PREPARED BY

Mead & Hunt

# Historic Context: West Virginia Bridges, 1965-1980

WEST VIRGINIA STATEWIDE HISTORIC BRIDGE SURVEY UPDATE

Prepared for:

WEST VIRGINIA DEPARTMENT OF HIGHWAYS

February 2025

# CONTENTS

CONTENTS



TABLES

# 1. Introduction and Background

The West Virginia Statewide Historic Bridge Survey Update is the latest study initiated by the West Virginia Division of Highways (WVDOH) to aid in the management and preservation of historic bridges. Consideration of options for historic bridges is mandated by federal law, in particular Section 106 of the National Historic Preservation Act of 1966 (Section 106) and Section 4(f) of the U.S. Department of Transportation Act of 1966 (Section 4(f)). The identification and, where possible, preservation of historic bridges in the U.S. are established parts of the federal process for maintaining and improving the nation's transportation infrastructure.

The WVDOH completed a historic bridge inventory in 2014 that evaluated approximately 2,800 bridges built prior to 1965. The project assisted the WVDOH with the management of the state's historic bridges and provided recommendations for National Register of Historic Places (National Register) eligibility to comply with Section 106 and Section 4(f). Within the pre-1965 bridge population, 296 bridges were determined eligible for or listed in the National Register. It is understood that 103 of these bridges have been demolished to date.

This West Virginia Statewide Historic Bridge Survey Update will identify and evaluate the National Register eligibility of bridges built between 1965 and 1980. This span of years is referred to as the study period. The evaluation of eligibility will apply the Advisory Council on Historic Preservation's *Program Comment for Common Post-1945 Concrete and Steel Bridges* (Program Comment) and *Exemption Regarding Historic Preservation Review Process for Effects to the Interstate Highway System* (Interstate Exemption).[1]

The Survey Update will be completed in multiple phases. This phase consists of the development of a historic context that builds on the previous studies and encompasses the study period. The context includes topics that focus on significant historical events and trends under National Register *Criterion* A*: History* and *Criterion C: Engineering*, blending a national perspective on developments in bridge types, methods, and materials with the standards and trends prevalent during this period in West Virginia. This context focuses on types not addressed by the Program Comment; however, analysis of the bridge population includes all bridges built from 1965-1980. Research was directed toward understanding significant developments in bridge building nationally and whether these were important in West Virginia during the study period. Research consisted of a literature review of national trends in bridge engineering and technology, interviews with WVDOH personnel active during the study period, and primary and secondary research in West Virginia. Retired WVDOH engineers who were interviewed for this project included Randolph Epperly Jr., James Sothen, Garland Steele, and Greg Bailey. In addition, Dr. GangaRao Hota, professor of Civil Engineering at West Virginia University (WVU), was interviewed regarding his involvement in bridge-related research during the study period.

---

[1] Advisory Council on Historic Preservation, *Program Comment Issued for Streamlining Section 106 Review for Actions Affecting Post-1945 Concrete and Steel Bridges* (Federal Register, Vol. 77, No. 222, November 16, 2012); Advisory Council on Historic Preservation, *Exemption Regarding Historic Preservation Review Process for Effects to the Interstate Highway System* (Federal Register, Vol. 70, No. 46, March 10, 2005).

After historic context development, the next phase will be to develop criteria for evaluation of National Register eligibility. The criteria will be applied to the 1,420 structures across the state of West Virginia built from 1965 to 1980. The context themes will inform the criteria to evaluate the state's historic bridges based on the standards of the National Register. This comprehensive review will result in a list of bridges that will be recommended for field survey and National Register evaluation. The identification of significant bridges at the end of this study will allow the WVDOH to make informed and timely reviews of proposed projects that will impact bridges determined eligible for the National Register.

## 2. National Trends in Bridge Building from 1965 to 1980

The period from 1965 to 1980 saw a number of significant advances in bridge design and construction nationally, including the increased use of posttensioning and the introduction of segmental prestressed concrete box girders. Computers played a growing role in bridge design, facilitating rapid calculations for standard spans as well as more complex designs. The field of bridge design witnessed both innovation and continuity of established types. While many existing span types continued to be used widely, particularly those incorporated in standard plans from earlier decades, new materials and construction methods were also applied to existing span types, and several new types evolved as well.

Period literature and trade journals indicate that while states such as California, Florida, and Michigan were at the forefront of technology and innovation, many other states were slower to adopt new materials, structure types, and construction methods. During the 15-year study period, government and professional organizations continued to advise and oversee bridge design, and the U.S. Congress passed several pieces of legislation that would affect the planning, design, construction, and maintenance of bridges across the country.

### A. Legislation, standards, and federal oversight

From the mid-1960s through the 1970s federal legislative efforts reshaped the process by which state agencies planned, built, and maintained highway infrastructure. A new law introduced standardized bridge inspections while others provided additional autonomy for state highway departments. Congress also authorized legislation that required studies to determine the impact of federally funded projects on the natural and built environments. With the passage of the Public Works and Economic Development Act of 1965, the federal government provided funds for regional commissions in areas such as the Upper Great Lakes, Ozarks, and Appalachia. Although broadly aimed at rural economic development, these commissions also provided funding for transportation development. Throughout much of this period construction also continued on portions of the Interstate Highway System. As rural sections were completed, work turned towards construction through urban areas.

This period also saw the restructuring of the federal agencies responsible for oversight of the nation's highways. In order to promote greater coordination and a balanced transportation system, the U.S. Department of Transportation (USDOT) was established by an act of Congress in 1966 and began to operate on April 1, 1967. The Bureau of Public Roads (BPR), which had overseen federally funded roadbuilding since the 1910s, was transferred from the Department of Commerce to the new USDOT and became the Federal Highway Administration (FHWA).[2] The FHWA continued to oversee the federal funds provided for construction and maintenance of a vast network of Interstate, U.S., and State Highways, although the Federal-Aid Highway Act of 1973 contained a provision defining the federal-state

[2] "The Trailblazers: Brief History of the Direct Federal Highway Construction Program," *Federal Highway Administration*, September 2017, http://www.fhwa.dot.gov/infrastructure/blazer01.cfm.

relationship as a “federally assisted State program,” preventing the availability of federal-aid highway funds from infringing on states’ rights on select projects.[3]

In addition to administering funding for federal-aid highways, the FHWA was charged with ensuring compliance with the many new regulatory requirements that were introduced over the course of the 1960s. These requirements applied directly to the many new bridges constructed to carry the Interstate Highway System. Standards developed for the system mandated at least two lanes in each direction, as well as minimum lane, median, and shoulder widths, necessitating wider bridges to carry the Interstate Highways and longer bridges for roads that crossed them. Additional funding prerequisites were codified by the impactful Federal-Aid Highway Act of 1968 that brought about large-scale changes to bridge safety, repair, and replacement standards and allowed for oversight on these matters.

Various changes to FHWA responsibilities and funding appropriations occurred throughout the next two decades, including two Federal-Aid Highway Acts (1970 and 1973) that served as the primary source of funding for the Interstate Highway System during this period. The Federal Aid Highway Amendments Act of 1974 established the Federal Aid Off-System Bridge Replacement Program, also known as the Off-System Roads Program, which provided additional funding to meet federal and state goals to improve bridge safety through improvements such as reconstruction or repairs.[4]

As the Interstate Highway System drew nearer to completion, institutions began to consider how other forms of transportation might supplement vehicular travel. In 1973 the American Association of State Highway Officials (AASHO) was renamed the American Association of State Highway and Transportation Officials (AASHTO) to broaden its mission and membership to include all forms of transportation. This goal was furthered in 1976, when AASHTO established committees to represent various multimodal forms of transportation, including aviation, water, and public transportation.

Specific programs and legislation impacting bridge construction during the period are discussed in chronological order.

### (1) National Bridge Inspection Program

The National Bridge Inspection Program (NBIP) created the first nationwide standard for bridge inspections, establishing unified bridge inspection procedures for decades to come. Enacted as part of the Federal-Aid Highway Act of 1968 and implemented in 1971, this legislation established a set of National Bridge Inspection Standards (NBIS), including inspection procedures, frequency of inspections, qualifications of personnel, and a state-maintained inventory of federal-aid highway system bridges.[5]

---

[3] Richard F. Weingroff, “Busting The Trust Supplement,” *Federal Highway Administration*, July 2013, http://www.fhwa.dot.gov/publications/research/general/busttrust/index.cfm.

[4] United States Senate, “The Federal-Aid Highway Amendments of 1974, Report of the Committee on Public Works United States Senate Together With Minority Views to Accompany S. 3934, Report No. 93-1111” (U.S. Government Printing Office, 1974).

[5] Jacob Feld and Kenneth L. Carper, *Construction Failure* (N.p.: John Wiley & Sons, 1997), 144.

This federally mandated program was created in direct response to the catastrophic failure of the Silver Bridge between Ohio and West Virginia in 1967.[6] The Silver Bridge Disaster section below (see Section 3.A.(2)) provides greater detail regarding the collapse of the Silver Bridge and the ensuing investigation. Considered one of the most tragic highway bridge collapses in the United States, this event highlighted the need for more comprehensive bridge inspection programs.

At the time of enactment, the NBIP applied to all bridges more than 20 feet in length located on federal-aid highway systems (including the Interstate Highway System and other primary State Highways), as well as secondary and feeder routes. The required inventory of federal-aid highway system bridges became the National Bridge Inventory (NBI), which required states to comply with the new law by maintaining detailed data records for each bridge under standardized categories. Requirements of the program were amended in 1978 as part of the Surface Transportation Assistance Act, which extended the NBIP to all bridges over 20 feet in length on public roads.[7] With AASHTO and FHWA revising manuals in 1978 and 1979, more direct guidance was established for states to better comply with the provisions of the NBIS.

**(2) Lasting impact of environmental legislation**

Growing environmental and social concerns in the 1960s led to the enactment of environmental legislation that affected the process by which local, state, and federal governments identified potential environmental impacts of various projects aided by federal funding, including bridge construction. The 1962 publication of Rachel Carson's *Silent Spring*, a book credited with popularizing the modern environmental movement, helped usher in a new era of consideration for environmental factors, including those related to roadbuilding.[8] In the years that followed, new federal regulations mandated environmental studies to determine a proposed project's impact on its surroundings, requiring state highway departments to demonstrate that the benefits of the project outweighed any negative impacts on the environment.[9] Laws enacted to protect the environment included the Clean Air Act (1963), National Historic Preservation Act (NHPA, 1966), Section 4(f) of the U.S. Department of Transportation Act (Section 4(f), 1966), National Environmental Policy Act (NEPA, 1970), and substantial 1972 amendments to the Federal Water Pollution Control Act.

The legislative acts passed in the late 1960s and early 1970s extended protection for resources with historic and social significance. The Federal-Aid Highway Act of 1968 required USDOT projects to comply with a wide range of environmental and historic preservation regulations and increased the associated

---

[6] Federal Highway Administration, *Highway Bridge Inspection: State-of-the-Practice Survey* (McLean, Va.: U.S. Department of Transportation, April 2001), 1, http://www.fhwa.dot.gov/publications/research/nde/pdfs/01033.pdf.

[7] Federal Highway Administration, Department of Transportation, *23 CFR Part 650 [FHWA Docket No. FHWA-2017-0047] RIN 2125-AF55, National Bridge Inspection Standards* (Federal Register, Vol. 84, No. 218, November 12, 2019).

[8] "The Battle of Its Life," *Federal Highway Administration,* May/Jun 2006, https://www.fhwa.dot.gov/publications/publicroads/06may/05.cfm.

[9] "Public Roads - Busting the Trust," *Federal Highway Administration,* July/August 2013, http://www.fhwa.dot.gov/publications/publicroads/13julaug/03.cfm; Edward Cohen, "Long-Span Suspension Bridges: The American Approach," *Annals of the New York Academy of Sciences* 352 (n.d.): 27.

public input requirements. The NHPA, NEPA, and Section 4(f) mandated that responsible agencies must identify bridges having potential for historic significance and evaluate any impacts that a project may have on those resources. These legislative acts affected bridge replacement in the subsequent decades, as compliance with all three applied to historic bridges proposed for replacement using federal funds.

#### (3) Federal-aid Highway Act of 1970 and Special Bridge Replacement Program

The Federal-aid Highway Act of 1970 brought about multifaceted changes to highway and bridge projects throughout the country that had lasting impacts throughout the study period. Changes to funding allocation were enacted as part of this legislation, with federal funding for non-Interstate Highway projects increasing from 50 percent to 70 percent and federal funding for bridge replacement set at 75 percent.[10]

Aside from funding changes, this legislation brought about a comprehensive program aimed at addressing bridge safety through rehabilitation and replacement. The Special Bridge Replacement Program was created as part of the Federal-aid Highway Act of 1970 specifically for upgrades to or replacement of federal-aid highway system bridges. With $816 million apportioned for bridge improvements through 1978, the Special Bridge Replacement Program established a process for classifying bridges for replacement priority, based on categories such as serviceability, safety, and essentiality for public use.[11] This program was extended in 1978 to include rehabilitation of existing bridges, as part of the Highway Bridge Replacement and Rehabilitation Program, which applied to both on-system and off-system bridges.[12]

#### (4) Federal-aid Highway Act of 1973 and Highway Safety Act of 1973

In 1973 Congress passed another Federal-aid Highway Act that provided additional funding to complete the Interstate Highway System and to construct new urban and rural primary and secondary roads.[13] One provision of the law, known as the Highway Safety Act of 1973, provided funding to research safety improvements for roadway and bridge design, and established the Safer Roads Demonstration Program specifically to improve safety through the removal of potential obstacles on off-system roads. To continually improve highway and bridge construction standards under this law, the USDOT was mandated to collect data, gather research, and conduct demonstration programs aimed at improving safety.

The Federal-aid Highway Act of 1973 also included new provisions that incentivized mass transit projects and represented what historian Richard F. Weingroff termed "landmark intermodal legislation" as federal priorities shifted from large highway projects to focus on mass transit and improved metropolitan

---

[10] The Louis Berger Group, *The Interstate Highway System in the United States: Draft Final Historic Context Report* (East Orange, N.J.: prepared for the U.S. Department of Transportation, Federal Highway Administration, December 2004), 8.

[11] Elliott Himelfarb, "Unsafe Bridges," *Transportation USA*, Summer 1978, 27.

[12] Federal Highway Administration, Office of Engineering, Federal-Aid and Design Division, *A Guide to Federal-Aid Programs, Projects and Other Uses of Highway Funds, Publication No. FHWA-PD-92-018* (US Department of Transportation, Federal Highway Administration, 1992).

[13] Weingroff, "Busting The Trust."

transportation planning efforts.[14] Despite this broader, multi-modal focus, the law also provided $175 million in additional funds for states to replace or reconstruct bridges on the federal-aid system. The program did not allocate funds for use at a state's discretion, but instead evaluated individual projects nationwide and provided a 75/25 percent federal/state match.[15]

Federal funding allocation for state highway projects was also changed through provisions of the Federal-aid Highway Act of 1973, which were directly influenced by the gasoline shortage that defined the energy crisis of 1973-1974. To encourage fuel conservation, the Federal-aid Highway Act of 1973 set restrictions that limited federal funding for highway and bridge projects to those state governments that implemented a statewide 55 miles per hour speed limit. Additionally, beginning in 1975 ten percent of all funding dispersed as part of the Federal-aid Highway Act of 1973 was earmarked for the purchase of services and materials from Minority Business Enterprises (MBE).

#### (5) Surface Transportation Assistance Act of 1978

The Surface Transportation Assistance Act of 1978 established the Highway Bridge Replacement and Rehabilitation Program, replacing the similar Special Bridge Replacement Program.[16] The program intended to rehabilitate or replace bridges that were both on and off the federal-aid system, and met priority criteria set by the Secretary of Transportation.[17] Funds for these activities would be acquired through an 80/20 federal to state ratio, with funding under the law set to expire at the end of fiscal year 1982.[18]

#### (6) Civil rights and urban renewal

The Civil Rights Movement cast a national spotlight on issues of segregation, discrimination, lynchings, and policies that oppressed Black Americans and other underrepresented groups. Protestors disrupted societal norms that promoted segregation, such as occupying businesses or spaces designated as "Whites only" or by marching across transportation infrastructure, such as roads and bridges, that were critical to the circulation of the city.

During the Jim Crow era, infrastructure played a significant role in the oppression of such groups, particularly the Black population. Development of major highways threatened land acquisitions, displacement, and residential demolitions in established ethnic minority neighborhoods. In the 1960s and 1970s a major cause of displacement for underrepresented communities nationwide was Interstate Highway System projects that were often routed through inner city minority neighborhoods.

---

[14] Weingroff, "Busting The Trust."

[15] E.S. Preston and Associates, *Ohio Transportation Development Program Report: A Focus on Highways* (N.p.: Ohio Department of Transportation, 1974), 5–2.

[16] 95th Congress of the United States, "Surface Transportation Act of 1978, Public Law 95-599 - Nov. 6, 1978, 92 STAT. 2689" (United States Government Printing Office, November 6, 1978).

[17] 95th Congress of the United States, "Surface Transportation Act of 1978, Public Law 95-599 - Nov. 6, 1978, 92 STAT. 2689."

[18] 95th Congress of the United States, "Surface Transportation Act of 1978, Public Law 95-599 - Nov. 6, 1978, 92 STAT. 2689."

In the 1960s and 1970s two federal programs often worked hand in hand to cause detrimental effects to underrepresented communities nationwide. Urban renewal projects, funded through federal grants, sought to redevelop “blighted” urban areas, with stated goals of reducing crime, boosting commerce, and providing new housing that met modern health and safety standards. In practice, the program resulted in the disproportionate displacement of minority communities from their homes so the land might be redeveloped for more lucrative residential or commercial use, most often by majority White communities.[19] Interstate Highway projects, which coincided with urban renewal, also resulted in significant displacement of underrepresented communities by routing new roadways through these communities. Because the two programs selected project locations using similar criteria, namely “slum clearance,” the two frequently worked hand in hand, either by design or happenstance, to redevelop the same areas.[20] In some cases city and state officials integrated urban renewal and interstate project plans by pooling resources to clear project areas and planning highways to grant optimal access to urban renewal areas. Between the 1950s and the early 1970s, interstate highways and urban renewal projects combined resulted in the displacement of nearly one million families nationwide.[21]

## B. Bridge building: continued use of established types

Many of the tried-and-true span types developed in earlier decades remained in widespread use into the mid-1960s, such as slab and multi-beam/girder spans. Reinforced concrete continued to be used for a variety of bridge types nationwide. Precast concrete slabs and I-beams grew in popularity in the post-World War II (postwar) period, and precast box culverts replaced the earlier cast-in-place monolithic culverts typical of the prewar period (see Figure 1 through Figure 3 for typical examples).[22] State highway departments often used early-twentieth-century variations on slab structures, such as concrete tee- and channel-beams in standardized designs into the 1960s and 1970s. Reinforced-concrete box beams, developed in the late 1930s, featured longitudinal voids to reduce weight. Although this span type also persisted into the 1960s and a number of standardized shapes and forms were developed, the reinforced type was eventually supplanted by a prestressed variation.[23] These prestressed-concrete box beams, developed in the early 1950s, remained popular throughout the period due to the ease and speed of assembly.[24]

---

[19] “Renewing Inequality: Family Displacement through Urban Renewal 1950-1966,” *American Panorama*, n.d., https://dsl.richmond.edu/panorama/renewal/#view=0/0/1&viz=cartogram&cityview=holc&city=charlestonWV&project=1663&loc=16/38.3553/-81.6338.

[20] Jason Reece, “Confronting the Legacy of ‘Separate but Equal’: Can the History of Race, Real Estate, and Discrimination Engage and Inform Contemporary Policy?,” *The Russell Sage Foundation Journal of the Social Sciences* 7, no. 1 (February 2021): 116.

[21] Farrell Evans, “How Interstate Highways Gutted Communities—and Reinforced Segregation,” *HISTORY*, September 21, 2023, https://www.history.com/news/interstate-highway-system-infrastructure-construction-segregation; “Renewing Inequality: Family Displacement through Urban Renewal 1950-1966.”

[22] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types* (prepared for the National Cooperative Highway Research Program, Transportation Research Council, and National Research Council, October 2005), 3:97-3:100, http://onlinepubs.trb.org/onlinepubs/archive/NotesDocs/25-25(15)_FR.pdf.

[23] Federal Highway Administration, “Post-1945 Highway Bridge Engineering,” *FHWA | Environmental Review Toolkit*, n.d., https://www.environment.fhwa.dot.gov/histpres/post-1945_engineering/this_bridge.asp.

[24] Federal Highway Administration, “Post-1945 Highway Bridge Engineering.”

*Figure 1. Example of a typical prestressed-concrete slab. Mead & Hunt photograph.*

*Figure 2. Example of a reinforced-concrete tee-beam structure. Mead & Hunt photograph.*

*Figure 3. Example of a prestressed-concrete box beam structure. Mead & Hunt photograph.*

First developed in the late 1940s, prestressed concrete initially saw limited use, but by the late 1950s organizations such as the BPR, American Society of Civil Engineers (ASCE), Prestressed Concrete Institute (PCI), and American Concrete Institute (ACI) assembled a significant body of research and innovation.[25] Into the early 1960s most multi-span, precast, prestressed bridges in the country consisted of a series of simple spans using standard girders developed by AASHTO and the PCI.[26] AASHTO's *Interim Manual for Prestressed Concrete*, published in 1963, included standard drawings for a number of prestressed-concrete elements. In the manual, AASHTO provided drawings for various substructural elements as well as beams in four standard sizes (Type I-IV, see Figure 4) intended for spans from 30-100 feet, as well as standard box beams and slabs in four standard sections (Type BI-BIV, see Figure 5) in 36- and 48-foot lengths. These girders could be produced economically at casting plants, and many states incorporated them into standard bridge plans.[27] Precast, pretensioned I-beams offered a cost-effective alternative to steel during the Interstate Highway construction boom after 1956 (see Figure 6).[28] Eliminating the need for on-site forms to cast elements in place, precasting became a standard production method in the 1960s. This important advancement allowed bridge elements to be produced in

[25] *Standard Specifications for Highway Bridges* (Washington, D.C.: American Association of State Highway Officials, 1961), xxiii.

[26] Walter Podolny Jr., "An Overview of Precast Prestressed Segmental Bridges," *PCI Journal*, n.d., 58–59, http://www.pci.org/uploadedFiles/Siteroot/Publications/PCI_Journal/1979/DOI_Articles/jl-79-january-february-4.pdf.

[27] Podolny Jr., "An Overview of Precast Prestressed Segmental Bridges," n.d., 58–59.

[28] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types*, 3:101.

a factory or casting yard near the job site, using reusable forms. Precast, prestressed concrete production in the U.S. and Canada grew from virtually zero in 1959 to a $1.4 billion industry by 1974.[29]

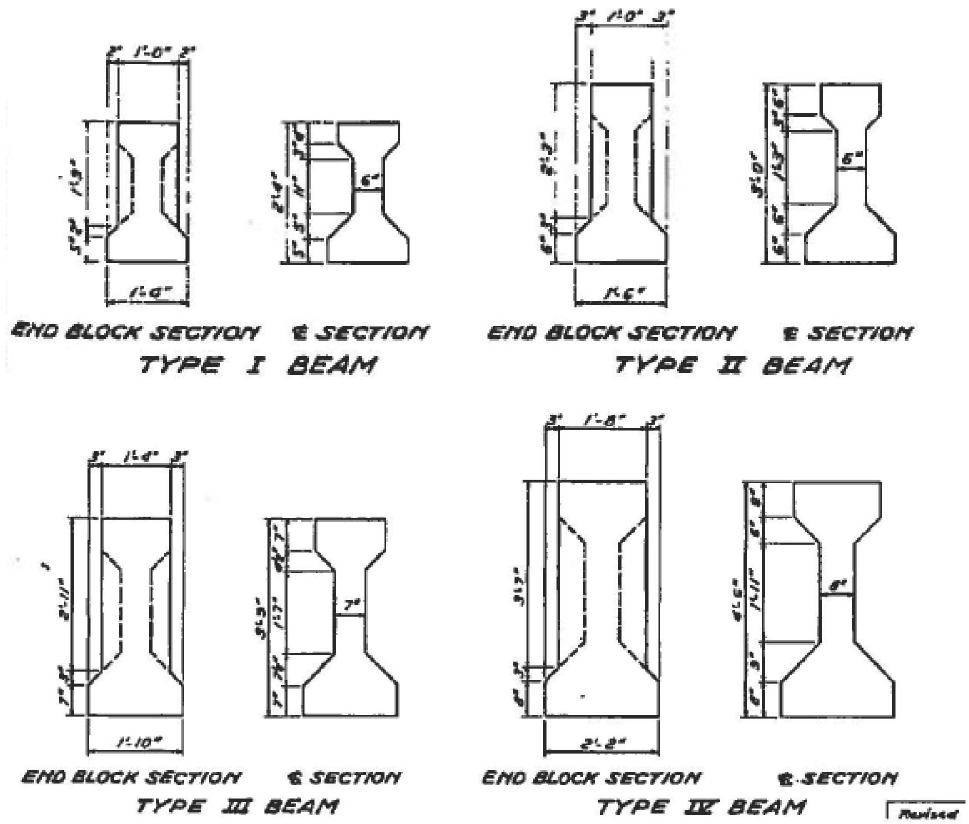


*Figure 4. Plans showing cross sections for Types I through IV standard prestressed-concrete I-beams.*[30]

[29] Tung Y. Lin and Felix Kulka, "Fifty-Year Advancement in Concrete Bridge Construction," *Journal of the Construction Division* 101, no. 3 (1975): 494–95.

[30] American Association of State Highway Officials, Committee on Bridges and Structures, and Prestressed Concrete Institute, *Tentative Standards for Prestressed Concrete Piles, Slabs, I-Beams and Box Beams for Bridges and an Interim Manual for Inspection of Such Construction,* (Washington, 1963).

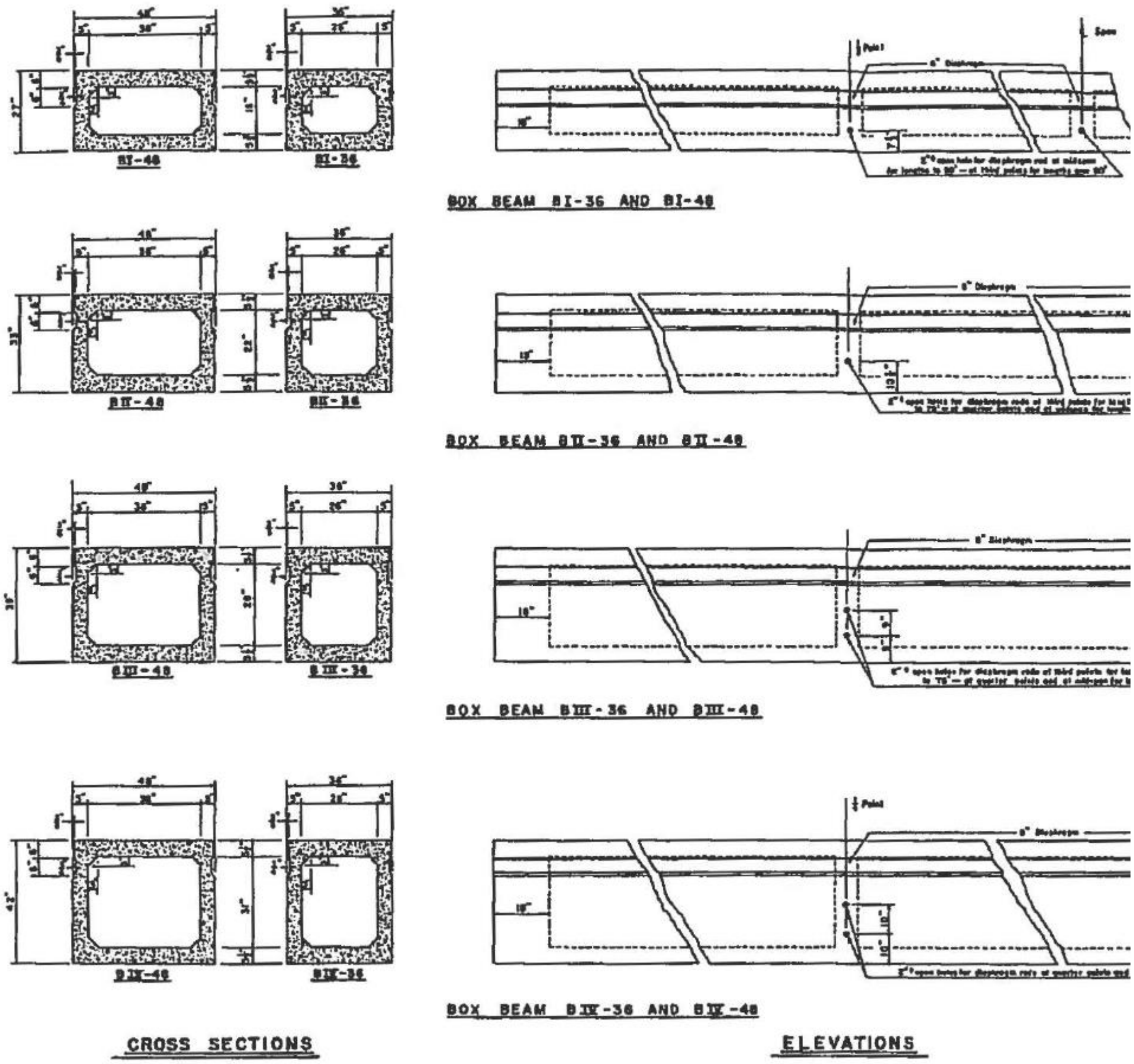


*Figure 5. Plans showing AASHTO's prestressed-concrete box beams in four standard cross sections (Types BI, BII, BIII, and BIV).*[31]

[31] American Association of State Highway Officials, Committee on Bridges and Structures, and Prestressed Concrete Institute, *Tentative Standards for Prestressed Concrete Piles, Slabs, I-Beams and Box Beams for Bridges and an Interim Manual for Inspection of Such Construction*.

*Figure 6. Example of a prestressed-concrete I-beam bridge constructed as part of the new Interstate Highway System. Mead & Hunt photograph.*

Truss bridges were rarely used nationally during the study period, and account for only a fraction of one percent of those recorded in the NBI. Trusses were most economical for medium-length crossings between 500 and 1,500 feet. While this span type had previously been chosen for applications beyond the recommended lengths for a plate girder structure but not great enough to justify a suspension span, by the mid-1960s improved technology enabled designers to use longer steel and concrete girders. The development of the cable-stayed girder bridge also provided an alternative to trusses for medium-length crossings (see Section 2.C.(1) for more on cable-stayed girder bridges).[32]

Timber was a common bridge material through the late nineteenth century, and although it was replaced successively by iron, steel, and concrete, states continued to construct timber spans in the second half of the twentieth century. Primarily timber stringer (see Figure 7) and slab spans, these bridges were typically used on secondary or low-volume roads, such as those found in state, county, or city parks, or as approach spans to concrete or steel structures.[33] Most states constructed fewer than three dozen bridges with timber main spans within the study period, although Montana, Michigan, and Iowa constructed at least several hundred, and Louisiana and Minnesota built more than 500 timber bridges during this time.[34]

[32] Thomas L. Saaty and Luis G. Vargas, *Models, Methods, Concepts & Applications of the Analytic Hierarchy Process* (N.p.: Springer Science & Business Media, 2012), 98.

[33] Sheila Rimal Duwadi and Michael A. Ritter, “Timber Bridges in the United States,” *Public Roads* 60, no. 3 (Winter 1997), https://www.fhwa.dot.gov/publications/publicroads/97winter/p97wi32.cfm.

[34] Obtained from 2015 NBI data for bridges classified as 7: Wood or Timber in field 43A (main span material).

*Figure 7. 1965 timber stringer bridge in Raleigh County, West Virginia.*[35]

Timber structures were typically treated with chemical preservatives, such as creosote, for greater durability. By the mid-1940s researchers had developed a method of laminating layers of wood with a waterproof adhesive suitable for outdoor use. These glued-laminated (glulam) beams were most commonly used in girder and slab spans, although some arch spans were constructed during the 1960s as well.[36] The use of timber trestles also declined as a result of the increased clear-span capabilities of glulam.[37]

## C. Developments in types, methods, and materials

Many advancements in bridge design and construction technology in the study period originated 10-20 years earlier in Europe, where the design/build process (as opposed to the U.S. model, which separated design services from construction work) encouraged greater innovation.[38] By the late 1960s a number of European designs and construction techniques had proven successful and were accepted in the U.S. These techniques, combined with the FHWA's directive in the late 1970s that any major bridge projects consider competing designs in both concrete and steel, eventually fostered the growth of bridge technology in the U.S.[39] Foremost among emerging bridge building trends in the country in the 1970s

---

[35] "WVDOT Assets," *AssetWise Inspections*, 2024, https://wvdot-it.bentley.com/report_summary_view.aspx.

[36] Duwadi and Ritter, "Timber Bridges in the United States."

[37] *U.S. Forest Service Timber Bridge Manual* (Washington, D.C.: United States Department of Agriculture, Forest Service, 1992), 2–13.

[38] Juan A. Murillo, "Modern Bridge Construction and Engineering Services," in *Managing Innovation: Cases from the Services Industries*, ed. Bruce R. Guile and James Brian Quinn (Washington, D.C.: National Academies, 1988), 168–70.

[39] Murillo, "Modern Bridge Construction and Engineering Services," 170.

were the use of closed-box-section bridges of concrete and steel and the introduction of corrosion resistant materials such as weathering and galvanized steel. [40]

### (1) Materials and types

While European countries increasingly favored prestressed-concrete bridges, in the U.S. bridge superstructures were predominantly constructed of steel in the 1960s and 1970s. From the mid-1960s onward prestressed concrete construction surged to outstrip the use of reinforced concrete, but steel bridge construction continued to account for approximately 60 percent of bridge construction nationwide (as measured in dollars) in 1975.[41] Figure 8 shows the distribution of prestressed concrete bridge construction for 1975, indicating the regional differences in materials choice. With the exception of Florida, a pioneer in prestressed concrete use, most eastern states favored steel (possibly due to locations closer to steel production facilities), while the upper Midwest and many western states constructed a higher percentage of prestressed concrete structures.[42]

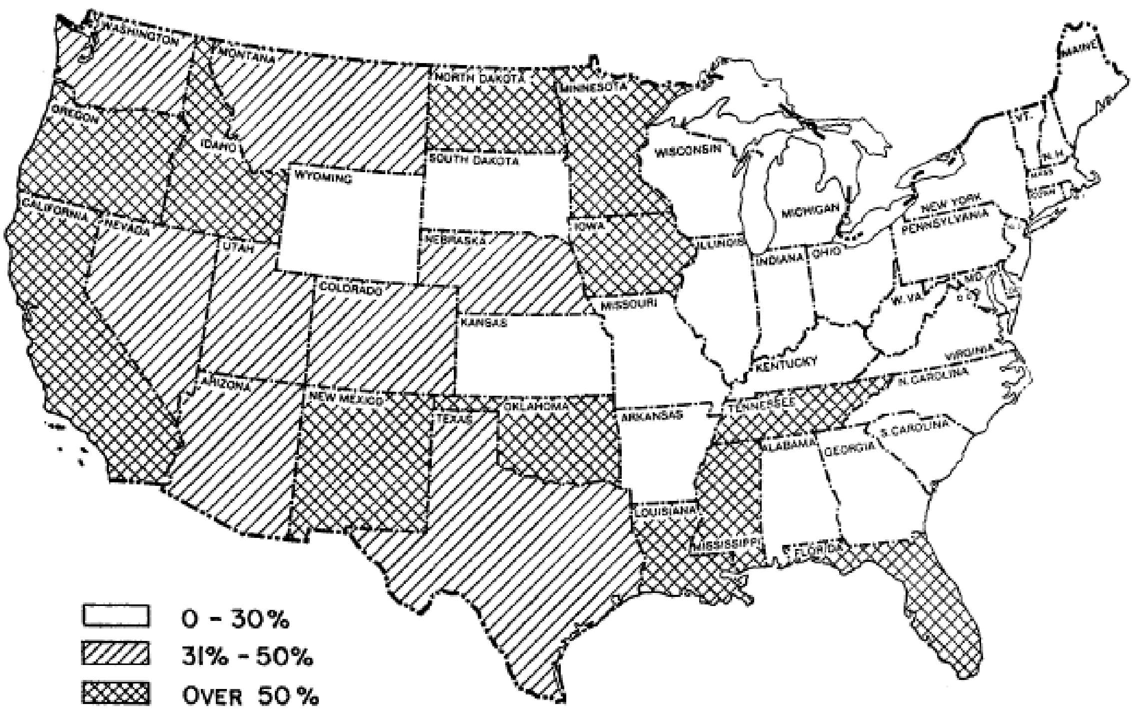


**Fig. 18. Use of prestressed concrete for bridges throughout the United States. (Data from "New bridge construction and major reconstruction authorized during calendar year 1975" issued by the FHWA.)**

*Figure 8. Distribution of prestressed-concrete bridge construction nationwide in 1975.*[43]

---

[40] Kneeland A. Jr. Godfrey, "The 1970's: Civil Engineering Forecast Part I, Structures and Underground Construction," *Civil Engineering - ASCE* 40, no. 4 (April 1970): 68.

[41] Lin and Kulka, "Fifty-Year Advancement in Concrete Bridge Construction," 492–93.

[42] John J. Kozak and Thomas J. Bezouska, "Twenty Five Years of Progress in Prestressed Concrete Bridges," *Journal of the Prestressed Concrete Institute* 21, no. 5 (n.d.): 109.

[43] Kozak and Bezouska, "Twenty Five Years of Progress in Prestressed Concrete Bridges," 100.

***(a) Steel***

Advances in metallurgy, engineering, and computer science enabled the construction of more advanced designs in steel, and standard plate girders (of the type often used for railroad spans) gave way to more complex and customized designs. Notable developments in steel construction during the study period include the introduction and increasing use of curved girders and box girders, and the introduction of cable-stayed girders and orthotropic steel.[44]

The layout of many urban areas in the U.S. required curved bridges to provide better alignments. In response to this need, horizontally curved steel girders came into more widespread use over the course of the late 1960s and early 1970s, particularly in California and New York, although Kansas, Kentucky, Michigan, and Minnesota each reported more than 20 such structures by 1970.[45] Of just over 500 examples in the country, more than half were constructed in 1968 and 1969, indicating the rapid increase in this variation.[46]

Utilizing the deck as an integral part of the structure, orthotropic steel represents another significant development in long-span steel girder bridge design, allowing increased span lengths.[47] However, the use of an orthotropic deck made curved deck design more difficult. As a result, orthotropic decks did not enter use until the late 1960s, when improvements to computer technology enabled more sophisticated design and analysis. Comprised of a steel deck plate with longitudinal and/or transverse stiffening ribs (see Figure 9), orthotropic decks can be used in plate girder, box girder, arch, or suspension spans. This deck type is useful in long spans, movable bridges, where conditions required rapid construction and/or extended service life, or in regions where cold weather makes the use of cast-in-place concrete difficult.[48]

---

[44] Edward A. Burroughs, "Fifty-Year Development Construction of Steel Girder Bridges," *Journal of the Construction Division* 101, no. 3 (1975): 464.

[45] Federal Highway Administration, *Manual for Design, Construction, and Maintenance of Orthotropic Steel Deck Bridges*, FHWA-IF-12-027 (U.S. Department of Transportation Federal Highway Administration, 2012), 11, https://www.fhwa.dot.gov/bridge/pubs/if12027/if12027.pdf; Subcommittee on Curved Girders: Joint AASHO-ASCE Committee on Flexural Members, "Survey of Curved Girder Bridges," *Civil Engineering - ASCE* 43, no. 2 (February 1973): 54–55.

[46] Subcommittee on Curved Girders: Joint AASHO-ASCE Committee on Flexural Members, "Survey of Curved Girder Bridges," 54–55.

[47] Burroughs, "Fifty-Year Development Construction of Steel Girder Bridges," 463.

[48] Federal Highway Administration, *Manual for Design, Construction, and Maintenance of Orthotropic Steel Deck Bridges*, 10–11.

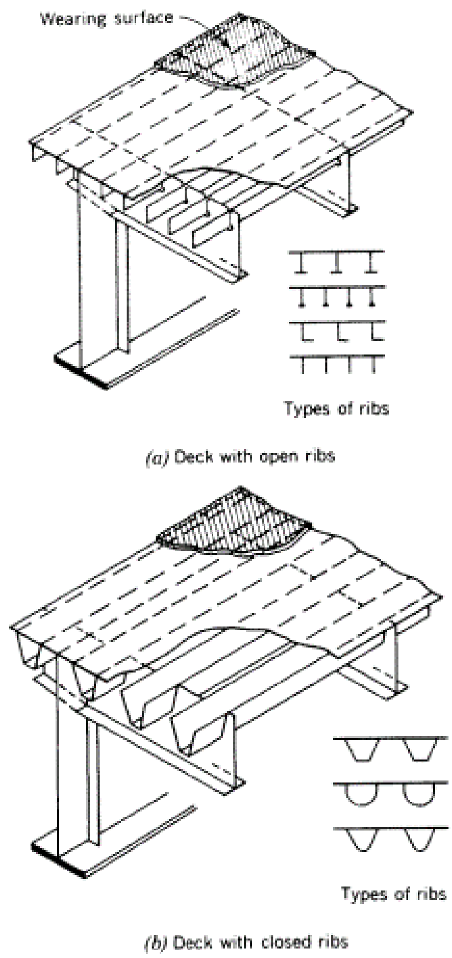


*Figure 9. Two basic types of orthotropic steel plate bridge decks.*[49]

Orthotropic steel decks were originally developed in Germany in the 1930s, but while European nations constructed a number of significant examples in the 1950s, the technology took more than a decade to see common use in the United States. The American Institute of Steel Construction (AISC) published a design manual for orthotropic steel plate deck bridges in 1963, and the Poplar Street Bridge, the first steel orthotropic structure in the U.S., was constructed the following year over the Mississippi River in St. Louis.[50] Built in 1965, the 680-580 Test Bridge, named for the highways it carries in Dublin, California, is an early example of a plate girder span with orthotropic deck that remains in service today. Three examples of steel box girder bridges incorporating orthotropic decks in California and Michigan were also constructed in 1967, including the San Mateo-Hayward Bridge in San Francisco (see Figure 10). In addition to girder spans, the orthotropic deck design offered a light cross section well-suited for suspended spans

[49] Roman Wolchuk, *Design Manual for Orthotropic Steel Plate Deck Bridges* (New York: American Institute of Steel Construction, 1963), 1.

[50] W.A. Milek, Jr., "AISC Orthotropic Plate Design Manual," *AISC Engineering Journal*, April 1964, 40; Carl Condit, *American Building Materials and Techniques from the First Colonial Settlements to the Present* (Chicago: University of Chicago Press, 1968), 227.

(cable-stayed, suspension, and arch), and a prominent early example in the U.S. is the Fremont Bridge in Portland, Oregon, constructed in 1973.[51]

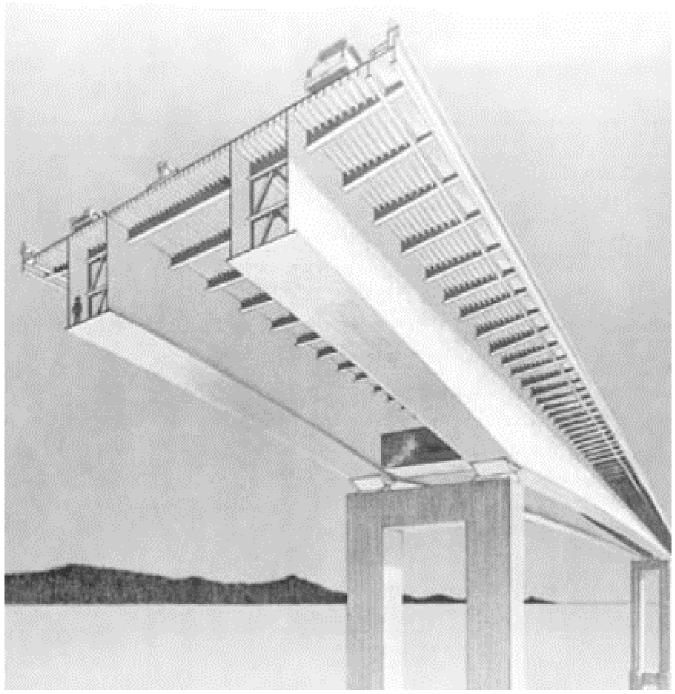

*Figure 10. The San Mateo-Hayward Bridge utilizes continuous, variable-depth box girders beneath an orthotropic steel deck.[52]*

Advances in materials technology in the mid-1960s also provided alternatives to frequent repainting of steel structures as galvanizing gained acceptance. First applied industrially in the mid-nineteenth century, the hot-dip galvanizing process involves the coating of steel parts with molten zinc to provide a corrosion-resistant layer.[53] With little data available to indicate how galvanized structures behaved under load, however, bridge designers did not attempt to design all-galvanized bridges until the 1960s. At that time, existing Interstate Highway bridge specifications prohibited the use of galvanizing on the surfaces of friction-type bolted joints, and engineers were uncertain how galvanized elements would perform under dynamic loading. In order to provide up-to-date information, at the request of the International Lead Zinc Research Organization, Inc., in 1964 the University of Illinois Department of Civil Engineering initiated a study investigating the behavior of galvanized structural joints assembled with galvanized high-strength bolts. The study found that galvanization did not negatively affect performance, and

---

[51] Federal Highway Administration, *Manual for Design, Construction, and Maintenance of Orthotropic Steel Deck Bridges*, 12–15.

[52] Federal Highway Administration, *Manual for Design, Construction, and Maintenance of Orthotropic Steel Deck Bridges*, 13.

[53] Vlastimil Kuklik and Jan Kudlacek, *Hot-Dip Galvanizing of Steel Structures* (N.p.: Butterworth-Heinemann, 2016), xiii, 2.

offered recommendations for design and fabrication. The first all-galvanized steel bridge in the U.S.—the Stearns Bayou Bridge, a steel beam bridge in Ottawa County Michigan—was completed in 1966 and was only the second in the world at that time (see Figure 11). By 1970, however, the practice of hot-dip galvanizing all elements in a steel bridge was becoming widespread, and the zinc coating could enable a structure to complete its service life without the need for maintenance painting at all.[54] Galvanizing also provided protection from salt corrosion, and the FHWA encouraged states to try galvanized rebar in concrete bridge decks as well. The problem of protecting reinforcing steel from corrosive salt remained, and in 1973 the FHWA also began to advocate the use of epoxy-coated rebar in experimental bridges.[55]

*Figure 11. The Stearns Bayou Bridge, built in 1966, was the nation's first documented use of galvanized steel throughout a bridge superstructure.*[56]

Other attempts to create low-maintenance steel structures involved the use of weathering steel. Similar to the centuries-old process of "browning" gun barrels with a thin coat of iron oxide, this process creates a rust-like, corrosion-resistant layer of oxide film on an exposed steel surface and eliminates the need for painting. Although earlier applications occurred in the 1930s through the 1950s on buildings and electrical transmission towers, the first weathering steel bridge in the U.S. was constructed over the New Jersey Turnpike in 1964, and other states soon followed suit,

[54] P. C. Birkemoe and D. C. Herrschaft, "Bolted Galvanized Bridges - Engineering Acceptance Near," *Civil Engineering - ASCE* 40, no. 4 (April 1970): 42.

[55] Gene Dallaire, "Designing Bridge Decks That Won't Deteriorate," *Civil Engineering - ASCE* 43–48, no. 8 (August 1973): 46–47.

[56] American Galvanizers Association, *Stearns Bayou Bridge, Ottawa County, MI*, n.d., https://www.galvanizeit.org/project-gallery/gallery/stearns-bayou-bridge.

including Iowa, Ohio, and Michigan. By 1980 the use of weathering steel in bridges accounted for approximately 12 percent of the total steel market, and all but four states (Arizona, Hawaii, Nevada, and South Dakota) had adopted the material for use where practical. Due to performance issues in some areas, however, weathering steel fell out of favor, and by the late 1980s was discontinued in West Virginia, Indiana, Iowa, Michigan, Washington, Alabama, Florida, Georgia, Oklahoma, New Mexico, South Carolina, California, and South Dakota.[57]

***(b) Concrete***

As acceptance of prestressed concrete grew in the late 1950s, its use increased rapidly. The number of prestressed bridges constructed across the country climbed from a few hundred per year in the mid-1950s to several thousand annually by the early 1960s, a level that persisted throughout the study period.[58] While the use of prestressed concrete remained relatively steady from 1965 to 1980, this period saw tremendous technological advancement in its application in bridges, spurred in large part by the massive construction program required to build the Interstate Highway System.[59] New technologies included the shift from pretensioning to posttensioning, and the introduction of new span types including segmental box girders and cable-stayed spans.

Prestressing of concrete adds strength to beams, girders, and other members, allowing them to support larger loads with a shallower depth than a conventional reinforced member. In order to fabricate a prestressed-concrete structural member, tension is applied to steel cables within the concrete. The pretensioning method involves tightening the cables before the concrete is poured into the form; in post-tensioning, the cables are tensioned after the concrete has been cast and cured. Despite the fact that the first large prestressed-concrete girders used in the groundbreaking Walnut Lane Bridge (1951, Philadelphia) employed posttensioning, most prestressed bridges in the U.S. used pretensioning until the mid-1960s. From that point on posttensioning became more common for larger bridges, because the technique was particularly useful in the construction of longer cast-in-place and/or segmental structures.[60]

As bridge spans increased, precast, prestressed-concrete girders remained popular, but handling and transportation logistics generally limited these to approximately 120- to 150-foot spans. To provide longer spans, designers began to employ large box girders for multi-span structures, and the California Division of Highways constructed a number of cast-in-place, box-girder structures in the late 1960s.[61] Rather than earlier precast box beams similar in scale to the standard I-beam

---

[57] Bashar McDad et al., *Performance of Weathering Steel in TxDOT Bridges* (prepared for the Texas Department of Transportation, June 2, 2000), 2–5, http://www.smdisteel.org/~/media/Files/SMDI/Construction/Bridges%20-%20WS%20-%20Report%20-%20Performance%20of%20WS%20in%20TX%20DOT%20Bridges%20by%20B%20McDad%20-%2006-02-2000.ashx.

[58] Based on 2015 NBI data.

[59] Kozak and Bezouska, “Twenty Five Years of Progress in Prestressed Concrete Bridges,” 111.

[60] Lin and Kulka, “Fifty-Year Advancement in Concrete Bridge Construction,” 493–95.

[61] Geoffrey C. Lacey, John E. Breen, and Ned H. Burns, “State of the Art for Long Span Prestressed Concrete Bridges of Segmental Construction,” *PCI Journal* 16, no. 5 (October 1971): 57.

girders (as shown in Figure 6 in Section 2.B), these larger structures often relied on one or two much larger hollow or multi-cell segmental girders to support the roadway (see Figure 12). The girders could be either square or trapezoidal in section, and some featured cantilevered wings on either side. Through the use of extensive formwork, the entire span could be cast in place and posttensioned to create individual spans of 300 feet or more.[62] The introduction of segmental construction was the next major advance in this area, and could be done using precast transverse segments or by casting short segments in place successively and posttensioning the span when completed. Cast-in-place segmental construction began in Europe in the early 1950s, and spans using precast segments were constructed in France in the early 1960s.[63] Both techniques were introduced in the U.S. in the early 1970s and are discussed in Section 2.C.(2)(b).

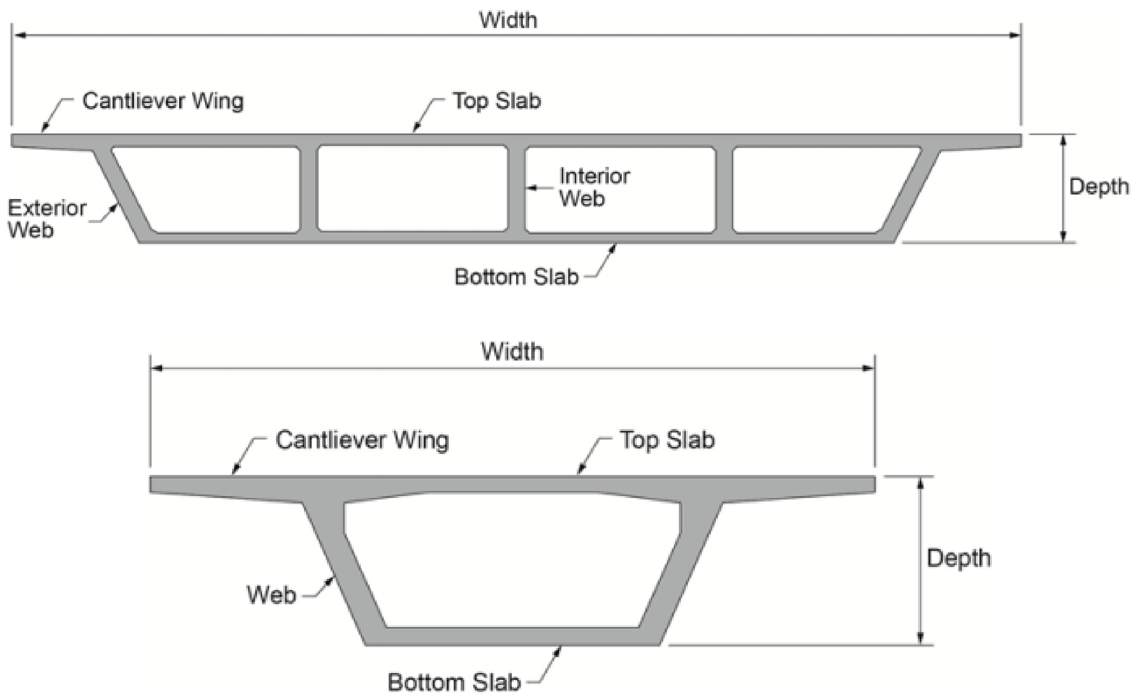


*Figure 12. Examples of prestressed-concrete box girder cross sections.*[64]

As a new span type developed in the postwar period, the cable-stayed girder bridge was considered more attractive than a truss, particularly for certain lengths of crossings.[65] Unlike a traditional suspension bridge, the cables in this type ran directly from the tower to support the

---

[62] Walter Podolny Jr., "An Overview of Precast Prestressed Segmental Bridges," *PCI Journal* 24, no. 1 (February 1979): 60, http://www.pci.org/uploadedFiles/Siteroot/Publications/PCI_Journal/1979/DOI_Articles/jl-79-january-february-4.pdf.

[63] Podolny Jr., "An Overview of Precast Prestressed Segmental Bridges," February 1979, 60–61.

[64] Federal Highway Administration, "Post-Tensioned Box Girder Design Manual" (Federal Highway Administration, June 2016), 3, https://www.fhwa.dot.gov/bridge/concrete/hif15016.pdf.

[65] William L. Gute, "First Vehicular Cable-Stayed Bridge in the U.S.," *Civil Engineering - ASCE* 43, no. 11 (November 1973): 51.

deck below. Improved calculation methods and computer-based analysis made it easier to predict the structure's behavior, and there were no special issues related to construction or deck surfacing, as with an orthotropic. Widely used in Europe since the 1950s, the first example in the U.S. was constructed in Sitka, Alaska, in 1971 (see Figure 13).[66] This span type could be constructed using either steel girders or a one-piece deck in the form of a solid prestressed-concrete slab or using variations on a concrete box girder.

While steel remained the more common cable-stayed girder material in the U.S. throughout the 1980s, the first cable-stayed bridge using precast prestressed concrete was constructed in 1972. The Pasco-Kennewick Bridge over the Columbia River in the state of Washington utilized a cross section comprised of two triangular-section prestressed-concrete girders integrated into the underside of the deck. A number of subsequent examples used prestressed concrete as well.[67] Some in the engineering profession predicted the increased use of this span type for crossings that were too long for a truss and not long enough for a suspension bridge. Most other major examples were constructed after 1980, including the Neches River and Fred Hartman Bridges (Texas), Varina-Enon Bridge (Virginia), and Sunshine Skyway (Florida).[68]

*Figure 13. The O'Connell Bridge in Sitka, Alaska, is the first cable-stayed girder bridge constructed in the U.S.*[69]

[66] Gute, "First Vehicular Cable-Stayed Bridge in the U.S.," 51.

[67] Fritz Leonhardt, "Cable Stayed Bridges with Prestressed Concrete," *PCI Journal*, October 1987, 64–66.

[68] Burroughs, "Fifty-Year Development Construction of Steel Girder Bridges," 465.

[69] Jet Lowe, *O'Connell Bridge, Sitka Harbor, Sitka, Alaska, HAER No. AK-27*, Photograph, 1991, Historic American Engineering Record, Library of Congress, http://www.loc.gov/pictures/item/ak0342.photos.033413p/.

### *(c) Aluminum*

Although never a common bridge-building material, aluminum offered many advantages, such as economy, strength, ease of handling, corrosion resistance, and minimum maintenance. The first known all-aluminum bridge was a 100-foot plate girder structure built in 1946 to carry a rail line over the Grasse River in Messena, New York. Four years later the first all-aluminum highway bridge was completed over the Saguenay River in Arvida, Quebec.[70] A four-span continuous aluminum girder bridge was constructed in Des Moines, Iowa, in 1958 as part of a developmental project intended to stimulate the use of aluminum in highway bridges.[71] The ASCE first published specifications for aluminum structures in 1952, but the Aluminum Association's 1967 design specifications eventually supplanted the ASCE publication and contained engineering data for bridges and other structures.[72] While aluminum elements, such as orthotropic decks, are sometimes incorporated to save structural weight, few known examples use aluminum as the primary superstructure material.[73]

### *(d) Timber*

Glulam structural members had been in use since the 1940s, but builders continued to use solid timber as well until the 1960s and 1970s, when glulam essentially replaced solid timber due to the increased cost and declining availability of high quality logs.[74] The U.S. Forest Products Laboratory (FPL) and the glulam industry conducted joint research in the late 1960s and early 1970s in order to determine whether changes to lumber grade requirements could increase beam strength. Based on this research, in 1971 the American Institute of Timber Construction published new standard specifications for glulam structural members.[75]

While wooden bridge decks had previously used ordinary sawn lumber, glulam bridge decks were introduced in the early 1970s as an alternative to conventional wooden decking for timber and steel stringer bridges, and provided another deck option that would not be damaged by deicing salts.[76] This system utilized vertically laminated panels up to 4 feet wide, which were laid transversely to the bridge stringers with steel dowels connecting each panel on edge.[77] Virginia was a leader in experimenting with glulam, especially a variation known as press-lam or laminated veneer lumber (LVL), made of rotary-cut veneer laminated with the glue line in a

---

[70] Narendra Taly, *Design of Modern Highway Bridges* (N.p.: McGraw-Hill, 1998), 49.

[71] "Aluminum Highway Bridge," *Public Works*, no. 89 (March 1958): 163; "Aluminum Sections Make a First in Road Bridges," *Engineering News-Record*, no. 161 (September 25, 1958): 32.

[72] J. Randolph Kissell and Robert L. Ferry, *Aluminum Structures: A Guide to Their Specifications and Design* (N.p.: John Wiley & Sons, 2002), 217–18.

[73] Taly, *Design of Modern Highway Bridges*, 49.

[74] R. Gutkowski and T. Williamson, "Timber Bridges: State-of-the-Art," *Journal of Structural Engineering* 109, no. 9 (September 1, 1983): 2179.

[75] Gutkowski and Williamson, "Timber Bridges," 2178.

[76] Michael M. Sprinkel, *Glulam Timber Deck Bridges* (prepared for the Virginia Highway & Transportation Research Council, November 1978), 1, http://ntl.bts.gov/lib/36000/36300/36340/79-R26.pdf; W.J. McCutcheon and F.L. Tuomi, *Simplified Procedure for Glued-Laminated Bridge Decks* (Madison, Wis.: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, 1974), 1.

[77] McCutcheon and Tuomi, *Simplified Procedure for Glued-Laminated Bridge Decks*, 1.

vertical orientation. In 1977 the FPL and Virginia Department of Highways and Transportation jointly sponsored construction of a prototype bridge using Press-Lam stringers and deck panels provided by the FPL.[78] Virginia also developed a standard for steel beam bridges with glulam flooring and installed this deck type on two test bridges in 1978.[79]

## (2) Methods

### *(a) Design*

As standardized bridges continued to provide economical solutions, computer programs that could perform calculations much more rapidly than humans sped the design process for both standardized structures and made the analysis of complex spans possible.[80] Georgia was an early pioneer in developing computer-aided design programs using the FORTRAN programming language beginning in the late 1950s.[81] Other states began to adopt Georgia's program for their own use, and by the early 1970s engineers frequently used computers to perform calculations necessary to design superstructures, as well as pile and spread footings for abutments and retaining walls.[82]

In the early years of computer-assisted bridge design, engineers developed programs in order to perform specific analytical or design functions. Into the 1980s most calculations were still performed on large mainframe computers using punch-cards, and programs were typically written in order to solve particular problems dealing with specific span types.[83] Despite the cumbersome nature of the computing process, the 1970s saw the emergence of software programs that could handle multiple aspects of structural analysis. The forerunners of modern structural analysis software, these so-called "general purpose" programs enabled users to modify and extend the program as new elements were developed.[84] By the mid-1970s computer programs for analysis and design were considered one of the most significant advances in the field of bridge engineering.[85]

---

[78] *U.S. Forest Service Timber Bridge Manual*, 2–6, 2–8.

[79] Sprinkel, *Glulam Timber Deck Bridges*, 2, 28–29.

[80] Lacey, Breen, and Burns, "State of the Art for Long Span Prestressed Concrete Bridges of Segmental Construction," 71.

[81] Glenn H. Sikes, *The Analysis of Continuous Beams for Highway Bridges IV Computer Program Fortran IV.* (N.p.: State Highway Department of Georgia, 1971), ii.

[82] E.F. Roberts and M. Lohrmann, "Designing Computer Programs for Bridge Foundations," *Civil Engineering - ASCE* 41, no. 12 (December 1971): 64; TranSystems Corporation, *Historic Context for Construction of 1959-1968 On-System Bridges in Colorado* (prepared for the Colorado Department of Transportation, August 2014), 11.

[83] John Rathke, Mead & Hunt, Inc. engineer, Interview with Mead & Hunt, Inc., January 12, 2016.

[84] E. L. Wilson et al., "SAP — A Structural Analysis Program for Linear Systems," *Nuclear Engineering and Design* 25, no. 2 (July 1973): 257.

[85] Lin and Kulka, "Fifty-Year Advancement in Concrete Bridge Construction," 508.

#### *(b) Construction*

Construction procedures for steel bridges did not change appreciably during the study period, although by the late 1970s high-strength bolted connections had replaced welding as the preferred connection method for plate girders.[86] Construction crews continued to rely on the same basic methods: lifting complete spans into position, constructing partial spans using falsework or other temporary supports, or cantilever construction.[87] In contrast, the introduction of segmental construction proved to be one of the notable advances in concrete bridge construction in the early 1970s.

Handling and transportation logistics generally limited the use of precast, prestressed-concrete girders to a practical length of approximately 120 feet. Segmental construction eliminated the difficulty of handling long precast spans, instead using short segments that could be precast and placed end to end or cast in place successively. The entire span could then be posttensioned, enabling engineers to achieve spans of up to 800 feet. Both the precast and cast-in-place methods were initially developed in Europe.[88] Some bridges could incorporate both methods, as was the case with a structure built across the Umpqua River near Sutherlin, Oregon, in 1970. Although most of the four-span, 580-foot structure comprised precast I-girders, a 120-foot, cast-in-place, box-girder segment straddled the central pier and the entire structure was post-tensioned together.[89]

Used in tandem with post-tensioning methods, segmental construction also enabled builders to construct the span outward from a pier or tower in a cantilever fashion without any falsework, and work could be staged entirely from the top of the completed portion of the bridge.[90] This was particularly useful where site conditions included deep ravines, navigable waterways, or delicate ecologies that could make it difficult to erect the necessary falsework.[91] In the "balanced cantilever" method, precast segments could be added, or moveable forms could be used to cast short segments on alternating sides of a pier. After a number of high-profile successes in Europe in the 1960s, this method was subsequently accepted in the U.S.[92] Other methods included "progressive placing," wherein the cantilevered construction proceeded from one end of the structure to the other. Precast segments could be lifted up at one end of the structure and moved along on falsework, or falsework could be eliminated through "incremental launching," in which

---

[86] Federal Highway Administration, "Post-1945 Highway Bridge Engineering."

[87] Burroughs, "Fifty-Year Development Construction of Steel Girder Bridges," 465.

[88] Podolny Jr., "An Overview of Precast Prestressed Segmental Bridges," February 1979, 56, 60–61.

[89] Reid W. Castrodale and Christopher D. White, *Extending Span Ranges of Precast Prestressed Concrete Girders* (Transportation Research Board, 2004), A3:10.

[90] Lin and Kulka, "Fifty-Year Advancement in Concrete Bridge Construction," 495.

[91] Podolny Jr., "An Overview of Precast Prestressed Segmental Bridges," n.d., 56.

[92] Murillo, "Modern Bridge Construction and Engineering Services," 170; Wai-Fah Chen and Lian Duan, *Handbook of International Bridge Engineering* (N.p.: CRC Press, 2013), 65; Godfrey, "The 1970's: Civil Engineering Forecast Part I, Structures and Underground Construction," 68.

segments were cast on-site and each one was posttensioned to its predecessor before being shoved longitudinally across the gap.[93]

In general, the decision to use cast-in-place or precast segments seems to have been the result of several factors, including site conditions and accessibility, available erection equipment, project timeframe, and the relative cost of transporting finished segments versus raw materials.[94] The Pine Valley Creek Bridge, constructed near San Diego, California, in 1974, represents the first major example of balanced, cantilevered, cast-in-place, segmental construction using traveling forms.[95] The first major example of precast segmental construction in the U.S. occurred in 1973, when the JFK Memorial Causeway was completed in Corpus Christi, Texas. A 1979 article notes at least 23 additional precast segmental structures in the U.S. at that time.[96] In total, several dozen segmental box girder structures were built during the study period, including examples in California, Colorado, Illinois, Indiana, Kentucky, Maryland, Michigan, Oregon, Texas, and West Virginia. The majority of these carried Interstate Highways or access ramps.[97]

In an attempt to reduce the weight of structural elements, some states began to explore the use of different concrete mixes, including air-entrained concrete and lightweight aggregate. By the early 1960s most states used air-entrained concrete as a standard practice for decks to avoid the spalling that occurred due to road salt.[98] Air-entrained concrete, made by trapping tiny bubbles of air within the concrete mixture, improved workability and reduced separation of water from the mix (“bleeding”). Far more watertight than regular concrete, it was also easier to use in cold weather.[99] While lightweight aggregates such as expanded shale had also been available for several decades, California began incorporating the material into concrete box-girder structures in the mid-1970s. The Napa River Bridge, near Napa, California, was constructed in 1975-1977 using lightweight concrete in a post-tensioned, segmental, box-girder structure.[100] The Parrots Ferry Bridge, completed in 1979 near Columbia, California, was the longest such span constructed prior to 1980, with an approximately 640-foot main span utilizing a variable-depth box girder. In both cases, lightweight concrete provided a substantial cost savings over standard weight concrete or a steel box girder design alternative. [101] While lightweight concrete proved

---

[93] Podolny Jr., “An Overview of Precast Prestressed Segmental Bridges,” February 1979, 67.

[94] Podolny Jr., “An Overview of Precast Prestressed Segmental Bridges,” February 1979, 63.

[95] Murillo, “Modern Bridge Construction and Engineering Services,” 170; Chen and Duan, *Handbook of International Bridge Engineering*, 65; Godfrey, “The 1970’s: Civil Engineering Forecast Part I, Structures and Underground Construction,” 68.

[96] Murillo, “Modern Bridge Construction and Engineering Services,” 170.

[97] Based on 2015 NBI data.

[98] Dallaire, “Designing Bridge Decks That Won’t Deteriorate,” 44.

[99] R. T. Kreh, *Masonry Skills* (N.p.: Cengage Learning, 2003), 521.

[100] James E. Roberts, “Lightweight Concrete for California’s Bridges,” *Engineered Concrete Structures* 10, no. 3 (December 1997): 1–2.

[101] K.D. Raithby and F.D. Lydon, “Lightweight Concrete in Highway Bridges,” *International Journal of Cement Composites and Lightweight Concrete* 3, no. 2 (1981): 133–46.

popular in some states, others, such as Minnesota, did not find their experiments with the material to be successful and discontinued its use.

## D. Aesthetics

In early-twentieth-century designs, aesthetic treatments served to call attention to the bridge in order to make it stand out from its surroundings through the artistic or ornamental treatment of structural elements. Bridges were often used as symbolic entry points or gateways into cities or as memorials to important individuals and events. In the latter half of the twentieth century, aesthetics in bridge design was realized through simple and clean lines, with little or no applied ornamentation, that seamlessly fit into the expanding network of highways. Aesthetic considerations played a minor role in bridge design between 1965 and 1980, when cost, safety, and functionality were the primary considerations for design selection; most changes in design during these years resulted from safety concerns. Even so, safety considerations and the need to economize materials also resulted in designs that proved to be more aesthetically pleasing. Technological advancements in materials and refinements to structural analysis procedures using computer-aided design enabled engineers to create longer, lighter, and more graceful structures that were central to the emerging new interest in aesthetics. While these capabilities were often showcased on large, high-profile structures, there was also some influence on more modest structures.[102]

Improvements to overpass design are one example of how more pleasing aesthetics were often a byproduct of increased attention to safety and efficient design during the study period. Unlike structures that carried traffic over a water crossing or other topographical feature, overpasses (particularly for freeways) had to accommodate vehicular traffic both upon and below the structure. In 1967 safety concerns prompted AASHTO's Traffic Safety Committee to issue a recommendation in favor of eliminating bridge piers adjacent to roadway shoulders when constructing highway overpasses. In the late 1960s and early 1970s the FHWA also encouraged states to eliminate hazards by increasing median and shoulder widths, improving horizontal and vertical clearances, and eliminating columns, piers, and other fixed objects adjacent to travel lanes. These recommendations resulted in more aesthetically pleasing structures with clean, streamlined designs.[103]

Over Interstate Highways and other divided highways, eliminating piers on the right side of the travel lane required construction of two-span structures with a single pier in the median (see Figure 14 and Figure 15). In order to safely transport standard precast, pretensioned AASHTO girders from the casting plant to the job site by truck, the maximum practical length of the girders was typically limited to 100-120 feet. This length was often insufficient to eliminate intermediate piers, prompting the development of other means to achieve longer spans. A joint study by the PCI and Portland Cement Association published in 1968 proposed an alternative using standard precast girders that were field-spliced together and posttensioned for continuity. Ultimately, the spliced girder method did not become popular, although the inclined or haunched piers also mentioned in the study did see use where it was desirable to increase span

[102] Based on 2015 NBI data.
[103] Kozak and Bezouska, "Twenty Five Years of Progress in Prestressed Concrete Bridges," 98–100.

length.[104] The continuous girder remained the preferred solution, and California Department of Transportation (Caltrans) engineers discovered that a continuous, cast-in-place, prestressed span provided an economical and aesthetically pleasing means of constructing much longer spans, and this method became the more common practice.[105] As Caltrans engineers described it:

> Aesthetics, economics, and concern for public safety influenced designers to find ways to eliminate the bent at the right side of the roadway. Removing the columns on the driver's right side improves safety, the resulting two-span bridge allows for future widening, and a two-span continuous bridge looks better than four spans of approximately the same length.[106]

*Figure 14. Highway overpass in Minnesota constructed in 1962 with intermediate piers adjacent to travel lane. Mead & Hunt photograph.*

*Figure 15. Bridge over Highway 50 in Sacramento, constructed in 1971 with single central pier for improved safety and aesthetics. Mead & Hunt photograph.*

---

[104] Podolny Jr., "An Overview of Precast Prestressed Segmental Bridges," n.d., 59.
[105] Kozak and Bezouska, "Twenty Five Years of Progress in Prestressed Concrete Bridges," 99–100.
[106] Kozak and Bezouska, "Twenty Five Years of Progress in Prestressed Concrete Bridges," 98.

As in California, engineers nationwide sought to eliminate intermediate piers and provide a single span. Despite the fact that these designs were often more costly, they were preferable for safety and offered a bit of aesthetics in their form. Decked bulb-tee structural members with inclined struts and cantilevered side span girders could be used to achieve the needed spans (typically in the 150-200-foot range), but engineers also began to select concrete and steel box girders for this reason, and by the mid-1970s examples had already been constructed in Florida and Arizona.[107]

While some changes in design (such as the elimination of intermediate piers) were rooted in safety enhancement, the utilitarian, standardized nature of many highway bridges led to concern that the emphasis on function, safety, and cost could override aesthetics. States such as California and Virginia created aesthetic guidelines, adapting existing standard designs to provide an improved appearance at a minimal additional cost.[108] These guidelines emphasized clarity of design with simple lines, symmetry, consideration of the proportion between elements, and gentle transitions for variable span depth (see Figure 16 and Figure 17).[109]

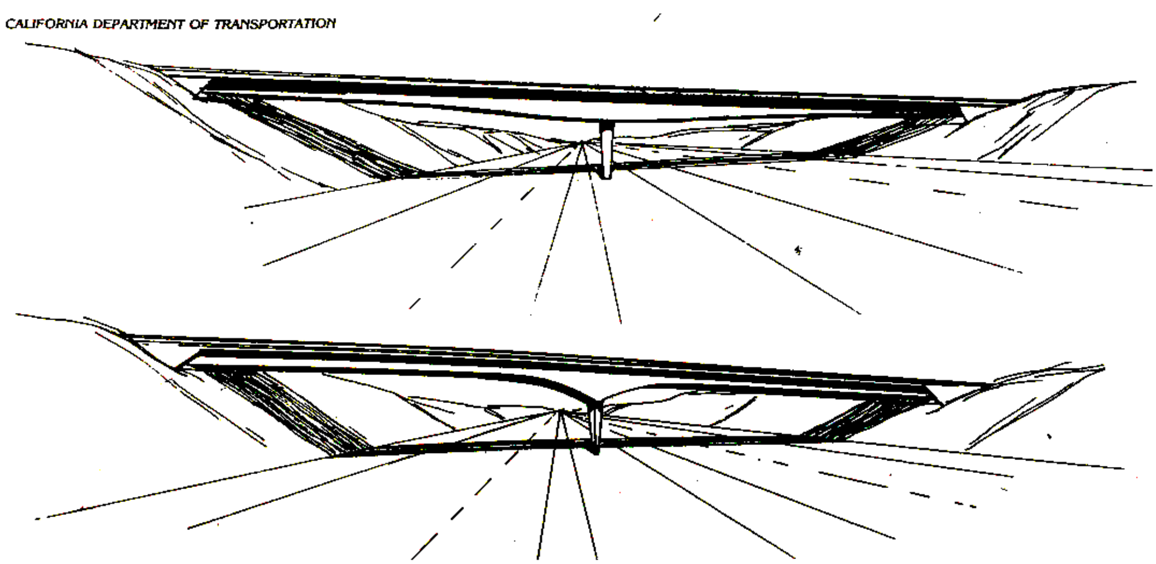


*Figure 16. Caltrans illustration showing the preferable appearance of long girder haunches (above) over more abrupt short haunches (below).[110]*

[107] Kneeland A. Godfrey, "Cutting the Cost of Short-Span Bridges," *Civil Engineering - ASCE* 45 (July 1975): 45.

[108] William Zuk, *Bridge Esthetic Guidelines* (prepared for the Virginia Highway & Transportation Research Council, 1975), 1; Edward P. Wasserman, "Aesthetics for Short- and Medium-Span Bridges," in *Bridge Aesthetics Around the World* (Washington, D.C.: Transportation Research Board, 1991), 61.

[109] Zuk, *Bridge Esthetic Guidelines*, 3–4.

[110] Wasserman, "Aesthetics for Short- and Medium-Span Bridges," 62.

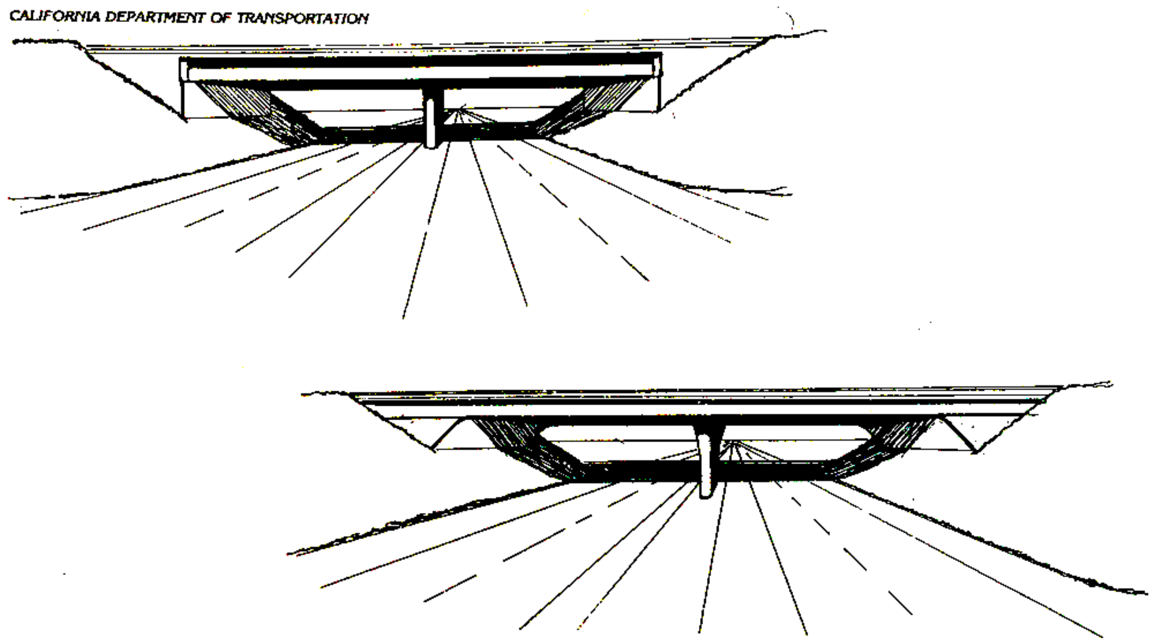


*Figure 17. Caltrans illustration showing preferable appearance with dynamic, sloping lines (below) rather than static, vertical lines (above).[111]*

A paper presented by a Chicago-based engineer at the ASCE's Environmental Engineering Meeting in 1969 summarized guidelines in use by various states. For short span bridges across highways, smaller waterways, or railroad grades, the chief factors were slenderness, lack of mass, continuity of lines, simplicity of details, and compatibility with the adjacent environment.[112] The idealized designs were compatible with their location and surroundings and featured shallow superstructures and slender piers, with a smooth flow of lines connecting the various elements of the structure. Designers were advised to avoid mixing steel and concrete in the same structure, minimize projections and distracting details, and minimize the number of pier columns for long viaducts.[113] Overall, these guidelines favor a modern, minimalist appearance that avoids severity and accentuated continuity and flow.[114] In long-span girder bridges, this could be achieved through the use of long, graceful haunches in the box section, while box-girder spans could make use of long cantilevered wings on either side to give a lighter appearance.[115]

The Genesee Park Bridge, which carries a county road over Interstate Highway (I-) 70 in Golden, Colorado, exemplifies these ideals in its minimalist design and attention to the surrounding environment. Constructed in 1970, the bridge was the first continuous, steel, box-girder structure in the state. By omitting the center pier, the design frames the mountain vista to the west (see Figure 18) and was

---

[111] Wasserman, "Aesthetics for Short- and Medium-Span Bridges," 61.

[112] Reece H. Wengenroth, "Bridge Engineer Looks at Esthetics of Structures," *Journal of the Structural Division* 97, no. 4 (1971): 1227.

[113] Wengenroth, "Bridge Engineer Looks at Esthetics of Structures," 1237.

[114] Wasserman, "Aesthetics for Short- and Medium-Span Bridges," 58, 61–62.

[115] Committee on General Structures, Subcommittee on Bridge Aesthetics, *Bridge Aesthetics Around the World* (Washington, D.C.: Transportation Research Board, National Research Council, 1991), 23, 26.

recognized by the AISC for its "simple and straightforward design with graceful, slender lines." The award for "Most Beautiful Bridge – Highway Grade Separation" was awarded in 1971, the first time a Colorado structure had ever received the award.[116]

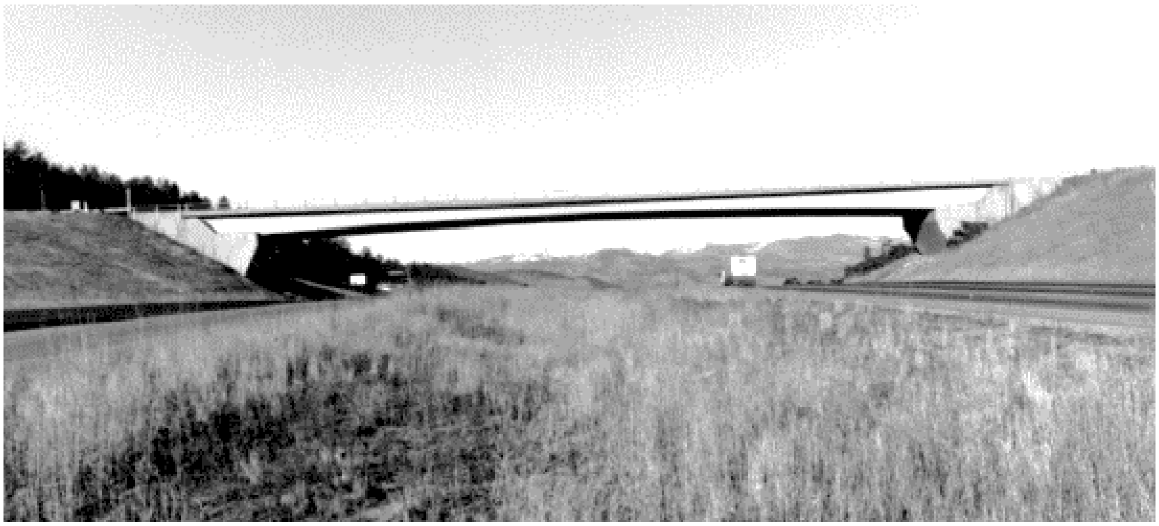

*Figure 18. Genesee Park Bridge near Golden, Colorado.*[117]

In addition to the more common adaptations of standardized highway bridge design, unique designs intended to meet particular site constraints also incorporated a simplified, minimalist aesthetic. Segmental box girders (both concrete and steel) constructed in 1978 at Vail Pass, Colorado, also exemplify both the technological advances and environmental and aesthetic considerations of the study period. The alignment was carefully selected based on geology and ecology, and the bridges' graceful designs utilized beveled parapets and diamond-section piers to provide aesthetically balanced structures.[118]

The Lilac Road Overcrossing in San Diego County, California, is a striking example of a bridge designed to complement areas of natural beauty (see Figure 19).[119] Completed in 1978, the bridge is a 695-foot, post-tensioned, prestressed-concrete box girder supported by a reinforced-concrete cellular arch. Straddling I-15 across an unusually wide, deep cut, the bridge was designed to frame the motorists' vista and form a gateway. The gateway aesthetic is complemented by a decorative Gothic arch framing of the chain-link safety fencing along both sides of the bridge deck.

---

[116] Rebecca Herbst, "State Inventory Form, I.D. No. 5JF 398 - F-15-CI, Genesee Park Interchange" (Colorado Historical Society, December 1985).

[117] Herbst, "State Inventory Form, I.D. No. 5JF 398 - F-15-CI, Genesee Park Interchange."

[118] Paul C. Harbeson, "Architecture in Bridge Design," in *Bridge Aesthetics Around the World* (Washington, D.C.: Transportation Research Board, 1991), 115–19.

[119] Harbeson, "Architecture in Bridge Design," 117–19.

*Figure 19. Lilac Road Overcrossing in San Diego County, California, c.1980. Caltrans photograph.*

# 3. Bridge Building in West Virginia from 1965 to 1980

This section explores historical events which influenced bridge building in West Virginia during the study period. Identification of an individual bridge serves as an example but does not necessarily indicate significance or eligibility for listing in the National Register. Instead, the bridge is identified to assist in understanding historical themes and associations within West Virginia's bridge-building history.

## A. Background

Established in 1917, the West Virginia State Road Commission (SRC) was the agency responsible for construction and maintenance of state and federal highways within West Virginia at the beginning of the study period. In 1970 the SRC was renamed the Department of Highways (DOH), though with little apparent change to the department's operations or administration. The same advisory board oversaw the new department and ongoing projects continued without disruption.[120] In 1989 the DOH became a division of the newly created West Virginia Department of Transportation. At that time, the department took on its current name, the West Virginia Division of Highways (WVDOH).[121] For the purposes of this report, the agency will be referred to by the name that is appropriate to the time period being discussed. Throughout this historic context, the acronym DOH should therefore be understood to refer to the Department of Highways, not its successor the Division of Highways. In those instances where the time period being discussed is more general, such as sections covering trends that spanned the entire study period, DOH will be used for consistency to represent both the SRC and the DOH during their respective periods of operation.

For administrative purposes, the WVDOH is subdivided into ten districts, each with its own offices responsible for maintenance of WVDOH roads and bridges within that district. Under certain circumstances, district crews may also have been responsible for construction of bridges during the study period. In some cases, administrative differences between different regions may have yielded slightly different trends for bridge building. In other cases, individual districts may be discussed as a shorthand for illustrating regional differences throughout West Virginia. Figure 20 shows a current map of the WVDOH districts.

---

[120] "Minute Book: State Road Commission 1959-1980" (Advisory Board of the Department of Highways, 1980), State Road Commission papers, West Virginia State Archives; "Division of Highways," *The West Virginia Encyclopedia*, 2023, https://www.wvencyclopedia.org/articles/375.

[121] "Division of Highways."

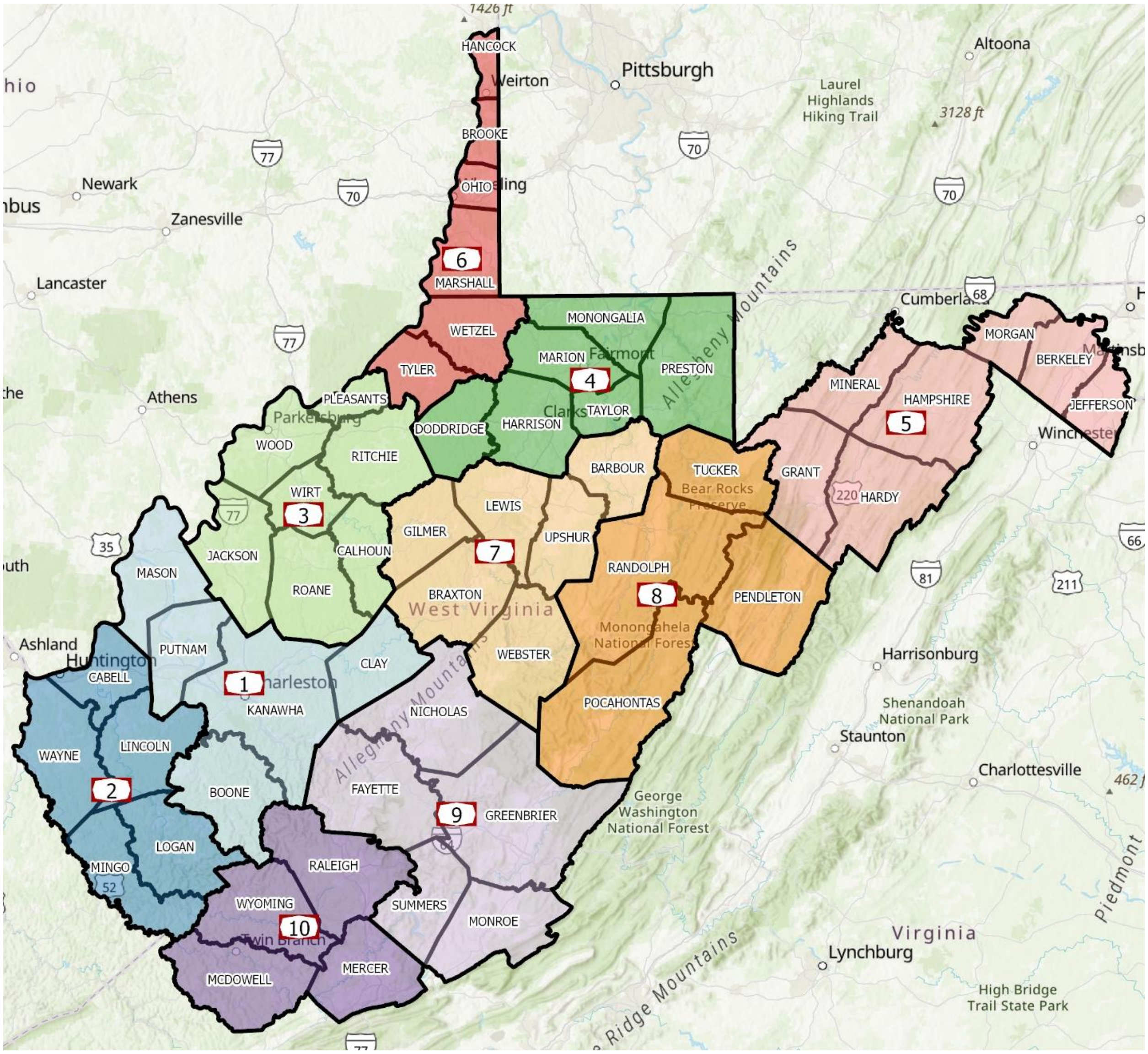


*Figure 20. Map showing the locations of* WV*DOH districts.*

The DOH's work during the study period was defined by a number of large-scale development initiatives, including the construction of the Interstate, Appalachian Corridor, and Highland Scenic Highway Systems. Beginning in the early 1960s the SRC began reorganizing the department and hiring additional staff to help address the massive demands of the Interstate Highway System, which was projected to be completed in 1972.[122] By 1965 congressional approval of the Highland Scenic Highway System and Appalachian Development Highway System had substantially increased the demands on SRC staff. That same year the SRC updated its ten-year plan to include the new systems, predicting that all three

---

[122] *A Report on the Present, A Plan for the Future* (Charleston, WV: the State Road Commission of West Virginia, 1963), West Virginia University Archives.

systems, totaling 1130 miles of new highway, would be complete by 1972.[123] In addition to federal obligations, West Virginia had, in the 1930s, consolidated all state and county road systems under the management of the SRC. Unlike most other states in the country, the DOH was thus responsible for the maintenance and construction not only of large federal and state highways, but also the smaller-scale county road systems.[124]

A major focus of the DOH's bridge program during the study period was Ohio River bridges, which spanned the border between West Virginia and Ohio and played an essential role in interstate commerce. Small riverside communities often found the nearest city to be on the opposite side of the river, making good bridges necessary for convenient access to commercial centers, employment opportunities, and even vital medical care. As a result, good bridges across the Ohio River were considered by politicians and business leaders throughout the state to be essential to the state's economy. The temporary closure of Ohio River bridges following the Silver Bridge Disaster of 1967 (see below) led to assessments that losing even a single bridge could result in a loss of more than $1 million per month to the local economy.[125] During the study period and immediately after, West Virginia planned and constructed more than a dozen major bridges across the Ohio River, both as replacements for deficient or substandard spans and for completely new routes designed to increase ease of travel between Ohio and West Virginia. Having ownership of nearly the entire Ohio River, West Virgina held primary responsibility for both the construction and funding of all Ohio River bridges. In most cases, the Ohio Department of Transportation was responsible for only approaches and abutments on the Ohio shores.[126]

## B. The Silver Bridge Disaster and fallout

By far the most impactful bridge-related event from the study period was the collapse of the Silver Bridge. Completed in 1928, the 2,235-foot, eye bar-chain suspension bridge spanned the Ohio River between the communities of Point Pleasant, West Virginia, and Gallipolis, Ohio.[127] Due in part to the unusual construction method, deterioration of the bridge had gone undetected, and on December 15, 1967, at approximately 5 p.m., the Silver Bridge collapsed without warning into the Ohio River. This single, 60-second event caused dramatic systematic changes at DOH for decades to come. The stunning and dramatic failure left 46 dead and two missing out of the 64 individuals in 31 vehicles on the bridge at the time.[128] As discussed in the National Bridge Inspection Program section above (see Section 2.A.(1)), major federal legislation requiring the routine inspection of bridges nationwide was passed the following

---

[123] *An Enlarged Plan for the Future: Seven Year Program... 1966-1972* (Charleston, WV: the State Road Commission of West Virginia, 1965), West Virginia University Archives.

[124] Gregory Bailey, Telephone interview with Mead & Hunt, Inc., Telephone, December 20, 2023.

[125] "LBJ Reveals Crash Plan for Bridge," *The Charleston Daily Mail*, February 7, 1968.

[126] Unlike most other places where a river forms the boundary between states, West Virginia retains ownership of nearly the entire Ohio River, giving the state the lion's share of responsibility for funding and constructing Ohio River bridges between West Virginia and Ohio. As such, West Virginia retains ownership of all of the state's Ohio River border bridges. "West Virginia Water Laws, Water Regulations, and Water Rights" (Office of Legal Services, West Virginia Department of Environmental Protection, 2013).

[127] Feld and Carper, *Construction Failure*, 142.

[128] Abba G. Lichtenstein, "The Silver Bridge Collapse Recounted," *Journal of Performance of Constructed Facilities* 7, no. 4 (November 1993): 254.

year. In West Virginia the disaster caused significant changes to the way engineers approached bridge design and inspired a major overhaul of the state's bridge inspection program, resulting in numerous major bridge replacement projects in the 1970s and 1980s.

The Silver Bridge collapse captured attention at the highest levels, resulting in the appointment of three task forces by President Johnson: one to determine the causes of the failure, another to plan a replacement, and a third to examine existing practices of bridge inspections, the latter to be conducted by the National Transportation Safety Board (NTSB). The investigation revealed the haphazard nature of existing inspection and maintenance practices. In 1967, for example, the exact number of bridges in the U.S. was unknown and there was no systematic inspection program to monitor the condition of existing bridges. Testimony from SRC personnel further revealed a great deal of inconsistency in the state's bridge inspection procedures. Inspection checklists in the SRC manual were not always used, and only those members that were easily accessible from the ground or the bridge deck were closely inspected. SRC inspectors testified that binoculars were used to visually inspect the highest eye-bars on the Silver Bridge.[129] The following year, in 1968, Congress approved the National Bridge Inspection Standards, and in subsequent years began to appropriate funding for bridge inspections, rehabilitation, and replacement.[130]

Beginning in early 1968, the West Virginia legislature extensively debated initiating a state investigation into the disaster. In January a resolution authorizing a committee to investigate the disaster and any agency or state employees "relating to the [SRC] methods and procedures for bridge inspection and maintenance" was unanimously passed in the house of delegates.[131] Due to concerns about the cost of duplicating the efforts of the NTSB investigation, the bill was ultimately killed in the senate and all investigation was left to the federal government.[132] While the West Virginia legislature did not ultimately conduct its own formal investigation, various branches of the state government spent years dealing with the fallout of the Silver Bridge Disaster.

---

[129] "Record of Poor Bridge Inspection Practice Disclosed by Hearing," *The Raleigh Register*, May 9, 1968.

[130] Lichtenstein, "The Silver Bridge Collapse Recounted," 259–60; "Hearing on Highway Bridge Inspections, Statement of King W. Gee, Associate Administrator for Infrastructure and Gary Henderson, Director, Office of Infrastructure Research and Development, Federal Highway Administration, U.S. Department of Transportation," October 23, 2007, www.transportation.gov/content/highway-bridge-inspections.

[131] "SRC Bridge Study Procedures Will Be Considered in House," *The Raleigh Register*, January 26, 1968; "Bridge Probe Is Approved by Unanimous Vote," *Beckley Post-Herald The Raleigh Register*, January 28, 1968.

[132] "What Didn't Pass?," *The Charleston Daily Mail*, February 9, 1968.

**St. Marys Bridge**

Just three days after the Silver Bridge collapsed, a nearly identical bridge, located approximately 90 miles upstream at St. Marys, was closed to traffic pending a detailed inspection. The SRC quickly commissioned an independent consultant to determine whether the bridge was at risk of a similar failure.[133] While state and federal bridge engineers were understandably concerned about a similar disaster occurring at St. Marys, investigations into the cause of the collapse were slow to yield actionable results. As a result, the SRC struggled to determine the best course of action with regards to the St. Marys bridge closure. Without an understanding of the nature of the Silver Bridge failure, it was nearly impossible to determine if this bridge was likely to fail in a similar way.[134] The SRC faced immense pressure to quickly reopen the bridge from political leaders and citizens who were both concerned with the economic impacts of the closure and inconvenienced by long detours necessary to bypass the bridge.[135]

Having passed the consultant's inspection, the SRC had no justifiable reason to keep the bridge closed. Because the nature of the Silver Bridge collapse was still unknown, the SRC compromised by reopening the St. Marys bridge with a significantly reduced load capacity in February 1968.[136] By the end of 1968 the NTSB investigation had determined that the cause of the Silver Bridge Disaster was breakage of an eye-bar, which served as an essential part of the bridge's suspension system.[137] Having determined that the failure of this fracture-critical member (a bridge element whose failure would likely result in complete failure of the structure) was the cause of collapse, it became clear that the nearly identical St. Marys bridge was susceptible to a similar disaster. As a result, the St. Marys bridge was closed permanently in January 1969 (see Figure 21).[138] The SRC immediately began planning for a replacement bridge to be constructed as quickly as possible. By early 1971 Governor Arch Moore declared a state of emergency in St. Marys to fast-track progress and speed the allocation of federal funds to the project. Construction on the replacement Hi Carpenter Bridge (BARS #37A028) began in 1973 and was completed in 1977 (see Figure 22).[139]

[133] "Bridge Closed at St. Marys," *The Charleston Daily Mail*, December 18, 1967.

[134] Henry Petroski, "Silver Bridge," *American Scientist* 99, no. 5 (September 2011): 368–72; "Governor Plans Inspection of All Major W. Va. Spans," *The Weirton Daily Times*, January 6, 1968.

[135] "Silver Bridge's 'Sister' Closed," *The Raleigh Register*, December 31, 1968; "Mayor Flays Bridge Delay," *Beckley Post-Herald*, November 13, 1969.

[136] "St. Marys Bridge Reopened to Autos," *The Raleigh Register*, February 26, 1968; "Letter from H. A. Carpenter to Governor Hulett C. Smith," January 16, 1968, Governor Hulett Smith Papers, SRC General (I-Z) 1968, Bridges Folder, West Virginia State Archives; "St. Marys Seeks Ferry Service," *The Weirton Daily Times*, December 29, 1967.

[137] "Inspection Ruled Out -Tentatively- as Factor in Silver Bridge Collapse," *The Charleston Daily Mail*, November 19, 1968.

[138] "Stress, Corrosion Enter Bridge Tragedy Causes," *Beckley Post-Herald*, January 1, 1969.

[139] "Bridge Status Reports Issued," *The Weirton Daily Times*, June 27, 1973.

*Figure 21. The St. Marys bridge being dismantled in 1971 to make way for its replacement.*[140]

*Figure 22. The Hi Carpenter Bridge (BARS #37A028) replaced the St. Marys bridge in 1977.*[141]

[140] *Demolition of the St. Marys Bridge*, Black and white photoprint, 1971, DOH Communications, AR1993 Box 1, St. Marys Bridge Folder, West Virginia State Archives.

[141] "WVDOT Assets."

By early January 1968 similar inspections were planned for all major bridges in West Virginia. The state contracted with a number of consulting firms to assist SRC staff with bridge inspections statewide.[142] While the SRC never clearly defined what was meant by "major spans," inspections began with the largest Ohio River bridges and worked toward smaller spans. As a result of the inspections, several other bridges, including bridges at Chester, Enterprise, and Hinton, were either closed to traffic entirely or subject to reduced load limits. The imposition of a 5,000-pound load limit on the Chester-East Liverpool Bridge proved to be an extremely contentious issue. Governor Hulett Smith received numerous letters of complaint from businessmen in Hancock County who were concerned with the economic impacts of the bridge's closure to large trucks.[143] Meanwhile, police and SRC personnel struggled to enforce the load limit. The SRC ultimately resorted to constructing 7-foot clearance bars on the bridge's approaches to prevent large trucks from entering the bridge. For their part, the state police began arresting load limit violators.[144]

West Virginians had very mixed reactions to the state's response to the disaster. While some considered the inspections and bridge closures an overreaction with dire economic consequences, many others took the opposite position, raising concerns over the safety of bridges in communities across West Virgnia. The governor and SRC received numerous letters complaining about bridges in poor condition and requesting inspections, closures, or replacements, and newspapers published editorials, articles, and letters to the editor about public concerns over bridge safety.[145] Both the governor and SRC were quickly overwhelmed with bridge inspection or replacement requests from across the state. While they struggled to reassure the public that they were safe and the issue was being handled appropriately, their replies often grimly acknowledged that corrective action was severely limited by available funds. One such letter from Governor Smith's office asked a community leader to encourage concerned citizens to support a new bond issue, the Road Development Amendment of 1968, in the general election held that year.[146] For further discussion of this and other road funding legislation, see Section 3.A.(3), Legislation and funding, below.

[142] "Governor Plans Inspection of All Major W. Va. Spans."

[143] "Letter from Charles D. Taylor, President of the Northern Hancock County Development Organization to Governor Hulett C. Smith," May 1, 1968, Governor Hulett Smith Papers, SRC General (I-Z) 1968, Bridges Folder, West Virginia University Archives.

[144] "Chester Bridge Arrest Made," *The Weirton Daily Times*, February 20, 1968; "Boost Is Given Chester Bridge," *Beckley Post-Herald The Raleigh Register*, February 11, 1968.

[145] "Resolution of the Huntington Board of Realtors," January 10, 1968, Governor Hulett Smith Papers, SRC General (I-Z) 1968, Bridges Folder, West Virginia University Archives; "Letter from Charles D. Taylor, President of the Northern Hancock County Development Organization to Governor Hulett C. Smith," January 3, 1968, Governor Hulett Smith Papers, SRC General (I-Z) 1968, Bridges Folder, West Virginia University Archives; "Letter to Governor Hulett C. Smith from The County Court of Mineral County," February 5, 1968, Governor Hulett Smith Papers, SRC General (I-Z) 1968, Bridges Folder, West Virginia University Archives; "Steubenville City Council Fearful of Bridge Safety," *The Weirton Daily Times*, September 15, 1971.

[146] "Letter to James V. Morris from Paul Crabtree, Executive Assistant to the Governor," April 3, 1968, Governor Hulett Smith Papers, SRC General (I-Z) 1968, Bridges Folder, West Virginia University Archives.

### (1) West Virginia's Bridge Inspection Program

During the NTSB's investigative hearings held in 1968, the Silver Bridge's inspection record received heavy criticism from investigators. Testimony revealed that the bridge inspections occurred irregularly and infrequently, that the state's bridge inspection manual was rarely followed, and that only those structural members accessible from the ground or roadway were closely inspected.[147] At the time of the Silver Bridge Disaster, it was common practice for less accessible bridge elements to go uninspected for decades or, at best, to be inspected from a distance using binoculars.[148] In the years that followed the disaster the SRC's Structures Division, under the leadership of engineer Bob Smith, began to rebuild the inspection program from the ground up.[149] New inspectors were hired to work out of district offices throughout the state, underwater inspection crews were created to investigate piers for scour below the waterline, and regular inspection schedules were implemented. New inspection procedures required every part of a bridge to be inspected at a distance no greater than arm's length and non-destructive tests, such as ultrasonic and magnetic particle tests, were required for any non-visible components.[150]

Because the SRC's efforts to rebuild its bridge inspection program coincided with the FHWA's efforts to create the NBI and the NBIS, it is difficult to know which elements of the state's inspection program originated with the SRC and which were the result of federal requirements. What is certain is that the Silver Bridge Disaster significantly impacted the way SRC (and later DOH) personnel thought about bridge safety and bridge inspection. By the early 1970s the DOH had a goal of inspecting bridges not on the two-year cycle required by the NBIS, but annually.[151] DOH bridge inspectors became notorious for their vigilance and adherence to strict safety standards while engineers reevaluated their attitudes toward bridge design, focusing on the elimination of non-redundant members from new bridge designs.[152]

To complement the restructured bridge inspection program, the DOH's Materials Control, Soils, and Testing Division, which had been created in 1962 with responsibility for various aspects of quality assurance, construction oversight, and materials testing, stepped up its own testing and inspection procedures. During the study period this division, headed by engineer Garland Steele, employed a team of inspectors who were based in fabrication shops across the state with responsibility for oversight of bridge member manufacturing. These inspectors continually inspected bridge members as they were manufactured, maintaining exacting standards for compliance with design specifications. Other teams within the department inspected bridges as they were being constructed, enforcing safety standards and ensuring the quality of materials and workmanship on site. In the event of a bridge failure or construction accident, the division was tasked with conducting investigations and tests to determine causes and

---

[147] "Record of Poor Bridge Inspection Practice Disclosed by Hearing."

[148] Garland Steele, Telephone interview with Mead & Hunt, Inc., Telephone, December 20, 2023.

[149] Randolph Epperly Jr., Telephone interview with Mead & Hunt, Inc., Telephone, December 14, 2023; James Sothen, Telephone interview with Mead & Hunt, Inc., Telephone, December 19, 2023.

[150] "Bridge Inspection Program Costly, But Provides Safety," *The Raleigh Register*, June 3, 1976; Richard Carelli, "Greater Safety Awareness Credited to Tragedy," *The Charleston Daily Mail*, December 15, 1972; Sothen, Telephone interview with Mead & Hunt, Inc.

[151] Carelli, "Greater Safety Awareness Credited to Tragedy."

[152] Bailey, Telephone interview with Mead & Hunt, Inc.; Sothen, Telephone interview with Mead & Hunt, Inc.; Epperly, Telephone interview with Mead & Hunt, Inc.

lessons learned that could be applied to future projects. For its efforts, the Materials Control, Soil, and Testing Division gained a reputation for vigilance and rigid adherence to the rules, which gave the state's bridge engineers confidence that their designs were being constructed to the highest possible standards.[153]

**(2) Silver Memorial Bridge (BARS #27A063)**

After the collapse of the Silver Bridge, the SRC wasted little time in planning a replacement to alleviate the economic toll of the bridge's loss. Just two months after the collapse President Lyndon Johnson announced a "crash program" for the bridge's replacement. The program would utilize a combination of federal highway and Appalachian Regional Commission (ARC; discussed below in Section 3.D) funds to provide 100 percent federal funding for the new bridge.[154] The Federal-Aid Highway Act of 1968, passed eight months later, allocated $50 million in emergency funds to the West Virginia Department of Transportation, $14.3 million of which was earmarked for the Silver Bridge replacement project. Using these funds, the ARC's contribution was returned and the project, including right-of-way acquisition, design, engineering, and construction, was completed entirely with federal highway funds. To fast track the project into the construction phase, the SRC committed to soliciting existing bridge plans, thus bypassing the lengthy design process.[155] Engineering firm E. Lionel Pavlo was selected to design the superstructure using plans for a three-span, cantilevered through truss bridge, which had been prepared for a Mississippi River crossing at Vicksburg, Mississippi. [156] The plans were quickly adapted for the selected site and construction contracts were awarded just four months later on June 11, 1968. Work on the substructure began five days later on June 16, 1968.[157]

Construction on the new bridge progressed quickly, but not without difficulties. In August 1969 three workmen who had been engaged in painting the bridge publicly raised concerns that it was unsafe. Several newspapers carried the story, reporting that the workmen had encountered numerous loose bolts on the structure and that they had been instructed to paint over rust that was already appearing on the new span. While the whistleblowers were subject to rapid backlash from their employer, having been laid off just days after the articles were published, federal inspectors took the claims seriously and arrived on the scene to conduct an investigation two days later.[158] While the contractor's representatives denied claims that anything unsafe had occurred, the State of West Virginia ultimately brought criminal charges against the project's superintendent for failing to comply with state safety regulations. The case ultimately ended in a hung jury and the charges were dropped following assurances that the contractor would comply with all safety regulations going forward.[159] Despite safety concerns during construction, the

---

[153] Steele, Telephone interview with Mead & Hunt, Inc.; Sothen, Telephone interview with Mead & Hunt, Inc.

[154] "LBJ Reveals Crash Plan for Bridge."

[155] "4-Lane Span Planned for Pt. Pleasant," *The Weirton Daily Times*, February 24, 1968.

[156] "Fact Sheet- Silver Memorial Bridge" (West Virginia State Road Commission, 1969), Department of Highways Communications AR1993-Box 1- Silver Memorial Bridge Folder, West Virginia State Archives.

[157] "Fact Sheet- Silver Memorial Bridge."

[158] "Span Critics Not Working," *Beckley Post-Herald*, August 26, 1969; "Henderson Bridge Will Be Checked," *The Raleigh Register*, August 27, 1969.

[159] "Charges Are Dismissed," *Beckley Post-Herald*, September 19, 1969; "Span Safety Chief Denies Flaw Charge," *Beckley Post-Herald The Raleigh Register*, August 30, 1969.

bridge ultimately passed the final inspection conducted by state and federal bridge engineers and the span opened on December 15, 1969, two years to the day after the Silver Bridge Disaster.[160] With enormous support from communities on both sides of the river, Ohio and West Virginia officials agreed in early December 1969 that the new structure would be named the Silver Memorial Bridge (BARS #27A063, see Figure 23).[161]

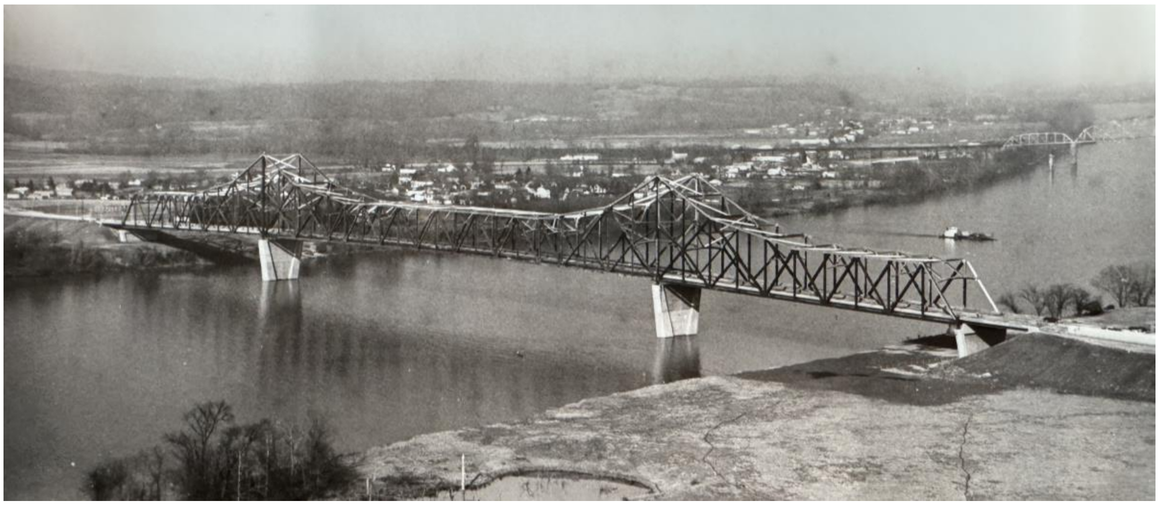

*Figure 23. Silver Memorial Bridge (BARS #27A063) shortly after its completion in 1969, photo by the West Virginia Department of Highways.*[162]

## C. Appalachian Development Highways

In 1960 governors from states throughout the Appalachian region formed the Conference of Appalachian Governors to formulate a regional plan to address the overwhelming poverty that plagued the region. At the time of the conference the Appalachian Region was loosely defined as those states that had some land within the Appalachian Mountain range. Participating states included Alabama, Kentucky, Maryland, North Carolina, Pennsylvania, Tennessee, Virginia, and West Virginia.[163] In 1963 President John F. Kennedy, having made a campaign promise to address poverty in Appalachia, invited the governors to meet with him in Washington, D.C. Shortly thereafter, President Kennedy created the President's Appalachian Regional Commission and tasked the Appalachian governors with studying the poverty issue in their area. The commission was to submit a report to the president with a detailed explanation of the problem and recommendations for how it might be addressed. The commission's report, published in April 1964, contained a wide array of recommendations, but chief among them was that the federal

---

[160] "Silver Memorial Bridge Gets Final Inspection," *The Charleston Daily Mail*, December 11, 1969; "Point Pleasant Braces for Huge Dedication Crowd," *The Charleston Daily Mail*, December 12, 1969.

[161] "New Span Named 'Silver Memorial,'" *The Charleston Daily Mail*, December 5, 1969.

[162] *Silver Memorial Bridge*, Photograph, black & white, 1969, Department of Highways Communications AR1993-Box 1- Silver Memorial Bridge Folder, West Virginia State Archives.

[163] "Conference of Appalachian Governors Counties, June 1962," 1963, Warren I. Cikins Personal Papers. Federal Employment, 1954-1969. Executive Office of the President (White House), 1957-1966. Conference of Appalachian Governors, 1962-1963 (folder 1 of 3)., John F. Kennedy Presidential Library and Museum, https://www.jfklibrary.org/asset-viewer/archives/wicpp-022-001#?image_identifier=WICPP-022-001-p0044.

government invest heavily in Appalachia and create a permanent regional commission to oversee economic development programs for the region. On the commission's recommendation, Congress passed the Appalachian Regional Development Act (ARDA) of 1965.[164]

The ARDA required the formation of a permanent Appalachian Regional Commission (ARC) tasked with creating and overseeing a variety of programs designed to bolster the economy of Appalachia, including developing new highways, public health and education facilities, environmental conservation programs, and studies of new and existing industries. The ARC is comprised of the Governors of Appalachian states and a single federal representative. The ARDA defined Appalachia as a region comprised of 360 counties spanning 11 states with "mountainous, high hill, or rugged terrain."[165] Since the ARDA was passed, more than 60 counties have been added to the region. By 1967 these expansions had brought two additional states into the commission, bringing the total to 13 states. Of the 13 member states, West Virginia is the only state contained entirely within the Appalachian Region, as defined by the ARC.[166] Figure 24 provides a map of the various states and counties included in the Appalachian Region.

Both the 1964 report by the presidential commission and Congressional hearings associated with the passage of the ARDA stressed the importance of providing adequate transportation infrastructure throughout Appalachia as an essential first step for the ARC. As a result, approximately 84 percent of the federal funds initially authorized by Congress were earmarked for the Appalachian Development Highway (ADH) System. Plans for the ADH called for a total of 3,280 miles of highway, comprising 24 "Appalachian Corridor" highways, lettered A through X, to be constructed throughout the region.[167] These highways were to serve as connectors between existing Interstate Highways and improve access of rural Appalachian communities to major markets (see Figure 25).

---

[164] *Appalachia Then and Now: Examining Changes to the Appalachian Region Since 1965* (Appalachian Regional Commission, 2015), https://wayback.archive-it.org/3259/20200430193817/https://www.arc.gov/assets/research_reports/AppalachiaThenAndNowCompiledReports.pdf; Tom D. Miller, "Appalachian Regional Commission," *The West Virginia Encyclopedia*, 2023, https://www.wvencyclopedia.org/articles/249.

[165] Ann DeWitt Watts, "Does the Appalachian Regional Commission Really Represent a Region?," *Southeastern Geographer* 18, no. 1 (1978): 19–36.

[166] *Appalachia Then and Now: Examining Changes to the Appalachian Region Since 1965*.

[167] While "Appalachian Development Highway System" is the official name for this system, individual roadways within that system are referred to as "Appalachian Corridors." Today, these roadways are commonly cosigned with other state or federal highways, but they are still most commonly called by their ADH designation (e.g. "Corridor D").

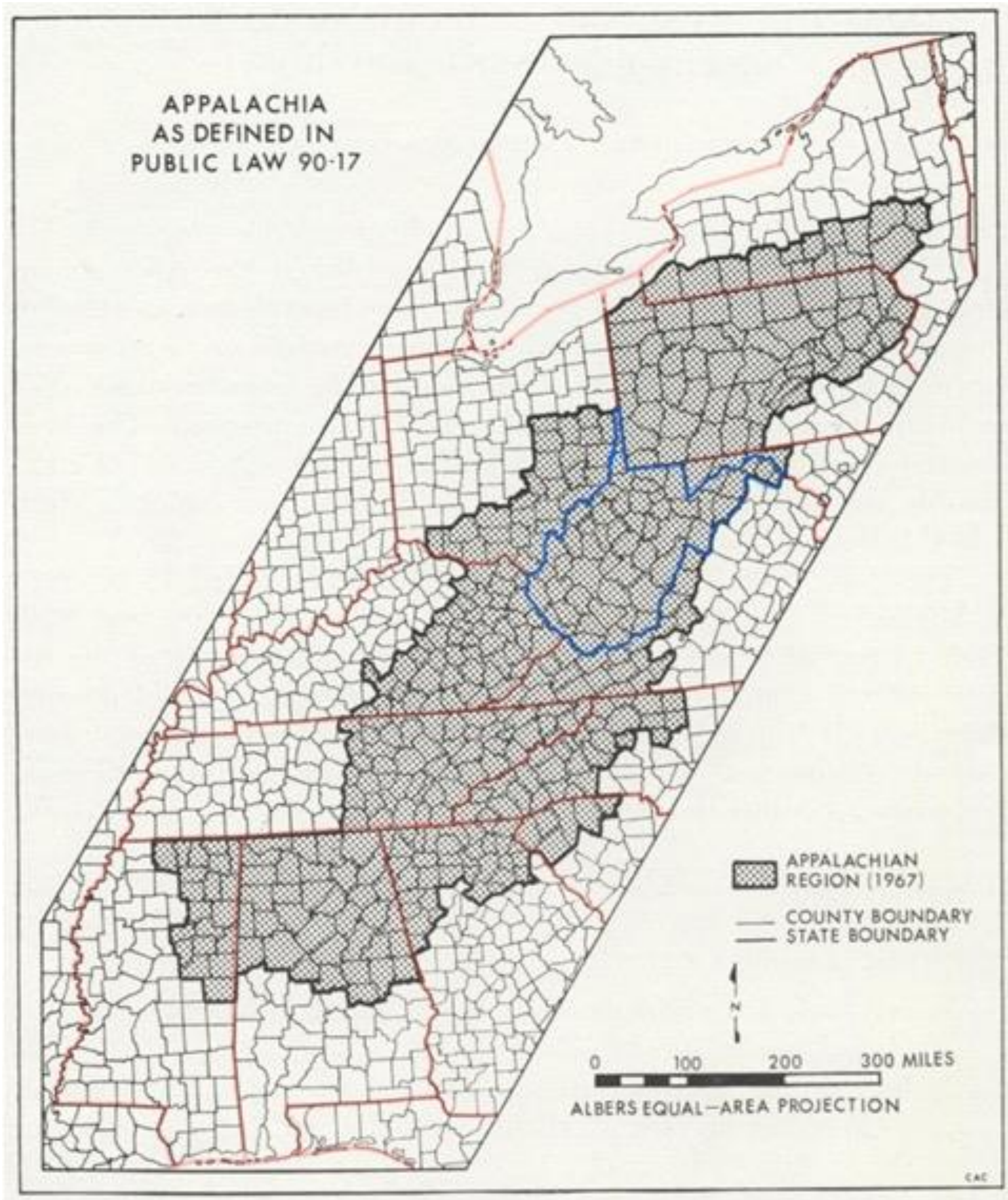


*Figure 24. Appalachia as Defined in Public Law 90-17. A map of counties included in the Appalachian Region as defined by the Appalachian Regional Commission, 1967. West Virginia outlined in blue.*[168]

[168] Watts, "Does the Appalachian Regional Commission Really Represent a Region?," 20.

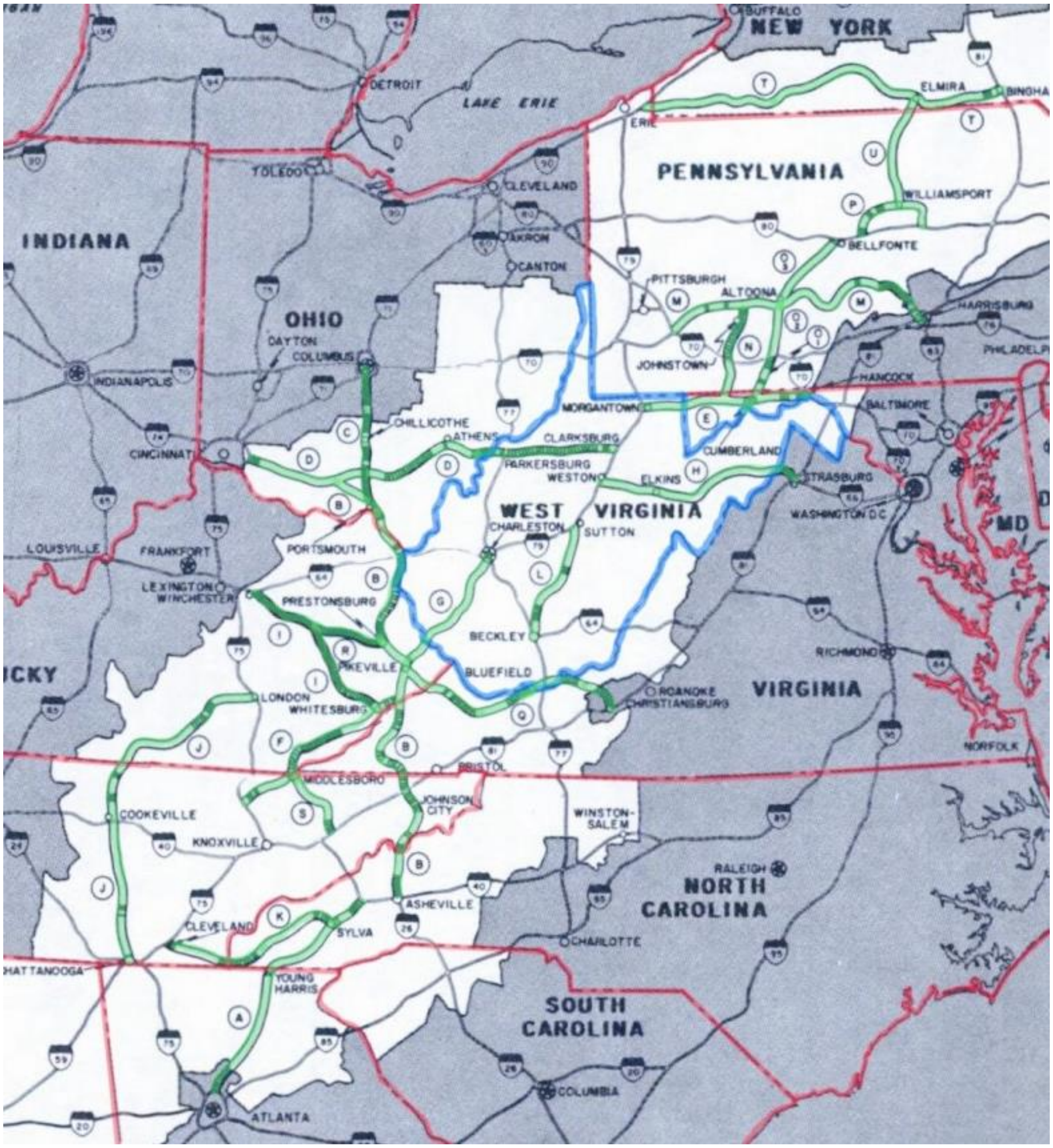


*Figure 25. 1966 map of the planned Appalachian Development Highway System. States are outlined in red, West Virginia in blue. Green lines indicate planned ADH routes.[169]*

The ARC played a significant role in road and bridge development in West Virginia throughout the study period. As the only state contained entirely within the defined Appalachian Region, West Virginia received a great deal of funds from the ARC throughout the study period. Having a central location within the region, relatively few Interstate Highways, and more Appalachian counties than any other state, six of the 24 planned Appalachian Corridor Highways (Corridors D, E, G, H, L, and Q in Figure 25) were routed

[169] *The Appalachian Regional Commission Annual Report: 1965* (Washington D.C.: Appalachian Regional Commission, 1965).

through West Virginia.[170] The six corridor highways combined were to total 451 miles in West Virginia, more than any other state.[171] While states throughout the Appalachian Region struggled to produce their share of ADH construction funds, a 1976 report by the ARC commended West Virginia's efforts in this regard. By 1980 West Virginia had managed to fund and begin construction on 60 percent (255 miles) of the planned Appalachian Corridor Highways, more than any other state.[172]

Construction on the Appalachian Development Highway System in West Virginia began with Corridor D in 1965.[173] Slowed by rapidly rising construction costs, insufficient federal funds, and new environmental permitting and approval processes, the DOH fell short of its initial goal of having all corridor highways completed or under construction by 1971.[174] Despite the delays, by the end of the study period the DOH had completed construction on four of the six planned Appalachian Corridor Highways (D, E, L, and Q) and construction had begun on the remaining two corridors with small segments complete and further work planned (see Figure 26). By 1980 approximately 250 miles of Appalachian Corridor Highways and nearly 100 associated bridges had been constructed in West Virginia. Corridor G was completed in the 1990s, while the longest of the planned highways, Corridor H, was seriously delayed by political controversy. For decades, politicians argued over the location of Corridor H and debated whether it was more prudent to preserve some of the state's natural areas rather than opening them up to highway development. While progress has been made in recent years, Corridor H was only approximately 75 percent complete in 2023.[175]

[170] *The Appalachian Development Highway System in West Virginia: Too Little Funding Too Late?*, Report to the Congress (Washington D.C.: Comptroller General of the United States, 1976), 4.

[171] John M. Munro, "Planning the Appalachian Development Highway System: Some Critical Questions," *Land Economics* 45, no. 2 (1969): 150, doi:10.2307/3145121.

[172] *The Appalachian Development Highway System in West Virginia: Too Little Funding Too Late?*, i, 8; *1980 Annual Report of the Appalachian Regional Commission* (Washington D.C.: Appalachian Regional Commission, 1980).

[173] *A Summary Presentation of the Appalachian Development Highway System* (the State Road Commission of West Virginia, January 1968), West Virginia University Archives.

[174] *The Appalachian Development Highway System in West Virginia: Too Little Funding Too Late?*

[175] Carol Melling, "Appalachian Corridor Highways," *The West Virginia Encyclopedia*, 2023, https://www.wvencyclopedia.org/articles/244.

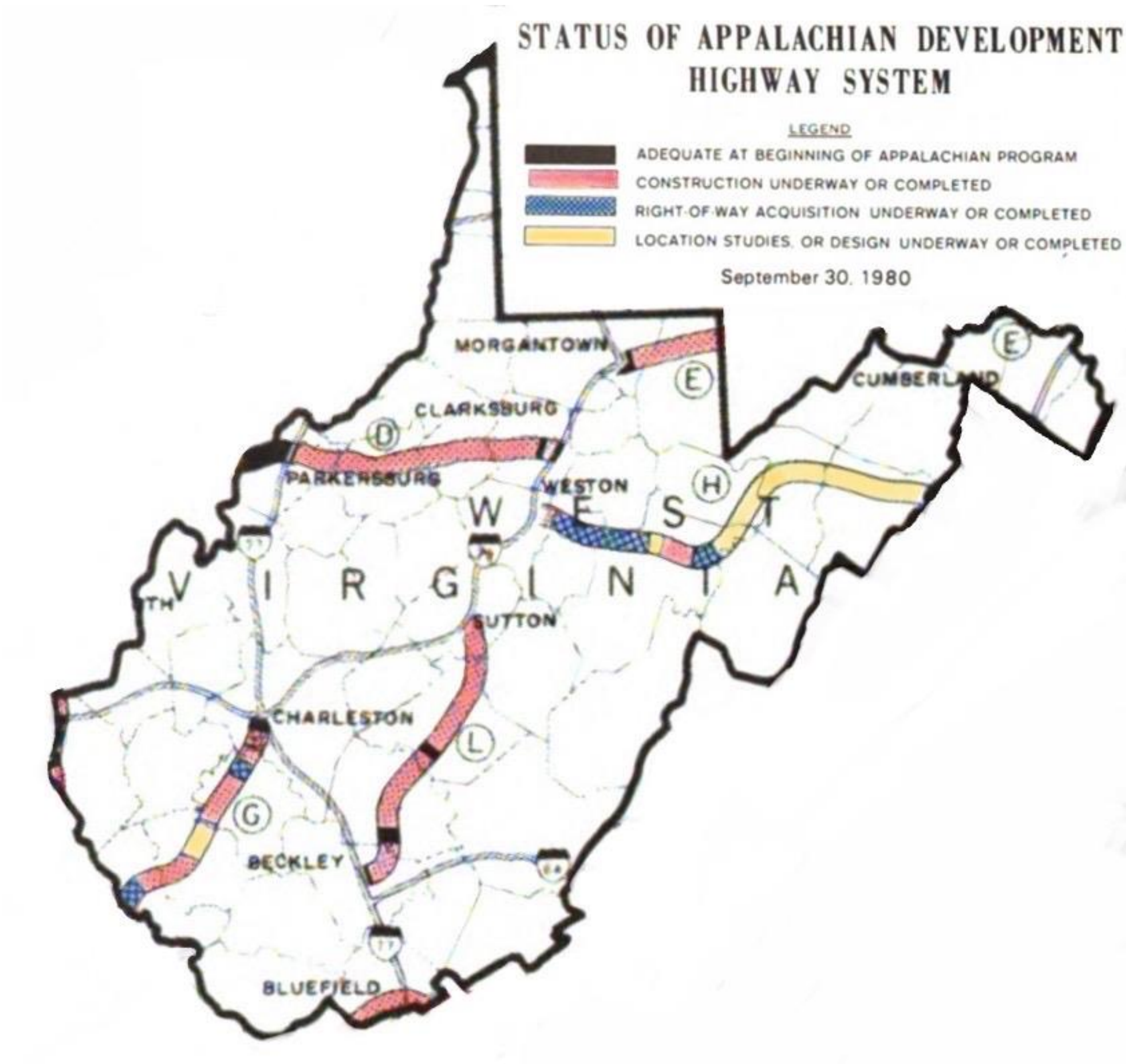


*Figure 26. Map showing the planned Appalachian Development Highway System in West Virginia and construction progress in 1980.*[176]

### (1) New River Gorge Bridge

Perhaps the most significant structure constructed under the Appalachian Development Highway System was the iconic New River Gorge Bridge (BARS #10A214). Designed by Michael Baker Jr., Inc. and completed in 1977, the bridge created an essential connection on Appalachian Corridor L by spanning the massive New River Gorge. At more than 800 feet deep, the New River Gorge had long posed a significant challenge to road and bridge building in the area. The new bridge was planned to replace a roadway that required motorists to follow a series of winding switchbacks to the bottom of the gorge, where they would cross the river via a steel truss bridge before driving back up the other side of the gorge. When completed, the New River Gorge Bridge reduced travel times to cross the river from 45

[176] *1980 Annual Report of the Appalachian Regional Commission*.

minutes to approximately 45 seconds.[177] While the bridge's overall structure length was more than 3,000 feet, its 1,700-foot central span set a record as the longest steel arch span in the world, a record the bridge held for nearly 25 years. The massive steel arch rises 876 feet above the New River and required the construction of four 330-foot-tall towers to carry two, 3-inch-thick cableways that were used to hoist bridge members into place during construction (see Figure 27).[178]

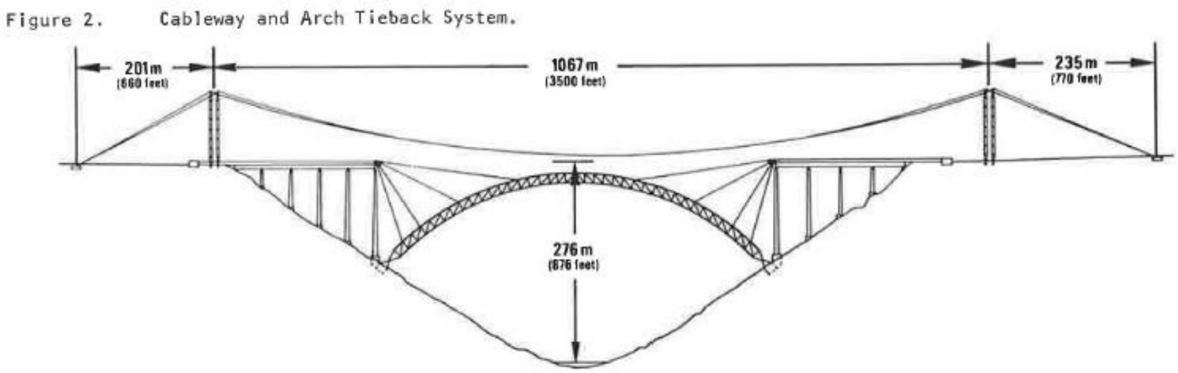


*Figure 27. Diagram depicting the cableway system that was used to hoist bridge members for the New River Gorge Bridge into place during construction.*[179]

The New River Gorge Bridge immediately gained national recognition for both its engineering and its beauty, but to West Virginians it represented much more. The bridge marked a major step forward in the construction of the Appalachian Corridor Highways that would link rural communities with nearby commercial centers. One newspaper said of the bridge's dedication ceremony, "It is rather like driving the golden spike that linked East and West…" The article goes on to discuss the potential economic benefits of the corridor highways: "The 'Corridor L Community' has all kinds of room for development and could in time become a solidly settled and modernized continual community…"[180] For its significant engineering and vital role in the transportation infrastructure of West Virginia, the New River Gorge Bridge was listed in the National Register in 2013 with significance under *Criterion A: Transportation* and *Criterion C: Engineering*. Despite being only 36 years of age at the time, the bridge was listed using *Criteria Consideration G* due to its "exceptional importance as a major engineering and construction achievement as well as for its extreme importance in linking this part of Appalachia with the rest of the state" (see Figure 28).[181] In honor of the bridge's significant engineering and aesthetics, West Virginia citizens voted to use an image of the New River Gorge Bridge on their state quarter in 2005.[182]

---

[177] Larry Sonis, "New River Gorge Bridge," *The West Virginia Encyclopedia*, 2023, https://www.wvencyclopedia.org/articles/1639.

[178] C. V. Knudsen and J. F. Cain, "The Design and Construction of the New River Gorge Bridge," *Transportation Research Record*, Transportation Research Record, Bridge Engineering Volume 2, no. 665 (1978).

[179] Knudsen and Cain, "The Design and Construction of the New River Gorge Bridge," 143.

[180] "Golden Spike?," *Beckley Post-Herald The Raleigh Register*, October 23, 1977.

[181] National Register of Historic Places, New River Gorge Bridge, Fayetteville, Fayette County, West Virginia, National Register #13000603.

[182] Sonis, "New River Gorge Bridge."

*Figure 28. The completed New River Gorge Bridge (BARS #10A214), c.1977.*[183]

## D. Legislation and funding

### (1) Legislation

#### *(a) Better Roads Amendment (1964) and Roads Development Amendment (1968)*

In the early 1960s the SRC was struggling to plan for the next decade's road development. Chief among its concerns was the daunting 1972 federal deadline for completion of the Interstate Highway System. Having completed only 137 of West Virginia's planned 520 miles of Interstate, the SRC undertook an extensive investigation to determine what would be needed to complete the system on time.[184] In early 1963 the SRC published *A Report on the Present, A Plan for the Future*, an expansive document that included financial estimates and timetables for the construction of the Interstate Highway System and other state and federal roads, as well as general highway maintenance, SRC operations, and possible funding sources for the next ten years. This "Ten Year Program" as it came to be known, was intended to serve as a road map for the SRC over the next decade. In addition to a significant increase in staffing, the report determined that the SRC would need a sizable increase in funding to achieve the goals laid out in the plan.[185]

Though the federal government would provide significant funds, at a rate of 90/10 for Interstate Highways and 50/50 for all other federal aid projects, the state was responsible for furnishing the remainder of the funds. This requirement, combined with the SRC's existing roadbuilding, maintenance, and staffing requirements, meant the state would require a significant increase to

[183] West Virginia Department of Highways, *Completed New River Gorge Bridge*, Photograph, black & white, c.1977, Available in Highways Collection, AR1993- Box 1- New River Gorge Folder, West Virginia State Archives.
[184] *A Report on the Present, A Plan for the Future*, II-A-2.
[185] *A Report on the Present, A Plan for the Future*, I–1.

the SRC's budget over the next decade. The state legislature thus proposed a constitutional amendment, to be approved by the voters in the general election of November 1964, which would allow the state to issue $200 million in road bonds over the next ten years. The measure, known as the Better Roads Amendment, was widely supported by state politicians, citizens groups, and individuals and passed easily with nearly 80 percent of the electorate voting in favor of the amendment.[186]

Just four years later the additional burden of constructing the Appalachian Development Highway system (ADH; see Section 3.D) and repairing or replacing bridges following the Silver Bridge Disaster was being exacerbated by rapidly rising construction costs. The estimated cost of construction of the ADH system alone would increase by 60 percent between 1966 and 1972.[187] In 1968 the state legislature proposed a second constitutional amendment, known as the Roads Development Amendment, to supplement the funds approved four years earlier.[188] This second amendment would "authorize the Legislature to issue and sell state bonds not exceeding $350 million… for the development of the Appalachian Highway System and a network of modern roads and highways throughout the state of West Virginia."[189] The amendment was again widely supported, receiving nearly 70 percent approval from the electorate.[190]

***(b) Better Highways Amendment***

The issue of insufficient road funding came back to the voters again five years later in the form of the Better Highways Amendment, which was put before them during a special election held in 1973. Faced with continually expanding construction costs, an ever-growing list of bridges needing replacement, and several other state and federal highway projects in need of funds, the West Virginia state legislature proposed a third amendment to allow the sale of additional road bonds totaling $500 million. This time, the amendment provided very clear guidance for how the money was to be spent. Bridge replacements and improvements were to be allocated $120 million, while an additional $130 million was earmarked for ADH construction. The remaining $250 million was to be divided amongst various federal, state, and local road projects. The amendment was again widely supported by the electorate, with 74 percent voting in favor of its passage.[191]

---

[186] "Roads Amendment Gets Strong Backing," *Beckley Post-Herald*, October 30, 1964; "W. VA. Bond Issue Non-Political," *The Weirton Daily Times*, October 7, 1964; "West Virginia Better Roads Amendment, Amendment 1 (1964)," *Ballotpedia*, accessed December 8, 2023, https://ballotpedia.org/West_Virginia_Better_Roads_Amendment,_Amendment_1_(1964).

[187] *The Appalachian Development Highway System in West Virginia: Too Little Funding Too Late?*, 8.

[188] "Road Bonds New Budget Plan Okehed," *Beckley Post-Herald*, November 6, 1968.

[189] "West Virginia Roads Development, Amendment 2 (1968)," *Ballotpedia*, accessed December 8, 2023, https://ballotpedia.org/West_Virginia_Roads_Development,_Amendment_2_(1968).

[190] "West Virginia Roads Development, Amendment 2 (1968)."

[191] "West Virginia Better Highways Amendment, Amendment 2 (1973)," *Ballotpedia*, n.d., https://ballotpedia.org/West_Virginia_Better_Highways_Amendment,_Amendment_2_(1973).

In total these three amendments provided the SRC (and later the DOH) with access to well over $1 billion in road-building funds during the study period. In addition to providing an administrative understanding of the means by which roads were built, their consistent passage with significant margins also serves as evidence of West Virginians' enthusiasm for improving transportation infrastructure during the study period. At the same time, the DOH was committed to taking advantage of the unprecedented federal-aid highway and bridge replacement funds on offer at the time. Staff were thus encouraged to get as many projects designed and approved as possible so they could take advantage of the federal money before it was gone.[192] These federal funds, combined with strong public support and ample road bonds, allowed the DOH to make significant improvements to the state's transportation infrastructure during the study period, including the completion of hundreds of miles of state and federal highways and construction of more than 1,500 bridges.

### (2) Federal funding

#### *(a) Jennings Randolph*

During the study period, West Virginia's most powerful advocate was U.S. Senator Jennings Randolph (1902-1998), who served as Chairman of the Senate Public Works Committee and its successor, the Senate Environment and Public Works Committee, from 1965-1981 (see Figure 29). Among other things, this committee is responsible for oversight and legislation relating to public works, bridges, and dams. Randolph became known to many as the father of the Interstate Highway System and influential in securing federal funding to meet the infrastructure needs of his home state.[193] He championed the Appalachian Regional Development Act in 1965, all its subsequent legislation, and various Federal-Aid Highway Acts during his tenure. By 1971 West Virginia, despite its small size and population, ranked fourth in the nation in overall highway contracts and mileage completed or improved and third in federal aid contract awards, exceeding the expenditures and awards of larger, more populous states including California, Pennsylvania, and Virginia.[194]

---

[192] Epperly, Telephone interview with Mead & Hunt, Inc.

[193] Martin Weil, "Former Sen. Jennings Randolph Dies," *Washington Post*, May 9, 1998.

[194] "State in Nation's Top Five in 1971 Construction," *West Virginia Highways*, March 1972, West Virginia Highways - Box Hig 1. 4/2 - 1935-1972 - 1972 Folder, West Virginia State Archives.

*Figure 29. President Richard Nixon turns to Senator Randolph (far left) as he signs the Federal-Aid Highway Act of 1973.*[195]

### *(b) Federal-Aid Highway Acts and the Emergency Relief provision*

Several Federal-Aid Highway Acts were passed during the study period. The Federal-Aid Highway Act of 1968 reauthorized the Interstate Highway System, continuing federal funding through 1974. The 1970 act introduced a bridge inventory requirement and inspector training programs. In 1973 another act reauthorized funding of the Interstate Highway System to its expected completion in 1980, appropriating $20 billion toward the construction of interstate, rural, and urban roads in addition to mass transit.

Perhaps most impactful for West Virginia during this period were Senator Randolph's efforts to champion expansion of federal Emergency Relief provisions. Mechanisms had been in place since 1934 for emergency repairs of roads damaged by natural disasters, such as floods or earthquakes, but only regularly apportioned funds could be used. The Federal-Aid Highway Act of 1956 codified an emergency fund of up to $30 million annually, but the language limiting its use to impacts of natural disasters remained.[196] In light of the Silver Bridge collapse, Randolph proposed an amendment to open emergency relief funds to highway structures that had suffered "catastrophic failures."[197] As a result, changes to the Federal-Aid Highway Act of 1968 allowed for

[195] Weingroff, "Busting The Trust."

[196] United States. Federal Highway Administration. Office of Program Administration, "Report Number: FHWA-IF-99-006: A Guide to Federal-Aid Programs and Projects," May 1, 1999, 87, https://rosap.ntl.bts.gov/view/dot/4070.

[197] "Emergency Funds Seen for Bridge at Point Pleasant," *The Charleston Daily Mail*, July 12, 1968.

the Silver Bridge replacement project to benefit from federal emergency relief funds up to 100 percent of the cost of a comparable replacement facility.[198] This did not cover the situation at St. Marys, however, or other places where bridges had been closed to prevent catastrophic failures. Senator Randolph then championed another federal aid bill amendment.[199] As a result, Section 109 of the Federal-Aid Highway Act of 1970 allowed the federal government to pay for reconstruction and repair of roads and highways damaged by natural disasters and catastrophic failures, as well as the replacement of bridges closed between 1967 and 1970 due to imminent danger of collapse.[200]

Emergency relief funds paid for the replacement of several bridges in West Virginia during the study period. In 1971 the Washington Street Bridge in Charleston collapsed into the Elk River due to soil erosion issues.[201] Governor Arch Moore declared a state of emergency, and the DOH announced that federal funds would pay for its replacement.[202] Emergency relief funds also covered the total cost of replacing three bridges in Logan County due to the Buffalo Creek disaster, one of the deadliest dam failures in U.S. history and the impetus for the passage of the 1972 National Dam Inspection Program. On February 26, 1972, 132 million gallons of water and coal refuse broke through a mining dam managed by the Pittston Coal Company and surged through ten communities, killing 125 people, leaving another 4,000 homeless, and causing an estimated $50 million in damages. In August 1972 the DOH opened bids to reconstruct bridges lost to the flood in Crites, Crown, and Craneco, though local citizens' legal battles with Pittston Coal continued until 1974.[203]

In 1974 Senator Randolph met with Federal Highway Administrator Norbert Tiemann to review the construction timetable for the Chester-East Liverpool Bridge in Hancock County.[204] This bridge was also paid for with federal emergency funds, and Randolph was hopeful the bridge could be completed a year sooner than planned.[205] Tiemann suggested using temporary approaches to complete the main span more quickly and told Randolph he would appoint a FHWA coordinator for the project in hopes of a 1976 completion date.[206] The bridge (BARS #15A025), which was named for Randolph, opened in 1977.

---

[198] "Public Law 90-495: Federal-Aid Highway Act of 1968" (United States Congress, August 23, 1968), https://uscode.house.gov/statviewer.htm?volume=82&page=829.

[199] "Turnpike Funding Passes Major Obstacle," *Raleigh Register*, December 18, 1970.

[200] "Public Law 91-605, Federal-Aid Highway Act of 1970" (United States Congress, December 31, 1970), https://www.Congress.gov/91/statute/STATUTE-84/STATUTE-84-Pg1713.pdf.

[201] "Federal Fund Approval for Charleston Bridge," *West Virginia Highways*, November 1971, West Virginia Highways - Box Hig 1. 4/2 - 1935-1972 - 1971 Folder, West Virginia State Archives.

[202] "Federal Fund Approval for Charleston Bridge."

[203] "'G,' Bridge Contracts Awarded," *Logan Banner*, August 21, 1972, Department of Highways Communications AR1993-Box 1- Buffalo Creek Folder, West Virginia State Archives.

[204] "Randolph Wants Bridge Work Rushed," *The Weirton Daily Times*, January 16, 1974.

[205] "Randolph Wants Bridge Work Rushed."

[206] "Randolph Wants Bridge Work Rushed."

### *(c) Highway Safety Act of 1970 and the Special Bridge Replacement Program*

In 1970 West Virginia Representative Robert Mollohan introduced a special bridge replacement program to the House of Representatives to "enable states to replace bridges over major rivers when it is determined that those bridges either fail to adequately serve communities along the river or are in danger of collapse."[207] At the time West Virginia had the highest proportion of older bridges of any state with 3,962 built before 1935.[208] The program was passed as a provision of the 1970 Highway Safety Act and authorized the Secretary of Transportation in consultation with the states to classify bridges on the federal-aid highway system based on their "serviceability, safety, and essentiality to public use," taking into consideration not just safety but a bridge's importance to the economy of its local community. The program allotted $100 million for the 1972 fiscal year and $150 million for the 1973 fiscal year, which covered up to 75 percent of the cost of replacement bridges.[209]

In 1971 West Virginia's number one priority bridge was the Parkersburg-Belpre Bridge (BARS #54A103), noted as the fifth least safe bridge in the nation. A new bridge was approved that year at a cost of $12 million, with $8 million (75 percent) in federal funds, $3 million from West Virginia, and $1 million from Ohio; however, the bridge did not open until 1980. The second priority was the Market Street Bridge, a 1905 steel suspension bridge in East Steubenville that was eventually rehabilitated and listed in the National Register in 2019. At the time, the local planning commission was also concerned about the safety of the Fort Steuben Bridge, directly north in Weirton, but was told this bridge was not listed as a priority structure and that West Virginia had already filled its allotted list of ten priority structures. It was also not eligible for emergency funds since it had not closed between 1967 and 1970.[210] The Weirton/East Steubenville area did not receive a replacement structure until the completion of the Veterans Memorial Bridge (BARS #05A060) in 1990. The Fort Steuben Bridge was demolished in 2012.

### *(d) Surface Transportation Assistance Act of 1978*

The 1978 Surface Transportation Assistance Act established the Highway Bridge Rehabilitation Program and Replacement Program, which replaced the special bridge replacement program and extended federal funding to bridge rehabilitation projects. The legislation allotted $4 billion to the program and added bridge safety inspection requirements such as underwater and fracture-critical inspections. The East Huntington Bridge (BARS #06A215), the second cable-stayed bridge designed in the United States, was funded through a special provision of this act as a demonstration project, though it was not completed until 1985.[211]

---

[207] "Bridge Bill Presented by Mollohan," *The Weirton Daily Times*, September 17, 1970.

[208] "Bridge Bill Presented by Mollohan."

[209] Federal Highway Administration, "Happy 50th Anniversary - National Bridge Inspection Standards," *Highway History*, accessed February 21, 2024, https://www.fhwa.dot.gov/highwayhistory/national_bridge_inspection_standards.cfm.

[210] "Market St. Span Has Priority," *The Weirton Daily Times*, September 16, 1971.

[211] "East Huntington Bridge: Single-Tower Design Will Have First American Use," *West Virginia Highways*, Fall 1980, West Virginia Highways - Box Hig 1. 4/2 - 1978-1980 - Fall 1981 folder, West Virginia State Archives.

### *(e) National Historic Preservation Act of 1966 and National Environmental Policy Act of 1969*

During the study period, Congress passed landmark environmental legislation that had a lasting impact on the design, placement, and scheduling of bridge and highway construction. The use of federal funding in the construction of major bridges necessitated compliance with these laws and created delays that led to design changes and had economic ramifications for the communities involved. The National Historic Preservation Act of 1966 created the National Register and required federal agencies to consider effects of federally funded projects on nearby historic properties and archaeological sites. The National Environmental Policy Act imposed these same considerations on the environmental, social, and economic effects of federally funded projects.

On June 18, 1973, the DOH established the Project and Environmental Review Division to coordinate increased public involvement in the consideration of economic, social, and environmental effects of its infrastructure projects.[212] Within the division, the new Environmental Review Unit monitored projects to ensure all necessary procedures were followed. The unit was headed by Robert Titus, who had previously been the director of Traffic Engineering and author of the "Action Plan" that recommended the new division.[213]

Complicated and disputed environmental impact statements (EISs) created delays almost immediately on major bridge projects, particularly on the Ohio River bridges. First proposed in the 1950s to relieve traffic pressure on Huntington's 6th Street Bridge, the East Huntington Bridge (BARS #06A215) was not completed until 1985. Political and environmental disputes led to several site changes with concerns about effects to the historic Madie Carroll House, which was listed in the National Register in 1973, and Pleasant View Park.[214] In the Parkersburg area, Appalachian Corridor D from I-77 to the Ohio state line remained unfinished for decades due to historic, environmental, and financial concerns. The highway was complete up to I-77 by the late 1970s; however, the initial EIS for the corridor bridge stipulated that the piers could not touch Blennerhassett Island to protect its wetlands and bird habitats.[215] The island also contains significant historic and archaeological sites investigated by Bettye J. Broyles, Archaeology Head of the West Virginia Geological Survey, in the 1970s, and the entire island was listed in the National Register in 1972.[216] The Blennerhassett Bridge (BARS #54A200) did not open until 2008, finally completing Corridor D.

---

[212] "Project & Environmental Review Division Established," *West Virginia Highways*, July 1973, West Virginia Highways - Box Hig 1. 1/4 - 1973-1981 - 1973 Folder, West Virginia State Archives.

[213] "Project & Environmental Review Division Established."

[214] "East Huntington Bridge: 'Phantom' with a History," *Herald-Advertiser*, July 29, 1973, Clippings - Bridges - General, West Virginia State Archives.

[215] Joe Deneault, PE, "Bridging the Past," *Modern Steel Construction*, January 2007, https://www.aisc.org/globalassets/modern-steel/archives/2007/01/2007v01_bridging_the_past.pdf.

[216] National Register of Historic Places, Blennerhassett Island Historic District, National Register #72001294. "Blennerhassett Island Restoration - Wilderness Eden May Bloom Again," *The Charleston Daily Mail*, August 16, 1974.

Similar issues delayed the Veterans Memorial Bridge in Weirton. The 1972 EIS revealed a historic site, and the Advisory Council on Historic Preservation did not approve a memorandum of understanding at the planned location until 1975. As in Huntington, the location of the bridge was the subject of other local disputes, and a second EIS was drafted in 1977. This was delayed by the U.S. Coast Guard, which felt the bridge's impact on the First Federal Land Office in Steubenville had not been thoroughly examined.[217] The Veterans Memorial Bridge (BARS #05A060) was dedicated in 1990, nearly 30 years after its preliminary engineering report.

Beyond compliance with environmental legislation, the DOH was also involved in bridge restoration projects during the study period. In 1971 the DOH spent $17,000 to restore an 1821 covered bridge in Milton (BARS #06A061) with new pine rafters, cedar shakes, and log guard rails to replace incompatible metal replacement elements.[218] That year, Governor Arch Moore announced that an 1832 stone arch bridge (BARS #02A072) over Opequon Creek in Berkeley County (now known as the Van Metre Ford Stone Bridge) would be preserved as a historic site and repaired with state funds; its modern replacement was relocated.[219] In Greenbrier County, community fundraising efforts saved a 1914 concrete arch bridge that was bypassed by the DOH in 1977 and scheduled for demolition.[220]

Letters in his personal archives indicate that WVU civil engineering professor Emory Kemp, who was hired to perform bridge inspections during the study period, also made recommendations to the state regarding the historic significance of its bridges. He authored West Virginia's first historic bridge inventory in 1983.

**The Vulcan Bridge and Foreign Aid**

Once a thriving mining community in Mingo County, Vulcan lost its only access to the outside world when a turn-of-the-century wood suspension bridge collapsed into the Tug Fork River in 1975.[221] After failed appeals to both state and federal officials, self-appointed "mayor" John Robinette sent letters to the Soviet Embassy and to communist officials in East Germany requesting foreign aid to construct a new bridge. Interested in a story about the government's neglect of this isolated community, Soviet journalist Iona Andronov visited Vulcan on December 17, 1977, coincidentally the day West Virginia announced that it would build the bridge.[222] Robinette's story was covered in newspapers across the country and attracted the attention of Hollywood producers (see Figure 30). [223] The million-dollar Vulcan Bridge (BARS #30A278) opened in 1980, though Andronov maintained that if the state had not built the bridge, the Soviet Union would have.[224]

[217] "U.S. Coast Guard Readies Bridge Impact Statement," *The Weirton Daily Times*, December 1, 1976.
[218] "Department Restoring Milton Covered Bridge," *West Virginia Highways*, June 1971, West Virginia Highways - Box Hig 1. 4/2 - 1935-1972 - 1971 Folder, West Virginia State Archives.
[219] "140-Year-Old Stone Bridge to Be Retained as Historical Site," *The Pennsboro News*, October 21, 1971, Clippings - Bridges - General, West Virginia State Archives.
[220] John G. Morgan, "Pride Sparks Campaign for Historic Span," *The Charleston Gazette*, November 4, 1978, Clippings - Bridges - General, West Virginia State Archives.
[221] Tom Friedman, "Russian Aid? Nyet!," *Charleston Daily Mail*, n.d., Clippings - Bridges - General, West Virginia State Archives.
[222] "Vulcan Bridge near Completion," *The Anniston Star*, December 31, 1979.
[223] "Vulcan Bridge near Completion."
[224] "Vulcan Bridge near Completion."

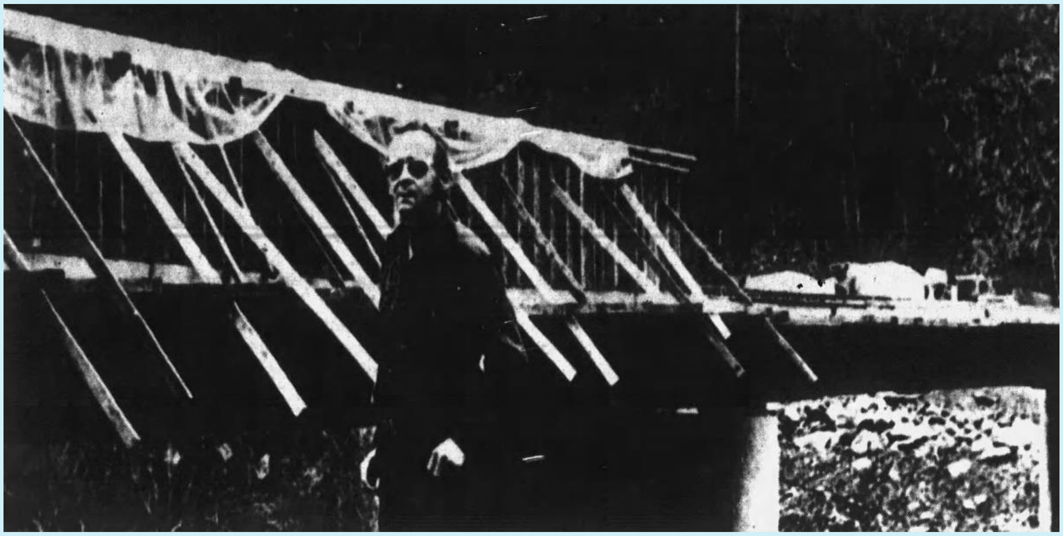

*Figure 30. John Robinette pictured in an Alabama newspaper in front of the Vulcan Bridge (BARS #30A278) during its construction in 1979.[225]*

## E. Civil Rights and displacement

As discussed in the Civil Rights section of the national context above (see Section 2.A.(6)), the early part of the study period corresponds with major social changes occurring throughout the country, including West Virgina. *Renewing Inequality* from The Digital Scholarship Lab at the University of Richmond shows five West Virginia cities with urban renewal projects that resulted in displacements: Huntington, Bluefield, Charleston, Wheeling, and Benwood.[226] The downtown Huntington project is located near the current site of the 1994 Robert C. Byrd Bridge (completed 1994; BARS #06A222) and the nonextant Sixth Street Bridge (completed 1926) it replaced, but based on research conducted to date, the construction of an I-77 bridge for the Triangle neighborhood project in Charleston caused displacement of underrepresented groups in the neighborhood.

The Triangle neighborhood of Charleston, West Virginia, was severely impacted by urban renewal and Interstate Highway projects. In November 1965 Charleston's Urban Renewal Authority began planning a project for the Triangle neighborhood, located in central Charleston near the confluence of the Elk and Kanawha Rivers. The area was home to thousands of mostly low-income Black residents, representing about one third of the city's Black population.[227] Plans called for the Triangle to be cleared and redeveloped, though what form the new development would take was far from clear in 1965. Despite this lack of clarity, early descriptions of the project made clear that the "area involved will be bisected by interstate highway construction."[228] By 1966 ongoing planning for West Virginia's Interstate Highways had determined that several major Interstate and U.S. Highways should meet along the north bank of the Elk

---

[225] "Vulcan Bridge near Completion."

[226] "Renewing Inequality: Family Displacement through Urban Renewal 1950-1966."

[227] *Census Tracts: Charleston, W. VA. Standard Metropolitan Statistical Area*, 1970 Census of Population and Housing (Washington D.C.: U.S. Department of Commerce Bureau of the Census, 1970).

[228] "URA Triangle Study Given Green Light," *The Charleston Daily Mail*, November 5, 1965.

River, just northwest of the Triangle neighborhood. Working in coordination with the urban renewal planners, the SRC determined that a bridge located along the northeast edge of the Triangle would carry I-77 over the Elk River (see Figure 31).[229]

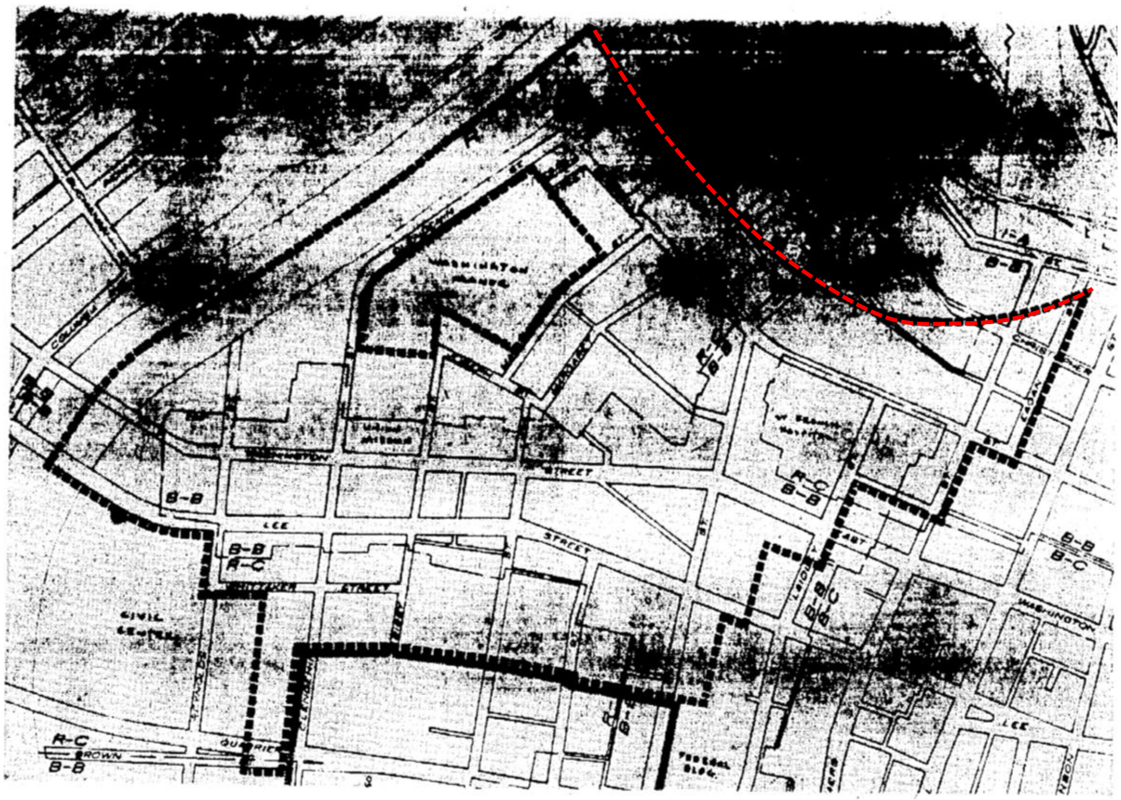


*Figure 31. 1966 map, published in the* Charleston Daily Mail*, showing the boundaries of the Triangle project. The caption of the map read, in part, "Interstate construction would follow the curved line (red) at the top of the map."*[230]

Between the urban renewal project, the Interstate, and a new water treatment plant planned for the area, more than 800 homes were slated for acquisition through imminent domain in the late 1960s. With a population that was more than 70 percent Black, the Triangle neighborhood was considered "the city's predominant Negro area" and residents raised serious concerns about the destruction of their community and insufficient relocation resources for displaced families.[231] The Triangle community and Charleston's National Association for the Advancement of Colored People (NAACP) chapter rapidly organized a coordinated opposition campaign for the projects under the name the Triangle Improvement Council

[229] "Investment Opportunity," *Sunday Gazette-Mail*, June 9, 1974; "Survey Boundary," *The Charleston Daily Mail*, February 9, 1966.

[230] "Survey Boundary."

[231] *Census Tracts: Charleston, W. VA. Standard Metropolitan Statistical Area*; "Census Tracts - 1910 to 2014," *Nhgis.Org*, n.d., https://umn.maps.arcgis.com/apps/webappviewer/index.html?id=ef554b42643141829f9e8c4b8001f93a; "NAACP Opposes Triangle Project," *The Charleston Daily Mail*, January 13, 1969.

(TIC). In December 1968 the TIC filed a federal lawsuit against the SRC to challenge the I-77 project. As the complex case made its way through federal court, land acquisition for the I-77 project continued. By the time the case was heard by the Supreme Court in March 1971, right-of-way acquisitions had removed all but ten Triangle residents from the proposed I-77 corridor, causing the court to rule against the TIC on the assumption that public interest outweighed the interests of those ten people. In the late 1960s the Triangle case and other similar lawsuits resulted in the passage of the Uniform Relocation Assistance and Land Acquisition Policies Act of 1970, which created a set of uniform standards and procedures for land acquisition undertaken for any federal or federally assisted projects.[232]

By 1971 right-of-way acquisition for the I-77 project was complete. In the years that followed land acquisition for the city's urban renewal project was completed and contractors began clearing land for redevelopment. By the end of the study period the Triangle had been cleared almost entirely of its residents and was well on its way to being redeveloped, and the I-77 corridor and bridge were complete.[233] Construction continued into the 1980s, replacing the Triangle's small community businesses, churches, and single-family homes with a collection of new high-rise apartments, hotels, banks, and even a convention center and "superblock" shopping mall, all hemmed in by the imposing form of the newly completed I-77 Elk River bridge (BARS #20A408); see Figure 32.[234]

[232] Thomas W. Lucke, "Relocation Assistance Advisory Programs: A Need for Early Judicial Review," *Administrative Law Review* 27, no. 1 (1975): 17–30.

[233] "Urban Renewal Patience Urged," *The Charleston Daily Mail*, May 19, 1975; "Triangle Improvement Council et al., Petitioners, v. William S. RITCHIE, Commissioner, State Road Commission of West Virginia, et Al.," *LII / Legal Information Institute*, n.d., https://www.law.cornell.edu/supremecourt/text/402/497.

[234] "Historic Aerials: Viewer, Charleston, WV," *Historic Aerials by NETROnline*, 1971, https://historicaerials.com/viewer; "Historic Aerials: Viewer, Charleston, WV," *Historic Aerials by NETROnline*, 1985, https://historicaerials.com/viewer.

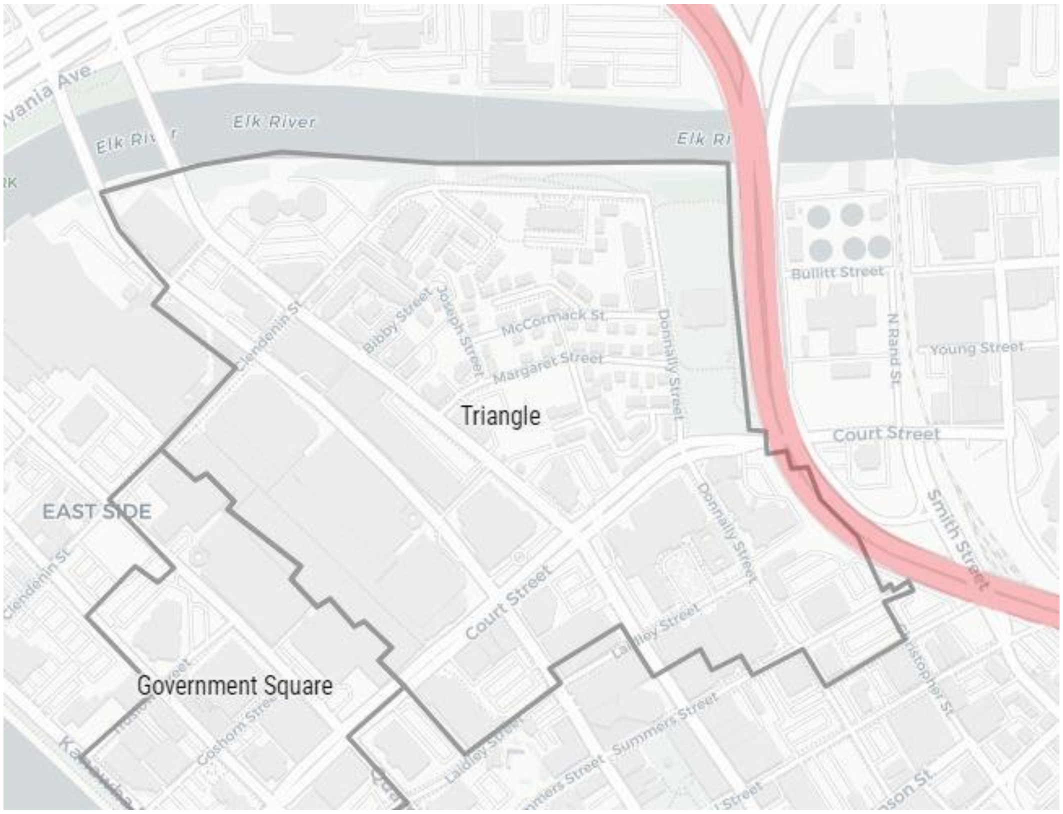


*Figure 32. Excerpt from Renewing Inequality website showing the boundaries of the Triangle neighborhood with the massive I-77 bridge (BARS 20A408) highlighted in red.*

## 4. Bridge Engineering in West Virginia from 1965 to 1980

During the study period bridge engineering in West Virginia was largely defined by three major factors. The first was the state's desire to improve safety in the wake of the Silver Bridge Disaster. These efforts included the inspection and replacement of substandard bridges, implementation of new design methodologies focused on improving redundancy and reducing fracture-critical members, and improvement of engineers' understanding of material characteristics and capabilities. This desire led to significant investment in research projects, funded by the DOH and carried out by various West Virginia universities. These projects investigated various bridge types and materials and worked to improve design, construction, and inspection methodologies.

The second major factor that affected bridge engineering during the period was a strong desire to improve efficiency at all levels of the state's bridge program. DOH leadership initiated numerous programs aimed to help the state design and construct bridges faster and more efficiently. As the state's primary and secondary road systems expanded, the DOH created a Small Bridge Program to efficiently design and construct the numerous short-span bridges demanded by the state's topography. The program's success hinged on the development of a set of standard plans for short-span bridges which could be quickly and easily built without the need for complex design analysis, large scale construction equipment, or specialized crews. As a result of this program, the DOH would increasingly rely on district crews for small bridge construction, which would influence the popularity of certain easily constructed bridge types.

The third major factor affecting bridge design during this period was technological advancement, which allowed engineers to refine existing bridge types with improved materials and develop new types entirely. The most significant technological advancement during the study period was the adoption of computer-aided design programs, which allowed engineers to quickly and easily conduct complex calculations, thus increasing the flexibility of designs, reducing design time, and inspiring more innovative structures. Metallurgical innovations in the form of weathering and galvanized steels proved to be stronger and less susceptible to corrosion and became increasingly popular during the study period. At the same time, researchers developed new inspection equipment capable of detecting flaws in metal that was obscured from view or too small to be seen with the naked eye, thus increasing confidence in welded connections and opening up new design avenues.

These three factors in combination defined the character of bridge building during the study period. Fueled by the DOH's desire to improve safety and efficiency, and supported by new and developing technologies, bridge engineering at this time was characterized by refinement of existing bridge types and the application of new technologies to existing engineering principles.

### A. Bridge types and materials

This section explores the bridge types and materials used in West Virginia during the study period. West Virgina has 1,418 extant bridges and bridge-class culverts built in this period that are more than 20 feet in structure length.[235] Identification of an individual bridge in this section serves as an example but does not necessarily indicate significance or eligibility for listing in the National Register. Instead, the bridge is

---

[235] This number includes bridges and pedestrian structures owned and maintained by the WVDOH, and bridges with other owners that are also maintained by the WVDOH.

identified to assist in understanding historical themes and associations within West Virginia's bridge-building history.

Most bridge types and materials established prior to 1965 continued to be constructed through the study period, with some general widescale changes prompted by materials testing and greater understandings of long-term performance of bridge designs in various regions of the state. Figure 33 and Tables 1 and 2 provide a distribution of the 1965-1980 extant bridges by material and type, respectively.

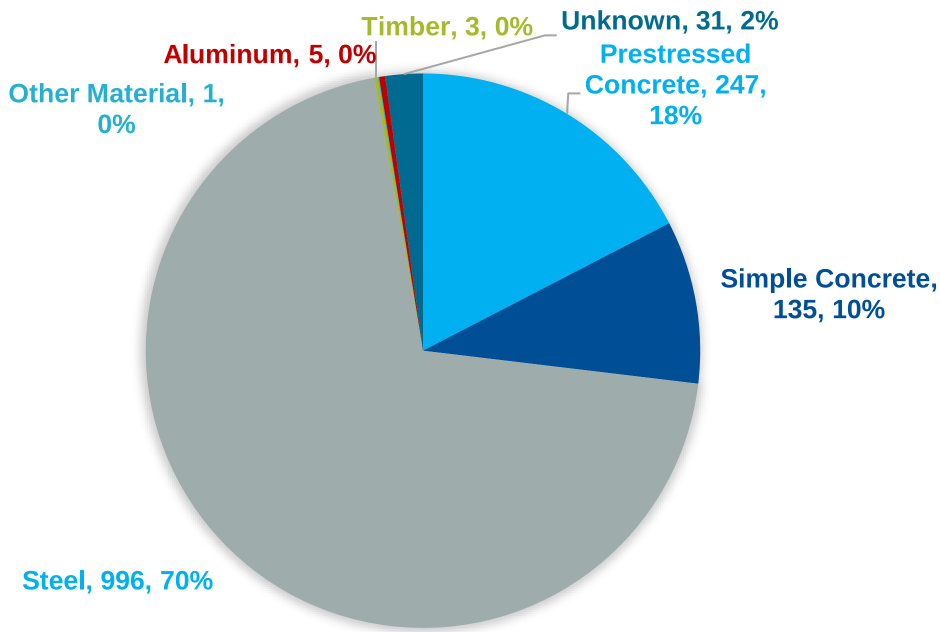


*Figure 33. Distribution of extant 1965-1980 bridges in West Virgina by material.*

**Table 1. Extant 1965-1980 bridges in West Virginia by material**

| Bridge material | Total bridges | % of total |
|---|---:|---:|
| Prestressed Concrete | 247 | 17.4% |
| Simple Concrete[236] | 135 | 9.5% |
| Steel | 996 | 70.3% |
| Timber | 3 | 0.2% |
| Other Material | 1 | 0.1% |
| Aluminum | 5 | 0.4% |
| Unknown | 31 | 2.2% |
| **Total** | **1,418** | **100.0%** |

[236] Simple concrete refers to reinforced concrete that has not been prestressed.

**Table 2. Extant 1965-1980 bridges in West Virginia by type**

| Type | Total bridges | % of total |
|---|---|---|
| Arch | 7 | 0.5% |
| Culvert | 162 | 11.4% |
| Frame | 11 | 0.8% |
| Other Type | 6 | 0.4% |
| Suspension | 1 | 0.1% |
| Truss | 15 | 1.1% |
| Concrete Box Beam (including continuous) | 5 | 0.4% |
| Concrete Channel Beam | 7 | 0.5% |
| Concrete Slab (including continuous) | 19 | 1.3% |
| Concrete Tee Beam | 1 | 0.1% |
| Concrete Multi-beam | 2 | 0.1% |
| Concrete Segmental Box Beam | 1 | 0.1% |
| Prestressed Concrete Box Beam | 106 | 7.5% |
| Prestressed Concrete Channel Beam | 45 | 3.2% |
| Prestressed Concrete Mixed Types | 1 | 0.1% |
| Prestressed Concrete Multi-Beam | 18 | 1.3% |
| Prestressed Concrete Multi-beam (continuous) | 6 | 0.4% |
| Prestressed Concrete Slab | 66 | 4.6% |
| Prestressed Concrete Tee Beam | 2 | 0.1% |
| Steel Box Beam | 15 | 1.1% |
| Steel Girder and Floorbeam System (including continuous) | 54 | 3.8% |
| Steel Multi-Beam | 303 | 21.3% |
| Steel Multi-Beam (continuous) | 530 | 37.3% |
| Steel Segmental Box Beam | 1 | 0.1% |
| Timber Multi-Beam | 3 | 0.2% |
| Unknown | **31** | 2.2%` |
| **Total** | **1,418** | **100.0%** |

## B. Research and development of new materials and techniques

In the 1950s WVU's Civil Engineering Department and the SRC began cultivating a close working relationship that would come to shape bridge innovation in West Virginia during the study period. In the late 1950s the SRC and WVU created a jointly sponsored civil engineering training program that allowed students to work towards a degree in civil engineering at WVU while receiving on-the-job training with the SRC.[237] Two research contracts, awarded in 1961, marked the next major step forward in this relationship. Under these contracts WVU was to conduct the necessary research to develop improved paving systems for the SRC.[238] Subsequent research projects conducted over the ensuing decades

[237] "WVU-SRC Training Program Deadline Set," *The Raleigh Register*, February 17, 1964.
[238] "Road Near Sophia Part of WVU Research," *Beckley Post-Herald The Raleigh Register*, May 29, 1966.

cultivated a close relationship, wherein the DOH relied heavily on WVU to conduct a variety of vital road- and bridge-related research on its behalf.

By the mid-1960s WVU's Civil Engineering program had a sterling reputation and the faculty was expanded with experts who could contribute to the department's growing research activities.[239] At the same time, the DOH's research needs were increasing. Tasked with the construction and maintenance of an ever-increasing system of primary and secondary roads and the bridges that carried them, the DOH sought new ways of building roads and bridges faster, safer, and more economically. While the DOH's limited staff made it almost impossible for the department to conduct its own research, WVU had some of the brightest academic minds in civil engineering, access to better research facilities, and a team of graduate students with the time and interest to conduct such research. As part of the federal initiative to complete the Interstate Highway System, the FHWA offered not only matching funds for design, construction, and right-of-way acquisition to the states, but also for transportation research. Determined to make optimal use of such funds, the DOH initiated a variety of research projects during the study period using both state and federal funds.[240]

While universities across the state conducted research for the DOH, the lion's share of research contracts were awarded to WVU during the study period.[241] Professors such as noted bridge historian Dr. Emory Kemp and civil engineer Dr. GangaRao Hota were contracted to conduct a variety of road and bridge related research during the study period. Research conducted at the university during the study period included topics surrounding strength, service life, and effective use of prestressed concrete for bridges; development of cost effective short-span bridge plans; selection of bridge designs based on 'value engineering'[242]; the effects of scour around bridge piers; and other aspects of bridge design and construction.[243] While former DOH employees recollect that not all research projects conducted during the study period yielded actionable results, the DOH remained committed to investing in innovation throughout the study period and after.[244]

Some of the earliest research projects undertaken at WVU focused around gaining a greater understanding of existing materials and how they might be most effectively and efficiently used. As the study period progressed, however, focus shifted toward the development of new and improved materials,

---

[239] GangaRao Hota, Telephone interview with Mead & Hunt, Inc., Telephone, December 12, 2023.

[240] Epperly, Telephone interview with Mead & Hunt, Inc.

[241] Epperly, Telephone interview with Mead & Hunt, Inc.; Sothen, Telephone interview with Mead & Hunt, Inc.

[242] A 1988 article on the topic defines value engineering as "an organized approach to cost reduction [which] endeavors to increase the efficiency of a product while maintaining its quality and reliability through 'systematic' use of analytical, decision, and creative techniques." GangaRao V. S. Hota, Richard Ward, and Victor Howser, "Value Engineering Approach to Low-Volume Road Bridge Selection," *Journal of Structural Engineering* 114, no. 9 (1988): 1962–77.

[243] Hota, Telephone interview with Mead & Hunt, Inc.; Hota, Ward, and Howser, "Value Engineering Approach to Low-Volume Road Bridge Selection"; GangaRao Hota and Narendra B. Taly, "Conceptual Substructural Systems for Short-Span Bridges," *Transportation Engineering Journal of ASCE* 104, no. 1 (January 1978): 15–29; G. R. Hopkins, R. W. Vance, and B. Kasraie, "Scour Around Bridge Piers" (Federal Highway Administration, Office of Research & Development, March 1975).

[244] Epperly, Telephone interview with Mead & Hunt, Inc.

including epoxy coated rebars, fiber reinforced polymers, weathering and galvanized steels, and glue laminated or stress laminated timbers. Research, led in large part by Dr. Hota, worked to develop these materials and offered guidance for their use.[245] Though the DOH was slow to adopt these new technologies, experimental materials began to work their way into West Virginia's bridges toward the end of the study period. One article documents a total of 14 bridges constructed in the state using epoxy coated rebar during the 1970s.[246] Having developed slightly earlier than some of the other materials listed above, weathering steel rapidly gained popularity during the study period, with the massive New River Gorge Bridge serving as a well-known example of a weathering steel bridge.

WVU's engineering department also conducted research to assist the DOH with developing effective inspection and assessment procedures for bridges that were difficult to evaluate. During the early part of the study period, DOH's bridge inspectors and engineers were often limited in their effectiveness by the computing capabilities of the day. Prior to the development of computing technology, assessment of complex bridge systems was extremely difficult, and the accuracy of hand calculations was limited. While engineers had developed methods for accurately assessing new bridge designs, calculating load capacities for bridges that had been in service for some time was much more difficult. The long-term effects of continual usage and weather-related deterioration of bridge materials was nearly impossible to calculate on theory alone. To improve understanding of the effects of long-term use, researchers at WVU tested samples from bridges that had been in service for some time to determine the rate of deterioration of various materials. Using their results, a set of practical guidance including inspection methodology and load rating guidance was developed for DOH inspectors.[247]

## C. Technological advancements

By far the most influential technological advancement in bridge design during the study period was the advent of computer-aided design (CAD). While the first computing programs for bridge design and analysis were developed in the late 1950s and gained popularity in the 1960s, the DOH was slow to adopt the technology and did not have access to computers until the mid-1970s. At the beginning of the study period, SRC bridge engineers' main calculating tool was the slide rule. For more complex calculations or those requiring a high degree of accuracy, two desktop calculators were shared among dozens of DOH engineers. Though these devices were an improvement over slide rules and hand computations, they were limited to basic addition, subtraction, multiplication, division, and square roots.[248] During the early study period the computing limitations of the day dictated which types of bridges could be used. Without calculators or computers capable of more complex calculations, bridge designs were limited to systems whose behavior under stress could be effectively calculated entirely by hand. Certain

[245] Sothen, Telephone interview with Mead & Hunt, Inc.; Hota, Telephone interview with Mead & Hunt, Inc.
[246] J. L. Smith and Y. P. Virmani, "Performance of Epoxy Coated Rebar in Bridge Decks" (Federal Highway Administration, Office of Research & Development, 1994).
[247] Epperly, Telephone interview with Mead & Hunt, Inc.; Hota, Telephone interview with Mead & Hunt, Inc.
[248] Sothen, Telephone interview with Mead & Hunt, Inc.

bridge types, considered to be "statically determinate," such as trusses, simple and cantilever beams, and some arch systems were favored by engineers prior to advances in computing technology.[249]

In the early 1970s the first pocket calculators, capable of performing more complex algebraic and trigonometric functions, became widely available. With these devices, engineers were able to complete designs faster and experiment with more structurally complex designs.[250] Though pocket calculators marked a major step forward, the truly revolutionary technology was the computer. With the invention of CAD programs, engineers could use computers to test a structure's behavior under specific conditions before it was built. With this advancement it became possible for designers to easily test a number of design variations and fine-tune their plans in record time. Despite growing claims that "engineers who still persist in ignoring the electronic computer… [were] courting extinction in the near future," the DOH was slow to adopt the technology.[251] Due to concerns that the computers would be ineffective or that they would be used as little more than a toy by the department's engineers, the DOH held off on purchasing a computer longer than many other states. In spite of these concerns, a computer was purchased for the shared use of a number of state government departments in the mid-1970s.[252]

Despite the time and labor-saving qualities of this new technology, computer-based analysis programs during the 1970s were anything but fast. The state had purchased a computer that was capable of running a structural design program known as STRUDL, but the program required a great deal of time to process data. To run calculations, engineers would have to fill out a series of punch cards, each representing an individual line of code. Engineers would complete their punch cards, often in sets of hundreds or thousands, and deliver them to an operator who would run them through the program. Because the computer was shared with other departments and the bridge calculations were so extensive, the STRUDL program was only run overnight during low-usage times. Engineers would deliver their punch cards in the evening and collect the results the following morning. Any time a change was made to the design, a new series of cards would need to be punched and the program run again.[253]

While these programs were slow compared with today's technology, they offered two major advantages that improved bridge designs. First, they made the complex calculations necessary for designing new types of bridges possible; and second, they allowed designers much more flexibility in the design process. Using a computer program to analyze a design allowed engineers to tweak their plans for

---

[249] A bridge is considered to be statically determinate if the effects of any forces on the structure can be calculated using a set of three relatively simple equations. Statically determinate structures were favored prior to computer-aided design because engineers could reliably predict the behavior of the structure under various loads and stresses with simple hand calculations. In contrast, statically indeterminate structures required much more complex calculations and computer modeling software to predict the system's reaction to foreseeable stress. Bailey, Telephone interview with Mead & Hunt, Inc.

[250] Anuli Akanegbu and Ricky Ribeiro, "The History of Calculators: Evolution of the Calculator (Timeline)," *EdTech Magazine*, November 20, 2012, https://edtechmagazine.com/k12/article/2012/11/calculating-firsts-visual-history-calculators; Sothen, Telephone interview with Mead & Hunt, Inc.

[251] "New Idea Roundup," *Edmonton Journal*, June 19, 1967.

[252] Sothen, Telephone interview with Mead & Hunt, Inc.

[253] Sothen, Telephone interview with Mead & Hunt, Inc.

optimal strength, stability, and economy. Before CAD technology, making almost any change to a bridge design amounted to scrapping the entire plan and starting the calculations over from scratch, adding months to the design process. With STRUDL, the process of rerunning calculations was reduced to a matter of hours or days, increasing design flexibility and significantly reducing the time needed to complete a set of plans.[254]

One of the first major bridge developments facilitated by computer analysis during the study period was the adoption of curved steel girder bridges. In the 1950s and 1960s bridge designers nationwide recognized that curved bridges would be necessary, both to safely accommodate the higher design speeds for new highway systems and to fit the necessary on and off ramps into densely developed urban areas.[255] In West Virginia, highway designers saw an additional need for such structures driven by the state's mountainous topography, which rarely allowed for long straightaways in highway alignments. While a series of "chorded" straight girders with a curved deck were traditionally used to achieve a curved bridge, the design was not ideal because the varied alignment of deck and girder made the structure behave unpredictably.[256] A curved girder, meanwhile, would uniformly align deck loads with the supporting girders, improving predictability and making it easier to build and rate for load limits. Construction of such structures was limited in the pre-computer era because hand analysis of curved girders was nearly impossible.[257] STRUDL, however, was capable of analyzing curved bridges, allowing engineers to confidently design and build safer and better performing structures.[258] Using computer analysis, West Virginia began to shift from chorded straight girders to curved girders in the mid-1970s.[259]

In the years prior to its adoption of computer technology, the DOH had two major strategies for addressing the slow nature of bridge design and its limited capacity of complex calculations. The first, and simplest, was to hire engineering consultants who had computers to design more complex structures. While the DOH had its own team of in-house engineers, limited staffing meant that they could not design all of the state's bridges. Generally, DOH engineers would design the simpler, more routine bridges and consultants would be assigned the larger, more complex, or time-consuming projects.[260] Having adopted computing technology earlier than the DOH, consulting firms were capable of designing newer, more complex bridge types years before the DOH. The Consultant Review Section of DOH's Structures Division quickly learned which of the state's consultants had computing capabilities and began to assign the most complex projects to those firms.[261]

---

[254] Epperly, Telephone interview with Mead & Hunt, Inc.

[255] Wolchuk, *Design Manual for Orthotropic Steel Plate Deck Bridges*, 11.

[256] A "chorded" straight girder bridge uses a series of straight girders with angle changes at the piers to achieve a curved structure. (John Corven et al., *Bridge Geometry Manual* (Washington D.C.: Federal Highway Administration: Office of Bridges and Structures, April 2022), https://www.fhwa.dot.gov/bridge/pubs/hif22034.pdf.)

[257] Bailey, Telephone interview with Mead & Hunt, Inc.

[258] Sothen, Telephone interview with Mead & Hunt, Inc.

[259] West Virginia Division of Highways, "National Bridge Inventory: West Virginia," 2023, National Transportation Atlas Database, https://www.fhwa.dot.gov/bridge/nbi/disclaim.cfm?nbiYear=2023/delimited&nbiState=WV23.

[260] Epperly, Telephone interview with Mead & Hunt, Inc.

[261] Sothen, Telephone interview with Mead & Hunt, Inc.

The second major strategy focused on increasing the efficiency of the bridge design process prior to the adoption of computers. Beginning in the early 1970s the DOH began conducting research and developing designs to create a set of standard bridge plans. Focused primarily on short-span bridges, standard plans were developed to quickly move projects from the design phase to construction with minimal original design work needed.[262] West Virginia's standard bridge plans are discussed in greater detail in Section 4.F, Development of state standard plans, below.

## D. Established types and materials

In West Virginia, 1965-1980 marked a period of transition in bridge design and materials. However, through most of the study period, and in opposition to broader national trends, steel continued to be preferred over prestressed concrete for reasons both practical and political. West Virginia's steel industry peaked between the end of World War II and the early 1960s, and during this time Weirton Steel was the state's largest employer and taxpayer.[263] Steel production was centered in the Northern Panhandle at Wheeling Steel and Weirton Steel, but smaller companies operated in Parkersburg and the Kanawha Valley.[264]

As Europe rebuilt its industrial infrastructure in the decades following World War II, it became increasingly less reliant on American steel. At the same time the United States also began importing cheaper foreign products, and American steel companies failed to keep up with innovative research in Europe and Japan.[265] The result was that every year after 1959, America was a net importer, and the industry began to fall behind major international producers.[266] Under this pressure, Wheeling Steel merged with Pittsburgh Steel in 1968 and filed for bankruptcy in 1985, and Weirton Steel was bought out by its employees in 1983.[267] Despite the industry's decline through the study period, steel production remained significant to West Virginia's economy and its use ensured employment for many West Virginia workers. As a result, both political pressure and longstanding familiarity with the material ensured that steel remained the preferred material for West Virginia bridges.[268]

Steel was also a more cost-effective choice in the 1960s and into the 1970s due to the proximity of companies in Ohio and Pennsylvania that manufactured prefabricated steel bridge sections, such as the American Bridge Company near Pittsburgh.[269] This reduced transportation costs as compared to shipping prestressed concrete structural components from other states, and many of these companies purchased

---

[262] Bailey, Telephone interview with Mead & Hunt, Inc.

[263] Lou Martin, "Steel Industry," *The West Virginia Encyclopedia*, 2023, https://www.wvencyclopedia.org/articles/586; David T. Javersack, "Weirton Steel," *The West Virginia Encyclopedia*, 2023, https://www.wvencyclopedia.org/articles/973.

[264] Martin, "Steel Industry."

[265] David G. Tarr, "The Steel Crisis in the United States and the European Community: Causes and Adjustments," in *Issues in US-EC Trade Relations* (University of Chicago Press, 1988), 173–200, http://www.nber.org/chapters/c5960.

[266] Tarr, "The Steel Crisis in the United States and the European Community: Causes and Adjustments."

[267] Martin, "Steel Industry."

[268] Epperly, Telephone interview with Mead & Hunt, Inc.

[269] Hota, Telephone interview with Mead & Hunt, Inc.

their steel from West Virginia producers.[270] As late as 1970 it was still less expensive to build a steel bridge than a prestressed concrete bridge in most areas of West Virginia.[271] FHWA also required alternate plans for bridges, so complete bridge plans were drawn utilizing both steel and concrete, and contracting firms could choose the design they wanted to build.[272] The combination of familiarity and cost-effectiveness resulted in the predominance of steel bridges, as seen in NBI data.

Unlike most other states, West Virginia has no county-maintained road or bridge system. When the state legislature consolidated all road maintenance responsibilities under the SRC in 1933, all but a small number of municipal and private bridges came under the purview of the state. As a result, local district crews were responsible for maintenance and, in the case of short spans, construction of bridges both during and after the study period. Because they had limited resources, district crews relied on manageable designs and familiar materials, such as prefabricated steel components and concrete box-beam structures. Continued use of steel also enabled smaller contracting firms in the state to be more competitive, particularly in rural areas and on shorter spans. Although large out-of-state firms such as E. Lionel Pavlo and Michael Baker were hired for major crossings, smaller local firms continued to be competitive in steel bridge design.[273]

In the early part of the study period, trusses were simply more predictable designs than other types of bridges. Until the DOH adopted the use of CAD in the 1970s, trusses were easier to analyze than continuous structures (both steel and concrete) as they lend themselves to a more predictable load path analysis. Continuous structures were more difficult to analyze by hand but became increasingly possible in the 1970s as engineers grew more confident in their analyses through the use of advanced calculators and computer programs. Trusses were also predictable in terms of construction as compared to other types of bridges. Their elements were smaller, easier to handle in the field, and lighter than equivalent girder elements, but this became less of a deterrent as contractors improved their bridge building equipment.[274]

Generally, through most of the study period, bridge design in the United States had fallen behind engineering innovations seen in Europe, and West Virginia’s expansive gorges and wide rivers still required an arch or truss to span their breadths.[275] This began to change toward the end of study period with the first approvals of cable-stayed bridges (see Section 4.E, New types and materials); however, most of the bridges constructed over major rivers like the Kanawha and Ohio continued to utilize steel truss designs. A notable example of a steel truss bridge constructed during the study period is the Jennings Randolph Bridge connecting Chester, West Virginia, and East Liverpool, Ohio (see Figure 34). Designed by the E. Lionel Pavlo Engineering Company, the Jennings Randolph Bridge (BARS #15A025)

---

[270] Hota, Telephone interview with Mead & Hunt, Inc.
[271] Epperly, Telephone interview with Mead & Hunt, Inc.
[272] Sothen, Telephone interview with Mead & Hunt, Inc.
[273] Sothen, Telephone interview with Mead & Hunt, Inc.
[274] Bailey, Telephone interview with Mead & Hunt, Inc.
[275] Sothen, Telephone interview with Mead & Hunt, Inc.

is the longest simple-span truss bridge in the United States with a main span of 745 feet.[276] When it opened, it was also the only bridge crossing the Ohio River between East Steubenville, West Virginia, and Shippingport, Pennsylvania, capable of carrying heavy truck traffic, necessary to the regional industrial economy.[277] This bridge was dedicated on November 7, 1977. Other notable truss bridges constructed during the study period include the Hi Carpenter Bridge (BARS #37A028) and Silver Memorial Bridges (BARS #27A063) discussed earlier, which have the longest cantilevered truss spans in West Virginia (both 900 feet).

*Figure 34. The Jennings Randolph Bridge (BARS #15A025) between Chester, West Virginia (foreground) and East Liverpool, Ohio (background), 1977.*[278]

In addition to the continued use of familiar types within the state, the study period marked the first adoption of steel rigid frames in West Virginia. Having been first introduced in the United States in the 1920s, rigid frame bridges were favored for their simple design, economical use of materials, elimination of intermediate supports, and pleasing aesthetics. While concrete rigid frame bridges were the most

[276] "Jennings Randolph Bridge Dedication, November 7, 1977," 1977, Department of Highways Communications AR1993-Box 1- Chester Jennings Randolph Bridge Folder, West Virginia State Archives.
"Selected Noteworthy Simple Truss Spans In The United States" (Historic Bridge Foundation, 2015), https://historicbridgefoundation.com/wp-content/uploads/2015/03/simplespans.pdf.

[277] West Virginia Department of Highways, "Fact Sheet: Jennings Randolph Bridge," 1977, Department of Highways Communications AR1993-Box 1- Chester Jennings Randolph Bridge Folder, West Virginia State Archives.

[278] West Virginia Department of Highways, *New Ohio River Bridge*, Photograph, black & white, 1977, Department of Highways Communications AR1993-Box 1- Chester Jennings Randolph Bridge Folder, West Virginia State Archives.

popular, steel variations developed around the same time and slowly grew in popularity throughout the early twentieth century, though the type was never widely used.[279] Approximately 140 examples were constructed nationally prior to the study period, mostly in the Northeast.[280] In the 1960s a new variation of the type, with slanted legs, was developed, allowing the rigid frame to reach greater span lengths, and making it a particularly useful type for spanning gorges and highway corridors with steeply sloped sides, in locations where it was preferable to avoid building a pier in the median.[281] While steel rigid frame bridges were used in small numbers by highway agencies across the nation in the late 1960s, West Virginia did not adopt the type until 1970, when the South Park Bridge (BARS #21A015) was constructed. Over the course of the study period, the State built a total of five steel rigid frame structures, four of which used the new slant-leg (also called a K-frame) design.[282] In 1972 the Loudermilk Road Bridge (BARS #13A122, see Figure 35), constructed in Greenbrier County, had the longest maximum span length of any steel rigid frame bridge in the nation, a title the bridge held until the Major Martin Robinson Delany Memorial Bridge (BARS #19A059) was constructed in Jefferson County in 2012.[283]

*Figure 35. The Loudermilk Road Bridge (BARS13A122) inspection photo, 2023.*

[279] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types*.

[280] U.S. Department of Transportation, Federal Highway Administration, "National Bridge Inventory," 2023, National Transportation Atlas Database, https://www.fhwa.dot.gov/bridge/nbi/disclaim.cfm?nbiYear=2023allstatesallrecsdel&nbiZip=zip.

[281] Richard M. Casella, *Engineering Significance of the Prowse Memorial Bridge & History of the Welded Steel Rigid-Frame Slant-Leg Highway Bridge* (prepared for Preservation Company and the New Hampshire Department of Transportation, April 2010), 17, https://www.historicdoc.com/reports/HES-RigidFrameSlantLegBrg.pdf.

[282] West Virginia Division of Highways, "National Bridge Inventory: West Virginia."

[283] U.S. Department of Transportation, Federal Highway Administration, "National Bridge Inventory."

## E. New types and materials

During the 1960s new steels emerged to compete with the standard A36 steels, promising greater longevity with less maintenance.[284] Weathering steel was first developed by U.S. Steel in the 1930s to construct hopper cars for the company's ore mining industry. Believing the new steel to have other potential uses, the company trademarked it "Cor-Ten" to advertise its corrosion resistance and tensile strength. The long-term advantage of this steel was that surface oxidation created a protective layer that did not require paint. It is a low-alloy steel that features nickel and most importantly copper, which aids in bonding the oxide layer to the metal. Initial standards from American Standards for Testing and Materials (ASTM) for A242 weathering steel were first published in 1941, but standards for a later modification known as A588 were published in 1968. One of the most famous applications of the new A588 steel is the New River Gorge Bridge, where it was used to great aesthetic effect as the rusted patina blends with the surrounding landscape. Still, the greatest consideration in the use of weathering steel was the savings in maintenance as a bridge of this scale would have cost the state approximately $1 million every time it needed to be painted.[285]

Many of the earliest weathering steel bridges were built in the 1960s in Michigan, where early indications of bridge deterioration led to a moratorium on its use in 1979.[286] Other concerns for the material arose from corrosion due to early design errors such as leaky joints and poor drainage.[287] Signs of corrosion on the New River Gorge Bridge necessitated the development of a special deicing material as it was found that weathering steel did not perform well under extensive exposure to either marine or deicing salts.[288] While Michigan eventually lifted its moratorium, many states stopped using weathering steel.[289] West Virginia, however, continued its use and currently has approximately 100 extant weathering steel bridges, 17 of which date to the study period.[290] Beyond the New River Gorge Bridge, another notable example is a 1979 deck truss bridge constructed as a parallel twin to the National Register-eligible 1954 Charlton Memorial Bridge in Mercer County (see Figure 36).

---

[284] Steel grades are identified first by a letter, which refers to its properties or alloys, then by a number, which can refer to its alloy composition or mechanical properties. Here "A" stands for "austenitic," one of the five classes of stainless steel. In the case of A36 steel, the 36 refers to its minimum yield strength in kilo pounds (1,000 pounds) per square inch. Thus, A36 steel is an austenitic steel with a strength of 36,000 pounds per square inch.

[285] National Register of Historic Places, New River Gorge Bridge, Fayetteville, Fayette County, West Virginia.

[286] Karl E. Barth and Jennifer Righman McConnell, "An Assessment of Weathering Steel Bridges in West Virginia" (Proceedings of 8th International Conference on Short and Medium Span Bridge, 2010), https://www.shortspansteelbridges.org/wp-content/uploads/2020/07/CSCE_Paper_Barth_Weathering-Steel.pdf.

[287] Barth and Righman McConnell, "An Assessment of Weathering Steel Bridges in West Virginia."

[288] "Bridge Facts: New River," *West Virginia Department of Transportation*, n.d., https://transportation.wv.gov:443/highways/bridge_facts/Modern-Bridges/Pages/NewRiver.aspx.

[289] Barth and Righman McConnell, "An Assessment of Weathering Steel Bridges in West Virginia."

[290] Barth and Righman McConnell, "An Assessment of Weathering Steel Bridges in West Virginia."

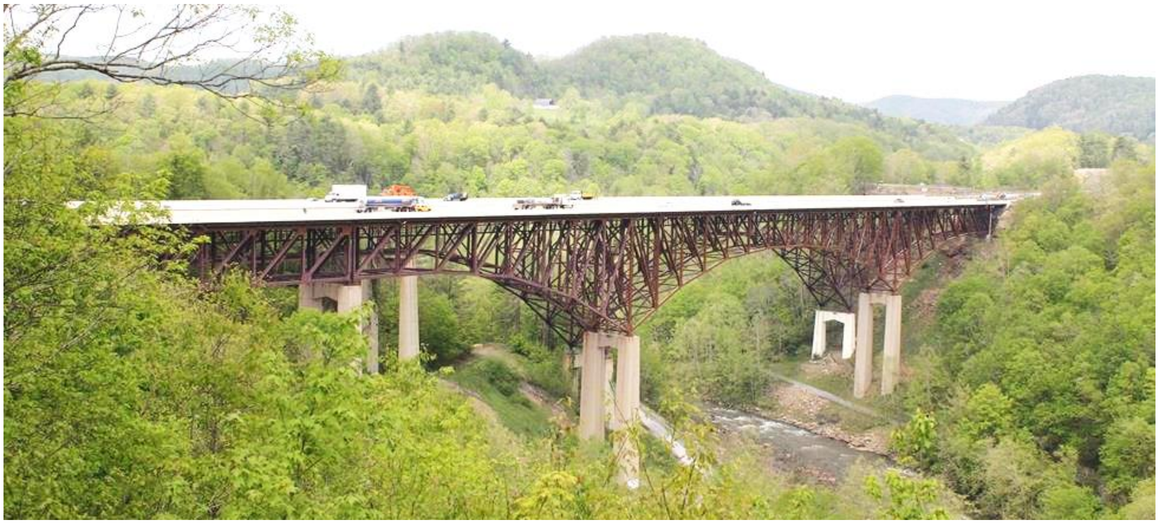

*Figure 36. The Charlton Memorial Bridges over the Bluestone River in Mercer County. The 1954 bridge (BARS #28A216) is visible in front of the later 1979 bridge (BARS #28A215).*[291]

Galvanized steel, first developed in the nineteenth century, also came into wider use for bridge construction during this time.[292] The nation's first bridge constructed completely of hot-dip galvanized steel opened in Grand Haven, Michigan, in 1966.[293] As with weathering steel, galvanized steel promised prolonged corrosion resistance with limited maintenance. However, if the steel was not properly coated in the hot zinc, it could become brittle.[294] This material was never widely used in West Virginia beyond individual components like gusset plates and bolts.[295] However, in the 1970s West Virginia began using coated reinforcing in its bridge decks, which eventually involved materials such as stainless and galvanized steels.[296] This was an innovation resulting from the need to protect reinforcing members from salt infiltration over time.[297] West Virgina examples from this period are the 1973 Kevin Ritchie Memorial Bridge (BARS #10A245), a 1,262-foot deck truss for which contractors W.P. Dickerson & Sons utilized stay-in-place galvanized steel forms to pour the concrete deck, and the Jennings Randolph Bridge in Chester (BARS #15A025, see Figure 37).[298]

[291] "WVDOT Assets."

[292] Todd Danielson, "Engineered Solutions: Transcending Time – Hot-Dip Galvanized Steel Provides Solution to Combat Corrosion on Bridges Old and New," *Informed Infrastructure*, December 19, 2018, https://informedinfrastructure.com/44155/engineered-solutions-transcending-time-hot-dip-galvanized-steel-provides-solution-to-combat-corrosion-on-bridges-old-and-new/.

[293] Danielson, "Engineered Solutions: Transcending Time – Hot-Dip Galvanized Steel Provides Solution to Combat Corrosion on Bridges Old and New."

[294] Hota, Telephone interview with Mead & Hunt, Inc.

[295] Hota, Telephone interview with Mead & Hunt, Inc.

[296] Bailey, Telephone interview with Mead & Hunt, Inc.

[297] Bailey, Telephone interview with Mead & Hunt, Inc.

[298] "Progress of Corridor 'L' at Hico in Fayette County," *Beckley Post-Herald*, April 23, 1973. "Bridge Linkup Nears," *The Evening Review*, January 3, 1976.

*Figure 37. 1976 image of the galvanized steel forms in place on the Jennings Randolph Bridge (BARS #15A025) before the deck was poured.[299] The corrosion-resistant material helps to prolong the life of the deck.*

Alterations in the design of steel bridges changed during the study period due to the influence of AASHTO and the FHWA as well as innovations in steel production, which resulted in lighter bridges. In West Virginia, this eventually reduced costs and overall materials but initially posed problems during construction, particularly for designs in which the parapets were part of the load-carrying ability of the bridges. Until that time contractors generally worked with their equipment parked on the bridge deck, but this became an issue with these lighter, more flexible bridges. Eventually heavy equipment was prohibited from the deck due to cracks found during bridge inspections, resulting in at least two replacements in Logan County.[300]

Other changes to steel bridges during this period were the connections, as rivets and bolts began to be replaced with welds. Riveted connections were still favored in the 1950s, but by the 1960s more bridges were constructed with bolted connections.[301] In other regions, welded connections became more common starting in the 1930s, but engineers were concerned about fatigue due to stress on the welds as well as difficulties associated with accurately assessing the quality of welds. West Virginia's topography and largely industrial economy meant long span bridges and high axial loads, and in those cases rivets and bolts were preferred. The circular reamed holes for the joints provided relief of stress concentrations, and the connections provided a kind of shock absorption.[302] Later, X-ray and other nondestructive techniques were developed to evaluate welded connections in the wake of the Silver Bridge Disaster. Eventually with

[299] "Bridge Linkup Nears."
[300] Epperly, Telephone interview with Mead & Hunt, Inc.
[301] Sothen, Telephone interview with Mead & Hunt, Inc.
[302] Hota, Telephone interview with Mead & Hunt, Inc.

the growth of the bridge inspection program, the DOH became more comfortable using whichever connection the bridge designer specified, provided that plans aligned perfectly with the current NBIS standards.[303] NBI data shows nearly 200 welded multi-beam or girder bridges constructed in West Virginia between 1965 and 1980, with numbers increasing significantly beginning in the early 1970s. [304]

The study period also marks a shift away from steel roller bearings and bearing plates toward the use of elastomeric bearing pads (see Figure 38). Prior to their use, DOH maintenance crews were consistently called out to bridges to free bulky steel rockers or support these elements and keep them in place.[305] In 1957 the first elastomeric bearing pads were used to support a prestressed concrete bridge in Victoria, Texas.[306] AASHTO published the first specifications for their use in 1961 based on experimental research by DuPont, which led to their wider adoption. Elastomeric bearing pads are used more often in concrete bridges than steel and work to transfer girder loads to the substructure.[307] Compared to steel bearings, these polychloroprene (neoprene) elements required no maintenance and were an economical choice that came into routine use by the 1970s in West Virginia. [308]

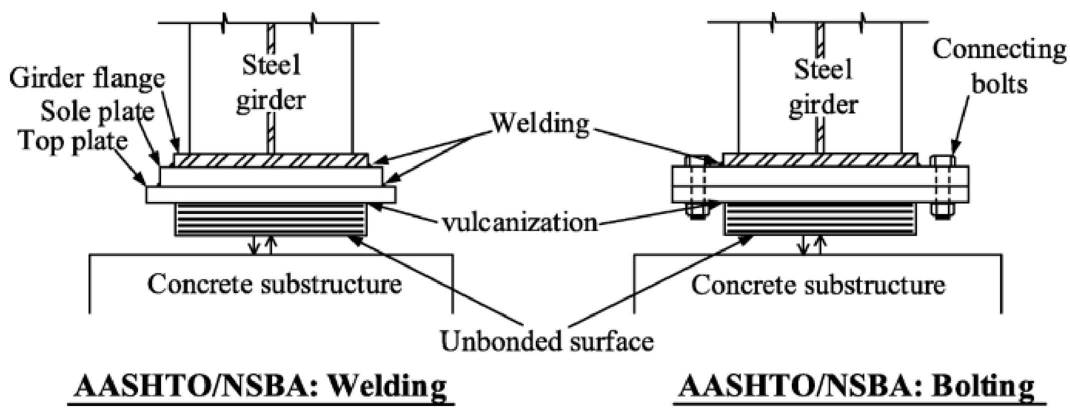


*Figure 38. This image shows elastomeric bearing pads in place on steel girder bridges using different methods to connect the top plates above the pads to the superstructure. The pads themselves are layers of neoprene and steel plates.[309]*

Exceptions to the continued use of steel early in the study period are found in West Virginia's Eastern Panhandle in District 5. Proximity to producers of prestressed concrete, such as Shockey Brothers, Inc. in Winchester, Virginia, made it less expensive to transport concrete members than steel. As a result, prestressed concrete was adopted earlier in that region. Eventually the preference for steel waned with

---

[303] Sothen, Telephone interview with Mead & Hunt, Inc.

[304] West Virginia Division of Highways, "National Bridge Inventory: West Virginia."

[305] Sothen, Telephone interview with Mead & Hunt, Inc.

[306] J. McDonald, E. Heymsfield, and R.R. Avent, "Investigation of Elastomeric Bearing Pad Failures in Louisiana Bridges" (Louisiana Transportation Research Center, September 1999), https://www.ltrc.lsu.edu/pdf/2008/fr_330.pdf.

[307] McDonald, Heymsfield, and Avent, "Investigation of Elastomeric Bearing Pad Failures in Louisiana Bridges."

[308] Sothen, Telephone interview with Mead & Hunt, Inc.

[309] Z. Mohammed Mohamedmeki, F. Jihan Esmail, and E. Awadh Ajeel, "Fatigue Life Analysis of Laminated Elastomeric Bearing Pad," *Materialstoday: Proceedings*, 2021.

the expansion of concrete companies in Kentucky and Ohio, as well as West Virginia companies, such as Centurial Products in Parkersburg, which manufactured prestressed concrete channel sections and voided slabs. Some DOH Districts began to prefer concrete's clean lines and ease of construction with what were basically modular units.[310] Additionally, similar to weathering steel, concrete did not need to be painted.

Engineers soon discovered the limitations of prestressed concrete in certain applications. Prestressed channel beam sections had a lifespan of about 35 years and eventually fell out of favor, and even box beam sections were found to have durability issues such as corrosion and cracking.[311] NBI data shows 45 prestressed channel beam bridges constructed between 1970 and 1978. Most prestressed concrete bridges constructed during this time were multi-box beam or girder structures; data shows a total of 101 built throughout the study period, with more dating to the 1980s.[312] Research and use of special concrete design mixes to increase the strength and durability of prestressed concrete started in the 1970s, and now are commonly used in West Virginia.[313]

Overall, bridge design did not change greatly during the study period, and it was marked more by changes in approaches to and materials for established bridge types. After the failure of the Silver Bridge, engineers placed an emphasis on more hyperstatic structures, such as jointless systems, and worked to relieve causes of fatigue and deterioration to enhance bridge durability and safety.[314] Hyperstatic structures increase redundancy in bridge design to increase safety. In a hyperstatic structure, the failure of one element does not lead to the collapse of the bridge, as was the case with the Silver Bridge; instead, the stress path realigns, redirecting the load to other elements of the bridge.

The notable innovation in bridge design during the study period is the first approval of cable-stayed bridges in the 1985 East Huntington Bridge, designed by Arvid Grant and Associates with the German firm Leonhardt und Andra Partners, and the 1990 Veterans Memorial Bridge, designed by Michael Baker. Both bridges represent decades of development that began in the study period.

Due to lawsuits, location disputes, and funding shortages for what was eventually a $38 million span, the East Huntington Bridge (BARS #06A215) took more than 20 years to build.[315] A disputed EIS was finally approved in 1974, and funding problems were partially solved when the federal government made the bridge a demonstration project through the 1978 Federal-Aid Highway Act.[316] The East Huntington Bridge was the second cable-stayed bridge designed in the country; the first was the 1978 Ed Hendler Bridge

---

[310] Hota, Telephone interview with Mead & Hunt, Inc.

[311] Hota, Telephone interview with Mead & Hunt, Inc.

[312] West Virginia Division of Highways, "National Bridge Inventory: West Virginia."

[313] Bailey, Telephone interview with Mead & Hunt, Inc.

[314] Hota, Telephone interview with Mead & Hunt, Inc.

[315] "At Last! Governor Dedicates Much-Delayed East Huntington Bridge (Press Release)" (West Virginia Department of Highways, August 8, 1985), Department of Highways Communications AR1993-Box 2- East Huntington Bridge Folder, West Virginia Archives & History.

[316] "Highway News Press Release" (West Virginia Department of Highways, January 23, 1981), Department of Highways Communications AR1993-Box 2- East Huntington Bridge Folder, West Virginia State Archives.

connecting Pasco and Kennewick in Washington state. The Maxon Construction Company of Dayton, Ohio, began work on Huntington's two main river piers in 1974, which were completed in 1977.[317] Two plans were drawn for the superstructure: a steel option by E. Lionel Pavlo Engineering Company, which designed the bridge approaches, and a concrete option by Arvid Grant, which was chosen for the project.[318] The DOH began receiving bids in spring 1981 and chose Melbourne Brothers Construction Company of Canton, Ohio, and York Russel, Inc. of Toronto, Canada, to construct the 370-foot tower with its 62 radiating cables (see Figure 39). [319] The East Huntington Bridge opened on August 8, 1985.

*Figure 39. Undated construction image of the East Huntington Bridge (BARS #06A215).*[320] *Barge cranes were used to construct the deck segments.*

Similar issues plagued the Veterans Memorial Bridge (BARS #05A060) in Weirton, with delays due to design changes, new environmental policies, and funding shortages. The preliminary engineering report for this bridge was completed in 1961, but the location and design were not approved until 1978.[321] The river piers were constructed between 1979 and 1980, and the superstructure was constructed between

---

[317] "East Huntington Bridge Contracts" (West Virginia Department of Highways, n.d.), Department of Highways Communications AR1993-Box 2- East Huntington Bridge Folder, West Virginia State Archives.

[318] "East Huntington Bridge Facts" (West Virginia Department of Highways, n.d.), Department of Highways Communications AR1993-Box 2- East Huntington Bridge Folder, West Virginia State Archives.

[319] "Highway News Press Release."

[320] Dr. Man-Chung Tang, "Special Report: Construction of East Huntington Bridge," *PCI Journal*, December 1987, https://www.pci.org/PCI_Docs/Design_Resources/Guides_and_manuals/references/bridge_design_manual/JL-87-November-December_Construction_of_East_Huntington_Bridge.pdf.

[321] "Veterans Memorial Bridge Dedication," May 4, 1990, Department of Highways Communications AR1993-Box 1- Weirton Bridge (Veterans Memorial Bridge) Folder, West Virginia State Archives.

1983 and 1990 after a redesign by Michael Baker, Jr.[322] The Veterans Memorial Bridge was dedicated on May 4, 1990, and marked a new period of development in Weirton (see Figure 40). The bridge carries the U.S. Highway 22 bypass, which opened a few years after the bridge and increased access from the community to downtown Pittsburgh.[323]

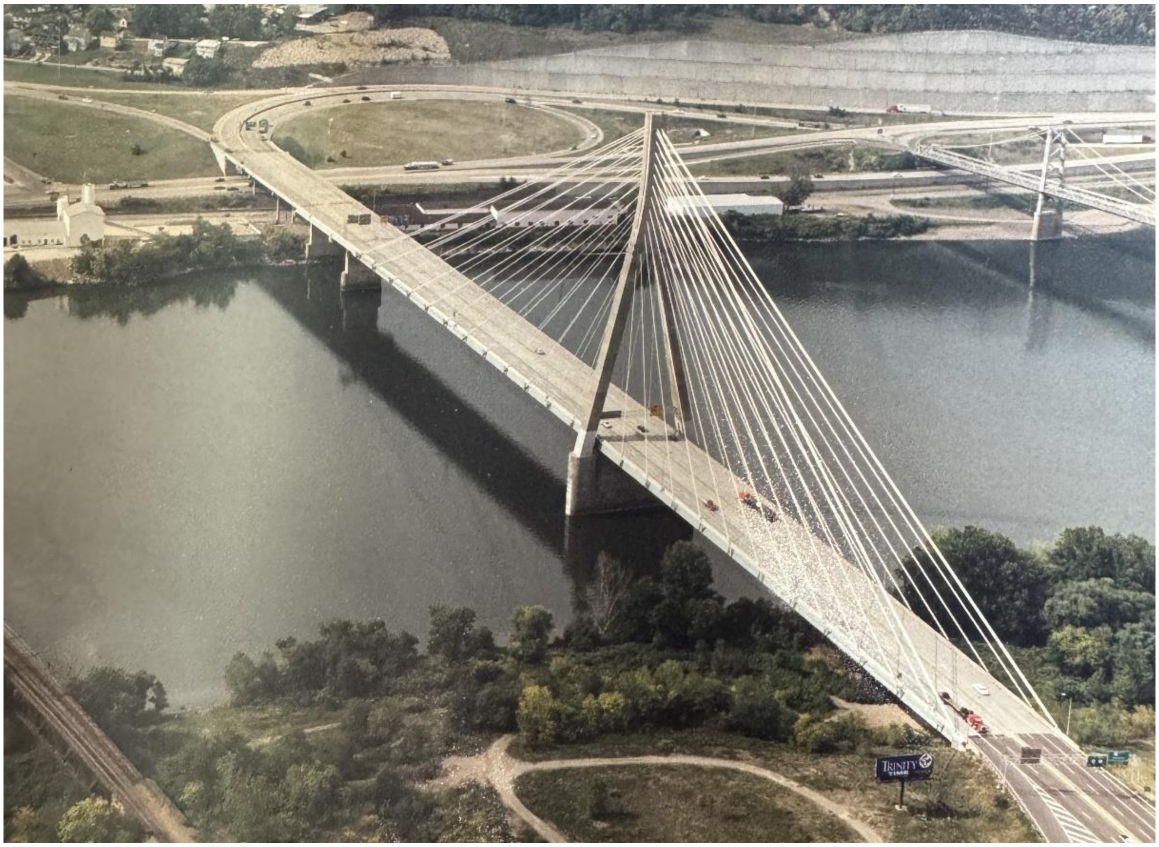

*Figure 40. The Veterans Memorial Bridge in Weirton (BARS #05A060), c.1990.*[324]

## F. Development of state standard plans

The vast majority of the bridges constructed in West Virginia during the study period were far simpler than the notable bridges discussed in previous sections. In particular, West Virginia's topography required a great deal of short-span bridges to cross creeks and streams or to traverse the state's mountainous topography. In West Virginia, a full half of the bridges constructed during the study period had a total structure length of 100 feet or less.[325] Early in the study period, the SRC began investigating methods for streamlining the design and construction process for such bridges. In the early 1970s, the DOH began

[322] "Veterans Memorial Bridge Dedication."

[323] Amy Braniff, "Bridge, Bypass Sparked a New Era for City," *Weirton Daily Times*, July 2, 1997, Clippings - Bridges - General, West Virginia State Archives.

[324] West Virginia Department of Highways, *Weirton Bridge (Veterans Memorial Bridge)*, c.1990, Department of Highways Communications AR1993-Box 1- Weirton Bridge (Veterans Memorial Bridge) Folder, West Virginia State Archives.

[325] West Virginia Division of Highways, "National Bridge Inventory: West Virginia."

developing a series of standard plans for short span bridges, which allowed it to bypass parts of the design process and quickly move projects to the construction phase. At the same time, increased familiarity with standard plan sets allowed manufacturers to fabricate components quickly and reliably. In turn, construction crews were able to assemble structures with increasing efficiency.

The first step to creating what would come to be known as the “Small Bridge Program” or the "Category Six” bridge program was to initiate research projects to identify the best bridge types and materials for short span bridges.[326] In 1971 the DOH contracted with researchers Dr. GangaRao Hota and Dr. Emory Kemp at WVU, tasking them with researching and developing a set of standard specifications for short span bridges.[327] In the years that followed researchers at WVU conducted numerous additional research projects to investigate various topics related to developing and optimizing standard short-span bridge plans. By the end of the decade Dr. Hota and his colleagues would publish at least a half dozen articles on the topic of short span bridge design.[328] Toward the end of the study period and in the years that followed, research conducted by WVU’s Civil Engineering department shifted focus by investigating strategies for optimizing efficiency and economics in bridge design.[329]

Using insights gained through research done at WVU, DOH engineers developed standard plans for short span bridges in the early to mid-1970s.[330] Designed to be simply adapted to any project site, standard plans focused on superstructure design. Because every site was different, standardization of substructural elements was nearly impossible. Instead, engineers used a set of standards to design customized piers and abutments which were suited to the specific site conditions. By streamlining the design process with standard plans, simple, run of the mill projects occupied far less of a DOH engineer’s time and freed them up to focus on more complex projects which required more attention.[331] NBI data for the state appears to indicate that DOH began constructing bridges using standard plan sets beginning around 1974.[332]

In addition to streamlining the design process, development of state standard plans for short span bridges greatly contributed to the state’s ability to construct such structures quickly and efficiently by offering improved predictability to designers, manufacturers, and construction crews. When manufacturers were working from a set of known standard plans, they became familiar with the components they were fabricating and could keep sets of standard molds and forms, which allowed them to quickly fabricate

---

[326] In West Virginia, the term “Category Six” referred to bridges less than 60 feet in length, the original length limit imposed on bridges eligible for the Short Bridge Program. In the decades that followed the end of the study period, the DOH developed additional plan sets and the small bridge program came to include bridges up to 100 feet long. Throughout its history, the Small Bridge Program was intended for use only on secondary road systems. Standard plans were never developed for roadways that operated at highway speeds. Sothen, Telephone interview with Mead & Hunt, Inc.; Bailey, Telephone interview with Mead & Hunt, Inc.

[327] Hota, Telephone interview with Mead & Hunt, Inc.

[328] Hota and Taly, “Conceptual Substructural Systems for Short-Span Bridges.”

[329] Hota, Ward, and Howser, “Value Engineering Approach to Low-Volume Road Bridge Selection”; GangaRao Hota and Thomas Zelina, “Development of Economical Low-Volume Road Bridges,” *Journal of Structural Engineering* 114, no. 9 (1988): 1941–61.

[330] Sothen, Telephone interview with Mead & Hunt, Inc.

[331] Bailey, Telephone interview with Mead & Hunt, Inc.

[332] West Virginia Division of Highways, “National Bridge Inventory: West Virginia.”

needed components with less notice and minimal setup time. As a result, the DOH and contractors became increasingly confident in a manufacturer's ability to deliver the components that they needed with reliable quality and consistency. Over time both the DOH and contractors began to develop mutually beneficial relationships with manufacturers that they trusted. In doing so, engineers could select designs based on the known availability and cost of certain components and contractors could efficiently source construction materials. In turn, construction crews gained increasing familiarity with the designs, improving construction speed, and allowing then to offer lower and more accurate construction estimates.[333]

In addition to simplifying construction for contractors, state standard plans made it increasingly easy for the DOH to use its own construction crews, eliminating the need for contractors entirely. In doing so the construction cost was significantly reduced, and projects moved more quickly to the construction phase when the contracting process was eliminated. DOH engineers, recognizing the advantages of such an arrangement, began to design standard bridge plans with district construction crews in mind. Bridge types were selected for ease of construction. Because district crews rarely had access to large-scale construction equipment, engineers worked to develop designs which could be constructed with minimal heavy-duty equipment.[334] In the mid-to-late 1970s state standard plans and increasing reliance on DOH construction crews resulted in a rapid rise in popularity for a few specific bridge types, including prestressed concrete box beams, channel beams, and slabs.[335]

The development of state standard plans coincided with the growth of the concrete industry in West Virginia and contributed to the material's increasing popularity. While concrete prices were falling and prestressing yards were becoming increasingly accessible in the state, DOH engineers were seeing greater value is designing bridges for district crews to construct. In many cases, prestressed concrete offered the ideal material for those designs. Engineers quickly determined that prestressed concrete box beam and slab bridges required minimal on-site construction work. To complete assembly, crews need only prepare abutments and then place the beams or slab. Because box beams allowed for the top of the beam to serve as the road surface, crews did not even need to pour a concrete deck, which may require complex formwork and specialized equipment to achieve the cross-slopes necessary for the bridge to properly shed water. In those instances where deck slopes were required, a layer of asphalt could be easily applied using the equipment that crews already had.[336] Beginning in 1974 with the implementation of the Small Bridge Program, West Virginia's usage of prestressed concrete significantly increased from an average of four prestressed concrete bridges constructed per year prior to the program's implementation to an average of 29 per year after.[337]

## G. Aesthetics

During the study period, safety, maintenance, and construction costs were the primary drivers of design, with aesthetics treated as a secondary consideration. In the case of the visually striking New River Gorge

[333] Sothen, Telephone interview with Mead & Hunt, Inc.; Epperly, Telephone interview with Mead & Hunt, Inc.
[334] Bailey, Telephone interview with Mead & Hunt, Inc.
[335] West Virginia Division of Highways, "National Bridge Inventory: West Virginia."
[336] Sothen, Telephone interview with Mead & Hunt, Inc.; Bailey, Telephone interview with Mead & Hunt, Inc.
[337] West Virginia Division of Highways, "National Bridge Inventory: West Virginia."

Bridge (BARS #10A214), the long span required an arch, truss, or suspension design, and only an arch was practical in that elevated location. Likewise, the russet-colored patina of the weathering steel was secondary to considerations of construction and long-term maintenance costs. This began to change in the 1980s and 1990s in West Virginia and more broadly in the United States, which had fallen behind Europe in its approach to bridges as a form of structural art. In *Civil Engineering* in 1983, Professor Rowland Richards, Jr. lamented "the bias toward mediocrity" in American bridge building, pointing to a disconnect between engineers and contractors that limited creativity and progress.[338]

Through the 1960s aesthetics in West Virginia bridges generally referred to applied ornamental details such as railings, light posts, or designs built into bridge substructures. During the study period even superficial treatments were limited. A modern emphasis on aesthetics can be seen in the 2023 painting of the now blue and gold 1954 and 1983 twin Chuck Yeager Memorial Bridges (BARS #20A640 and #20A639) in east Charleston. In contrast, through the 1960s and 1970s available paint colors were limited to gray, blue, tan, or green, and the state did not color its concrete for aesthetic purposes.[339] In 1972 West Virginia introduced a new "Design blue," which aligned with federal standards for bridge safety as the bright aqua hue was more visible at night while still noted as "soothing" during the day.[340] Early bridges painted this color included the Roby Road Bridge in Huntington (nonextant) and a Little Kanawha River bridge in Parkersburg (likely referring to the 5th Street Bridge (BARS #54A037), a 1935 Warren truss).[341]

In the 1970s and especially after, the approach to aesthetics began to change, driven in part by innovations in prestressed concrete, which enabled ever longer spans of clean lines that were able to complement surrounding topographies with curved and sloping forms. In the 1980s and into the present day, environmental legislation and considerations also led to a preference for designs that were more sympathetic to the surrounding landscape. Environmental concerns impacted the locations of bridges and roads but also led to design changes like fewer piers in waterways. Other legislation that impacted design and aesthetics during the study period was the ARDA (discussed in Section 3.C, Appalachian Development Highways), which required designers to use native materials on Appalachian corridor highways whenever possible in order to receive federal funding. On West Virginia bridges, this generally meant alterations to approaches and end treatments to utilize wood posts native to the state.[342]

Several bridges constructed in West Virginia during the study period were recognized at a national level by the American Institute of Steel Construction (AISC) in its annual awards of the "the most beautiful

---

[338] Rowland Richards, Jr., "U.S. Bridges: The Bias Toward Mediocrity," *Civil Engineering*, April 1983, Emory Kemp Papers Regarding Industrial History - A&M 4230 - Box 216 - Clippings 1979-1983 Folder, West Virginia University Archives.

[339] Bailey, Telephone interview with Mead & Hunt, Inc.

[340] "No Blues Over New Bridge Color," *West Virginia Highways*, November 1972, West Virginia Highways - Box Hig 1. 4/2 - 1935-1972 - 1971 Folder, West Virginia State Archives.

[341] "No Blues Over New Bridge Color."

[342] Epperly, Telephone interview with Mead & Hunt, Inc.

bridges opened to traffic."[343] In 1973 Frederic R. Hams. Inc. of Stamford, Connecticut, received the Award of Merit for a "Special Purpose" structure with the design of its Elevated (PRT) Guideway over Monongahela Boulevard in Morgantown.[344] In 1976 the Bigley Interchange in Charleston, designed by Howard, Needles, Tammen & Bergendoff (now HNTB), of Kansas City, Missouri, received the Prize Bridge Award in the "Elevated Highways or Viaducts" category.[345] In 1978 Michael Baker, Jr., Inc., received the Award of Merit for a "Long Span" for the firm's iconic New River Gorge Bridge.[346] Finally, in 1980 the Caddell Bridge over Cheat River, designed by Yule, Jordan & Associates of Philadelphia, received the Prize Bridge Award in the "Elevated Highways or Viaducts" category.[347]

Research into available AISC documents about the organization's annual competition revealed no information on the process for nominating bridges for consideration by the jury and there is no information available indicating the process by which the above bridges came to be included in the group of candidates. It is unclear how many structures were nominated each year for the competition, which has vague criteria and an unknown nomination process. The AISC text in the available award documents sheds no light on the bridges' broader importance nationally in terms of aesthetics, and whether they are unique or simply examples of many similar "beautiful" bridges that may not have been offered as candidates. It seems possible the AISC award process is similar to other engineering and architectural awards that have candidates submitted by the designing or building firms themselves and, in those cases, become industry vanity awards important only to a very limited degree within the industry itself. While the New River Gorge Bridge was the recipient of an AISC award, and later listed in the National Register in 2013, the AISC award was not determinative in its National Register listing, which was under *Criteria A* and *C* for exceptional importance as a major engineering and construction achievement. The award indicated little more than the fact that the AISC also found the bridge to be an aesthetically interesting, long bridge. There is no evidence of these awards having any impact or consequence other than the award recipients possibly appearing in the newspaper upon announcement of the award.[348] Therefore, receipt of an AISC award does not warrant consideration in the development of criteria for evaluation of National Register eligibility.

---

[343] American Institute of Steel Construction, "Prize Bridges/1973" (American Institute of Steel Construction, 1973), https://www.aisc.org/globalassets/nsba/prize-bridge-brochures/1973prizebridgebrochure.pdf.

[344] American Institute of Steel Construction, "Prize Bridges/1973."

[345] American Institute of Steel Construction, "Prize Bridges/1976" (American Institute of Steel Construction, 1976), https://www.aisc.org/globalassets/nsba/prize-bridge-brochures/1976prizebridgebrochure.pdf.

[346] American Institute of Steel Construction, "Prize Bridges/1978" (American Institute of Steel Construction, 1978), https://www.aisc.org/globalassets/nsba/prize-bridge-brochures/1978prizebridgebrochure.pdf.

[347] American Institute of Steel Construction, "Prize Bridges/1980" (American Institute of Steel Construction, 1980), https://www.aisc.org/globalassets/nsba/prize-bridge-brochures/1980prizebridgebrochure.pdf.

[348] See "Interchange Bridge Voted One of 8 Most Beautiful," *Sunday Gazette-Mail*, September 5, 1976.

# 5. Conclusion

The period from 1965 to 1980 saw changes in bridge design and construction nationally, such as the increased use of posttensioning and the introduction of segmental prestressed concrete box girders. However, while West Virginia adopted prestressed concrete for primarily short- and medium-span bridges, it continued to rely on steel for longer spans. West Virginia also continued to use steel truss bridges for major crossings and employed weathering steel where environmental conditions allowed. Computers played an increasing role in bridge design and construction, both nationally and in West Virginia, facilitating rapid calculations for standard spans as well as more complex designs including the use of curved steel girders throughout the state.

Legislative factors also played an influential role during the study period. A number of new federal regulations mandated an environmental study to determine a proposed project's impact on its surroundings, requiring states, including West Virginia, to demonstrate that the benefits of the project outweighed any negative impacts on the environment. Work also continued on the Interstate Highway System, requiring construction of many new bridges that met a national design standard applicable to the system. Federal legislation also established the National Bridge Inspection program, created in direct response to the Silver Bridge Disaster in 1967, which highlighted the need for comprehensive bridge inspection programs. In the aftermath of the disaster, West Virginia replaced several similar bridges and implemented a more robust inspection program that revealed thousands of bridges in need of repair. During the study period, the development of the ADH System had a major impact on Appalachian communities in West Virginia. Increased federal funding to implement highways in the ADH, as well as for Interstate Highways and bridges resulted in the construction of scores of new bridges during the study period.

Aesthetic considerations played a minor role between 1965 and 1980 nationally. With bridge construction booming, cost and safety were the primary considerations for design selection. While select bridges were designed with aesthetics in mind or to address environmental concerns, West Virginia typically followed the national trend during these years of prioritizing cost and safety over aesthetics.

## Bibliography


"4-Lane Span Planned for Pt. Pleasant." *The Weirton Daily Times*. February 24, 1968.

95th Congress of the United States. "Surface Transportation Act of 1978, Public Law 95-599 - Nov. 6, 1978, 92 STAT. 2689." United States Government Printing Office, November 6, 1978.

"140-Year-Old Stone Bridge to Be Retained as Historical Site." *The Pennsboro News*, October 21, 1971. Clippings - Bridges - General. West Virginia State Archives.

*1980 Annual Report of the Appalachian Regional Commission*. Washington D.C.: Appalachian Regional Commission, 1980.

*A Report on the Present, A Plan for the Future*. Charleston, WV: the State Road Commission of West Virginia, 1963. West Virginia University Archives.

*A Summary Presentation of the Appalachian Development Highway System*. the State Road Commission of West Virginia, January 1968. West Virginia University Archives.

Advisory Council on Historic Preservation. *Exemption Regarding Historic Preservation Review Process for Effects to the Interstate Highway System*. Federal Register, Vol. 70, No. 46, March 10, 2005.

———. *Program Comment Issued for Streamlining Section 106 Review for Actions Affecting Post-1945 Concrete and Steel Bridges*. Federal Register, Vol. 77, No. 222, November 16, 2012.

Akanegbu, Anuli, and Ricky Ribeiro. "The History of Calculators: Evolution of the Calculator (Timeline)." *EdTech Magazine*, November 20, 2012. https://edtechmagazine.com/k12/article/2012/11/calculating-firsts-visual-history-calculators.

"Aluminum Highway Bridge." *Public Works*, no. 89 (March 1958): 163.

"Aluminum Sections Make a First in Road Bridges." *Engineering News-Record*, no. 161 (September 25, 1958): 32.

American Association of State Highway Officials, Committee on Bridges and Structures, and Prestressed Concrete Institute. *Tentative Standards for Prestressed Concrete Piles, Slabs, I-Beams and Box Beams for Bridges and an Interim Manual for Inspection of Such Construction,*. Washington, 1963.

American Galvanizers Association. *Stearns Bayou Bridge, Ottawa County, MI*, n.d. https://www.galvanizeit.org/project-gallery/gallery/stearns-bayou-bridge.

American Institute of Steel Construction. "Prize Bridges/1973." American Institute of Steel Construction, 1973. https://www.aisc.org/globalassets/nsba/prize-bridge-brochures/1973prizebridgebrochure.pdf.

———. “Prize Bridges/1976.” American Institute of Steel Construction, 1976. https://www.aisc.org/globalassets/nsba/prize-bridge-brochures/1976prizebridgebrochure.pdf.

———. “Prize Bridges/1978.” American Institute of Steel Construction, 1978. https://www.aisc.org/globalassets/nsba/prize-bridge-brochures/1978prizebridgebrochure.pdf.

———. “Prize Bridges/1980.” American Institute of Steel Construction, 1980. https://www.aisc.org/globalassets/nsba/prize-bridge-brochures/1980prizebridgebrochure.pdf.

*An Enlarged Plan for the Future: Seven Year Program... 1966-1972*. Charleston, WV: the State Road Commission of West Virginia, 1965. West Virginia University Archives.

*Appalachia Then and Now: Examining Changes to the Appalachian Region Since 1965*. Appalachian Regional Commission, 2015. https://wayback.archive-it.org/3259/20200430193817/https://www.arc.gov/assets/research_reports/AppalachiaThenAndNowCompiledReports.pdf.

“At Last! Governor Dedicates Much-Delayed East Huntington Bridge (Press Release).” West Virginia Department of Highways, August 8, 1985. Department of Highways Communications AR1993-Box 2- East Huntington Bridge Folder. West Virginia Archives & History.

Bailey, Gregory. Telephone interview with Mead & Hunt, Inc. Telephone, December 20, 2023.

Barth, Karl E., and Jennifer Righman McConnell. “An Assessment of Weathering Steel Bridges in West Virginia.” Proceedings of 8th International Conference on Short and Medium Span Bridge, 2010. https://www.shortspansteelbridges.org/wp-content/uploads/2020/07/CSCE_Paper_Barth_Weathering-Steel.pdf.

Birkemoe, P. C., and D. C. Herrschaft. “Bolted Galvanized Bridges - Engineering Acceptance Near.” *Civil Engineering - ASCE* 40, no. 4 (April 1970): 42–46.

“Blennerhassett Island Restoration - Wilderness Eden May Bloom Again.” *The Charleston Daily Mail*. August 16, 1974.

“Boost Is Given Chester Bridge.” *Beckley Post-Herald The Raleigh Register*. February 11, 1968.

Braniff, Amy. “Bridge, Bypass Sparked a New Era for City.” *Weirton Daily Times*, July 2, 1997. Clippings - Bridges - General. West Virginia State Archives.

“Bridge Bill Presented by Mollohan.” *The Weirton Daily Times*. September 17, 1970.

“Bridge Closed at St. Marys.” *The Charleston Daily Mail*. December 18, 1967.

“Bridge Facts: New River.” *West Virginia Department of Transportation*, n.d. https://transportation.wv.gov:443/highways/bridge_facts/Modern-Bridges/Pages/NewRiver.aspx.

“Bridge Inspection Program Costly, But Provides Safety.” *The Raleigh Register*. June 3, 1976.

“Bridge Linkup Nears.” *The Evening Review*. January 3, 1976.

“Bridge Probe Is Approved by Unanimous Vote.” *Beckley Post-Herald The Raleigh Register*. January 28, 1968.

“Bridge Status Reports Issued.” *The Weirton Daily Times*. June 27, 1973.

Burroughs, Edward A. “Fifty-Year Development Construction of Steel Girder Bridges.” *Journal of the Construction Division* 101, no. 3 (1975): 463–75.

Carelli, Richard. “Greater Safety Awareness Credited to Tragedy.” *The Charleston Daily Mail*. December 15, 1972.

Casella, Richard M. *Engineering Significance of the Prowse Memorial Bridge & History of the Welded Steel Rigid-Frame Slant-Leg Highway Bridge*. Prepared for Preservation Company and the New Hampshire Department of Transportation, April 2010. https://www.historicdoc.com/reports/HES-RigidFrameSlantLegBrg.pdf.

Castrodale, Reid W., and Christopher D. White. *Extending Span Ranges of Precast Prestressed Concrete Girders*. Transportation Research Board, 2004.

“Census Tracts - 1910 to 2014.” *Nhgis.Org*, n.d. https://umn.maps.arcgis.com/apps/webappviewer/index.html?id=ef554b42643141829f9e8c4b8001f93a.

*Census Tracts: Charleston, W. VA. Standard Metropolitan Statistical Area*. 1970 Census of Population and Housing. Washington D.C.: U.S. Department of Commerce Bureau of the Census, 1970.

“Charges Are Dismissed.” *Beckley Post-Herald*. September 19, 1969.

Chen, Wai-Fah, and Lian Duan. *Handbook of International Bridge Engineering*. N.p.: CRC Press, 2013.

“Chester Bridge Arrest Made.” *The Weirton Daily Times*. February 20, 1968.

Cohen, Edward. “Long-Span Suspension Bridges: The American Approach.” *Annals of the New York Academy of Sciences* 352 (n.d.): 27–39.

Committee on General Structures, Subcommittee on Bridge Aesthetics. *Bridge Aesthetics Around the World*. Washington, D.C.: Transportation Research Board, National Research Council, 1991.

Condit, Carl. *American Building Materials and Techniques from the First Colonial Settlements to the Present*. Chicago: University of Chicago Press, 1968.

“Conference of Appalachian Governors Counties, June 1962,” 1963. Warren I. Cikins Personal Papers. Federal Employment, 1954-1969. Executive Office of the President (White House), 1957-1966. Conference of Appalachian Governors, 1962-1963 (folder 1 of 3). John F. Kennedy Presidential Library and Museum. https://www.jfklibrary.org/asset-viewer/archives/wicpp-022-001#?image_identifier=WICPP-022-001-p0044.

Corven, John, Thomas Eberhardt, Brian Watson, Brandon Chavel, Jason Mash, Duncan Paterson, and Thomas Anthony. *Bridge Geometry Manual*. Washington D.C.: Federal Highway Administration: Office of Bridges and Structures, April 2022. https://www.fhwa.dot.gov/bridge/pubs/hif22034.pdf.

Dallaire, Gene. “Designing Bridge Decks That Won’t Deteriorate.” *Civil Engineering - ASCE* 43–48, no. 8 (August 1973): 43.

Danielson, Todd. “Engineered Solutions: Transcending Time – Hot-Dip Galvanized Steel Provides Solution to Combat Corrosion on Bridges Old and New.” *Informed Infrastructure*, December 19, 2018. https://informedinfrastructure.com/44155/engineered-solutions-transcending-time-hot-dip-galvanized-steel-provides-solution-to-combat-corrosion-on-bridges-old-and-new/.

*Demolition of the St. Marys Bridge*. Black and white photoprint, 1971. DOH Communications, AR1993 Box 1, St. Marys Bridge Folder. West Virginia State Archives.

Deneault, PE, Joe. “Bridging the Past.” *Modern Steel Construction*, January 2007. https://www.aisc.org/globalassets/modern-steel/archives/2007/01/2007v01_bridging_the_past.pdf.

“Department Restoring Milton Covered Bridge.” *West Virginia Highways*, June 1971. West Virginia Highways - Box Hig 1. 4/2 - 1935-1972 - 1971 Folder. West Virginia State Archives.

“Division of Highways.” *The West Virginia Encyclopedia*, 2023. https://www.wvencyclopedia.org/articles/375.

Duwadi, Sheila Rimal, and Michael A. Ritter. “Timber Bridges in the United States.” *Public Roads* 60, no. 3 (Winter 1997). https://www.fhwa.dot.gov/publications/publicroads/97winter/p97wi32.cfm.

“East Huntington Bridge Contracts.” West Virginia Department of Highways, n.d. Department of Highways Communications AR1993-Box 2- East Huntington Bridge Folder. West Virginia State Archives.

“East Huntington Bridge Facts.” West Virginia Department of Highways, n.d. Department of Highways Communications AR1993-Box 2- East Huntington Bridge Folder. West Virginia State Archives.

“East Huntington Bridge: ‘Phantom’ with a History.” *Herald-Advertiser*, July 29, 1973. Clippings - Bridges - General. West Virginia State Archives.

“East Huntington Bridge: Single-Tower Design Will Have First American Use.” *West Virginia Highways*, Fall 1980. West Virginia Highways - Box Hig 1. 4/2 - 1978-1980 - Fall 1981 folder. West Virginia State Archives.

“Emergency Funds Seen for Bridge at Point Pleasant.” *The Charleston Daily Mail*, July 12, 1968.

Epperly, Randolph Jr. Telephone interview with Mead & Hunt, Inc. Telephone, December 14, 2023.

E.S. Preston and Associates. *Ohio Transportation Development Program Report: A Focus on Highways*. N.p.: Ohio Department of Transportation, 1974.

Evans, Farrell. “How Interstate Highways Gutted Communities—and Reinforced Segregation.” *HISTORY*, September 21, 2023. https://www.history.com/news/interstate-highway-system-infrastructure-construction-segregation.

“Fact Sheet- Silver Memorial Bridge.” West Virginia State Road Commission, 1969. Department of Highways Communications AR1993-Box 1- Silver Memorial Bridge Folder. West Virginia State Archives.

“Federal Fund Approval for Charleston Bridge.” *West Virginia Highways*, November 1971. West Virginia Highways - Box Hig 1. 4/2 - 1935-1972 - 1971 Folder. West Virginia State Archives.

Federal Highway Administration. “Happy 50th Anniversary - National Bridge Inspection Standards.” *Highway History*. Accessed February 21, 2024. https://www.fhwa.dot.gov/highwayhistory/national_bridge_inspection_standards.cfm.

———. *Highway Bridge Inspection: State-of-the-Practice Survey*. McLean, Va.: U.S. Department of Transportation, April 2001. http://www.fhwa.dot.gov/publications/research/nde/pdfs/01033.pdf.

———. *Manual for Design, Construction, and Maintenance of Orthotropic Steel Deck Bridges*. FHWA-IF-12-027. U.S. Department of Transportation Federal Highway Administration, 2012. https://www.fhwa.dot.gov/bridge/pubs/if12027/if12027.pdf.

———. “Post-1945 Highway Bridge Engineering.” *FHWA* | *Environmental Review Toolkit*, n.d. https://www.environment.fhwa.dot.gov/histpres/post-1945_engineering/this_bridge.asp.

———. “Post-Tensioned Box Girder Design Manual.” Federal Highway Administration, June 2016. https://www.fhwa.dot.gov/bridge/concrete/hif15016.pdf.

Federal Highway Administration, Department of Transportation. *23 CFR Part 650 [FHWA Docket No. FHWA-2017-0047] RIN 2125-AF55, National Bridge Inspection Standards*. Federal Register, Vol. 84, No. 218, November 12, 2019.

Federal Highway Administration, Office of Engineering, Federal-Aid and Design Division. *A Guide to Federal-Aid Programs, Projects and Other Uses of Highway Funds, Publication No. FHWA-PD-92-018*. US Department of Transportation, Federal Highway Administration, 1992.

Feld, Jacob, and Kenneth L. Carper. *Construction Failure*. N.p.: John Wiley & Sons, 1997.

Friedman, Tom. “Russian Aid? Nyet!” *Charleston Daily Mail*, n.d. Clippings - Bridges - General. West Virginia State Archives.

“‘G,’ Bridge Contracts Awarded.” *Logan Banner*, August 21, 1972. Department of Highways Communications AR1993-Box 1- Buffalo Creek Folder. West Virginia State Archives.

Godfrey, Kneeland A. “Cutting the Cost of Short-Span Bridges.” *Civil Engineering - ASCE* 45 (July 1975): 42–46.

Godfrey, Kneeland A. Jr. “The 1970’s: Civil Engineering Forecast Part I, Structures and Underground Construction.” *Civil Engineering - ASCE* 40, no. 4 (April 1970): 68-?

“Golden Spike?” *Beckley Post-Herald The Raleigh Register*. October 23, 1977.

“Governor Plans Inspection of All Major W. Va. Spans.” *The Weirton Daily Times*. January 6, 1968.

Gute, William L. “First Vehicular Cable-Stayed Bridge in the U.S.” *Civil Engineering - ASCE* 43, no. 11 (November 1973): 50–55.

Gutkowski, R., and T. Williamson. “Timber Bridges: State-of-the-Art.” *Journal of Structural Engineering* 109, no. 9 (September 1, 1983): 2175–91.

Harbeson, Paul C. “Architecture in Bridge Design.” In *Bridge Aesthetics Around the World*. Washington, D.C.: Transportation Research Board, 1991.

“Hearing on Highway Bridge Inspections, Statement of King W. Gee, Associate Administrator for Infrastructure and Gary Henderson, Director, Office of Infrastructure Research and Development, Federal Highway Administration, U.S. Department of Transportation,” October 23, 2007. www.transportation.gov/content/highway-bridge-inspections.

“Henderson Bridge Will Be Checked.” *The Raleigh Register*. August 27, 1969.

Herbst, Rebecca. “State Inventory Form, I.D. No. 5JF 398 - F-15-CI, Genesee Park Interchange.” Colorado Historical Society, December 1985.

“Highway News Press Release.” West Virginia Department of Highways, January 23, 1981. Department of Highways Communications AR1993-Box 2- East Huntington Bridge Folder. West Virginia State Archives.

Himelfarb, Elliott. “Unsafe Bridges.” *Transportation USA*, Summer 1978.

“Historic Aerials: Viewer, Charleston, WV.” *Historic Aerials by NETROnline*, 1971. https://historicaerials.com/viewer.

“Historic Aerials: Viewer, Charleston, WV.” *Historic Aerials by NETROnline*, 1985. https://historicaerials.com/viewer.

Hopkins, G. R., R. W. Vance, and B. Kasraie. “Scour Around Bridge Piers.” Federal Highway Administration, Office of Research & Development, March 1975.

Hota, GangaRao. Telephone interview with Mead & Hunt, Inc. Telephone, December 12, 2023.

Hota, GangaRao, and Narendra B. Taly. “Conceptual Substructural Systems for Short-Span Bridges.” *Transportation Engineering Journal of ASCE* 104, no. 1 (January 1978): 15–29.

Hota, GangaRao V. S., Richard Ward, and Victor Howser. “Value Engineering Approach to Low-Volume Road Bridge Selection.” *Journal of Structural Engineering* 114, no. 9 (1988): 1962–77.

Hota, GangaRao, and Thomas Zelina. “Development of Economical Low-Volume Road Bridges.” *Journal of Structural Engineering* 114, no. 9 (1988): 1941–61.

“Inspection Ruled Out -Tentatively- as Factor in Silver Bridge Collapse.” *The Charleston Daily Mail*. November 19, 1968.

“Interchange Bridge Voted One of 8 Most Beautiful.” *Sunday Gazette-Mail*. September 5, 1976.

“Investment Opportunity.” *Sunday Gazette-Mail*. June 9, 1974.

Javersack, David T. “Weirton Steel.” *The West Virginia Encyclopedia*, 2023. https://www.wvencyclopedia.org/articles/973.

“Jennings Randolph Bridge Dedication, November 7, 1977,” 1977. Department of Highways Communications AR1993-Box 1- Chester Jennings Randolph Bridge Folder. West Virginia State Archives.

Jet Lowe. *O’Connell Bridge, Sitka Harbor, Sitka, Alaska, HAER No. AK-27*. Photograph, 1991. Historic American Engineering Record. Library of Congress. http://www.loc.gov/pictures/item/ak0342.photos.033413p/.

John Rathke, Mead & Hunt, Inc. engineer. Interview with Mead & Hunt, Inc., January 12, 2016.

Kissell, J. Randolph, and Robert L. Ferry. *Aluminum Structures: A Guide to Their Specifications and Design*. N.p.: John Wiley & Sons, 2002.

Knudsen, C. V., and J. F. Cain. “The Design and Construction of the New River Gorge Bridge.” *Transportation Research Record*, Transportation Research Record, Bridge Engineering Volume 2, no. 665 (1978).

Kozak, John J., and Thomas J. Bezouska. “Twenty Five Years of Progress in Prestressed Concrete Bridges.” *Journal of the Prestressed Concrete Institute* 21, no. 5 (n.d.): 90–111.

Kreh, R. T. *Masonry Skills*. N.p.: Cengage Learning, 2003.

Kuklik, Vlastimil, and Jan Kudlacek. *Hot-Dip Galvanizing of Steel Structures*. N.p.: Butterworth-Heinemann, 2016.

Lacey, Geoffrey C., John E. Breen, and Ned H. Burns. “State of the Art for Long Span Prestressed Concrete Bridges of Segmental Construction.” *PCI Journal* 16, no. 5 (October 1971): 53–77.

“LBJ Reveals Crash Plan for Bridge.” *The Charleston Daily Mail*. February 7, 1968.

Leonhardt, Fritz. “Cable Stayed Bridges with Prestressed Concrete.” *PCI Journal*, October 1987, 52–80.

“Letter from Charles D. Taylor, President of the Northern Hancock County Development Organization to Governor Hulett C. Smith,” January 3, 1968. Governor Hulett Smith Papers, SRC General (I-Z) 1968, Bridges Folder. West Virginia University Archives.

"Letter from Charles D. Taylor, President of the Northern Hancock County Development Organization to Governor Hulett C. Smith," May 1, 1968. Governor Hulett Smith Papers, SRC General (I-Z) 1968, Bridges Folder. West Virginia University Archives.

"Letter from H. A. Carpenter to Governor Hulett C. Smith," January 16, 1968. Governor Hulett Smith Papers, SRC General (I-Z) 1968, Bridges Folder. West Virginia State Archives.

"Letter to Governor Hulett C. Smith from The County Court of Mineral County," February 5, 1968. Governor Hulett Smith Papers, SRC General (I-Z) 1968, Bridges Folder. West Virginia University Archives.

"Letter to James V. Morris from Paul Crabtree, Executive Assistant to the Governor," April 3, 1968. Governor Hulett Smith Papers, SRC General (I-Z) 1968, Bridges Folder. West Virginia University Archives.

Lichtenstein, Abba G. "The Silver Bridge Collapse Recounted." *Journal of Performance of Constructed Facilities* 7, no. 4 (November 1993): 249–61.

Lin, Tung Y., and Felix Kulka. "Fifty-Year Advancement in Concrete Bridge Construction." *Journal of the Construction Division* 101, no. 3 (1975): 491–510.

Lucke, Thomas W. "Relocation Assistance Advisory Programs: A Need for Early Judicial Review." *Administrative Law Review* 27, no. 1 (1975): 17–30.

"Market St. Span Has Priority." *The Weirton Daily Times*. September 16, 1971.

Martin, Lou. "Steel Industry." *The West Virginia Encyclopedia*, 2023. https://www.wvencyclopedia.org/articles/586.

"Mayor Flays Bridge Delay." *Beckley Post-Herald*. November 13, 1969.

McCutcheon, W.J., and F.L. Tuomi. *Simplified Procedure for Glued-Laminated Bridge Decks*. Madison, Wis.: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, 1974.

McDad, Bashar, David C. Laffrey, Mickey Dammann, and Ronald D. Medlock. *Performance of Weathering Steel in TxDOT Bridges*. Prepared for the Texas Department of Transportation, June 2, 2000. http://www.smdisteel.org/~/media/Files/SMDI/Construction/Bridges%20-%20WS%20-%20Report%20-%20Performance%20of%20WS%20in%20TX%20DOT%20Bridges%20by%20B%20McDad%20-%2006-02-2000.ashx.

McDonald, J., E. Heymsfield, and R.R. Avent. "Investigation of Elastomeric Bearing Pad Failures in Louisiana Bridges." Louisiana Transportation Research Center, September 1999. https://www.ltrc.lsu.edu/pdf/2008/fr_330.pdf.

Melling, Carol. "Appalachian Corridor Highways." *The West Virginia Encyclopedia*, 2023. https://www.wvencyclopedia.org/articles/244.

Milek, Jr., W.A. “AISC Orthotropic Plate Design Manual.” *AISC Engineering Journal*, April 1964.

Miller, Tom D. “Appalachian Regional Commission.” *The West Virginia Encyclopedia*, 2023. https://www.wvencyclopedia.org/articles/249.

“Minute Book: State Road Commission 1959-1980.” Advisory Board of the Department of Highways, 1980. State Road Commission papers. West Virginia State Archives.

Mohamedmeki, Z. Mohammed, F. Jihan Esmail, and E. Awadh Ajeel. “Fatigue Life Analysis of Laminated Elastomeric Bearing Pad.” *Materialstoday: Proceedings*, 2021.

Morgan, John G. “Pride Sparks Campaign for Historic Span.” *The Charleston Gazette*, November 4, 1978. Clippings - Bridges - General. West Virginia State Archives.

Munro, John M. “Planning the Appalachian Development Highway System: Some Critical Questions.” *Land Economics* 45, no. 2 (1969): 149–61. doi:10.2307/3145121.

Murillo, Juan A. “Modern Bridge Construction and Engineering Services.” In *Managing Innovation: Cases from the Services Industries*, edited by Bruce R. Guile and James Brian Quinn, 165–74. Washington, D.C.: National Academies, 1988.

“NAACP Opposes Triangle Project.” *The Charleston Daily Mail*. January 13, 1969.

National Register of Historic Places, New River Gorge Bridge, Fayetteville, Fayette County, West Virginia. National Register #13000603.

———, Blennerhassett Island Historic District. National Register #72001294.

“New Idea Roundup.” *Edmonton Journal*. June 19, 1967.

“New Span Named ‘Silver Memorial.’” *The Charleston Daily Mail*. December 5, 1969.

“No Blues Over New Bridge Color.” *West Virginia Highways*, November 1972. West Virginia Highways - Box Hig 1. 4/2 - 1935-1972 - 1971 Folder. West Virginia State Archives.

Parsons Brinckerhoff and Engineering and Industrial Heritage. *A Context for Common Historic Bridge Types*. Prepared for the National Cooperative Highway Research Program, Transportation Research Council, and National Research Council, October 2005. http://onlinepubs.trb.org/onlinepubs/archive/NotesDocs/25-25(15)_FR.pdf.

Petroski, Henry. “Silver Bridge.” *American Scientist* 99, no. 5 (September 2011): 368–72.

Podolny Jr., Walter. “An Overview of Precast Prestressed Segmental Bridges.” *PCI Journal* 24, no. 1 (February 1979). http://www.pci.org/uploadedFiles/Siteroot/Publications/PCI_Journal/1979/DOI_Articles/jl-79-january-february-4.pdf.

———. “An Overview of Precast Prestressed Segmental Bridges.” *PCI Journal*, n.d. http://www.pci.org/uploadedFiles/Siteroot/Publications/PCI_Journal/1979/DOI_Articles/jl-79-january-february-4.pdf.

“Point Pleasant Braces for Huge Dedication Crowd.” *The Charleston Daily Mail*. December 12, 1969.

“Progress of Corridor ‘L’ at Hico in Fayette County.” *Beckley Post-Herald*. April 23, 1973.

“Project & Environmental Review Division Established.” *West Virginia Highways*, July 1973. West Virginia Highways - Box Hig 1. 1/4 - 1973-1981 - 1973 Folder. West Virginia State Archives.

“Public Law 90-495: Federal-Aid Highway Act of 1968.” United States Congress, August 23, 1968. https://uscode.house.gov/statviewer.htm?volume=82&page=829.

“Public Law 91-605, Federal-Aid Highway Act of 1970.” United States Congress, December 31, 1970. https://www.congress.gov/91/statute/STATUTE-84/STATUTE-84-Pg1713.pdf.

Raithby, K.D., and F.D. Lydon. “Lightweight Concrete in Highway Bridges.” *International Journal of Cement Composites and Lightweight Concrete* 3, no. 2 (1981): 133–46. doi:10.1016/0262-5075(81)90007-5.

“Randolph Wants Bridge Work Rushed.” *The Weirton Daily Times*. January 16, 1974.

“Record of Poor Bridge Inspection Practice Disclosed by Hearing.” *The Raleigh Register*. May 9, 1968.

Reece, Jason. “Confronting the Legacy of ‘Separate but Equal’: Can the History of Race, Real Estate, and Discrimination Engage and Inform Contemporary Policy?” *The Russell Sage Foundation Journal of the Social Sciences* 7, no. 1 (February 2021): 110–33.

“Renewing Inequality: Family Displacement through Urban Renewal 1950-1966.” *American Panorama*, n.d. https://dsl.richmond.edu/panorama/renewal/#view=0/0/1&viz=cartogram&cityview=holc&city=charlestonWV&project=1663&loc=16/38.3553/-81.6338.

“Resolution of the Huntington Board of Realtors,” January 10, 1968. Governor Hulett Smith Papers, SRC General (I-Z) 1968, Bridges Folder. West Virginia University Archives.

Richards, Jr., Rowland. “U.S. Bridges: The Bias Toward Mediocrity.” *Civil Engineering*, April 1983. Emory Kemp Papers Regarding Industrial History - A&M 4230 - Box 216 - Clippings 1979-1983 Folder. West Virginia University Archives.

“Road Bonds New Budget Plan Okehed.” *Beckley Post-Herald*. November 6, 1968.

“Road Near Sophia Part of WVU Research.” *Beckley Post-Herald The Raleigh Register*. May 29, 1966.

“Roads Amendment Gets Strong Backing.” *Beckley Post-Herald*. October 30, 1964.

Roberts, E.F., and M. Lohrmann. “Designing Computer Programs for Bridge Foundations.” *Civil Engineering - ASCE* 41, no. 12 (December 1971): 64–66.

Roberts, James E. “Lightweight Concrete for California’s Bridges.” *Engineered Concrete Structures* 10, no. 3 (December 1997): 1–3.

Saaty, Thomas L., and Luis G. Vargas. *Models, Methods, Concepts & Applications of the Analytic Hierarchy Process*. N.p.: Springer Science & Business Media, 2012.

“Selected Noteworthy Simple Truss Spans In The United States.” Historic Bridge Foundation, 2015. https://historicbridgefoundation.com/wp-content/uploads/2015/03/simplespans.pdf.

Sikes, Glenn H. *The Analysis of Continuous Beams for Highway Bridges IV Computer Program Fortran IV.* N.p.: State Highway Department of Georgia, 1971.

“Silver Bridge’s ‘Sister’ Closed.” *The Raleigh Register*. December 31, 1968.

*Silver Memorial Bridge*. Photograph, black & white, 1969. Department of Highways Communications AR1993-Box 1- Silver Memorial Bridge Folder. West Virginia State Archives.

“Silver Memorial Bridge Gets Final Inspection.” *The Charleston Daily Mail*. December 11, 1969.

Smith, J. L., and Y. P. Virmani. “Performance of Epoxy Coated Rebar in Bridge Decks.” Federal Highway Administration, Office of Research & Development, 1994.

Sonis, Larry. “New River Gorge Bridge.” *The West Virginia Encyclopedia*, 2023. https://www.wvencyclopedia.org/articles/1639.

Sothen, James. Telephone interview with Mead & Hunt, Inc. Telephone, December 19, 2023.

“Span Critics Not Working.” *Beckley Post-Herald*. August 26, 1969.

“Span Safety Chief Denies Flaw Charge.” *Beckley Post-Herald The Raleigh Register*. August 30, 1969.

Sprinkel, Michael M. *Glulam Timber Deck Bridges*. Prepared for the Virginia Highway & Transportation Research Council, November 1978. http://ntl.bts.gov/lib/36000/36300/36340/79-R26.pdf.

“SRC Bridge Study Procedures Will Be Considered in House.” *The Raleigh Register*. January 26, 1968.

“St. Marys Bridge Reopened to Autos.” *The Raleigh Register*. February 26, 1968.

“St. Marys Seeks Ferry Service.” *The Weirton Daily Times*. December 29, 1967.

*Standard Specifications for Highway Bridges*. Washington, D.C.: American Association of State Highway Officials, 1961.

“State in Nation’s Top Five in 1971 Construction.” *West Virginia Highways*, March 1972. West Virginia Highways - Box Hig 1. 4/2 - 1935-1972 - 1972 Folder. West Virginia State Archives.

Steele, Garland. Telephone interview with Mead & Hunt, Inc. Telephone, December 20, 2023.

"Steubenville City Council Fearful of Bridge Safety." *The Weirton Daily Times*. September 15, 1971.

"Stress, Corrosion Enter Bridge Tragedy Causes." *Beckley Post-Herald*. January 1, 1969.

Subcommittee on Curved Girders: Joint AASHO-ASCE Committee on Flexural Members. "Survey of Curved Girder Bridges." *Civil Engineering - ASCE* 43, no. 2 (February 1973): 54–55.

"Survey Boundary." *The Charleston Daily Mail*. February 9, 1966.

Taly, Narendra. *Design of Modern Highway Bridges*. N.p.: McGraw-Hill, 1998.

Tang, Dr. Man-Chung. "Special Report: Construction of East Huntington Bridge." *PCI Journal*, December 1987. https://www.pci.org/PCI_Docs/Design_Resources/Guides_and_manuals/references/bridge_design_manual/JL-87-November-December_Construction_of_East_Huntington_Bridge.pdf.

Tarr, David G. "The Steel Crisis in the United States and the European Community: Causes and Adjustments." In *Issues in US-EC Trade Relations*, 173–200. University of Chicago Press, 1988. http://www.nber.org/chapters/c5960.

*The Appalachian Development Highway System in West Virginia: Too Little Funding Too Late?* Report to the Congress. Washington D.C.: Comptroller General of the United States, 1976.

*The Appalachian Regional Commission Annual Report: 1965*. Washington D.C.: Appalachian Regional Commission, 1965.

The Louis Berger Group. *The Interstate Highway System in the United States: Draft Final Historic Context Report*. East Orange, N.J.: prepared for the U.S. Department of Transportation, Federal Highway Administration, December 2004.

"The Trailblazers: Brief History of the Direct Federal Highway Construction Program." *Federal Highway Administration*, September 2017. http://www.fhwa.dot.gov/infrastructure/blazer01.cfm.

TranSystems Corporation. *Historic Context for Construction of 1959-1968 On-System Bridges in Colorado*. Prepared for the Colorado Department of Transportation, August 2014.

"Triangle Improvement Council et al., Petitioners, v. William S. RITCHIE, Commissioner, State Road Commission of West Virginia, et Al." *LII / Legal Information Institute*, n.d. https://www.law.cornell.edu/supremecourt/text/402/497.

"Turnpike Funding Passes Major Obstacle." *Raleigh Register*, December 18, 1970.

United States. Federal Highway Administration. Office of Program Administration. "Report Number: FHWA-IF-99-006: A Guide to Federal-Aid Programs and Projects," May 1, 1999. https://rosap.ntl.bts.gov/view/dot/4070.

United States Senate. "The Federal-Aid Highway Amendments of 1974, Report of the Committee on Public Works United States Senate Together With Minority Views to Accompany S. 3934, Report No. 93-1111." U.S. Government Printing Office, 1974.

"URA Triangle Study Given Green Light." *The Charleston Daily Mail*. November 5, 1965.

"Urban Renewal Patience Urged." *The Charleston Daily Mail*. May 19, 1975.

"U.S. Coast Guard Readies Bridge Impact Statement." *The Weirton Daily Times*. December 1, 1976.

U.S. Department of Transportation, Federal Highway Administration. "National Bridge Inventory," 2023. National Transportation Atlas Database. https://www.fhwa.dot.gov/bridge/nbi/disclaim.cfm?nbiYear=2023allstatesallrecsdel&nbiZip=zip.

*U.S. Forest Service Timber Bridge Manual*. Washington, D.C.: United States Department of Agriculture, Forest Service, 1992.

"Veterans Memorial Bridge Dedication," May 4, 1990. Department of Highways Communications AR1993-Box 1- Weirton Bridge (Veterans Memorial Bridge) Folder. West Virginia State Archives.

"Vulcan Bridge near Completion." *The Anniston Star*. December 31, 1979.

"W. VA. Bond Issue Non-Political." *The Weirton Daily Times*. October 7, 1964.

Wasserman, Edward P. "Aesthetics for Short- and Medium-Span Bridges." In *Bridge Aesthetics Around the World*. Washington, D.C.: Transportation Research Board, 1991.

Watts, Ann DeWitt. "Does the Appalachian Regional Commission Really Represent a Region?" *Southeastern Geographer* 18, no. 1 (1978): 19–36.

Weil, Martin. "Former Sen. Jennings Randolph Dies." *Washington Post*, May 9, 1998.

Weingroff, Richard F. "Busting The Trust." *Public Roads* 77, no. 1 (August 2013). https://highways.dot.gov/public-roads/julyaugust-2013/busting-trust.

———. "Busting The Trust Supplement." *Federal Highway Administration*, July 2013. http://www.fhwa.dot.gov/publications/research/general/busttrust/index.cfm.

———. "The Battle of Its Life." *Public Roads* 69, no. 6 (June 2006). https://www.fhwa.dot.gov/publications/publicroads/06may/05.cfm.

Wengenroth, Reece H. "Bridge Engineer Looks at Esthetics of Structures." *Journal of the Structural Division* 97, no. 4 (1971): 1227–37.

"West Virginia Better Highways Amendment, Amendment 2 (1973)." *Ballotpedia*, n.d. https://ballotpedia.org/West_Virginia_Better_Highways_Amendment,_Amendment_2_(1973).

"West Virginia Better Roads Amendment, Amendment 1 (1964)." *Ballotpedia*. Accessed December 8, 2023. https://ballotpedia.org/West_Virginia_Better_Roads_Amendment,_Amendment_1_(1964).

West Virginia Department of Highways. *Completed New River Gorge Bridge*. Photograph, black & white, c 1977. Available in Highways Collection, AR1993- Box 1- New River Gorge Folder. West Virginia State Archives.

———. "Fact Sheet: Jennings Randolph Bridge," 1977. Department of Highways Communications AR1993-Box 1- Chester Jennings Randolph Bridge Folder. West Virginia State Archives.

———. *New Ohio River Bridge*. Photograph, black & white, 1977. Department of Highways Communications AR1993-Box 1- Chester Jennings Randolph Bridge Folder. West Virginia State Archives.

———. *Weirton Bridge (Veterans Memorial Bridge)*, c 1990. Department of Highways Communications AR1993-Box 1- Weirton Bridge (Veterans Memorial Bridge) Folder. West Virginia State Archives.

West Virginia Division of Highways. "National Bridge Inventory: West Virginia," 2023. National Transportation Atlas Database. https://www.fhwa.dot.gov/bridge/nbi/disclaim.cfm?nbiYear=2023/delimited&nbiState=WV23.

"West Virginia Roads Development, Amendment 2 (1968)." *Ballotpedia*. Accessed December 8, 2023. https://ballotpedia.org/West_Virginia_Roads_Development,_Amendment_2_(1968).

"West Virginia Water Laws, Water Regulations, and Water Rights." Office of Legal Services, West Virginia Department of Environmental Protection, 2013. https://dep.wv.gov/wwe/wateruse/documents/wv_waterlaws.pdf.

"What Didn't Pass?" *The Charleston Daily Mail*. February 9, 1968.

Wilson, E. L., K. J. Bathe, F. E. Peterson, and H. H. Dovey. "SAP — A Structural Analysis Program for Linear Systems." *Nuclear Engineering and Design* 25, no. 2 (July 1973): 257–74.

Wolchuk, Roman. *Design Manual for Orthotropic Steel Plate Deck Bridges*. New York: American Institute of Steel Construction, 1963.

"WVDOT Assets." *AssetWise Inspections*, 2024. https://wvdot-it.bentley.com/report_summary_view.aspx.

"WVU-SRC Training Program Deadline Set." *The Raleigh Register*. February 17, 1964.

Zuk, William. *Bridge Esthetic Guidelines*. Prepared for the Virginia Highway & Transportation Research Council, 1975.