top of the bearing castings below. Thus the load of the span is transmitted to the drum frame through eight articulated points of bearing.

Although the 525′ long swing span has operated for about sixty-eight years without major problems, it is no longer in accordance with modern functional needs. The Coast Guard, therefore, is planning to permanently close the Fort Madison swing span and replace its operation with a vertical lift span matching the existing trusses. Two of the existing fixed spans will be removed for this alteration. In addition, the navigation channel will be moved about 450′ toward the Illinois side of the river.[20] The longest and heaviest swing span ever built on the Mississippi River will thus remain in existence, but will no longer operate as designed.

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[20]Roger K. Wiebusch, bridge administrator, United States Coast Guard, St. Louis, MO to Lowell Soike, historian, Bureau of Historic Preservation, Des Moines, IA, 13 September 1994, a letter contained in the files of the State Historical Society of Iowa, Des Moines, IA.

APPENDIX
IMPLICATIONS FOR FURTHER RESEARCH

Several questions concerning the Fort Madison Bridge arose during the research and writing of this report. Some of these questions, due to limitations in the scope of the Iowa Historic Bridges Recording Project, have remained unanswered. It is suggested that scholars interested in this bridge consider pursuing the following:

1. Why did the railroad build a swing span instead of a vertical lift bridge?
2 What is the history of Union Bridge and Construction Company?
3. How was the overall cost divided between superstructure cost and substructure cost?
4. Who was A.F. Robinson?

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This appendix is an addendum to a 14-page report previously transmitted to the Library of Congress.

APPENDIX: ADDITIONAL REFERENCES

Interested readers may consult the Historical Overview of Iowa Bridges, HAER No. IA-88: "This historical overview of bridges in Iowa was prepared as part of Iowa Historic Bridges Recording Project - I and II, conducted during the summers of 1995 and 1996 by the Historic American Engineering Record (HAER). The purpose of the overview was to provide a unified historical context for the bridges involved in the recording projects."