WASHINGTON STATE CANTILEVER BRIDGES
Washington State Historic Bridges
Olympia
Thurston County
Washington

HAER No. WA-106

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HISTORIC AMERICAN ENGINEERING RECORD

WASHINGTON STATE CANTILEVER BRIDGES
1927-1941

HAER No. WA-106

Olympia, Thurston County

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Since the turn of the century, the steel cantilever truss bridge has played a significant role in spanning wide or treacherous water crossings in the state of Washington. Its very form is important: where steel truss anchor arms connected to points on the shore support truss panels projecting or cantilevering outward from piers over the water. These cantilever arms, in turn, were either connected at mid-span or more commonly supported or suspended a simple truss between them.

The seven bridges included in this study and in individual reports are either one-of-a-kind structures, or representative of types used in the state of Washington during a particular period. All but two span the Columbia River, or major streams that make up the Columbia River system, whose drainage includes eastern Washington, Northern and central Idaho, southeastern Oregon, western Montana, and southeastern British Columbia. The bridges are: the Snake River Bridge at Lyons Ferry (1927 and 1968), HAER No. WA-88; the Longview Bridge (1930), HAER No. WA-89; the Aurora Avenue Bridge (1932), HAER No. WA-107; the Deception Pass Bridge (1935), HAER No. WA-103; the Columbia River Bridge at Grand Coulee Dam (1935), HAER No. WA-102; the Columbia River Bridge at Kettle Falls (1941), HAER No. WA-91; and the Spokane River Bridge at Fort Spokane (1941), HAER No. WA-113.

In the late nineteenth century, the steel cantilever truss bridge became a standard design type favored by railroads because of its capability to span much greater distances than simple trusses and consequently reducing the need for costly piers. Cantilevers are advantageous for deep gorges or wide, fast-flowing rivers where scaffolding is impossible to build. But Carl Condit, a noted engineering history authority, believed that late-nineteenth-century American steel cantilever truss bridges were "the ugliest examples of pure empirical forms at the time." They had evolved to the point in 1935 that he "ranked [them] among the handsomest of all bridges."[1]

The Snake River Bridge at Lyons Ferry is a good example of early twentieth-century steel through cantilever design with sloped top and bottom chords. It looks like an amalgam of several spans with its suspended Parker truss at mid-stream presenting a definite break in structural form from the heavily-braced anchor and cantilever spans. The bridge's original site was near Vantage, where the North Central Highway met ferry landings on the Columbia after dropping down to the river elevation from the high surrounding plateau. The river at this point was 2,500' wide at high water and 800' wide at low water, with a swift 55' deep channel. Combined with marginal pier foundations, these conditions necessitated building a structure consisting of many short approach spans with several bents to disperse dead load, and a long cantilevered mid-section to avoid costly and impracticable falsework for arch spans.[2]

The Washington Department of Highways-designed steel anchor spans and cantilever spans have sloped top and bottom chords for structural balance. This arrangement, instead of a horizontal bottom chord, also permitted using shorter main piers, reducing the amount of concrete needed but still achieving a 70' clearance at mid-channel for shipping traffic on the river. The suspended span is connected to the cantilevers through sliding joints, in part used during erection and later to provide for structural expansion and contraction due to temperature changes and live load. The contractor, Kuckenberg-Wittman Company of Portland, bid $628,496.25 to build the carbon steel main spans and approaches.[3]

The Washington Department of Highways dismantled the bridge in the early 1960s to make way for rising waters behind Wanapum Dam on the Columbia. It re-erected the steel portions at Lyons Ferry, on the Snake River, in 1968, where rising waters behind Lower Monumental Dam made the stream-powered ferry impracticable. New piers, road deck, and safety barriers were the only modification made to the bridge while maintaining its historical and structural integrity.

Washington's next cantilever structure was the Longview Bridge built in the late 1920s on the lower Columbia River. The Strauss Engineering Corporation of Chicago, Illinois, completed plans for the bridge, spanning between Longview, Washington, and Rainier, Oregon, in 1927. The design complied with a federal permit stipulating that the bridge be built to accommodate a clear channel width of 1,000'. In addition, it gave a 185' minimum vertical clearance at the channel piers and 195' at mid-span. The structure's extremely long and tall cantilevered portion and unusually long anchor arms were required to comply with the permit's order to construct only one pier between the main channel and the Longview pier-head line. This was because Longview's nearby commercial rival, Portland, Oregon, wished to halt construction of any bridge over the Columbia at Longview to prevent consumers from shopping there instead of Portland. It petitioned the federal government to set unrealistic height and width requirements for the approved design with hopes that the bridge would be too costly to construct. Entrepreneurs built it anyway.[4]

The Longview Bridge was a record-setting structure. The 1,200' central section was the longest of any cantilever in North America. Its closest competitors at the time of construction were the Strauss-designed Montreal South Shore Bridge in Montreal, Quebec, Canada, with its 1,000' cantilevered section; and the Monongahela River Bridge in Pittsburgh, Pennsylvania, with its 812' cantilevered section.[5]

On 5 June 1929, the first steel was placed on the Oregon side. The last rivet on the bridge was driven on 7 March 1930. Concrete paving on the cantilevered and suspended spans was poured shortly thereafter and the bridge opened for traffic on the 29th. Joseph Strauss's design called for 12,500 tons of structural silicon steel. Bethlehem Steel fabricated 6,000 tons at its mill in Steelton, Pennsylvania. The Wallace Bridge and Structural Steel Company supplied the remainder of the order. Built-up sections with lacing were used on all main members: rocker bents, towers, trusses, of the main and side spans. The unit working stresses he adopted were 24,000 pounds per square inch (psi) in tension and 22,500-75 l/r in compression. Ordinary structural carbon steel used throughout the rest of the structure had unit working stresses of 16,000 psi in tension and 15,000-50 l/r in compression.[6]

Another long span bridge was completed shortly after the Longview Bridge. Three design choices and four locations were narrowed to a long deck-cantilever structure on Aurora Avenue in Seattle. All of them involved spanning the long, wide lowlands of the lake and canal northeast of Queen Anne Hill. Looking for efficiency and economy in design, consulting engineers Jacobs and Ober decided between the simple truss, the suspension, and the cantilever forms. The simple truss was the least expensive for moderate length structures, but the cantilever was more economical in longer bridges. A suspension span was seriously considered for the Aurora Avenue crossing, but poor foundations made it a costly alternative.[7]

Jacobs and Ober drafted plans for a nearly 2,955' structure with a 800' steel deck-cantilever span. The Department of War approved its shipping clearance, a point of contention among some captains of high-masted vessels. But the day of the tall ships had passed and the specifications were set at a minimum 135' over a 150' main channel. Soon construction began on the $4.5 million bridge.[8]

The bridge was completed by early 1932, with only the roadway approaches of a newly realigned Aurora Avenue yet to finish. The Aurora Avenue Bridge became the second longest cantilever in the state, outdistanced only by the Longview Bridge, completed in 1930, on the lower Columbia River (HAER No. WA-89).

The Washington Department of Highways constructed many steel truss bridges in the 1920s, 30s, and 40s. They all conformed to an evolving set of standardized plans that the agency created in the 1920s and periodically updated with improved rolled sections and other components that kept the bridges efficient and cost-effective. In 1935, it designed and built two 950′ steel cantilever structures, a deck truss over Deception Pass in Puget Sound and a through truss over the Columbia River at the site of Grand Coulee Dam.

Striking similarities exist between the Deception Pass Bridge and the Grand Coulee structure. The dimensions of their cantilever arms and suspended spans are identical and total 550′. Even though the Grand Coulee Dam bridge is a through truss and the Deception Pass Bridge is a deck truss, their bracing patterns were quite similar, if not identical. Both have sloping bottom chords, but the Grand Coulee's becomes horizontal under the suspended section, while the Deception Pass's continues its taper to mid-span. Washington Department of Highways engineer O. R. Elwell designed the Deception Pass Bridge, while the Grand Coulee Bridge was a collaborative effort between R. W. Finke (Washington Department of Highways) and A. F. Walter and H. R. McBirney, engineers for the Bureau of Reclamation. Both bridges were designed with an H-15 load rating prescribed by the American Association of State Highway Officials for most structures on primary roads. The Grand Coulee Dam bridge, though, has a floor and floor framing strengthened to an H-20 rating to safely accommodate heavy construction equipment.[9]

The Grand Coulee Bridge was erected 3,000′ down river from the dam site and connected the United States Bureau of Reclamation's "Engineers' Town," on the river's west side, with the civilian contractor's employee town, Mason City, to the east. It served an important role in the Grand Coulee Dam's construction by carrying truck traffic associated with the project. Later, after the dam's completion, the bridge and the adjoining road became part of the state's improved highway system.[10]

The Washington Department of Highways chose the cantilever structure over other options, including steel or reinforced-concrete arches or steel through trusses, at Grand Coulee Dam and other locations on the Columbia River system because it was the most prudent alternative given the geology. For many Columbia

River crossings, other designs were less economical to construct. The broad, deep main channels of the river made the falsework arches costly. At Grand Coulee Dam, the stream's width, over 600', necessitated a series of at least two deck or through arches, with one or more heavy piers to counter thrust. A series of simple through or deck truss spans also required several piers in the channel, where excavation to firm foundations was costly and time consuming. A prime objective in constructing the Grand Coulee bridge was to erect it in a timely manner so that the Grand Coulee Dam project could use it. The chosen design, with its 950' steel section rested on two stepped concrete piers founded near the edges of the Columbia River's channel.

The Deception Pass Bridge and the nearby Canoe Pass Bridge (HAER No. WA-104), a steel deck arch, are surrounded by steep cliffs of Whidbey Island and Pass Island, which split the ship passage into Deception Pass and Canoe Pass. Treacherous swirling currents, combined with Deception Pass's width made an arch similar to the Canoe Pass bridge impracticable. A structure that was compatible with the steel arch and provided a sense of continuity for the crossings was necessary. The best design alternative given concerns for aesthetics, economics, and engineering efficiency made a deck truss cantilever the best choice for the location.

For both the Grand Coulee and Deception Pass cantilever structures, all major members, upper and lower chords, vertical posts, diagonals, deck beams, and top struts were constructed of pairs of built-up channel and strap lattice to form light-weight members. Lesser components similarly consist of angle steel connected by a lattice web. The suspended spans' configuration was a simple Warren truss.[11]

As much silicon steel as possible was included in the bridges' design because of its working stress of 24,000 psi, compared to carbon steel with its working stress of 18,000 psi, gave it greater capacity for the same member dimensions. All connections were riveted except where pins attached the anchor arms to anchorage shoes, where the suspended span met the cantilevered spans, and where the structure rested on the main piers. The four positions where the suspended span attached to the cantilevers were pinned with allowance for structural expansion and contraction. The lower connections, however, were fitted with shear locks to prevent transverse motion.[12]

Truss bridge construction in Washington had evolved a bit from 1935 to 1940. Several simple truss spans and two larger steel cantilever structures, the Columbia River Bridge at Kettle Falls and the Spokane River Bridge at Fort Spokane, all show this with liberal use of economically-produced punch plate in diagonal bracing and aesthetically-pleasing curved portal and overhead bracing.[13]

The Columbia River Bridge at Kettle Falls with its 600′ steel-truss cantilevered and suspended structure has the longest central span of any highway bridge built in the state of Washington in the 1940s. The U.S. Bureau of Reclamation financed construction of this structure and the Spokane River Bridge at Fort Spokane as part of a highway relocation program in conjunction with the Grand Coulee Dam--Columbia Basin Reclamation Project. The dam's construction raised the Columbia River, creating the Franklin D. Roosevelt Lake. The reservoir's formation necessitated replacing the two highway bridges and one railroad structure.[14]

Because the Grand Coulee Dam construction was ahead of schedule, the Department of Highways and the Great Northern Railroad had to rapidly select and construct replacement bridges near Kettle Falls. The existing highway structure, a steel deck cantilever, had a truss depth of 90′ at its piers. But even with their taper at mid-span, the trusses were too low for the higher anticipated water level. Reusing the existing bridge by placing it on extended piers required creating longer and higher approach spans and embankments to reach the road deck. Compounding this was the need to maintain traffic access to the bridge because of its importance on the state's primary and secondary highway systems. The solution was to build a new, parallel structure and demolish the 1929 bridge at its completion.[15]

The design for the riveted steel truss portion of the bridge proved cost-effective. Its sloping bottom chords on the anchor and cantilever spans produced a savings in pier construction. Unlike the proposed remodelling of the 1929 bridge, the new structure's through-truss design provided necessary shipping clearance without extraordinary fill to keep the truss above the high water line. The 1941 bridge provided 45′ clearance from the anticipated mean water level of Lake Roosevelt, which was over 100′ higher than the naturally flowing Columbia River at this point.[16]

Unlike the Kettle Falls structure, with its sloped bottom chords on its cantilever and anchor arm spans, the Spokane River Bridge at Fort Spokane is truly a through truss with its bottom chords continuously horizontal. Close shoreline clearances did not permit using anchor arm trusses with sloped bottom chords. The Spokane River Bridge's design harkens back to the early twentieth century structures, with its cantilever and anchor arm top chords sloping downward from above the channel piers before connecting to the suspended span and anchor points. But its modified Warren truss panels are free from the cluttered appearance that intermediate bracing gave to those bridges and also falls in line with the Washington Department of Highways' mandate to produce sturdy, reliable, and economical bridges through standardized-plan--standardized-component methods.[17]

Specifications called for both much silicon steel in addition to carbon steel in the structure. Again, as with the Columbia River Bridge at Kettle Falls, the Department of Highways used rolled channels with riveted punch plates. Likewise, a curved lower member was employed in both the overhead and portal bracing. In addition to providing pleasing outlines, its shape gave additional rigidity because of the thrusting action of the arch to the verticals and inclined endposts, respectively. The floor system consists of I-beam construction.[18]

Cantilever bridge construction in Washington rings true to Carl Condit's comments on this design form. Advances in steel components and steel construction methods, along with changing ideas of aesthetics in truss bridge design, in general, caused an evolution in cantilever bridges in North America. One sees a progression in design form and advances in components in comparing the Vantage Ferry/Lyons Ferry and Longview bridges of the late 1920s with the Deception Pass and Grand Coulee Dam bridges of the mid-1930s with the Kettle Falls and Fort Spokane bridges of the 1940s, one sees a progression in Washington's cantilever bridge design. Furthermore, those cantilever highway bridges in the state that are no longer extant or are still in use but not part of the study bolster this argument. In sum, steel cantilever bridges were and are a significant part of Washington highway bridge history.

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NOTES

[1] Carl Condit, *American Building Art, the Nineteenth Century* (New York: Oxford University Press, 1960), 152-54; Condit, *American Building Art, the Twentieth Century* (New York: Oxford University Press, 1961), 104 (quote).

[2] Charles E. Andrew, "Recent Bridge Work of the Washington State Highway Department," *Western Construction News* 2 (10 March 1927): 30-31.

[3] Washington, Department of Highways, *Eleventh Biennial Report of the State Highway Engineer, 1924-1926*, 59-60; Andrew, "Recent Bridge Work of the Washington State Highway Department," 30-31; "Vantage Bridge, No. 7/201," Kardex Cards in "Snake River Bridge at Lyons Ferry, No. 261/125," Correspondence File, Bridge Preservation Section, Washington State Department of Transportation, Olympia, WA [WSDOT].

[4] "The 1,200-Ft. Cantilever Bridge at Longview, Wash.," *Engineering News-Record* 104 (15 May 1930): 804-06; "Cantilever Span One of Longest," *Longview Daily News*, Bridge Opening Edition, 29 March 1930.

[5] Ibid.

[6] "Here's Chronological Story of Bridge from Beginning," *Longview Daily News*, Bridge Opening Edition, 29 March 1930; "Longview-Rainier Interstate Bridge Over Columbia River," *Western Construction News* 4 (10 August 1929): 403; "The 1,200-Ft. Cantilever Bridge at Longview, Wash.," 805.

[7] T. G. McCrory, "Lake Union Bridge Completed," *Civil Engineering* 1 (September 1931): 1092-94; "Lake Union Bridge Provides New Traffic Ling in Seattle," *Engineering News-Record* 108 (3 March 1932): 313.

[8] McCrory, "Lake Union Bridge Completed," 1092-94; "Lake Union Bridge, Seattle, Washington," *Western Construction News*, (10 May 1930): 226-27; "Approval of Location and Plans of Bridge, September 1929," in "Aurora Avenue Bridge, No. 99/560," in Correspondence Files, Bridge Preservation Section, Washington State Department of Transportation, Olympia, WA [WSDOT].

[9] "Long Steel Bridges Added to Washington Highway System," *Engineering News-Record* 113 (25 October 1934): 519.

[10] Walter A. Averill, "Grand Coulee Low Dam," *Pacific Builder and Engineer* 40 (6 October 1934): 17.

[11] "Long Steel Bridges Added to Washington Highway System," 519; Department of the Interior, Bureau of Reclamation, *Columbia River Highway Bridge at Grand Coulee Dam: Schedules, Specifications, and Drawings* (Washington, DC: Government Printing Office, 1934), drawings 1-52; "Columbia River Bridge at Grand Coulee, No. 155/101," Kardex Card File, Bridge Preservation Section, WSDOT.

[12] "Long Steel Bridges Added to Washington Highway System," 519; Department of the Interior, Bureau of Reclamation, *Columbia River Highway Bridge at Grand Coulee Dam: Schedules, Specifications, and Drawings*, drawings 1-52.

[13] One extant example of the standard-plan truss bridge used by the Washington Department of Highways in the late 1930s and early 1940s is the Chehalis River Riverside Bridge, HAER No. WA-111.

[14] Department of the Interior, National Park Service, "National Register of Historic Places Nomination Form for the Columbia River Bridge at Kettle Falls, Ferry and Stevens counties, Washington," 1991, sec. 7, p. 1.

[15] Lewis Nullet and Joan Nullet, *A Brief History of Kettle Falls: the First Fifty Years* (n.p., 1992), 75-76.

[16] Ibid.

[17] "Spokane River Bridge at Fort Spokane, No. 25/6," Kardex Card File, Bridge Preservation Section, WSDOT.

[18] Nullet and Nullet, *A Brief History of Kettle Falls*, 75-76.