HISTORIC AMERICAN ENGINEERING RECORD

PITTSBURGH & LAKE ERIE RAILROAD, OHIO RIVER BRIDGE
(Beaver Bridge)

HAER No. PA-510

Location:	Spanning Ohio River, west of Beaver River, Beaver, Beaver County, Pennsylvania.
USGS Quadrangle:	Beaver, Pennsylvania (7.5-minute series).
UTM Coordinates:	17/559875/4504710
Date of Construction:	March 1908 to May 1910.
Basis for Dating:	Secondary sources.
Designers:	A. R. Raymer (Assistant Chief Engineer, Pittsburgh & Lake Erie Railroad); Albert Lucius (consulting engineer, New York); Paul L. Wolfel (Chief Engineer, McClintic-Marshall Construction Co.).
Fabricator:	McClintic-Marshall Construction Co. (Pittsburgh).
Builders:	Dravo Contracting Co. (Pittsburgh), substructure; McClintic-Marshall Construction Co. (Pittsburgh), superstructure.
Present Owner:	CSX Transportation.
Present Use:	Railroad bridge.
Structure Types:	Pin-connected cantilever through truss with suspended span; pin-connected subdivided camelback through truss.
Significance:	The Beaver Bridge is significant for its relatively long and heavy cantilever truss, planned shortly before the Quebec cantilever bridge collapse of 1907. Rather than select a different design, the railroad proceeded, implementing design checks and strict quality control procedures. Despite a conservative overall design, the Beaver Bridge includes a number of innovative structural details. The substructure is also significant for its early use of concrete pier caissons.
Historian:	Justin M. Spivey, April 2001.

Project Information: The Historic American Engineering Record (HAER) conducted the Pennsylvania Historic Railroad Bridges Recording Project during 1999 and 2000, under the direction of Eric N. DeLony, Chief. The project was supported by the Consolidated Rail Corporation (Conrail) and a grant from the Pennsylvania Historical and Museum Commission (PHMC). Justin M. Spivey, HAER engineer, researched and wrote the final reports. Preston M. Thayer, historian, Fredericksburg, Virginia, conducted preliminary research under contract. Jet Lowe, HAER photographer, and Joseph E. B. Elliott, contract photographer, Sellersville, Pennsylvania, produced large-format photographs.

Description and History

The Pittsburgh & Lake Erie Railroad (P&LE) was incorporated in 1875 by Pittsburgh investors seeking to compete with other lines serving northeastern Ohio. The railroad never reached its namesake destination, terminating instead at Youngstown. P&LE historian Harold H. McLean called it "an essentially local enterprise," noting that major trunk lines were hesitant to add more tracks into Pittsburgh after the financial panic of 1873.[1] Another account by Michael Bezilla, however, states that the New York Central Railroad (NYC) invested heavily in the new company and acquired a controlling interest by 1889. Nonetheless, P&LE remained a "semi-autonomous subsidiary" until 1979, when NYC successor Conrail dropped the route. P&LE existed as an independent railroad for just over a decade, although deeply affected by the decline of Pittsburgh's steel industry.[2] CSX Transportation acquired the route in 1991, and presently operates it as a freight line.

The most outstanding structure on the P&LE main line has always been the Ohio River crossing, popularly known as the Beaver Bridge. The railroad follows the Ohio River out of Pittsburgh, traveling on the southwest bank. At Monaca, it crosses the Ohio into the city of Beaver and continues up the west bank of the Beaver River toward New Castle. P&LE acquired former Pennsylvania & Ohio Canal right-of-way for most of this route, which must have simplified grading work.[3] The bridge across the wide Ohio River, just downstream of its turbulent confluence with the Beaver River, was probably the greatest challenge of the original construction campaign. The first structure at this location was a single-track wrought-iron bridge designed and built in 1878 by the Philadelphia Bridge Works (a firm also known by the surnames of its proprietors, Joseph H. Cofrode and Francis H. Saylor). The main channel span was a double-intersection Pratt through truss 442'-9" long between end bearings.[4]

After adding a second track to its main line, P&LE contracted for new trusses on the existing piers around 1890. The piers were not wide enough for a two-track superstructure, so the replacement bridge carried a single gauntlet track. This arrangement did not suffice long into the twentieth century, as increasing traffic soon justified a four-track main line. P&LE began designing a new bridge with two pairs of gauntlet tracks, on an alignment 300'-0" upstream from

the old bridge.[5] The change in location required permission from the U.S. War Department, which had jurisdiction over navigable waterways. Approval was contingent upon the railroad providing a 700'-0" clear channel for shipping.[6] Taking a slight skew and pier protection into account, the main span would have to be 769'-0" long. This was beyond the capabilities of any simple truss design, but within the range of a cantilever, which uses structural continuity over the piers to distribute loads to adjacent spans called anchor arms (see Figure 1).

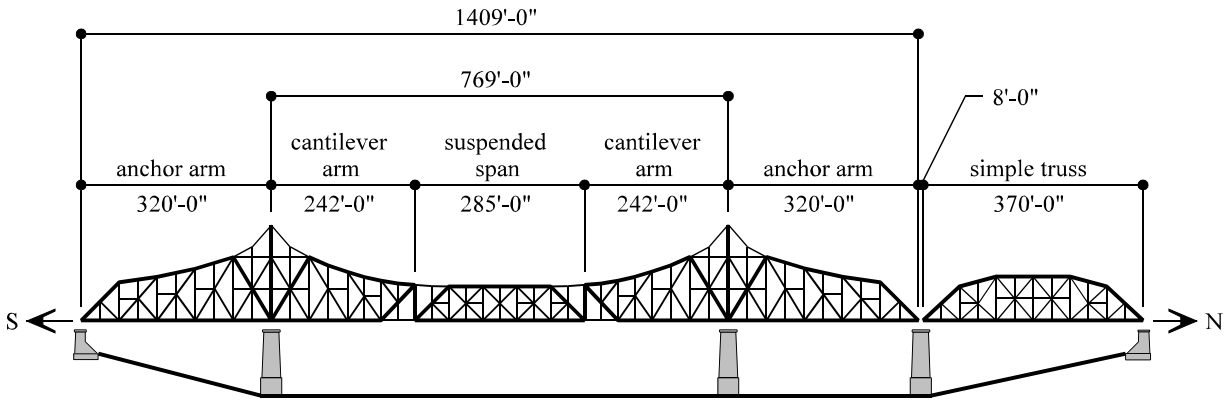

Figure 1. East elevation of Beaver Bridge. Sketch by author.

The railroad announced its plan to construct a cantilever bridge in July 1907, news which was temporarily eclipsed by the infamous Quebec Bridge disaster.[7] What would have been the world's longest cantilever span across the St. Lawrence River at Quebec collapsed during construction on 29 August of that year. The incident not only cast doubt on the Phoenix Bridge Co.'s engineers and ended the career of consultant Theodore Cooper, who had double-checked the design, but also raised suspicions about the cantilever form itself. As noted by engineering historian Henry Petroski, "no other major cantilever bridge would be completed until the 1930s."[8] Despite the P&LE bridge's impressive size among its counterparts on the Ohio River, the proposed 769'-0" main span was less than half of the Quebec Bridge's 1,800'-0". Instead of abandoning its plan, the railroad proceeded with confidence tempered by strict attention to details.

After the Canadian government investigated the Quebec disaster and it ceased to be a news item, the engineering press paid significant attention to progress of the Beaver Bridge project. Its designers had discarded all previous assumptions, reported *Engineering Record,* instead of "simply enlarging a smaller structure and adopting characteristics unsuitable for the changed conditions."[9] This may have been intended as a subtle reference to the doomed Quebec span, the weight of which had been underestimated by 4,000 tons. P&LE's consultants wanted not only to distance their design from the Quebec disaster, but also to break new ground in bridge construction. A series of thirteen articles in *Engineering Record* described innovative features of the Beaver Bridge's design and erection procedure. Readers learned about the pioneering use of unreinforced concrete caissons for the tower piers, the design of reusable erection equipment, the

invention of a wedge bearing to prevent "hammering" of the anchor arms, special tapered rivets, and a novel traveling crane that avoided the "enormous erection stresses" that plagued previous cantilever bridges.[10] The word "Quebec" was not used even once.

In his history of the P&LE, McLean states that the Beaver Bridge is considered the greatest work of German-born consulting engineer Albert Lucius.[11] Lucius came to the U.S. in 1865 and, after working for the Phoenix Bridge Co., established his own consulting practice in New York in 1886. He created the preliminary design, performed stress calculations, and developed typical details, giving the Beaver Bridge its basic shape. Loath to repeat his former employer's mistakes in Quebec, his design is simple, conservative, and relatively heavy. Bridge historian David Plowden emphasizes Lucius's somewhat retarditaire use of eye-bars and pinned connections to create a statically determinate, and therefore easy to calculate, design.[12] To further protect its reputation, however, P&LE required the superstructure contractor to accept all responsibility for the final design and submit shop drawings for Lucius's approval. The successful bidder, Pittsburgh-based McClintic-Marshall Construction Co., designed the individual members and devised the erection procedure, with Lucius double-checking their work.[13] Paul L. Wolfel, Chief Engineer for McClintic-Marshall, and his staff therefore deserve a share of the credit. A number of outstanding details reported in *Engineering Record* — such as custom-built erection equipment and "remarkably accessible" rivets in splice connections — were in fact outside Lucius's scope of work.[14]

The Beaver Bridge's significance lies not only in the length and weight of the cantilever truss, but also in P&LE's decision to proceed with construction after the Quebec disaster. Despite a conservative overall design, the bridge includes a number of innovative structural details devised by Lucius and Wolfel. Through strict specifications, design checks, and materials testing, P&LE Assistant Chief Engineer A. R. Raymer maintained quality control and ensured the project's success.

Notes

1. Harold H. McLean, *Pittsburgh & Lake Erie* (San Marino, Calif.: Golden West Books, 1908), 18, 20.

2. Michael Bezilla, "Pittsburgh & Lake Erie Railroad," in *Encyclopedia of American Business History and Biography: Railroads in the Age of Regulation, 1900-1980,* edited by Keith L. Bryant, Jr. (New York: Facts on File, 1988), 349-50.

3. Thomas T. Taber III, *Railroads of Pennsylvania: Encyclopedia and Atlas* (Muncy, Pa.: Thomas T. Taber III, 1987), 436.

4. "Note on Bridge Erection — Pittsburgh and Lake Erie R. R.," *Proceedings of the Engineers' Club of Philadelphia* 1, No. 1 (Jan. 1879): 85. A company advertisement cites the overall length of 446'-0"; see *Railroad Gazette* 22, No. 23 (6 June 1890): xliv.

5. A. R. Raymer, "The Substructure of the Pittsburgh & Lake Erie Railroad Bridge over the Ohio River at Beaver," *Proceedings of the Engineering Society of Western Pennsylvania* 26 (1910): 1.

6. "The Pittsburgh & Lake Erie Cantilever Bridge over the Ohio River at Beaver," *Engineering Record* 63, No. 4 (28 Jan. 1911): 92.

7. "Railway Bridges," *Railway Age* 44, No. 1 (5 July 1907): 30.

8. Henry Petroski, *Engineers of Dreams: Great Bridge Builders and the Spanning of America* (New York: Alfred A. Knopf, 1995), 111.

9. *Engineering Record,* "The Pittsburgh & Lake Erie Cantilever Bridge," 92.

10. The *Engineering Record* articles are, in order:
"Construction of the Beaver Bridge Piers," *ER* 60, No. 11 (11 Sep. 1909): 299-300,
"The Beaver Bridge Piers," *ER* 62, No. 21 (19 Nov. 1910): 574-76,
"The Pittsburgh & Lake Erie Cantilever Bridge over the Ohio River at Beaver," op. cit.,
"The Beaver Bridge Main Post and Rocker Bearing," *ER* 63, No. 8 (25 Feb. 1911): 226-27,
"The Bottom Chords of the Beaver Bridge," *ER* 63, No. 10 (11 Mar. 1911): 273-75,
"The Truss Members of the Beaver Bridge," *ER* 63, No. 12 (25 Mar. 1911): 336-38,
"Anchor Pier Bearings and Typical Connections, Beaver Bridge," *ER* 63, No. 6 (22 Apr. 1911): 450-53,
"The Suspended Span of the Beaver Bridge," *ER* 63, No. 18 (6 May 1911): 506-07,
"The Expansion Connections of the Beaver Bridge," *ER* 63, No. 20 (20 May 1911): 562-64,
"The Erection of the Anchor Arm of the Beaver Bridge," *ER* 63, No. 22 (3 June 1911): 615-19,
"The Erection Adjustments of the Beaver Bridge," *ER* 63, No. 23 (10 June 1911): 650-52,
"The Erection Travelers Used in Erecting the Beaver Bridge," *ER* 63, No. 25 (24 June 1911): 704-06, and
"The Erection of the Cantilever Arm of the Beaver Bridge," *ER* 64, No. 1 (1 July 1911): 22-24.

11. McLean, *Pittsburgh & Lake Erie,* 73.

12. David Plowden, *Bridges: The Spans of North America* (New York: Norton, 1974), 176.

13. *Engineering Record,* "The Pittsburgh & Lake Erie Cantilever Bridge," 93. This is more likely than the joint responsibility suggested by Richard Cook in *The Beauty of Railroad Bridges in North America, Then and Now* (San Marino, Calif.: Golden West Books, 1987), 76.

14. Quote from *Engineering Record,* "The Erection of the Cantilever Arm," 24.

Acknowledgment

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Additional Sources

1. Frank W. Skinner, "The Beaver Bridge over the Ohio River," *Engineering* (London) 95, No. 2454 (10 Jan. 1913): 41-44; No. 2455 (17 Jan. 1913): 78-82; No. 2457 (31 Jan. 1913): 146-49; No. 2460 (21 Feb. 1913): 249-50; No. 2465 (28 Mar. 1913): 421; No. 2467 (11 Apr. 1913): 489-90; No. 2469 (25 Apr. 1913): 556-60; and No. 2472 (16 May 1913): 657-61, contains many of the same details in the *Engineering Record* articles.

2. Joseph White and M. W. von Bernewitz, *The Bridges of Pittsburgh,* 1st ed. (Pittsburgh: Cramer Printing & Publishing Co., 1928), 78.