Historic Bridge Bulletin

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From the Director's Desk

"The beginning of wisdom is the definition of terms."
— Socrates

Lately, I've noticed that many people tend to refer to historic bridges as "old" bridges. I find myself reacting each time I hear that categorization, and I've been thinking about why I have such a negative response to the word.

We recognize that words can't change reality, but they can change how we perceive reality. The words we use to describe things, both to ourselves and others, influence how we think and act. In short, words have power.

Let's think about what the word "old" suggests when talking about a bridge—that the bridge in question is in a state of disrepair, run-down, ramshackle, rickety, unsound, or decayed, to name just a few synonyms. Now let's think about the word "historic" when describing a bridge—important, significant, notable, remarkable, celebrated. See the difference?

The language we speak impacts the way we perceive and categorize the world. Words have a dramatic effect on what we know and the decisions we make. Words change our relationships, our demeanor, our beliefs, and even our businesses. Consequently, simply uttering a single word like "old," sends a message that makes our jobs as preservationists that much harder.

So, for those of us who are bridge enthusiasts, I feel we have a responsibility to these engineering treasures by speaking about them with the respect they deserve. To refer to them as old demeans their importance to our history. Let's make sure we take time to refer to them as historic and just maybe we can help others recognize their true value.

Kitty Henderson
Executive Director

In This Issue:

The McMillin Bridge:
Preservation of a Unique Engineering Treasure

By Craig Holstine and Robert Krier

Recently a bridge demolition didn't occur as planned in Washington State. In fact a bridge was preserved, and the Historic Bridge Foundation (HBF) played a significant role in its preservation. And the Washington State DOT and US Army Corps of Engineers learned an important lesson: Never underestimate the power of consulting parties in the Section 106 process.

Actually the Corps knew very well the important role consulting parties play in compliance per 36CFR800.6(a), which is unequivocal in its requirement that agencies involve consulting parties in development of alternatives that "could avoid, minimize or mitigate adverse effects to historic properties." After WSDOT announced plans to build a new bridge over the Puyallup River on State Route 162 between the cities of Sumner and Orting, about 14 miles east of Tacoma, preservationists began objecting to the proposed demolition of the historic McMillin Bridge. Repeated requests from the fifteen Section 106 consulting parties (including HBF) for defensible justifications for removing the historic bridge prolonged the nearly seven-year consultation process. Eventually, in July 2015, WSDOT withdrew its application to the Corps for a demolition permit, allowing construction of the new bridge downstream from McMillin to proceed.

Robert Krier & Craig Holstine on the McMillin Bridge, with the new bridge at right, Oct. 23, 2015. *Photo by WSDOT.*

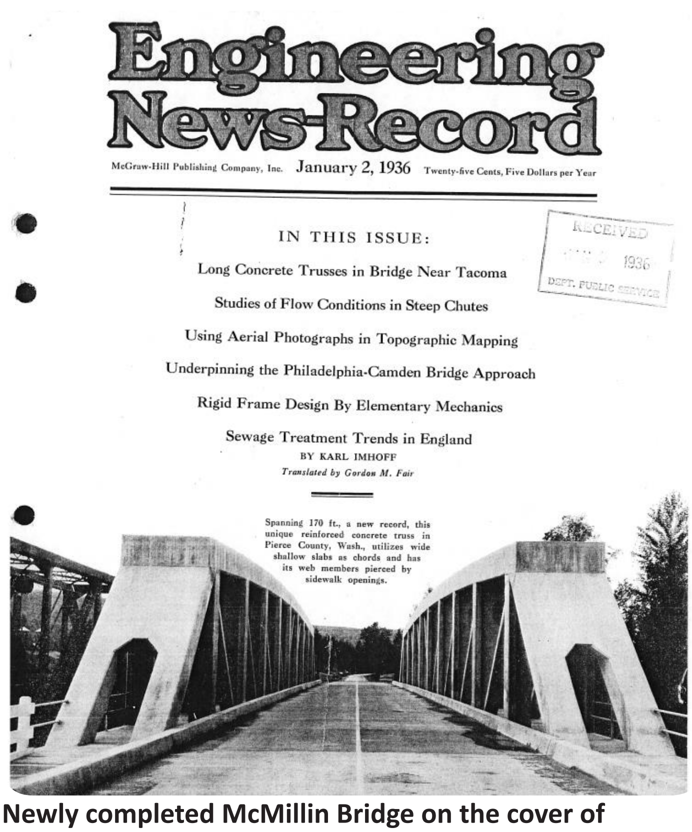
Today the NRHP-listed bridge stands where it was built over eight decades ago, accessible only to pedestrians from the nearby Foothills Trail. A steel through truss formerly on a branch line of the Northern Pacific Railway now carries the trail across the Puyallup River a few feet upstream of the McMillin Bridge. No interpretive signage has been installed that could attest to the McMillin Bridge's significant engineering features, nor to its famed inspirational designer. Not even its name appears anywhere on the landscape that would allow an Internet search to reveal its history. As if gazing on

Historic McMillin Bridge (left) and recently completed new bridge, Oct. 23, 2015. *Photo by WSDOT.*

Stonehenge, visitors are left to ponder the meaning of this structural curiosity.

Background

After flooding during the winter of 1933-34 undermined piers on a steel truss highway bridge across the Puyallup River near the small community of McMillin in rural Pierce County, Washington, county officials called for bids to replace the damaged structure. To the surprise of commissioners, one bid was for building a concrete through truss. At $826 less than the lowest of the six other bids proposing to construct a steel bridge, the low bid proposed building a bridge unlike any other in the world. Despite their likely skepticism at the wisdom of funding a bridge of unprecedented design, they awarded a contract for $35,912 to Dolph Jones of Tacoma. Given the complexity of construction, requiring special concrete mixes and complicated pouring sequences, it seems unlikely that Mr. Jones profited from the venture. Challenges for the contractor mounted in October 1934 as flooding shut work down after only a month on the job, and didn't resume until spring.



Engineering News-Record

McGraw-Hill Publishing Company, Inc. January 2, 1936 Twenty-five Cents, Five Dollars per Year

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IN THIS ISSUE:

Long Concrete Trusses in Bridge Near Tacoma

Studies of Flow Conditions in Steep Chutes

Using Aerial Photographs in Topographic Mapping

Underpinning the Philadelphia-Camden Bridge Approach

Rigid Frame Design By Elementary Mechanics

Sewage Treatment Trends in England
BY KARL IMHOFF
Translated by Gordon M. Fair

Spanning 170 ft., a new record, this unique reinforced concrete truss in Pierce County, Wash., utilizes wide shallow slabs as chords and has its web members pierced by sidewalk openings.

Newly completed McMillin Bridge on the cover of *Engineering News-Record*, Jan. 2, 1936.

New McMillin concrete truss between the old highway bridge (left) and railroad bridge (right), Sept. 12, 1935.

When completed in September 1935, the McMillin Bridge was the longest reinforced concrete span, excluding arches, ever built in the US. The noted journal *Engineering News-Record* featured a photo of the bridge on the cover of its January 2, 1936 issue. In their article for the journal, former Pierce County Engineer W.E. Berry and George Runciman, President of the W.H. Witt Company, stated that the bridge "employs a through truss of novel design whose breadth and stiffness are such that lateral bracing of the trusses above the roadway is dispensed with. Sidewalks on both sides of the roadway are neatly handled by running them through the trusses on their longitudinal center lines." In fact the novel design of the trusses with their "neatly handled" sidewalks are among the features that make the McMillin Bridge unique.

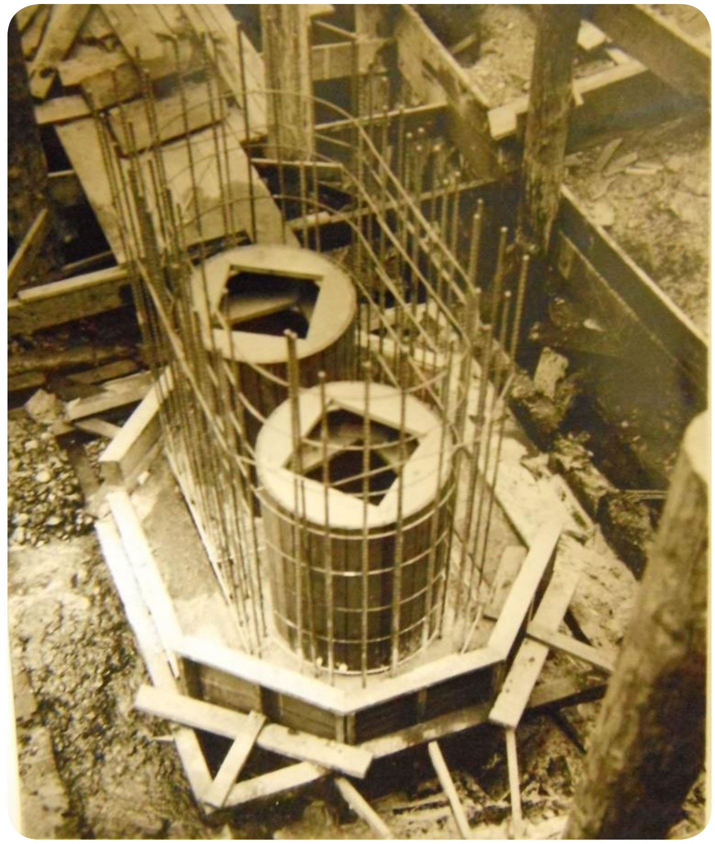
The McMillin Bridge's concrete trusses are far more substantial and complex than the four other known American concrete trusses. The Broad Street Bridge (1918) in Mason, Texas, is a small, one-lane deck truss with trusses rising above the deck to serve as guardrails. The Variadero Bridge (ca. 1915) in San Miguel County, New Mexico, is a four-span, half-through bridge whose concrete trusses extend both above and below its deck. In Seattle, two concrete deck trusses remain from the 1920s: the Admiral Way Bridge (built 1927) and the Magnolia (formerly Garfield Street) Bridge (built 1929). Both bridges were severely damaged in the 2001 Nisqually Earthquake and have been rehabilitated (Buswell 2012).

Other concrete trusses exist around the world, but none is like the McMillin. In Paris, France, the Luxembourg Street Bridge (1928) consists of through

The small population of concrete truss bridges found worldwide includes the Ovoid Sewer Aqueduct over the Barwon River in Australia, built 1913-15. *Photo Courtesy Heritage Council of Victoria.*

concrete trusses of crossed diagonal member design. The structural stiffness is much like that of the McMillin in that the need for overhead lateral bracing was eliminated. The concrete trusses of the six-span Pratt through Tacuarembo Arroyo Chico Bridge in Uruguay (1930s) are light and lack the portal sidewalks of the McMillin. The Castlemaine Concrete Truss Bridge (1914) is a short pedestrian pony truss in the State of Victoria, Australia. Also in the State of Victoria is the Barwon Sewage Aqueduct, a 2,280 foot-long concrete aqueduct carried by 14 cantilevered reinforced concrete truss spans.

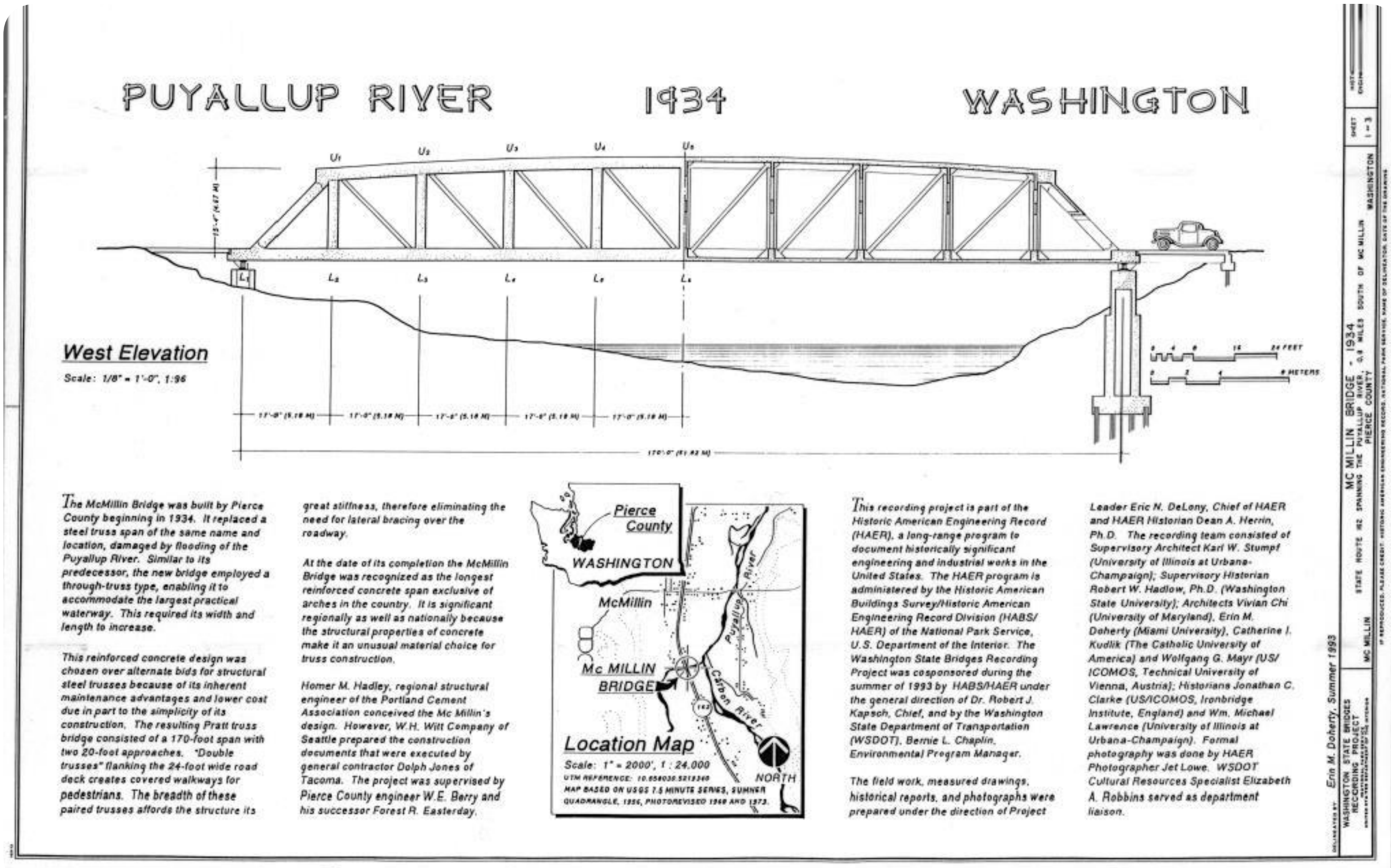
Complex network of reinforcing steel in a truss member. *Photo By Asahel Curtis, June 27, 1935.*



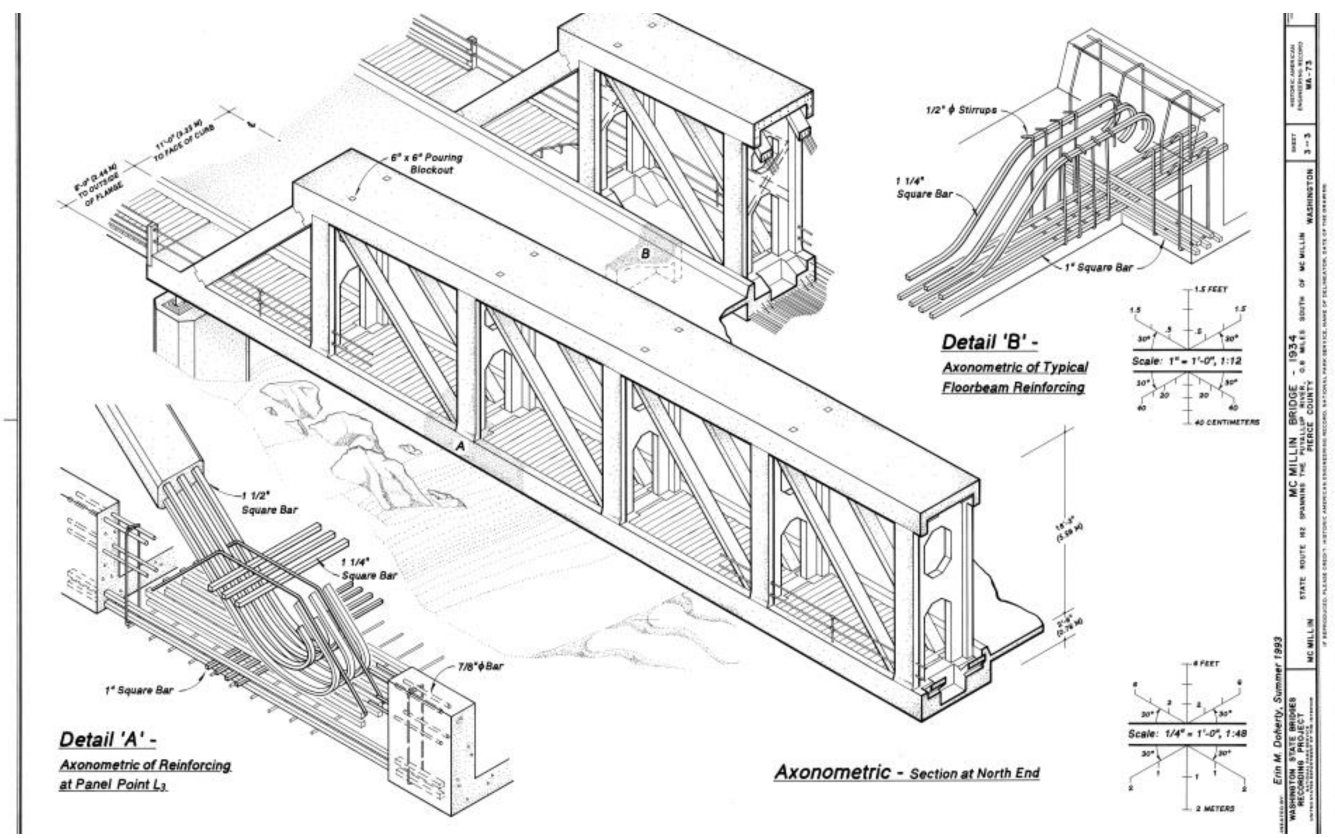
So-called "banana crate" construction of the hollow concrete piers, ca. 1934.

Unique Engineering

The McMillin Bridge is a reinforced concrete Pratt through truss. The main span consists of ten 17-foot panels varying in height from 20 feet at the center of each truss to 17 feet 6 inches at the ends, creating parabolic top chords. Both trusses are 7 feet wide, with the bottom chords extending an additional foot under the roadway to support the deck. The deck is 24 feet wide, leaving a 22-foot-wide roadway between the 1-foot-wide concrete curbs. The chords and end posts are U-shaped in section, consisting of a concrete slab with two legs or flanges extending from their edges. The vertical truss posts are like I-beams in section, that is, with flanges attached to both sides. The flanges of each 8-inch-thick, 2-foot-wide post are flush with the outer surfaces of the chords. Between the flanges are 8-inch-thick web walls pierced by two openings, which lighten the weight of the webs. Each web contains a 7-foot-high, 3-foot-wide portal through which pass wooden sidewalks on both sides of the deck. The walkways passing through the massive concrete trusses are unique in bridge design,



Historic American Engineering Record (HAER) Drawing. *Courtesy, HAER No. WA-73, Erin M. Doherty, NPS, 1993.*



HAER drawing showing truss reinforcing. *Courtesy, HAER No. WA-73, Erin M. Doherty, NPS, 1993.*

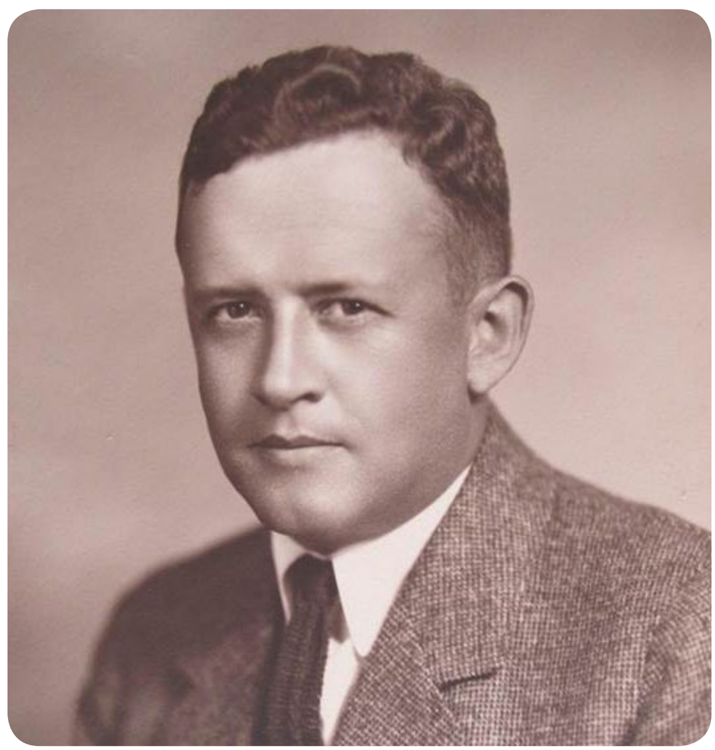
Reinforcing steel and framing awaiting concrete pouring, ca. 1935.

being the most distinctive features of the McMillin Bridge.

Above the sidewalks portals are octagonal openings of unequal sides, their odd shapes determined by arrangements of crossed sets of reinforcing bars within the concrete. Unusual reinforcing techniques in this bridge include bars with hooked ends, welded bars, and the bars in criss-crossed patterns in the web walls. Long tension member lengths required welding of steel plates to abutting reinforcing bars in the bridge's chords. Longitudinal bars are bent in semi-circular fashion over the tops of chords. Bends and sweeps at the ends of all diagonals provide secure anchorage. Where the end posts meet the top chords, "exceptionally large" full hooks join the bars of the last diagonals of the end panels. Complicated reinforcement required concrete mixes varying in concentrations of cement and small aggregate capable of passing through complex forms and steel bars.

Steel bearing assemblies support the ends of the trusses on four octagonal reinforced concrete pier shafts, one under each bearing point. The unusually large, heavy trusses would have warranted immense piers constructed in a conventional manner. To save weight and concrete (and obviously cost), the individual pier shafts are hollow, each containing two, 3-foot-diameter void spaces within the shafts. The concrete pier shafts are rectangular in section with truncated corners, joined at their tops by deep connecting diaphragms. Designers anticipated extending steel H-piles to an average of 25 feet below the bottoms of the footings. However, due to the softer than anticipated soils on the north end of the bridge, additional wood piles were driven under each shaft, and the lengths of the steel piles were increased to 40 feet.

Although pouring concrete of varying consistencies and aggregates in sequences that avoided cracking and structural failure was not unheard of, doing that in trusses of highly unusual sections containing complex patterns of steel reinforcing was extremely innovative. An electrical internal vibrator was essential in accomplishing that task, a method of consolidating the concrete that was relatively new at the time. The result was an unprecedented structure



Homer M. Hadley, structural engineer, Portland Cement Association, inspired the McMillin Bridge design. *Photo source: Pacific Builder and Engineer, July 7, 1928..*

McMillin Bridge portals in trusses. *Photo by Nathan Holth.*

of artistic expression representing engineering at its finest. The McMillin Bridge was listed in the NRHP in 1982 and should now be recognized at the national level of significance.

Inspirational Designer of the McMillin Bridge

The authors of an *Engineering News-Record* article extolled the McMIllin Bridge's design as "simplicity from a construction standpoint." Although the W.H. Witt Company of Seattle prepared the plans, the authors gave credit to an individual who otherwise wouldn't be known for the bridge's design: "The major features and layout of this bridge were suggested by Homer M. Hadley, regional structural engineer of the Portland Cement Association." The idea for using reinforced concrete in trusses did not originate with Hadley, however. Wilbur J. Watson, in his *General Specifications for Concrete Bridges*, published brief guidelines for designing concrete trusses in 1908 (and in subsequent editions) with which Hadley was surely familiar. Two years before construction began on the McMillin Bridge, Hadley expressed admiration for the innovative concrete deck truss design of the Garfield Street (now Magnolia) Bridge built in Seattle in 1929. He was no doubt also familiar with the Admiral Way Bridge, also a concrete deck truss built in Seattle in 1927.

Homer More Hadley was born in Cincinnati, Ohio, in November 15, 1884. The son of George and Elizabeth More Hadley, Homer attended school in Toledo before heading west to enroll at the University of Washington in 1908. Occasional jobs surveying for railroads in Alaska, Canada and elsewhere took him away from school until he finally left the university in 1916 without graduating. During World War I, Hadley worked for the Emergency Fleet Corporation in Philadelphia. There he designed the concrete ships and barges that would later inspire his idea for a floating concrete pontoon bridge on Lake Washington in Seattle. As regional structural engineer with the Portland Cement Association, Hadley spent 26 years promoting the use of concrete in structures, mostly bridges.

A pioneer in the use of concrete, Hadley is credited with the inspiring the design for the first concrete box girder bridge built (1936) in the US, the Mashel River Bridge near Eatonville, Washington. Built later that year also in Pierce County, Washington, the Hadley-inspired Purdy Bridge was the longest reinforced concrete box girder bridge in the US. Pierce County Engineer F.R. Easterday credited Hadley with suggesting, "Major features of the layout" and that he "was responsible for the design" of the Purdy Bridge.

Another Hadley-inspired bridge, the 1936 Purdy Bridge was the longest reinforced concrete box girder bridge in the US. *Photo by Nathan Holth.*

McMillin Bridge before construction of new highway bridge, Aug. 24, 2014. *Photo by Nathan Holth.*

Carl Condit said in his seminal work *American Building Art: The Twentieth Century* that the Purdy Bridge was the "nearest American rival to Freyssinet's girder spans [in Europe] . . . This structure rates as one of the few box-girder bridges in the United States and has the longest single span among concrete-girder forms."

Among the many bridges whose designs he suggested was the first floating concrete pontoon bridge in the world built on Lake Washington in Seattle in 1940, now known as the Lacey V. Murrow Memorial Bridge. His contribution to floating concrete bridges is memorialized in the Homer M. Hadley Bridge, also a floating concrete pontoon structure adjacent to the Murrow Bridge across Lake Washington.

Robert Krier on the historic McMillin Bridge, with the new bridge at right, Oct. 23, 2015. *Photo by WSDOT.*

Later in private practice with his son Richard, Hadley continued his penchant for concrete innovations. In 1955 he designed a prototype cable-stayed type bridge using box steel girders filled with vermiculite concrete for the cable stays in the Benton City-Kiona Bridge over the Yakima River in south central Washington. Today cable-stayed bridges are often built in cities as signature structures, and concrete-filled steel tubes are now a major component of long-span bridges around the world, particularly in China.

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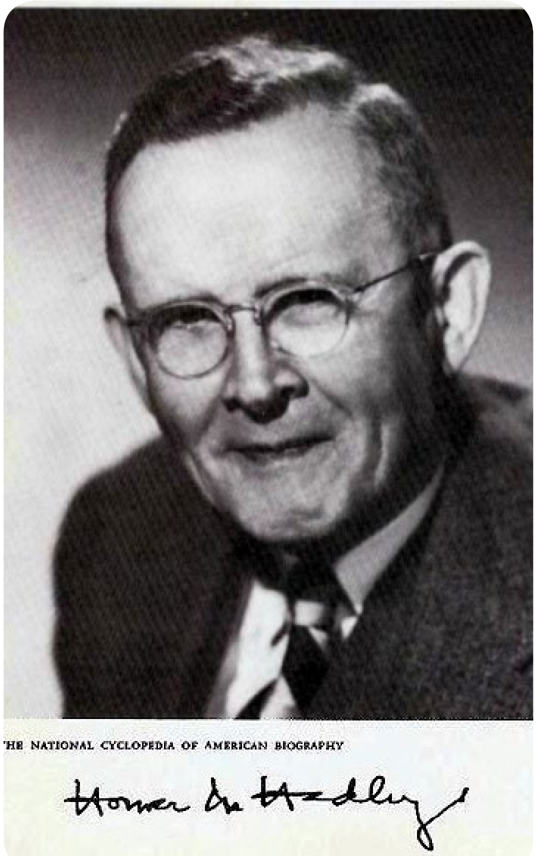

Homer M. Hadley. *Photo source: National Cyclopedia of American Biography, 1973.*

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Craig Holstine holds an M.A. in history from Washington State University. He has been a historian with the Washington State Department of Transportation for 17 years, and is the co-author with Richard Hobbs of Spanning Washington: Historic Highway Bridges of the Evergreen State.

Bob Krier holds a B.S. in civil and structural engineering from the University of Washington and is a registered professional engineer. He was employed with the Washington State Department of Transportation for 31 year, retiring in 1988.

Bridge to the Past:
A Review of PennDOT's Historic Metal Truss Bridge Management Plan

By Tyra Guyton

Background

In June 2016, the Pennsylvania State Historic Preservation Office (SHPO) created the new position of Transportation Special Initiatives Coordinator. The position was created through a special funding agreement with the Pennsylvania Department of Transportation (PennDOT) to assist both agencies in the development of a marketing program for the state's historic metal truss bridges. The position helps both PennDOT and the SHPO preserve the remaining population of historic metal truss bridges. To date, work has largely been focused on two tasks: marketing metal truss bridges for adaptive reuse at a new location and helping to develop and implement a management plan to rehabilitate these bridges as part of the transportation system.

During peak construction of metal truss bridges in the late 19th century, Pennsylvania's vast iron and steel industry encouraged the location of a number of bridge manufacturing companies in the state, like the Keystone Bridge Company in Pittsburgh and the Phoenix Bridge Works in Phoenixville. Consequently, the historic metal truss bridge is a testament to Pennsylvania's significant contributions in bridge engineering and technology. To learn more about the history of metal truss bridges in Pennsylvania, read "Fall in Love with a Metal Truss Bridge" (https://pahistoricpreservation.com/fall-love-with-metal-truss-bridge/) on the SHPO's blog.

Modern traffic needs in combination with insufficient maintenance funding, especially for locally owned bridges, has made the rehabilitation and retention of metal truss bridges expensive. Pennsylvania's once impressive and diverse collection of metal truss bridges is fast disappearing. In 2001, a statewide bridge survey identified 847 potentially eligible metal truss bridges and determined 321 of these bridges as eligible for listing in the National Register of Historic Places. In the last 15 years, 50% of these bridges have been demolished. As of December 2016, only 424 historic metal truss bridges remain statewide and this number decreases monthly. Of the remaining metal truss bridges in Pennsylvania, 183 are eligible for listing on the National Register.

Challenges

Historic metal truss bridge preservation in Pennsylvania is a complex and multifaceted issue. An estimated 80% of the remaining bridges are under local ownership, in many cases by municipalities that are unaware of their heritage value. Most local

Shanley Road "Maxwell Run" Bridge over Clarion River, Elk County, Pennsylvania. Replacement bridge under construction to right. Historic bridge built 1891, demolished 2004. *Photo by Nathan Holth.*

A pickup truck crosses the Dotter Road Bridge in Venango County, Pennsylvania. *Photo by Nathan Holth.*

owners lack sufficient funds to maintain their bridges, let alone rehabilitate them. Many localities see these bridges as a burden to their transportation network since metal truss bridges were not designed to meet modern traffic needs and engineering standards. A fully rehabilitated metal truss bridge is often posted for a capacity of 15 tons. That means the average ambulance may cross the bridge, but not a fully loaded school bus, a fire truck, or a loaded snow plow. While the actual needs of a crossing may not warrant use by vehicles weighing over 15 tons, this can be a tough sell for local municipalities that have worked for years to get a crossing programmed for state or federal funding and believe they are in the final stages of replacing the bridge and improving their transportation infrastructure. Efforts are needed to help localities better understand both the historic significance of metal truss bridges and how alternatives to demolition may best serve community needs. Without local support for bridge preservation and the development of a maintenance and management plan, many more historic metal truss bridges will be lost to demolition.

All transportation projects start at the planning stage, move into the design phase, progress to construction, and end, ideally, with maintenance. Compliance with laws and regulations that take into consideration the effects of federal projects on historic resources, such as the National Environmental Policy Act (NEPA) and Section 106 of the National Historic Preservation Act, is carried out during the design phase of a project. By this point in the process many planning decisions have already been made and rehabilitation of the existing historic bridge may not be given full consideration as a project alternative. Introduction at the planning stage of the project about the kind of consultation required under Section 106 could result in greater consideration for historic bridge rehabilitation as a preferred design option.

If historic metal truss bridges cannot be preserved in place, which is always the most favored preservation outcome, as moveable resources they can be relocated to serve a new function. Nonprofit groups such as trail organizations may need bridges to fill trail gaps, but timing and funding often constrain the success of this option. For bridge replacement projects, the amount of time a historic bridge is available for marketing is usually limited by the construction schedule for the new structure. Recipients willing to relocate historic metal truss bridges need time to hire engineers, prepare site plans, build abutments, apply for grant money, and arrange for transport and reconstruction. Marketing of historic metal truss bridges in the design phase makes it more challenging to coordinate timing between the current owner and future recipient. While storage may be a viable option for bridges with a guaranteed recipient, there are concerns that storage would be costly, drain funds that could be used to assist the future recipient, and result in a bridge "graveyard." While the historic bridge management plan does not prohibit bridge storage,

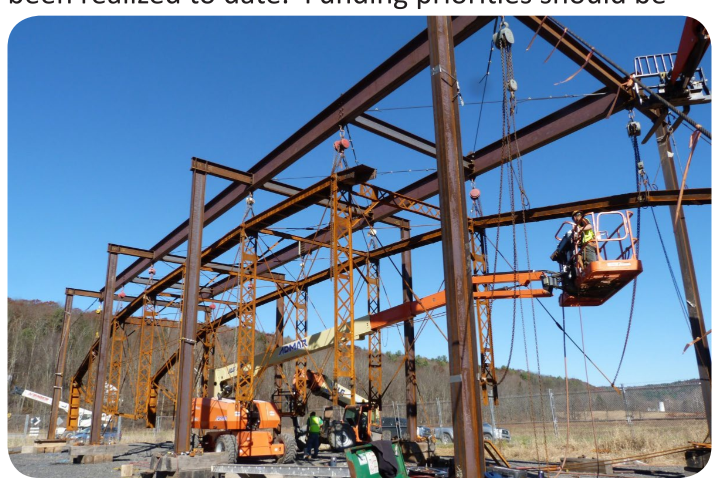
The Carlton Bridge in Mercer County, Pennsylvania was marketed to a private owner. Extensive coordination with PennDOT, multiple contractors, and multiple schedules was required. *Photo by Nathan Holth.*

The Strawtown Koteewi Park Bridge in Hamilton County, Indiana was assembled from in-storage truss bridges removed at two different times from two different counties. In Pennsylvania, storage of dismantled truss bridges is still under investigation as a component of PennDOT's management plan. *Photo by Nathan Holth.*

it may be advisable to do so only when there is an identified new owner awaiting receipt of the bridge or a high likelihood of a successful relocation. Storage of dismantled metal truss bridges is still under investigation as a component of PennDOT's management plan, as there may be willingness on their part to hold a bridge under special conditions.

The most significant challenge facing historic metal truss bridge rehabilitation efforts is inadequate funding. PennDOT acknowledges the need for funding in their management plan and is currently investigating options. Currently, historic metal truss bridges must compete with all other state bridges to be awarded state or federal funding. Often, by the time metal truss bridges are slated for funding, their condition is so poor that rehabilitation is cost prohibitive and no longer a viable option. Funding also needs to address routine maintenance. Regularly scheduled maintenance reduces the likelihood of structural failure and lowers a bridge's life-cycle costs, which are generally proportional to the condition of the bridge.

A lack of funding complicates and limits the success of bridge marketing as well. There is no shortage of groups that want or need a bridge. Trail organizations may prefer a historic bridge over a new bridge as they embrace the ideals of recycling, reuse, and connecting with regional heritage. Often the Federal Highway Administration (FHWA) pays the federal share of the cost to disassemble and transport a historic bridge to another location through use of "cost of demolition" funds-- the amount FHWA would have spent to demolish the bridge. While "cost of demolition" funding is helpful, it is often insufficient to give these bridges a better chance for reuse. Ultimately, lack of funding for rehabilitation and reassembly costs prohibits many willing groups from accepting a bridge. A fund to help offset these costs is essential to the success of PennDOT's marketing program or certainly to greater success than has been realized to date. Funding priorities should be



Disassembly of the Pierceville Bridge in Wyoming County, Pennsylvania for restoration and relocation to a nearby park. *Photo courtesy Bach Steel.*

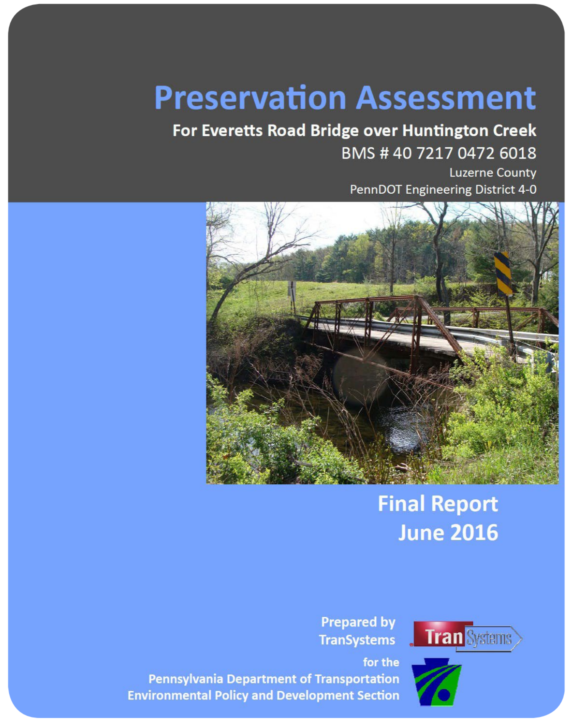
established for bridges with high historic significance, for those best suited for rehabilitation, and for those with a greater level of public interest in preservation.

Plan Elements

PennDOT's historic metal truss bridge management plan has been developed to address these critical challenges. A summary of the plan and its elements can be found on PennDOT's website, "Bridge to the Past: A Management Plan for Pennsylvania's Historic Metal Truss Bridges." (https://www.paprojectpath.org/penndot-crm/bridges/truss-bridge-management-plan/truss-bridge-management-plan-summary) The goal of the plan is to seek to preserve the remaining population of historic metal truss bridges, with an emphasis on those deemed to have high or exceptional significance or local support. PennDOT has created a protocol to categorize the remaining metal truss bridges as an exceptional, high, or moderate preservation priority to help guide planning decisions.

One of the most important elements of the plan is a study that takes advantage of a new transportation planning approach called PennDOT Connects. (http://www.penndot.gov/Pages/all-news-details.aspx?newsid=297) PennDOT Connects is a collaborative and coordinated planning effort with all stakeholders to initiate early dialogue and partnered decision making about the kinds of transportation projects that will help a community achieve its transportation goals. Through this initiative, PennDOT, in coordination with the SHPO,

Valley Crossroad Bridge, McKean County, Pennsylvania. Earlier this year, PennDOT met with stakeholders to discuss this bridge and its Preservation Assessment document. *Photo by Nathan Holth.*



Cover page from the Preservation Assessment for a metal pony truss bridge in Luzerne County, Pennsylvania.

is meeting with local governments (often the owners of historic metal truss bridges), Metropolitan Planning Organizations (MPOs) and Rural Planning Organizations (RPOs), as well as other invited stakeholders, to discuss the transportation needs at these historic metal truss bridge crossings. PennDOT has prepared "preservation assessments" for each bridge which provides detailed information about historic significance and preservation priority, character defining features, roadway and site data, safety and crash statistics, alternate route and network details and reports on bridge condition, load sufficiency and structural deficiencies. A cost model for bridge rehabilitation using a benchmark 15-ton capacity and an assessment of the effect on the bridge's historic characteristics is also included in each assessment. Adding this information to a defined purpose and need statement for each bridge crossing is an essential goal of PennDOT's planning effort. Providing this information early in the planning process will help owners make better informed decisions about their metal truss bridges.

In addition to focusing on the engineering significance of bridges, PennDOT's metal truss bridge management plan acknowledges that the level of public interest in the preservation of a bridge should be considered in the decision-making process.

The 1887 Old Forge Bridge in York County, Pennsylvania is noted for its use of wrought iron Phoenix columns. *Photo by Nathan Holth.*

Thus, the collaborative planning effort approach includes outreach to historic preservation groups and advocates as contributing stakeholders in the process. Having local support is crucial to save a bridge, especially the support of the local elected officials.

The metal truss bridge planning meetings not only provide valuable information to bridge owners, but also to PennDOT itself. The meetings inform PennDOT as to which bridges have potential to serve in long term vehicular use and will benefit from rehabilitation and which will be better served by marketing for adaptive reuse. This allows PennDOT a more timely and complete project design process, providing additional time for marketing when necessary, and may also result in a more realistic project budget that better meet local transportation needs.

The SHPO recognizes that not all bridges can be rehabilitated in place. Each bridge and its setting present specific needs and constraints. Recently, as part of the historic metal truss bridge management plan efforts, PennDOT met with the owner of an 1887 wrought iron Pratt through truss bridge designed by the Phoenix Bridge Company. PennDOT's preservation assessment of the bridge cited it as a high preservation priority due in part to the use of wrought iron in its design. The meeting revealed that to continue using this historic bridge, it would be necessary to replace many of the wrought iron members with steel, diminishing the integrity of the bridge and its ability to convey its engineering significance. A better preservation outcome would be to immediately begin marketing the bridge for adaptive reuse as a pedestrian bridge at a new location. Early exploration of project alternatives and concerns quickly identified the best preservation option for this important historic bridge as relocation with the added advantage of additional time to find a new relocation site.

Conclusion

The time to save Pennsylvania's historic metal truss bridges is now. At the current rate of demolition, the remaining population of bridges will be lost within the next 15 years. PennDOT's bridge management plan is a step in the right direction to help save the state's most significant bridges. Early planning that helps inform bridge owners about the historic significance of their bridges, along with a comprehensive funding strategy for maintenance, rehabilitation, and relocation, will provide a better chance at preserving Pennsylvania's beautiful and historic metal truss bridges.

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Upcoming Conferences

Preserving Historic Places: Indiana's Statewide Preservation Conference

Location: Wabash, IN
Date: April 25-28, 2017
Website: https://www.indianalandmarks.org/tours-events/preserving-historic-places-conference/

Architectural Photography & Social Media for Preservation Campaigns

Location: New York, NY
Date: April 26, 2017
Website: http://www.preservationdirectory.com/PreservationNewsEvents/NewsEventsDetail.aspx?id=5889

2017 Georgia Statewide Historic Preservation Conference
Location: Madison, GA
Date: May 18-20, 2017
Website: http://www.georgiashpo.org/StatewideConference

Society of Architectural Historians 2017 Annual International Conference
Location: Glasgow, Scotland
Date: June 7-11, 2017
Website: http://www.sah.org/conferences-and-programs/2017-conference-glasgow

2017 Preserve Iowa Summit
Location: Fort Dodge, IA
Date: June 8-10, 2017
Website: https://iowaculture.gov/history/preservation/education-and-outreach/preserve-iowa-summit

SIA 2017 Annual Conference, Houston, Texas, May 18 - 21

The 46th Annual SIA Conference is set for May 18 through 21, 2017, in Houston, Texas. Local organizer T. Arron Kotlensky welcomes SIA members to explore the industrial heritage of Space City.

The conference hotel is the Houston Marriott at 6580 Fannin Street. Located approximately 5 miles southwest of downtown Houston, the Fannin Street Marriot (or Marriot Medical Center, as it is also called) is conveniently situated along the Houston Metro light rail corridor, which provides regular service to the nearby Museum District and downtown area. A hotel shuttle will be available for use as well. For dining and refreshment, there are a number of nearby restaurants and bars in the Rice Village neighborhood, located west of the hotel adjacent to the Rice University campus. An additional attraction of the hotel is that the meeting and presentation space is located above the lobby and will be less open to cross-traffic.

Online registration begins March 20, 2017 at http://www.sia-web.org/sia-46th-annual-conference-houston-texas/.

Houston industry is diverse, and this year’s site tours reflect the many influences that combine to make the city an amazing choice!

Houston takes its nickname from the presence of NASA. The Johnson Space Center (JSC), located in Clear Lake, is about half way between Houston and Galveston. A visit to the Space Center includes a combination of behind-the-scenes visits to astronaut training facilities, mission control center, and launch vehicle assemblies that are preserved on site.

Visits to oil and gas related sites will include a refinery tour, an active drilling site, a well pipe fabricator/bender, and a manufacturer of “high head” (high pressure) valve assemblies, such as LMG/Lockwood. Marty Melosi, a public historian with the University of Houston, will lead the tour.

The Houston Ship Channel, opened in 1914, serves as the region’s central maritime artery, with much of the nation’s refining capacity lining its banks, as well as a number of freight and intermodal facilities. The centerpiece of this tour will be a narrated cruise aboard the M/V Sam Houston. The Ship Channel tour will also include a visit to the Battleship Texas, BB-35, commissioned in 1914. Additional Ship Channel tour sites will focus on vessel construction and maintenance-related sites.

A big concrete themed tour will include a visit to the Astrodome, a subterranean fresh water cistern built in 1926 and recently opened to the public, a local manufacturer of pre-stressed, precast concrete, and a visit to some of the bridges that span the Houston Ship Channel, such as the Fred Hartman Bridge or the Sam Houston Ship Channel Bridge.

Spanning the Klickitat River in Washington State:

A New Era In Public Bridge Building

By Sharon Boswell

The Twin Bridges over the Klickitat River in south-central Washington State were completed in mid-February of 1955. A front-page story in the local newspaper described this "unique" project and cited Klickitat County Road Engineer William Cavanaugh's claim that it represented "a new era in public bridge building." According to Cavanaugh, the county's new prestressed concrete bridges, which utilized innovative prefabricated girders, were not only the longest prestressed concrete spans in the state, but also the first to be installed on public roads.[1] (Photo 1)

Photo 1. View of the east channel span of the Twin Bridges, later known as the Klickitat River Bridge No. 142/9, ca. 2009. *From the Washington State Department of Transportation.*

The Klickitat County project had its beginnings two years earlier and provides an interesting case study of the conditions that led to the rapid adoption of prestressed concrete in bridge construction at the state and local level. The Walnut Lane Memorial Bridge in Philadelphia, Pennsylvania, which opened to traffic in early 1951, is recognized as the first prestressed concrete beam bridge built in the United States. The project's success encouraged engineers across the country to consider new applications for prestressed concrete and ultimately revolutionized American bridge construction.[2]

In Washington, an innovative bridge designer willing to experiment with new technology, a manufacturing facility well-positioned to prefabricate concrete girders, and the availability of funding and agency support for new construction on secondary roads were among the factors that ultimately led to the very early acceptance of prestressed concrete bridge technology in the state. Within two years of completion of the Twin Bridges, the Washington State Department of Highways had begun to develop its own standard plans for this type of bridge. Within a decade, prestressed concrete had become the material of choice for most new highway bridge construction around the state.

Rural Bridge Funding

Construction of the first major road through the center of Klickitat County had begun in 1934 during the height of the Great Depression. The route, which connected the Columbia River town of Lyle with Goldendale, the county seat, crossed the Klickitat River at several places, including a site about 18 miles from Lyle where a small island separated the rushing water into channels. There the county initially erected two almost identical timber trusses that became known as the Twin Bridges. (Photo 2) In a heavily forested region like the Northwest, wooden bridges were cheap and easy to build, but, unlike concrete or steel, they also required constant maintenance and deteriorated quickly.[3]

Within twenty years, the Twin Bridges were already in bad condition, and the county began to look for

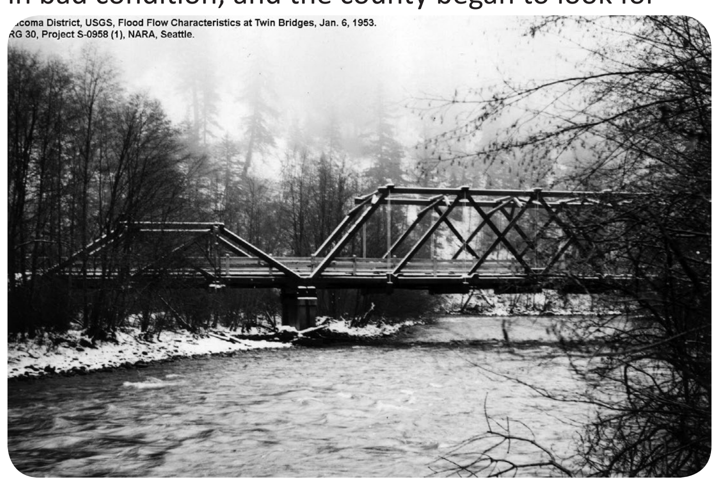


Photo 2. The original Twin Bridges were timber trusses. This view is of the east channel bridge, looking south ca. 1953, just before it was replaced. *From Tacoma District, U.S. Geological Survey.*

funds to replace them. In the early 1950s, funds for secondary road construction became more widely available from state bonds as well as an extension of the Federal Aid Secondary Road program that included more county projects. Under the program, county officials chose the projects and prepared plans, specifications, and cost estimates, but the Bureau of Public Roads (later the Federal Highway Administration) as well as the State Department of Highways retained oversight.[4] For Klickitat County, the new funding offered the opportunity to replace the decaying bridges on the Lyle-Goldendale Road, a high-priority project because this route provided the main access to rich timber country and to sawmills that were among the county's major employers.[5]

Bridge Designer Harry Powell

In early 1953, the Klickitat County road engineer, William Cavanaugh, retained Harry Powell, a Seattle, Washington consulting engineer and bridge designer, to prepare plans for new spans over the Klickitat River. It is not known if Powell had worked on previous projects in the county, but he was well respected in his field and had lengthy experience in the region. Born and raised in Canada, and with an engineering degree in hydraulics and reinforced concrete from the University of Toronto, Powell had opened an office in Seattle in 1926. Over the next few decades, he designed more than 40 concrete bridges as well as a similar number of timber spans.[6]

Powell later went on to design several outstanding steel bridges that earned him a number of national prizes and even international accolades. Among these award-winning structures was a steel arch span, also in Klickitat County, called the White Salmon River or B-Z Corner Bridge, which was honored in 1958 by the American Institute of Steel Construction. Powell's work was judged for both its utility and design, and in an interview, he explained the philosophy that guided all of his bridge projects: "It always has been my belief that bridges should be beautiful as well as useful and I have tried to work out my designs with due regard for aesthetic values…However, it isn't necessary to deviate from sound building practice to accomplish this end because modern design depends almost entirely on interesting structural solutions for its aesthetics."[7]

Despite his success with steel, Powell was also an early proponent of prestressed concrete bridge design. Both Powell and one of his associates, Leonard Narod, had expertise in concrete construction and recognized the strength and flexibility that prefabricated prestressed girders offered. Narod, a fellow Canadian who had studied at the University of British Columbia and then Columbia University, worked directly with Powell on a number of his early concrete bridges, including the Klickitat County project.[8]

The Powell firm likely designed the first prestressed concrete bridge in Washington State. Logging companies, which were required to construct their own roads for access to government timber sites, were evidently willing to experiment with prestressed concrete technology. Prefabricated concrete girders provided a quick and cost-effective means to bridge rivers in very remote areas and had the advantage of being competitively priced and easily erected, yet strong enough to support heavy logging trucks. In a newspaper interview, Powell remembered that his earliest commission of this type was for an Aberdeen, Washington company, Anderson and Middleton Logging, which needed a bridge to span the east fork of the Humptulips River in the Olympic National Forest.[9]

At the same time that Powell first talked with Cavanaugh about the Klickitat River bridges, he was also in the process of completing a precast, prestressed concrete bridge for the Albion Creek Logging Company of Seattle. (Photo 3) In a letter of recommendation for Powell, the firm's manager

Photo 3. Prestressed concrete girder bridge, designed by Harry Powell for the Albion Creek Logging Company, shown ca. 1953. *From WSDOT Contract 4752.*

expressed his satisfaction with the design and construction of the Burma Bridge over the Calawah River in Clallam County, Washington. He particularly noted that the bridge, built in early 1953, "carried loaded logging trucks, traveling bumper to bumper, without a quiver," and that personnel standing under the bridge at those times "noticed a complete lack of vibration and sound." In addition, the logging company was extremely pleased that the cost of the bridge, which was 136 feet in length, was also 60 percent lower than the bids they had received for a more conventional cast-in-place box girder design of the same dimensions.[10]

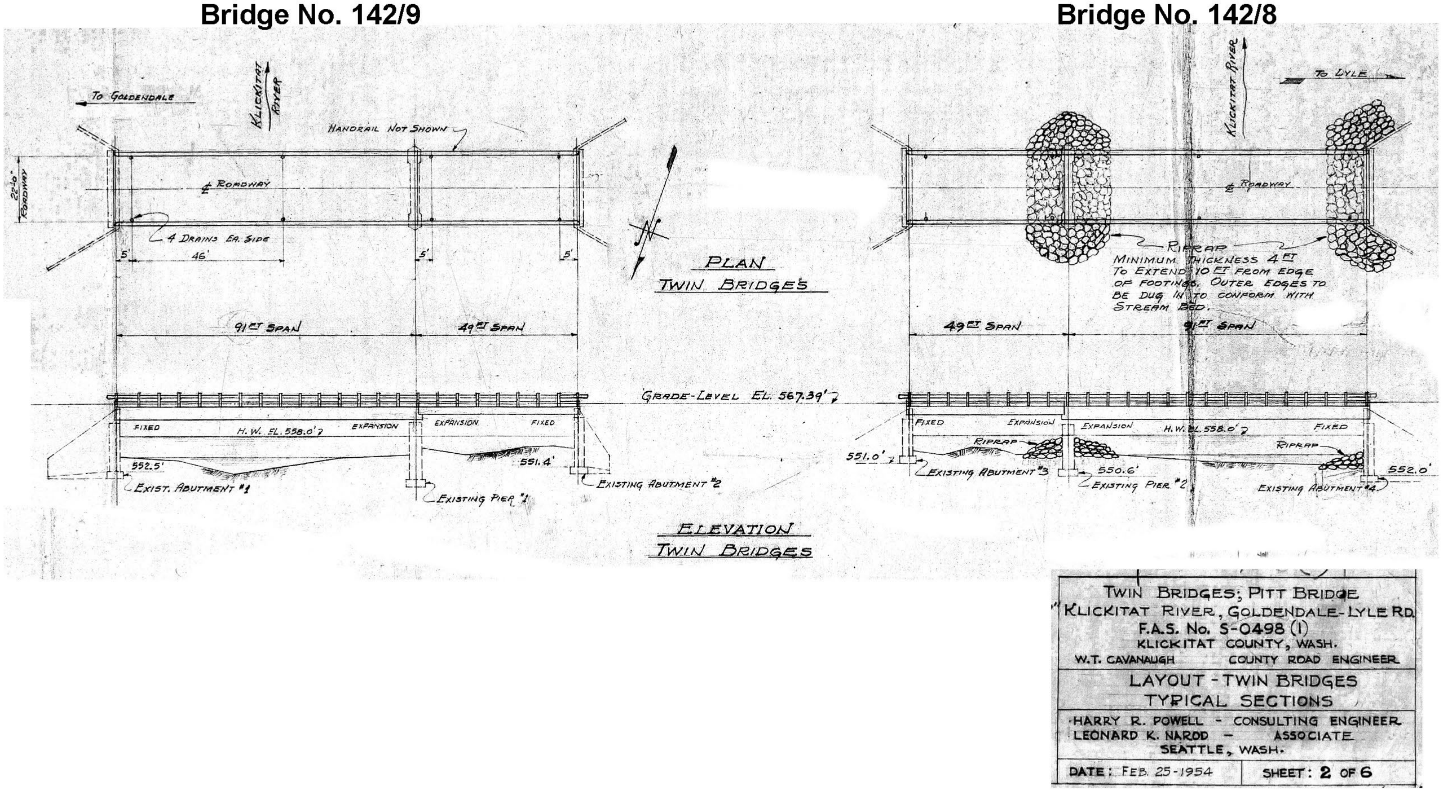
Selection of Prestressed Concrete

Despite these recommendations, Powell did not receive immediate acceptance for the use of prestressed concrete in the Klickitat County bridges. When he was hired to proceed with the design for the new Twin Bridges in February of 1953, County Engineer Cavanaugh suggested the use of cast-in-place concrete box spans to replace the timber trusses. As a cost-saving measure, the county also hoped to use the existing piers to support a new superstructure. Since this project was one of the first in Washington to receive Federal Aid Secondary Road funds, the Bureau of Public Roads took a close interest in the design details, as did the Washington State Department of Highways. Powell was required to submit all plans, specifications, and estimates to both offices for review and approval prior to any advertisements for construction bids.[11]

When Powell proposed using precast, prestressed concrete girders for the project, George Stevens, the chief engineer of the Highway Department, went out to the site to make a personal inspection. In consultation with the Bureau of Roads, he provided his preliminary cost estimates for three suggested alternatives and, like Cavanaugh, recommended that the county build cast-in-place box girder superstructures on the old piers. He estimated the cost of a prestressed concrete girder bridge would be nearly 20 percent more than the box girder design, but also offered Powell the opportunity to provide additional information if he continued to favor that alternative.[12]

Powell vigorously defended a precast, post-tensioned bridge superstructure, suggesting a number of factors that would provide construction advantages

Bridge No. 142/9 Bridge No. 142/8



Bureau of Public Roads, Record Group (RG) 30, Project S-0958 (1), National Archives and Records Administration (NARA), Seattle.

Photo 4. Layout of the Twin Bridges, Feb. 25, 1954, drawing by designer Harry Powell. From Bureau of Public Roads, Project S-0958(1).

and cost savings in the designs he proposed. In particular, he argued that the use of precast girders would limit traffic disruptions during installation and simplify the inspection process. The contractor would not have to ship all of the concrete materials long distances to the bridge's isolated location. In addition, he planned to use a girder design that could be cast in smaller segments to enable cheaper and easier transport by truck to the site. Finally, Powell also cited his past experience with comparable precast, prestressed concrete bridges to support his arguments. In a letter to George Stevens, he expressed his belief that "enough contractors have been educated to this type of construction so that we will get 3 or 4 intelligent bids on prestressed girders for the Klickitat County bridges."[13]

Apparently the information Powell furnished convinced the Highway Department and the Bureau of Public Roads to follow his recommendations. On June 1, 1953, the agencies authorized him to proceed with his plan for prestressed concrete girders in the design of the Klickitat River bridges. (Photo 4) For economy of scale, County Engineer Cavanaugh decided to add a third prestressed concrete bridge, the Pitt Bridge over the Klickitat River, to the project. Finally, in late July of 1954, the State of Washington, acting through the Director of Highways, entered into a contract with the winning bidders, Louis B. Elterich Company of Port Angeles, Washington, and Guy J. Norris, of Seattle, to erect all three precast and prestressed concrete bridges for the sum of $97,247.00 as part of Federal Aid Project No. S-0958(1).[14]

In the meantime, another Washington county had decided to use a prestressed concrete bridge on their road system. Clark County, which bordered the Columbia River in the southwestern corner of the state, built the Venersborg Bridge to carry a local roadway over Salmon Creek about 18 miles outside of Vancouver, Washington. Concrete Engineering Company of Tacoma manufactured the girders for the small, 60-foot prestressed concrete bridge, which was erected over a three-week period in July of 1954.[15]

Manufacturing Prestressed Concrete Girders

Concrete Engineering Company, which was later renamed Concrete Technology Corporation, was also the contractors' choice to manufacture the precast, prestressed concrete girders for the three Klickitat River bridges. The owners of the company, brothers Arthur and Thomas Anderson, were both structural engineers who had trained in the East, but had returned to their hometown of Tacoma, Washington, in 1951 to start their business. They were among the country's early proponents of prestressed concrete technology, and their groundbreaking work in the industry added to the significance of the Klickitat River bridge project.[16]

Background of Prestressed Concrete Development

The use of concrete in bridge construction had begun in the late nineteenth century. By the 1920s, when county and state highway departments were growing at a rapid rate to accommodate the burgeoning automobile industry, the economies of reinforced concrete, and particularly the limited need for maintenance, encouraged highway bridge engineers to choose that material over steel, especially for shorter spans. Over longer distances, reinforced concrete beams had a tendency to develop cracks along the bottom edge due to tension. Increases in the size or depth of the beams could reduce this tendency, but as length increased, the size necessary to counteract this effect became impractical.[17]

Engineers in Europe had long recognized this problem and by 1928, a Frenchman, M. Eugene Freyssinet, patented a system of prestressing concrete in which he tensioned high-strength steel wire within a beam composed of high-quality concrete. Freyssinet was a visionary, called by some the "father of prestressed concrete," but recognition of the practical applications of his work spread slowly. It was not until Dr. Gustave Magnel, a professor at the University of Ghent in Belgium, conducted further experimentation and published a book on the subject that prestressed concrete gained widespread acceptance. Magnel also helped to introduce the principles of prestressed concrete in the United States when he made a speaking tour across the country, and then in 1948 an English version of his pioneering book became available.[18]

By this time, the use of prestressed concrete for bridge projects had become widespread in Europe, spurred by the need to replace many bridges destroyed during World War II and also by the limited availability of steel and other materials needed for new construction. In the United States, prestressed concrete technology was in use for circular storage tanks and similar structures, but there was little experimentation in other applications. Magnel's lectures illustrated the simple translation of this technology to the bridge-building industry and helped to overcome some of the skepticism of the American engineering community.[19]

Magnel also developed the design for a prestressed concrete bridge project that changed the course of prestressed concrete technology in the United States. The City of Philadelphia advertised for bids to design and build the Walnut Lane Memorial Bridge, which crossed high above a road and waterway in Fairmount Park. The proposed structure would be the first in the United States to utilize prestressed concrete for a long bridge span, yet city engineers evidently had confidence in the design, with one writing that "enough bridges have been and are being built in Europe to have established precedents for the basic design and method of prestressing and erection."[20] Magnel's proposal was also significantly lower in cost than other bids received, but the final hurdle was met when the city's very powerful Art Jury also approved the aesthetics of the design.[21] (Photo 5)

Concrete Engineering Company

The successful completion of the Walnut Lane Memorial Bridge project had a direct impact on the

Photo 5. The Walnut Lane Memorial Bridge, Philadelphia, Pennsylvania, is recognized as the first prestressed concrete beam bridge built in the United States. From the National Park Service, HAER PA-51; PHILA-715-4.

Anderson brothers and their pioneering work in the early design, manufacture, and use of prestressed concrete girders for both bridges and buildings in the Pacific Northwest. Arthur Anderson, who graduated from the University of Washington engineering program and then earned a Ph.D. at the Massachusetts Institute of Technology (MIT), had focused his studies on instrumentation, testing, and stress analysis of concrete. His background led to his involvement as the tester for a prototype prestressed concrete girder proposed for use on the Walnut Lane Memorial Bridge. When the experimentation was completed, the performance of the girder throughout all loading stages evidently exceeded all expectations. From Anderson's perspective, the testing was "historically significant because it instilled public confidence in prestressed concrete and marked the beginning of sophisticated instrumentation and testing procedures for the product."[22]

The success of the Walnut Lane project also convinced both Anderson and his brother, Tom, another MIT graduate, that prestressed concrete construction would be a logical family business. The two took a research trip to Europe in the fall of 1950 to meet with Magnel and other prestressed concrete experts and to tour plants, research facilities, and construction projects. They had particular concerns, also voiced by other American engineers, about issues related to the cost of labor versus materials. In Europe, scarce resources often drove up construction expenses and so the emphasis in bridge design was on material savings, while in the United States, higher labor costs required time-saving design considerations. Visits to plants in Sweden and England showed that mass-production techniques could be used to produce precast, prestressed girders that retained their quality but at the same time reduced the amount of site work needed. The Andersons returned to the United States believing that prestressed concrete girders, if mass produced in a controlled factory environment, could be a viable manufacturing opportunity.[23]

The Northwest offered several distinct advantages for the development of prestressed concrete technology. The use of reinforced concrete in construction was well accepted in the region. Iron and steel production had never gained a foothold, making the use of steel highly expensive, while timber, the cheapest building alternative, had issues with longevity and maintenance. The manufacture of Portland cement got its start quite early in both Washington and Oregon, and the local availability of high-quality gravel, sand, and aggregate helped to promote the concrete industry. In addition, national trends, including the accelerated pace of both building and highway construction after World War II as well as the shortage of structural steel, also made the early 1950s an advantageous time to enter the concrete industry.[24]

Among the most important business lines for the company in its early years was the fabrication of prestressed concrete bridges to replace the obsolete timber trusses that were so prevalent throughout Washington, particularly in rural areas. Often existing abutments and piers remained useable, and the Andersons lobbied both city and county road engineers and contractors to consider replacing wood superstructures with prestressed concrete girders. The Andersons began to develop in-house standardized bridge plans and produced precast "I" and "T" sections that were both an economical and time-saving option for local use.[25]

These strategies as well as the rapid expansion of highway building during the 1950s ultimately led to increasing demand for Concrete Engineering's prestressed concrete products and solidified the company's leadership role in the industry. (Photo 6) Within a few years, the original four people who operated the plant, including the Anderson brothers, could no longer keep up with production needs. As Arthur Anderson's son, Karl, remembered: "It was probably 1953 to 1954 when they finally started getting acceptance of the products that we started adding staff. By 1958, we probably had 100 people in here working, because we were busy. We were making a lot of girders."[26]

Klickitat County Bridges

Concrete Engineering Company's early research and development efforts led to their involvement in the Klickitat River bridges project. The Andersons worked with the contractors and designer Harry Powell to produce the precast, prestressed concrete girders for the project. Construction of the Twin Bridges and the Pitt Bridge began in 1954 and was completed in early 1955. Not only were these spans among the first prestressed bridges in the state, but they were also the first of this type to receive federal funding from the Bureau of Public Roads through its Federal Aid Secondary Road program.[27]

Concrete Engineering Company also developed its first segmentally precast, post-tensioned beams for this project, an innovation that allowed for easier transportation and placement of the girders as part of the bridge construction process. Harry Powell realized that the 90-foot girders were too long and heavy to be transported on the remote, substandard

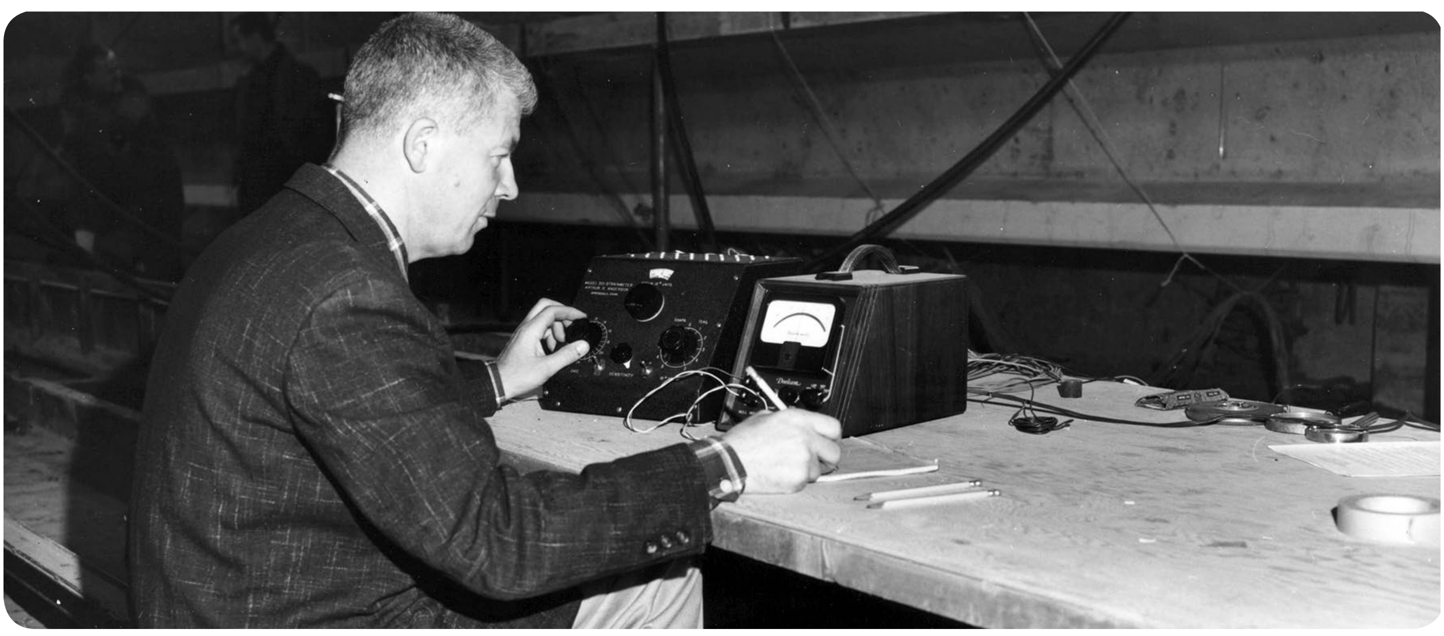


Photo 6. Gustav Magnel visited the Concrete Engineering Company plant in 1954. *From PCI Journal 1961:230.*

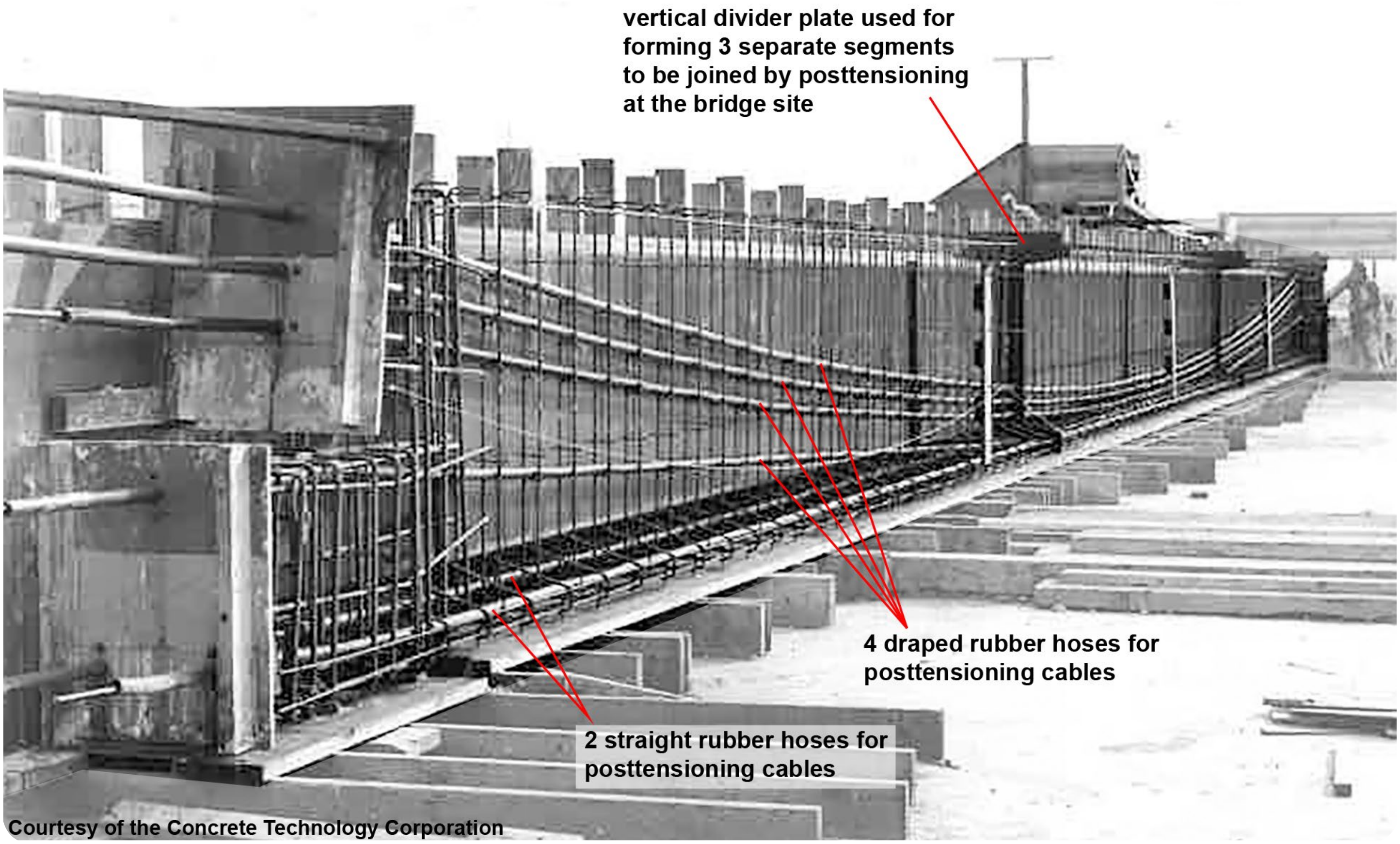


Photo 7. Concrete Engineering Company fabricated the 91-foot prestressed girders with divider plates so they could be shipped more easily. *From Concrete Technology Corporation, Tacoma, WA.*

Photo 8. The prestressed concrete girders for the Twin Bridges were installed on the existing piers in early 1955. *From Concrete Technology Corporation, Tacoma, WA.*

roadway to the bridge site. In addition, cranes were not available at that time to lift such heavy loads. He inserted a provision in the Klickitat County contract specifications to allow the girders to be fabricated in 30-foot segments. Concrete Engineering Company cast the girders with divider plates at the third points. Rubber hoses, 1½ inches in diameter, were positioned in the concrete casting bed to provide longitudinal ducts through the length of the girder for placement of the tensioning cables in the field. The hoses were then extracted 16 hours after the pouring of the concrete in the girder forms.[28] (Photo 7).

The girders were trucked to the bridge site where they were positioned in place on temporary falsework and the steel cables were threaded through the ducts in each section. (Photo 8) The cables were then stretched or tensioned to a predetermined load, and this process forced the sections to behave structurally as a solid member for the entire length. Arthur Anderson designed what he called the Anderson Post-tensioning System to perform the tensioning and anchor the tensioned cables. Once this process was completed, a non-shrink cement grout was pumped

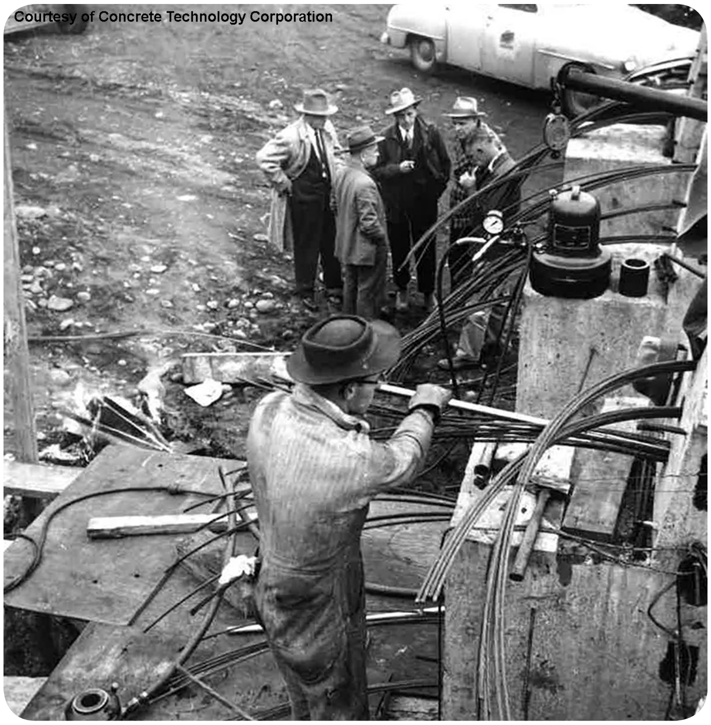


Photo 9. A worker posttensions the girders at the Twin Bridges site in 1955. *From Concrete Technology Corporation, Tacoma, WA.*

into the tubular holes surrounding the cables. (Photo 9) The concrete deck slabs were then poured between the top flanges of the girders.[29]

The Twin Bridges opened to traffic in mid-February of 1955, and the Pitt Bridge followed a few days later. It was at this time that the newspaper article appeared in which County Engineer William Cavanaugh addressed the project's innovative design and construction methods and proclaimed the beginning of "a new era in public bridge building."[30] Cavanaugh's assessment proved to be accurate. Very quickly it became apparent that prestressed concrete eliminated the need for constant maintenance to repair and replace the wooden decking and other structural members of the timber truss bridges that were so common across Washington, yet also provided a strong, long-lasting, and much more cost-effective alternative to steel.

Postscript

The successful experience with the Klickitat River bridges encouraged both state transportation engineers and other local agencies to utilize prestressed concrete in much of their new bridge construction. Within a year, the Department of Highways completed its first prestressed concrete span on a state highway just outside of Seattle, and then in early 1957 developed the first set of standard plans for state-wide prestressed concrete bridge construction, based, in part, on the Concrete Engineering Company's designs. Over the next few decades, as population growth and increased federal funding fueled the rapid expansion of the state's highway system, a critical need developed for bridges that could be erected quickly and efficiently. Prestressed concrete became the material of choice, and today nearly 40 percent of all bridges managed by the State of Washington are of this type.[31]

The original Twin Bridges are no longer part of this group. The bridge over the west channel of the Klickitat River was damaged by a devastating flood in January of 1974 and replaced in the following year with a new prestressed concrete span. The east channel bridge, which became known as Klickitat River Bridge No. 142/9, remained in place and in 2002 was determined eligible for listing in the National Register of Historic Places because of its significant role in bridge engineering as well as in the development of Washington's prestressed concrete industry. Unfortunately, over time water and weather took their toll, and for safety reasons, the Washington State Department of Transportation replaced the historic structure with a new prestressed concrete bridge in 2016.[32]

Notes

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[11] William T. Cavanaugh to Powell and Eldridge, 13 July, 1953; George Stevens to Harry R. Powell, 25 February, 1953, in DOH, Bridge Contract No. 4752 File, WSDOT, Olympia, WA.
[12] George Stevens to Powell and Eldridge, 14 April, 1953, DOH, Bridge Contract No. 4752 File, WSDOT, Olympia.
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[23] Anderson, PCI Journal (July-August 1979), 34; Billington, *Historical Perspective*, 23.
[24] Anderson, *PCI Journal* (November-December 1979), 221; Clarke, Material Concerns, 35–36.
[25] Anderson, *PCI Journal* (November-December 1979), 82–84; Karl Anderson and Steve Seguirant. Recorded interview conducted by Sharon Boswell and Robert Krier, June 27, 2016, Tacoma, WA. Copy on file, WSDOT, Olympia, WA.
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