Texas Department of Transportation

TxDOT Non-truss Bridge Survey Update Historic Context

March 2025

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Introduction

The Texas Department of Transportation (TxDOT) hired ICF, with Hunter Research as a subconsultant (hereinafter referred to as "the team"), to complete tasks related to the survey update of non-truss bridges in Texas (hereinafter referred to as the "project").[1] This Historic Context supplements the historic context included in TxDOT's Historic Road Infrastructure of Texas, 1866–1965 Multiple Property Documentation Form (MPDF), and it provides additional information about the development of Texas's extant pre-1946 non-truss bridges and 1946–1950 masonry **substructure** non-truss bridges (hereinafter referenced as the Study Population). This document represents the first iteration of research completed and, coupled with the MPDF, provides an understanding of important historical themes in the history of pre-1946 non-truss bridge building in Texas. As the project progresses, this historic context will be expanded with additional information found in the research of individual bridges.[2]

This project began with over 6,800 non-truss bridges and bridge-class culverts built in Texas before 1946 and 16 bridges with masonry substructures built between 1946 and 1950. The team removed several classes of bridges from consideration in this project, including structures that TxDOT incorrectly coded as non-truss types, were built after the subject time period, or involved rudimentary construction techniques (e.g., timber bridges over water). Additionally, the team removed park road bridges inside state parks, bridge-class concrete pipe or metal pipe culverts, bridges already listed on the National Register of Historic Places (NRHP), exempt interstate highway bridges, and many widened bridge-class culverts.[3] For more information on the bridges removed from the study, please see the *TxDOT Non-truss Bridge Survey Update Population Report* dated August 2021. The team removed approximately 2,950 bridges from the study, and there are approximately 3,850 bridges that constitute the Study Population for this project.

The Study Population includes about two dozen bridge types, with just four bridge types — reinforced concrete bridge-**class box culverts**, **reinforced concrete flat slabs**, **reinforced concrete tee beams**, and **steel I-beams** — constituting approximately 92 percent of the Study Population. Unsurprisingly, the only **superstructure** standard plans that the Texas Highway Department (THD) issued before 1946 were for these four bridge types. As a result, this study references these four bridge types as ***common bridge types*** or standard bridge types in the text below. The team references the less common bridge types in this document as ***uncommon bridge types*** or non-standard bridge types, as they required engineers to create special designs for them.

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[1] The definition of "bridges" includes structures over 20 feet long, and it includes bridge-class culverts and bridge structures.

[2] The team found little new information about important bridge engineers. The team anticipates finding additional research during the individualized bridge research, particularly as research on unusual bridge types may illuminate who the important bridge engineers were in this period.

[3] The team kept widened bridge-class culverts located in historic districts and on the Old Spanish Trail (OST) in the Study Population.

The purpose of this Historic Context is to summarize the important events, trends, people, and engineering development associated with the design and construction of the Study Population bridges. This context, along with the MPDF, provides an overall framework for evaluating the bridges' NRHP significance under Criteria A, B, and C.[4] This Historic Context also includes a typology section that outlines the extant bridge types and their character-defining features. This typology connects the historic context statement to the extant bridge population's characteristics and design, and it provides the basis for evaluating the bridges under Criterion C in the project's next steps.

Based on research and analysis of the Study Population, this historic context focuses on three main areas of significance, with two focusing on Criterion A and one on Criterion C as follows:[5]

- Transportation and Public Policy (Criterion A)
- Community Planning (Criterion A)
- Engineering (Criterion C)

At the end of this document, there is a section that outlines potential major bridge projects based on their structure length and/or numbers of obstacles crossed. This section is a stand-alone chapter because these bridges may have associations under all areas of significance noted above.

This preliminary draft historic context is intended to inform the creation of the evaluation methodologies that the team will use to assess the historical significance of the Study Population bridges in future stages of the project. Based on TxDOT review and as the project develops, the team will revise and update this document to include the subsequent research and incorporate TxDOT's comments. To help the reader understand the bridge terminology used in this report and the differences between the bridge types, a Visual Glossary is included at the end of this document as **Appendix A**. The first use of terms per section are hyperlinked to the definition and graphic provided in **Appendix A**.

This historic context is not intended to be a comprehensive discussion of bridge construction in Texas; rather, it focuses on identifying the important themes, trends, and bridge types only for the Study Population bridges. The MPDF should be referenced as the State's overall historic context for Texas's road and bridge infrastructure. TxDOT has thoroughly researched and documented several topics previously (such as the Depression-era funding and associated work-relief programs); therefore, this document focuses more heavily on topics that have less established research (such as grade-separation bridges). In addition, all the bridges referenced in this document are within the Study Population, unless otherwise noted. This Historic Context includes references to NRHP-listed bridges and bridges with Historic American Engineering Record (HAER) documentation as illustrative

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[4] It should be noted that TxDOT has determined that the project team will not be researching or providing historic context development for linear historic road districts or contexts (such as the named highways/auto-trails like the OST).

[5] Bridges are rarely eligible under Criterion B (Important Persons), and this Historic Context does not include a theme under Criterion B. If bridges have an important association with a person of significance (particularly bridge engineers), they are often most applicable under Criterion C as the work of a master.

examples, but most of the discussions focus on the Study Population bridges. Lastly, the team obtained the numbers, types, and distribution of Study Population bridges referenced in this document from the ICF project database. ICF created this database in 2021 based on bridge data obtained from TxDOT’s Bridge Division via AssetWise and TxDOT Environmental Affairs Division-Historical Studies Branch’s records of NRHP-listed and NRHP-eligible bridges.

Overview: Major Influences on Highway Bridge Building in Texas

The Study Population includes bridges built from 1900 to 1945, with a small number of masonry bridges built between 1946 and 1950. Before the turn of the twentieth century, road construction was primitive at best. As a rural state with dispersed population centers connected by railroads, unimproved roads with poor drainage were typical throughout the state in the nineteenth and early twentieth centuries. At the time, local governments controlled and funded highway and bridge construction. Counties were faced with a difficult juxtaposition: they were tasked with constructing and maintaining local roads and bridges but lacked the funds to do so properly. They often lacked the funds to hire, and often did not recognize the need to hire, professional engineers. As a result, early county bridges were often simple timber bridges or truss bridges constructed from kits. Larger cities and urban counties, such as Fort Worth and Tarrant County, issued bond initiatives to create paved roads and build bridges in their communities.

The dawn of the state highway system, along with the era of the professional engineer, began in the 1910s when the U.S. Congress passed the Federal Aid Road Act of 1916, requiring that all states establish a state highway department to administer funding and oversee design and construction of projects on state highways. Although the counties maintained control of the road systems within their county borders, using Federal Aid funds to build roads in their counties required that they hire professional engineers from a list approved by the State. To help counties, the federal Bureau of Public Roads (BPR) and the newly established THD issued several standard bridge plans that could be used for a variety of span lengths. During this time, large cities also began focusing on urban planning and creating more functional and liveable cities in keeping with City Beautiful Movement ideals, often hiring urban planners and bridge engineers coming to Texas from other states.

Recognizing the inherent problems of keeping control of state highway development in the hands of hundreds of county governments with divergent priorities, the U.S. Congress passed the Federal Aid Road Act of 1921, which shifted the control of highway building to state highway departments and began the “Golden Age” of highway building in Texas and the U.S. During this period, widespread bridge standardization enabled a small team of THD bridge engineers to help build the Texas state highway system. As the state’s population grew during the 1920s, safety measures became abundantly important, and the THD, counties, cities, and railroad companies began heavily focusing on eliminating at-grade roadway-railway crossings throughout the state. Cities such as Fort Worth, which heavily relied on its railroad transportation, undertook expensive grade-separation construction programs.

During the Great Depression in the early 1930s, the federal government looked for ways to help alleviate unemployment and put out-of-work laborers back to work, particularly in the construction of infrastructure projects. The state highway departments had the experience, ability, and professional capabilities to administer large sums of federal funding. However, the Depression-era Federal Aid funding was different from the previous Federal Aid programs, as the New Deal funding instituted during the Depression focused on improving the state highway system created during the late 1910s and throughout the 1920s, as well as aiding in the upgrade of secondary or “feeder” roads in rural areas. Masonry construction became one of the hallmarks of this period, as it helped keep people employed for longer periods at each project, it used locally quarried materials, and it embodied the Rustic stylistic ideals that were popular at the time. Part of improving the highway system included a federal grant program to pay 100 percent for railroad grade-separation structures, which was available to the THD, counties, and (for the first time with any Federal Aid Program) cities. The upgrade of state highways continued through the 1930s and into the early 1940s, as the U.S. entered World War II. With Texas’s large concentration of military installations, wartime support industries, and raw materials, the THD upgraded highways first with the New Deal funding and then with funding created by the Federal Defense Act of 1941. The history of road and bridge building in Texas during the first half of the twentieth century set the stage for the massive population explosion and freeway construction that occurred in the post-World War II years.

Criterion A: Transportation and Public Policy in Texas Road and Bridge Construction

Local Administration of Texas County Roads and Bridges Prior to 1917[6]

In the late nineteenth and early twentieth centuries, railroads were the main transportation system providing connectivity within Texas and to locations outside the state. Railroads provided year-round, all-weather, consistent transportation of people, goods, and crops. The Texas agricultural economy, based heavily on ranching, cotton, and oil production, boomed in areas of the state where investors built railroads. From the panhandle to the Rio Grande, railroads were the main transportation system that allowed Texas to grow in its first century of development. Roadways, on the other hand, were generally primitive paths and trails that connected places. Early roadways were often difficult to traverse in dry conditions and were virtually unusable in wet weather. Additionally, roads had sharp curves and right-angles in some cases, with simple rudimentary timber bridges, fords, and ferries at rivers, creeks, and bayous.

Leading into the 1900s, the Good Roads Movement was taking shape as the American public demanded better, hard-surfaced roads. As automobiles increased in popularity through the early 1900s, so did the demand for connectivity via roads. Good Roads advocacy groups like the National Good Roads Association and the Automobile Club of America worked cooperatively with the Office of Public Roads (an early forerunner of the BPR) and state highway agencies throughout the U.S. to improve over 250,000 miles of roads in the country by 1916.[7] Specific citizen groups, such as the Meridian Road Association and Dixie Overland Highway, named, promoted, and constructed inter-regional and cross-country roads. Booster groups tended to promote specific roads at a national and local level, such as the Bankhead Highway, Meridian Highway, OST, and the Dixie Overland Trail.[8]

While the named highway groups focused on inter-regional road development, counties controlled roadway development, particularly in Texas where there was no centralized highway department until 1917. As a result, the counties handled the majority of road and bridge construction and maintenance in the state, with some cities building their own roads and bridges. In most counties, the

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[6] There are few extant county bridges in the Study Population built before the establishment of the THD in 1917. As a result, individualized research of this population of bridges will be conducted in later phases of the project. In the Final Historic Context, which will be produced later in the project development, this section will be updated and expanded with specific case studies and any commonalities that were found among these bridges through the individualized research.

[7] Bruce Jensen, et. al., *Historic Road Infrastructure of Texas, 1866–1965 Multiple Property Documentation Form*, https://ftp.txdot.gov/pub/txdot-info/env/toolkit/420-13-gui.pdf, accessed on April 2, 2023, E19.

[8] TxDOT and THC have completed extensive research about the named highway associations; please see the MPDF pages E17 through E26 and the Texas Historical Commission’s study of the Bankhead and Meridian Highways at https://www.thc.texas.gov/preserve/projects-and-programs/historic-texas-highways.

commissioners’ court determined which roads were built and upgraded in the county, and they established road districts to complete construction projects.[9]

As a Good Roads Association report noted, many of the county road departments were highly political entities, and roads “have been built without regard to line, to grade or to permanence…and many so-called roads are not roads, but trails and in many instances hardly passable trails.”[10] Around the turn of the twentieth century, some local entities gained an appreciation and understanding of how all-weather roadways and bridges could help farmers and local industries. Dictated by limited funds and lack of education about proper construction techniques, counties often attempted to construct roads, bridges, and culverts without consulting an engineer. As noted by one Office of Road Inquiry (another forerunner agency of the federal BPR) engineer working in the Wichita Falls area, “Good construction is often sacrificed in favor of more mileage.”[11] Furthermore, after construction, maintenance of these poorly constructed facilities exhausted county road funds.

Other areas of rural America had similarly poor construction and limited maintenance of roads and bridges, as was common in Texas counties. Road construction throughout the rural United States was so poor that the Office of Road Inquiry sent skilled engineers to show counties how to build roads and bridges, a program called “Object Lesson Roads.” Between 1908 and 1910, the Office of Public Road Inquiry built 15 of these roads in Texas. Details from Object Lesson Road projects in various counties show that the lengths of the roads varied from 600 feet to 15,700 feet (3 miles). Surface widths varied from 12 to 27.4 feet, with 15 to 18 feet used most often.[12] Public response to the Object Lesson Roads appears to have been uniformly positive, and county commissioners were generally grateful for the federal government’s assistance in demonstrating how to economically build high-quality roads. (To date, the team has not been able to confirm if counties built any of the Study Population bridges as part of the Object Lesson Roads. The team anticipates that the individualized research of bridges will indicate if any have associations with this program.)

During the early years of road construction in the early twentieth century, counties routinely purchased prefabricated metal truss bridges, and as the MPDF notes, they became the prominent bridge type for local efforts.[13] The truss bridges arrived at the nearest railroad depot to the project site, and a company agent would guide the local workers on how to erect these bridges. County governments also built simple, short, non-truss bridge types, with timber **stringer** bridges being one

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[9] “Treatment of the Gravel and Macadam Roads of Texas,” n.p., n.d., Cushing Good Roads Association Papers, Folder 3, Box 6, Cushing Memorial Library and Archives, Texas A&M University, College Station, Tex., 2.

[10] “Treatment of the Gravel and Macadam Roads of Texas,” 2.

[11] Letter to Vernon M. Peirce, January 15, 1912, Box No. 45, General Correspondence, 1893-1916, Records of the Bureau of Public Roads, Record Group 30, National Archives and Records Administration (NARA), College Park, Md.

[12] Texas Historical Commission, *The Development of Highways in Texas: A Historic Context of the Bankhead Highway and Other Historic Named Highways*, https://www.thc.texas.gov/public/upload/preserve/survey/highway/Section%20I.%20Statewide%20Historic%20Context.pdf, accessed April 2, 2023. Note, one of the primary authors of this current pre-1946 bridge study (M. Russo) authored sections regarding the Object Lesson Roads in the Texas Historical Commission report.

[13] Jensen, E12.

of the most widespread types, particularly in areas far from railroads and in wooded regions of the state.[14]

While the technology to build more complex reinforced concrete, rolled steel beam, and **built-up** steel girder bridges existed throughout the U.S. in the early twentieth century, many county governments in Texas lacked the money to hire professional engineers to design them or contractors to build them. The counties with larger populations had the funding to have their own professional engineers or pay professional consulting engineers to work on their projects, and some the state's most notable bridges from this period are in these urban counties. For example, in 1915, Bexar County built a **closed spandrel arch** bridge on Somerset Road over the Leon Creek (NBI No: 150150B32065001) south of the city of San Antonio. This four-span arch bridge was located outside the city but included decorative features such as an urn-type **balustrade**.[15] Likewise, Travis County likely hired a professional engineer to design the 1915 masonry arch bridge (NBI No. 142270210001002) over Cat Creek on a county road (present-day Ranch-to-Market [RM] 2222), which was outside the city of Austin at the time of its construction. (The road was noted as a scenic county road in newspaper articles at the time, and this bridge provided access across the mouth of Cat Creek at Bull Creek.[16])

In the mid-1910s, the traveling public and Good Roads advocacy groups demanded better quality, all-weather roadways as vehicle ownership increased. Between 1913 and 1916, the number of registered motor vehicles jumped from 32,000 to nearly 139,000. During that time period, 138 Texas counties approved over $6.5 million in road and bridge bonds, with the most populous counties having the largest bonds.[17] However, during this period, development of the highway system focused heavily on individual county needs, rather than building a unified road network throughout the state. While advocacy groups associated with the Good Roads Movement supported the concept of intrastate and interstate roads, road and bridge construction lacked consistency in quality, and there was little funding to build roads and bridges needed to handle the increased vehicular traffic demands. For detailed information about pre-1917 road and bridge history, including details about the Good Roads Movement, please see the MPDF pages E5 through E27.

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[14] Jensen, E12.

[15] Historic Bridges.org, "Somerset Road Bridge," https://historicbridges.org/bridges/browser/?bridgebrowser=texas/somersetroadbridge/#photosvideos, accessed August 29, 2023.

[16] "Petition for a New Bridge Across Creek," *Austin American-Statesman* (July 29, 1915) 8. "Ed Allen Prepares for Beautiful Auto Drive to Bull Creek," *The Austin American* (June 3, 1917) p.23.

[17] Laurence I. Hewes and James W. Glover, Highway Bonds: A Compilation of Data and an Analysis of Economic Features Affecting Construction and Maintenance of Highways Financed by Bond Issues, and the Theory of Highway Bond Calculations, Bulletin of the U.S. Department of Agriculture no. 136 (Washington, D.C.: Government Printing Office, 1915), 47. Frank M. Stewart, Highway Administration in Texas: A Study of Administrative Methods and Financial Policies, Bureau of Research in the Social Sciences Study No. 8, The University of Texas Bulletin No. 3423 (Austin, Texas: The University of Texas, 1934), 16-19.

A Significant New Transportation Policy: The Early Federal Aid Program, 1917–1921

With the growing need for better roadway facilities in both Texas and the U.S., the U.S. Congress passed the Federal Aid Road Act of 1916, which allocated $75 million in funding to states over five years. Congress specifically designated the funding to build the rural road system, and cities with more than 2,500 people were not eligible for the funding.[18] Local connectivity was not the intent of this law, rather, the overall intent (and result) was the movement of commodity goods, such as cattle, cash crops, and oil, from rural locations to markets to help grow the American economy. To accomplish this goal, the 1916 Act (and future Federal Aid Road Acts) fostered inter-regional transportation that considered the entire state's economic and population growth.

Bruce Seely notes in *Building the American Highway System: Engineers as Policy Makers,* one of the Act's main purposes was to stop counties from building roads under "loose or non-existent" state authority.[19] The cornerstone of the Act required that each state create a highway department to ensure proper administration of the funding and oversight of the federally funded projects. As a result, the 35th Texas Legislature passed House Bill 2 to create the Texas Highway Commission and the THD in 1917. The Office of Public Roads (later renamed BPR) helped four states to set up and organize new state highway departments, which included Texas and its new THD.[20] As outlined in the THD's *First Biennial Report*, the agency's primary mission was building a uniform system of highways throughout the state. This mission was in direct response to the inconsistent quality of roads and bridges and the lack of connectivity across regions. Yet, as noted in the MPDF, the Texas Legislature created a weak highway department with little power and kept the control of the highway system in counties' hands.[21] The THD's main functions only included reviewing and approving plans to ensure that counties built high-quality facilities, administering Federal and State Aid to counties, and collecting automobile registration fees. The State legislature also provided State funds (albeit very limited) to the University of Texas at Austin (UT) and Texas Agricultural and Mechanical (Texas A&M) University to complete research and materials testing for the THD.[22]

To staff the THD, the majority of the hired engineers were former railroad and city engineers, like George Wickline (a former railroad and city bridge engineer), M.C. Wilborn, and Julian Montgomery (both former City of Austin engineers). Just three months after the creation of the THD, the U.S. entered World War I, and the financial demands of the war effort and supplies for defense operations took priority nationwide. Additionally, a large percentage of the workforce fought in the war or otherwise supported war efforts. After the war ended in November 1918, approximately one-fifth of all

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[18] Richard Weingroff, *Creation of a Landmark: The Federal Aid Road Act of 1916*, https://highways.dot.gov/sites/fhwa.dot.gov/files/landmark.pdf (accessed July 15, 2023) 67.

[19] Bruce Seely, *Building the American Highway System: Engineers as Policy Makers* (Philadelphia, PA: Temple University Press, 1987) 48.

[20] Seely, Building the American Highway System, 49.

[21] Jensen, 28.

[22] State Highway Department of Texas, Seventh Biennial Report for September 1, 1928 to August 31, 1930 (n.p., 1931) 15.

professional American engineers and roadbuilders were sent to Europe to help rebuild roads, especially in heavily damaged France.[23] This effort left a void in the number of qualified engineers to design and build Federal Aid Program roads within the U.S., resulting in many counties either not finding qualified engineers or hiring engineers with limited or no experience in highway construction.[24]

With highway funding made available through the Federal Aid Program, counties scrambled to find engineers who could design the Federal Aid Program roads to meet the THD's and BPR's requirements. Many counties used their bond money to hire their own engineers, while less populated counties hired consulting engineers. A THD's *Texas Highway Bulletin* from 1922 noted that in the THD's first years, they had been "breaking in railroad engineers, city engineers, and surveyors to become highway engineers, and…changing railroad contractors, ditch diggers, and paving contractors into road builders," many of which had never designed or built roads before the Federal Aid Program.[25] The Texas Legislature codified that the THD determined who qualified as competent engineers, with the main requirement being that engineers designing Federal or State Aid projects must be graduates of a "first class school of civil engineering."[26] After reviewing engineers' qualifications, the State Highway Engineer provided a certificate to each engineer approved to work on THD-reviewed projects. The THD also only hired graduates of engineering colleges, with most of the agency's early engineers being educated at UT and Texas A&M University. To help county governments find qualified engineers, the THD published a list of approved engineers who the THD "deemed competent," including some engineers located in other regions of the United States.[27]

With counties leading highway construction efforts and being responsible for most of the matching funds for Federal Aid projects, counties used their share of the collected vehicle registration fees to help pay for road and bridge construction. However, the collected fees were not sufficient to supply counties with the matching funds required for participation in the Federal Aid program, especially in rural counties where there were fewer registered vehicles. As a result, county-issued bonds continued to serve as the main source of county highway funds, particularly in rural counties where vehicle registration fees were minimal compared to bond funds. For example, in Smith County, where the county improved State Highway (SH) 31 under Federal Aid Project 147, the county received only $10,400 in registration fees from July 1917 to December 1918, but the county raised $150,000 in road and bridge bonds during the same period.[28] Structures built as part of this Federal Aid and bond-funded project included the bridge-class concrete box culvert on County Road (CR) 1134 at Lewellen Creek (NBI No. 102120AA1134101).

In an attempt to create an inter-regional, statewide system, the THD designated 22 tentative numbered state highways in 1917, which largely followed the inter-regional named highways such as

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[23] Federal Highway Administration, *America's Highways 1776–1976: A History of the Federal-Aid Program* (Washington, D.C.: U.S. Government Printing Office, 1977) 103.
[24] "The Work of the State Highway Department," *Texas Highway Bulletin*, vol. 2, no. 8 (August 1922), 4.
[25] "The Work of the State Highway Department," *Texas Highway Bulletin*, vol. 2, no. 8 (August 1922), 4.
[26] State Highway Department of Texas, *First Biennial Report for July 1917 to December 1918* (Austin, TX: Von Boeckmann-Jones Co., Printers, 1919) 15.
[27] State Highway Department of Texas, *First Biennial Report*, 50-51.
[28] State Highway Department of Texas, *First Biennial Report*, 28 and 32.

the Bankhead Highway (SH 1), the Meridian Highway (SH 2), and OST (SH 3). Two years later, THD's number of state highways increased to 38 in 1919.[29] To increase uniformity in the design of these roads and their bridges, the BPR and THD tried to standardize the design and construction phases as much as possible. The railroad industry's use of standard plans illustrated that standardized bridge design was the most efficient and cost-effective way to build infrastructure. Bridge standardization was especially important because most engineers were unfamiliar with bridge design. Research completed at universities' research stations provided the basis for many of the design standards, with the best funded and most prolific research occurring at the University of Illinois and University of Iowa Experiment Stations. These universities published bulletins that summarized their tests, and both universities created reinforced concrete culvert and concrete girder designs. (The University of Illinois issuing the most bulletins as they had three times the budget as the University of Iowa.[30])

Based on research conducted through the 1910s, the BPR and THD issued standard bridge plans and specifications for construction contracts. The BPR issued the earliest standard bridge plans found in TxDOT Bridge Division records, with standard details dated August 1917 for 11- to 40-foot-long steel I-beam bridges and concrete box culverts with 16-foot-wide roadways and accommodating 15-ton truck design. The THD issued its first sets of standard bridge plans in 1918, after the agency hired George Duren (the first State Highway Engineer), beginning with standard plans for concrete slab spans. In February 1918, the agency issued bridge standard plans for 8- to 20-foot-long reinforced concrete slab spans with clear widths of 16, 20, and 24 feet (labeled the "CB" plan), with engineer Julian Montgomery signing as the designer. Just a few months later, George Wickline designed standard plans for reinforced concrete tee beam spans — the "G1" and "G2" standards. These and later concrete tee beam span standards note that the THD adapted them from federal standards. The G1 standard plans were for 16- to 24-foot-long tee beam spans, and the G2 standard plans were for 28- to 40-foot-long spans.[31] While BPR issued standards for steel I-beam spans, they were rarely used in the late 1910s, as rolled steel beams were difficult to acquire during and immediately following the war. During the early Federal Aid period from 1917 to 1921, only about a dozen steel I-beam bridges are extant and in the Study Population, many of which do not appear to have been constructed using THD bridge standards (from a review of photographs). Instead, George Wickline noted in a 1922 *Texas Highway Bulletin* article that most state highway short span bridges were reinforced concrete structures that followed the THD's standard plans.[32] A review of the extant Study Population bridges built between 1917 and 1921 revealed that counties most often built flat slab bridges, followed by concrete tee beam bridges and bridge-class culverts.

The THD also issued standard plans for railings and substructures, which taken together with the superstructure standard plans, allowed roadway designers to create a full bridge design for crossings using the THD's bridge standards. Special-designed bridges of non-standard bridge types were rare on

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[29] Jensen, 29.

[30] Seely, Building the American Highway System, 350.

[31] Standard plans referenced herein are available at TxDOT's PlansOnline (non-public) website.

[32] George G. Wickline, "Bridge Problems in Texas," *Texas Highway Bulletin,* vol. 2, no. 9 (September 1922), 9.

early Federal Aid projects, and counties only built new bridges for longer spans when absolutely necessary. In many cases, if a bridge existed at a crossing, the county would leave the bridge in place to avoid the expense of constructing a new non-standard bridge. Use of Federal Aid funding required non-standard bridges to be designed by an experienced bridge engineer, and the approval process for non-standard bridges was much longer and arduous. Newspaper articles from the time period noted that the BPR heavily scrutinized non-standard bridges' design and construction, with repeated reviews of plans and many visits made to project sites during construction. When possible, the THD's small group of engineers created special designed structures, like the unusual NRHP-listed Farm-to-Market (FM) 1579 cantilevered concrete girder bridge at the East Navidad River in Fayette County (NBI No. 130760149801002) designed by Armour Townsend Granger in 1921. The recent graduate of UT's master's degree program completed the design under Wickline's supervision.[33]

To ensure quality during construction, THD also issued their *Specifications and Contract* document in 1918, which provided the basis for counties to create their contracts, with terms, conditions, and instructions for all phases of road and bridge construction. The document specifies that counties should use standard plans for "usual conditions," and that any change to the designs must be approved by the State Highway Engineer.[34] THD's issuance of bridge standards and construction specifications not only allowed for uniformity on construction, but it also helped to prevent a significant backlog and bottleneck of review at the THD.[35]

While counties drafted, submitted, and received approval for their projects, the highway and bridge construction under the new Federal Aid program experienced a sluggish start. As noted above, the timing of World War I caused significant delays due to lack of engineers and construction workers, as well as supply chain issues and local governments' access to construction materials. One exception was the construction of the Main Street/CR 416 Bridge over Foster Creek on the outskirts of Schulenberg in Fayette County (NBI No. 130760AA0300001). It was part of one of the earliest constructed Federal Aid funded projects in the state, which included the paving and straightening of an 8-mile-long segment of SH 3, which was also the alignment of the OST.[36] The County built this reinforced concrete girder bridge as part of Federal Aid Project 37 with funds allocated in fiscal year 1917. The County apparently completed the bridge in 1918 since the roadway engineer used George Wickline's "G2" standard plan for this bridge. The THD's *First Biennial Report* shows dozens of projects in various phases of approval, with only five federally funded projects fully constructed and inspected by the end of 1918.[37]

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[33] Gregory Smith, *East Navidad River Bridge National Register Nomination* (2014), https://atlas.thc.texas.gov/NR/pdfs/14000497/14000497.pdf, accessed July 17, 2023.

[34] State Highway Department of Texas, *Specifications and Contract* (1918), https://ftp.dot.state.tx.us/pub/txdot-info/des/specs/historic-bridge/1918.pdf, accessed May 12, 2023.

[35] "Pennybacker Gets Engineer Award," *The Austin American* (February 19, 1954) C12.

[36] State Highway Department of Texas, *First Biennial Report*, 44.

[37] State Highway Department of Texas, *First Biennial Report,* 47.

Another reason for limited road construction was the newly implemented BPR review process. Not only was there a limited number of available federal engineers in the U.S., but the reviewing federal engineers heavily scrutinized applications and plans, requiring several rounds of revisions for most applications.[38] These stringent examinations began to severely deteriorate the relationship between the BPR and the states, and it led to frustrations among county officials and the public, with the BPR being blamed for holding up the implementation of the Federal Aid program.

By the end of 1918, Iowa Highway Department's Thomas MacDonald took over as Chief at the BPR. MacDonald's leadership of the BPR greatly improved the agency's efficiency in approving federally funded projects, providing guidance to states, and shifting the federal government's role to an advisory role in road and bridge building. As a former state highway engineer, MacDonald understood the frustrations felt at the state and local levels. One of his first duties as head of BPR was to significantly accelerate BPR's review process, and 90 percent of BPR reviews took less than one week to complete by 1920.[39] These accelerated reviews were possible especially after he opened regional BRA branches, including a BPR district office located within the THD Fort Worth District Office.[40] Within the BPR Fort Worth District office, Captain J.D. Fauntleroy led a team of engineers assigned to review plans and construction projects for particular areas of the state, allowing for the BPR engineers to become familiar with local conditions, personnel, and contractors.

MacDonald also recognized that building an inter-regional and interstate highway system would be exceedingly slow if the federal government dictated requirements and standards to the states. To mitigate this, he forged a close relationship between BPR and the American Association of State Highway Officials (AASHO), a professional organization of senior-level state highway officials formed in 1914. AASHO played a vital role in the early cooperation between the road booster groups, state highway agencies, and the federal government.[41] AASHO's leadership included many of MacDonald's former state highway department counterparts. Close BPR and AASHO collaboration allowed the BPR to create standardized requirements for highways and bridges, ask for AASHO input, and then have AASHO serve as the mouthpiece for and disseminator of national standardization.[42] When the U.S. Congress began considering additional funding through a new Federal Aid Road Act, MacDonald was instrumental in pushing lawmakers to require states to have more control over the highway development process, shifting the control away from county governments, and keeping the BPR as an advisory agency with limited power over state highway departments.

Around the time that American engineers' involvement in wartime recovery in Europe ended in late 1919 and early 1920, the material supply chains also began to flow more efficiently. MacDonald specifically lobbied the Interstate Commerce Commission and railroad companies to give priority to

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[38] Seely, Building the American Highway System, 49.
[39] Seely, Building the American Highway System, 55.
[40] State Highway Department of Texas, *Second Biennial Report for December 1, 1918 to December 1, 1920* (Austin, TX: Von Boeckmann-Jones Co., Printers, 1919) 85.
[41] Jensen, E32.
[42] Seely, Building the American Highway System, 60.

the movement of steel and Portland cement to facilitate road and bridge construction. A significant uptick in the construction of Texas roads and bridges coincides with these events. By December 1920, there were a total of 115 projects completed with state and federal funds, totaling just under 1,000 miles of roadway, and another 174 projects under construction.[43]

Despite the increase in construction projects under the Federal Aid program, the THD had a problem retaining its engineers during their early years. In June 1921, M.C. Welborn, lead division engineer, resigned from the THD just four years after holding the position. As a former city of Austin engineer, he left the THD to take a position as a city engineer in Paris, Texas. Welborn told *The Waco Times-Herald* that he was leaving for more pay, as the THD, by law, did not allow for competitive pay for engineers. Additionally, he had an intense workload at the THD, overseeing projects in 21 counties. The newspaper article about Welborn's departure from the THD stated that at least 10 engineers left the agency for similar reasons.[44] Despite the turnover, George Wickline provided consistency in the THD's bridge section. Beginning with the THD in 1918, Wickline led bridge design for his entire career at the THD, which ended with his untimely death in 1943 (for detailed information about Wickline, see MPDF page E119).

By the 1920s, Wickline became the main proponent for widespread changes in county-completed bridge construction. One of the main problems that Wickline's Bridge Section cited in the THD's *Second Biennial Report* was the inconsistencies in regional road transportation, particularly for through truck traffic, as Federal Aid Projects stopped at county lines. This discontinuity significantly impacted transportation and economic growth, as trucks could not drive on a multi-county, inter-regional road (such as SH 3) without running the risk of not being able to cross deficient bridges in certain counties. This inconsistency occurred because some counties used Federal Aid funding to build or upgrade a state highway, while adjacent counties improved the same state highway using county funds or did not improve that same stretch of state highway at all. Where counties used Federal Aid funding, the THD's and BPR's review of plans and finished construction ensured that the state highways built had all-weather pavements, appropriate crowns for drainage, and the capacity to carry 15-ton trucks. However, the THD had no oversight in the quality of the roads and bridges on the state highway where counties used only county funds. Even after the Federal Aid Road Act of 1916, counties continued the practice of buying bridges from manufacturers solely on the basis of span length, rather than load capacity, on a cost competitive bid basis. Wickline articulated the THD Bridge Section's frustrations over the construction of county-built bridges without THD oversight in a 1922 *Texas Highway Bulletin* article called "Bridge Problems in Texas." He noted that county "structures were 'skimped' in every way in order to meet competition," with bridge companies over-estimating and incorrectly assessing the load capacity of the bridges.[45] Additionally, the bridges were typically erected on poor foundations with footings that were not dug at sufficient depths, resulting in collapse during flood events. Wickline also noted that many counties resisted replacing the longer bridges on the

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[43] State Highway Department of Texas, *Second Biennial Report*, 28.

[44] "Division Engineer Welborn Resigns Effective June 22," *The Waco Times-Herald* (June 11, 1921) 3.

[45] Wickline, "Bridge Problems in Texas," 9-10.

newly designated state highways, many of which were built in the late nineteenth century, primarily due to the cost of replacing these large structures to meet THD standards. As a result, counties often stopped Federal Aid projects at major crossings to avoid paying for the design and construction of a non-standard bridge.[46]

To remedy the issue of inconsistent county-built bridges' loading and quality of construction, the THD asserted that the Texas Legislature should give the THD the power to regulate the type and load capacity of bridges built on any designated state highways, regardless of funding.[47] The THD's desire for control over their state road systems was common among state highway departments, and the next Federal Aid Road Act focused on providing states more control over state highway development. For more information about the Federal Aid Road Act of 1916 and the THD's creation, please see the MPDF, pages E26 through E31 and E118 through E123.

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[46] Wickline, "Bridge Problems in Texas," 10.

[47] State Highway Department of Texas, *Second Biennial Report*, 47-48.

Development of the THD-Controlled State Highway System, 1922-1932

With the passage of the Federal Aid Road Act of 1921 in November 1921, the U.S. Congress laid the foundation for a new era of roadway construction, which is often referenced as the "Golden Age" of highway and bridge construction. The 1921 Act specifically outlined that seven percent of state highways were eligible for Federal Aid funding, which included approximately 11,500 miles of roadway in Texas. To pay for this work, the Act allocated another $75 million to states, and to combat the increasing inflation of the post-World War I years, the allowable amount increased from $10,000 per mile to $20,000 per mile.[48] The period between 1922 and 1932 represents the build-up of statewide organizational, financial, and technical capacities to support a highway improvement campaign of unprecedented scale and scope. The hallmark of this building period was the widespread standardization in bridge design, with approximately 97 percent of the Study Population bridges built outside cities being common bridge types.

Recognizing the inherent problems with the county-led construction efforts under the Federal Aid Road Act of 1916, the 1921 Act required that states take full responsibility for all state highways and provide the match funds for the Federal Aid projects by 1925. This essentially took the state highway systems out of county control and into the hands of the state highway departments. Yet, until states could take over financial, design, construction, and maintenance responsibility of the state highway system, counties still drove the Federal Aid projects and provided the matching funds. As a result, many of the problems that plagued road and bridge construction continued in the early 1920s.

With such a dramatic shift in power over highway development, some local governments raised strong opposition. A 1924 *Texas Highways Bulletin* article by Lieutenant Governor T.W. Davidson noted that seven Texas counties refused to cooperate with the THD, including one county that had more than 160 miles of state highways within its boundaries.[49] Critics of the Federal Aid programs said that the financial responsibility of the state highway system shifted out of the hands of the people into the hands of big government.[50] Additionally, some counties felt they could manage the projects more efficiently than the THD since the County Commissioners had close relationships and long-standing connections to the contractors in their communities. However, Texas Governor Pat Morris Neff characterized the intent of the Act as taking "the building of designated highways out of local politics, and…placing the construction and maintenance of this system of highways under the supervision of trained men."[51]

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[48] Federal Highway Administration, 113.

[49] T.W. Davidson, "Highway Program Depends Upon Success of State Maintenance System – Cooperation Essential," *Texas Highways Bulletin*, vol. 4, [no. unreadable] ([month unreadable] 1924) 19.

[50] H.M. Hubbard, "Texas in Great Danger of Losing Federal Aid," *Texas Highway Bulletin*, vol. 2, no. 9 (September 1922) 1.

[51] "Governor Neff Speaks Before Texas Highway Association," *Texas Highway Bulletin*, vol. 2, no. 4 (April 1922) 2.

To adhere to the 1921 Act's requirements, the THD needed more staff, more funding, and more power over the design and construction of the state highway system. The first big change at the THD came just three months after the passage of the 1921 Act, when the Texas Highway Commission hired J.D. Fauntleroy, the lead BPR Fort Worth District engineer, as the Texas State Highway Engineer. Fauntleroy's appointment highlighted the state's alignment with BPR policies and philosophies, particularly in the emphasis on uniformity and standardization. Soon after his appointment, Fauntleroy began a public relations campaign to tout the new Federal Aid Road Act and help squelch the concerns arising from County Commissioners and their constituents. In newspaper articles published throughout the state, he emphasized the financial and administrative relief on county governments and the importance of creating a uniformed highway system that would benefit the economy throughout the state.[52]

Next, to adhere to the 1921 Federal Aid Road Act's requirements, the Texas Legislature had to give the THD authority over the highway system. As a result, the 38th Texas Legislature in January 1923 gave the THD control over the state highway system design, construction, and maintenance. After two years of fierce political debates and resistance from many counties, which ultimately ended with a Texas Supreme Court decision (Robbins vs. Limestone County), the 39th Texas Legislature solidified the THD's control over the highway system in 1925. With complete control of the state highway system, the THD could now decide which roads to upgrade and which bridges to replace, determine the appropriate bridge designs, and replace longer, non-standard bridges when needed.

The 1921 Federal Aid Road Act also required that the Texas Legislature provide additional funding so that the state could provide the matching funds needed for Federal Aid projects. There was little debate that Texas should access as much of the Federal Aid money as possible, particularly with increased truck traffic and the intensified importance of vehicular transportation to agricultural fields and oil production sites. Based on its number of designated state highway miles, Texas had the potential to receive the most federal aid funding of any U.S. state.[53] As a result, the Texas Legislature increased vehicle registration fees and the THD's allocation of those fees. Additionally, like more than a dozen other U.S. states at the time, the legislature levied a $0.01 per gallon gas tax to help pay for the THD's expanded responsibilities and supply its matching funds.[54] Unlike other states, Texas legislators were adamant that Texas would be a "pay-as-you-go state" and not issue state bonds to pay for the state highway system.[55] However, the funds provided in the Legislature's 1920s acts were not sufficient to cover all the state's matching needs, so the state relied on county assistance to build its roads and bridges throughout the 1920s.

As Texas made adjustments in the administration and funding required for the Federal Aid projects under the 1921 Act, a national movement emerged to create an interstate highway system using

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[52] "Laws of State Must Change to Benefit by U.S. Road Fund," *Fort Worth Star-Telegram* (February 12, 1922) 16.

[53] Hubbard, 1.

[54] Jensen, E32.

[55] Gibb Gilcrest, *Texas Highway Department 1927-1937* (n.p., 1937, Texas Department of Transportation Photo Archives, Austin, Texas) Conclusion.

Federal Aid funds. Although not specifically dictated in the 1921 Act, newspapers and state highway officials, like H.M. Hubbard, the Chairman of the Texas Highway Commission, immediately surmised that the Act's ultimate purpose was to promote a system of national highways that state and federal governments would build and fund. By 1925, the BPR required a standardized numbering system and safety signage on state highways.

With all the rapidly occurring changes in highway and bridge construction, the THD grew significantly, and the agency reorganized in 1925. One of the main focuses of the reorganized agency was maintenance, which counties universally neglected. In 1925, the number of THD districts increased from 16 to 18 offices, with each division under the direction of a Division Engineer and two Maintenance Superintendents. The Division Engineer supervised maintenance and construction activities on designed state highways within their respective districts.[56] The design of bridges remained centralized with the bridge design section.

By 1928, the THD created the Bridge Division as its own group separate from the Engineering Division. The new division appeared to consist of three main teams. The first team included 12 staff, including Wickline (the State Bridge Engineer), six additional bridge engineers, and five draftsmen. This group completed non-standard designs and rehabilitation plans for the THD. The second team consisted of three "Class A Draftsmen and Checkers," who worked with the roadway engineers to select the appropriate standard plans for crossings, compile the full set of bridge standard plans for each crossing, and obtain bridge engineer approval for the selected plan sets. The third team included 15 "Resident Engineers" who oversaw the THD's bridge construction projects.[57]

During this time, the Bridge Division worked closely with the Testing and Materials Division to conduct physical tests on materials for use in bridge construction. Much of the bridge-related testing during the 1920s and 1930s focused on concrete testing, and specifically the analysis of local materials near job sites. The testing engineers would receive a sample of local aggregate, and they tested the material by varying the aggregate proportions with cement to obtain the required strength in the concrete, even if the aggregate was of an inferior quality than other aggregate that could be obtained from other locations. The ability to use local aggregates, even with the testing, helped reduce construction costs. Yet, the materials testing need was significant due to the many reinforced concrete bridges erected during this time period, coupled with the materials testing needed for gravels and asphalt. The Texas Legislature placed both UT and Texas A&M University at the THD's disposal for research and materials testing beginning in 1917; however, the THD used the UT laboratory more due to its proximity to the THD headquarters in Austin. While the Texas A&M laboratory completed some tests, the THD's rare use of Texas A&M's facilities is reflected in their modest allocation of $3,000 or less

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[56] State Highway Department of Texas, *Fifth Biennial Report for September 1, 1924 to September 1, 1926* (Austin, TX: A.C. Baldwin & Sons State Printers, 1927) 7. Note, the use of the terms of division and district engineers are described in the biennial report exactly as they are noted herein. These terms are different from those used in TxDOT today, and the biennial report's usage may be in error or the organizational nomenclature was different at the time of the biennial report's publication.

[57] State Highway Department of Texas, *Sixth Biennial Report for September 1, 1926 to August 31, 1928* (San Antonio, TX: Eagle Publishing Company, 1929) 47-48.

from the Legislature through the 1920s.[58] In 1924, lead UT testing engineer, H.R. Thomas, spearheaded the small group of just five total laboratory employees who handled most of the materials testing in the state. UT could handle the number of tests in the THD's early years, with only 300 tests in 1919, but the number of tests increased ten-fold by 1924.[59] That year, the THD decided to turn to the private sector to handle the agency's increased testing needs, with UT and Texas A&M checking the test results.[60]

During the 1922–1932 period, as the THD focused heavily on Federal Aid program projects, engineers consistently used bridge standards for the construction of upgraded and new roads. County-led design and construction efforts continued from 1922 to 1924, and counties built a modest number of roads and bridges, with approximately 150 extant bridges in the Study Population dating to this three-year period. Yet, after the THD took over all design and construction on state highways in 1925, Federal Aid projects began in earnest around the state, reaching a pinnacle between 1928 and 1930. In 1925 and 1926, The THD completed a notable project in the upgrade of SH 2/US 281 in Jim Wells County, where the THD constructed 18 standard reinforced **concrete box culverts** and **concrete tee beam bridges**, likely to service the many oil fields surrounding the town of Alice. During the construction boom of 1928 to 1930, the THD built several state highways, including SH 12 (now US 59) near the Texas coast from Wharton to Beeville, SH 3 (now US 90) in the remote areas west of Uvalde, and SH 19 in northeastern Texas from Palestine to northern Henderson County. In each of these projects, engineers chose similar bridge types for the entire road, perhaps to provide economies of scale during construction. Since very short spans could be used, engineers selected standard bridge-class concrete box culverts for most of the crossings on SH 12 and SH 3. On SH 19, the engineers opted for concrete tee beam spans, such as the SH 19 bridge at Otter Creek (NBI No. 100010010806021), which had a maximum span length of 26 feet, 8 inches.

With the THD using standard bridge plans routinely for nearly every crossing they built during the 1922–1932 period, understanding why the THD selected bridge types on these and other roads provides perspective for which bridge types remain in the Study Population today. Research showed that THD engineers had certain parameters for selecting different bridge types during this period. Each of the THD's 1920s and early 1930s biennial reports repeatedly note that THD's short-span bridges are constructed with reinforced concrete. When the THD could use shorter 10- to 20-foot spans, engineers selected concrete box bridge-class culverts, particularly at ephemeral streams and for cattle passes. The THD considered these bridge-class culverts to be the most economical bridge type, largely because their bottom slab eliminated the need to construct **abutments**, **piers**, or pilings. The sturdy box shape could withstand foundation undermining, and the box culverts were preferred when soil conditions indicated that foundation degradation was likely.[61] If the THD required a longer clear-span,

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[58] Bruce Seely, "Research, Engineering, and Science in American Engineering Colleges, 1900–1960," *Technology and Culture* (April 1993) 351.

[59] State Highway Department, *Fourth Biennial Report for December 1, 1922 to September 1, 1924* (Austin, Texas: Von Boeckmann-Jones Co, 1925), 34-36.

[60] State Highway Department, *Seventh Biennial Report,* 67-68.

[61] State Highway Department, *Fourth Biennial Report*, 42.

the engineers typically selected reinforced concrete flat slabs; however, during this period these bridges typically only had a 20-foot-long clear span. Analysis of the Study Population showed that all simple slab bridges built between 1922 and 1932 measured 25 feet or less. When the THD required longer spans, they typically selected reinforced concrete tee beam bridges, which had standard span lengths that could reach 40 feet. The THD used concrete tee beam bridges the most frequently of all the bridge types in the Study Population during this period. A review of the biennial reports from this time indicates that the THD reserved steel bridges, including **I-beams**, **plate girders**, and trusses, for their longest spans.

With over 1.3 million cars on Texas roads by 1930 and road projects proceeding at a fast pace, application of standard bridge designs was essential. During the 1922–1932 time period, the THD revised existing standard bridge designs and issued new standard designs for the four most common bridge types — reinforced **concrete slabs**, reinforced **concrete tee beams**, reinforced **concrete box culverts**, and **steel I-beams** (also known as common bridge types or standard bridge types in this study) — with a primary focus on increasing bridge widths and developing standard designs for spans with skews. While the agency's standard bridge roadway widths included 16-foot widths before the 1921 Federal Aid Road Act, the 1921 Act required that bridge widths for new structures measure at least 18 feet wide, and by 1928, the THD opted to use a standard bridge roadway width in areas without "heavy traffic" of at least 20 feet wide. In areas with high traffic volumes, THD implemented a standard bridge roadway width of 24 feet and, in some areas, such as between Dallas and Fort Worth, the THD built bridges with 40-foot roadway widths.[62]

The Bridge Division also focused on identifying and replacing or rehabilitating bridges that counties built before the THD's creation and that remained on the state highway system. As previously noted, many counties resisted replacing the larger, non-standard bridges due to the expense of hiring a bridge engineer. The THD's *Fifth Biennial Report* published in January 1926 states that "the rapid increase in use of motor driven equipment such as trucks and tractors and the development of oil fields in various section of the state brings forcibly to the attention of the State and County officials…that the old bridges will have to be strengthened temporarily and rebuilt."[63] Many bridges collapsed during this time, and the THD received multiple reports of bridge collapses every month. The situation became so dire that the Bridge Division conducted a systematic bridge survey of all existing county-built bridges on state highways with a minimum of 20-foot-long spans. The THD completed the survey in 1928 and found that approximately 1,000 bridges over 50 feet in length needed immediate strengthening and should be replaced within six years.[64] Due to the sheer number of deficient bridges, many of the Bridge Division's engineers focused on strengthening these existing bridges with various methods, such as reinforcing the floor systems by adding **stringers**, and/or placing supplementary

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[62] State Highway Department, *Sixth Biennial*, 49.

[63] State Highway Department, *Fifth Biennial Report*, 49.

[64] State Highway Department, *Sixth Biennial Report,* 45.

bents under the **superstructures**. These measures allowed the THD to momentarily postpone the inevitable need to embark on a major bridge construction campaign.

During the 1922–1932 period, THD's small staff of Bridge Division engineers began designing more non-standard bridge types than they had in the THD's first years. During this time period, most of the non-standard bridges that the THD designed and built were steel truss spans, as evidenced by the special projects' lists included in the THD's biennial reports. Because the THD focused on building the state highway system as efficiently and cost effectively as possible, the THD built relatively few numbers of the uncommon non-truss bridge types, particularly those that are considered aesthetically pleasing like the **variable-depth concrete slabs**, **variable depth concrete tee beams**, and **open** and **closed spandrel arches**. In fact, today, the majority of the uncommon bridge types are found in cities, where bridge design aesthetics were heavily considered due to the visibility of the structures. The **Urban Planning and City Beautiful** theme below provides information about bridge construction in cities.[65] For more detailed information about the history of the Federal Aid Program in Texas and the development of the THD-controlled state highway system during the 1922 to 1932 period, please see the MPDF pages E31 through E36 and E127 through E129.

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[65] In the Study Population, there are no apparent THD-constructed non-standard bridges. It is likely that during the course of the project, individualized research of the less common bridge types that currently categorized as city bridges may reveal that THD actually constructed them. At that time, this section of the report will be updated.

Make Work for the New Deal and Improving the Texas State Highway System, 1933-1941

After the late 1929 collapse of the stock market and banking sector, the Great Depression's effects, including high rates of unemployment, began to radiate across Texas in 1930. The federal and state government sought ways to combat the Great Depression's effects and to put people back to work. This included the establishment of various federal funding programs known as the First and Second New Deal. As the federal government was ready to inject money into infrastructure construction to help ease the effects of the Great Depression, the federal programs were set up to use existing appropriation mechanisms and policies to the greatest extent possible.

In 1930 and 1932, the U.S. Congress passed a series of emergency appropriation bills that allocated additional federal aid for state road programs.[66] This influx of aid allowed the THD to continue road and bridge projects that would have otherwise been stalled due to a lack of matching state funds. In 1932, President Hoover signed the Emergency Relief and Construction Act, which lent millions of dollars to states for bank and business loans.[67] The bill also provided $5.5 million to Texas for public works that included road and bridge construction.[68] One year later, the Federal Emergency Relief Act established the Federal Emergency Relief Administration (FERA), and it provided funds for labor on drought and flood relief road projects in Texas.[69]

By 1933, the National Industrial Recovery Act (NIRA) created a series of federal agencies to aid in regulation and stimulation of the national economy. In Texas, NIRA replaced the earlier Federal Aid programs with an expanded National Recovery Highway Program that spent almost $33 million on the state highway system without requiring matching funds for construction.[70] NIRA also established the Public Works Administration (PWA), which assisted in the development and construction of public works, including several large-scale bridge projects in Texas.[71]

The federal relief programs up to the mid-1930s were commonly referenced as the first New Deal. The Roosevelt Administration established the second New Deal programs after the U.S. Supreme Court ruled that the earlier programs were unconstitutional. With the second New Deal came "the most comprehensive program of the Depression Era to provide unemployment relief through public work projects: the Works Progress Administration (WPA)."[72] (For a more detailed discussion of the first and second New Deal funding programs, please see the MPDF pages E36 through E51.)

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[66] Jensen, E37.

[67] Jensen, E39.

[68] Jensen, E39.

[69] State Highway Department of Texas, Ninth Biennial Report for September 1, 1932 to August 31, 1934 (n.p., 1934), 5. State Highway Department of Texas, Tenth Biennial Report for September 1, 1934 to August 31, 1936 (n.p., 1936), 9, 44-45.

[70] Jensen, E42.

[71] For a detailed description of the bridge projects referenced in the MPDF, please see pages E42 through E43. Note that none of the bridges cited in the MPDF are within the Study Population.

[72] Jensen, E45.

State highway departments were the perfect recipients of federal funding since they had established governmental systems and structures experienced in completing projects using large allocations of federal funding. They had teams of professional engineers with established working relationships and review protocols with the BPR on the federal side and county and city government officials at the local level. State highway departments also worked with an entire industry of highway and bridge contractors with experience constructing projects to the state and Federal Aid standards. As a result, the THD and other state highway departments were able to quickly take the funding to put unemployed people back to work, while building needed roadway infrastructure.

While the Federal Aid programs of the 1910s and 1920s focused on the creation of the Texas roadway system, the Depression-era's Federal Aid programs reflected a distinct departure from the earlier programs. During the Great Depression, the Federal Aid Programs focused heavily on improving the previously established state highway system, upgrading deficient county-built bridges still on the highway system, improving drainage on county roads, eliminating dangerous at-grade railroad crossings, and beautifying the overall roadway landscape. These efforts focused on solving "point problems" related to capacity, efficiency, and safety. With Depression-era funding, the federal government also prioritized linking the secondary road system to primary highways in all states.[73] States could focus on improving secondary roads and other feeders to the primary system that were previously under the sole purview and responsibility of the county governments, rather than just focusing on the first-order connectivity and standardization that marked the previous Federal Aid funding programs. In Texas, the improvements to secondary roads positively impacted the economy and lifeways of residents in rural areas.[74] Overall, the work raised the quality, durability, and lifespan of all types of roads and bridges throughout the state.

Another of the main differentiators of the New Deals' Federal Aid Programs (when compared to previous eras) was the use of hand-labor, with masonry construction becoming the physical representation of the "make-work" unemployment relief. With masonry construction, skilled and unskilled laborers could be employed, and the painstakingly detailed work required for masonry structures kept workers employed longer, while creating aesthetically pleasing bridges that fit the Rustic Style. Additionally, the federal make-work funding resulted in aesthetic detailing on bridges in some locations. The funding programs also mandated other provisions for hand labor such as hand-painting structural steel, erection of form work, and the use of boring holes in piles and forms.[75]

Early Federal Relief Projects

In the early years of the Great Depression, the THD, Texas counties, and other entities made efforts to put people to work as quickly as possible. The state's existing Drought Relief Work program enabled state administrators to focus employment efforts on the construction of bridges (and other road-related resources) in the areas of west and northwest Texas and the Panhandle, where the drought

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[73] Jensen, E48.

[74] Jensen, E48.

[75] Jensen, E42.

was already causing major impacts to the economy.[76] In other parts of the state, the THD, Texas counties, and other entities received special appropriations to address the effects of flooding and hurricane damage.

Citizens took an active role in the governments' efforts to identify and undertake relief projects. One example was a large meeting held in Amarillo in late 1933. A group of representatives from 30 Panhandle counties gathered on November 16, 1933, to discuss the region's highway improvement needs to be funded by the Drought Relief Work program. During the meeting, attendees appointed a delegation to travel to Austin for meetings with state legislators about the delayed highway improvement program funding and to develop ways to provide unemployment relief. Research has not yet revealed if the construction was the direct result of the citizens' efforts, but the THD built approximately a dozen Study Population bridges in the Panhandle during these early years of the work relief programs.

Concentrations of extant Study Population bridges were built in the early years of the work relief programs (1933-1934) at a few other locations in the state — Eastland County, San Antonio, Austin, and Tyler areas. Research has not yet revealed information about specific reasons that resulted in the concentrations of extant bridges in Eastland County, San Antonio, and Austin. However, flooding in east Texas during this time period instigated building bridges and making other flood-related improvements to roadways in east Texas. For example, there is a small concentration of extant bridges in Gregg County, southwest of Longview, that may have been built during this period after flooding in the area. Two examples of bridges from this concentration carry Old State Highway 135 over Big Caney Creek (NBI No. 100930AA0119005) and Peavine Creek (NBI No. 100930AA0119004). Similarly, the focus in south and coastal Texas during this period was on construction projects for flooding and hurricane disaster relief. The small concentration of four extant bridges (NBI Nos. 132410008907031, 132410008910032, 132410008910033, and 132410008910034) carrying present-day West Business 59R at the southwest edge of Wharton may be examples of such bridges. The east, south, and coastal Texas flooding and hurricane relief projects were funded jointly by PWA, through BPR, and FERA, through the Texas Relief Administration. THD financed the engineering control and had general supervision of the work.[77]

While flooding relief may have been one of the reasons for the construction of some concentration of bridges in the Tyler area, there may have also been another influence driving bridge construction in the Tyler area, in general. On October 3, 1930, the East Texas Oilfield was discovered southeast of Tyler, and the area quickly experienced an economic boom and influx of large numbers of oil companies and field developers. This, in turn, substantially increased traffic to the area.[78] THD and other sponsors likely needed to upgrade unimproved roads and construct bridges that could handle

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[76] The deleterious effects of the Dust Bowl would not occur until later in the decade, but these areas of the state were already seeing effects of the drought in the early 1930s. E.C. Woodward, "Paper read at A. & M. Short Course," April 9, 1941, TxDOT Depression-era Files H005108.

[77] State Highway Commission of Texas, *Ninth Biennial Report,* 4.

[78] Julia Cauble Smith, "East Texas Oilfield," *Handbook of Texas Online,* accessed September 10, 2023, https://tshaonline.org/handbook/entries/east-texas-oilfield. Published by the Texas State Historical Association.

the loads of the oilfield equipment in this rural area. A concentration of four extant bridges carrying FM 15 (NBI Nos. 102120049101001, 102120049101002, 102120049101003, and 102120049101004) in southeast Smith County may exemplify the THD's need to improve roads and construct bridges to accommodate oilfield traffic.[79]

Masonry Construction

Prior to the Depression-era, local governments used masonry construction in some areas of state, primarily in Austin, San Antonio, and central and north-central Texas, where shallowly buried limestone bedrock was readily available as a building material on buildings and bridges. Locally built bridge types using stone ranged from **concrete slab bridges** with masonry **substructures** to **masonry arch bridges**. Masonry construction required specialized instruction and skill, and it could be quite expensive.[80] As a result, there are only 32 Study Population bridges with masonry components built before 1930, and as noted in the MPDF, masonry construction was not used on a regular basis to construct road bridges prior to the Depression.[81] During the Depression, however, masonry construction became one of the hallmarks of the New Deal programs. It was the physical representation of the "make-work" unemployment relief and economic stimulus initiatives. Another tenet of the relief programs was the use of local materials, with construction crews often quarrying stone from roadside sources for bridge construction as a way to meet both tenets of hand labor and use of local materials.

Database query results indicate there are concentrations of masonry Study Population bridges in the TxDOT-Brownwood, Childress, and Fort Worth Districts. For example, there is a series of extant masonry **substructure** bridges (NBI Nos. 230680AA0217001, 230680AA0210001, and 230680AA0210002) carrying county roads over the Sabana River in Eastland County in TxDOT's Brownwood District. On the other hand, database query results indicate there are concentrations of Study Population bridges without masonry components in the same areas. An example of a concentration of bridges without masonry components is located in Brown County, a relatively short distance south of the aforementioned concentration of masonry substructure bridges. The concentration of bridges includes NBI Nos. 230250AA0487001, 230250AA0417003, 230250AA0417004, 230250AA0406003, and 230250AA0411004. It is anticipated that local research in a later phase of the project may illuminate the reasons for the differences in bridge types in the same general areas. The research may also reveal if stone was quarried for use as aggregate, in addition to being used for construction of substructures.

US 90 connects Jacksonville, Florida to San Diego and Los Angeles, California via Texas

US 90 across Texas, portions of which followed the OST corridor, is an example of a major THD initiative to construct new roadway segments and upgrade existing ones, including structures, throughout the Depression era. Between 1933 and 1942, the THD constructed at least 193 bridges

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[79] It should be noted that NBI Nos. 102120049101003 and 102120049101004 are within the boundaries of the TxDOT previously determined eligible East Texas Oilfield.

[80] Jensen, E12.

[81] Jensen, E12.

along US 90 between Houston and Van Horn. The THD constructed approximately 75 percent of the 193 bridges between 1937 and 1942. There were several reasons the THD focused on US 90 during this period. First, it was a main east-west travel corridor across the southern United States, and there were collective national efforts to make it a paved highway from Jacksonville, Florida to San Diego and Los Angeles, California.[82] For example, in the approximately 75-mile stretch of US 90 between Marfa and Van Horn in west Texas, THD constructed over 100 bridges. Secondly, the region around Marfa and Van Horn was becoming a popular tourist destination for visitors to the Davis Mountains who sought hiking, camping, recreational, and educational opportunities. Established in 1933, the Davis Mountains State Park provided visitors hiking, camping, and nature education opportunities.[83] Built in 1932, the University of Texas's McDonald Observatory also drew tourists to the region.[84] Van Horn capitalized on the popularity of these travel destinations and began advertising the city as a destination for travelers.[85]

The THD also upgraded US 90 due to high accident rates along the segment of the highway between Houston and San Antonio, as well as a bottleneck section in Fort Bend County with the increased traffic levels.[86] According to a 1938 *Fort Worth Star Telegram* article, the segment of US 90 between Houston and San Antonio was the fifth most hazardous highway in the state.[87] At the same time as the upgrades to the segment between Houston and San Antonio, THD upgraded the segment between San Antonio and Ciudad Acuña.[88]

Waning Days of the Work Relief Construction

Database queries indicate there are 16 extant masonry **substructure** bridges with a date of construction between 1946 and 1950. It is possible these bridges were funded through one of the Depression-era programs, but construction was not completed until after World War II ended. As discussed in more detail in the section below entitled **Wartime Transportation: Access to Military Bases and Critical Industries, 1942-1944**, bridge building and roadway improvements largely ceased during World War II unless the road and bridge were on a critical defense highway network. As the project progresses, the team will investigate each of the 16 bridges in the 1946 to 1950 period to see if the team can discern the situation with these bridges and identify any potential connection to a Depression-era program.

For more details about the Depression era theme, please refer to the MPDF, pages E36 to E61.

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[82] "Work Order Signed for Highway 90," *El Paso Herald Post* (October 20, 1936): 5.

[83] Martin Donell Kohout, "Davis Mountains State Park," *Handbook of Texas Online*, accessed September 13, 2023, https://www.tshaonline.org/handbook/entries/davis-mountains-state-park. Published by the Texas State Historical Association.

[84] David S. Evans, "University of Texas at Austin McDonald Observatory," *Handbook of Texas Online*, accessed September 13, 2023, https://www.tshaonline.org/handbook/entries/university-of-texas-at-austin-mcdonald-observatory. Published by the Texas State Historical Association.

[85] "Van Horn, Texas," *The El Paso Times* (October 27, 1935): 67.

[86] "Hazardous Highways Are Charted for State Patrol," *Fort Worth Star Telegram* (May 15, 1938): 8. "State to Widen U.S. Highway 90," *Austin American Statesman* (February 18, 1941): 10.

[87] "Hazardous Highways Are Charted for State Patrol."

[88] "State to Widen U.S. Highway 90."

Railroad Grade Separations: When Transportation Systems Conflict, Pre-1946

As vehicular travel became more widespread and roads crisscrossed the landscape in the late nineteenth and early twentieth century, the intersections of railroads and vehicular roads became some of the most dangerous locations on both transportation systems. Railroad crossing elimination initiatives began at a national level before the THD's creation, with railroad companies leading the charge to eliminate at-grade crossings. Following the Federal Aid Road Act of 1916 and the creation of the THD, the agency focused on at-grade elimination projects, with collective efforts and funding primarily from local governments and railroad companies, and to a lesser extent, the federal government. With Depression-era grant funding programs in the mid-1930s, the federal government began providing funding specifically for grade-separation structures, and the number of these structures increased significantly. There are a total of 229 railroad-grade separation bridges in the Study Population, with 85 built before the federal grant programs and 144 built after the federal government created the grant programs for building railroad grade-separation bridges.

Railroad companies spearheaded early coordination efforts to eliminate at-grade railroad crossings because accidents on their railroad facilities often interrupted their service, caused damage to transported goods, and, worst of all, resulted in injuries and fatalities. Railroad companies began a unified effort to eliminate railroad crossings in December 1915, soon after the American Railway Association reported that between 1905 and 1915, nearly 10,000 fatalities occurred at crossings and another 22,000 people had been injured.[89] The American Railway Association appointed a special committee of seven railroad company representatives to draft a comprehensive plan for eliminating railroad crossings. The association had a heightened awareness about accidents because incidents steadily increased between 1909 and 1915, which directly corresponded to the increase in automobile usage, especially in rural areas. The group recommended a comprehensive effort to depress railroads under or elevate tracks over roadways; however, they stopped short of recommending who should lead such an effort. The biggest issue the group cited was funding, with the average cost of grade-separations being approximately $50,000 per crossing in 1915. The association noted that local officials often wanted the grade-separations and supported their construction, but they could not or did not want to prioritize funding these structures.[90]

Rural Railroad Grade-Separations Before 1934

Financial assistance for grade-separation structures came in 1916 with the passage of the Federal Aid Road Act, and the THD was a staunch supporter of eliminating at-grade crossings after its creation. While the 1916 Act did not specifically include provisions for grade separations, counties could use Federal Aid funding to pay for grade separation structures. As counties led the road and bridge building efforts during the late 1910s and early 1920s, they could apply for Federal Aid money or

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[89] "Safety Hints at Grade Crossings," *The Houston Post* (December 18, 1915) 8.

[90] "Safety Hints at Grade Crossings."

State Aid funds that the Texas Highway Commission set aside specifically to eliminate at-grade separations.

With 7,000 fatalities in the U.S. associated with at-grade crossing accidents in 1921, BPR strongly advised states to prioritize elimination of at-grade crossings on Federal Aid projects. Each state needed to submit a list of railroad grade crossings to the BPR that would be eliminated by the THD, with a total financial commitment from each state for the next several years. For fiscal years 1923, 1924, and 1925, the THD set aside $75,000, $100,000, and $125,000, respectively.[91] The Texas Legislature set aside additional state funds for grade separations in 1924, when the Legislature required that the State Railroad Commission and THD split the cost of eliminating at-grade crossings.

Given their commitment to the at-grade railroad crossing elimination initiative, the THD looked for ways to eliminate at-grade crossings in their review of Federal and State Aid projects on rural roads. They did so most often by realigning or relocating roads to minimize the number of times that the road crossed railroads. If at-grade crossings could not be eliminated on an alignment, the THD created specific geometric design requirements to maximize visibility at crossings and required nationally mandated safety signage. If a crossing could not meet the THD's geometric requirements, engineers designed and built overpass and underpass structures. By 1923, the State Railroad Commission reported that 9,313 rural road and 533 urban street at-grade railroad crossings existed in Texas, which revealed the magnitude of the problem. At that time, the THD and counties eliminated 244 railroad crossings with state or federal aid funding, including 203 crossings eliminated through road realignment or relocation, 31 underpasses, and 10 overpasses, which the State Railroad Commission and railroad companies helped fund.[92] In fact, the need to eliminate at-grade crossings was so great that railroad companies had teams of employees specifically dedicated to designing and coordinating underpasses with government officials, as well as coordinating with local and state governments on county- and later THD-designed overpass bridges.[93]

Through the 1920s, THD Bridge Engineer George Wickline remained vigilant on the crusade to eliminate at-grade crossings. As noted above, the pinnacle years of highway and bridge construction occurred between 1928 and 1930, which included projects associated with the at-grade elimination initiative. The THD's *Seventh Biennial Report* states that between 1928 and 1930, the THD eliminated 146 at-grade crossings, including construction of 17 underpasses and 17 overpasses, which was greater than in any past biennium.[94] Close cooperation between state and local governments helped significantly, as did a willingness by all entities to focus their financial resources on the initiative. By 1930, when not part of Federal Aid funded project, the state and counties collectively paid approximately 50 percent of underpass and overpass construction on state highways, with state funds

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[91] State Highway Department of Texas, *Third Biennial Report for December 1, 1920 to December 1, 1922* (Austin, Texas: Von Boeckmann-Jones Co., Printers, 1923), 91.

[92] State Highway Department, *Third Biennial Report*, 15.

[93] G.G. Wickline, "Grade Crossing Elimination," *Texas Highway Bulletin*, vol.4, no.1 (January 1924) 25.

[94] State Highway Department, *Seventh Biennial Report*, 56.

coming out of the THD and Texas Railroad Commission funding. Railroad companies contributed the remaining 50 percent.[95]

Urban Railroad Grade-Separations Before 1934

Cities also focused their attention on eliminating at-grade railroad crossings, as cities had numerous conflicts with the railroads and railroad yards, which were often located in or adjacent to downtown areas containing numerous pedestrians and motorists. Railroads and their large railyards were not only dangerous, but they were also considered unsightly, and efforts to eliminate at-grade crossings were a focus in many cities' urban planning and beautification efforts. (For information about grade-separation structures built as part of city-wide urban planning efforts, please see the **Urban Planning and City Beautiful** section below.)

Before 1934, many cities constructed grade-separation bridges on an as-needed basis when funds were available. Due to the bridges' substantial expense, city governments needed to use city bond funds, as well as to find willing railroad companies who would share the financial burden of design and construction and be willing to suspend their operations during construction. One example of a cooperative project between a local government and a railroad company was the construction of two underpasses on Corinth Street in Dallas. In 1932, the City of Dallas, Dallas County, and the Missouri-Kansas-Texas (MKT) Railroad built two **rigid frame** bridges that were locally called the Corinth Railroad Viaduct structures (NBI Nos. 1805709C6210001 and 1805709C6210002). While these bridges provided access between downtown and the north banks of the Trinity River, they were not part of an overall city-wide program to eliminate railroad at-grade crossings.

On the other hand, Fort Worth undertook early and very expensive efforts to eliminate their at-grade railroad crossings, particularly on the south side of downtown at the Texas & Pacific (T&P) Railroad's yards and terminal. After residents approved $600,000 in road improvements in June 1929, the city and T&P negotiated an agreement to equally split the cost to build seven large underpasses, which newspapers called "subways" or "tunnels" due to their extensive length.[96] The program began with construction of the Henderson Street Underpass (NBI No. 022200ZH4400001) and Main Street underpass (NBI No. 022200017201039), which were completed in 1931 and 1932, respectively. T&P designed both bridges to be reinforced **concrete slabs** with modest incised panels along the facias and repeating arch concrete railing. Each underpass also had sidewalks flanking the street under the tracks. The Henderson Street structure cost $327,000 and the Main Street underpass cost $250,000, illustrating the substantial financial commitment required from the city and T&P.[97]

Federal Grants for Rural and Urban Projects

The funding of railroad under- and overpasses remained largely the same through the early 1930s, although state and local governments' funding sources, as well as the railroad companies'

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[95] State Highway Department, *Seventh Biennial Report*, 56-57.

[96] "$715,365 Paid for City Bonds," *Fort Worth Record-Telegram* (March 10, 1931) 5.

[97] Richard Howe, "Fort Worth, District 7: Bridges, Viaducts, etc." (1935), Works Progress Administration Records, 1935-1945, available at the University of Texas at Austin, Dolph Briscoe Center, 2.

contributions, dwindled significantly due to the Great Depression. The initiative to construct railroad grade-separation structures received a significant boost when the U.S. government passed its largest work-relief-related legislation at the time — NIRA of 1933 — which provided specific funding for the construction of grade-separation structures. The THD immediately began constructing new grade-separation structures. In their *Ninth Biennial Report*, the THD noted one of its earliest significant projects was the construction of three underpasses (NBI Nos. 121020B31281003, 121020B31281004, and 121020B31281005) completed in 1934.

Soon after the NIRA, the U.S. Congress passed the Emergency Relief Appropriation Act (ERAA) of 1935, which provided Texas with $10.8 million specifically for the construction of railroad grade-separation bridges in the state.[98] Congress's intent for passing the ERAA was to eliminate railroad and road conflicts on all roads throughout the U.S., regardless of their location in or outside cities. As a result, unlike other federal funding in prior Federal Aid programs, grade-separation elimination funds through NIRA and the ERAA could be issued to municipalities, with the THD administering the funds and overseeing construction. Both acts also provided the funding as 100 percent grant and required no matching funds from local governments, state highway departments, or railroad companies. The federal government's commitment to eliminating dangerous at-grade railroad crossings was evident in this grant-type funding program, which was one of the largest up to that time.

After the passage of the federal grant funding for grade-separation bridges, Fort Worth continued its railroad grade elimination program in earnest, building dozens of grade-separation bridges, many of which are in the Study Population. Examples of the federal grant-funded grade-separation structures include the 1936-built Business 287 underpass (NBI No. 022200017201039), 1937-built E. Vickery Blvd underpass (NBI No. 022200ZV3900002), and another Main Street Underpass at Burlington Northern Santa Fe (BNSF) and Union Pacific Railroad (UPRR) Railyards that was built in 1937 (NBI No. 022200ZM0670001).

Amarillo also significantly benefited from the federal grant funding, where the city, two railroad companies, and the THD worked together to build a series of eight **steel I-beam** underpass bridges near downtown in 1936 (NBI Nos. 041880004107056, 041880004107057, 041880004107058, 041880004107059, 041880004107060, 041880004107061, 041880004107062, and 041880004107063). This project required extensive excavation of a 26-foot-deep trench that stretched nearly 500 feet. The bridges carried the railroad yards and lines of two companies — the Rock Island Railroad and the Fort Worth and Denver Railroad — over Buchanan Street (now US 60 Northbound Lanes). Adorned with Art Deco detailing in the concrete railings and posts, this $400,000 project was one of the largest federal grant-funded grade-separation projects in the Southwestern U.S.[99]

Federal funding for the construction of railroad grade-separation structures continued through the late 1930s and into the early 1940s. In 1938, the U.S. Congress allocated an additional $2.7 million to

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[98] Jensen, E58.

[99] "Underpass to Open June 1," *The Amarillo Globe-Times* (May 14, 1937) 2.

Texas for grade-separation bridges.[100] During World War II, the U.S. Congress passed the Federal Aid Highway Act of 1944, which allowed states to use up to 10 percent of their allocated funds to the construction of railroad under- and overpasses. Additionally, the Study Population includes examples of where the THD built railroad under- and overpasses as part of the regular Federal Aid Program projects, such as the MKT Railroad bridge over US 77 in Ellis County (NBI No. 180710044203002), which was built as part of the upgrade of US 77 in 1938.

Railroad Grade-Separation Bridge Design

With regards to grade-separation bridge design, the facility carried by the bridge (either the railroad or highway) dictated who designed the bridge and what design the engineers selected. For railroad underpass bridges, where the bridge carried the railroad tracks and spanned the roadway, railroad companies led or supervised the design and construction, regardless of funding. These railroad bridges carried heavier loads than roadway bridges and had their own unique requirements.

When railroad companies built railroad underpass bridges, they — like the THD — used their standard plans unless the crossing required a specially designed bridge. Each railroad company issued its own set of standard bridge plans released by their central office engineers. Much like the THD, railroad standard bridge plans included **superstructure** and **substructure** variations. Railroad companies' standard plans often included timber trestle and creosote-covered timber **stringer** bridges.[101] While once widely used for underpass structures, there are only seven timber railroad underpass bridges in the Study Population.

Engineers also opted for **steel I-beam** bridges for modest span lengths (up to 50 feet), and they carried roads and railroads. For overpass structures, the THD sometimes used a steel I-beam variation where the **steel I-beams were encased in concrete**. These special-designed, non-standard bridges survived longer than other steel beam bridges, as emissions released from the trains would not corrode the bridge's structural members prematurely. These bridges consisted of longitudinally placed steel stringers (to carry the **deck**'s load) with concrete cast and poured over the stringers to protect the steel. At first glance, these bridges appeared to have unusually deep **rebar**-enforced concrete girders supporting the deck; however, these deep girder-like members have solid steel rolled I-beams within them. One example of a THD-designed steel I-beam encased bridge is the SH 45 (now US 190) at the UPRR built in 1931 (NBI No. 172360021301001) in Walker County. The THD built this bridge as part of the State Aid-funded project to upgrade SH 45 between Huntsville and the Walker/San Jacinto County line. Another example is the SH 15 overpass bridge at the Atchison, Topeka, and Santa Fe (AT&SF) Railroad (NBI No. 041480035501002). While the THD designed this bridge in 1932 as part of a Depression-era federal funds (National Recovery Secondary [NRS]), the THD recorded its project completion in 1934.[102]

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[100] Gilcrest, 174.

[101] Numerous standard plans for timber bridge types are available in the AT&SF and BNSF Railroad Archives at the Temple Railroad and History Museum in Temple, Texas.

[102] It is unclear why THD opted to encase steel I-beams in some locations, but not others. The team will attempt to determine the reasoning for the use of this bridge type during individualized bridge research.

For spans over 50 feet, engineers frequently used **steel plate girder** bridges to carry railroads. These bridges had **built-up** steel members, with a web plate **bolted** or **riveted** to two **flange** plates. Since each plate was a separate piece, the **webs** could be quite deep and could carry heavy loads for longer distances, making them ideal to carry railroads over roadways. In the Study Population, most of the plate girder bridges of every type (with **through**, part-through, with **floor systems**, or tightly spaced without floor systems) were built as underpass structures. Many of these bridges, particularly the through plate girder bridges, appear to be standard designs, as they have uniform lengths, although research to date has not confirmed that assumption. One of the most notable plate girder underpasses was the MKT Railroad bridge over US 77 in Ellis County (NBI No. 180710044203002). THD constructed this MKT-designed steel plate girder with floor system with a 124-foot-long clear span over all lanes of US 77 as part the road’s upgrade in 1938. For the longest span lengths, engineers generally opted for truss bridges. To protect the steel superstructures of bridges spanning railroads, bridge engineers often attached “blast guard plates” to the bottom side of superstructures to deflect locomotive exhaust and protect the superstructure from corrosive effects. The blast guard plates were usually rectangular, heavy gauge, wrought-iron plates. Less frequently, blast plates were made of asbestos-cement boards or steel plate coated in an asbestos product.

Engineers in Texas typically reserved construction of reinforced concrete grade-separation bridges for cities, where the clean lines and smooth surfaces of the concrete fit well into urban settings. In cities like Fort Worth, Amarillo, and Dallas, engineers opted for **concrete slabs** and **rigid frame** bridges. The aforementioned Corinth Railroad Viaduct used rigid frame bridges. These bridges were aesthetically pleasing with their arch-like silhouettes, incised panels decorating the super- and substructures, and the concrete repeating arch **balustrade**. The county and city built these 1932 structures as part of a city-wide planning effort to beautify and increase safety in the downtown Dallas area. Like most underpass railroad bridges, engineers designed sidewalks on either side of the road since pedestrian safety was one of the main tenants of the at-grade elimination initiatives in cities. For more information about city planning initiatives in Dallas and other Texas cities, please see the **Urban Planning and City Beautiful** section below.

Wartime Transportation: Access to Military Bases and Critical Industries, 1942-1944

Historians often view World War II, which officially began for the United States on December 7, 1941, as a lull in American and Texas highway and bridge building. Logically, the military and defense-related industries urgently needed steel, concrete, and other building materials for critical military uses, and material shortages plagued much of the infrastructure building in the country. Likewise, the armed services and wartime industries employed engineers and other workers of military age, resulting in widespread staff shortages. The Texas MPDF states that "road and bridge construction was limited during the war," yet there are approximately 200 extant Study Population bridges with dates of construction in 1942, 1943, and 1944, which paradoxically is during the height of the war.[103] The relatively large number of bridges built in Texas during World War II seems to be related to two trends that are identified by the MPDF: the slow winding down of the WPA funding program and the size of the state and number of military bases and wartime industries.

Texas attracted the military and defense industry during World War II due in part to temperate climates and available petroleum.[104] As a large state, Texas also had vast areas of sparsely populated land to accommodate camps and airfields.[105] According to the Texas Historical Commission (THC), Texas would ultimately have "175 major military installations plus minor ones — including 65 Army airfields, 35 Army forts and camps, and seven naval stations and bases. There were also more than 60 base and branch prisoner of war camps… and three internment camps…"[106] With this large number of military installations across the state, THD undertook a large initiative to upgrade highways identified as critical to accessing military bases or transporting raw materials and supplies.

As far back as 1922, identification of important Texas roads for national defense resulted in the creation of the "Pershing Map."[107] This map served as the basis for discussions about the defense road network when the BPR and the War Department restudied priorities for military highways in 1935.[108] In turn, state highway departments used these priorities in their planning for highway programs. After Germany seized control of Czechoslovakia and turned attentions to invading Poland in 1939, these planning efforts suddenly became urgent. Surveys showed the urgency of the situation in that the U.S.'s network of strategic and defense highways was woefully inadequate to provide the capacity needed for the military vehicles and the anticipated high levels of traffic between military installations and strategic industrial complexes.[109] Thus, the Public Roads Administration (PRA), the successor organization to the BPR, initiated efforts to lobby the U.S. Congress for the necessary appropriations to fund upgrades to the strategic defense highway network across the country. However, Congress

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[103] Jensen, E60.

[104] Jensen, E60.

[105] Loyd Uglow, A Military History of Texas (Denton, Tex: North Texas University Press, 2022), 318.

[106] Texas Historical Commission, *Texas in World War II*: *Fundamentals of Military Oral History*, https://www.thc.texas.gov/public/upload/TxWWII_OrlHstry_01_22_14.pdf (accessed on September 9, 2023) 6.

[107] The project team anticipates providing a copy of the Pershing Map in a future version of this historic context.

[108] Federal Highway Administration, 142.

[109] Federal Highway Administration, 142.

waited to appropriate money to fund transportation improvements for the defense highway network, among other categories for the funding, until 1940 after Germany invaded Denmark and the U.S. began war mobilization efforts.[110]

In the initial phase of funding defense highway network improvements, many roads were not eligible for the funding because they were not on the Federal Aid or state highway systems.[111] To fill in the gaps until Congress could pass new funding legislation, states used WPA funds wherever possible to improve and upgrade roads to defense installations. The federal government waived several WPA funding requirements to facilitate the rapid deployment of the funding.[112]

Presumably, the THD selected which defense highway projects would be initiated based on the planning efforts undertaken in the late 1930s. However, the THD was not receiving funding for access roads to military installations. The Federal Highway Administration (FHWA) history, *America's Highways*, indicates the Secretary of the Army or Secretary of the Navy requested projects, and the Federal Works Administrator also had the authority to initiate their projects with the passage of the Federal Highway Act of 1940. The states in which the projects were located incurred the costs for those projects.[113]

Given the ever-increasing military presence in Texas during this period, it stands to reason that the THD's participation in the WPA program remained somewhat robust well into 1942, even as other states were ending their programs to fill the funding gaps for military defense-related highway improvements. Although the Great Depression is generally acknowledged to have ended in 1939, the WPA remained a significant work relief program for several years afterward in many regions and localities. As late as mid-1942, Congressmen were claiming that the WPA was still needed for workers too old for military service and lacking skills needed in wartime industries. This attitude, as well as available federal funds appropriated by Congress, appears to have kept the WPA going in Texas longer than in many other states. The WPA's latter years may have been especially important in poor rural areas with aging populations. The WPA program remained active in Texas until June 1943 when President Roosevelt issued an order that all WPA activity must cease. Approximately 118 Study Population bridges were constructed in 1942; however, a review of as-built plans for many bridges (such as NBI Nos. 090980025102048 and 010810001004084) indicates the bridges were designed and funded in earlier years (e.g., 1940 or 1941) but not completed until 1942. For example, THD designed and built most of the SH 16 **masonry arch** bridge over the Brazos River (NRHP-listed, NBI No. 021820036202003) in 1940 and 1941, but its final completion occurred in 1942, which is its "year built" date in TxDOT's records.

While the WPA program filled some of the funding gaps for the THD's initiatives to upgrade the defense highway network, passage of the federal Defense Highway Act of 1941 served to more readily advance the THD's initiatives. This law designated special funding for highways identified as critical to

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[110] Federal Highway Administration, 143.

[111] Federal Highway Administration, 143.

[112] Federal Highway Administration, 144.

[113] Federal Highway Administration, 144.

accessing military bases or transporting raw materials and supplies needed by wartime industries. The MPDF points out that Texas was a major beneficiary of this funding due to its numerous forts, airfields, naval bases, and military training facilities, as well as its international border and coastline (which needed defending), and links to the petroleum industry.[114] The different military branches identified specific needs and established priorities, and then relied on highway department engineers in each state to locate, design, and oversee the construction of defense-related highways and bridges. This was a practical strategy since the highway departments had the existing organization to complete this work while the military engineers focused on other defense-related assignments. In this way, the THD contributed to the war effort, even though it was not a military engineering organization *per se*.

The MPDF refers to a "Texas Strategic Military Network," which had roadway miles designated as first, second, or third priority. A review of the bridge database showing those bridges constructed between 1942 and 1944 indicates there is a correlation between the distribution of the bridges from that time period and the locations of the World War II military installations across the state, as shown in the map included in the THC brochure entitled *Texas in World War II*.[115] The patterns of distribution between the two maps are remarkably similar.

In the *Fourteenth Biennial Report*, THD specifically highlighted several bridges constructed in the biennium between September 1942 and August 1944. For example, the bridge (NBI No. 022200008007050) built over the Clear Fork of the Trinity River in southwest Tarrant County on present-day southbound US 377 provided a connection between Fort Worth's military installations and war-time industrial complexes to those near Stephenville and Brownwood. The bridge carrying present-day eastbound Spur 482 over Elm Fork over the Trinity River (NBI No. 180570009403013) was a principal bridge that provided military-related traffic with an alternate route between Dallas and Fort Worth. A third example of principal bridges from the 1942–1944 biennium is NBI No. 110030017603054, which carries US 59 over the Neches River between Livingston and Lufkin. The THD constructed it in conjunction with three other bridges over Neches River Reliefs (NBI Nos. 110030017603055, 110030017603056, and 110030017603057). Research suggests the US 59 corridor was likely a vital north-south link through East Texas to connect military installations in the southeast/Houston-Galveston region of the state with those in the northeast region of the state, as well as the approximately ten prisoner of war camps located between the two regions.[116]

Within the population of bridges constructed between 1942 and 1944, there are several concentrations of bridges located on roadways that may have served as major transportation corridors between military installations. For example, there are six bridges (NBI Nos. 230470018301042, 230470018301043, 230470018301044, 230470018301045, 230470018301046, and 230470018301047) on SH 36 between Hamilton on the southeast end of the corridor and Comanche on the northwest end. There are also numerous bridges from this period along US 281 northeast of Hamilton (NBI Nos. 020730007904027, 020730046702002, 020730046702003, 020730046702004,

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[114] Jensen, E59.

[115] Texas Historical Commission, *Texas in World War II,* 7.

[116] State Highway Commission of Texas, Fourteenth Biennial Report, September 1, 1942, to August 31, 1944 (n.d., 1944), 14.

020730046702005, 090980025101041 090980025101044, and 090980046701001) and southwest of Hamilton (NBI Nos. 090980025102048 and 090980025102049). These two roadway corridors are in an area of the state where there were multiple military installations and prisoner of war camps. Another example includes two bridges (NBI Nos. 171450033503011 and 171450033503013) on SH 7 in Leon County. SH 7 appears to have been a principal corridor between the Army installations in western Louisiana and Fort Hood in Kileen. In the Corpus Christi area, there is concentration of six bridges (NBI Nos. 162050010104026, 162050010104027, 162050010104028, 162050010104029, 162050010104030, and 162050010104031) along US 181, presumably the primary corridor from the Corpus Christi Naval Air Station to other areas of the state prior to the construction of Interstate Highway 37, which now serves as the region's primary transportation corridor.

A February 17, 1942, article in the *Austin American Statesman* newspaper discusses highway bids the THD was scheduled to open two days after the article, which included bids for an estimated $1,120,000 for Army access roads, $290,000 for Navy access roads, and $1,500,000 on state projects.[117] The article mentioned several Central Texas projects, including projects on the military highway loop (present-day S.W. Military Drive/Loop 13 in San Antonio). The article also mentioned construction of a bridge near Kelly Field (formerly Kelly Air Force Base) in Bexar County. Research indicates this is likely the bridge that carries present-day S.W. Military Drive/Loop 13 over Leon Creek (NBI No. 150150052103004). Another Bexar County bridge (NBI No. 15015005210100) was constructed on the same roadway east of the Leon Creek bridge. Additional individual bridge research will be conducted to identify bridges that were funded through the federal defense act program and to assess whether there might be bridges that have exemplary contexts associated with the war effort.

In the *Fourteenth Biennial Report* (September 1942–August 1944), the THD described several new structures as concrete girder or slab bridges constructed to upgrade crossings on critical roadways between military installations and/or vital industrial complexes. Additionally, the THD used the examples of the main and relief bridges (no longer extant) on SH 103 over the Neches River at the Angelina and Houston County line to illustrate the use of second-hand materials, including a second-hand steel truss span salvaged from another bridge, to construct new structures due to limitations on materials.[118] A database query indicates that approximately 40 **steel I-beam** or **steel plate girder** bridges were constructed during the same biennium, despite the restrictions on the use of steel and special approval requirements. Bridges, such as NBI No. 021840AA0441001 constructed in 1944, also appear to support the second-hand material reuse concept given the different sized steel I-beams evident in photos of the bridge. Individualized research for these steel bridges will be required in a later phase of the project to determine if any of them represent the special approval required for the use of steel or if they all represent the reuse of materials.

For more details about the World War II era theme, please see the MPDF, pages E58 to E61.

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[117] "Board to Open Highway Bids Thursday," *Austin American Statesman* (February 17, 1942), 3.

[118] State Highway Department of Texas, Fourteenth Biennial Report, September 1, 1942, to August 31, 1944 (n.d., 1944), 14.

Criterion A: Community Planning

Urban Planning and City Beautiful

Throughout the study period, cities with populations over 2,500 residents were ineligible for most of the Federal Aid funding that paid for the road infrastructure throughout Texas because the U.S. Congress specifically established the Federal Aid program for building rural road systems. Conversely, city governments' infrastructure improvements focused on the movement of people, improving their residents' quality of life, and facilitating development within relatively small geographic spaces while supporting local businesses and industries. Cities had highly individualized needs, and as expected, engineers used a wide variety of bridge types to fulfill their needs and build local transportation systems. As a result, most of the Study Population's uncommon bridge types (nearly 72 percent) are currently located within Texas's cities.[119]

By the late nineteenth century, a collective architectural and urban planning movement emerged as civic leaders acknowledged the value of creating enjoyable living conditions for their cities' residents. As the large metropolitan centers on the U.S. East Coast and Upper Midwest focused their efforts on improving their maturing cities in the nineteenth century, Texas was still a largely rural state with just a few large communities, such as San Antonio and Galveston. When Texas cities developed in the late nineteenth century, industrialization and growth occurred at a rapid pace, with little consideration for the separation between different functional areas of the community, with industrial, commercial, and residential development often located directly adjacent to each other. Railroads played a vital role in the establishment of cities, as communities with one or more railroads became the economic, social, and cultural hubs for farms, ranches, and oil fields in their regions. Yet, the railroad and industrial development in city centers swelled with unfettered expansion.

The urban planning movement occurring nationally was dubbed the City Beautiful Movement. Based on the ideals of the Progressive Movement and Beaux Art Classicism, the City Beautiful Movement gained popularity in the U.S. in the 1890s. It reached its peak popularity nationally around the turn of the twentieth century, but it reached its zenith in Texas around a decade later.[120] In 1900, Texas cities were still relatively small, with San Antonio being the largest city with approximately 53,000 residents.[121] By 1910, however, the state's largest cities (San Antonio, Houston, Dallas, and Fort Worth — listed in order by population) saw exponential growth, and city leaders began to acknowledge the importance of investing in beautifying their cities. (Specific information about these cities' urban

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[119] Uncommon non-truss bridge types include (but are not limited to) concrete arches, concrete variable-depth slabs, concrete variable-depth girders, masonry arches, and variable-depth steel plate girders.

[120] Cory Edwards, et. al., San Antonio Downtown and River Walk Historic District National Register Nomination (June 2016) Section 8, 71.

[121] Texas Almanac, *Texas Almanac: City Population History from 1850—2000*, https://www.texasalmanac.com/drupal-backup/images/CityPopHist%20web.pdf#:~:text=Texas%20Almanac%3A%20City%20Population%20History%20from%201850%E2%80%932000%20The,figures%20are%20given%20where%20census%20figures%20are%20unavailable (Accessed July 13, 2023).

planning efforts are outlined below by city.) Some of the earliest proponents of urban planning were local business leaders who formed Chambers of Commerce. They recognized that economic development and city growth were heavily reliant on the livability of their cities. At their promptings, some city governments hired nationally renowned landscape architects to develop comprehensive city plans. The most prominent urban planner working in Texas during the early twentieth century was George E. Kessler, a nationally revered landscape architect who studied urban planning principles in Europe in the late nineteenth century. He gained national fame after he designed the St. Louis World's Fair grounds in 1904.[122] With this accomplishment, Kessler became a sought-after urban planner, with the cities of Dallas, Fort Worth, Houston, and El Paso all hiring him to design long-range city improvement projects, and other cities, such as San Antonio, hiring him for smaller planning projects.

Together with ideas proposed by local city planners, many cities had plans to create parks and open spaces for residents to enjoy and improve their health. City governments established parks in natural spaces, particularly along rivers and creeks, with meandering boulevards and aesthetically pleasing bridges.[123] Plans also included strategies for creating a distinct separation between city residents and railroad facilities. Because many railroad companies built their railroad yards directly adjacent to the downtown areas, the railroad facilities were not only an eye-sore, but the numerous at-grade railroad crossings posed safety hazards for pedestrians and motorists. Therefore, most city plans included numerous grade-separation structures in and adjacent to their downtowns.

Funding became the main issue with cities completing the recommendations in urban master plans. City bonds were the primary way that cities paid for the infrastructure construction proposed in the plans, but these beautification efforts were sometimes delayed or not funded mainly because communities had infrastructure improvements that could not be set aside. For example, many of Texas's largest cities were located on major rivers — such as the Trinity River in Dallas and Fort Worth, the San Antonio River in its name-sake city, Buffalo Bayou in Houston, and the Colorado River in Austin — which required continual efforts and funding to fight flooding, as well as replacement and maintenance of numerous bridges crossing these waterways. Cities that worked closest with their county governments, like Fort Worth and Tarrant County, as well as Austin and Travis County, had county funds to use in addition to their city funds, which greatly influenced how many infrastructure projects could be built.

By the 1930s and the onset of the Great Depression, city coffers were generally empty, and city governments could not build infrastructure projects without the help of the work-relief funding that came through the federal government. As part of work-relief programs in the mid-1930s, the U.S. Congress passed laws that fully funded the construction of grade-separation bridges throughout the U.S., regardless of the location within or outside of cities. For the first time, cities had access to federal highway funding to build their infrastructure, while beautifying their communities. For more

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[122] David G. McComb, *Spare Time in Texas: Recreation and History in the Lone Star State* (Austin, TX: University of Texas Press, 2008) 40.

[123] McComb, 40.

information about grade-separation bridges' funding, please see the **Railroad Grade Separations: When Transportation Systems Conflict, Pre-1946** section above.

Aligning with the beautification intentions of the City Beautiful Movement, city engineers often designed reinforced concrete bridge types with elegant lines, such as **open spandrel arches**, **closed spandrel arches**, **variable-depth slabs**, **variable-depth tee beams**, and rigid frame bridges. As described in the **Non-Truss Bridge Types, circa 1900-1946: Typology and Character-Defining Features** section below, each bridge type had specific advantages for particular locations and necessary span lengths. Engineers would also incorporate bridge design features to beautify bridges that reflected the popular architectural styles of the day, including Beaux Art, Art Deco, Art Modern, and Rustic. For more information on the types of aesthetic treatments used on Texas bridges, please see **The Significance of Aesthetic Treatments** section below.

While hundreds of small and mid-sized cities had their own city planning initiatives, research shows that they focused primarily on less expensive, localized road improvements, landscaping particularly surrounding important buildings (especially courthouses), and park improvements, rather than overall comprehensive beautification plans and implementation. A 1928 full-page article entitled *More Than 30 Cities and Towns in Texas Have Launched Phases of City Planning and Zoning* outlined the city planning efforts for several cities around the state, including the planning efforts in the smaller and mid-sized cities, such as Abilene, Corpus Christi, Galveston, Brownwood, and San Angelo. Their efforts were heavily focused on improving specific thoroughfares by paving and widening them, as well as creating or improving parks. For example, San Angelo proposed to spend $75,000 to create parks, including a zoo, on the banks of the Concho River. Interestingly, the article also noted that a citizen-based planning organization in Dallas, called the Kessler Plan Association, hosted planners and engineers from other smaller cities to observe the planning efforts completed or proposed in Dallas, including their street configuration, utility line locations, and park locations. The association also established a special fund for aiding smaller cities and towns that could not afford their own comprehensive city plans. As a result, they initially aided several small communities surrounding Dallas, such as Denton, Mount Pleasant, Grand Prairie, Garland, Mesquite, and Lancaster. They also helped other cities, including Lubbock, Tyler, Waco, Taylor, Jasper, Wichita Falls, and Coleman.[124] Likewise, historian Mark Osborne, author of "Lone Star Beautiful: The City Beautiful Movement in Texas," observed that smaller cities made improvements based on the City Beautiful Movement, but their execution was not as grand or extensive as those proposed and carried out in the larger cities that could afford their own comprehensive plans.[125]

The following paragraphs outline urban planning and City Beautiful initiatives in cities with comprehensive planning efforts.

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[124] Katherine Pollard, "More Than 30 Towns and Cities In Texas Have Launched Phases of City Planning and Zoning," *Wichita Daily Times* (November 18, 1928), part 2, 17.

[125] Mark Osborne, "Lone Star Beautiful: The City Beautiful Movement in Texas" (December 2012), osborne_research_paper_lone_star_beautiful.pdf, accessed on July 17, 2023.

Dallas

The City of Dallas had early consideration for city beautification, as they had several generous donors who contributed open space to them, including James J. Eakins's 10 acres at Browder's Springs in 1876 and William G. Gaston's land gift for the State Fair grounds in 1886.[126] In 1904, the State Fair Association and the City of Dallas hired George Kessler to replan and landscape Fair Park's grounds. Based on his 1904 designs at the St. Louis World's Fair grounds, Kessler's plans for Fair Park incorporated grand driveways and promenades, as well as provided input on the design of the new structures. As author Willis Cecil Winters notes, Kessler's plan for Fair Park was "a manifestation of his interpretation of the City Beautiful Movement."[127] In 1905, the city amended its City Charter to create a Board of Park Commissioners, which focused on the development of parks and creation of a citywide park system.[128] Just a few years later in 1908, a devastating flood in West Dallas punctuated the need for a comprehensive plan for the growing city. To help avoid future devastating flooding and aid in overall city development, the City Plan and Development League of the Dallas Chamber of Commerce strongly emphasized the need for an overall city planning effort. The Chamber promised to promote the advantages and benefits that city improvements would bring in the short and long term.[129] The city selected Kessler to complete their citywide plan after having a favorable experience with him on the Fair Park plan. The city specifically requested that Kessler develop a water management and long-range growth plan.[130]

In 1910, Kessler created "A City Plan for Dallas," also commonly called the "Kessler Plan." The plan had two main recommendations that influenced bridge construction in Dallas and resulted in many of the Study Population bridges' construction: constructing a parkway along Turtle Creek and eliminating railroad at-grade crossings. To create an attractive city and conserve property values, Kessler suggested that the city build a comprehensive system of parks and boulevards, as well as segregate railroads and manufacturing facilities from all residential properties. He also noted the importance of building a levee system along the Trinity River, straightening the river, and creating a 1,200-foot-wide basin from the mouth of Turtle Creek southwestward for four miles to protect the entire city.[131]

One of the cornerstones of Kessler's plan was the creation of a boulevard system that would encircle the northern part of Dallas, beginning with a scenic parkway along Turtle Creek, which Kessler envisioned as a linear park. The City of Dallas moved forward with the parkway design and construction, building a series of reinforced **concrete closed-spandrel arch** bridges in the 1910s. Of particular note is the Maple Avenue bridge over Turtle Creek (NBI No. 1805709M0980004), with its

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[126] McComb, 40.

[127] Willis Cecil Winters, *Fair Park* (Charleston, SC: Arcadia Publishing, 2010) 21.

[128] George E. Kessler, *A City Plan for Dallas, 1911*, https://texashistory.unt.edu/ark:/67531/metapth129158, (accessed May 20, 2023) 5.

[129] Kessler, 5.

[130] City of Dallas Office of Historic Preservation, "City Beautiful: The Kessler Plan," https://cityofdallaspreservation.wordpress.com/tag/city-beautiful/, accessed on March 28, 2023.

[131] Kessler, 8-9.

graceful arch design emphasized by a scored **arch ring** and recessed paneled **spandrel**, pilasters at **abutment** corners, and classicized concrete **balustrades** with urn-shaped balusters.

Another aspect of Kessler's plan was eliminating at-grade railroad crossings. He noted that at-grade crossings should be eliminated as soon as possible, citing that the railroads' and industrial facilities' proximity to downtown caused significant congestion and posed public safety hazards. He stated that "the seriousness of this obstacle to the proper growth of the retail section will be more and more pronounced as the city grows."[132] Kessler recommended either depressing the railroad tracks or depressing the streets, as determined most appropriate in consultation with railroad companies. He went on to recommend entirely removing and relocating several railroads from downtown and moving them to areas east of Fair Park, with detailed recommendations for each railroad located downtown.

Unsurprisingly, railroad companies did not comply with Kessler's recommendations to relocate their lines out of downtown, but his recommendations for building grade-separation bridges throughout downtown gradually came to fruition with joint city, county, and railroad company projects. Such projects included the Corinth Railroad Viaducts (NBI Nos. 1805709C6210001 and 1805709C6210002), the Cadiz Street Railroad Viaducts (NBI Nos. 1805709C0130001 and 1805709C0130002), and the Industrial Boulevard underpass (NBI No. 1805709I3600003). In keeping with the City Beautiful aesthetic, all had repeating arch motifs either in their railing or under the **deck** in the **substructures**. Years later, with federal grant funding in hand during the 1930s, the city completed other grade-separation projects, including the NRHP-listed and National Historic Landmark (NHL) Triple Underpass Bridge adjacent to Dealy Plaza (NBI No. 1805709C5460001). For more information about grade-separation bridges, please see the **Railroad Grade Separations: When Transportation Systems Conflict, Pre-1946** section above.

The main purpose of Kessler's plan was to prevent flooding along the Trinity River and maintain connectivity between Dallas and the Oak Cliff neighborhood south of the river. However, the cost of implementing Kessler's recommendation to build a levee system and straighten the river caused that aspect of the plan to lose support. Additional flooding in 1921 and 1922 led the City of Dallas to create a board to review and resurrect some of Kessler's recommendations, with C.E. Ulrickson leading the board and creating a new implementation plan. In 1928, Ulrickson's bond issue passed and provided nearly $7 million for four bridges crossing the Trinity River, including the Corinth Street Viaduct (NBI No. 1805709C6240001, constructed in 1935) and the Commerce Street Viaduct (NBI No. 1805709F7325005, constructed in 1930). Francis Dey Hughes, a consulting engineer with no formal engineering education, and Jean H. Knox, a University of Illinois graduate, designed both of these reinforced **concrete variable-depth tee beam** bridges.[133]

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[132] Kessler, 14.

[133] Robert Jackson, Historic American Engineering Record, "Commerce Street Viaduct," HAER No. TX-35 (1996): 8-11.

Fort Worth

Fort Worth's geographic setting was somewhat similar to Dallas, as Fort Worth was also a city surrounded by the Trinity River, its tributaries, and numerous railroad lines. In 1909, Fort Worth hired George Kessler to create a comprehensive plan for the city, which was much shorter and less detailed than the Dallas plan he created two years later. Similarities in the plan included Kessler's recommendations to create a system of parks linked by waterways and scenic parkways and to eliminate railroad at-grade crossings; however, Kessler did not provide as sophisticated or specific justifications and discussions of each recommendation as he provided in his Dallas plan.

One of the areas that Kessler noted as an obstacle to growth for the community was the connection to areas of the city on the north, east, and west sides of the Trinity River and its branches, the Clear Fork and West Fork. Kessler's plan specifically included the Paddock Viaduct (NRHP-listed, NBI No. 0222000008101001) as part of a park and parkway located directly north of the Tarrant County Courthouse. The city and Tarrant County built four additional bridges to span the Trinity River, including Samuels Avenue Bridge (NBI No. 022200ZS0687001).[134] The Samuels Avenue Bridge provided vital connectivity to areas north of the river, including the 258-acre Fort Worth Stockyards and the city's meat packing district. The city also contributed money due to the bridges' locations on the edge of the then-city limits, but most of the funding came from a county bridge bond. S.W. Bowen, an engineer at Brennke and Fay of St. Louis, designed four of the bridges, including the Paddock Viaduct and the Samuels Avenue Bridge. Brennke wrote a paper entitled, "The Design and Construction of Four Reinforced Concrete Viaducts at Fort Worth, Texas," which stated that he designed two of the largest bridges as **variable-depth tee beam** bridges with self-supporting three-hinged ribbed arches. However, the Samuels Avenue and the (non-extant) East Fourth Street Viaducts were smaller, continuous concrete girder bridges that were built using falsework in the river to help save money.[135] A 1914 newspaper article noted the community's pride in the bridges and local leaders' anticipation of growth beyond the Central Business District after the bridges' construction.[136]

As the city continued to grow, with a population of over 100,000 by 1920, city officials decided to hire another firm in 1927 to complete a comprehensive plan for the city, specific to the city's streets and general urban development. The city hired Harland Bartholomew & Associates of St. Louis to prepare *A System of Major Streets for Fort Worth, Texas.* The Bartholomew document outlined a detailed plan for the city's continued growth, with specific streets recommended for widening and extension, as well as the recommended construction of new bridges and grade-separation structures shown on a map.[137]

As a result of the Bartholomew recommendations, the city and the county began a massive campaign to construct bridges over the Clear Fork and the West Fork of the Trinity River and to build numerous

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[134] The other bridges built at the same time were the West 7th Street Bridge, the Riverside Bridge, and the 12th Street Bridge, all of which are no longer extant.

[135] S.W. Bowen "The Design and Construction of Four Reinforced Concrete Viaducts at Fort Worth, Texas," *Transactions of the American Society of Civil Engineers*, vol. 78 (1915), 1258.

[136] "Fort Worth's $600,000 Chain of Bridges," *The Fort Worth Star Telegram* (December 14, 1913) 21.

[137] Harland Bartholomew & Associates, *A System of Major Streets for Fort Worth, Texas* (1927), http://www.fortworthtexasarchives.org/digital/collection/p16084coll17/id/138/rec/1, accessed on July 17, 2023.

grade-separation projects. To proceed with the plan, the county issued a $4.12 million highway bond, with a $500,000 appropriation for 14 river bridges. They hired Francis D. Hughes, the same self-taught bridge engineer who designed several Trinity River bridges in Dallas, to design their new bridges. Hughes's designs included three extant bridges over the West Fork of the Trinity River: the Henderson Street Viaduct (now SH 199, NBI No. 022200017105017) built in 1931, the Riverside Drive Viaduct Southbound Bridge (NBI No. 022200ZR5050001) built in 1931, and the East Belknap Street Viaduct, now designated US 77 (NBI No. 022200008101001) built in 1932. Hughes designed the Henderson Street and East Belknap Street Viaducts as **variable-depth concrete tee beam** bridges, with graceful arch designs and repeating arch railings. In Bartholomew's plan, the Henderson Street Viaduct was part of a scenic drive from the Central Business District to Lake Worth. Bartholomew's Plan also recommended constructing the East Belknap Street Viaduct, which was especially large, measuring 1,274 feet long, as the bridge spanned the river and railroad tracks of four railroads.[186] The Riverside Drive bridge was built as a **variable-depth steel plate girder** bridge (reasons for the selection of that main span type have not been found to date) with repeating arch railings.

As part of the Bartholomew Plan, the city and Tarrant County also began a large railroad at-grade elimination program in conjunction with railroad companies, particularly on the south side of downtown where the T&P Railroad had its railroad yards and terminal. Recognizing the importance of railroad grade-separation structures, city residents approved $600,000 in road improvements in June 1929 to help pay the city's portion of seven large underpasses.[138] The program included Henderson Street Underpass (NBI No. 022200ZH4400001) and Main Street underpass (NBI No. 022200017201039), which were completed in 1931 and 1932, respectively. Both bridges were reinforced concrete slabs with modest incised panels along the facias and repeating arch concrete railing.

After the NIRA and ERAA funding paid for grade-separation projects throughout the U.S., including on city streets, Fort Worth continued to build grade-separation structures, primarily of reinforced concrete bridge types. Examples include the 1936-built Business 287 underpass (NBI No. 022200017201039) and 1937-built East Vickery Boulevard underpass (NBI No. 022200ZV3900002). For more information about the railroad grade-separation bridges, please see the **Railroad Grade Separations: When Transportation Systems Conflict, Pre-1946** section above.

San Antonio

As the largest city in Texas until 1930, San Antonio's growth as a mission-based town occurred earlier than most Texas cities. Beautification of the city began with the establishment of Brackenridge Park at the turn of the twentieth century, when George Brackenridge gave the city of San Antonio 199 acres along the San Antonio River in 1899. To help manage and design the landscape within the park, which the city opened in 1901, the city created a position for a Park Commissioner to oversee the construction of roads, bridges, and eventually other amenities within the park.[139] Although early park

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[138] "$715,365 Paid for City Bonds," 5.

[139] Maria Watson Pfeiffer and Steve A. Tomka, *Brackenridge Park National Register Nomination* (June 2011), https://atlas.thc.texas.gov/NR/pdfs/11000513/11000513.pdf (accessed July 22, 2023), Section 8, 47-48.

commissioners, Ludwig Mahncke and Ray Lambert, had no formal training as landscape architects or planners, they were staunch advocates within the city government for the beautification of San Antonio.[140]

As the City Beautiful Movement ideals were pervasive in American culture by 1910 and San Antonio residents enjoyed the benefits of the urban oasis at Brackenridge Park, San Antonio Mayor Augustus Jones ran on a platform of city beautification in 1912. Soon after his election, he established a City Plan Committee to determine the appropriate ways to increase livability in the city. A young local architect named Atlee B. Ayers served as the committee's chairman. Together with Civic Improvement League director T. Noah Smith, Ayers's committee immediately focused on the need to improve the downtown area around the San Antonio River, which had become a "dumping ground," according to River Commissioner George Surkey.[141] The group noted that the river was the focal point for the city's business district, and the City Plan Committee prioritized beautifying the river. The committee gathered proposals from local architects Alfred Giles and Harvey L. Page, who both drafted plans for beautification along the river. The committee selected Page's plan for a 13-mile-long improvement project that included the concrete lining of the river and creating a series of locks and dams along the river to maintain a consistent water level. Page drafted plans to line the riverbed plus build dams and aesthetically pleasing concrete bridges, with a total construction cost of $1 million.[142]

After October 1913 floods of the San Antonio River through downtown, the city delayed the beautification project and expanded the river channel through downtown.[143] The city also created the River Park, a precursor to the Riverwalk, along the San Antonio River through downtown in 1914. The city passed a $100,000 bond to construct new reinforced concrete bridges across the San Antonio River in 1915.[144] One of the earliest examples of the aesthetically pleasing bridges in downtown was the St. Mary Street bridge over the San Antonio River (NBI No. 150150B30135003), which was built as a **variable-depth reinforced concrete girder** design, with two types of girder framing systems, including one that likely carried trolleys or streetcars and the other that carried all other traffic. The bridge has a deep **cantilevered** **deck** section with brackets and molded fascia, as well as a Beaux Art-inspired architectonic humped **balustrade** that has paneled friezes with swags.

Flooding of the San Antonio River in 1921 led to another wave of bridge construction in the 1920s. Not only were about a dozen bridges severely damaged, but city engineer J.G. Jeffery recommended that the city replace bridges that had **substructure** elements or other possible obstructions that could exacerbate flooding. For example, the city council approved the hiring of a consulting engineer to remove the Travis Street bridge and construct a new concrete variable depth girder bridge (NBI No. 150150B34690003); however, it appears that city engineers J.G. Jeffery and C. Raeber designed many

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[140] Pfeiffer and Tomka, Section 8, 52.

[141] Lewis F. Fisher, *American Venice: The Epic Story of San Antonio's River* (San Antonio, TX: Maverick Publishing Company, 2015) 33.

[142] Fisher, 35.

[143] Pfeiffer and Tomka, Section 8, 72.

[144] Jensen, E116.

of the 1920s bridges along the San Antonio River downtown.[145] Funding for these and most city bridges appears to have come directly from a small annual bridge bond, which was a fraction of the bond funding for flood improvements and park improvements.[146]

Like many city governments, the city of San Antonio also worked directly with railroad companies to eliminate at-grade railroad crossings; however, research did not reveal that elimination of at-grade railroad crossings was part of the city's overall planning efforts. Rather, city council records show that the city petitioned several railroad companies to build grade-separation projects without the city's contribution. This different relationship with railroad companies may have been directly related to the fact that San Antonio's commercial core was void of major railroad facilities.

Houston

Houston was one of the fastest growing cities in the state, with the convergency of about a dozen railroads in the city and 44,600 residents by 1900. The city had just one small 20-acre park (Sam Houston Park) around that time, and city beautification was not at the forefront of city officials. The city's growth progressed so quickly that the Houston Business League, later renamed the Chamber of Commerce, asked the city to consider planning measures around the turn of the twentieth century. By 1911, the Chamber's president Edward A. Peden urged the city to create a formal planning process to create a more desirable community for area residents as a way to attract new businesses. Newspaper articles refer to Peden's petition as a "clean-up" plan, indicating that residents needed a place to get away from the consistent building and improvement projects in downtown Houston.[147] The Houston Parks and Boulevards Commission, led by E.B. Parker, hired Arthur C. Comey to create a master planning document for the city.[148] Comey, a Massachusetts-based landscape architect and engineer, was a newly practicing city planning consultant at the time, and was a recent graduate from Harvard, where he studied landscape architecture under Frederick Law Olmstead, Jr.[149]

In April 1913, Comey drafted a proposed plan of parkways, boulevards, and parks, with a specific focus on emphasizing the city's natural topography and bayous. His plan, entitled *Houston: Tentative Plans for Its Development*, mapped out the proposed parks and roads, as well as the cost of construction.[150] Of the main tenants of city planning, Comey identified circulation and connectivity of primary importance in Houston. In particular, the Comey plan suggested the creation of boulevards and parkways as scenic roads through green spaces and future parks. He specifically noted that bridges should be constructed of reinforced concrete with "high long-span arches" over the city's deep bayous. He also noted the importance of beautifying bridges as much as possible so they enhanced

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[145] San Antonio City Council Minutes, Book J, 503.

[146] Example of bond funding amounts in 1928 and 1929 listed in San Antonio City Council Minutes, Vol. K, 379.

[147] "Clean-up Campaign Now Agitating Bayou City," *The Galveston Daily News* (March 25, 1912) 5.

[148] "City Parkway Plans Embodied in Report," *The Houston Post* (April 23, 1913) 10. Peter C. Papademetriou, *Transportation and Urban Development in Houston: 1830-1980* (Houston, TX: Metropolitan Transit Authority of Houston, n.d.) 17.

[149] "Arthur Coleman Comey," *The Cultural Landscape Foundation: Connecting People and Places*, https://www.tclf.org/pioneer/arthur-coleman-comey, accessed July 14, 2023.

[150] Arthur C. Comey, *Houston: Tentative Plans for Its Development* (Boston: Press of George H. Ellis Company, 1913) 8. Papademetriou, 17.

the landscape. Additionally, Comey's plan provided specific recommendations for bridges. For example, he noted that the Franklin Avenue bridge at Buffalo Bayou required replacement due to its insufficient width and geometry adjacent to Washington Street. As a result, the city built a new bridge (NBI No. 121020B25401001) at that location in 1914.

Comey also noted how the reinforced **concrete open-spandrel arch** bridge carrying Main Street (already under construction at the time of his planning) over Buffalo and White Oak Bayous and UPRR (NBI No. 121020B41697003) would fit in nicely with the western boulevards he proposed. The city heeded Comey's recommendation for the Main Street bridge, with City Bridge Engineer Frank L. Dormant designing the structure.[151] After it became clear to the city's bridge committee that the Main Street Viaduct could not be constructed solely with local funds, efforts including newspaper advertisements, city-wide meetings, and bond propositions led to city-wide support of this bridge construction.[152] The Houston Electric Company contributed to the financing of this bridge to the sum of $100,000.[153] Based on their advertisement in the *Houston Daily Post*, the company wanted to run electric streetcars over all bridges that crossed the Buffalo Bayou, and they wanted to show residents the power of cooperation between private companies and city officials for the purpose of city improvements.[154] Others showed their support for the bridge in the newspaper, claiming it would bring the "fifth warders" increased access to the bourgeoning commercial district just south of the proposed bridge, and subsequently increase property values.[155]

While Comey created a very detailed and comprehensive plan, there was little widespread support in the city to follow through on most of Comey's plans on a broad scale. University of Texas professor, Archie Henderson, noted that the city's constituents heavily resisted city planning efforts, especially zoning and subdivision ordinances.[156] After a plea from city engineer J.C. McVea, who cited major deficiencies in the layout of the city, with the foremost being a lack of a major street plan, Mayor Halcomb appointed a City Planning Commission in 1922. With widespread support for park development and acquisition, the city of Houston Park Board hired George Kessler in 1925 as an advisor to acquire and develop plans for Hermann Park, which included parkways and boulevards.[157] By 1929, the City Planning Commission had a report that listed several solutions to the gridlocked traffic and safety concerns that plagued the city. Many of the recommendations included the construction of several railroad grade-separation bridges, and the plan also noted that the city should

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[151] "Viaduct Planned by F. L. Dormant," *Houston Daily Post* (April 20, 1913), 59.

[152] "For A Viaduct" *The Houston Post* (August 5, 1910): 11.

[153] "To The People of Houston," *Houston Daily Post* (May 2, 1913), 10.

[154] "To The People of Houston," 10.

[155] The fifth ward in Houston was comprised of freed African Americans following emancipation in the 1800s. Though known for its strong African American community and black-owned businesses, the ward was overrun with poor municipal and public services. The area was cut-off from more prosperous portions of Houston due to the lack of transportation routes over the Buffalo and White Oak Bayous. See *Texas Happens*, "History of Fifth Ward, Houston." Accessed August 28, 2023. History of Fifth Ward, Houston | Texas Happens; see also, "For A Viaduct" *The Houston Post* (August 5, 1910): 11.

[156] Archie Henderson, "City Planning in Houston, 1920-1930," *The Houston Review*, https://www.houstonhistorymagazine.org/wp-content/uploads/2015/12/9.3-City-Planning-In-Houston-1920-1930-Archie-Henderson.pdf, accessed on June 15, 2023.

[157] Houston City Planning Commission, *Report of the City Planning Commission, Houston, Texas* (Houston: The Forum of Civics, 1929) 93.

build parkways along Buffalo Bayou and White Oak Bayou.[158] It appears that some of the bridges built as part of the 1929 plan are Franklin Street at Buffalo Bayou (NBI No. 121020B25401002), North Sheppard Drive at White Oak Bayou (NBI No. 121020B58977002), and White Oak Drive at White Oak Bayou (NBI No. 121020B69161263). As noted in the MPDF, Houston continued to construct their parkway boulevard and street extension plan into the 1930s, with bridge engineer J.G. McKenzie designing these bridges.[159]

Austin

Of the cities with comprehensive city-wide planning studies, the city of Austin was by far the smallest, with a population of only 22,000 by 1900.[160] As the state's capitol city, city residents and officials focused on beautifying the city in the early twentieth century. As early as 1904, citizen groups worked with local leaders to make the city more livable. This included city residents building sidewalks and city officials passing ordinances for construction in public right-of-way.[161] Following a major flood of the Colorado River in 1907, the city and county governments worked together to help control flooding by building a new dam and constructing a new, higher bridge across Congress Avenue (NBI No. 142270B00425007). The county issued a $350,000 bond to pay for the dam and the bridge, with $200,000 allocated specifically for the bridge.[162] The city engineer, M. Iredell, urged the citizen-based Congress Avenue Bridge Campaign Association and county commissioners of the importance of building a reinforced concrete bridge at the Colorado River. He explained that the logical choice for the crossing would be a reinforced concrete arch bridge, and he argued against building a truss bridge at the crossing. His plea for an arch bridge illustrated how the City Beautiful Movement married well with bridge design:

> "From the point of beauty, a well-designed concrete bridge is much superior to the steel bridge. The gracefully curved arches reaching from **pier** to pier add beauty to the landscape and give an appearance of strength and solidity. The view from the bridge is not obstructed by steel trusses or girders extending above the level of the eyes, and far overhead in many instances. The reinforced concrete bridge has no parts higher than the ordinary railing. The floor would necessarily be paved the same as a street, and would be durable and comfortable to travel. Such a structure is permanent, does not rust, or its part work loose and vibrate, nor does it require painting. In maintenance, therefore, it is economical, the expense being limited to keeping the road and foot ways in good repair. With an arched bridge of artistic design at Congress Avenue…the beauty of the river front will be much enhanced."[163]

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[158] Houston City Planning Commission, 10.

[159] Note, none of the bridges cited in the MPDF are in the Study Population, and therefore are not mentioned herein.

[160] Texas Almanac.

[161] Rebekah Dobrasko, *West Fifth Street Bridge at Shoal Creek National Register Nomination* (2019), https://atlas.thc.texas.gov/NR/pdfs/100004750/100004750.pdf (accessed on August 5, 2023) Section 8, 10.

[162] "Engineers are Heard," *The Austin Daily Statesman* (August 23, 1908) 6.

[163] "Reinforced Concrete Superior to Steel," *Austin American-Statesman* (June 14, 1908) 2.

Upon the urging of Iredell, as well as UT Professor T.U. Taylor, the county commissioners selected out-of-state firms to design and build the bridge. The bridge's engineers were Dr. J.A.L. Waddell and his young partner John Lyle Harrington, and they designed an **open-spandrel arch bridge** for the crossing. A December 1910 newspaper article cited their firm, Waddell & Harrington (Kansas City, Missouri), as winning the contract based on Waddell's reputation as a well-respected engineer and author of several publications, including and ironically *The Designing of Ordinary Iron Highway Bridges* published in 1884. The county hired William P. Carmichael Company of Williamsport, Indiana to build the bridge, and the company sent an experienced resident engineer from Portland, Oregon to oversee the construction.[164]

As the capitol city and the home of UT, the city continued to grow, with 34,000 residents in 1920.[165] In 1926, the city voted to shift its governmental structure from a ward form of government to a council-manager system. Historian Rebekah Dobrasko stated that this change "reflected a new, business-like approach to governing with urban planning—zoning, infrastructure, and beautification—as the means by which to improve the economy and functionality of the city."[166] After this shift in the city government, business leaders urged the city to improve and beautify the city to attract new businesses. As a result, the city established a city planning commission, who in turn proposed hiring an urban planning firm to help enhance the city's beauty and functionality. The city received several bids from urban planning companies, including Hare and Hare of Kansas City, Missouri ($11,000), Ford of New York ($10,500), and Terrel Bartlett of San Antonio ($7,500). The winning bid, however, came from the Dallas-based firm of Koch and Fowler ($4,000). O.H. Koch won the job because he not only had the least expensive price, but he also promised the city that he would personally complete the entire study, rather than using his staff to complete the project. So, together with two assistants, Koch undertook the project.[167]

In newspaper articles, Koch noted that Austin had a natural beauty that was unparalleled and just needed to be enhanced. He noted that his main purpose was to determine the best locations for various types of state government buildings, the routing of public service utilities, locations of parks, and "all such things which affect a city's beauty and efficient functioning of the community as a whole."[168] In addition to working with city officials, Koch worked directly with state officials and university leaders to enhance the areas directly adjacent to the state capitol and the university campus as well. Traffic was a major consideration as well, with Koch undertaking an analysis of traffic patterns in the city. He also looked in a three-mile radius around the then-city limits to plan out the inevitable growth that he correctly predicted would come.[169]

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[164] "The Colorado Bridge," *Austin American-Statesman* (December 4, 1910) 2.

[165] Texas Almanac.

[166] Dobrasko, Section 8, 10-11.

[167] "City Planners Map Austin Growth: Koch and Fowler Busy Here," *The Austin American-Statesman* (June 12, 1927), 2.

[168] "City Plan Commission Will Meet Today to Hear Report on Six Moths Survey," *The Austin American* (January 4, 1928), 1.

[169] "Koch Starts Work on Paving Program as First Step in Plan," *The Austin American* (June 1, 1927) 2.

The plan stated that the city needed to improve the connectivity along and across the Colorado River, Shoal Creek, Waller Creek, and Blunn Creek (in Travis Heights) with a series of parkways running along each of the waterways. The plan noted a preference for ornamental reinforced concrete bridges to be used, and even stated that "it would be criminal to build an ugly steel structure" for a new bridge at 24th Street over Shoal Creek.[170] The plan noted that constructing these reinforced concrete bridges would have minimal additional cost and would prove very expensive in the future to change.

As a result of the recommendations in Koch's plan, submitted to the city in January 1928, Mayor McFadden called for a $4.25 million bond issue to be voted on in the May 1928 election.[171] With the passage of the bond, the city built dozens of bridges along the aforementioned waterways over the next decade, with the first wave of construction occurring by 1931. Currently, there are many extant bridges in the Study Population along these waterways, with nearly all of them exhibiting some type of ornamentation in their **superstructure** design (e.g., reinforced concrete arch bridges) or in their railing.

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[170] Koch & Fowler, "City Plan for Austin, Texas" (Austin, Texas: City of Austin, 1928, reprinted by City of Austin in 1957) 67.

[171] "Bond Election For City Will Be Held on May 19." *The Austin American* (March 27, 1928) 1-2.

Criterion C: Engineering

Non-Truss Bridge Engineering, 1900-1945

Of the 3,850 bridges in the Study Population, only 50 bridges (approximately one percent) predate 1917, and no bridges date prior to 1900. This means that the construction year of a vast majority of Study Population bridges falls within a 28-year period that began just after the formation of the THD in 1917 and continued until the end of World War II in 1945. The MPDF contextualizes the time period from 1919 to 1945 as the "Early Development of the Texas Highway Department and U.S. Highway System." According to the MPDF*,* noteworthy trends in bridge engineering during this time were standardization, increasing uniformity in bridge materials, and matching bridges to highway classification and topography. The MPDF also states that Texas engineers "showed a growing appreciation and awareness of bridge aesthetics" particularly in "urban areas, and structures located adjacent to park and railroad lines" where an emphasis was placed on simple clean lines and applied decorative details to **abutments**, **piers**, and railings.[172]

Implicit in each of the trends identified by the MPDF is the professionalization of engineering as a public service career. As noted above, the late 1910s to the 1920s witnessed a shift in control over technical decisions in highway bridge engineering. County road officials and private contractors ceded technical control to federal and state government agency engineers. From a policy perspective, lawmakers began investing heavily in highway systems of a statewide and national character, largely in service to rural populations and motorists. Engineers occupied the nexus of where this policy met its execution and were in a unique position to dictate technical requirements for roadways and bridges. The government engineers were usually young men, college-educated, and trained to view their profession as an applied science. This marked a significant break from practices of the pre-automobile era, where technical decisions had been made locally, often based on established personal relationships or sales pitches, and professional engineers mostly confined themselves to working in the private sector, particularly for railroad companies or as consultants on major bridge projects. The large cities that had professional city engineers were an exception.[173]

The THD was an agency of change from its outset. Its founding mission was the distribution of new sources of federal and state highway funds to counties in an effort to improve rural highways and "get farmers out of the mud," as well as develop road networks capable of supporting long-distance automobile travel. In implementing this program, the principal concern of engineers of the THD and the federal BPR, which the U.S. Congress charged with overseeing each state's implementation of the Federal Aid Road Act of 1916, was ensuring that projects built with these funds met minimum technical standards. George Wickline, the THD's first State Bridge Engineer, was an engineering

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[172] Jensen, E57 and E129.

[173] For an excellent overview of the technical impacts of America's highway policy, see Bruce E. Seely, *Building the American Highway System: Engineers as Policy Makers* (Philadelphia, Pennsylvania: Temple University Press, 1987).

graduate from UT in 1904, a former Dallas city engineer, and only 36 years old when appointed to the job of creating a statewide highway bridge program. He fit the mold of a new generation of college-educated engineers, primed to make a difference in the way Texas built highway bridges. The most important of his new responsibilities was overseeing the design and approving plans for what eventually totaled over the course of a 25-year career to be thousands of highway bridges.[174] Serving in the post until his death in 1943, Wickline ensured that the THD's bridge engineers consistently referenced and relied on standards, specifications, guidelines, and policies to validate their designs.

In other words, in a short but critical time during the late 1910s to the 1930s, the THD adopted practices and methods that remain relevant to how bridges are designed and built to the present day. Wickline and his colleagues could not be sure at the time they started just how successful and prolific they would ultimately be, but the path was clear once the public and elected officials had fully embraced the automobile and the convenience of rapidly improving highway systems and their bridges.

The Historical Significance of Standardization

Standardization is a significant trend in methods of bridge design that influenced the decisions that Texas bridge engineers needed to make about the suitability of specific bridge types to any given project. Paradoxically, federal and state legislators intended the highway aid programs to improve transportation in rural counties and market towns, the very places that usually lacked access to local professional engineering expertise. A state law passed in 1905 required every Texas county commission to appoint a county engineer, but this position was frequently filled by individuals with local political connections, some experience in construction, and no formal college-level training.[175] The same was true across most of the United States. BPR engineers, who had been working with rural counties across the United States on demonstration road and bridge projects since the 1890s, knew from hard-won experience that the county governments and county engineers were a weak link in the BPR's goal of improving rural roads and bridges for automobile travel. Counties preferred low-cost solutions such as lightweight metal truss bridges with low load capacities and untreated wood bridges that quickly deteriorated and needed frequent maintenance or replacement.[176]

Federal and state engineers had numerous other concerns about local bridge building practices. Counties had a history of selecting contractors who did not use bridge types, materials, or methods that met BPR and THD requirements. Specifically, federal and state engineers were suspicious of the lightweight, prefabricated, pin-connected, metal-truss bridges of the type common in Texas and most other states up to the 1910s. Bridge companies and their salesmen that showed up at county courthouses to bid on projects resisted outside professional oversight. The companies had financial incentives to cut corners and undersize truss members, especially in the work performed for cost-conscious county governments. These bridges sometimes buckled or failed under heavy loads.

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[174] Peggy Hardman, Historic American Engineering Record, East Navidad River Bridge, HAER No. TX-79 (2000): 3.

[175] The State of Texas Passed at the Regular and First Called Sessions of the Twenty-Ninth Legislature, Special Laws of Texas, 1905 (Austin, Texas: The State Printing Company, 1905): 322.

[176] Federal Highway Administration, 64-89.

Furthermore, federal and state engineers wished to avoid the use of patented and proprietary bridge types and construction systems. Many of the early reinforced-concrete bridge builders such as Daniel Luten held patents on reinforcing bars or reinforcing systems that federal and state engineers considered of dubious value. The government engineers preferred unpatented alternatives informed by professional knowledge and college-level training. By establishing standards, federal and state engineers made it increasingly difficult for private contractors to market their own designs since there was no room to deviate from the federal or state requirements.

Another factor in standardization was the simple fact that THD engineers were few in number and were motivated to find methods that would allow a small staff to oversee a statewide highway program of unprecedented scope. In 1919, THD had only three bridge engineers for the entire federal and state aid program. They quickly focused on standardization as an approach to bring construction projects into line with their professional judgement as to the most appropriate bridge types, details, and methods of construction. A relatively small number of standard bridge drawings could fulfill the needs of a much larger number of projects. By 1920, the THD Bridge Section had developed standard drawings for timber trestle, concrete slab, concrete tee beam, steel I-beam, and steel truss bridges in various span lengths up to 60 feet. If counties and contractors followed the plans, their projects would be eligible for federal and state aid, a strong financial incentive for cash-strapped county governments. Engineers only needed to approve the standard drawings once, confirm that the design was cost effective through an open bidding process, and at final inspection check the completed bridge against the standard to ensure that it had been built according to plan. In 1922, State Bridge Engineer Wickline wrote that the counties "had used standard plans on almost every state and federal aid bridge project that had come through his office."[177]

In 1923, the THD assumed administrative control over the state highway system, which relieved some of the inherent technical difficulties in allowing counties control over federal and state aid projects. After the State Highway Act of 1925, which resolved the legal and administrative process by which the THD assumed ownership of county roads and bridges, the THD had "total control" over state highway construction and maintenance.[178] By this time, THD had reorganized Wickline and his small but growing staff into the THD Bridge Division. Although control of the quality of work undertaken by counties no longer remained paramount, Wickline now used standardization to focus the Bridge Division's talents where they were needed most. The Bridge Division used standard bridge designs whenever possible, freeing time for engineers to focus on projects that presented unusual site conditions such as lengthy crossings and locations prone to unstable soils or flooding, where foundation and **substructure** designs needed special care and consideration.

THD's standard plans extended across a range of common **superstructure** types including **concrete tee beams**, **concrete slabs**, **concrete box culverts**, steel trusses, **steel I-beams**, and timber **stringers** and trestles. Typically, the plans applied to a range of lengths and roadway widths within that superstructure's load-carrying capacities. For example, plans for concrete tee beam

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[177] State Highway Department, *Third Biennial Report*, 53.

[178] Jensen, E33.

superstructures prepared between 1918 and 1943 covered span lengths from 28 to 40 feet in 2-foot increments. The plans also accommodated roadway widths from 20 to 40 feet. The THD's bridge engineers also prepared plans for bridge substructure components such as concrete solid-stem and open-web **piers**, concrete **abutments**, concrete pile **bents**, timber pile bents, and concrete **wingwalls**. Early standard-design railings ranged from simple steel pipe railings to concrete **balustrades** with urn-shaped balusters. The most popular standard railing was a two-rail-high concrete railing with concrete posts spaced 1 foot apart.[179]

From the mid-1920s onward, the THD Bridge Division continually reviewed and updated its standard drawings. The number of standards grew quickly into the hundreds. New standards replaced older ones, often reflecting adaptations and variations in common bridge types like concrete slabs, concrete tee beams, and steel I-beams for wider roadways, longer spans, material costs, and constructability. By the late 1920s and early 1930s, the THD Bridge Division's use of standard bridge designs for steel I-beam and concrete box culvert, slab, and tee beam bridges was one of its hallmark tendencies and would remain so through 1945 and beyond.

The Historical Significance of Uniformity of Materials

Prior to the late nineteenth century, materials used in bridge construction, or for that matter almost any other construction, rarely required manufacturers of those materials to meet uniform and quantifiable specifications. In most instances, manufacturers sold materials in a market economy where buyers judged quality based on reputation and perhaps a few rudimentary tests. Professional engineers working for America's railroads were the first to acknowledge the desirability of materials that met uniform specifications. Specifically, frequent failure of steel railroad rails motivated the engineers to assert greater control. They formed the American Society for Testing Materials in 1898, a few years later changing the name to the American Society for Testing and Materials (ASTM).

The ASTM was and still is a voluntary scientific committee of industry, academic, and government representatives who voted to approve specifications. ASTM did not compel manufacturers to meet the specifications, yet those manufacturers had little choice but to comply when their large corporate and governmental customers adopted ASTM standards. The federal government established a National Bureau of Standards (NBS) in 1901, but manufacturers and engineers resisted the idea of a federal government agency mandating national specifications. Instead, NBS became mostly a compiler of standards issued by various professional organizations such as the ASTM. A result was a nationwide system of materials classification where a non-governmental voluntary society, the ASTM, came to set national specifications for most types of construction materials. One of ASTM's first specifications was "Structural Steel for Bridges," approved in 1901. The following year ASTM members formed a committee on Cement, Lime and Clay Products, approving a specification for Portland cement used in making structural concrete.

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[179] Texas State Highway Department, Reinforced Concrete Deck Girder Spans, Standard Drawings [98 plan sets], 1918-1945; Jensen, E122.

In 1914, BPR engineers led in forming the AASHO (later renamed AASHTO), which also had as its mission a voluntary and cooperative adoption of policies intended to promote improved design and construction practices among a growing number of state highway departments. After 1916, federal engineers of the BPR encouraged state highway department engineers to adopt ASTM and AASHO specifications with federal aid projects. In 1918, THD's bridge engineers began requiring contractors to use materials meeting ASTM and AASHO specifications in any project receiving federal and state aid. They had every reason to desire ASTM-approved materials that had quantifiable and uniform physical properties such as density, elasticity, resistance to corrosion and decay, and **compressive**, **tensile**, and shear strength.[180]

Over time, THD bridge engineers developed extensive knowledge of the properties, availability, cost, and constructability of materials used to build highway bridges in Texas based on local conditions. They knew the cost of shipping or availability of a material from in-state or out-of-state manufacturers. The THD's engineers used this knowledge to refine and update designs for standard bridge components — beams, columns, **decks**, walls, foundations, etc. — matching those designs to the physical properties and structural performance of various grades of steel and concrete. They also paid careful attention to the constituent parts of concrete — Portland cement, sand, gravel, and water — as well as a host of other materials used in bridge construction including paint, bronze, stone, brick, bituminous asphalt, galvanized metal, structural timber, and timber preservatives. The THD issued updated specifications in 1926, and a year later in 1927 Texas State Bridge Engineer Wickline, as a member of the AASHO Sub-committee on Bridges, was one of 25 state bridge engineers who cooperatively agreed to adopt a common "Standard Specification for Highway Bridges and Incidental Structures." The specifications of 1927, the first of their kind on a national level, had the "purpose of encouraging and promoting a more uniform practice in the design and construction of highway bridges." The Sub-Committee on Bridges adopted 21 provisions for materials, cross-referenced to ASTM's specifications. Texas's specifications closely aligned with AASHO's.[181]

Concrete – Nearly every bridge in the Study Population makes use of concrete. Concrete is found in railings, **decks**, **slabs**, **beams**, **arches**, and **substructure** units. Pre-1945 concrete, and most concrete today, is a composite material of Portland cement, aggregate (washed river gravel or crushed rock), sand, and water. Portland cement reacts with the water to harden and set, binding the entire mass into a monolithic material with high **compressive** strength. Builders pour the wet concrete mix into forms, which can be sized and shaped to meet specific design requirements. Concrete's initial plasticity is one of its greatest advantages as a building material, as well as a limitation; builders need to support the forms while the heavy concrete sets or risk collapse. Scaffolding, though temporary, becomes in itself a structural challenge to design and may present limits in constructability, especially as spans become longer, heavier, or span deep and fast-flowing streams. THD kept most of its standard concrete bridge plans to a modest length well within the limits of the materials' capacities.

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[180] Texas State Highway Department, *Specifications and Contract* (1918).

[181] Texas State Highway Department, *Road and Bridge Specifications* (1926); American Association of State Highway Officials (AASHO), *Standard Specifications for Highway Bridges and Incidental Structures* (July 1, 1927).

AASHO's and the THD's bridge specifications required all Portland cement used in bridge construction to adhere to standards similar to ASTM Standard Specification C9.[182] Portland cement is the key ingredient in concrete. It was and still is made by heating limestone (calcium carbonate) and other materials such as clay and iron oxides in a kiln to approximately 2,600°F. At this temperature, a chemical reaction releases carbon dioxide and forms calcium silicate. Manufacturers grind the resulting hard substance, called clinker, with a small amount of gypsum to make Portland cement. In the United States, the first large-scale production of Portland cement took place in northeast Pennsylvania during the 1870s. The last quarter of the nineteenth century witnessed significant experimentation with concrete and an ever-widening list of applications.

Texas emerged early among states where its manufacturers produced a large quantity of Portland cement. Entrepreneurs who started Texas's first Portland cement plants took advantage of local sources of limestone, clay, iron oxide, and gypsum. Portland cement factories are invariably located next to limestone quarries since cement is about 75 percent limestone. In 1882, two cement factories operated in San Antonio and one in Austin, and those remained the primary producers for nearly three decades. The Texas cement industry grew rapidly from 1909 to 1929, by which time ten plants had an annual production capacity of over 7.3 million barrels, or approximately 1.1 million tons of cement, much of it destined for highway pavements and bridges.[183] The Texas cement industry was not insignificant, ranking the twelfth most valuable industry in the state in 1925 and the second largest cement producing state by volume in the nation in 1945.[184]

AASHO and the THD took care to specify that water used in concrete was to be reasonably clear and free from oil, salt, and alkali "subject to approval of the resident engineer." THD required the resident engineer to oversee the preparation of samples of concrete made with water of satisfactory quality and then make comparative tests during construction. Any reduction in strength greater than 10 percent was sufficient cause to reject a water source. THD specifications graded aggregate and sand as "fine" or "course" with a further definition of Grade A fine, used in structural applications, as meeting 100 percent of the required **compressive** and **tensile** strength of samples at the age of 7 days and 28 days per ASTM Specification C9.

Steel Reinforcement Bars – By 1918 when the THD formed, Texas bridge engineers and contractors already had a maturing knowledge of reinforced concrete, a composite material consisting of concrete with steel reinforcing bars placed in the tension zones of structural members such as **arches**, **slabs**, **boxes**, and **tee beams**. Reinforcing was key to the adaptability of concrete to bridge applications since unreinforced concrete has low tensile strength and thus susceptibility to cracking, bending, and buckling. Engineer Ernest Ransome's Alvord Lake Arch Bridge of 1889 in San Francisco's Golden Gate

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[182] ASTM C9, which had been updated in 1926, required compressive strength of 2,000 pounds per cubic inch after 28 days, tensile strength of 325 pounds per cubic inch, as well as other qualities such as fineness of the cement, extent of impurities, percentage of water for standard cements, and setting times of no less than 45 minutes to an hour. U.S. Department of Commerce, National Bureau of Standards, *Standards and Specifications for Nonmetallic Minerals and Their Products,* Miscellaneous Publications No. 110 (Washington, D.C.: Government Printing Office, 1930): 287-88.

[183] A standard cement barrel was 4 cubic feet or 30 gallons, weighing 376 pounds.

[184] Texas State Historical Association, *Cement Production* (1976, updated December 1, 1994), electronic document, https://www.tshaonline.org/handbook/entries/cement-production [accessed August 2023].

Park is typically acknowledged as the first reinforced-concrete bridge constructed in the United States, so engineers had accumulated nearly three decades of experience with reinforcing by the time THD embarked on establishing specifications for reinforcing bars.

The period of greatest experimentation in concrete bridge reinforcing systems happened during the decades of the 1890s and the 1900s. Engineers and architects used and took out numerous patents for systems using steel wire mesh, bars, and girders as reinforcing; however, engineering opinion had consolidated around the suitability of steel reinforcement bars by 1910. Practical experience and scientific testing showed that adequate strength could be achieved with comparatively small diameter bars of one-quarter to one-and-one-quarter inches in diameter spread out across a tension zone in order to prevent stresses from concentrating at any one point in the concrete. Engineers still debated the shape and texture of the bars with plain round, plain square, twisted and deformed bars having their supporters. Deformed rounded bars, which had projections or depressions on all surfaces, eventually won out during the 1920s as furnishing the greatest bond between concrete and steel as proven through experience and scientific testing.

Engineers working in cities like Milwaukee, Pittsburgh, Philadelphia, and Washington, D.C. from 1895 to 1910, or for particular railroads such as the Delaware, Lackawanna and Western Railroad or the Florida East Coast Railway, proved the viability of reinforced concrete on large-scale transportation projects. Historians regard the Oregon State Highway Department's Columbia River Highway construction in 1913–1922 as the first of the nation's state highway departments to apply reinforced-concrete bridge building technology to a large number of bridges on a major highway project. Long-span **closed** and **open-spandrel arches** were the earliest major reinforced-concrete bridges in the United States, reflecting a relatively conservative engineering outlook that concrete was best suited as a substitute for stone. By 1905, engineers had started applying techniques of bar reinforcing to short-span bridges such as box culverts, slabs, and tee beams. The Office of Public Roads, predecessor to the BPR, published Bulletin No. 39, *Highway Bridges and Culverts* in 1911, offering practical advice to state and county highway officials on building reinforced concrete slab bridges up to 20-foot span and tee beam bridges up to 50-foot span. Texas bridge engineers designed reinforced concrete bridges of all types by around 1910 taking advantage of knowledge that was spreading rapidly through publications and practical experience.[185]

The THD's and AASHO's bridge specifications as adopted in 1926 and 1927 required that reinforcing bars meet or be similar to ASTM Standard Specification A15, adopted in 1914. This specified that all structural grade reinforcing bars have a tensile strength of 55,000 to 70,000 pounds per square inch, with higher requirements for intermediate grade and hard grade bars.[186] AASHO further required that all bars be made by the open-hearth steel manufacturing process, generally considered more appropriate to structural steel than the Bessemer process. While Texas had significant in-state sources

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[185] Charles H. Hoyt and William H. Burr, *Highway Bridges and Culverts,* U.S. Department of Agriculture, Office of Public Roads Bulletin No. 39 (Washington, D.C.: U.S. Government Printing Office, 1911): 12-15; Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types*, NCHRP Project 25-25, Task 15 (October 2005): 3:53-70.

[186] Irving H. Cowdrey and Ralph G. Adams, *Materials Testing, Theory and Practice* (New York: John Wiley & Sons, 1925), 118; Texas State Highway Department, *Specifications for Design of Structures* (October 1935): Sheet 5.

for the manufacture of Portland cement, in-state sources of reinforcing bars were limited. The Texas Rolling Mill Company of Fort Worth advertised its ability to producing reinforcing steel meeting the specifications of ASTM in the *Texas Trade Review and Industrial Record* publication of 1915, a year after ASTM had adopted the Standard Specification A15.[187] George W. Armstrong & Company of Forth Worth manufactured bar iron and reinforcing steel according to an ad in the *Southwestern Railway Journal* of 1921.[188] In 1928, BPR Chief Thomas MacDonald testified before Congress that Texas was among states where reinforcing bar supplies sometimes ran short. He said "approximately a fifth of the reinforcing steel used recently on Federal-aid projects in Texas has been foreign manufacture. No foreign cement has been used on Federal-aid work in this State, but a small amount has been used in some of the coast county work. No foreign cement is being used on the 51 contracts awarded by the State last year; but nearly 4,000,000 pounds of foreign reinforcing steel is being used." The testimony suggested that THD's contractors purchased the imported reinforcing bars at competitive prices, yet MacDonald told Congress that the main factor driving shortages of reinforcing bars and other construction materials needed to execute federal and state highway policies was that no other country in the world was attempting to carry traffic on major rural highways to the degree attempted by the United States.[189]

Structural Steel – Historians consider the refinement of technologies capable of producing vast quantities of structural steel a significant trend in America's industrialization over the course of the second half of the nineteenth century. The iron and steel industry was a quintessential leading economic sector spawning many offshoots, including the metal-truss bridge fabricators that feature prominently in Texas bridge history prior to 1918. The development of open hearth steel and the advance of major steel makers, particularly Carnegie, in dominating the market for mass production of structural steel in the 1880s and 1890s set the stage for a high degree of engineering confidence in steel for constructing high-rise buildings and long-span bridges. By 1901, ASTM permitted only open-hearth steel for structural shapes for bridges, meaning that any angle, channel, bar, plate, or **I-beam** procured by a bridge builder in Texas met ASTM's Specification A7. Properties of this steel included phosphorus not over six one-hundredths of a percent and tensile strength of 55,000 to 65,000 pounds per square inch.[190]

Texas has never been a major steel producer, and all structural steel used for bridges prior to 1945 originated from out of state.[191] Perhaps the most consequential development to Texas highway bridge engineering of the period covered by this non-truss study was the reduction in cost of structural steel. Between 1900 and 1919, the price of steel fell 30 percent, and by 1930 it had fallen 48 percent

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[187] Texas Trade Review and Industrial Record, (May 15, 1915): 1.

[188] *Southwestern Railway Journal*, Volume XV, Number 11 (November 1921): 11.

[189] Roads, Hearings before the Committee on Roads, House of Representatives, Seventieth Congress, First Session on The General Authorization Bills and Proposed Amendments to the Federal Highway Act (Washington, D.C.: Government Printing Office, 1928): 255-256.

[190] U.S. Department of Commerce, Bureau of Standards, *Standards and Specifications for Metals and Metal Products,* Miscellaneous Publication No. 120 (Washington, D.C.: Government Printing Office, 1933): 249-250.

[191] Wayne Gard and Diana J. Kleiner, *Iron and Steel Industry* (Texas State Historical Association, 1976, Updated April 4, 2017), electronic document, https://www.tshaonline.org/handbook/entries/iron-and-steel-industry [accessed August 2023].

compared to 1900 prices. The price of steel held relatively steady throughout the Great Depression until the outset of World War II, when steel prices began climbing.[192] Major steel corporations such as U.S. Steel (Carnegie Division), Bethlehem Steel, Jones and Laughlin, Phoenix, and Pencoyd (all with headquarters in Pennsylvania) dominated the market for structural steel sections. These firms and a few others produced the angles, channels, plates, and I-beams that formed the basic building components of truss, **plate girder**, and **steel I-beam bridges**.

Engineers received a boon in the supply of I-beams, in particular, due to advances in the methods of manufacturing them. In 1905, Bethlehem Steel purchased the rights in the United States to the Grey Universal Beam Mill, invented by Englishman Henry Grey. The mill was equipped with both horizontal and vertical rolls, which enabled it to roll H-section beams directly from blooms (a mass of red-hot steel), avoiding the elaborate and labor-intensive **riveting** previously needed to produce the largest beams. In 1908, Bethlehem Steel began selling its Grey mill beams, usually referred to as wide-**flange** beams, noting that the beams offered a 10 to 20 percent decrease in weight without a decrease in strength compared to conventional I-beams then being manufactured by U.S. Steel and other competitors. Bethlehem's beams were also deep, up to 24 inches, as of 1911.[193] U.S. Steel, which marketed its beams as "Carnegie" beams, invested in new rolls in 1911 to compete with Bethlehem; however, even with the same height and flange width, Bethlehem's beams were thinner and had a weight-to-strength advantage. The competition between Bethlehem Steel and U.S. Steel came to head in the mid-1920s when U.S. Steel, facing continued erosion in its share of market for structural steel I-beams, invested in new universal mills of the Grey type at its mills in Homestead, Pennsylvania and Chicago, Illinois, agreeing in 1927 to take out a license to use the Bethlehem process. Bethlehem also invested in increased capacity, opening two new Grey mills at the Lackawanna works in Buffalo, New York in 1926–1927. Between 1923 and 1929, the available depth of beams increased from 24 inches to 36 inches.[194] Engineers had been building I-beam bridges since the middle decades of the nineteenth century, but these developments on the supply side opened up a longer range of span lengths and greater load capacity to the I-beam bridge type. THD bridge engineers quickly exploited these advantages starting around 1929.[195]

Wood – In 1911, federal bridge engineers giving advice to state and county engineers dismissed timber as a material inferior to others "of a more permanent and substantial nature, such as concrete and steel." They noted that "the life of timber…is at best only a few years" and "there is no real need for its use to be encouraged."[196] Wood left in an outdoor environment was susceptible to rot, insect

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[192] David S. Jacks, "From Boom to Bust: A Typology of Real Commodity Prices in the Long Run," *Cliometrica*, Volume 13, Number 2 (2019): 201-220.

[193] Bethlehem Steel Company, Catalogue of Bethlehem Structural Shapes Manufactured by Bethlehem Steel Company, South Bethlehem, Pa. (1911): 2-7.

[194] Carnegie Steel Company, *Pocket Companion* (Pittsburgh, Pennsylvania: 1923): 7; Carnegie Steel Company, *Carnegie Shape Book* (Pittsburgh, Pennsylvania: 1929): 2.

[195] Thomas J. Misa, A Nation of Steel: The Making of Modern America, 1865-1925 (Baltimore, Maryland: Johns Hopkins University Press, 1995): 170; Kenneth Warren, Big Steel: The First Century of the United States Steel Corporation, 1901-2001 (Pittsburgh, Pennsylvania: University of Pittsburgh Press, 2001): 89-97; Kenneth Warren, Bethlehem Steel: Builder and Arsenal of America (Pittsburgh, Pennsylvania: University of Pittsburgh Press, 2008): 94-95.

[196] Hoyt and Burr (1911): 12.

damage, and wearing out under heavy traffic. Nonetheless, engineers and contractors found wood an indispensable material. Builders needed little skill or money to construct a bridge of logs or sawn timbers supporting a floor of wood planking, and engineers acknowledged timber **stringer** bridge types as indispensable to the upkeep of minor or low-volume rural roads in many locations in Texas. Wood was also used in significant quantities during construction, particularly to build temporary scaffolding and forms for pouring concrete.

The THD's and AASHO's specifications of 1926 and 1927 specified wood used as **stringers** to be at a minimum 4 to 5 inches of thickness and 8 inches of depth continuing in two-inch increments to a maximum of 24 inches depth. Spacing of the stringers should be no more than 6 feet when combined with a concrete floor and 4 feet when combined with a wood plank floor. Engineers specified graded timber of the dense select or select grades as defined by the American Lumber Standard. The American Lumber Standard Committee, a voluntary national organization comprised of manufacturers and distributors of lumber, first published the standards in 1922. While the specifications noted more than three dozen species of wood in common use for bridge construction, Douglas fir and southern yellow pine had already emerged as two fast-growing, softwood species considered suitable for timber framing. AASHO and THD offered advice on how to select Douglas fir and southern yellow pine for density and strength.[197]

Federal and state engineers also focused specifications on the timber piles driven into the ground to establish foundations or form columns for **bents**. They expected variability in the natural growth of trees, depending on the species and conditions under which the tree grew, but THD's engineers nonetheless required timber piles to have minimum diameters of 8 inches at the tip if less than 40 feet long, diameters of 7 inches if from 40 feet to 60 feet long, and diameters of 6 inches if over 60 feet long. All piles over 40 feet long needed to have "butt end" diameters of no less than 13 inches and a maximum diameter of 20 inches.[198]

AASHO determined in 1927 that the only preservatives acceptable for the treatment of wood were creosote oils distilled from coal-gas tar or coke-oven tar. The typical production process involved pressure-soaking wood at high temperatures in a bath of creosote and other chemicals. The process made the resulting wood resistant to insects, fungi, spores, rodents, and weathering. ASTM Specifications D38 and B168 governed the quality of the oils, and the methods of pressure or surface treating the wood.[199] Creosoting originated in England in the late 1830s and transferred to North America in the 1850s with the use of creosote ties on the St. Lawrence and Atlantic Railroad between Montreal, Quebec and Portland, Maine. Many railroad companies built their own creosoting plants, spreading the technology across the United States during the latter decades of the nineteenth century and early years of the twentieth century. Following the success of applying creosote to track ties in the middle decades of the 19th century, railroads soon began applying creosoted wood to bridges, retaining walls, platforms, signal posts and other trackside structures. Domestic production of creosote

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[197] Texas State Highway Department (1926); AASHO (1927): 13-14.

[198] The "butt end" is the uppermost end of the pile receiving the hammer blow to drive it into the ground. AASHO (1927): 14-15.

[199] Texas State Highway Department (1926): Item 83; AASHO (1927): 16-17.

increased rapidly with the development of American highway systems where creosoted timber piles, beams and planks found application as bridge-building materials. The volume of creosote produced nationally increased from 42.7 million gallons in 1917 to 127.8 million gallons in 1929. By 1929, the United States boasted 203 creosote plants processing 360 million cubic feet of wood, including 60 million crossties.[200] Manufacturers distilled creosote from coal tar mostly in coal regions or near large cities with plants producing coal gas where creosote was a useful byproduct of the leftover tar; however, creosoting plants that treated the wood could be found throughout much of the United States including Texas. As of 1929, commercial plants existed in Denison, Texarkana, Orange, Beaumont, and Houston, while the Southern Pacific Railroad had its own plant (est. 1899) in Houston and the AT&SF Railway had a plant (est. 1904) in Somerville. The life expectancy of creosoted timber is over 50 years, although favorable conditions, particularly dry ones like those in west Texas, can increase the life expectancy of creosoted timber to over 100 years. [201]

Texas bridge engineers and builders had no shortage of wood suitable for structural members or piles due to the robust lumber economy of east Texas. The Texas lumber industry reported an annual cut of more than 2.25 billion board feet of lumber (third largest in the United States) in 1907. Although structural lumber output declined during the 1920s and the 1930s due to exhaustion of virgin timber holdings, there was a gradual shift toward replanting cut-over lands with plantations of fast-growing pine, which could be used for creosoted structural beams and piles. The THD shifted its practices during the late 1920s to the 1930s to use less wood in bridge construction since engineers considered it maintenance intensive under heavy traffic and not permanent enough for the arterial highways of the state system. Wood, however, remained one of the most widely available and economical bridge-building materials, and did not require builders to have a great deal of skill or experience to build an adequate short-span crossing for a lightly trafficked, rural county highway.[202]

Stone – Parts of central Texas were historically rich in building stone that masons found suitable for construction of bridge **abutments** or **piers**, and occasionally for use in structural arches or as a veneer. A notable example is the West Sixth Street Bridge in Austin, built in 1887, a three-span **masonry arch** constructed of locally quarried limestone and one of the oldest extant bridges in the state.[203] Use of stone expanded greatly in bridge construction for a short period during the mid-1930s to early 1940s as a result of New Deal programs. The largest of these, the WPA, initiated hundreds of projects to improve and beautify roads and bridges. Stone was often a material of choice of the WPA-

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[200] Dead or Creosote Oil, Letter from the Chairman of the United States Tariff Commission Transmitting in Response to Senate Resolution No. 470 (Seventy-First Congress), a Report on Dead or Creosote Oil (Washington, D.C.: Government Printing Office, 1932): 8-9.

[201] Paul Sweeney, “Creosote Blues Revisited,” *Texas Observer* (April 18, 2008); Creosote Council, *Timeline: A History of Creosote Wood Preservation* (2023), electronic document, https://creosotecouncil.org/timeline/ [accessed August 2023]; Union Pacific, *The Former Houston Wood Preserving Works Site, Historical. Timeline* (2022), electronic document, https://www.houstonwoodpreservingworks.com/about/historical-timeline/ [accessed August 2023].

[202] Robert S. Maxwell, *Lumber industry* (Texas State Historical Association, 1976, updated February 15, 2012), electronic document, https://www.tshaonline.org/handbook/entries/lumber-industry [accessed August 2023].

[203] Robert W. Jackson, West Sixth Street Bridge, Historic American Engineering Record, HAER No. TX-51 (August 1996).

sponsored projects since masonry work created hundreds of labor-intensive jobs for unemployed men who could also learn basic construction skills.

Historically, bridge builders rarely transported stone far from local sources, and therefore stone's use in bridges tended to be limited to those areas where the material was already being actively, commercially quarried. Texas's limestone quarries with grades of stone suitable for dimensional construction, i.e., squaring and cutting of stones, were (and still are) mostly located within a geologic band of Upper Mesozoic limestone beds centered on Austin and stretching northeast toward Dallas and southwest toward San Antonio. The best limestone has a white to cream color and is known commercially as Austin Limestone. Sandstone quarrying was more widely dispersed across the state, except for the coastal plains of southeast Texas. Important sources of sandstone were located in Salado in the Texas Hill Country, Gordon to the west of Fort Worth, and Monahans in West Texas. Other than limestone and sandstone, the only other stone quarried in Texas for dimensional stone was granite, with the center of this industry at Granite Mountain, a dome of distinctive, pink-red colored rock west of Marble Falls in Burnet County.[204]

AASHO bridge specifications of 1927 provided general guidance for the quality of stone desirable for use in bridge construction. The state bridge engineers who drafted the specifications drifted somewhat from their usual precision since stone was a natural material of high variability. They wrote, "Preferably stone shall be from a quarry the product of which is known to be of satisfactory quality," and that it should be of the type specified in plans, "tough, dense, sound and durable, resistant to weathering action, reasonably fine grained, uniform in color and free from seams, cracks, pyrite inclusions or other structural defects." As a final check on the quality and uniformity of the stone, they required contractors to submit samples of stone (a minimum of a 6-inch cubical block) and certification of the quarry from which it had been obtained. During construction, a resident engineer was to check on the stone furnished against the approved sample. The engineers who wrote THD's specifications of 1926 and 1935 remained largely silent on structural stone, although they did provide guidance on crushed stone to be used in paving or aggregate. This silence likely indicated their intention to avoid or minimize the use of stone for **superstructures** and **substructure** applications.[205]

The Historical Significance of Matching Bridges to Existing Topography and Highway Classification

BPR and THD engineers intended bridge standardization and materials specifications to speed up project approvals and construction schedules; however, resident engineers at bridges' project sites always had some leeway to adapt to existing topography or unanticipated conditions. The resident engineers, working alongside state and county forces and private contractors, came to realize that accurate hydrological and soils data were as critical as the design standards and specifications. Decisions made at the project site to increase bridge span lengths or vertical clearances because of an

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[204] J. R. Kyle and B.A. Elliott, "Past, Present, and Future of Texas industrial Minerals," *Mining, Metallurgy & Exploration*, Volume 36 (2019): 475-486.

[205] Texas State Highway Department (1926); AASHO (1927): 44; Texas State Highway Department (1935).

"error discovered in drainage area" were all too common during the late 1910s to the 1920s. Projects encountered further delays when assumptions about soil conditions were wrong, leading to resident engineers requiring deeper foundation excavations or an order for longer pilings.[206]

Texas state engineers who set the early design standards and materials specifications for highway bridges during the 1910s to mid-1920s had little foresight into the rapid growth of the volume, speed, and weight of motorized traffic. They typically designed based on existing conditions, not those in the future. Hard-won experience as the bridges became bottlenecks or wore out under heavy traffic soon taught them the necessity of planning ahead. The MPDF notes that "by the late 1920s, bridge engineers were paying special attention to traffic and safety factors and designing bridges with straighter roadway alignments and greater roadway width and bridge loading capacities. In order to accommodate pedestrian concerns, the THD also began installing sidewalks on bridges located in or near communities."[207] The need for these changes in "right sizing" bridges to the traffic they served was not so obvious in the late 1910s and early 1920s, but it had become standard practice by the late 1920s and 1930s and increasingly sophisticated by the 1940s based on reams of traffic data collected by THD planners.

By the early 1930s, the THD's Bridge Division had adapted to a more sophisticated design approach that relied on detailed topographical surveys of each bridge site, as well as a sufficient number of soil borings or river soundings to execute a plan that was less likely to need field revisions. Field data collected by surveyors and relayed back to the Bridge Division engineers assisted in selecting an appropriate standard design and the degree to which the engineers might need to undertake revisions or design details specific to each bridge's location. The topographic surveys assisted in establishing horizontal and vertical alignments that covered an entire flood zone so that a highway remained usable under heavy flooding conditions. Sub-surface data ensured that contractors knew ahead of time the anticipated depth of excavation and the equipment and materials needed to execute the plan, with less and less uncertainty that might require a major design change while a bridge was under construction. By 1940, the THD operated nine test boring rigs dedicated to collecting data for bridge work. Hydrological data also became increasingly significant to bridge design. Wickline noted in 1936 that the Bridge Division's engineers measured drainage areas, considered the probable size and volume of drift in a stream, and assessed river bottoms subject to scour or silting to determine the size of waterway opening to be provided under every bridge. If the engineers found the proposed bridge site susceptible to flooding, drift, or frequently shifting channels, they often designed bridges with longer spans, taller **piers** with open webs, and deep foundations. Another approach was to use continuous-design, **steel I-beam** bridges and **concrete slab** bridges with relatively modest span lengths supported on timber or concrete pile **bents**. The continuous design spread the load out over additional substructure units, reducing the amount of work needed in the ground.[208]

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[206] Jensen, E123.

[207] Jensen, E127-E128.

[208] Jensen, E127-E128.

THD engineers weighed several factors in matching bridge designs to specific locations, but they gave increasing weight to highway classification and traffic volumes. During the 1930s, collection of data on traffic volumes began to inform the THD's funding decisions and design of bridges carrying Texas's most heavily traveled highways. The THD targeted these highways first for widening of existing bridges or realignment. They straightened sharp curves at bridge approaches, eliminated railroad grade crossings, and made provisions on bridge roadways for safety sidewalks of about 2-foot width to either side of the travel lanes. Ironically, these bridge locations were often the same ones that had been improved in the first round of federal and state-aid programming in the late 1910s to the mid-1920s, but the standard lane widths of 18 or 20 feet now required a minimum of 24 feet, or even 40 feet with safety walks and shoulders, to safely carry wider and faster cars and trucks.

BPR Chief Engineer Thomas MacDonald used Texas's traffic volume data in hearings before the U.S. Congress in 1940 as an example of how states carefully coordinated "the type of improvement with the traffic."[209] THD's highway classification system at the time consisted of state highways in the federal-aid system, other state highways (non-federal aid), and county roads. It did not include city streets since those fell outside of the federal and state-aid eligible categories. Unsurprisingly, THD planners undertaking traffic counts in 1936 demonstrated that the bulk of the heavily traveled mileage was found on the federal-aid system with the lesser systems each being progressively less traveled. Texas's 12,343 miles of federal-aid highway constituted about 7 percent of the total system mileage, yet carried 56 percent of the traffic volume, averaging 1,028 vehicles per day over each mile. The 8,464 miles of state highways not on the federal-aid system constituted about 5 percent of the total system mileage and carried 15 percent of the traffic volume averaging 407 vehicles per day over each mile. The 162,547 miles of county roads constituted 88 percent of the total system mileage and carried 28 percent of the traffic volume averaging 39 vehicles per day over each mile. THD further broke down these numbers by those roads with average daily traffic counts of greater than 1,500 vehicles per day, defined as the most heavily traveled roads in the state. What THD's engineers and planners discovered in doing this analysis was that 20 percent of the mileage of the federal-aid highways carried over 1,500 vehicles per day, while 13 percent of the other state highways and one-tenth of one percent of the county roads carried that volume. Only 1 percent of the federal-aid road mileage and 3 percent of the other state highway mileage carried less than 50 vehicles per day, as compared to 81 percent of the county road mileage. With data such as this for nearly every mile of highway, bridge engineers were able to justify design decisions regarding appropriate load-carrying capacity, bridge width, and alignment. TxDOT continues to this day to rely on traffic count data to inform design decisions.[210]

THD's bridge engineers of the late 1910s to mid-1920s designed bridges on the federal and state highway systems for a minimum 15-ton **live load**. The design approach to this, as recommended by the BPR in its *Typical Specifications for the Fabrication and Erection of Steel Highway Bridges*, published in 1913, was assuming a 15-ton road roller plus a uniform load on the portion of the bridge

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[209] Federal Highway Act of 1940, Hearings before the Committee on Roads, House of Representatives, Seventy-Sixth Congress, Third Session on H.R. 7891 (Washington, D.C.: Government Printing Office, 1940): 198.

[210] Federal Highway Act of 1940 (1940): 193.

deck not occupied by the roller. THD sometimes also used a 20-ton road roller in its early bridge designs. AASHO's Subcommittee on Bridges specifications for 1927, which were reissued in their first printed edition as *AASHO Standard Specifications for Highway Bridges* in 1931, led to a revision of the THD's live load criteria. An innovation in these specifications was the use of a motor truck system of live load instead of road rollers. The basis of the loadings were two-axle trucks of 20, 15, and 10 tons, designated H-20, H-15 and H-10 loadings, with a basic truck in each lane of the bridge, preceded and followed by a train of trucks each weighing three-quarters as much as the basic truck. Furthermore, the THD assigned minimum loadings to each highway classification, which meant that the federal-aid highways gradually updated to the H-20 loadings, while the H-15 and H-10 loadings could be used on the lesser traveled highways. In 1941, AASHO and THD revised the loadings for basic two and three-axle truck design loads. The adoption of the new load rating systems in each instance resulted in some reworking of the standard plans and application to all new bridge designs going forward from that date.[211]

Evidence for the impact of roadway classification, loading, and roadway width are evident in comparing standard THD tee beam bridge plans from *circa* 1920, 1930, and 1940. One of the earliest tee beam standard plans, G-268 of March 1919, was for use on the federal-aid highways. Tee beam bridges built to this standard could be 28 feet to 40 feet long and had 20-foot-wide, two-lane roadways. The design was for a "concentrated load" of a typical 15-ton, two-axle truck. By the early 1930s, the THD continued to use standard plans for tee beam bridges in the same range of span lengths, but these now offered choices of roadway widths up to 40-foot wide, depending on traffic volumes. Bridges on heavily traveled classifications of highway were now being built to twice the width they had been a decade earlier. Standard tee beam plans of the early 1940s increased load ratings from 15-ton trucks to two 20-ton trucks. Bridges on heavily traveled classifications of highways were now being built with three-axle trucks weighing 40,000 pounds of live load versus the two-axle trucks weighing 30,000 pounds of a decade earlier. Over this 20-year period, the basic technology of the tee beam bridge types did not change, but the number of beams supporting a bridge increased from five beams in a 20-foot-wide bridge to eight in a 40-foot-wide bridge, and the depth of beams increased from 1 foot 10 inches in a 15-ton loaded bridge of 1930 to 2 feet 9 inches in a 20-ton loaded bridge of 1940. Tee beam bridges of 1920 were basically the same as those of 1940, except adapted to higher traffic volumes and heavier loads. Similar trends could be followed through all the common bridge types of the period between 1919 and 1945.[212]

The Significance of Aesthetic Treatments

Texas bridge engineers working in the field of highway bridge design during the late 1910s to the mid-1940s balanced many factors in their work. Chief among these were that governments had limited funding, and lawmakers had a passionate desire to develop improved automobile highways that served the greatest number of their constituents. The automobile unleashed a hunger for increasing

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[211] Federal Highway Administration, 429-433.

[212] Texas State Highway Department, Standard Concrete Deck Girder [Tee Beam] Spans, Plan No. G-268 (March 1919); Plan No. DG-6-22 (April 1929); DG-6-40-C (June 1930); no number (January 1942), on file, TxDOT, Bridge Division, Austin, Texas.

freedom to travel whenever and wherever a driver wanted. This meant that the public met every new mile of paved highway and each new bridge with nearly universal approval, at least until congestion and sprawl became increasingly evident, which for most Texans was barely a consideration until the 1960s or 1970s. To meet the demand of their political masters and the traveling public, highway bridge engineers working for the THD prioritized standardization, uniformity, classification, and topographical data. This left some space for aesthetics, but not much since custom details and finer finishes typically cost extra time and dollars.

Fortunately for Texas bridge engineers working in the public sector, they inherited an aesthetic that owed much to the City Beautiful Movement, discussed earlier in this document. This movement held that well-designed infrastructure and citywide planning uplifted the general public. The leading figures in the movement were architects and landscape architects, not engineers, and they tended to hold to a philosophy that civic buildings, parks, water and sewer utilities, and bridges best met the movement's aesthetic goals by establishing visible and permanent ties to the Classical architectural traditions of western civilization. A significant expression of the City Beautiful Movement in Texas is San Antonio's Commerce Street Bridge over the San Antonio River, constructed in 1915. The bridge, which is listed on the NRHP as a contributing feature of the San Antonio River Walk Historic District, displays numerous Neoclassical details from sculptural relief to geometric patterns in concrete and stone.

The THD, in a very muted fashion, incorporated the City Beautiful Movement's aesthetic into the program for statewide bridge improvements. This was most apparent in standard railing treatments such as concrete parapets relieved by repeating patterns of rectangular panels and posts with hipped or rounded caps. Occasionally, THD employed simple concrete **balustrades**, usually with square balusters, although urn-shaped balusters might be used near a park or town. An abutment corner might be adorned with a simple pilaster. These aesthetic touches were far from significant in their own right and were far from constituting a significant use of the Neoclassical style, yet they illustrated an aesthetic intent and an alternative to purely function steel-pipe railings and **precast** and **cast-in-place** concrete rails with simple square posts.

The MPDF observed that during the 1930s the THD Bridge Division began paying closer attention to architectural treatment for bridges that were "readily visible to the public." This usually meant bridges near or in towns and cities, parks, or railroad lines, not the bridges out on the open highways. Engineers adopted some new tendencies, especially when it came to railings and the exposed outward-facing surfaces of **piers**, **abutments**, and **wingwalls**. Chief among these, engineers picked up on the Art Deco and Art Moderne architectural styles, which peaked in popularity during the 1930s. Typical details found on bridges influenced by these styles tend to be horizontal and vertical scoring, stepped railing posts and pilasters, flared wingwalls, and concrete finishes used in contrast.

Concrete finishing techniques proved especially adaptable to New Deal programs such as the WPA and Civilian Conservation Corps (CCC) since hand application of the finishes was labor intensive and served the purpose of increasing the number of workers enrolled in the programs. The CCC, which was active in building bridges in U.S. Forests and other remote areas of Texas, even had a curriculum to teach the skills of concrete finishing to its participants.[213] The most common concrete finish techniques used during the 1930s were brushing, acid washes, rubbing, and tooling (or bush hammering). Brushing took place ideally within 24 hours of the pouring of the concrete and usually applied only to horizontal surfaces. Workers applied a stream of water to the concrete, washing away the surface film. They then brushed the wet concrete with stiff-bristled brooms to create thin grooves similar to those that a broom would make in sand. More common than brushed finishes were acid washed finishes, also known as exposed aggregate finishes. This involved application of a weak acid to eat way the cement and leave the aggregate exposed. Careful selection of the aggregate, for example dark-colored crushed stones or quartz river pebbles, added intentional contrast to the new white concrete. Engineers often employed a rubbed finish to bridges when it was desirable to offer an appearance free of the lines and impressions made by wood formwork. This involved having workers remove the forms after about two days of setting and then rubbing the concrete by hand with blocks made of a soft stone or abrasive such as carborundum. Progressively smoother and reflective finishes could be achieved by rubbing the concrete with progressively finer abrasives. Another finish called bush hammering could take place up to two months after setting of the concrete. Workers used hammers with faces textured with conical or pyramidal points to apply texture to the concrete. Engineers sometimes specified bush hammer finishes to apply contrast to architectural details such as panels, setting them off from a surrounding concrete that may have been rubbed smooth.[214]

Although Texas bridge engineers gave architectural treatments a place in their designs, aesthetics of bridges during the first half of the twentieth century increasingly trended toward Modernist ideas of form following function. In other words, to find structural art, engineers embraced the idea that structure was the primary function and beauty could be achieved "when the structure and the form became indissolubly one," to borrow a phrase used by two scholars of bridge engineering, Carl W. Condit and David P. Billington.[215] BPR and THD engineers rarely expressed themselves in this way except that they did understand that a visually pleasing design had functional clarity, as well as line, shape, proportion, balance, and scale. Of particular concern when working in the neighborhood of a city, town, park, or railroad, the engineers did think about how their bridges integrated into the site and its environment and landscape, functionally as well as visually, if not entirely aesthetically.

THD, county, and city engineers most often employed a bridge type with arched lines or **soffits** when they wanted a bridge to harmonize or defer to its setting. While concrete **closed** and **open-spandrel arches** fit this bill in the 1910s and the 1920s, engineers increasingly turned to **variable-depth steel girders**, **variable-depth concrete tee beams**, **variable-depth concrete slabs**, and **concrete rigid frames** during the 1920s to the mid-1940s. Arched shapes expressed both function and form since arches clearly expressed their function to direct loads downward toward the ends of the arch,

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[213] U.S. Department of the Interior, Office of Education, Vocational Division, *Concrete Construction, Outlines of Instruction for Educational Advisers and Instructors in Civil Conservation Corps Camps* (Washington, D.C.: Government Printing Office, 1935): 83-85.

[214] George A. Hool and W. S. Kinne, *Reinforced Concrete and Masonry Structures* (New York, New York: McGraw-Hill Book Company, 1924, rev. 1944): 150-153.

[215] David P. Billington, *The Tower and the Bridge: The New Art of Structural Engineering* (Princeton, New Jersey: Princeton University Press, 1983): 163.

and the arch curvature also directed a viewer’s eye upward to the crown. Perceptive engineers knew that repeating an arch pattern across several spans established a visual rhythm that often pleased the eye. A somewhat less “honest” use of the arch form sometimes seen among Texas bridges occurred when an engineer or builder applied a stone-arch veneer that was not load bearing. This outwardly presented a traditional use of the stone arch, but the actual load-carrying members behind the stone were often standardized **steel I-beams**, **concrete tee beams**, or **concrete slabs**.

Non-Truss Bridge Types, circa 1900-1946: Typology and Character-Defining Features

The purpose of this chapter is to describe and contextualize each of the common and uncommon bridge types in the pre-1946 non-truss Study Population (**Table 1**). The typology used in this study follows some standard guidelines for evaluating historic bridges. It classifies bridges by the date of construction, material, and design of the **superstructure**, i.e., the principal load-carrying member that spans the feature(s) crossed by the bridge. **Substructures** may be reused and older than the existing superstructure, but the substructure date is not considered the date of construction for the bridge for the purposes of typology. TxDOT's current classification system is a starting point of the typology, with a few refinements for older historic bridge types such as breaking out the uncommon **steel I-beam bridges with jack arch decks** from the common, simply supported, **steel I-beams**. This is standard practice in bridge inventories because superstructure is character-defining of all bridges.

Contextualization acknowledges that any given individual bridge, no matter the superstructure typology, is also a combination of discrete structural elements and materials including railings, decks, and substructure units such as **abutments**, **piers**, and **bents**. For example, a theoretical steel I-beam bridge may have reinforced concrete composing its railings, deck, and abutments; a bituminous wearing surface on which vehicles' tires directly roll; cast-steel drainage scuppers for allowing rain to run off the deck and into a stream; and a bronze builder's plaque. Its concrete abutments may rest on a foundation of timber piles. The concrete abutments could even predate the existing superstructure; they may have once supported an earlier superstructure of a different kind. The engineers who designed this theoretical bridge considered the physical properties, availability, cost, and constructability of each of the superstructure and substructure elements and the various materials that compose them.

Combining structural elements and materials in various ways may result in bridges that have different appearances and character, even though they are of the same superstructure typology. A steel I-beam bridge with a wood plank deck and steel angle railings could suggest historical associations with a low-volume, rural county road. Alternatively, a steel I-beam bridge with a concrete deck and standard concrete **balustrades** could suggest a federal-aid bridge on an arterial highway. The I-beam typology of these two bridges is identical but the other materials and the way they have been combined, even in the simplest of fashion, may associate the bridge with different transportation contexts. The typology is nonetheless critical for the purposes of comparing and evaluating bridges within a type, period, and method of construction common to all bridges with a steel I-beam superstructure.

Table 1: Study Population Bridge Types, circa 1900-1945

Bridge Type	Bridges in the Study Population
Timber	
Multiple Timber **Stringer**	7
Masonry	
Masonry Arch	15
Steel	
Steel I-beam (**simple** and **continuous**)	656
Steel I-beam – concrete encased	22
Steel I-beam – jack arch deck	6
Steel I-beam – **cantilevered** with **suspended span**	19
Steel Plate Girder – Through	49
Multiple Plate **Girder**	27
Variable Depth Plate Girder	4
Plate Girder with Floor System	10
Plate Girder – **cantilevered** with **suspended span**	2
Plate Arch	5
Other Steel	4
Concrete	
Bridge-class box culvert	1063
Flat Slab (**Simple** and **Continuous**)	944
Tee Beam (**Simple** and **Continuous**)	882
Rigid Frame	29
FS Slab with integrated curbs	2
Variable Depth Concrete Slab	9
Variable Depth Concrete Tee Beam	43
Concrete Arch, Closed Spandrel	41
Concrete Arch, Open Spandrel	7
Concrete pipe with masonry **headwalls**	1
Other Concrete	3
Total of Bridges	**3,850**

The following sections of this chapter address contextual considerations related to each of the bridge types in **Table 1**, i.e., a Study Population of non-truss bridges built prior to 1946 that exist in 2023. The bridge types are presented in rough chronological order of their historic periods of use. There are some methodological "blind spots" to this approach that the team finds noteworthy. For example, most bridges in Texas prior to the automobile era were probably timber **stringer** bridges on rural county wagon roads. These bridges have not survived in the Study Population and therefore need not be considered in much depth. Also, largely missing from this data are historical comparatives to bridges that may no longer exist, especially early examples of common or once-common bridge types. For instance, no archival record exists that could pinpoint with certainty the earliest concrete tee beam bridge built in Texas. We can surmise from contextual information that Texas bridge builders constructed the earliest tee beam bridges between 1905 and 1910, but the prototype may not survive.

With the exception of railroad bridges that intersect public roads, this study does not include railroad bridges. Contextually, railroad bridge engineers were as highly trained and experienced a group of bridge designers as could be found in Texas and the United States until the 1910s. State highway department bridge sections began to catch up with railroads in terms of the quality and experience of their engineering staff in the 1920s. With this study's focus on highway bridges, the team is mindful that from a technological perspective most of the bridge types considered in this document have railroad counterparts.

Multiple Timber Stringer

Multiple timber **stringer** bridges consist of a series of parallel, longitudinal beams supporting a **deck**. These bridges rely on the bending strength of the timber beams to carry **live** and **dead loads**. The Study Population of multiple timber stringer bridges is seven bridges with reported dates of construction between 1910 and 1940. All eight bridges carry railroads over public roads and associate with contexts of railroad transportation and grade-crossing eliminations. Seven of the eight bridges are associated with the UPRR, successor to the Southern Pacific Railroad system in Texas.

Timber stringer bridge technology dates to time immemorial, when felled trees were laid across streams and other obstacles. They were a very common type of roadway bridge from Texas's early settlement period into the early decades of the twentieth century. The MPDF, for instance, makes mention of timber bridges in Houston and San Antonio, with an early example of note carrying Commerce Street over the San Antonio River as early as 1803. Detailed archival documentation for timber stringer roadway bridges is modest, likely because timber stringer bridges were so traditional, ubiquitous, and technologically uncomplex to be beyond mention. Furthermore, builders had no expectations that the wood would last more than a few years or until the next flood wiped out the bridge. Prior to Texas having numerous sawmills, the stringers consisted of logs, perhaps roughly shaped for an upper flat surface to form a deck for wheeled traffic. Over time, sawmills supplied cut squared timbers for the beams and planks for the decks. Builders sometimes added wood railings for the convenience and safety of pedestrians and horse-drawn vehicles, but they were not a requirement. Substructures consisted of simple timber sills or cribs in the early days, but stone **abutments** and timber pile **bents** became more common over time as crossings took on a more permanent character.

After the establishment of the THD in 1917, timber stringer bridges were among the low-cost bridge types that continued in use, but they were generally not considered desirable for federal or state-aid highway projects due to their "impermanency." Construction of timber bridges took place when steel, concrete, and other bridge-building materials were too expensive for budgets or in short supply. No timber stringer bridges built before 1945 carry Texas highways today, a not unsurprising fact since it would be a highly unusual situation for wood fabric to have survived in use for more than 85 years. Federal, state, and county transportation policies have long favored more permanent, lower maintenance construction of concrete and steel highway bridges.[216]

The same cannot be said of the railroads. Railroad companies continued to build and maintain timber stringer bridges even after the bridge type slowly fell out of use on automobile highways during the course of the twentieth century. The main reason was that railroads had ample supplies of creosoted wood and operated their own creosoting plants, which meant their costs were generally lower for materials. They also had the manpower to frequently inspect timber bridges. Section gangs charged with maintenance of the railway checked bridges on a regular schedule and easily identified timbers showing splits, decay, or other signs of deterioration. The standard dimensional timbers and construction using augers to drill holes for the heavy steel **bolts** and washers used in joinery made the bridges relatively easy for the railroads to build and maintain.[217]

Although creosote was initially a treatment for railroad ties, it spread to other applications including bridge beams, trusses, and piles and was widespread by the early years of the twentieth century. In 1892, the Southern Pacific Railway's Superintendent of Bridges and Buildings reported that his company "had our own [creosote] works at Houston" and was building timber stringer bridges on timber pile or bent **substructure** on "15-foot centers." He added that the railroad's standard practice was to make "a floor [or deck] of creosoted 10x12 [beams] then 8 inches of gravel on top of that, making a continuous roadbed." By 1908, the Southern Pacific Railroad also owned the International Creosote Works at Beaumont. The American Railway Engineering Association expressed the industry's devotion to creosote in its January 1919 *Report on Wood Preservation*, stating unequivocally "that creosote is the best timber preserving agent known for all purposes." The Southern Pacific Railroad produced creosoted structural timber at its Houston facility as late as 1984.[218]

Character-Defining Features: Timber stringer bridges are among the simplest of engineered bridge structures and are generally thought to have limited individual technological significance. They are, however, a long-lived technology that has been adaptable to modern needs, particularly with the availability of wood preservative treatments. Typical character-defining features of timber stringers bridges are 1) longitudinal timber beams, 2) arrangement and length of spans, 3) solid wood plank or open railroad tie deck, 4) original hardware such as **bolts**, spikes, washers, etc., 5) wood preservative

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[216] Jensen, E9, E12-E13, E30, E87, E155-E156.

[217] George A. Hool and W. S. Kinne, *Steel and Timber Structures,* Second Edition (New York, New York: McGraw-Hill Book Company, 1924, 1944): 372-404.

[218] Walter G. Berg, comp., *American Railway Bridges and Buildings, Official Reports, Association of Railway Superintendents, Bridges and Buildings* (Chicago, Illinois: Roadmaster and Foreman, 1898): 211; Southern Pacific Wood Preserving Works Photograph Album [catalogue entry] (1908), on file at the California State Railroad Museum Library and Archives, Sacramento, California; "Report on Wood Preservation," *Bulletin of the American Railway Engineering Association,* Volume 20, Number 213 (January 1919): 150; Clint Schelbitzki, "Union Pacific Calls for Accuracy and Collaboration in Response to Houston Dioxin Study," *Inside Track* (September 28, 2022).

treatments, typically creosote, and 6) substructure elements of timber bents and stone/concrete abutments.

Since wood species, wood preservative treatments, standard dimensional timber sizes, and iron hardware have changed considerably or become unavailable during the past 50 years, assessment of a timber stringer railroad bridge requires careful investigation and comparison of original and replacement fabric. Railroads rebuild bridges frequently and "beef up" for greater load capacity or longevity, which can result in bridges that have significantly different **superstructure** characteristics from their predecessors.

Masonry Arch

Masonry's principal building characteristic is high **compressive** strength and very low **tensile** strength. This is why builders can use stone or brick to build massive walls, but the material is easily chipped or shattered with a blow from a hammer. These qualities make masonry a highly suitable material for **arch** bridges where the **arch ring** holds individual masonry blocks in compression, and for use in walls and wall-like structures, like bridge **abutments** and **piers**, which rely on the force of gravity and the stone's own weight to hold the **substructure** in place. Other than for arches and substructure units, builders have seldom used masonry in other bridge applications due to its poor tensile strength. During the twentieth-century, engineers and architects frequently applied stone as a veneer on steel and concrete bridges for aesthetic reasons.

Most building stone in Texas is limestone or sandstone, coming from the state's dominant bedrock geology. Each type of rock has specific building qualities, particularly the way it cleaves and forms straight edges and blocks, as well as its relative durability and hardness. Stone used in bridge construction has been "worked" to some degree even if it is stone that has been roughly dressed in a few blows from a hammer to trim it to size or square it up. Masons refer to finely dressed stone as "tooled," giving it smooth surfaces or decorative qualities. A stone that has been precisely squared off into a block and finely dressed is described as *ashlar*. Stonework can also be ***coursed***, placing the stones in regular horizontal layers; *randomly coursed*, similar to coursed but using stones of more irregular shapes and sizes; and *uncoursed*, stones of uneven shapes arranged with no regard to a regular pattern of horizontal layering.

The method of laying up masonry can vary greatly with the type of stone available and the skills of the masons. The masons' first order of business was determining whether to build a structure using mortar or to dry lay, meaning without mortar. **Dry-laid** masonry required intensive labor to work the stones and ensure tight joints. Dry-laid masonry has advantages; if done well, it will resist the damaging effects of frost and ice since water can drain out the faces of the wall. Dry-laid structures can also be built in winter since they require no mortar, which will not bond in cold weather. Mortar has the advantage of securely bonding stones together and filling the gaps between stones with a material that creates a uniform bearing. It also relieves masons from the hard labor of ensuring that each stone is precisely worked to fit with its neighbors. Most pre-1875 mortars were simple lime-based mortars, which were susceptible to moisture penetration and deterioration. After Portland cement became commercially available, masons used it as an additive to harden the mortar and make it less susceptible to moisture.

Arch bridges work under the principle that the arch ring compresses under **dead loads**, and the outward thrust at the base of the arch must be counteracted by the mass of the **abutments** or **piers**. Stone arch technology is ancient, with some examples in Europe and Asia dating back thousands of years. The Romans are generally acknowledged to have been master stone-arch bridge builders, and European stone-arch traditions carried through the Medieval and Renaissance periods to eventually make their way to North America via colonization. In general, builders constructed stone arch bridges in the United States anywhere where quarriable building stone could be found until the end of the nineteenth century, and occasionally for very specific reasons into the 1930s. The only areas where builders tended to not build stone arches were coastal zones that lacked quarries, primarily in the Southeast Atlantic and Gulf Coast areas, which includes southeast Texas.

Typical span lengths for masonry arch highway bridges were from about 3 to 4 feet at the short end to perhaps 45 to 50 feet at the upper end of the range. It is technically possible to build much longer spans, for example, the Cabin John Bridge of 1857–1864 outside of Washington, D.C., has a clear span of 220 feet, but this is exceptional and required the efforts of two brilliant engineers, Montgomery C. Meigs and Alfred Landon Rives.[219] By comparison, Texas's stone arches represent the craftsmanship of local masons and contractors working within the typical span lengths up to about 50 feet. Railroads also built stone arch bridges, favoring the arch form for its durability and high load carrying capacity. The Houston and Texas Central Railway, for instance, built three brick and stone arch bridges on its line northwest of Brenham in the latter part of the nineteenth century.[220]

Builders erect masonry arches on scaffolding, called falsework, and are not stable until the arch ring is "locked" in place with the setting of all of the stones. This makes long-span stone-arch construction particularly perilous since temporary wood scaffolding must support the great dead weight of the stonework; historically there are many examples of stone arches failing before they could be completed. Masonry arches, once erected, however, have exceptional load-carrying capacity and are very rigid and resistant to vibration from **live loads**.

Masonry arch bridges also have limitations based on site conditions. Arches require very stable foundations on which to place substructure. If abutments or piers are not set upon stable foundations, the substructure may settle or shift, leading to a phenomenon called "spreading" in which gaps appear among the stones that make up the arch ring. Ultimately, this can lead to arch failure. For these reasons, stone arch builders usually looked for natural locations where foundations can be built directly on bedrock or where footings can be built that spread the load over a wider area of soils judged to be sufficiently compacted to remain stable. This is another explanation why stone arches are

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[219] Dario Gasparini and David A. Simmons, "Cabin John Bridge: Role of Alfred L. Rives, C.E.," *Journal of Performance of Constructed Facilities*, Volume 24, Number 2, (April 1, 2010): 188-203.

[220] Patrick Feller, *BNSF Railroad Three Arch Bridge over Bullinger Creek* (2011), electronic document, www.flickr.com [accessed September 2023].

not usually found in coastal regions or across wide flood plains with shifting and deep sediments, conditions common to Texas.

All masonry arches are deck arches because the roadway is carried above the crown of the arch. The arch ring is made up of blocks called *voussoirs*, with the uppermost stone at the crown called the *keystone* because it is the last to be placed, locking the arch into compression prior to the removal of the falsework. The arch ring has a lower or outer side, called the *intrados*, and an upper or inner side, called the *extrados*. The extrados is usually not visible because it is covered by a backfill material, usually earth and rubble stone, that forms a smooth riding surface. The arch's sidewalls, called ***spandrels***, hold in the fill material. If the spandrels extend upward to enclose the roadway, the upper courses of the spandrel wall are usually referred to as ***parapets***.

Arch bridges are distinguished by the shape of the arch opening; the three most typical shapes known are semi-circular, segmental, and parabolic. The "classic" shape is a Roman semi-circular or barrel arch because its span and rise are equal. *Rise* is defined as the height as measured from the spring line of the arch (where it leaves the abutment) to the base of the crown. In a semi-circular arch, the arch ring comes to the abutment at close to a 90-degree angle. As the length of a semi-circular arch increases, the rise increases equally, meaning that a long span either needs to cross an equally deep gully or the arch needs to rise above the surrounding landscape creating a "humpbacked" appearance.

Since the seventeenth century, longer masonry arch bridges have been typically segmental arches, meaning that the arch ring's radius is greater than the bridge's span length, creating a shallower arch that is more suitable for sites with wider waterway openings or lower embankments. Segmental arches were not used in Europe until the Renaissance, but soon became the dominant arch shape. A challenge of designing segmental arches is that the longer the span and the shallower the arch, the greater the horizontal thrust against the substructure. Massive and costly abutments and piers may be required, and special care must be taken in designing multiple spans since the thrust of the arches to either side of a pier should ideally be equal. Elliptical arch openings are shaped like an ellipse with a variable radius. During the nineteenth century, architects determined that an ellipse or parabola offered the best shape for distributing **dead load** uniformly, but it also produced the greatest thrust at the base. It became commonly used for long-span stone arch bridges.[221]

Although all masonry arches use the same basic engineering principles, the degree of skill and workmanship can vary greatly. In terms of Texas's stone arch highway bridges, the skill is not so much seen in the engineering design, since few are exceptionally long spans, but in the quality of the masonry. This is seen mainly in the tightness of the fit of the joints, **mortar joint** patterns and the skill in smoothing, finishing and, occasionally, decorating the stone. Masonry arch bridges continued to

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[221] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types*, NCHRP Project 25-25, Task 15 (October 2005): 3:48-52; Historic Documentation Company, National Register of Historic Places, Multiple Property Documentation Form, Stone Highway Culverts, 1750-1930 (2009), E3 to E31, prepared for the New Hampshire Department of Transportation, Concord, New Hampshire.

be built into the twentieth century; however, the labor-intensive nature of erecting arches was difficult to justify when other materials, particularly reinforced concrete, offered more economical solutions.

The MPDF noted that Texas's remaining pre-1946 stone arch bridges have specific contexts related to City Beautiful aesthetics during the early part of the twentieth century or unemployment relief projects during the New Deal projects of the mid-1930s to early 1940s. Austin's city engineering department turned to stone arches in the early twentieth century for the principal streets crossing Shoal Creek and Waller Creek. The Study Population includes six stone arch bridges in Austin built from 1915 to 1940, with maximum span lengths of 20 to 35 feet. The Great Depression spurred labor-intensive projects that used stone as a material, frequently as a veneer on a concrete or steel superstructure. Many of these bridges appear to be arches because of the veneer, although they are not structurally acting as a stone arch. There are a handful of "true" stone arches from the New Deal period employing traditional stone arch construction methods. The SH 16 Bridge (NRHP-listed, NBI No. 021820036202003) over the Brazos River near Possum Kingdom Lake in Palo Pinto County was a WPA project resulting in an impressive 433-foot-long stone arch bridge in 1942. Builders acquired 3,830 yards of locally quarried limestone and employed around 300 workers.[222]

Character-Defining Features: Masonry arch bridges are a traditional bridge type used in the colonial North America and the United States from as early as the 1690s to the 1930s. Evidence exists for traditional masonry construction methods of workmanship reaching Texas in the early pioneer settlement period, with stone arch bridges of substantial character being built by the last quarter of the nineteenth century. Extant examples mostly date from the twentieth century and represent a continuation or revival of stone arch technology in specific contexts of builders making aesthetic choices or desiring to use a labor-intensive method of construction to maximize employment opportunities.

Typical character-defining features of masonry arch bridges are 1) length, width, and arrangement of spans, 2) shape and size of arch opening, 3) size and shape of stones or bricks, 4) method and craft in laying up the stone or bricks including coursing of spandrels and parapets, 5) method and craft in dressing, squaring, and tooling the stones, 6) mortar materials and style of mortar joints such as flush, raked, extruded, etc., 7) railings or parapets if originally present, and 8) original stone substructure.

The principal integrity issues with stone arches are retention of the quality of the design, materials, and workmanship, which can be severely impacted by widening or strengthening using newer materials such as concrete slabs or steel pipe. Another common alteration is pointing or re-pointing with hard cement-based mortars, often with the result of ruining or obscuring the original workmanship or cracking/damaging the stones.

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[222] Jensen, E259.

Steel Plate Girders

Plate **girder** bridges consist of two or more longitudinal beams (i.e., girders) supporting a **deck** system for carrying traffic. Engineers refer to these bridges as plate girder bridges because the main longitudinal beams are riveted, **built-up** members consisting of steel plates with angles for **flanges** and vertical **stiffeners**. Fabricators can also build-up plate girders by **welding**, but this was not a technique used for bridges in the United States until the 1920s and was not widespread until after 1945. The team will further investigate whether any bridges in the pre-1946 Study Population have welded girders, but preliminary investigations indicated that if welded girder bridges exist, the number is very small.

Pennsylvania's Philadelphia and Reading Railroad built a handful of wrought iron, **riveted**, plate girder bridges in the 1840s; however, the **built-up** girders were expensive and used sparingly prior to the Civil War. After 1865, plate girder bridges emerged from being a new technology to being a standard choice of railroad bridge builders due to their heavy construction. The plate girders proved to be among the strongest, stiffest, and most economical metal bridge types for railroad use. Improvements in the production of structural iron and steel, which led to reduced costs, meant that railroads widely employed plate girder bridges throughout the United States from the 1880s to the 1930s. Railroads also favored the technology because they could transport prefabricated plate girders to construction sites and erect the bridges quickly, with minimal disruption to traffic and no need for falsework. This made plate girder bridges ideal for overpasses and underpasses. Nearly 90 percent of the plate girder bridges in the Study Population are grade separations of highways and railroads, attesting to the bridge type's dominance in rail applications. In many instances, these bridges are associated with major programs to improve the efficiency of railroad train movements and the safety of the traveling public, especially in urban areas where congestion elevated the risks of accidents. Fort Worth, for instance, a major railroad hub, has an "exceptional network of railroad grade separations structures" with most of the work completed between 1910 and 1935.[223]

Span lengths were usually from 30 feet to 100 feet, after which other bridge types, particularly trusses, became economical. Plate girder depths can range from a few feet to 10 feet or more. Engineers found plate girder bridges somewhat less ideal for highway use because of the challenges of transporting long and heavy girders using the trucks and highways of the pre-interstate era. In 1918, THD bridge engineers specified plate girder bridges as an option for spans from 36 to 70 feet long, but steel pony trusses covered the same span range and the THD did not frequently employ plate girders in development of the Texas highway system.[224]

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[223] Robert W. Jackson, *Historic American Engineering Record, Belknap Street Viaduct*, HAER No. TX-49 (1996); *Fort Worth & Denver City Railroad Underpass*, HAER TX-93 (2000); *Gulf, Colorado & Santa Fe Railway Underpass*, HAER No. TX- 95 (2000); *Houston & Texas Central Railroad Underpass*, HAER No. TX-92 (2000); *Missouri, Kansas & Texas Railroad Underpass*, HAER No. TX-91 (2000); *St. Louis Southwestern Railway Underpass*, HAER No. TX-94 (2000); *Stockyards Viaduct*, HAER No. TX-89 (2000).

[224] Texas State Highway Department, *Specifications and Contract* (1918): Item 50; George A. Hool and W. S. Kinne, *Steel and Timber Structures,* Second Edition (1944): 295-327; Parsons Brinckerhoff and Engineering and Industrial Heritage (October 2005): 3:110-111; Jensen, E255-E256.

Variations in the steel plate girder bridge type consider the depth (constant or variable), the girder placement relative to the deck, and the arrangement of the flooring system.

Steel Plate Girders – Through*:* These bridges account for 49 of the 92, or about half, of the steel plate girder bridges in the Study Population. The "through" refers to the placement of the **floorbeams** in relationship to the main longitudinal **girders**. The floorbeams of a through girder are in line with the bottom **flanges** of the longitudinal girders. With through girders, the two exterior longitudinal girders usually extend above **deck** level and are thus visible to traffic. A main advantage of a through girder is that the girders do not extend below the deck level and reduce vertical clearance under the bridge. This makes them ideal for locations where railroads cross over highways or low-profile stream crossings. The Study Population bears out the significance of the through plate girder bridge type to railroads, with 47 of the 49 examples, dating from 1902 to 1941, carrying rail lines over highways or city streets.

Multiple Plate ***Girders****:* These bridges consist of multiple lines of steel plate girders supporting a **deck** placed level with the girders' top **flange**. The deck materials vary but are usually creosoted timbers or concrete slabs. As with the through girders, the multiple plate girders closely associate with railroad transportation systems, with 26 of the 27 bridges, dating between 1918 and 1940, currently or formerly carrying railroad lines over highways.

Plate Girders with Floor Systems*:* These bridges consist of longitudinal lines of plate girders with flooring systems consisting of transverse beams and those transverse beams supporting a deck. These bridges are closely related to the through girders, except the **floorbeams** are not in line with the bottom **flanges** of the main longitudinal girders but somewhere above the bottom flange, typically either in line with the top flange or resting on the top flange. The framing of the flooring system is visible from beneath the bridge, with the floorbeams transferring **live loads** to the main longitudinal girders. The floorbeams are almost always rigidly connected to the girders using **riveted** angles and clips. The plate girders with floor systems closely associate with railroad transportation, with 6 of the 10 bridges, dating between 1930 and 1943, carrying railroad lines over highways.

Variable-Depth Plate Girders*:* Most plate girder bridges have parallel **flanges** for a constant depth of beam, but engineers occasionally vary the depth of beam to create plate girders with curved lower flanges. Due to the extra fabrication steps, and thus costs, required to create variable-depth plate girders, engineers used them sparingly prior to 1945. The main reason was that variable depth plate girders, as well as other bridge types (discussed below), lend themselves to ***continuous*** *designs*, those where the main supporting members do not have joints over the **piers** and loads are distributed across two or more spans. In the case of plate girder bridges, engineers and fabricators could build up the longitudinal girders to sufficient depths to handle the high stresses that occur over the piers in a continuous design. This resulted in a curved girder that saved steel material where it was least needed at mid-span. Continuous designs had significant economic and constructability advantages, especially in longer spans. The main drawback was the difficulty in analyzing how the stresses traveled, there being so many variables that the designs were known as *indeterminate,* meaning they could not be solved using traditional statics (i.e., the study of forces and structures at rest). Academic engineers developed graphic methods to solve indeterminate design problems during the 1920s and 1930s, offering engineers nationwide increased confidence. The Study Population includes only four examples of variable-depth steel plate girders, dating from 1930 to 1935, with maximum span lengths between 90 and 120 feet. All four bridges are in the Dallas-Fort Worth metropolitan area and are non-standard designs with aesthetic architectural details. The Corinth Street Viaduct, built in 1929–1933 over the Trinity River (NBI No. 1805709C6240001), is characteristic of these bridges with a main span composed of a 120-foot-long, haunched, **riveted** steel girders, which were the largest fabricated in Texas at the time of construction.[225]

*Plate Girder – **Cantilevered** with **Suspended Span**:* The Study Population includes two cantilevered plate girder with suspended span bridges, built in 1940 and 1941 (NBI No. 1805709Z0540009, Zang Boulevard over Cedar Creek/Dart Railroad, Dallas County, and NBI No. 151630002406071, US 90 over Medina River, Medina County). The cantilevered with suspended span design consists of longitudinal girders that cantilever beyond the **piers** with a "drop-in" section placed between the two cantilevered arms to fill the gap where the center span crosses the river. The design allows for a longer clear span with a shallower girder than would be achievable with a non-cantilevered span of the same given length and load, and considerably less steel than a metal truss of similar length and load.

The design of both Texas bridges incorporates **pin-and-hanger connections** at the inflexion point where the cantilevered arms meet the drop-in sections. This detail harkens back to the pin connections of late-nineteenth-century metal trusses and had the advantage of making the stress calculations determinate. Nationally, cantilevered plate girder bridges using pin-and-hanger details were built from the 1890s to the 1970s, but they saw a particular peak in highway bridge applications during the late 1930s to the 1960s due to cost and constructability advantages in span lengths of 100 to 150 feet. They were particularly well adapted to interstate highway overpasses, so they normally have total lengths of 250 to 300 feet or more, with the center span crossing the highway's travel lanes and the end spans forming the transition to the approach roads. The two Texas bridges built prior to 1945 have maximum spans of 120 feet and 125 feet and total lengths of 378 feet and 482 feet. The use of the pin-and-hanger detail ended abruptly in 1984 after the collapse of Connecticut's Interstate 95 over Mianus River Bridge, which occurred with fatalities after a pin failed from fatigue. A considerable effort to retrofit, replace, or frequently inspect the pin-and-hanger details has been underway nationally ever since.[226]

Character-Defining Features: Steel plate girder bridges originated in railroad bridge applications and were in widespread use across the nation from the 1890s to the 1950s. The transition to highway applications was uneven and not widespread, except where railroads crossed highways. THD did not develop a standard steel plate girder design and did not often employ it in the development of the state highway system. Texas bridge engineers found special applications for the steel plate girder

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[225] Carl W. Condit, *American Building Art, The Twentieth Century* (New York: Oxford University Press, 1961): 82-103; Robert W. Jackson, Historic American Engineering Record, Corinth Street Viaduct, HAER No. TX-34 (1996).
[226] Lichtenstein Consulting Engineers, *Historic Context for Bridge Building Technology in Georgia* (1996): 7-8, prepared for the Georgia Department of Transportation, Atlanta, Georgia.

bridge technology after adapting it to variable depth girder and cantilever designs during the 1930s and early 1940s, but these applications were not widespread and were reserved for situations where the design met aesthetic or constructability goals.

Typical character-defining features of steel plate girder bridges are 1) placement of longitudinal girders and transverse **floorbeams** in through, multi-girder or flooring system configurations, 2) girder depth relative to length and width, 3) method of fabricating members and field connections (**riveted**, **welded**, **bolted**, **pin-and-hanger**, etc.), 4) simple or continuous design, 5) builder's plaque if present, 6) original railings if present, and 7) original **substructure** units.

Historical integrity of girder-floorbeam bridges tends to suffer most from loss of original materials to deterioration or replacement of floorbeam systems that are not compatible with the original girder-to-floorbeam connection and framing pattern.

Steel I-beams

The **steel I-beam** highway bridge has been one of the most ubiquitous and versatile bridge types used on Texas highways for more than a century. These bridges are sometimes referred to as *multi-beam* or ***stringer*** bridges, referring to the multiple strings (or lines) of parallel longitudinal beams. The I-shape cross-section of the beam is extremely efficient for carrying loads; the beam's **flanges** (or tops and bottoms of the "I") are wide and resist most of the bending stresses placed on a bridge, while the **web** can be varied in depth and matched to the span length and anticipated loads. I-beam bridges carry their decks directly on the beams. Deck material can be wood, metal, or concrete.

Historically, an I-beam is a specific type of beam that was rolled from a single piece of hot and malleable iron or steel. In cross-section, an I-beam has a relatively thick and narrow flange, as well as a tapered transition between the web and flanges. Wrought-iron I-beams were first rolled in America in 1853 at New Jersey's Trenton Iron Works. The innovative beams found most of their earliest applications in iron-frame buildings (not bridges), where architects and builders considered them a fire-proof material worth the extra cost. The I-beams eventually found their way into truss and girder bridges, where they were used principally for **floorbeams** and stringers. Cost was a limiting factor for iron I-beams, and nineteenth-century manufacturers could only roll them in a limited range of depth and lengths. Engineer J.A.L. Waddell, known for his textbook on iron bridge design, allowed in 1884 that **built-up** plate girders were stronger and stiffer than I-beams. He did not recommend I-beam bridges except for very short spans. As late as 1904, a standard reference work listed a length of 36 feet and a depth of 24 inches as the maximum for available I-beams. Iron or steel I-beam highway bridges predating the first decade of the twentieth century are no longer common in Texas or nationally. No such early examples appear to be in the Study Population.[227]

The turning point for the use of rolled, steel, I-shaped beams in bridge construction occurred in 1908 when Pennsylvania's Bethlehem Steel Company introduced the *wide-flange* or *W-beam*. This beam, as

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[227] J.A.L. Waddell, *The Designing of Ordinary Iron Highway Bridges* (New York, New York: John Wiley & Sons, 1884, Fifth Edition 1891): 55-57; Frank E. Kidder, *The Architect's and Builder's Pocket-Book, A Handbook for Architects, Structural Engineers, Builders, and Draughtsmen* (New York: John Wiley & Sons, 1904): 515.

compared to the earlier I-beam, has the cross-section of a sideways "H". A W-beam has flanges that are wider and thinner for the given depth of beam, with the transition between the flange and web nearly at right angles. This increased the load-carrying capacity as compared to a conventional I-beam of the same length and depth, with an approximately 10 percent savings in material. Since the early decades of the twentieth century, engineers have designed almost all rolled stringer bridges with W-beams or similar, not I-beams, although the older generic I-beam terminology has persisted.[228]

Steel I-beam – ***Simple****:* Most steel I-beam bridges in the pre-1946 Study Population are simple spans, also referred to by engineers as simply supported spans. These are bridges where the beam ends rest on **abutments** or **piers**. A bridge may be composed of a series of simply supported spans, with each pier having two bearings and the abutments one bearing. The Study Population includes 527 simply supported, steel I-beam bridges with dates of construction from 1900 to 1945. The principal structural feature of these bridges are the rolled steel beams, which steel manufacturers classified by weight and depth of beam. Longer spans require deeper and heavier beams to support the intended loads. During the course of the study period from 1900 to 1945, the size of beams available to engineers increased from a maximum of 24 inches deep and 100 pounds per foot in 1900 to 36 inches deep and 300 pounds per foot in 1940. The length of the beams available increased from 36 feet to 65 feet during the same period.[229] The pre-1946 Study Population reflects this gradual upscaling of steel I-beam bridges, with the spans reaching the near maximum of the beam lengths and depths by the late 1930s.

From 1918 to 1945, THD's bridge engineers prepared 88 standard drawing sets for steel I-beam bridges, indicating they considered the bridge type highly useful to a systematic approach to improving Texas highways. In 1918, the THD's bridge engineers prepared standard plans for steel I-beam bridges from 8 to 40-feet long, with a **live-load** design of a 15-ton road roller. These bridges made use of beams as shallow and lightweight as 9-inches deep and 21 pounds per foot for 8 to 10-foot-long spans to 24-inches deep and 80 pounds per foot for 37 to 40-foot-long spans. Engineers specified roadway widths of 16 to 20 feet for most of the steel I-beam standard plans of the late 1910s. By the mid-1930s, THD's bridge engineers had extended the use of steel I-beam bridges to spans of at least 70 feet following a major effort to revise the I-beam standard drawings between 1929 and 1935. For simply supported spans, the THD Bridge Division adopted standard beam lengths of 28, 40, 46, 50, 52, 60, and 70 feet, with the latter requiring Bethlehem Steel's 36-inch-deep and 250 pound per foot beams. Roadway widths ranged from 22 to 28 feet in 2-foot increments. Engineers prepared designs for both H-15 and H-20 load ratings.[230]

Engineers found steel I-beam bridges adaptable to a variety of deck treatments, including wood plank, reinforced concrete flat slab, steel plate, and open steel grid decks. After 1918, the THD engineers' invariable preference was for a concrete flat slab deck, but counties and city engineers sometimes

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[228] Misa, 170; Warren, *Big Steel,* 89-97; Warren, *Bethlehem Steel,* 94-95.

[229] Carnegie Steel Company, *Pocket Companion* (Pittsburgh, Pennsylvania: 1900): *1;* United States Steel, *USS Structural Sections* (1940): 12.

[230] Texas State Highway Department (1918): Item 50; Texas State Highway Department, Steel I-beam Bridges, Standard Drawings [88 plan sets] (1918- 1945); Jensen, E254-E255.

opted for other materials. Another deck type was the **concrete jack arch**, discussed further below. The concrete slab deck ultimately proved the most economical and ubiquitous for a variety of reasons. Monolithic reinforced-concrete slab floors originated in building construction in the 1880s and 1890s, transferring to bridge construction during the first decade of the twentieth century. Highway engineers quickly came to prefer concrete slab decks because they could be efficiently proportioned and strengthened with reinforcing bars for the anticipated truck loads. The decks could also be made composite with the superstructure by placing shear connectors (metal studs or triangular tabs on the top **flanges** of the beams), adding extra load-carrying capacity. Flat-slab decks could be poured in place, or they could be **precast** panels. Furthermore, the decks incorporated a wearing surface, usually the top half-inch or so of the deck, which could have grooves and other properties that improve the traction and safety for motorists. Flat-slab decks were the dominant deck type for steel I-beam bridges from about 1915 onward.[231]

Steel I-beam – Jack Arch Deck: Texas highway bridge engineers of the twentieth century, like their counterparts in other states, found the rolled steel I-beam technology extremely attractive due to simplicity, compactness, and price. One of the versatile characteristics of an I-beam bridge is its adaptability to various deck systems. One of the simplest deck solutions is a wood plank deck, which is designed to wear away and be replaced every decade or so. An early I-beam deck type that offered greater durability was the concrete jack arch deck, which found some applicability in Texas during the first three to four decades of the twentieth century.

The jack arch concept was not original to bridges but an adaptation from a building construction technique that likely began in New York City during the mid-1850s with the first iron-frame buildings. In these earliest instances, builders constructed the jack arches of brick. They considered the combination of iron framing and brick floors a fire preventative.[232] By the 1870s, the brick jack arch had made the transition to highway bridge construction but tended to be limited to only a few areas of the United States, particularly in the greater New York City area. In building and bridge construction, concrete replaced brick in the jack arches of the 1890s and early years of the twentieth century. This occurred nationally as highway bridge engineers sought out economical ways to improve short-span crossings by making use of I-beams and concrete. Builders created a concrete jack arch by placing an arch-shaped form liner between the beams. The liners could be wood falsework, sheet metal, or sections of **corrugated** metal pipes. The concrete was then poured over the form liner. Once the concrete had set, the arches integrated the deck with the I-beams and thus more evenly distributed the **live loads** to the beams.

The first introduction of I-beam bridges with concrete jack arch decks to Texas is unknown, but it was very likely a project completed by a bridge-building company working in the state between 1895 and 1905. The Austin Brothers Bridge Company and Berlin Iron Bridge Company, for example, used jack arch decks with I-beam bridges and short-span trusses. The jack arch deck technology remained in

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[231] Parsons Brinckerhoff and Engineering and Industrial Heritage (October 2005): 3:107-109.

[232] Carl W. Condit, *American Building Art: The Nineteenth Century* (New York, New York: Oxford University Press, 1960): 36.

use, particularly as a low-cost alternative for low-volume rural roads, through the 1930s. These bridges were rarely more than 40 feet long and could be built using force account labor, i.e., the state's or the county's own maintenance forces. The Study Population includes 6 steel I-beam with jack arch deck bridges built from 1925 to 1938, with maximum span lengths of 30 feet. Although rather late examples of the steel I-beam and concrete jack arch deck type, these bridges embody a method of construction that was important in the early adaptation of steel I-beams to short-span bridge construction.[233]

Steel I-beam – Concrete Encased: Concrete encasement was a technique introduced in the 1890s to protect steel beams from corrosion. Railroads adapted it first, using it for overhead crossings where the exhaust from steam locomotives accelerated the deterioration of steel. City engineers in locales like Pittsburgh, Pennsylvania and Newark, New Jersey also used encasement where noxious industrial pollution led to rapid corrosion of exposed metal surfaces. Some state highway departments such as Indiana and New Jersey adopted encasement as a standard practice. Encasement had the distinct disadvantage of adding deadweight to bridges, meaning that heavier steel beams needed to be used, but engineers of the time considered the trade-off acceptable. They did not anticipate, however, the long-term problems of encasement, which include the inability to inspect steel and the high likelihood that significant corrosion would take place once moisture penetrated and became trapped between the steel and concrete. Eight of the 22 concrete-encased steel I-beam bridges built between 1920 and 1940 in the Study Population span over railroads, leading some credence to the observation that the bridge type found favor where engineers perceived a need to protect the beams from locomotive exhaust.[234]

Steel I-beam – ***Cantilevered*** *with* ***Suspended Span***: The Study Population includes 19 cantilevered steel I-beam with suspended span bridges, built between 1932 and 1942. This design variation consists of longitudinal rolled I-beams that cantilever beyond the **piers** with a "drop-in" section placed between the two cantilevered arms to fill the gap where the center span crosses the river or other feature. The cantilevered span allows for a longer clear span with a shallower beam than would be achievable with a non-cantilevered span of the same given length and load, and considerably less steel than a metal truss of similar length and load. Texas's pre-1945 cantilevered steel I-beam with suspended span bridges have maximum span lengths between 66 feet and 90 feet, which non-coincidently was just beyond the available lengths of rolled steel I-beams during the pre-1945 period. The cantilevered arms and suspended spans allowed the engineers to stretch the steel I-beam maximum span length slightly beyond what could be achieved by a simply supported span. Satisfied with the performance of the earlier examples of this bridge type from the 1930s and early 1940s, the THD Bridge Division prepared standard drawings for the cantilevered steel I-beam bridges with suspended spans during the latter years of World War II in anticipation of using them frequently

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[233] Parsons Brinckerhoff and Engineering and Industrial Heritage (October 2005): 3:108; Historic Documentation Company, Historic Jack Arch Bridges of New Hampshire, Inventory and Significance Study (July 2010): 2.1-5, 3.1-12, prepared for New Hampshire Department of Transportation, Concord, New Hampshire; Jensen, E104.

[234] Lichtenstein Consulting Engineers, New Jersey Historic Bridge Inventory (1994): 72, prepared for the New Jersey Department of Transportation. As noted above in the Railroad Grade Separations section, bridge engineers also affixed "blast guard plates" to the bottom flanges of steel superstructures to protect the steel from the corrosive effects of the engine exhaust.

during the post-war construction campaigns. These standard drawings consisted of three-span units of 60-80-60 feet and 70-90-70 feet.[235]

Bridges of this type incorporate either a **shiplap** or **pin-and-hanger connection** detail at the inflexion point where the cantilevered arms meet the drop-in sections. The shiplap connection takes its name from a similar appearing joint used in carpentry, where the end of beams or planks rabbeted on opposite sides and then overlapped. In the steel I-beams to be shiplapped, steel fabricators notch the ends of the beams and fashion a saddle-like seat on the extended cantilevered arm to receive a bearing supporting the overlapping drop-in section. The pin-and-hanger connection detail harkens back to the pin connections of metal trusses and had the advantage of making the stress calculations determinate. Nationally and in Texas, engineers used both the shiplap connection and pin-and-hanger connections about equally during the 1930s, but the pin-and-hanger connections became dominant after 1945. As mentioned previously in the steel plate girder section, the collapse of the Mianus River Bridge in Connecticut in 1984 led to a complete abandonment of the pin-and-hanger detail.[236]

Steel I-beam – ***Continuous****:* Continuous spans are bridges where the principal structural members, in this case steel I-beams, are supported at three or more points by **abutments** and **piers**. Continuous design bridges are always more than one span. Engineers considered continuous design among the most important early to mid-twentieth-century trends in bridge engineering. Among the advantages of continuous designs were the ability to span greater lengths with shallower beams, saving material, and the elimination of interior deck joints.[237] College-educated engineers of the early twentieth century knew static load analysis. Using basic principles of physics and algebra, and knowledge of the weight and strength of materials and the intended loads of traffic, they could with a high degree of certainty design a bridge capable of safely serving its purpose. Continuous spans posed a dilemma because of the difficulty in analyzing how the stresses traveled, there being so many variables that the designs were known as *indeterminate,* meaning they could not be solved using traditional statics (i.e., the study of forces and structures at rest).

Several engineers successfully built major continuous-design bridges in the early decades of the twentieth century, the most famous of which was the Sciotoville Bridge over the Ohio River, a long-span continuous-truss railroad bridge designed by Gustav Lindenthal and opened in 1916. Nonetheless, engineers had their doubts about adopting the methods to everyday highway bridges, with sound reasoning since the economic payoffs of employing a labor-intensive design process would not be substantial except in long-span bridges. The situation changed in the late 1920s and early 1930s as new mathematical theories and methods developed to solve indeterminate design problems. Hardy Cross, a professor of engineering at the University of Illinois, made a major breakthrough in 1930 when he described in a publication a “moment distribution method” that allowed engineers to safely design structures. Cross’s follow-up publications and refinement resulted by 1936 in the method

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[235] Texas State Highway Department, Continuous Steel I-beam Bridges, Standard Drawings [29 plan sets] (1931-1945).

[236] Lichtenstein Consulting Engineers (1996): 7-8.

[237] Ohio Department of Transportation, Second Historic Bridge Inventory, Continuous Steel Deck Girder and Beam Bridges (2000).

becoming known widely as "the Hardy Cross method," which was used throughout the United States for almost all continuous designs until the 1960s and the advent of computer-oriented methods.[238]

The THD's bridge engineers moved into continuous design steel I-beam bridges in the late 1920s and the 1930s, and these bridges soon proved their worth in terms of reduced cost and efficiency of load-carrying capacity. Steel I-beam bridges particularly lent themselves to continuous designs, perhaps more than other types such as reinforced concrete slabs and tee beams, because of the simplicity of stringing the beams across piers and splicing beams end to end with **riveted**, **bolted**, or **welded** plates. The reinforced-concrete deck could also be made continuous over the interior piers, thus reducing the number of expansion joints, which easily fail and become a primary source of bridge deterioration.

From the late 1920s to the 1930s, the bridge engineers of the THD were aware of advances in engineering theory and knowledge and had the wherewithal to apply new methods of determining the moments and shears in continuous beam bridges. This allowed them to adopt the design methodology rather quickly. Between 1931 and 1934, the THD Bridge Division created a series of standard plans for continuous I-beam bridges consisting of two-span units of 15-15 feet and 20-20 feet. These bridges employed 15-inch-deep, 35 pound-per-foot I-beams for the 15-foot spans and 18-inch-deep, 47 pound-per-foot I-beams for the 20-foot spans. These relatively lightweight structures had reinforced-concrete decks and were supported on timber or concrete-pile **bent** **substructures**. Of the 129 continuous steel I-beam bridges in the Study Population, nearly all were built between 1930 and 1945. Continuous-design I-beam bridges were a very important post-World War II bridge type for bridges requiring individual maximum span lengths from about 25 to 150 feet. The THD began building them in great numbers during the late 1940s and into the era of interstate highways.[239]

Character-Defining Features: Steel I-beam bridges are one of the three most numerous pre-1946 bridge types in Texas, attesting to the I-beam's remarkable economy, versatility, and adaptability to standardization, which makes the population as a whole highly undifferentiated. Despite the large numbers of I-beam bridges in the Study Population, those pre-1945 examples with a high degree of historical integrity are fewer than 100, and those with design variations of concrete jack arch decks or encased beams even fewer in number.

Typical character-defining features of steel I-beam bridges are 1) length, width, and arrangement of spans, 2) the design as reflected in the arrangement, placement, and spacing of longitudinal I-beams, 3) beam depth relative to length and width, 4) type and method of fabricating beams, 5) simple, encased, jack arch, cantilever with suspended span or continuous design, 6) deck material and design (wood plank, jack arch, concrete slab, steel deck pan, open steel grid, etc.), 7) original railings if present, and 8) original substructure.

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[238] Emory Kemp, "Hardy Cross's Contribution to Structural Analysis," in Leonard K. Eaton, *Hardy Cross, American Engineer* (Urbana, Illinois: University of Illinois Press, 2006): 101-110.

[239] Texas State Highway Department, Continuous Steel I-beam Bridges, Standard Drawings [29 plan sets] (1931-1945).

The versatility of steel I-beam bridges extends to a myriad of ways to alter them for greater capacity and serviceability. Beams can be strengthened or repaired by adding welded cover plates, deck systems can be removed and replaced with those that are lighter weight and stronger, and roadway widening can be achieved by extending substructures and placing additional longitudinal beams to one or both sides of an originally narrower bridge. An automobile clattering over a wood plank deck, humming over an open steel grid deck or smoothly riding over a concrete deck can speak to different historic and technological contexts and periods of time. Widening typically results in the addition of beams, loss of original railings, and alterations to the substructure, impacting integrity of design, materials, and workmanship, as well as integrity of feeling since significantly wider bridges lose the "feel" of an early automobile highway where roadways were narrower and often more tightly enclosed by railings without shoulders or walkways.

Steel Plate Arch

The **steel plate arch**, a type of prefabricated structure, had its origins in the metal pipe industry. Fabricated sheet metal pipes came into use nationally during the last third of the nineteenth century, with the earliest examples consisting of sheet metal plates curved and **riveted** along the seams into a pipe or arch shape. **Corrugated** sheet metal pipes became available about 1905 but took some decades before they overtook cast iron as a pipe material of choice. Corrugated sheet metal pipes had the advantage of being lighter weight than cast iron, as well as less brittle and more flexible. Corrugation added strength to the thin sheet metal, and also offered greater surface area to increase the bearing area of the pipe against adjacent soil.

The nation's leading manufacturer, marketer, and supplier of corrugated pipe was the American Rolling Mill Company (ARMCO) of Middletown, Ohio. ARMCO was established in 1901 and had its roots in metal roofing. One of ARMCO's significant innovations was adapting the methods of continuous paper milling to rolling sheet steel. The company developed the new process in 1921, at which time ARMCO's reported capacity increased from about 520 tons of sheet per month to 40,000 tons per month. As a result, ARMCO's mills became among the most efficient and low-cost in the nation, and their ability to turn steel billets into flat, curved, or circular corrugated plates was prodigious. Leadership in milling technology gave ARMCO a major competitive edge, and during the 1920s it established plants and distributorships throughout the country.

ARMCO developed a successful product line in corrugated steel plate arches beginning in 1931. These arched plates were prefabricated and sent to the construction sites "knocked down" in a stack that could be unpacked and **bolted** together into arches with spans from 4 feet to 24 feet. Contractors needed no special skills or knowledge to erect the arches since ARMCO advertised that "local laborers simply bolt them together." **Live loads** limited the maximum span length and height of the arches once engineers considered the height and weight of the covering earth fill and **headwalls**. For example, a live truck load of H-20 limited the arches to a maximum of 18-foot span and 6-feet height of cover. Greater spans and heights could be used with lower live loads, making the steel plate arches particularly attractive for county roads. Another selling point was customers could "choose whatever type of spandrel walls you desire, since it's the metal that carries the load." The most visually appealing of the steel plate arch bridges had stone **spandrel** walls, harkening back to traditional stone arch construction. In 1935, ARMCO suggested that a more sophisticated look could be had with concrete spandrel walls adorned with architectural Art Deco-style pilasters. In 1941, ARMCO incorporated a separate division known as ARMCO Drainage and Metal Products to specialize in the marketing of pipes, arches, and other drainage products to engineers and builders. This coincided with the opening of an ARMCO steel mill in Houston by way of ARMCO's Sheffield Steel of Texas Division. These products came into widespread use after 1945.[240]

The Study Population includes five multi-span, steel plate arch bridges over 20 feet of total length built between 1930 and 1942.[241] This likely only represents a fraction of the steel plate arches built during this period since most will be culvert class and less than 20-feet span. Three of the five examples have stone headwalls and railings intended to give the steel plate arches the appearance of traditional stone arches.

Character-Defining Features: Typical character-defining features of steel plate arch bridges are 1) span length and roadway width, 2) material, fabrication method, and shape of arch, 3) stone or concrete headwall design, materials, and workmanship if present, and 4) railings if present.

The most common alteration to metal plate arches is replacement of corrugated metal panels after failure or deterioration. Metal plate arches also lend themselves to widening to one or both sides through the extension of new arch segments and fill. Widening is an impact to the integrity of design since it changes the proportions and outward appearance of the bridge, usually with changes in slope and vertical or horizontal relationship to the roadway. Widening may also result in alterations, replacement, or extensions to headwalls, changing the character of the bridge's appearance in elevation view.

Concrete Arch

Nationally, engineers and builders applied concrete materiality to arch bridge types before any others, with a great deal of innovation, debate, and competition among engineers, contractors, and inventors occurring during the last quarter of the nineteenth century. This continued until about 1905 when opinion began to consolidate around reinforcing systems making use of deformed **steel bars** in the tension zones of the arches. The substitution of concrete for stone was a logical first step due to the similarity in the materials' physical characteristics, both of which have high compressive strengths. The same principles that govern traditional stone arch construction govern concrete arch construction, only that stone arches are composed of blocks and concrete arches are monolithic material.

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[240] ARMCO, "Picture This Attractive Bridge in Your City," Engineering News-Record (September 12, 1935); ARMCO Drainage Products Association, Handbook of Culvert and Drainage Practice (Middletown, Ohio: 1945): 53-63; 93-118; Wayne Gard and Diana J. Kleiner, Iron and Steel Industry (Texas State Historical Association, 1976, updated 2017), electronic document, www.tshaonline.org/handbook/entries/iron-and-steel-industry [accessed September 2023]; Ohio History Connection, "American Rolling Mill Company," Ohio History Central, on-line at www.ohiohistorycentral.org/w/American_Rolling_Mill Company (2016).

[241] Two of the five bridges have reported dates of construction of 1930, which is likely an estimated date since ARMCO did not produce this bridge material until 1931. Further research is necessary to document the dates of construction of these two bridges.

Arches were either massed concrete or reinforced concrete. *Massed concrete* arches used the sheer mass of material to absorb stresses, while *reinforced-concrete* arches used steel bars embedded in the tension zones of the **arch ring** to absorb the tensile stresses. Reinforced-concrete arches were a more efficient design, since a lesser volume of material performed the same work done by the additional unreinforced mass. The moldable quality of concrete allowed arch bridge designers to select from semi-circular, segmental, or elliptical openings, and the choice was often influenced by site conditions, such as length of crossing and height of roadway above the stream or other feature. Aesthetic considerations also impacted the choice since the moldable qualities of concrete lent itself to architectural elaboration including corner pilasters, molded arch rings and **spandrels**, and **balustrades** and **parapets**. Many of the most aesthetically successful arch bridges were admirably matched to their settings, with the arch openings framing pleasing views.

Massed concrete arches found limited application in the United States during the 1880s to 1910s, and it is unlikely that any significant long-span examples were ever built in Texas based on the documentary evidence. By the early twentieth century, massed concrete arches had been relegated to short culvert-like spans where secondary stresses were considered low enough not to require reinforcing bars in the tension zones. In 1911, the federal Office of Public Roads recommended plain [unreinforced] concrete arches for clear spans of 6 feet, indicating that it would "be of service more often than those of larger spans" and probably only more desirable than box culverts when builders could not acquire steel reinforcing bars. In 1918, the THD's engineers specified "plain concrete arches" as only suitable for culverts of less than 12-foot span.[242]

Texas engineers and contractors built the state's earliest reinforced-concrete arches in the decade between 1905 and 1915, taking advantage of national trends and engineering knowledge distributed through technical journals and taught in engineering classes at Texas universities. According to the MPDF, one of the first documented reinforced-concrete arch bridges in the state was the Euclid Avenue Bridge, erected in 1908 across Turtle Creek in Highland Park (NBI No. 1805709HP230001). Other examples included the Main Street Bridge, built in 1910 over Town Creek in Weatherford (NBI No. 021840031302008), and the San Antonio Post Road Bridge, built in 1915 crossing Bunton Branch in Kyle in Hays County (NRHP listed, NBI No. 141060C00057001). While these were noteworthy bridges in a statewide context, Texas was not typically at the national forefront of reinforced-concrete arch technology. By the early 1910s, some of the longest and most impressive reinforced-concrete arch bridges ever built were already under construction in other parts of the United States. For example, the Delaware, Lackawanna & Western Railroad built a nearly half-mile-long, reinforced-concrete arch bridge to carry its main line over Tunkhannock Creek in northeast Pennsylvania between 1911 and 1915. Fort Worth's Main Street Viaduct, also known as the Paddock Viaduct, built in 1914 over the Trinity River (NRHP listed, NBI No. 22200001401325), has claim to technological significance for being the first reinforced-concrete arch bridge in the United States to employ self-supporting reinforcing steel. In this instance, "the reinforcing consisted of structural shapes which were designed to support

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[242] Hoyt and Burr, 16-17; Texas State Highway Department (1918): Item 42.2; George A. Hool, *Reinforced Concrete Construction,* Volume III, Bridges and Culverts (New York, New York: McGraw-Hill Book Company, 1928): 1-21; Parsons Brinckerhoff and Engineering and Industrial Heritage (October 2005): 3:65-68.

the weight of the forms and the plastic concrete in the arch ribs," eliminating the need for traditional arch centering and formwork.[243] S. W. Bowen of Brenneke and Fay, consulting engineers of St. Louis, Missouri, designed the Main Street Viaduct.[244]

Engineers in Texas and nationwide considered concrete arches well-established technology by the late 1910s. In 1918, THD's engineers considered concrete arches the only concrete bridge type suitable for spans over 65 feet. Reinforced-concrete arch bridge construction lasted in Texas through the mid-1940s, after which the bridge type was seldom if ever used. The decline was largely due to economic reasons since other concrete and steel bridge types proved faster to erect and used less material and labor.[245]

***Concrete Arch – Closed Spandrel**:* This bridge type has one or more **arch rings** supporting solid walls, called **spandrels**, that hold back earthen fill and carry the **deck** and railings. Closed spandrel arches may be very short, less than 20 feet, in which case they are classified as culverts by TxDOT and outside this study, or they may have spans of 100 feet or more in some of the longer monumental examples, making them quite versatile. The Study Population includes 41 closed-spandrel, concrete arch bridges built between 1908 and 1943. Nearly all these bridges are geographically located near the cities of Austin, Dallas, Fort Worth, San Antonio, and Waco, which speaks to the aesthetic appeal of the arch structural shape and moldability of concrete for City Beautiful projects in locations in or near downtowns, parks, and parkways.

***Concrete Arch – Open Spandrel**:* This bridge type differs from closed spandrel arches in that columns rest on the **arch rings** and support a **deck** slab. The arch rings can either be solid or ribbed. Open spandrels lessen the **dead load** on the arch but make for more complicated formwork. Engineers of the early twentieth century determined that an open-spandrel design was well suited for long spans from 100 to 250 feet or more with high rises where the savings in weight was well worth the effort of designing open spandrels. Open spandrel arches are usually graceful yet powerful, and many bridge historians consider them a pinnacle of early American concrete bridge engineering. Since open-spandrel arches often serve as major river crossings in urban or scenic settings, they also often have a high degree of artistic expression in pylons, railings, and exposed faces of the **piers**, **abutments**, and **wingwalls**. The Study Population includes seven open-spandrel, concrete arch bridges built between 1909 and 1938. The MPDF calls out several of these structures for unusual details including the Main Street Bridge (1914, NBI No. 121020B41697003) over Buffalo Bayou in Houston for use of a patented system of reinforcing bars in the arch barrel and the Guadalupe River Bridge (1934, NBI No. 150460001611016) in New Braunfels for high artistic expression. However, the benchmark for the open-spandrel arch bridge type in Texas is the Dallas-Oak Cliff Viaduct, also known as the Houston Street Viaduct (NRHP listed, NBI No. 180570000911079) over the Trinity River in

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[243] Hool (1928), 297.

[244] Robert W. Jackson, Historic American Engineering Record, Main Street Viaduct (Paddock Viaduct), HAER No. TX-50 (1996).

[245] Texas State highway Department (1918): Item 42.2; Condit (1961): 196-206; Jensen, F248.

Dallas. The nearly one-mile-long bridge consists of 51 open-spandrel arches and a concrete-encased steel plate girder main span over the river.[246]

Closed-spandrel and open-spandrel, concrete arch bridges are as types the most architecturally elaborated bridges in Texas. The arches range from plain utilitarian examples to those that have spandrel walls articulated by pilasters, arch scoring, and string courses. Engineers often finished concrete arch bridges with rubbed smooth, bush-hammer, or exposed aggregate finishes to create architectural texture. Some arch bridges have masonry veneers to simulate the appearance of stone arches. An example of a concrete arch with a stone veneer is San Jacinto Boulevard's crossing of Waller Creek in Austin (NBI No. 142270B0132001). The three-span bridge is faced with a veneer of randomly **coursed** limestone blocks.

Character-Defining Features: Typical character-defining features of concrete arch bridges are 1) span length, roadway width, and vertical clearance, 2) massed or reinforced concrete, including placement or reinforcing bars in tension zones, 3) arch shape barrel, semi-circular, elliptical, etc., 4) ratio of rise to length, 5) closed spandrel or open spandrel, 6) finish and architectural details such as pilasters, etc., 7) original **parapets**, **balustrades**, and railings if present, and 8) original **substructure** and wingwalls.

The principal integrity issues with concrete arches are that the quality of the design, materials, and workmanship can be impacted by widening that alters scale and obscures original elevations, or the application of concrete repairs such as stuccos that alter the original finishes. The replacement of railings is another common alteration, and concrete arches, unlike most other bridge types, tended to have railings that were architecturally compatible with finishes and applications of style to the entire bridge.

Concrete Slab

Slab bridges are the simplest type of reinforced concrete bridges. The slab functions as a wide shallow beam. Slab bridges are typically between 5-foot and 30-foot span lengths. If the slab is not under earth fill, then the slab itself acts as a bridge deck. Slab bridges have reinforcing steel in the tension zone that runs along the bottom of the slabs. The steel is typically placed from abutment to abutment, parallel to the direction of traffic.

The slab technology developed rapidly between 1895 and 1905, led by Minneapolis-based engineer Claude A. P. Turner and others, primarily for use in the flooring systems of reinforced-concrete frame factories. The technology, which relied on a cage of reinforcing bars in the tension zones of the slab that could act in both one-way and two-way flexures, depending on the design, quickly made the transition to bridges and culverts. Short-span slab bridges and culverts spread widely across the

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[246] Robert W. Jackson, Historic American Engineer Record, Dallas-Oak Cliff Viaduct, HAER No. TX-33 (1996); Jensen, F248-F249.

United States through college engineering curriculums and the practical experience of the many engineers and contractors who adopted reinforced concrete as a new and versatile material.[247]

Engineers and contractors found slabs simple to build and understand. Engineers of the U.S. Office of Public Roads in 1911, as well as those hired by THD in 1918, endorsed slab technology for short-span bridges and culverts on county and state roads. In 1911, the Office of Public Roads recommended slabs for spans from 10 feet to 20 feet long, although it expressed some reservations that the new technology might not yet be of uses "for greater spans in view of the possibilities of a nominal future growth in traffic requirements." The THD's bridge engineers adapted the same stance in their *Specifications and Contract*, published in 1918, which recommended slabs as a preferred bridge type for spans from 10 to 20 feet long and suggested that anything longer should be a tee beam or arch. THD's *Road and Bridge Specifications*, published eight years later in 1926, still advised slabs for use in a range of 10 to 20-foot spans, but a decade later in 1935 advised up to 24-foot spans. Slabs longer than this became too deep and used unnecessary amounts of material as compared to other alternatives, particularly the tee beam bridge type (see below).[248]

Over the course of the entire twentieth century, slab bridges were a workhorse type built for short-span stream crossings or in multiple spans for longer crossings. Advances in technology were primarily in the development and quality control of the materials and preparation of the reinforced concrete. These advances, like applying epoxy coatings to the reinforcing steel to enhance bonding and protect the steel from corrosion, tended to not be outwardly visible. Reduction in the number of expansion joints, savings in **substructure** design and economy of material, and slightly enhanced span lengths could also be achieved by making the slabs continuous or variable depth over interior substructure units.

With one or two exceptions, the slab bridges in the pre-1946 Study Population are **cast-in-place** concrete. **Precasting** was introduced nationally during the 1910s as a way of prefabricating slabs at off-site locations but was not widely used in Texas until the late 1940s and the 1950s, after the period of this study. Precast slabs could be erected quickly, making them ideal for locations like a railroad where the time to erect false work and cure a cast-in-place bridge (at least 30 days) would have created undesirable disruptions to railroad operations.

Concrete Slabs – ***Simple***: Concrete flat slabs that are simply supported, i.e., the ends of the slabs of each span rest on an **abutment** or **pier**, are among the most numerous bridge types in the pre-1946 non-truss Study Population, with 730 examples built between 1914 and 1945. In general, the slab population fits well within the anticipated dates of construction and span lengths proscribed by Office of Public Roads engineers in 1911 and THD engineers in 1918. Only 11 of the 730 slab bridges, about 1 percent, exceeded a maximum individual span length of 30 feet, and these longer exceptions all range between 31 and 40 feet long. The bridge-class slabs all have overall structure lengths of 20 feet

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[247] Parsons Brinckerhoff and Engineering and Industrial Heritage (October 2005): 3:83-85; Jensen, F242-F243.

[248] Hoyt and Burr (1911): 14; Texas State Highway Department (1918): Item 42.2; Texas State Highway Department, *Road and Bridge Specifications* (1926): Item 81.44; Texas State Highway Department, *Specifications for Design of Structures* (October 1935): Sheet 5.

or greater, but many are composed of multiple spans shorter than 20 feet, with the shortest individual span reported as 4 feet. The longest total slab structure lengths range from 500 to 1,200 feet long and composed of as many as 60 spans.

Between 1918 and 1945, THD's bridge engineers prepared at least 79 standard drawings for simple-supported slab bridges. The earliest standard, identified as Drawing No. CB1 of circa 1918, described a slab superstructure with clear spans of 8 feet to 20 feet in 1-foot increments. The depth of the slab increased with length of span, with the 8-foot-long slabs having 10-inch-deep slabs and 20-foot-long slabs having 18.75-inch deep slabs. The relative proportionality and limited dimensions made the standard easy for resident engineers and contractors to apply to most any given short-span crossing. Over the course of the 1920s to the 1930s, THD's bridge engineers updated the slab standards for wider roadways from the original 16, 18, and 20-foot-wide roadways of the late 1910s to the 22, 24, 26, and 28-foot roadways of the late 1920s to the 1930s. In some instances, the variations in standards had more to do with substructure design than superstructure, and the plans often made a distinction between slab bridges on solid-stem abutments versus "slab trestles" that rested on concrete pile bents. Standards also existed for skews of 30 and 45 degrees. A flurry of revisions undertaken from the late 1930s to the mid-1940s updated the standards for H-15 and H-20 truck loads and also began a shift toward standard lengths of 20, 25, and 30 feet. These longer spans, however, did not require slabs to be as deep as they had been a quarter century earlier due to improved strength in materials and efficiency in the placing of the reinforcing bar cages. For instance, a 20-foot-long slab built to THD's standard of 1918 for 15-ton trucks required a 17.25-inch-deep slab, while that same slab length and loading in 1945 required only a 13-inch-deep slab.[249]

Concrete Slabs – ***Continuous****:* The Study Population includes 214 multi-span, continuous flat (non-variable-depth) slab bridges, i.e., the slabs extend across one or more **piers**. The continuous slab bridges have dates of construction between 1914 and 1945, meaning that continuous design was a choice available to engineers and builders early in the development and usage of this bridge type. The continuous slab bridges have individual span lengths from 7 to 35 feet long, thus not differing much in that respect from the simple spans. The longest total continuous slab structure lengths are from 300 to 400 feet long and composed of as many as 20 to 24 spans, somewhat less impressive than the simple spans.

The principal advantage of the continuous spans in the context of its application in Texas appears to have been a reduction in the number of expansion joints and applicability to lighter concrete pile bent substructures. Judged by the distribution of surviving examples in the Study Population, county engineers and THD engineers developing plans for FM roads frequently built continuous slabs during the 1930s. THD bridge engineers prepared 25 continuous concrete slab standard drawings from 1937 to 1945 that had loadings and roadway widths of 26 feet to 44 feet applicable to the state highway system. These bridges had a variety of standard length configurations including two-span continuous units of 25-25 feet; three-span continuous units of 20-20-20 feet, 25-30-25 feet, and 30-40-30 feet;

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[249] Texas State Highway Department, Reinforced Concrete Slab Spans, Standard Drawings [79 plan sets] (1918-1945).

and four-span continuous units of 25-30-30-25 feet. The depth of slab of these continuous units was 13 inches for 20-foot spans, similar to the simple spans of the same lengths, an indication that engineers considered other factors such as elimination of expansion joints and savings in substructure when choosing a continuous design over a simple one.[33]

Variable-Depth Concrete Slabs – Variable-depth concrete slab bridges are multi-span bridges where the depth of the slab is greatest over the **piers** or **abutments**. These bridges usually have slightly curved or haunched **soffits**, giving them an elevation profile that may resemble a very shallow concrete arch. The Study Population includes nine variable-depth slab bridges built from 1905 to 1944. These bridges tend to be individualistic designs created for site-specific purposes. The oldest in the study is the Landa Park Drive Bridge, built in 1905 over the Comal River in New Braunfels' Landa Park (NBI No. 150460B00960003). The unusual two-span, 38-foot-long bridge, an early application of concrete slab bridge technology, has a very slightly arched slab faced with low stone curbs and two pylon-like stone lampposts at mid-span, in clear deference to the park setting. A much later example from 1943 is the Marine Creek Bridge, carrying SH 183 in Fort Worth (NBI No. 022200009405026). The three-span, 169-foot-long bridge has very thin slabs with arched soffits expressing a Modernist aesthetic where form follows function. Its maximum span length of 65 feet ranks it as the longest pre-1946 slab bridge in the study.[250]

FS Slabs with Integrated Curbs – The Study Population includes two FS Slab bridges with reported dates of construction of 1940, although it is likely these are estimated dates and the actual dates are 1945 or later. Engineers designed the FS Slabs to have monolithically poured curbs and thinner slabs than the pre-1946 standard slab bridges. The engineers reinforced the curbs and integrated them so that they perform a structural function in addition to a safety function. The two bridges will be researched within Texas's post-1945 bridge context to determine if they have significance as early prototypes.[251]

Character-Defining Features: Typical character-defining features of concrete slab bridges are 1) span length, roadway width, and vertical clearance, 2) monolithic slab of constant or variable depth, 3) concentration of reinforced bars in lower portions (tension zones) of slab, 4) simple or continuous spans, 5) **cast-in-place** or **precast**, 6) original concrete **balustrades**, **parapets**, or railings if present, 7) stone veneer if present, and 8) original substructure.

As a group, very few of the pre-1946 concrete slab bridges survive in an unaltered state. The most common alteration is widening to one or both sides, often increasing the width of the short-span bridges by more than 50 percent. Given that most of these early slab bridges were 20 to 30 feet long, increasing the roadway width greatly changes the feeling and appearance of the bridge. This is considered a significant alteration since it not only results in loss of original railings and elevations but is often accompanied by changes in the roadway grade and alignment. The widening not only impacts

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[250] Texas State Highway Department, Reinforced Concrete Slab Spans, Continuous Units, Standard Drawings [25 plan sets] (1937-1945).

[251] Mead & Hunt, Inc., *Historic Context for Texas Bridges, 1945-1965* (2009), prepared for the Texas Department of Transportation.

integrity of design (as expressed through scale and outward appearance) but also diminishes the integrity of setting and feeling when associated with an older highway that has been improved from its original alignment and width.

Concrete Tee Beam

Tee beams are **cast-in-place** bridges composed of longitudinal lines of reinforced-concrete beams. The beams are integral with the slab deck. The tee beam nomenclature describes the placement of the reinforcing steel connecting the beams with the slab; in section the reinforcing bars form a T-like shape. The main reinforcing steel in a tee beam is placed longitudinally in the bottom of the beam stem. The outer lines of beams are often recessed from the fascia of the deck, creating a **cantilevered** deck section. Engineers of the early twentieth century, including those of the THD, often referred to tee beam bridges as concrete deck girder bridges.

Tee beam technology developed contemporaneously with slab technology in the late 1890s and 1900s and became widespread nationally and in Texas during the 1910s. Tee beams were a longer span complement to slabs; the beams could be proportioned and spaced to achieve a strong and economical section beyond what might be achievable by a slab. The federal engineers of the Office of Public Roads commented in 1911 that the tee beam "type of construction supplements the slab type and begins to be practical in point of economy at the point where the slab ceases to be economical." They advised short-span uses though, noting that engineers had "designed for spans up to 50 feet long, but whether or not it is practical for spans as great as that may depend on several conditions, which must be carefully determined in each individual case."[252] By 1924, a standard textbook on reinforced concrete construction merely states that "with the growing demand for bridges on the public highways with wider roadways to accommodate fast moving traffic, the tendency has been to turn to the deck girder [tee beam]." The authors noted that the "rails on the deck girder present a…pleasing appearance" and the only true drawback being that a tee beam required a deep flooring system, which could result in raising the grade of the approaches.[253]

The heyday of tee beam technology in Texas and nationally was from the late 1910s to the early 1960s when the bridge type was used by the THD and other state highway department for the widespread development of the state highway systems.[254] The significance of tee beam bridges to a systems building approach to highway development is evident in the attention the THD's bridge engineers paid to the development of standard plans, producing nearly 100 variants of the tee beam standards to cover projects of different bridge lengths, widths, skews, and loadings between 1918 and 1945. The THD's first construction specifications of 1918 listed the tee beam bridges as appropriate for spans of 14 to 65 feet, a recommendation that remained relatively constant in subsequent editions of the specifications through the mid-1940s.[255] The most used of the standard tee beams plans from 1918 to about 1930 offered engineers a choice of lengths from 16 feet to 40 feet in 2-foot increments,

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[252] Hoyt and Burr (1911): 15.

[253] George A. Hool and W. S. Kinne, *Reinforced Concrete and Masonry Structures,* Second Edition (New York, New York: McGraw-Hill Book Company, 1944): 452.

[254] Parsons Brinckerhoff and Engineering and Industrial Heritage (October 2005): 3:88-89.

[255] Texas State Highway Department (1918): Item 42.2.

but after 1930 the most used standard plans changed to lengths from 25 feet to 50 feet in 5-foot increments. The more consequential variation in standard tee beam plans, however, were in load ratings and roadway widths, as the THD bridge engineers worked to keep up with the increasing weight, size, and speed of motor vehicles. All the earliest tee beam standards used a 20-ton road roller as the **live load** unit of design, which was a high standard for its time, but by the 1930s, THD bridge engineers were using H-15 and H-20 loads, which resulted in some beefing up of the girders.[256] Roadway widths turned out to be the least satisfactory characteristics of the early tee beams standards. One of the earliest standard plans of August 1918 had only a 16-foot-wide roadway, while others of later in 1918 and 1919 offered 18 or 20-foot roadways. By 1926, nothing less than a 22-foot roadway was allowable on a standard plan, and by October 1945 this had increased to a 28-foot-wide roadway for a typical two-lane highway.[257]

A disadvantage of tee beam technology, like all cast-in-place concrete, is that it required formwork to be erected and time to cure the concrete. By the late 1920s and early 1930s, tee beams faced price competition from steel I-beams over the same range of span lengths and lost their cost advantages. By the early 1960s, tee beams were a waning technology. Tee beams have continued to be built since then, but almost entirely as **precast**, prestressed-concrete structural components, not cast-in-place reinforced concrete. No precast examples exist in the pre-1946 Study Population.[258]

Concrete Tee Beam – ***Simple****:* Tee beams that are simply supported, i.e., the ends of the beams of each span rest on an **abutment** or **pier**, account for the vast majority of tee beam bridges in Texas from prior to 1946. The Study Population includes 870 examples built between 1910 and 1945. Span lengths range from a minimum of 11 feet to a maximum of 79 feet, though most fall in the 20-foot to 50-foot range. Engineers viewed the standard tee beam plans as a unit that could be repeated as many times as necessary to reach the length necessary to span even a major crossing of a floodplain. A few examples combine from 30 to 50 spans to reach total lengths of from one-fifth to one-quarter of a mile.

Concrete Tee Beam – ***Continuous****:* Tee beams that are continuously supported, i.e., the beams extend across one or more **piers**, benefit from the same economies as other continuous beam bridge types such as steel I-beams and concrete slabs. Namely, ability to span greater lengths with shallower beams as compared to simple spans, saving material, and the elimination of interior deck joints. The Study Population includes 12 continuous tee beam bridges with dates of construction from 1914 to 1935, exclusive of the continuous tee beam bridges with variable depth beams (discussed below). Several of these examples are early applications of continuous-design principles to tee beam technology, suggesting a degree of innovation in this area unseen in most other bridge types in the Study Population. Continuous tee beam bridges of interest include the Samuels Avenue Bridge, built in

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[256] The H-15 and H-20 load ratings assumed 15-ton and 20-ton trucks in each lane followed by trains of trucks each weighing three-quarters as much as the basic truck. This was a more sophisticated approach than designing for a single point load of a 20-ton roller.

[257] Texas State Highway Department, Reinforced Concrete Deck Girder Spans, Standard Drawings [98 plan sets] (August 1918-October 1945).

[258] Jensen, F244.

1914 over the West Fork Trinity River in Fort Worth *(*NBI No. 022200ZS0687001) and the Commerce Street Bridge, built in 1925 over the San Antonio River in San Antonio (NBI No. 150150B07505004).

Variable Depth Tee Beam*:* The aesthetic potential of both **simple** and **continuous**-design tee bridges expressed itself in Texas from the mid-1910s to the 1920s with a series of bridges constructed in San Antonio, with other examples appearing in Dallas in the late 1910s, Belton in the early 1920s, San Angelo in the early 1920s, and Houston in the mid- to late 1920s. The Study Population includes 43 variable-depth tee beam bridges dating from 1914 to 1945. The continuous spans pushed the limits of the **cast-in-place**, reinforced-concrete tee beams to the outer limits of the material, with the longest so-far identified span being the 164-foot-long main span of the East Belknap Street/US 377 bridge over the West Fork of the Trinity River, built in 1932 in Fort Worth (NBI No. 022200008101001).

The variable-depth tee beams typically have beams with shallow, arched **soffits**, which in the hands of a skilled engineer can result in a bridge with pleasing lines and aesthetic qualities without needing to resort to architectural embellishments. The arched beams often complement **piers** with arched caps. That said, engineers did not shy away from applying elements of architectural style, particularly in railing treatments. Another technique was for engineers to apply stone veneers to simply supported, variable-depth beams to give them the appearance of stone arches. County and city engineers, or their consultants, designed many of the earliest and finest examples of the variable-depth tee beams, which also associates these bridges with the City Beautiful Movement.

The MPDF noted that THD engineers built some of these variable-depth tee beam bridges, particularly from the 1930s onward, with the Waco District having a particular affinity for using them with grade-separation bridges.[259] By this time, engineers had grasped the Hardy Cross method of moment distribution and were also increasingly attuning to Modernist concepts that a well-designed bridge has a depth of beam section that closely follows the moment requirements from a minimum at the center of the spans to a maximum at the substructure supports. From this perspective, the best proportioned variable-depth tee beam bridges of the 1930s to the mid-1940s had interior spans from 1.3 to 1.4 times the length of the end spans, which was governed by the materials, loadings, and unit stresses typical of the time. As engineers at the Waco District must have recognized, there were certain bridge sites that lent themselves to a three-span configuration, where the piers could be placed on the stream bank or at the sides of the roadway with the longer center span crossing the river's main channel or the highway's travel lanes and the shorter end spans providing elegant transitions to the roadway approaches.[260]

Character-Defining Features: Typical character-defining features of concrete tee beam bridges are 1) span length, roadway width, and vertical clearance*,* 2) spacing and dimension of longitudinal beams, 3) placement of reinforced bars in characteristic T-beam pattern, 4) simple or continuous spans (continuous spans often have variable-depth beams, 5) flush or cantilevered deck section, 6) aesthetic

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[259] Jensen, F244.

[260] The Portland Cement Association made particular note of the suitability of this approach in its widely distributed publication, *Continuous Concrete Bridges* (Chicago: circa 1940): 3.

treatments such as stone veneer, pilasters, or scoring; 7) original **parapets**, **balustrades**, and railings, if present, and 8) original substructure units.

The most common alteration to T-beam bridges is widening, often with I-beams or prestressed-concrete beams, obscuring the original elevations, changing the relationship of the bridge deck to the beam (from flush to cantilevered, or from cantilevered to flush or more deeply cantilevered), and resulting in loss of railings. These are character-altering changes that have significant impacts on the aspects of integrity.

Concrete Rigid Frame

Reinforced **concrete rigid frames** are bridges in which the superstructure and the substructure are constructed as a single unit. The abutments of a rigid frame are sometimes referred to as legs. The longitudinal member of a rigid frame can appear to be a slab or beams (referred to as ribs and often looking like T-beams), with either a flat or shallow arch profile. It is common for laypeople to mistake rigid frames for arches, slabs, box culverts, or tee beams. The key to distinguishing a rigid frame from other bridge types is the reinforcing pattern where **steel bars** are placed in the bottom of the superstructure, longitudinally and vertically in the outside corners of the frame (referred to as the knee) and vertically in the face of the legs. Often the only way to identify a rigid frame is by referring to plans, especially in shorter examples that look like box culverts.

A rigid frame is an efficient use of reinforced concrete from the standpoint of reducing the quantity of materials. The rigid frame pattern of reinforcing and method of stress analysis developed in Germany during the late 1890s and the early years of the twentieth century. By the 1910s, some American engineers designed box culvert-like, short-span structures with the integration of the top slab with the legs by way of interlocking or bending the reinforcing bars together at the outside corners of the frame. During the 1920s, engineer Arthur G. Hayden of New York's Westchester County Parks Commission almost single-handedly brought to the attention of American engineers the possibilities of longer span rigid-frame bridges, although his influence was mainly Brazilian engineer Emilio Baumgart. Between 1922 and 1930, Hayden designed and oversaw the construction of a series of over 70 exceptionally well-detailed rigid frame bridges, mostly used as overpasses for the county's new parkway system. Hayden popularized the rigid-frame bridge type through a series of articles and a textbook published in 1931. By the late 1920s and early 1930s, many other engineers had recognized the advantages of rigid frame bridges. Rigid frames were also adaptable to multi-span continuous designs.[261]

A principal economic advantage of a rigid frame is that its inherent design of integrating the legs with the superstructure reduces the amount of excavation work needed for substructure units. They can rest rather lightly on existing topography. A rigid frame also lends itself to a slightly arched profile, often looking like an upside down "U" so that the superstructure achieves its maximum depth at the knees where the stress pattern is most complex. In longer spans, the arch profile or **soffit** is a

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[261] Arthur G. Hayden, *The Rigid-Frame Bridge,* Second Edition (New York: New York: John Wiley & Sons, 1940); Condit (1961): 213-215; Parsons Brinckerhoff and Engineering and Industrial Heritage (2005): 3:96-97.

necessary and economical use of material, but it also almost always results in a well-proportioned span with aesthetic appeal. The rigid frame is also capable of supporting a variety of architectural treatments, from molded architectural details to the application of brick and stone veneers. For these reasons, engineers and project sponsors found them particularly suited to urban parks and parkways.[262]

The Study Population includes 29 reinforced-concrete rigid frame bridges built between 1922 and 1945, a rather modest number for a state the size of Texas. The bridge type simply never caught on among most Texas engineers. By 1933, only 15 state highway departments throughout the nation reported that they regularly employed rigid frames, and THD was not among them.[263] One possible reason was that engineers did not typically prepare standard plans for rigid frame bridges, meaning they were almost always individual designs. The only surviving Study Population bridge example of a rigid frame overpass designed by the THD is the North Main Street Overpass, built in 1934 on US 77 in Schulenberg (NBI No. 130760026901036).

Unsurprisingly, counties or cities built most of the rigid frame bridges in this Study Population. The MPDF identifies San Antonio banker, builder, and consulting engineer John W. Beretta as "a champion" of the rigid frame bridge in Texas. He designed at least four rigid frame structures, including the Lincoln-Garden Street Bridge over the Comal River, erected in 1931 (NBI No. 150460B00590001), and the Upper Shoal Creek Bridge on Shoal Creek Boulevard, erected in 1934 (NRHP listed, NBI No. 142270B01356006). Most of the Texas examples are modest maximum span lengths, ranging from 10 feet to 35 feet in all but one of the bridges in the study. The East Cesar Chavez Boulevard Westbound Bridge, built in 1931 over the San Antonio River in San Antonio (NBI No. 150150B10170001), has a single span of 103 feet, making it by far the most ambitious and exceptional of the study's rigid frame bridges. Beretta claimed in an article published in *Engineering News-Record* in April 1931 that his design benefitted from shallow ribs and special **cantilever** footings to achieve a record length. The greatest concentration of rigid frame bridges is in Dallas County, where there are six bridges built between 1925 and 1940.[264]

Character-Defining Features: Typical character-defining features of concrete rigid frames are 1) span length, roadway width, and vertical clearance, 2) integral superstructure and substructure, 3) placement of reinforced bars in characteristic rigid frame pattern, 4) arched **soffit** of longer examples, 5) simple or continuous spans, 6) finish and architectural details, e.g., pilasters at the abutment corners or **wingwalls**, and 7) original **parapets**, **balustrades**, and railings if present.

Short-span rigid frame bridges may be widened to one or both sides by rigid frame or slab extensions. The principal integrity issues with longer rigid frame bridges are similar to those of concrete arches in that the quality of the design, materials, and workmanship can be impacted by widening that alters

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[262] Parsons Brinckerhoff and Engineering and Industrial Heritage (2005): 3:96-97.

[263] Portland Cement Association (*circa* 1940).

[264] Everett Lloyd, "Laredo – Down by the River," *National Magazine* (April 1921) :231-232; John W. Beretta, "Rigid-frame bridge of 101-ft. span at San Antonio," *Engineering News-Record,* Volume 106, No. 26 (June 25, 1931): 1048-1049; J. W. Beretta, "Rigid Frame Concrete Bridges, *American Concrete Institute Journal,* Volume 5, Number 3 (1934): 196-207; Jensen, E114, F249-F250.

scale and obscures original elevations, or the application of concrete patches and stuccos that cover the original finishes. The replacement of railings is another common alteration, and concrete rigid frames, like arches, tended to have railings that were architecturally compatible with the finish of the shallow arch **spandrel** walls.

Bridge-Class Concrete Box Culvert

Concrete box culverts are distinguished from short-span **concrete slabs** or **rigid frames** by having a rectangular cross-section integrating the top, two sides, and floor of the box into a monolithic structure. In 1911, federal Office of Public Roads engineers wrote that "the box culvert gets its name from its similarity to a box with open ends," and they considered it practical under most conditions for spans up to about 8 feet but could potentially be applied to spans of up to 20 or 30 feet. Box culverts were usually placed under earthen fill to carry the roadway, although the possibility existed for the top slab to provide a riding surface similar to a concrete slab. Hool and Kinne in their standard text, *Reinforced Concrete and Masonry Structures,* published in 1924 and reissued in 1944, listed several reasons for the commonness of box culverts, including simple formwork that reduced construction costs, distribution of load across the entire foundation enabling construction on earth foundations, the greatest maximum waterway area for a given width of opening when clearances were restricted, and the ability to accommodate greater lengths of opening by subdividing the box-shaped opening into two or more spans.[265]

The earliest uses of concrete box culverts in Texas are somewhat obscure but probably date to around 1905 to 1910. The THD's first *Standard Specification and Contract* of 1918 and the updated *Road and Bridge Specifications* of 1926 listed "reinforced concrete boxes" among other culvert types of concrete arches, concrete pipes, **corrugated** metal pipes, and cast-iron pipes, but clearly did not contemplate any of the culvert types exceeding 10 foot span. THD's revised *Specifications for Design of Structures*, issued in 1935, increased the acceptable box culvert span length to 24 feet, pushing even single-span examples into the greater than 20-feet bridge class category.[266]

The MPDF identified a trend in box culvert applications stating that, "By the late 1930s, [Texas State Bridge Engineer] Wickline had largely discontinued use of simple concrete slab structures for short-span bridges, relying instead on reinforced concrete multiple box culverts built in lengths of 20 to several hundred feet."[267] Archival documentation for why this shift took place toward long, multi-span box culverts has yet to be found, but it appears to be related to specific topographic and hydrologic site conditions. The approach adopted by Wickline clearly provided for overflow structures across wide and frequently dry floodplains, where the culverts were not under fill and the motor vehicles rode directly atop the culvert's top member. THD's engineers made an adaptation in design for these longer box structures by inserting expansion joints to handle expansion and contraction, a detail not usually associated with box culverts. The THD engineers did not place the joints at every span, just at

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[265] Hool and Kinne (1944): 628-631.

[266] Hoyt and Burr (1911): 13; Texas State Highway Department (1918): Item 42.2; Texas State Highway Department, (1926): Item 81.44; Texas State Highway Department (October 1935): Sheet 5.

[267] Jensen, E128.

intervals along the structure, usually every fourth to sixth span. In order to accommodate the bearing at the expansion joint, the side wall supporting the bearing had a wider seat. The longest identified example incorporating these details is the 50-span, 336-foot-long culvert carrying US 90 over Sanderson Canyon in Pecos County (NBI No. 061860002106019).

Bridge-class concrete culverts are the most numerous structure type in the Study Population of pre-1946 bridges with 1,063 examples with dates of construction between 1920 and 1945. This number, of course, includes only the box culverts that have an overall length of greater than 20 feet. It can readily be anticipated that the shorter-than-20-feet, non-bridge-class culverts are far more numerous and very likely include the older examples built prior to 1920.

Character-Defining Features: Typical character-defining features of bridge-class concrete box culverts are 1) span length, roadway width, and vertical clearance, 2) integral four-sided top, two side walls, and floor, 3) material of original head walls and wing walls if present, 4) expansion joints if originally present in longer examples, and 5) original railing treatment if present.

The most common alteration to concrete boxes is widening to one or both sides, often increasing the width of the short-span bridges by more than 50 percent or more. The widening not only impacts integrity of design (as expressed through scale and outward appearance) but also diminishes the integrity of setting and feeling when associated with an older highway that has been improved from its original alignment and width. Alterations may also include extending **headwalls** and **wingwalls** to hold back a great depth of fill. This is considered a significant alteration since it not only results in loss of original railings and covering of original elevation but is often accompanied by changes in the grade and alignment of the road.

Concrete Pipe

Concrete pipes are a very common type of drainage structure used to carry minor streams under highways in Texas and just about everywhere else in the United States. Pipes are always placed under earth fill, which carries the roadway, and they sometimes have **headwalls** to prevent erosion. Headwalls, if present, are typically built of concrete or stone. Pipes are prefabricated at factories and come in standard diameters and lengths and can come in circular or elliptical sections. Once delivered to a construction site, contractors place the pipes in a streambed and backfill with earth.

The moldable qualities of concrete made it an ideal material for casting pipes and an economical alternative to cast iron or clay. With the increased availability of artificial hydraulic cements in the late nineteenth century, companies specializing in vitrified clay pipes added concrete pipes to their product lines. The primary market for the material was initially sewers. By the early 1920s, the concrete pipe business was booming in most areas of the country, including Texas. Much of the new business was related to road improvements. Company catalogs indicated that pipes in diameters ranging from 15 inches to 6 feet were widely available to Texas builders by the early 1920s.[268]

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[268] Sweets Catalogue Service, Inc., *Sweet's Engineering Catalogue* (New York: 1922).

After the initial period of technological development, concrete pipes became a standardized product. Organizations such as the ASTM established specifications for material quality and load-carrying capacity, which were adopted as industry-wide standards. The THD provided specifications for cast-iron, corrugated metal, vitrified clay, and concrete pipes in its first published 1918 (Section 23), which was updated in 1925 to include discussion of the relevant ASTM materials specifications for Portland cement and steel reinforcing bars. The American Concrete Institute's first concrete pipe standard specification, published in 1926 with participation of the federal Bureau of Public Roads, provided for maximum diameter pipes of 84 inches (7 feet). THD's bridge specifications of 1934 were the first that it published to provide for specific **compressive** strengths of standard reinforced-concrete pipes from 12 inches to 36 inches in diameter.[269]

In wider streams, engineers sometimes set concrete pipes side by side to create a multi-cell structure to increase the hydraulic opening. When the total length of the pipes is greater than 20 feet, TxDOT currently classifies the structure as a bridge. The Study Population includes only one pre-1946, bridge-class, concrete pipe culvert with stone headwalls. This is on CR 140 (Wattsville Road) over Copperas Creek (NBI No. 140280AA0140001), built in 1940 in Caldwell County. It is composed of four, 6-foot-diameter concrete pipes.

Character-Defining Features: Typical character-defining features of bridge-class concrete pipe bridges are 1) span length, roadway width, and vertical clearance, 2) concrete pipe under earth fill, 3) multi-cell design for greater hydraulic opening, 4) diameter of pipes, and 5) headwalls design and material if present.

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[269] Texas State Highway Department (1918): Item 23.4; Texas State Highway Department, *Standard Specifications for Road and Bridge Construction* (1925): Item 90; American Concrete Institute, Joint Concrete Culvert Pipe Committee, *Reinforced Concrete Culvert Pipe* (Detroit, Michigan: 1926): 3; Texas State Highway Department, *Special Bridge Specifications* (April 1934): Item 85.

Major Bridge Projects

“Major” bridge projects are defined for this study as those that have exceptional structure length and/or that cross multiple obstacles. Long bridges crossing a wide waterway or floodplain or railroad yards can indicate a project that often cost great expense to the project sponsor but increased connectivity in a location. Likewise, a single structure crossing multiple obstacles (such as streets, railroads, and waterways) may also indicate an important project for a community or region. As a result, these major bridge projects may be eligible under Criterion A for transportation or community development. Other bridges may demonstrate innovative designs to span multiple obstacles and may have important design features under Criterion C.[270] Please see **Table B1** and **Table B2** in Appendix B for the lists of bridges discussed in this section.

Bridge of Exceptional Structure Length

To determine bridges with exceptional structure length, the team applied two standard deviations greater than the Study Population’s mean structure length. For this study, all bridges longer than 427 feet — a total of 120 bridges — are considered exceptionally long compared to the rest of the Study Population (see **Table B1** in Appendix B). Cities built the earliest of these bridges, likely because they identified a need early in city planning and development to cross the major rivers located adjacent to their downtowns. The earliest exceptionally long non-truss bridges outside cities date to the early 1920s, and there were only a handful of 1920s long rural bridges. Engineers built most of the exceptionally long bridges (85 bridges) in the 1930s. This time period directly corresponds to the historic context information provided above, which notes that counties often purposefully avoided applying for Federal Aid projects for major crossings that required expensive, non-standard designed bridges while they controlled the highway and bridge building in Texas. As previously noted, in 1928, the THD identified approximately 1,000 county-built bridges that needed immediate repair or replacement, with many of these bridges replaced in the 1930s (for more information on this topic see the **Development of the THD-Controlled State Highway System, 1922-1932** section above).

Of the 120 bridges, 24 are uncommon bridge types, with nearly all uncommon bridges of exceptional structure length located in cities. The exceptionally long uncommon bridges include plate girders **cantilevered** with **suspended span**, **concrete variable depth tee beams**, **steel plate through girders**, **concrete open-spandrel arches**, **steel I-beams** **cantilevered** with a **suspended span**, and **steel plate girders with a variable depth**. Engineers apparently selected most of these uncommon bridges for locations where they needed not only long structures, but they also needed long main spans for major river and railroad yard crossings, which required special, non-standard

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[270] When originally conceived, this section was intended to focus on large-scale projects that may have potential historical significance in and of themselves, without a particular connection to a previously identified theme; however, researching these bridges revealed that most of them had associations already discussed in the themes above. As a result, it is possible that the team will eliminate this section of the historic context in later iterations and incorporate the information about major bridge projects into other sections of this Historic Context.

bridge designs. Many of these urban uncommon bridges may be significant for transportation and community planning associations, but they also may be significant for their engineering. Because many of these bridges have notable designs, there are numerous HAER documentations for these bridges.

The locations of exceptionally long bridges are spread across Texas; however, there are distinct concentrations of these bridges in Fort Worth and Dallas. A cluster of four bridges of exceptional length in Tarrant County are within the city limits of Fort Worth, with three of these bridges spanning the West Fork Trinity River. The earliest of these Study Population bridges is the 1914 Samuels Avenue bridge over the West Fork Trinity River (NBI No. 022200ZS0687001), which is a reinforced **concrete variable-depth girder** with decorative railing and inset panels in the fascia. St. Louis-based engineer S.W. Bowen designed the Samuels Avenue bridge shortly after he designed the much longer and complex NRHP-listed Paddock Viaduct (NRHP-listed, NBI No. 022200001401325). Although the Samuels Avenue bridge only measures 450 feet in length, it still reflects a critical connection between the central business district and the Fort Worth Stockyards. The other two exceptionally long bridges that span the West Fork Trinity River are the Henderson Avenue Bridge (NBI No. 022200017105017) and the East Belknap Street Bridge (NBI No. 022200008101001). The 1927 Bartholomew Plan recommended the construction of both of these bridges to help increase connectivity across the river and, in the case of the East Belknap Street bridge, railroad yards. Engineer Francis Dey Hughes of Dallas, who had no formal engineering education, built these and 12 other bridges in Fort Worth during the 1930s following the Bartholomew Plan recommendations.

In Dallas, three of the six bridges of exceptional length are in the heart of downtown. Two of the downtown bridges span the Trinity River and its wide floodplain, the Corinth Street Viaduct (NBI No. 1805709C6240001) and the Commerce Street Viaduct (NBI No. 1805709F7325005). As part of the 1928 Ulrickson Bond initiative, the city of Dallas hired Francis Dey Hughes to design these two viaducts. Like his bridge designs in Fort Worth, Hughes designed the Corinth Street and Commerce Street Viaducts as reinforced concrete variable-depth girder bridges, with the Commerce Street Viaduct constructed in 1930 and the Corinth Street Viaduct built in 1935. Both bridges are notable for being the largest reinforced concrete girders fabricated locally in Dallas at the time of their construction, with the Corinth Street Viaduct being the longest Study Population bridge at 3,300 feet (0.625 mile) long.[271] The third exceptionally long bridge in downtown Dallas is a **continuous** **I-beam** bridge spanning eight railroad lines (NBI No. 1805709O2170001, constructed in 1937) and reflects the massive railroad grade-separation program that the federal government initiated during the Great Depression years. For more information about bridges built in Dallas, Fort Worth, or other large cities, please see the **Urban Planning and City Beautiful** section above.

Outside cities, the THD typically used common bridge types for the exceptionally long bridges in the Study Population. These bridges had many short repeating spans and were built where numerous **piers** or **bents** at a crossing were acceptable. The designs of these long common bridge types are often not complex, and engineers often built these bridges using bridge standard plans. For example,

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[271] Jackson, Corinth Street Viaduct.

SH 171 at Ash Creek (NBI No. 091100041802028) outside the town of Malone in Hill County is a reinforced **concrete slab** bridge with 40 repeating 20-foot-long slab spans using the S-2-24 standard superstructure plan. Research shows that this bridge was part of a realignment of SH 171 from Malone to Hubbard in 1940; however, no remarkable information about it has been found to date.

In addition to using the common bridge type's standard plans for long structures, the THD also created special designs for particular crossings using reinforced **concrete slab**, reinforced **concrete tee beam**, and **steel I-beam** types. One notable example is the THD's specially designed structure carrying US 83 (now Business 83) over the North Floodway west of Mercedes in Hidalgo County (NBI No. 211090003904026), which consists of 52 repeating 30-foot-long reinforced concrete tee beam girder spans and specially designed reinforced concrete pile bents. The International Boundary and Water Commission (IBWC) built the North Floodway (and the Arroyo Colorado) to move flood waters from the Rio Grande to the Laguna Madre to help alleviate flooding along the Rio Grande in the 1920s. After a 1933 hurricane hit South Texas, IBWC repaired and enlarged the North Floodway's main pilot channel and increased the levee heights with PWA funding.[272] The US 83 roadway, which was then known as SH 4, was the main east-west road along the north side of the Texas/Mexico border. However, after the North Floodway's reconstruction, a timber bridge provided access for small vehicles, but trucks could not use the timber bridge and were forced to use a long detour to Santa Rosa Road (now SH 107) north of Mercedes. The Mercedes City Council and Chamber of Commerce requested that the THD rebuild a bridge over the North Floodway. In 1936, the THD began designing a larger construction project to widen 26.5 miles of SH 4, and they built the exceptionally long bridge at that time. Once completed, newspaper articles touted the bridge as providing a vital link along the main thoroughfare of the Rio Grande Valley.[273]

Another example of a specially designed exceptionally long bridge is the THD-designed Nueces River Relief bridge at SH 3 (now US 90) in Uvalde County. This bridge needed to be quite long (1,564 feet) because the floodplain was very wide at this location. As a result, the THD designed a bridge with 34 concrete tee beam spans that each measured 46 feet long. Plans show that the THD designed this bridge as part of the SH 3 upgrade from Uvalde to Del Rio, and engineers knew that the bridge was prone to extreme flooding because they noted the "extreme h.w. [high water] level." In September 1932, while the bridge was under construction, the area from Uvalde to Del Rio experienced severe flooding, this bridge (and the adjacent Nueces River truss bridge) washed out, and the THD shut down the entire road from Uvalde to Del Rio.[274] The main river truss bridge and the relief bridge were immediately rebuilt and completed just a few months later. After this bridge and the road's completion, motorists traveling from Uvalde to Del Rio had the first hard-surface road between these two cities, with THD-designed bridges across the Nueces River and its wide floodplain.

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[272] Lila Knight, *A Field Guide to Irrigation in the Lower Rio Grande Valley*, https://ftp.txdot.gov/pub/txdot-info/env/toolkit/420-07-gui.pdf (accessed August 20, 2023): 50-51.
[273] "Delay In Action on Floodway Bridge," *The Monitor* (August 29, 1935): 3. "Bridge Labor Offers Asked," *The Monitor* (February 11, 1937): 1.
[274] "Flood Damage is in Millions," *Fort Worth Star-Telegram* (September 3, 1932 Morning Edition): 2. "Highways Watched in Flood Area," *Fort Worth Star-Telegram* (September 3, 1932 Evening Edition) 2.

Bridges Over Multiple Obstacles

A total of 19 bridges within the Study Population cross multiple obstacles (see **Table B2** in Appendix B). According to TxDOT's codes for service types under bridges, there are seven bridges span highways and roads, six cross highways and waterways, five cross railroads and a waterway, and one bridge crosses a highway, waterway, and railroad. However, upon further investigation, nearly all of these structures are railroad grade-separation structures, including the earliest of the group, the 1914 Main Street bridge over Buffalo Bayou, White Oak Bayou, and UPRR (NBI No. 121020B41697003). Interestingly, 16 of the 19 bridges in this group are grade-separation structures built after 1935 in cities, when the federal government initiated its massive at-grade railroad elimination program funding through the ERAA (for more information about Depression-era programs, please see **Railroad Grade Separations: When Transportation Systems Conflict, Pre-1946** section above). Therefore, it appears that this group includes mainly grade-separation bridges (under- and overpasses) that happen to cross multiple features, but they were built specifically for the purposes of eliminating at-grade railroad crossings.

The THD's *Tenth Biennial Report* and the *Texas Parade* specifically highlighted one of the bridges in this group, the 1,325-foot-long bridge carrying US 271 over the St Louis Southwestern Railroad and a drainage in Tyler (NBI No. 102120016501025). A 1937 *Texas Parade* touted the completion of this federally funded ERAA project and praised coordination between the railroad, city officials, county commissioners, THD, and BPR. As one of the longest overpass bridges completed during the 1930s, the bridge connected the northeast and southeast parts of the city and its major traffic arteries (SH 31 and SH 64). The *Texas Parade* article noted that it created a "major link in the plan to facilitate movement of traffic into and through Tyler."[275] The THD's *Tenth Biennial Report* noted the complexity of this bridge's design, including the steep horizontal curve to accommodate the required railroad under-clearance. The article also stated that the design was further complicated by the 12 tracks at various angles under the bridge, which required that THD individually design each bent at different skewed angles.[276] The structure cost approximately $250,000.[277] Purvis & Betraham of Fort Worth won the bid for construction, under the supervision of the Tyler Division Engineer Dewitt C. Greer (future State Highway Engineer).[278] The *Texas Parade* article quoted Texas Highway Commission Chairman, Robert Lee Bobbitt, who said the bridge was an excellent example of "cooperation, engineering, and science."[279]

One of the outliers of this group that does not cross a railroad is the reinforced **concrete variable-depth concrete tee beam** bridge carrying Beauregard Avenue (now Business 67 Westbound) over the North Concho River and Veterans Memorial Drive (NBI No. 072260007709044) in San Angelo. The 1922 bridge replaced an older truss bridge at this location, and Tom Green County and the city of San

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[275] Charles E. Simons, "Progress: The Poplar-Beckham Overpass at Tyler," *Texas Parade* (August 1937): 26.

[276] State Highway Department, *Tenth Biennial Report,* XVI.

[277] State Highway Department, *Tenth Biennial Report,* XVI.

[278] Simons, 27.

[279] Simons, 28.

Angelo worked together to fund the new bridge, with the county funding $65,000 and the city spending $10,000.[280] They proposed the truss bridge's replacement due to fears that the old bridge would collapse, particularly since 1,220 vehicles per day used the bridge in 1921.[281] Newspaper accounts note that Tom Green County engineer, Gibb Gilcrest (later the State Bridge Engineer), oversaw the project and asked the THD to review the bridges plans.[282] Tom Green County built the North Concho River bridge directly adjacent to the Civic League Park. The THD's *Fourth Biennial Report* notes that the girders were constructed with an "…arched effect which gives a more pleasing appearance to the structure."[283] In addition, the original concrete ornamental railings were specially designed for a more aesthetically pleasing appearance to the residents of San Angelo.[284]

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[280] "New Beauregard Viaduct in 1922," *San Angelo Evening Standard* (December 15, 1921): 1.
[281] "Bridge is Needed," *San Angelo Evening Standard* (December 14, 1921): 2.
[282] "Work on Viaduct Soon," *San Angelo Evening Standard* (July 11, 1922): 1.
[283] State Highway Department, *Fourth Biennial Report,* 42.
[284] "Change Highway," *The San Angelo Daily Standard* (July 27, 1922): 2.

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Appendix A: Visual Glossary

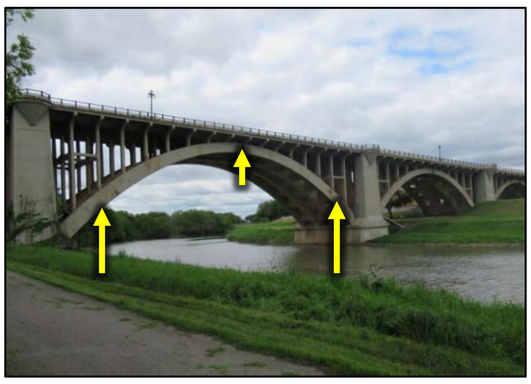
HISTORIC CONTEXT VISUAL GLOSSARY

TxDOT Non-truss Bridge Survey Update

Abutment/Wingwall

Abutment: A retaining wall that supports the ends of the superstructure. Abutments can be constructed of concrete, stone, steel or wood.

Wingwall: An angled wall that is attached to the corner of an abutment that helps stabilize earth embankments.

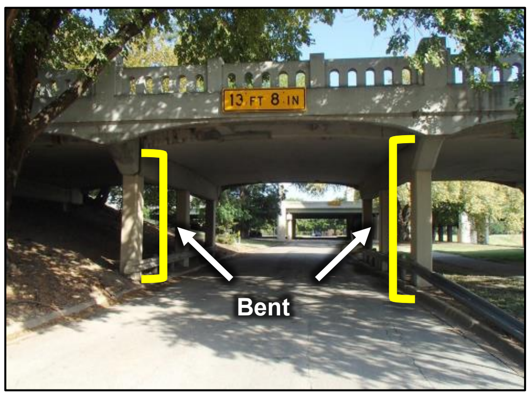


Arch Ring

The part of the arch that has a downward curve and distributes the weight of the bridge directly into the bridge's foundations.

Balustrades

Decorative railings supported by small, evenly spaced vertical columns or balusters.



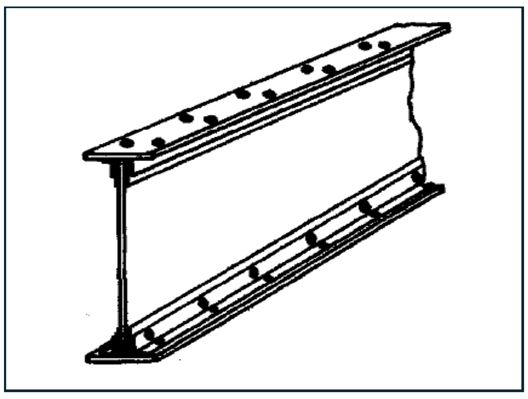
Bent

A type of pier, which is a support structure under the bridge. It generally includes vertical members (i.e. columns or piles) and a horizontal cap. The foundation of the bent (usually concrete footings or drilled shafts) is below grade.

See also ***Piers***

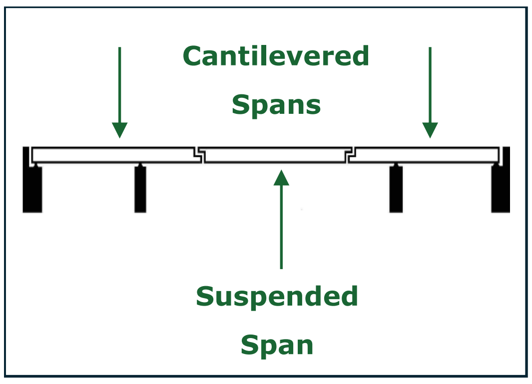
Bolt

A threaded metal fastener with a nut used to connect members of a bridge together. Square and hexagonal bolts have been in use since the 19th century. High-strength bolts replaced these older bolt types in the 1950s.



Built-up Beams

Steel girders composed of plates, channels, and angles that are joined together with rivets and bolts (and later welded joints).



Cantilevered span

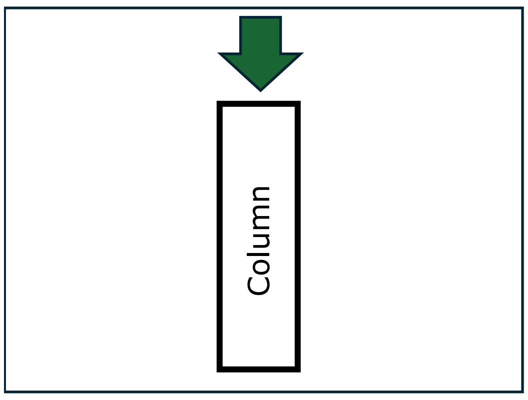
Spans that are only supported at one end. Projecting beams (called cantilevers) may meet at the middle or support a suspended span.

See also ***Suspended Span***

Cast-in-place/Precast

Cast-in-place: Concrete is poured into a wood or metal form at the project site. Often the impressions of wood or steel formwork can be seen after a bridge is built.

Precast: This is a construction method using a reusable form or mold, cured in a controlled environment, and transported to a construction site (not illustrated).



Compression

A force that squeezes and pushes material inward.

Concrete Arch Bridge

Concrete Arch, Closed Spandrel: This bridge type has one or more arch rings supporting walls, called spandrels, that hold back fill and carry the deck and railings.

See also ***Arch Ring***

Concrete Arch Bridge

Concrete Arch, Open Spandrel: Arch bridge that has columns that rest on the arch rings and support a deck slab. The arch rings can either be solid or ribbed.

See also ***Arch Ring***

Concrete Box Culvert

Structures with rectangular cross-section integrating the top, two sides, and floor of the box into a monolithic structure.

Concrete Rigid Frame

Bridges in which the superstructure and the substructure are constructed as a single unit. The abutments of a rigid frame are sometimes referred to as legs.

Concrete Slab Bridge

This bridge type functions as a wide, full-width shallow beam. Slab bridges have reinforcing steel that runs along the bottom of the slabs.

Concrete Slab Bridge

FS Slabs with Integrated Curbs*:* Slab bridges with monolithically poured curbs and thinner slabs than other pre-1946 slab bridges.

Concrete Slab Bridge

Variable-Depth Concrete Slab: Multi-span bridge where the depth of the slab is greatest over the piers or abutments. These bridges have a slightly curved or haunched soffit, which resembles a shallow arch.

See also ***Soffit***

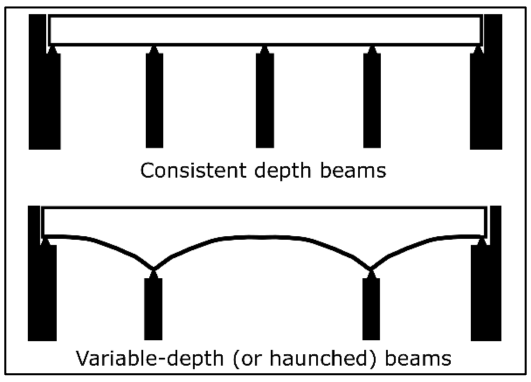
Concrete Tee Beam Bridge

Reinforced concrete cast-in-place bridges comprised of longitudinal laid beams. The name of the beams refers to the pattern of placement of the internal rebar, which looks like a “T” in cross section.

Concrete Tee Beam Bridge

Variable-Depth Concrete Tee Beam: Tee beam with shallow, arched soffits.

See also ***Soffit***

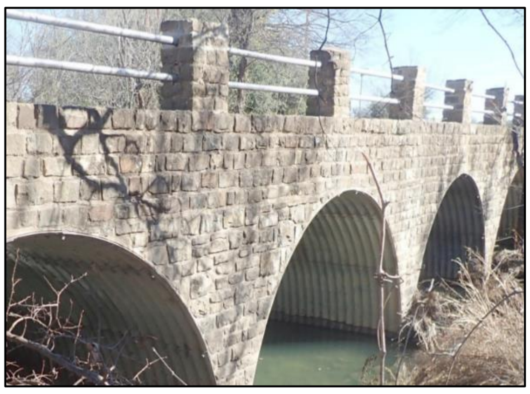


Continuous Span

A span without joints over two or more substructure supports, which distributes the load over a series of spans and supports. Continuous spans may have consistent or variable-depth beams. The opposite is a simple span.

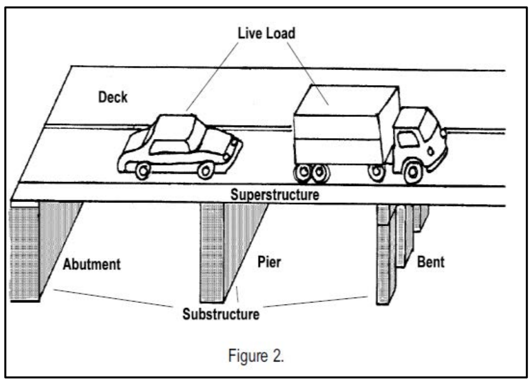
Corrugated Steel

Corrugated steel is a building material composed of sheets formed with a linear ridged pattern. In bridge applications, sheets are often curved to form arch segments or pipes.



Coursed Stone

A method of masonry using stone with similar height and widths to create level rows and a more uniform appearance. The opposite is random uncoursed stone.



Dead Load

This is the total weight of the bridge superstructure and substructure elements.

Live Load

Sometimes referred to as a "moving load," a live load consists of cars, pedestrians, trucks, and trains.

Deck

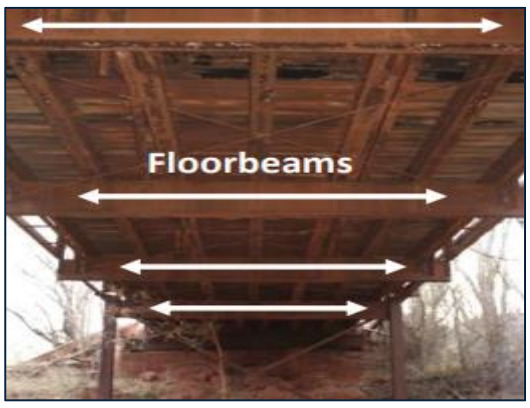
The roadway portion or riding surface of the bridge, including the shoulders.

Dry-laid stone

A method of construction where individual stones are stacked without the use of mortar or other binding materials between the individual stones.

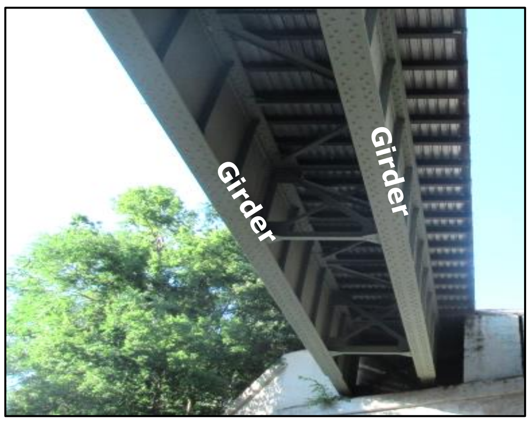
Flange

The horizontal parts of an I-beam or girder.



Floorbeams

Beams under and perpendicular to the deck transferring loads to the principal longitudinal bridge members.



Girder

A girder is generally the largest and strongest beam in a bridge. They are longitudinal beams that support all other bridge elements.

Headwall

A retaining wall placed around a culvert opening that helps to stabilize the embankment or fill material supporting the roadway.

Masonry Arch

Bridge type built of stone, which distributes its load via an arch ring to the abutments.

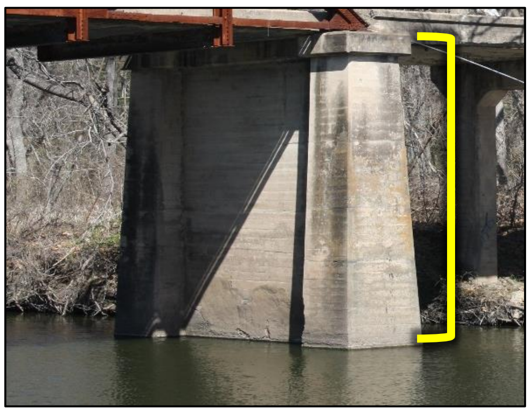
See also ***Arch Ring***

Mortar Joints

The spaces between bricks or concrete blocks that are filled with mortar. Mortar is a mixture of water, sand, and a binder such as cement.

Parapets

Solid railings on either side of the deck. Parapets are typically constructed of stone or concrete.



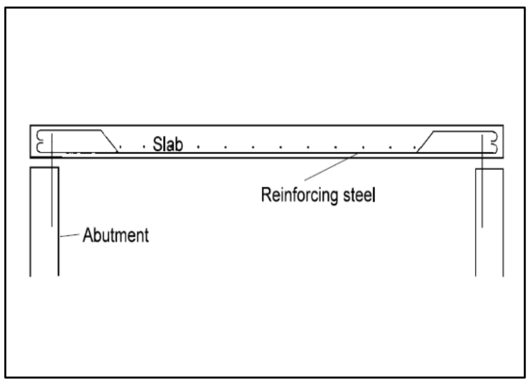
Piers

An intermediate substructure support for a bridge of more than one span. Piers have solid walls and columns (as shown below) or bents.

See also ***Bent***

Pin-and-Hanger Connections

A method of connecting the ends of two beams consisting of an assembly of two steel hanger pins and a hanger plate. These connections are used with cantilevered and suspended spans.



Reinforcing Steel Bars

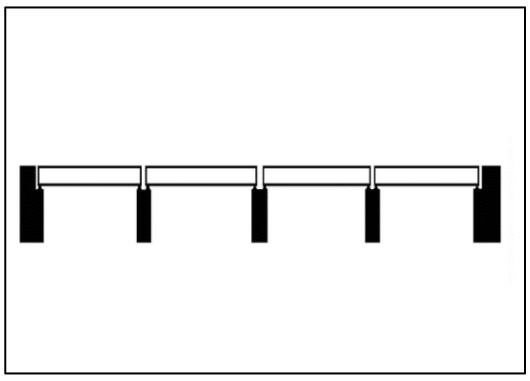
Also known as rebar, reinforcing steel bars increase the strength of concrete. Rebars are embedded in the tension zones of the concrete bridge member.

Rivets

Metal fasteners most often with rounded heads used to connect bridge members.

Shiplap connections

Ends of beams that overlap at right angles with the upper beam resting on the lower one. The connection takes its name from a similar appearing joint used in carpentry. These connections are used with cantilevered and suspended spans.



Simple Plan

A superstructure where the beams extend from one substructure support to the next with a joint or break at each support so that all loads are contained within a single span. The opposite of a continuous span bridge.

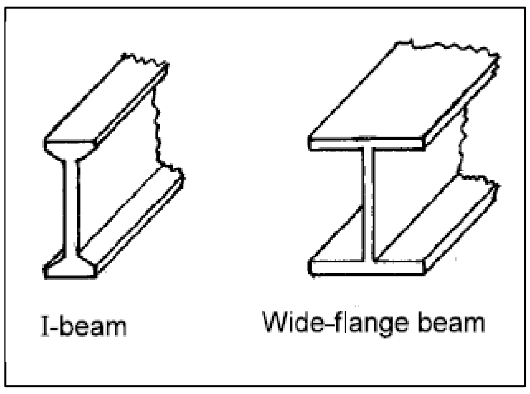
Soffit

The bottom surface of a bridge beam or slab.

Spandrel

The space between an arch ring and the deck.

See also ***Concrete Arch Bridge, Closed Spandrel*** *and* ***Concrete Arch Bridge, Open Spandrel***



Steel I-beam

A steel beam that looks like an "I" or a sideways "H" in cross-section. The "H" shaped beams are often called wide-flange beams and have only been in use since the early twentieth century. TxDOT often calls the wide-flange beams I-beams.

Steel I-beam Bridge

Sometimes referred to as multi-beam or stringer bridges, these bridges have multiple strings (or lines) of parallel longitudinal beams.

Steel I-beam – Concrete Encased

Steel I-beams covered in concrete to protect the beams from corrosion. This construction technique is most often found over railroads.

Steel I-beam with Jack Arch Deck

A bridge with a deck formed by shallow arches between the longitudinal I-beams. The arches are usually concrete poured over a form liner of wood or sheet metal. The form liners often were left in place.

Steel Plate Arches

Arch superstructures formed of prefabricated, corrugated sheet metal. The sheets are typically segmental arch shapes that are bolted together to form the desired length and rise of arch. Headwalls are required to support the fill material that carries the roadway.

Steel Plate Girder Bridge

Steel Plate Girder with Floor System*:* These bridges consist of longitudinal lines of plate girders with flooring systems consisting of transverse beams supporting and under a deck.

Steel Plate Girder Bridge

Steel Plate Girder - Through*:* Plate girder bridge with floorbeams that are in line with the bottom flanges of the longitudinal girders. On these bridges, vehicles drive through the steel plate girders.

Steel Plate Girder Bridge

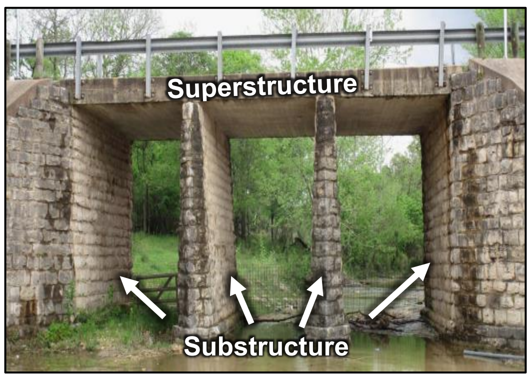
Variable-Depth Plate Girders*:* Steel plate girders with shallow arched soffits.

Stiffeners

On plate girders, these vertical pieces are affixed to the web and "stiffen" the web to add to the rigidity and strength of the girder.

Stringers

Beams supporting a bridge deck and placed parallel to the direction of travel. Stringers may be wood or metal.

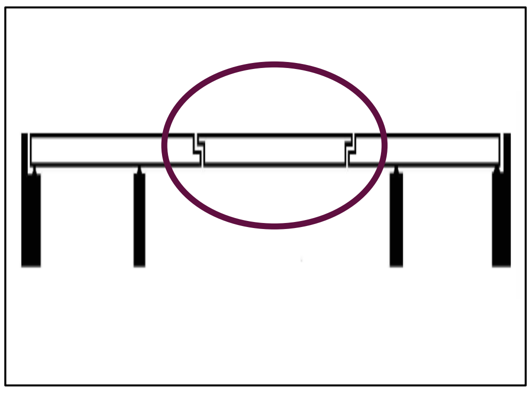


Substructure

Supports the superstructure and includes footing, abutments, wingwalls, piers, and bents.

Superstructure

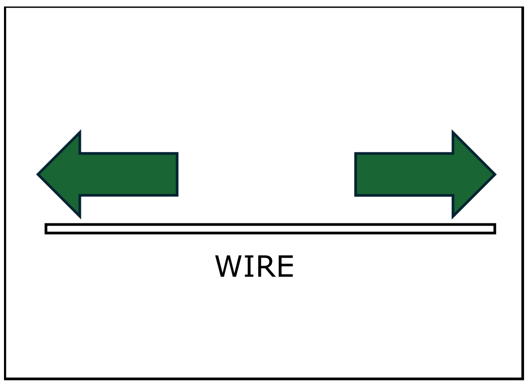
Rests on the substructure and includes components that span an obstacle, such as water, ravine, or road. This includes the bridge deck and railing.



Suspended Span

A "drop-in" section placed between the two cantilevered spans to fill the gap.

See also ***Built-up Beams***.

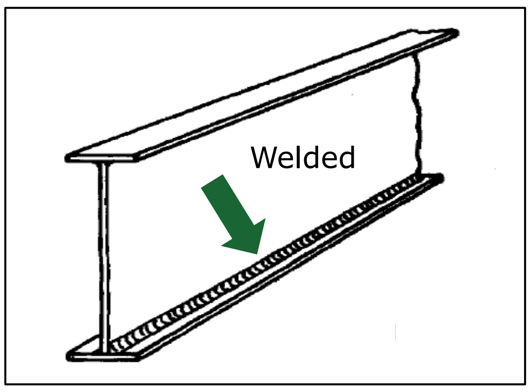


Tension

A force that pulls material apart or outward.

Web

Vertical section of a beam or girder.



Weld

A process of fusing two or more parts together though heat, pressure, or both and forming a joint as the parts cool.

Credits:

Drawings and diagrams are extracted from Patrick Harshbarger and Mary McCahon (Lichtenstein Consulting Engineers), Bridge Basics from Historic Bridge Types Common in North America Workshop, SIA Annual Conference, Milwaukee, Wisconsin, 2005.

Photographs provided by TxDOT.

Appendix B: Major Bridge Project Lists

Table B1: Bridges with Exceptional Structure Length

NBI Number	Facility Carried	Feature Crossed	Year Built	Structure Length (in feet)	Bridge Type
1805709C6240001	CORINTH ST	TRINITY RIVER	1935	3,300	Steel plate girder variable depth - multiple
180570009403013	SP 482 EB	ELM FORK TRINITY RIVER	1942	2,532	Steel I-beam - cantilevered with suspended span
1805709F7325005	COMMERCE ST	TRINITY RIVER	1930	1,969	Steel plate girder variable depth - multiple
152320002305037	US 90 EB ML	NUECES RIVER RELIEF	1932	1,564	Concrete girder - tee beam - simple
211090003904026	US 83 BUS	NORTH FLOODWAY	1937	1,560	Concrete girder - tee beam - simple
221360002302069	US 90	SYCAMORE CREEK	1932	1,431	Concrete girder - tee beam - simple
032440004305017	US 287 SB	PEASE RIVER	1928	1,418	Steel I-beam (stringer)
181300009503011	US 80 WB	EAST FORK TRINITY RIVER	1930	1,400	Concrete girder - tee beam - simple
100930039301017	SH 149	SABINE RIVER	1943	1,350	Steel I-beam (stringer) - continuous
142270011312089	UPRR	LP 343 & W RIVERSIDE DR.	1902	1,333	Steel plate girder - through girder
102120016501025	US 271	ST L/SW RR & DRAIN	1937	1,325	Steel I-beam (stringer)
121020B41697003	MAIN ST	BUFFALO & WHITE OAK BYU	1914	1,275	Concrete arch, open spandrel
081050036002026	US 380	DBL MTN FRK BRAZOS RIVER	1941	1,270	Steel I-beam (stringer) - continuous
071640003505021	US 83	SAN SABA RIVER	1932	1,259	Steel I-beam - cantilevered with suspended span
150150052103002	LP 13	UPRR & Local Streets	1940	1,254	Steel I-beam (stringer)
1805709O2170001	MALCOLM X BLVD	DART RR HICKORY ST	1937	1,235	Steel I-beam (stringer) - continuous
132410008910043	BU 59 R	WEST BERNARD CREEK	1928	1,200	Concrete flat slab
150950AA0555001	UNION PACIFIC RR	HOT SHOT LANE	1926	1,200	Steel plate girder - through girder
082170010604043	US 380	SALT FORK BRAZOS RIVER	1937	1,198	Steel I-beam (stringer)
151620051703016	SH 16	Nueces River	1940	1,047	Steel I-beam - cantilevered with suspended span

NBI Number	Facility Carried	Feature Crossed	Year Built	Structure Length (in feet)	Bridge Type
090980AA0350002	CR 203	LEON RIVER #206	1932	1,040	Steel I-beam (stringer)
230470007903022	US 67	LEON RIVER	1931	1,022	Concrete girder - tee beam - simple
111740017601141	US 59 BUS NB	SPRR & COX ST	1938	984	Steel I-beam (stringer)
132350008806020	BU 59/77	GUADALUPE RIVER REL #2	1930	981	Concrete girder - tee beam - simple
132350008806019	BU 59/77	GUADALUPE RIVER REL #1	1930	969	Concrete girder - tee beam - simple
151620051703015	SH 16	Nueces River Relief	1941	962	Steel I-beam (stringer)
142270B00425007	S CONGRESS AVE	LADY BIRD LAKE	1909	954	Concrete arch, open spandrel
100010019803014	US 175	NECHES RV	1930	949	Concrete girder - tee beam - simple
090500005504041	US 84	LEON RIVER	1938	945	Steel I-beam - cantilevered with suspended span
150950002902008	US 90	SAN MARCOS RIVER W REL	1930	912	Concrete girder - tee beam - simple
111740005901006	SH 7	ATTOYAC RIVER	1934	907	Steel I-beam (stringer)
090500018401008	SH 36	LEON RIVER	1941	895	Steel I-beam (stringer) - continuous
022200ZM0670001	SOUTH MAIN STREET	BNSF & UPRR	1937	892	Steel plate girder - through girder
070410026405015	US 277	COLORADO RIVER	1933	886	Steel I-beam (stringer) - continuous
062220002203012	US 90	Lozier Canyon	1933	884	Concrete girder - tee beam - simple
091610020901034	LP 2 EB (18TH ST)	UPRR, MARY AVE, WACO CRK	1935	857	Steel I-beam (stringer)
130900002601050	US 90	PEACH CREEK	1942	840	Concrete girder - tee beam - simple
150150007302004	US 281 SB	MEDINA RIVER	1935	823	Steel plate girder w/floor system
150460001611016	BUSINESS 35	GUADALUPE RIVER	1934	818	Concrete arch, open spandrel
220640030101020	SH 85	SOLDIER LAKE SLOUGH	1939	810	Steel I-beam (stringer) - continuous
091100041802028	SH 171	ASH CREEK	1940	800	Concrete flat slab
190340001010079	US 67	JENNINGS SLOUGH	1941	800	Steel I-beam (stringer)
072000B00255024	PARK AVE	ELM CREEK	1932	799	Steel I-beam (stringer)
162050008703014	SH 359	NUECES RIVER RELIEF	1932	798	Concrete girder - tee beam - simple

NBI Number	Facility Carried	Feature Crossed	Year Built	Structure Length (in feet)	Bridge Type
011170013602055	SH 224	MIDDLE SULPHUR RIV	1937	792	Steel I-beam (stringer)
130620014308038	US 87	GUADALUPE RI RELIEF	1938	782	Steel I-beam (stringer)
140280002903010	US 90	SAN MARCOS RIVER RELIEF	1935	780	Steel I-beam (stringer)
142460032003039	SH 95	PECAN BRANCH	1941	760	Steel I-beam (stringer)
152320002402006	US 90	FRIO RIVER	1931	750	Steel I-beam (stringer) - continuous
090140039804014	SH 317	LEON RIVER	1945	720	Concrete girder variable depth - tee beam
022200008101001	US 377 (E. BELKNAP)	TRINITY RIVER	1932	717	Concrete girder variable depth - tee beam
090980025101041	US 281	BOSQUE RIVER	1942	710	Steel I-beam (stringer) - continuous
170260011602032	SH 21 WB	EAST YEGUA CREEK	1939	700	Steel I-beam (stringer)
112100017505026	US 59	ATTOYAC RIVER	1936	690	Concrete girder - tee beam - simple
130900044501011	US 90A	PEACH CREEK EAST RELIEF	1938	689	Concrete girder - tee beam - simple
112040033806069	SH 105	PEACH CREEK	1943	665	Concrete girder - tee beam - simple
201810G00436001	OLD HWY 90	BAIRDS BAYOU	1922	660	Concrete flat slab
101080016403020	SH 31	NECHES RIVER RELIEF	1930	655	Concrete girder - tee beam - simple
121700033804065	SH 105	CANEY CREEK	1943	645	Concrete girder - tee beam - simple
172390018706020	FM 109	MILL CREEK	1930	636	Concrete girder - tee beam - simple
141440011601027	SH 21	MIDDLE YEGUA CREEK	1939	630	Steel I-beam (stringer)
222330016005017	US 277	RED BLUFF CREEK	1940	630	Concrete girder - tee beam - simple
102120024509008	FM 279	NECHES RIVER	1930	627	Concrete girder - tee beam - simple
130620015501017	US 183/US 77A	15 MILE COLETO CRK	1939	600	Steel I-beam (stringer)
161490044701027	US 59 SB	NUECES RIVER RELIEF	1939	600	Steel I-beam (stringer)
202290020008022	US 69	BIG CYPRESS CREEK	1932	600	Steel I-beam (stringer) - continuous
102500009601060	US 80 EB	LAKE FORK CREEK REL #2	1938	595	Concrete girder - tee beam - simple

NBI Number	Facility Carried	Feature Crossed	Year Built	Structure Length (in feet)	Bridge Type
150460025303006	US 281 SBML	CIBOLO CREEK	1933	587	Concrete girder - tee beam - simple
1805709J3480007	JEFFERSON BLVD WB	MOUNTAIN CREEK	1930	576	Concrete flat slab
071340014110022	LP 291	NORTH LLANO RIVER	1932	572	Steel I-beam (stringer)
090180012101038	SH 22	BOSQUE RIVER	1940	566	Steel I-beam (stringer) - continuous
161490AA0332001	MIKESKA RD (CR 151)	NUECES RIVER	1936	562	Other steel
152320003608008	US 83	DRY FRIO RIVER	1932	554	Concrete girder - tee beam - simple
112030011810046	SH 21	ATTOYAC RIVER RELIEF	1936	552	Concrete girder - tee beam - simple
130760021106022	US 77	Rabbs Crk & Rocky Crk	1932	549	Concrete girder - tee beam - simple
130760002603034	US 90	WEST NAVIDAD RIVER	1938	545	Steel I-beam (stringer)
061860014007049	SH 290	South Sheffield Draw	1932	542	Concrete girder - tee beam - simple
100370020604012	US 79	MUD CREEK (W)	1930	542	Concrete girder - tee beam - simple
160890008803014	US 59 SB	MANAHUILLA CREEK	1929	540	Steel I-beam (stringer) - continuous
141060AA0136002	UP RR	BLANCO R / CR136 & CR140	1935	538	Steel plate girder - through girder
130450002606039	US 90	Colorado River Relief	1940	525	Steel I-beam (stringer)
121020B01905096	AIRLINE DR	HBT RR	1941	522	Steel I-beam (stringer)
080770026303005	SH 70	DBL MT FK BRAZOS RIV	1934	520	Steel I-beam (stringer)
061860007502033	US 67	BURNT HOUSE CREEK	1937	518	Steel I-beam (stringer)
100370020604013	US 79	MUD CREEK (E)	1930	513	Concrete girder - tee beam - simple
152320002401005	US 90	DRY FRIO RIVER	1931	512	Steel I-beam (stringer) - continuous
102500009509065	US 80 EB	SABINE RIVER	1942	510	Concrete girder - tee beam - simple
102500009509066	US 80 EB	SABINE RIVER RELIEF	1942	510	Concrete girder - tee beam - simple
241160AA8883001	FT. HANCOCK INTL.BR	RIO GRANDE RIVER	1936	510	Steel I-beam (stringer)
170210005002014	SH 6 SB	NAVASOTA RIVER	1930	509	Steel I-beam (stringer) - continuous
180570019702089	T & NO RR	US 175	1939	507	Steel plate girder - through girder

NBI Number	Facility Carried	Feature Crossed	Year Built	Structure Length (in feet)	Bridge Type
161780010203007	US 77 SB	PETRONILA CREEK	1922	506	Concrete girder - tee beam - simple
010810001004085	US 67	BIG CRK	1942	500	Concrete flat slab
072260007709044	BUS 67 WB	N CONCHO RI & VET. MEM'L	1922	496	Concrete girder variable depth - tee beam
131210008905019	US 59 NB	Mustang Creek	1929	495	Concrete girder - tee beam - simple
081680033301001	SH 163	COLORADO RIVER	1941	490	Steel I-beam (stringer) - continuous
022200017105017	SH 199	W FRK TRINITY RIVER	1931	486	Concrete girder variable depth - tee beam
032440004306047	US 70/287 SB	BNSF RR & DUGAN CREEK	1936	486	Concrete girder - tee beam - simple
061860014017002	US 385 / IH 10 BUS	Comanche Creek	1931	485	Concrete girder - tee beam - simple
072180014116020	RM 3130	DRY LLANO RIVER	1934	484	Concrete girder - tee beam - simple
151630002406071	US 90	MEDINA RIVER	1940	482	Plate Girder - Cantilevered with Suspended Span
111140033602014	SH 7	NECHES RIVER RELIEF	1940	480	Concrete flat slab
111870017604056	US 59 SB	NECHES RIVER RELIEF 2A	1943	480	Concrete Flat Slab - Continuous
022200008007050	US 377 SBL	CLEAR FORK TRIN RIV	1944	477	Concrete girder variable depth - tee beam
072260B02310002	S OAKES ST	NORTH CONCHO RIVER	1930	472	Concrete girder variable depth - tee beam
160890015503005	US 183	MANAHUILLA CREEK	1930	465	Steel I-beam (stringer) - continuous
150150052103004	LP 13	Leon Creek	1943	462	Concrete girder - tee beam - simple
010750004506033	SH 56	BOIS D ARC CR	1931	456	Concrete girder - tee beam - simple
201010060101001	SH 326	CYPRESS CREEK	1939	456	Steel I-beam (stringer)
102500009601059	US 80 EB	LAKE FORK CREEK REL #1	1938	455	Concrete girder - tee beam - simple
202290021307066	US 190	NECHES RIVER RELIEF	1940	455	Concrete girder - tee beam - simple
142270AA1556001	OLD HIGHWAY 20 EB	GILLELAND CREEK	1936	452	Concrete girder - tee beam - simple

NBI Number	Facility Carried	Feature Crossed	Year Built	Structure Length (in feet)	Bridge Type
142460E00740002	SOUTH MAYS STREET	UPRR & MCNEIL RD	1935	451	Concrete girder - tee beam - simple
022200ZS0687001	SAMUELS AVE	WEST FORK TRINITY RIVER	1914	450	Concrete girder - tee beam - continuous
221360029902021	US 277	PINTO CREEK	1940	450	Concrete girder - tee beam - simple
041070003005028	US 83	Horse Creek	1939	440	Steel I-beam (stringer)
080170029502016	US 180	TOBACCO CREEK	1939	440	Steel I-beam (stringer)
201810002815061	SH 87	ADAMS BAYOU	1943	433	Concrete girder - tee beam - simple
090140032002010	SH 95	DARRS CREEK	1922	429	Concrete girder - tee beam - simple
150150001608027	SL 368 (AUSTIN HWY)	SALADO CRK & IRA LEE RD	1934	428	Concrete girder - tee beam - simple

Table B2: Bridges Over Numerous Obstacles

NBI Number	Facility Carried	Feature Crossed	Year Built	Bridge Type
An121020B41697003	Main St.	Buffalo & White Oak Bayous/ UPRR	1914	Concrete Arch, Open Spandrel
072260007709044	BUS 67 WB	N Concho River & Vet. Memorial	1922	Concrete Girder Variable Depth – Tee Beam
150150001608027	SL 368 (Austin Hwy)	Salado Creek & Ira Lee Rd.	1934	Concrete Girder – Tee Beam - Simple
091610020901034	LP 2 EB (18TH ST)	UPRR, Mary Ave., Waco Creek	1935	Steel I-beam (stringer)
141060AA0136002	UPRR	Blanco River / CR 136 & CR 140	1935	Steel Plate Girder – Through Girder
142460E00740002	South Mays St.	UPRR & McNeil Rd.	1935	Concrete Girder – Tee Beam – Simple
080770029603034	US 180	FM 57 and Abandoned RR	1936	Steel I-beam (stringer)
072260007706072	US 67 NB FR	N Concho River and Road	1936	Steel I-beam (stringer)
032440004306047	US 70/287 SB	BNSF RR & Dugan Creek	1936	Concrete Girder – Tee Beam - Simple
102120016501025	US 271	ST L/SW RR & Drain	1937	Steel I-beam (stringer)
102010054502001	SH 42	MPRR/FM 1513	1937	Steel I-beam (stringer)
1805709O2170001	Malcom X Blvd.	Dart RR and Hickory St.	1937	Steel I-beam (stringer) – continuous
111740017601141	US 59 BUS NB	SPRR & Cox St.	1938	Steel I-beam (stringer)
102120024506026	SH 64	MPRR/Highland St.	1939	Steel I-beam (stringer)
022200D00652001	RAILTRAN	Midway Rd./Big Fossil Creek	1939	Steel I-beam (stringer)
150150052103002	LP 13	UPRR & Local Streets	1940	Steel I-beam (stringer)
140110011404067	US 290	UPRR & Central Ave.	1941	Steel I-beam (stringer)
1805709Z0540009	SP 354/Zang Blvd.	Cedar Creek & Dart RR	1941	Plate Girder – Cantilevered with Suspended Span