Construction of the Eads Bridge

Margaret L. McGunegle
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“Science can do anything, however tremendous, if it has enough money.”

- James B. Eads
Purpose

To provide the class with an overview of the Eads Bridge to include its history, design, and construction.
References


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Outline

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Bridge Information

- Engineered and constructed by James B. Eads
- Built from 1867 to 1874 at a cost of $6 million ($12 million including land, tunnels, debt, and approaches)
- Oldest standing bridge across the Mississippi and one of the first
- Spans: 502, 520, and 502 feet
- Materials:
  - Steel: 2,390 tons
  - Wrought Iron: 3,156 tons
  - Timber Decking: 806 tons
  - Stone Masonry (limestone): 97,571 cubic yards
Engineering Innovations

- Largest bridge constructed at the time
- First major use of structural steel
- Use of cantilever support for superstructure
- First significant underwater use of compressed air in the United States
- Largest and deepest caissons used to date
- A variety of new mechanical inventions including the sand pump
James B. Eads

- Born on 23 May 1820 in Indiana
- Family moved to St. Louis in 1833
- In 1844, Eads began his own Mississippi River salvage business
- He taught himself engineering and designed his own salvage ships and diving bell
- Built ironclads for the Union during the Civil War
- Suffered from ill health, probably from his diving excursions, and took convalescent trips to Europe
- Engineered jetties for the Mississippi River Delta
- Proposed a huge ship-railway system across the Isthmus of Tehauntepec, Mexico
- Married twice with one daughter and three stepdaughters
- Died 08 March 1889 in the Bahamas
The Problem  (1 of 2)

- Railroads began to overtake rivers and canals as the preferred transportation of commerce
- Rapid expansion of Illinois and Chicago railroad lines
The Problem (2 of 2)

- Chicago railroads bridged the Mississippi at Rock Island with plans to bridge at Dubuque, Burlington, and Quincy
- Chicago rail moved deep into Saint Louis’ Trade Region
- Chicago’s population soared while Saint Louis’ stalled
The Solution (1 of 2)

- By 1866, civic and financial leaders of Saint Louis demanded a bridge to connect the five eastern and three western railroads near the city.
- The St. Louis and Illinois Bridge Company secured state and federal authorization to bridge the river.
- Early designs included:
  - A suspension-arch from John Roebling
  - A tunnel from the Mississippi Submerged Tubular Bridge Company
  - A lattice-girder truss with six piers from the Illinois and St. Louis Bridge Company
- The Illinois and St. Louis Bridge Company, led by Chicago capitalist Lucius Boomer, received the exclusive rights to build from Illinois side.
The Solution (2 of 2)

- Railroad financiers did not share the city’s enthusiasm because many were from Chicago.
- Steamboat men objected because it would cut into their commerce and add an obstruction to the river.
- Political opponents passed a Congressional Bill in 1865 which would require the bridge to have 500 ft spans and have a clearance of 50 ft above the City Directrix, the local survey base line.
- James B. Eads originally was not interested, but did not want the bridge’s control to fall into Chicago’s hands.
- Eads teamed up with the St. Louis and Illinois Bridge Company.
- Eads began circulating designs and became the company’s director by May 1867.
Bridge Design (1 of 2)

Eads was inspired by the Koblenz Bridge in Germany

- Eads design called for 3 steel arches supported by masonry abutments and piers
- Supports extend to bedrock for stability
Original design placed rail deck below the arches and included architectural accents.
Bridge Supports  (1 of 2)

• Constructed of limestone masonry
• The original plan called for the use of coffer dams to place all the supports
• Coffer dam for west abutment started in August 1867; cornerstone laid on 25 February 1868
• Masonry from bedrock: 113ft
Bridge Supports (1 of 2)

Air Lock

• In 1869, Eads discovered the *plenum pneumatic* method, excavating in caissons, while convalescing in Europe

• He brought it to Saint Louis to use on the remaining abutment and piers
Building the Piers *  (1 of 6)

1 of 6 – Builders construct a watertight caisson, over fifty feet long and nine feet high. It is made of oak timbers and covered with plate iron. Contained within the caisson are three open-bottomed air chambers that allow the structure to act as a diving bell – a technology Eads used while salvaging wrecks in the Mississippi.

* Taken from PBS American Experience, “Secrets of a Master Builder”
Building the Piers (2 of 6)

2 of 6 – To sink the caisson, seventeen-ton blocks are placed atop its roof. Wooden pilings guide its descent, and a passageway is left in the middle for stairs. Two 215-foot workboats are used to support the machinery and maneuver the blocks into place.
Building the Piers (3 of 6)

3 of 6 – Once the caisson reaches the sand, men enter the air chambers through the air locks and begin to excavate the riverbed, shoveling sand into a sand pump that suctions it up through a shaft and out through an opening at the top of the structure. Compressed air is pumped into the chamber to keep water out – the deeper the caisson sinks, the greater the air pressure needed.
Building the Piers (4 of 6)

The increased air pressure in the air chambers makes it difficult for the men to work. Many develop what is known as caisson disease, or the bends, which is an accumulation of nitrogen gas in the body. Sufferers experience dizziness, coughing, and in extreme cases, death. To prevent the disease, a worker should decompress two hours for every two hours he works at a depth of 100 feet. At first, workers spend only a few minutes in the air lock. Of the 119 who suffer from the disease, 14 die.
5 of 6 – Signs of bedrock reveal that the excavation is nearly complete. The caisson rests on the bedrock and serves as the foundation of the mighty pier. To fortify this foundation, the air chamber is filled with concrete and, as the men ascend to the surface, the core is filled behind them.
Building the Piers (6 of 6)

6 of 6 – The construction of the east and west piers, which descend over 100-feet below the surface of the Mississippi, takes seven months, 600 workers, and 40,000 tons of concrete. The St. Louis Bridge establishes James Eads as one of the most successful engineers of his time.
Caissons (1 of 2)

Derricks and Pontoons for the East Pier

Construction of east pier began on 17 October 1869; reached bedrock on 28 February 1870; masonry to bedrock: 193 ft

Plan View of Derricks and Pontoons

Construction of west pier began in early 1870; Reached bedrock 01 April 1870; masonry to bedrock: 172 ft
Caissons \(^{(2 \text{ of 2})}\)

- Eads’ caissons became a popular tourist attraction for Saint Louis society
- By this time, the competing bridge companies had settled their differences and merged
- Construction of east abutment began on 3 November 1871; reached bedrock in April 1871; masonry to bedrock: 197 ft
- The east abutment included an elevator and a floating hospital to treat workers with Caisson Disease
Problems with Iron and Steel (1 of 2)

• Metal manufacturing lacked any standards in the 1870s
• Keystone Bridge Company received contract to build superstructure
• Butcher Steel Company awarded contract for steel parts and Kloman Carnegie received contract for iron parts
• Butcher’s carbon steel failed all of Eads’ test so Eads used chrome steel instead
• In reality, amounts of chrome varied greatly in the steel pieces
• The improvement in quality is probably more linked to experience and acceptance of Eads’ exacting standards
Problems with Iron and Steel (2 of 2)

- Eads inspectors rejected iron sample braces from Kloman Carnegie
- A compromise was made when Eads lowered the tensile requirements and Kloman Carnegie improved quality control
- Keystone could not produce steel couplings without bubbles or internal flaws
- Eads had to resort to wrought iron couplings
- Metallurgical problems delayed bridge construction for at least two years
- Eads Bridge ended up being more than half wrought iron
Superstructure (1 of 4)

Superstructure
Connection to Masonry

Cross-Section of Pier
Superstructure (2 of 4)

Details of Steel Ribs

- A thin steel envelope bound the six steel staves together into a twelve foot rib
- Each end of the ribs was cut at a slight angle to make an arch
Superstructure (3 of 4)

Assembled Ribs Showing Couplings and Braces

Detail of Rib Joint with Coupling and Braces

Up Close of Joint
Superstructure (4 of 4)

West Abutment Train Tunnel

Road Deck Support
Erecting the Superstructure (1 of 3)

- Henry Flad, assistant engineer, devised a method of using cantilevers to construct the superstructure to keep the river clear of falseworks.
- Boatmen tried to stop construction of the arches in conjunction with Secretary of War Belknap and General A. A. Humphreys, Chief of the Corps of Engineers.
- Eads appealed to his friend, President Grant, who ordered Belknap to drop the case.
Erecting the Superstructure (2 of 3)

- Eads developed double threaded coupling to close the west span
- Flad attempted to close arches by packing them in ice, but had to resort to Eads’ coupling
Erecting the Superstructure (3 of 3)

Building the Road and Rail Decks – Spring 1874
Completion and Opening

- Decks finished on 15 April 1874, but Keystone refused to open bridge before it received a payment bonus.
- On 24 May, the city opened the sidewalks to pedestrians.
- On 03 June, the road deck was opened to vehicles.
- Grand-opening ceremony was a part of the 4th of July festivities.
History of Use (1 of 7)

Saint Louis -1874

- Bridge never lived up to its expectations
- Coordination was never made to connect major rail lines to bridge
- Bridge went bankrupt within a year and was sold in December 1878 for $2 million
History of Use (2 of 7)

• Rail traffic ceased on the bridge in 1974
• Vehicular traffic stopped in 1991
• Illinois side removed approach

Saint Louis - 1890

Eads Bridge – 1993 (note approach on east bank)
History of Use (3 of 7)

Saint Louis’ light rail system began to use rail deck and attached tunnels in 1993.
History of Use (4 of 7)

The bridge survived numerous floods.

Saint Louis - 1993

Saint Louis - 1994
History of Use (5 of 7)

The bridge continued to fall into disrepair and neglect.

Deterioration of Abutment Masonry

Rusting Toll Booth
Reopening Celebration

- Saint Louis lobbied for support and the bridge is now a protected National Landmark
- $25 million dollar restoration project began in late 1990s
- Bridge reopened during the 2003 4th of July festivities to pedestrian and vehicle traffic
Future Bridge in Saint Louis: estimated cost - $1 billion, estimated completion - 2010
Summary

• The events leading up to the construction of the Eads bridge
• The design and construction of the bridge’s supports and superstructure
• Obstacles and delays during construction
• The history of the bridge since its completion
Questions?
“Must we admit that because a thing never has been done, it never can be?”

- James B. Eads