UNITED STATES DEPARTMENT OF THE INTERIOR
National Park Service

National Register of Historic Places Multiple Property Documentation Form

This form is used for documenting property groups relating to one or several historic contexts. See instructions in National Register Bulletin *How to Complete the Multiple Property Documentation Form* (formerly 16B). Complete each item by entering the requested information.

_______ New Submission ____X____ Amended Submission

A. Name of Multiple Property Listing

Metal Truss, Masonry and Concrete Bridges of Vermont, 1820-1978

B. Associated Historic Contexts

(Name each associated historic context, identifying theme, geographical area, and chronological period for each.)

I. Metal Truss, Masonry, and Concrete Bridges in Vermont: 1820-1940 (Rudge 1989)
II. Bridge Construction in Vermont: 1940-1978
III. Vermont Bridge Engineers

C. Form Prepared by:

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D. Certification

As the designated authority under the National Historic Preservation Act of 1966, as amended, I hereby certify that this documentation form meets the National Register documentation standards and sets forth requirements for the listing of related properties consistent with the National Register criteria. This submission meets the procedural and professional requirements set forth in 36 CFR 60 and the Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation.

_________________________________ _________________________ ____________________________
Signature of certifying official Title Date

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State or Federal Agency or Tribal government

I hereby certify that this multiple property documentation form has been approved by the National Register as a basis for evaluating related properties for listing in the National Register.

___________________________________ ______________________________________
Signature of the Keeper Date of Action

Highway Bridges of Vermont, 1820-1978
Name of Multiple Property Listing

Vermont
State

Table of Contents for Written Narrative

Create a Table of Contents and list the page numbers for each of these sections in the space below.
Provide narrative explanations for each of these sections on continuation sheets. In the header of each section, cite the letter, page number, and name of the multiple property listing. Refer to *How to Complete the Multiple Property Documentation Form* for additional guidance.

Page Numbers

E. Statement of Historic Contexts
(If more than one historic context is documented, present them in sequential order.)

This multiple property documentation form (MPDF) incorporates and replaces the existing MPDF, Metal Truss, Masonry, and Concrete Bridges in Vermont: 1820-1940, completed in 1990 by Heather Rudge, Vermont Division for Historic Preservation. The historic context has been extended from 1940 to 1978.

I. METAL TRUSS, MASONRY, AND CONCRETE BRIDGES IN VERMONT: 1820-1940

EARLY BRIDGES IN VERMONT

The history of bridges in Vermont is largely the history of the evolution of public roads and the railroad. Over the course of settlement in Vermont between 1760 and 1830, roads usually evolved from foot and horse paths into rough wagon roads. Between 1790 and 1820 the establishment of postal delivery routes and a number of turnpike companies led to a few well-graded and maintained through-roads.[1] Water transportation along Lake Champlain and the Connecticut River encouraged development of some inter-town routes to the nearest shipping facilities. Most local roads, however, remained under the jurisdiction of district road commissioners in individual towns, and of course the burden of building and maintaining bridges on these roads also fell on local governments. This continued to be the case until the close of the nineteenth century, when the state established a highway commission to regulate the road system and bridge building in Vermont.

Railroad construction, beginning in 1846 with a line up the Connecticut River to Bellows Falls, did encourage some road construction linking towns to the rail lines, and in many towns a stream or river was bridged to provide a more direct route to the nearest railway depot. Overall, however, the railroads tended to delay major road construction rather than to promote it, though they themselves did undertake ambitious programs of bridge building and rebuilding during the last half of the nineteenth century and into the twentieth.

Since most roadway bridge building in Vermont during the nineteenth century fell to town governments, they in turn relied on local resources and, to the extent possible, on local expertise. Construction materials were hardly a problem for most of Vermont, with its bounteous quantities of timber and building stone. Timber, a favored material, was used in a number of applications. The simple Kingpost truss, a traditional, medieval European technology, sufficed for crossings of less than about 50'; to enhance durability, the trusses often were clad in boards.

For longer spans the most common form was a lattice truss, which utilized a web of closely spaced diagonal boards. Lattice trusses were often roofed and clad in boards to protect them from the weather; these are the original covered bridges of Vermont.

The covered bridges in Vermont have a few similarities to metal truss, masonry, and concrete bridges. Like the metal truss, all covered bridges were derived from several wood truss types, and many used pre-cut standardized members for construction. Although the covering contributed no strength to the structure itself, it did add a

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[1] Curtis B. Johnson and Elsa Gilbertson, eds., *The Historic Architecture of Rutland County* (Montpelier: Vermont Division for Historic Preservation [VDHP], 1988), 22-23.

picturesque element that is not found in any other bridge type. As in many masonry bridges that were handcrafted by a stone mason, often with identifiable characteristics, the roof, portals, and windows of covered bridges frequently reflect the craftsmanship and stylistic details of a particular builder. Covered bridges were economical to build and required no specialized skill to construct, characteristics shared with concrete bridges.

Masonry construction also took advantage of indigenous materials, but working the stone demanded more time than working timber, and the skill to properly construct a masonry arch was not always present. Vermont's most celebrated bridge mason, James Otis Follett of Windham County, was apparently self-taught. Although Follett worked late in the nineteenth century, the vernacular technology evident in his bridges accurately reflects the typical stone arch of the entire century. As a result of the apparent limited expertise, stone bridges were far less common than timber. They appear in clusters, such as Follett's work in the Townshend area, which makes up the Follett Stone Arch Bridge Historic District, and the two arches built over Kendron Brook in Woodstock (State Survey #1424-25 and #1424-27) by an unknown artisan. These groupings further indicate that the construction of stone rather than timber bridges in the nineteenth century depended on the presence of local skilled labor.[2]

Timber and stone also dominated bridge building in the rest of the country until the late 1860s, when iron works began supplying prefabricated truss members according to the designs of the emerging profession of structural engineering. Railroad companies built the first iron bridges, using the designs of their staff engineers. While the railroads fostered innovative work in response to specialized needs, two truss designs had already begun to predominate. The Pratt truss, patented in 1844, and the Warren truss, patented in 1848, offered simplified fabrication and construction because they used a limited number of different members in their webs. They also surpassed other designs in the ability to fully describe the distribution of stresses through mathematical analysis.

IRON TRUSS BRIDGES

The late 1850s and early 1860s saw the introduction of numerous technical improvements that paved the way for prefabricated iron bridges. In 1859 the Lehigh Valley Railroad in Pennsylvania built the first pin-constructed bridge in the United States, which considerably eased construction compared with the use of rivets and bolts, enabling assembly in the field rather than in the shop. The ability to ship unassembled members, rather than large pre-assembled components, permitted the erection of iron bridges on roads far distant from rail lines. In the same year the first all wrought-iron bridge went up, a considerable improvement because cast iron was

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[2] See the thematic National Register nomination on Follett's bridges on file at the VDHP, Montpelier.

recognized as a brittle material unsuitable for bridges. In 1863 the first all wrought-iron, pin-connected bridge demonstrated the technology that would propel the bridge industry for the next 30 years.[3]

After the Civil War, bridge engineers began their own firms, or joined with iron works, to design, fabricate, and market iron bridges for highway use. Even though Pratt and Warren trusses dominated the field, the 1870s and 1880s were a period of continued experimentation. Some of the new trusses and variants represented a genuine attempt at improvements through greater economy in materials and construction time. C.H. Parker of Boston developed a bowstring truss, which gained some strength from the arch effect of its curved top chord; the ca. 1870 bridge in Northfield, Vermont (State Survey #1213-85), which once carried Vine Street over the Central Vermont Railroad, is the earliest unaltered example of this important innovation in the state. C.H. Parker later designed a Pratt truss with a curved top chord, creating a pattern that found broad application and became known as the Parker truss. Other new forms were most important as marketing tools that allowed the firm that held the patent to offer exclusive access to the design. For example, Connecticut's Berlin Iron Bridge Company claimed that its lenticular truss on Town Highway 3 (State Survey #1404-33), which crosses the Second Branch of the White River in East Bethel, Vermont, was cheaper and better than the more common trusses, but its most important selling point was probably its novel appearance.[4]

The fabrication of truss bridges was a capital-intensive business that required rail access to be competitive. It was concentrated in the industrial regions of the Northeast and Midwest, mostly in cities. The fabricating shops bought rolled wrought iron in the shapes of channels, plates, and angles, then cut the pieces to the required length and shape, drilled or punched the holes for rivets that connected the pieces of composite members, and shipped the entire disassembled bridge to the buyer, by rail as far as possible. No significant fabricator worked in Vermont until the late 1880s, when the Vermont Construction Company of St. Albans was started as a subsidiary of a Springfield, Massachusetts, firm. Relatively poor access to material, equipment, and financing, and a lack of a diverse labor pool limited the abilities of Vermonters to participate in this business, ensuring that almost all the metal bridges would be brought from elsewhere. Specific fabricators, contractors, and designers that worked in Vermont are discussed at the end of Section E. A variety of arrangements were made for erecting the bridges on site. Some companies employed full-time erecting crews and moved them around to successive jobs. Others hired crews locally for each job. In many cases the fabricators had no part in the actual construction, but the purchasing town would contract separately for abutment and bridge construction.

Since the state government had no central transportation planning, construction, or maintenance responsibilities until the 1890s, the iron bridge companies sold their wares directly to town governments. Vermont proved a difficult market for most fabricators. Selling in Vermont required long journeys from the centers of production.

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[3] J.A.L. Waddell, *Bridge Engineering* (New York: John Wiley and Sons, 2 vols., 1916), I-23-29; Donald C. Jackson and Allen Comp, "Bridge Truss Types," *Historic News* 32(5-May 1977), unpaginated; Donald C. Jackson, "Railroads, Truss Bridges and the Rise of the Civil Engineer," *Civil Engineering* (October 1977):97-101.

[4] Waddell, I-29; Jackson and Comp.

Most of the fabricators issued advertising circulars periodically, usually featuring engravings of their bridges. Two firms, New York's Groton Bridge and Manufacturing Company and Connecticut's Berlin Iron Bridge Company, appear to have supplied many of the bridges in Vermont. Due to their proximity, these firms could afford to send sales agents to the small towns in Vermont, where they exploited every possible advantage in contending for contracts. Despite the best efforts of the sales agents, it appears that no more than two or three hundred iron truss bridges were constructed in Vermont in the nineteenth century.

MASONRY BRIDGES

Near the end of the nineteenth century, a specialized form of masonry bridge became popular: the commemorative, monumental arch usually found in town centers. While the masonry bridges built by Follett and other country artisans are more rugged in appearance, the town center bridges have a more formal aspect. The exposed stones have finished surfaces, and the bridge often incorporates decorative elements such as parapets, railings, and street lights. The town center bridges carried more than horses and wagons. They bore the community's pride in their own permanence and achievement. Metal truss bridges had become associated with the notion of progress, and now a fine masonry arch was seen as making a similarly positive statement about its community. Members of the local elite often contributed to build highly visible stone spans. Often these bridges were named after them, such as the Battell Bridge carrying Route 30 over the Otter Creek in Middlebury (State Survey #0111-50, listed in the National Register as part of the Middlebury Village Historic District, 11/13/1976).

CENTRALIZATION OF THE ROAD SYSTEM

In the last years of the nineteenth century, Vermont's inadequate roads compelled the state government to take action. Following the lead of New Jersey, which in 1891 pioneered centralized transportation planning and funding, the Vermont legislature in 1892 enacted the first steps that would lead to a state road system and a highway commission. By 1898 a Highway Commissioner was in place with the authority to regulate road construction and use.

In the early twentieth century, the highway system in Vermont was classified under four different systems that indicate administrative authority and financing: federal, state, state-aid, and town. All public roads in the state were classified as town highways prior to 1906. The state highway commissioner supervised the construction of roads, but towns were responsible for their maintenance and repair.[5]

The relatively light traffic on Vermont's roads and the high cost of even the simplest construction caused the Commission to move very slowly in its first years, building its ties with officials in towns and newly created highway districts, and establishing standards for road width and surface as well as for vehicle use. In establishing

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[5] Vermont State Highway Board, *Tenth Biennial Report* (1938-1940), 13.

priorities for highway expenditure, the Commission started viewing Vermont roads with inter-regional transport in mind. Before long the automobile began to transform this rural state along with the rest of the country.

Not only did motor vehicles increase the demand for better roads, they also provided a means to pay for them through road and gas taxes. Funding mechanisms for construction of highways and bridges in Vermont were first established early in 1904 with a motor vehicle registration fee, the proceeds of which were used for construction of permanent highways.[6] Although federal money was available on a 50-50 matching basis, the Department of Highways did not have sufficient funds to provide their share of the match. Gasoline taxes were levied to increase state appropriations for road and bridge work and take advantage of the federal funding.[7] As road construction began to increase in the 1920s, gasoline taxes were levied in 1923, 1925, 1927, and 1929. The initial gas tax started out at $0.01/gallon with $0.01 increases in 1925, 1927, and 1929.[8] By 1940, 81 percent of state highway revenue came from motor vehicle registration fees and gas taxes, amounting to almost $8.4 million.[9] The Commission was explicitly forbidden to spend state money to build bridges and culverts, but after 1912 was allowed to supply structural engineering services at the request of towns. Finally, in 1915 the legislature established a bridge fund, an annual appropriation that the Highway Commission could use to help towns build bridges. In 1917 the federal government-initiated funding for road improvements with the Federal Aid Road Act. The federal money was intended to improve mail delivery and was limited to communities of less than 2,500. All but a handful of Vermont towns qualified, and the state benefited from annually rising federal allotments.[10]

Along with increasing appropriations came the beginning of government approval and supervision of construction. The State Highway Commission began immediately to impose structural, geometric, and alignment standards for bridges once it could enforce them through power of the purse. Federal engineers reviewed every project paid for under the 1917 Road Act. Increased governmental technical participation accompanied rising funding into the mid-1920s. In 1922 the Highway Commission initiated a statewide bridge inspection to allocate maintenance efforts and identify candidates for replacement, and by 1926 they had a full-time staff engineer to supervise the accelerating construction programs.

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[6] Vermont State Highway Board, *Eleventh Biennial Report* (1940-1942), 9.

[7] *Burlington Free Press,* March 24, 1949, page 3.

[8] Vermont State Highway Board, *Eleventh Biennial Report* (1940-1942), 13.

[9] Vermont State Highway Board, *Tenth Biennial Report* (1938-1940), 14.

[10] Vermont Highway Commission, *Biennial Report* (1908), 5-12; *Biennial Report* (1910), 7; *Biennial Report* (1914), 11; *Biennial Report* (1916), 5-6; *Biennial Report* (1918), 7-10; *Biennial Report* (1922), 10. During the biennial of 1920-1922, the Vermont Highway Commissioner merged with the State Highway Board and so the biennial report is considered the twelfth biennial report of the Vermont Highway Commission and the first biennial report of the State Highway Board. This document is listed in the references cited under the Vermont Highway Commission.

BRIDGE STANDARDIZATION AND TECHNOLOGICAL ADVANCES

The broadening of state authority marked the beginning of standardization for Vermont’s bridges. Masonry bridges lost favor because the state would not pay for them. Stone bridges of the twentieth century invariably were built by town and private funds, usually out of some motivation beyond the technical or the economic. Barre’s 1920 granite arch (State Survey #1202-259), for instance, represented the importance of the local quarry industry. The 1915 “Marble Bridge” in Proctor (State Survey #1118-2: 9), actually a concrete bridge with marble facing and detail, was a gift of Mrs. Emily Proctor in memory of Fletcher Proctor, son of the former Vermont governor whose family controlled the quarries.

The Highway Commission much preferred concrete over stone. The materials were available throughout the state and the work of building wood forms or mixing and pouring concrete did not require any rare skill. The Commission alleviated the possible lack of engineering talent in a town by drawing up standard plans for concrete spans and offering them free of charge to the towns. McCullough noted, “By 1907, plans for culverts and bridges spanning fewer than four feet were being distributed by Vermont’s highway commissioner at no cost to towns. A year later, the commissioner reported that use of concrete for culverts was increasing rapidly and that properly constructed examples were proving superior to those built with other materials such as masonry or tile.”[11] Plans for bridges were available in 1915, when the state construction money became available. The 1924 bridge in Hyde Park (State Survey #0805-31) is a good example of the arched concrete spans erected according to the state’s specifications.[12]

The cost advantage of concrete over stone was not lost on the towns and cities that undertook their own improvements during this period. For example, the City of Rutland vastly expanded its construction function in the 1920s, resurfacing and extending roads, laying out new ones, and building bridges. Several very simple concrete bridges erected in Rutland under this program include those on Baxter Street (State Survey #1119-83), Granger Street (State Survey #1119-86), and Strongs Avenue (State Survey #1119-87). As a result of its reasonable cost and ease of construction, concrete bridges had widespread use across the state. In fact, the early twentieth-century advancements made in the use of concrete, both reinforced and prestressed, in combination with the developing truss technology is, today, the mainstay of our highway system.[13]

The concrete bridges of Vermont escaped complete repetition from site to site. Some towns made commemorative structures out of concrete, much like the more expensive decorative stone spans. The best example, the 1912 Barrett Memorial Bridge (State Survey #0910-52:59) in South Strafford village, even mimics

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[11] Robert McCullough, *Crossings; A History of Vermont Bridges* (Barre: Vermont Historical Society), 176.

[12] Vermont Highway Commission, *Biennial Report* (1910), 27; *Biennial Report* (1908), 5-12; *Biennial Report* (1910), 7; *Biennial Report* (1914), 11; *Biennial Report* (1916), 5-6; *Biennial Report* (1918), 7-10; *Biennial Report* (1922), 10. *Biennial Report* (1916), 5-6; *Biennial Report* (1924), 9, shows the 1924 bridge immediately after construction.

[13] Bryan VanSweden, Concrete Bridge Preservation, unpublished paper (Montpelier: on file, VDHP, 1987), 1.

masonry construction with its inscribed lines in the pattern of the voussoirs of a stone arch, and a raised central tablet in the imitation keystones. The other major deviation from the standard form was the open-spandrel concrete arch, a specialized form used mostly in long spans over deep gorges; by leaving much of the space between the ring of the arch and the roadway open, this form offered substantial economy of material in long crossings. One of the two surviving examples crosses the Winooski River and the Central Vermont Railroad in Colchester (1913, State Survey #0404-38). Vermont's other open spandrel, in Windsor Village (1930, State Survey #1423-29), is much shorter. In this case the decorative appearance of the open spandrel's graceful profile added to its desirability for this central location in the town.

The Commission's greatest impact on truss bridges resulted from its efforts to coordinate new bridge and road construction, affecting alignment, width, and other clearances. But factors outside the state's control exerted greater influence, particularly the use of motor vehicles and changes in the fabricating industry. Cars and trucks imposed progressively greater loading on bridges. Over the first 25 years of the twentieth century, bridges used thicker and heavier members in the effort to keep pace with increased volume and heavier vehicles.

Steel Truss Bridges

Changes in the bridge-fabricating industry in the late nineteenth century had begun to narrow the variety in types of trusses. Several bridge failures had made the companies and their designers more conservative in the face of an enraged public. The well-proven patterns–Pratt, Warren, and their variants–gained an insurmountable edge. Their relatively simple joints permitted engineers to determine how the load was distributed in them, and to design with the assurance that any failure would come within a member and not a joint. The consequent tendency to make the members larger contributed to the increasing heaviness of the trusses. The industry also adopted steel as the favored material. The first all-steel bridge in the United States went up in 1879 on the Chicago and Alton Railway, but engineers and fabricators distrusted steel, particularly for tension members, until the perfection of the open-hearth process of steel production around 1890. By that time, the common structural shapes (plates, channels, and angles) were available in steel at prices comparable to wrought iron. The final important technical change came in the means of assembling bridges in the field. Pinned connections had been favored for their ease of assembly, even though engineers realized that riveted connections provided superior rigidity. Late in the nineteenth century, innovations in pneumatic field riveting overcame the cost advantage of pinned joints, and riveting became standard.[14]

Economic consolidation in the fabricating industry solidified the technical changes that occurred. In a classic case of market dominance through financial manipulation, the banker J.P. Morgan in 1900 formed the American Bridge Company. In its first year American Bridge purchased 24 bridge companies, representing half of the nation's fabricating capacity, and made further acquisitions in 1901 and 1902. In 1901 American Bridge was itself purchased by U.S. Steel, the largest producer of structural steel. This combination of the leaders in

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[14] Jackson; Waddell, I-24–28; Charles M. Fowler, "Machinery in Bridge Erection," *Cassier's Magazine* 17 (February 1900):327-344.

both primary and secondary production achieved immediate control of the bridge market, leaving survivors to fight over scraps from the giant's table. The firms that had previously fabricated most of the metal bridges in Vermont, Berlin Iron Bridge and Groton Bridge and Manufacturing, were both among the first 24 absorbed by American Bridge. In a pattern repeated frequently, executives of the two acquired companies left American Bridge after a short time and started smaller competing shops in their home areas: Berlin Construction Company and Groton Bridge Company. Like the rest of the small firms, Berlin and Groton resigned themselves to compete in regional markets by capitalizing on their greater knowledge and contacts in their areas, as well as whatever incremental cost advantage in transportation they could offer over American Bridge. The strategy of competing by offering innovative designs disappeared, and as the twentieth century opened, the steel, rivet-connected bridge using a Pratt or Warren truss, or one of their variants, was clearly dominant. By 1910 the industry's inventories of wrought iron and of members suitable for pinning had been used up and riveted steel trusses achieved universal application.[15] ·

From its inception, American Bridge was very successful in Vermont. From 1900 to 1914, while American slowly reorganized its massive holdings, it undertook numerous joint contracts with United Construction of Albany, New York, with United responsible for the sales effort and bridge erection. After 1914 American Bridge sold directly; erection was either contracted for separately by the purchaser or subcontracted by American. Few smaller firms managed to win occasional contracts in Vermont but, to judge from the surviving structures, the only serious challenge to American Bridge came from Berlin Construction Company, and only then as part of the massive rebuilding effort after the·1927 flood.

Thus, in the first quarter of the twentieth century a number of forces converged to result in the beginnings of standardization among bridges in Vermont. Masonry became increasingly rare. The plans offered by the Highway Commission encouraged standardization for concrete bridges. The Commission determined many characteristics of truss bridges according to the needs of a comprehensive state road system. Meanwhile, growing conservatism among bridge designers, technological changes in bridge construction, and economic consolidation of the bridge industry all tended to limit experimentation and to promote a narrow range of technical options. These factors acted nationwide, not just in Vermont. But in rebuilding after the great flood of 1927, Vermont would achieve a degree of standardization far in advance of other states.

FLOOD OF 1927

On November 3 and 4, 1927, record rainfall devastated northern New England. Climaxing a wet autumn that had filled the reservoirs and the absorption capacity of the soil, the rain swelled brooks into rivers and rivers into raging torrents.[16] Approximately four billion tons of rain flooded the state. The heaviest rain was recorded

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[15] Victor C. Darnell, "Lenticular Truss Bridges from East Berlin, Connecticut," *Directory, The Journal of the Society for Industrial Archeology* 5(1979):3, 38, 85-86.

[16] Arthur F. Stone, *The Vermont of Today* (New York: Lewis Historical Publishing Company, Inc., 4 vols., 1929): I-163.

in Vermont's Winooski Valley, some 9.5 inches in 24 hours. Two billion cubic feet of rain fell on the 1,000 square miles that make up the Winooski basin, enough water to supply the 1927 population of New York City for three months.[17] The Cavendish Gorge, which is a half a mile long and as much as 100' deep and 600' wide, was created by flood water moving two million tons of earth in one night.[18] But no part of Vermont escaped the flooding, and the valleys of Otter Creek and the White, Ottauquechee, Passumpsic, Lamoille, and Missisquoi rivers all suffered serious property damage. Statewide, more than 1,200 bridges were washed away.[19]

With all the in-state communications disrupted, it took several weeks even to estimate the damage. Once the magnitude of damage to roads and bridges was clear, the governor supported Vermont's first use of public debt for transportation development, and by the end of November the legislature authorized $8 million in bond funding for rebuilding roads and bridges.[20] This funding centralized power in Montpelier, the capital, and increased the state's control over road and bridge building that traditionally had been supervised by individual towns.[21]

The state, however, could not complete such a massive effort by itself, and the governor did not object when the United States Congress appropriated more than $2.6 million for rebuilding bridges. The District Federal Office of the Department of Transportation sent 14 survey crews to help assess the damage and begin plans for reconstruction, the majority of which took place between 1928 and 1930. Prior to the flood the Highway Commission's Bridge Department included one engineer and 12 draftsmen, most of them temporary summer help. As soon as the surveys were completed the department grew to 35: three engineers designing steel structures, four designing concrete, 26 draftsmen, and two engineering technicians. Of utmost interest in terms of the structures that resulted, American Bridge Company loaned the agency a structural engineer to head the team designing steel structures. The other two steel designers came on temporary loan from the federal government.

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[17] Stone, 162.

[18] Stone, 168.

[19] A considerable body of literature has poured forth regarding the 1927 flood. For a sampling of the national coverage of the disaster see "Record Rainfall Causes Heavy Damage in New England States," *Engineering News-Record* 99 (November 10, 1927):770-773; Patrick E. Purcell, "The Flood of '27: The Factual Story of a Disaster in Vermont," *National Railway Bulletin* 42 (6-1977):4-10, 46. For descriptions of the devastation in various areas of the state, see Harold H. Chadwick, "Flood," *Vermont Life* (7-August 1952):8-13; Jerome E. Kelley, "Flood! Vivid Memories of the 1927 Catastrophe," *Vermont Life* (32-August 1977):30-35; J.M. French, "The Flood of 1927 in Lamoille Valley," *Vermonter* (35-March 1930):56-60; "The Flood of 1927 in Orleans County, *Vermonter* (33-January 1928):9-20; Rose L. Kent, "Flood-tides of Bennington," *Vermonter* (33-April 1928):55-62; "The Flood at Rutland," *Vermonter* (33-May 1928):70-76; Georgia White, "The Rebellion of 'The Long River," *Vermonter* (33-June 1928):86-93.

[20] Vermont Highway Commission, *Sixth Biennial Report* (1930-1932), 7-8.

[21] Jennie G. Versteeg, ed., *Lake Champlain: Reflections on Our Past* (Burlington: University of Vermont, 1987), 25.

Standard Bridge Designs

Because of the enormity of the work, it was decided to standardize as much work as possible. Standard slab spans were designed at 1-foot intervals between 4’ and 20’ in length, T-beam spans at 5-foot intervals between 25’ and 55’, and I-beam spans at 5-foot intervals between 25 and 70’. Options for all these types included open and solid rails, sidewalks, and varying widths of road. Standard abutments were designed at increments of 2’ in height up to 10’, and for square skews as well as standard variations of 15, 30, and 45 degrees.[22]

Standard steel trusses came in increments of 10’ in length between 60’ and 100’, and of 20’ for spans longer than 100’. The bridges under 100’ were Warren pony trusses. The principal variation came in the steel top chord. Most of the bridges featured a straight top chord parallel to the bottom chord (such as Fairfax, State Survey #0604-63). But for locations of heavier traffic, such as town centers or major through roads, the standard design called for a curved, polygonal top chord; examples include the bridges on Langdon .and School streets in Montpelier (State Survey #1211-197 and #121-198), and Route 100-C in Hyde Park (State Survey #0805-22). Between 100’ and 160’ in length, the standard was a Pratt through truss, although some overlap existed with the Warren pony trusses at the lower end; the typical Pratt truss can be seen carrying Town Highway 6 over the Missisquoi River in East Highgate (State Survey #0609-19). Above 160’ the engineers specified a Parker truss, the polygonal top chord variant of the Pratt truss, as seen on Town Highway 3 in Jonesville, Richmond (State Survey #0411-32).

Over 1,600 bridges were built by the end of 1930.[23] The standard plans, including beam and slab designs, accounted for about 75 percent of the new bridges constructed, and the great majority of the remaining crossings consisted of some combination of standard spans. Only very few crossings required a specialized design effort, the most notable being the “Checkered House” bridge in Richmond (State Survey #0411-18), a Pennsylvania truss that was the longest single span erected under the reconstruction program. All the truss bridges had a roadway width of about 21’. The most difficult fit between the standard plans and the actual conditions was in the alignments, since the standards permitted only limited variations of skew. In addition, for speed of reconstruction the engineers decided in many places just to cap the existing abutments with concrete and built the new bridge on the old alignment. As a result, many of the flood-era bridges that stand today are approached on 18 tightly curving roads that do not meet modern standards.[24]

The individual members of the standard trusses differed from the common practice evident before the flood. Pre-flood bridges virtually all featured “built-up” members: various combinations of plates, channels, and angles connected with rivets. The flood trusses used this technique for their top and bottom chords, but vertical and diagonal members between the chords were usually rolled I-beams that required no assembly. The obvious

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[22] “Reconstruction of Vermont Highways,” *Journal of the Boston Society of Civil Engineers* 15(10-December 1928):449-466.

[23] Stone, II-704–705.

[24] “Reconstruction of Vermont Highways,” 460-461.

advantage to such members was to speed reconstruction by minimizing shop time. They probably also cost less than built-up members. The prior reluctance to use rolled members (on a nationwide basis, not just in Vermont) was based on the greater resistance to twisting offered by built-up members. The horizontal stiffeners spanning the middle panels of the through trusses built after the flood helped to alleviate this problem. Furthermore, the presence of an American Bridge engineer gave the Highway Commission unprecedented access to expert advice on the availability and strength of various materials, particularly since U.S. Steel, the parent firm of American Bridge, ranked as the foremost source for rolled structural steel. The Vermont trusses built in 1928, 1929, and 1930, during the flood reconstruction program, had some national impact among bridge engineers. Before the flood, the steel industry had been improving its rolling technology and structural engineers had been moving toward the more simple made rolled members. The intensive design and construction effort following Vermont's 1927 tragedy provided a massive laboratory to test the efficacy of rolled members. In 1929, for the first time, the American Association of Highway Officials' "Standard Specifications for Highway Bridges" recommended all rolled sections for truss webs, and at least one engineering textbook was illustrated with examples from Vermont's reconstruction program.[25]

The vast extent of the reconstruction program strained not only the resources of the public agencies that took part, but also the private firms that stood to benefit from the massive surge in contract awards. American Bridge and a handful of other companies contributed to the reconstruction program, but many did not stay in the bridge business after the crisis had passed.

The flood reconstruction program, with its special funding and centralized engineering, put the Highway Commission a decade ahead of schedule and created a better road system than had existed before the flood. The program brought a systematic upgrading of older roads and construction of bridges that the Highway Commission had pursued on a piecemeal basis before the flood.

DEPRESSION ERA AND NEW DEAL PROGRAMS

In 1931 the Vermont General Assembly through Act No. 61 authorized the State Highway System, effectively transferring nearly all the highways that were in the federal-aid system, some 1,012.82 miles, to the state highway system, which transferred these roads from the jurisdiction of towns to the state.[26] With this transfer the Department of Highways became responsible for the construction and maintenance of approximately 1,000 bridges.[27] Total expenditures for bridge work in the 1930-1931 biennium was $427,881.[28]

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[25] Standards cited in Leonard C. Urquhart and Charles E. O'Rourke, *Design of Steel Structures* (New York: McGraw-Hill, 1930), 120; this same volume contains the illustrations of Vermont bridges.
[26] Vermont State Highway Board, *Tenth Biennial Report* (1938-1940), 13.
[27] Vermont State Highway Board, *Eighth Biennial Report* (1934-1936), 20.
[28] Vermont State Highway Board, *Sixth Biennial Report* (1930-1932), 17.

In the 1932-1934 biennium the State Highway Board suggested that the "Through Roads," which included secondary roads that connected major state routes, also be taken over by the state, adding an extra 735 miles to the state system.[29] These through roads, which provided convenient short cuts between major routes, contained approximately 621 bridges that became the responsibility of the state. A survey of these bridges revealed that 148 bridges had to be replaced within two years because of their condition. An additional 148 bridges needed to be replaced within five years.[30] As a result of the additions to the system in 1931 and 1935, funds obligated for bridge construction equaled over $1.9 million for the 1934-1936 biennial period.[31] The total expenditures for bridge work prior to these additions was $427,881.[32]

The 1938 New England hurricane damaged 75 bridges in the state and state-aid highway systems. The state requested Progress Works Administration (PWA) funds totaling over $800,000 to complete the repairs.[33] As of June 30, 1942, the total net cost to the state for the 1938 hurricane damage totaled over $3.2 million.[34]

Many of the deficient bridges that were brought into the state system in 1935 were replaced using PWA funds. From 1936 to 1938, 17 bridges were constructed under the PWA program at a total cost of $232,693.94 (Table E-1).[35] One of the last PWA funding requests or dockets, Docket 1 092, was set up to repair bridges damaged by a severe flood on December 21, 1938.[36] By 1940, 251 new bridges had been constructed and 303 existing bridges had been repaired under the PWA program, and 3,021 new culverts had been constructed.[37]

TABLE E-1

PWA BRIDGE PROJECTS FROM 1936 TO 1938

Town	Highway	Cost
East Montpelier	Route 14	$24,401.25
East Montpelier	Route 12	$14,562.85
Chelsea	Route 110	$14,750.19
Hartland	Route 12	$7,404.14
Warren	Route 100	$7,160.82
Addison	Route 19	$8,630.71
Hinesburg	Route 116	$8,231.87
Granville	Route 100	$13,245.58
Plymouth	Route 100	$11,417.00
Cornwall	Route 19	$20,993.47
Orwell	Route 30A	$8,335.64
Bridport	Route 19	$8,225.87
Granville	Route 100	$10,718.12
Londonderry	Route 8	$23,058.94
Jamaica	Route 30	$21,491.05
Enosburg	Route 108	$14,224.46
Topsham	Route 25	$15,841.98

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[29] Vermont State Highway Board, *Seventh Biennial Report* (1932-1934), 23.
[30] Vermont State Highway Board, *Eighth Biennial Report* (1934-1936), 20.
[31] Vermont State Highway Board, *Eighth Biennial Report* (1934-1936), 20.
[32] Vermont State Highway Board, *Sixth Biennial Report* (1930-1932), 17.
[33] "PWA Funds For Bridge Repairs Asked," *Burlington Free Press*, October 1, 1938, 2.
[34] Vermont State Highway Board, *Eleventh Biennial Report* (1940-1942), 69.
[35] Vermont State Highway Board, *Ninth Biennial Report* (1936-1938), 31.
[36] "Highway Dept. Has 43 Out of 112 PWA Bridges Under Way," *Burlington Free Press,* December 31, 1938, 2.
[37] "Past Motor Vehicle Registration Year Reached $2,631,494," *Burlington Free Press,* April 25, 1941, 2.

II. BRIDGE CONSTRUCTION IN VERMONT: 1940-1978

THE WAR YEARS, 1941-1945

The decade of the 1940s opened with America still struggling to emerge from a lagging economy. It was, nevertheless, a notable time for bridge construction across America as several large projects funded by the Works Progress Administration reached completion. In 1940 and 1941, big cantilever bridges were erected in Connecticut, Rhode Island, and Illinois and over the Mississippi in Louisiana at Baton Rouge, Greenville, and Natchez. The Natchez Bridge was the largest with two 875-foot spans, and the Housatonic Bridge on the Merritt Parkway in Connecticut was notable for its use of lightweight, open-grid steel flooring to reduce overall dead weight. Less floor weight provided for a reduction in the amount of structural steel required, resulting in a substantial cost savings. The innovations in bridge technology developed during the Depression to stretch the bridge-building dollar had come to fruition.

The longest fixed-end arch bridge in the world was built in Niagara Falls, and large tied arch bridges, a relatively new type for long spans, were erected in St. Georges, Delaware, and over the Mississippi at Davenport, Iowa. In New Jersey the Thomas A. Edison Bridge over the Raritan River opened, the first long, high-level plate girder bridge in the country, significant for establishing several new records in bridge building, including the lifting and placement of the largest and heaviest girder in the world. The simple, economical, plate-girder bridge, long used by railroads for its ease of construction and rigidity, had become popular for highway use in the deck design configuration, which placed the girders under the roadway and enhanced driver safety. Plate girder bridges were particularly suitable for applications of low vertical clearance, such as limited-access-highway overpasses.

World War II halted the plate girder's rise and dominance of the highway bridge market for over a decade. By 1942 the country was at war, and although several notable bridges were completed at that time, the war effort took precedence. The War Production Board ordered a stoppage of all new highway construction projects that cost over $5,000. Only emergency repairs to roads and bridges and regular maintenance were performed during the war because materials were reserved for the war effort. Nationwide, bridge-building expenditures plummeted from roughly $120 million annually in 1940 and 1941 to $58 million in 1942. Vermont was not as affected as other states by the work stoppage, as the Department of Highways road and bridge modernization program in the 1930s, as well as the funding of numerous bridges through federal public works programs, had already led to the construction of 290 long-span bridges and 109 short-span bridges between 1935 and 1942. Subsequently, the total number of new bridges dropped, to three in 1942 and one in 1944.

The Department of Highways completed contracts that were let prior to the outbreak of the war, which included construction of 32 miles of roads and 10 bridges. One of the bridges was the St. Johnsbury Viaduct carrying U.S. Route 2 over the Passumpsic River and two railroad lines.[38] Constructed in 1943, the nine-span steel girder

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[38] Vermont State Highway Board, *Twelfth Biennial Report* (1942-1944), 19.

bridge is 890' long, the longest highway bridge constructed in the state at that time. The next longest bridge was not constructed until the 1950s. Emergency work was completed in Orleans and Essex counties, where a storm damaged numerous bridges. Because of the wartime shortage of steel, the Department of Highways used wood to build temporary replacement bridges.[39] Later that year, Vermont Governor William H. Wills offered state iron bridges that had been destroyed and removed during the 1927 flood as scrap to support the war effort.[40]

POSTWAR PERIOD, 1946-1951

Technological Advances in Bridge Construction

A great number of important changes in the technology of highway bridge design and construction were ready to emerge from the aftermath of World War II. The coincident period of great economic prosperity in the United States fueled a commercial building boom that kept structural steel in short supply and high-priced. Many bridge designers increasingly turned to reinforced concrete for short-span bridges. The concrete industry aggressively financed research and development of new technologies, especially in the areas of precast and prestressed slabs, beams, and girders that could compete with the ease of construction offered by steel beams.

In Vermont approximately one-quarter of the 192 bridges built after the war until 1955 were concrete (Table E-2). Concrete slab was used for spans shorter than 30'.

TABLE E-2

POST-WORLD WAR II CONCRETE BRIDGES IN VERMONT

BRIDGE TYPE	TOTAL BUILT 1945-1955	SPAN RANGE (ft)
Concrete Slab	27	23 to 37
Concrete T-Beam	19	30 to 120
Concrete Rigid Frame	1	35
Reinforced Concrete Box (Culvert)	4	21 to 27
Prestressed Concrete Slab	4	30 to 76

Aluminum was also explored as an alternative to steel. Although much more expensive than steel or concrete, aluminum offered some first-cost savings in substructure and construction costs because it was light in weight. Aluminum's real benefits, however, were thought to be in the lower life-cycle cost that would result from longer service and lower maintenance costs because aluminum does not rust or require painting. In 1946 the first bridge

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[39] "Storm Damage Is Estimated at $180,825," *Burlington Free Press,* June 19, 1942, 2.

[40] "Highway Dept. Has 43 Out of 112 PWA Bridges Under Way," *Burlington Free Press*, September 23, 1942, 10.

constructed entirely of aluminum was built at Massena, New York, to carry railroad tracks over the Grasse River. The bridge was a 100-foot span deck plate-girder that weighed 40 percent of the same design in steel. It would be 12 years, however, before the first aluminum highway bridge would be built in the United States.

Meanwhile, the steel industry, while maintaining a secure grip on the long-span bridge market, was losing an ever-increasing share of the market to concrete in the short- and medium-span bridge classes. The steel manufacturers funded research in the areas of welding, improving and lowering the cost of high-strength and corrosion resistant steels, and using high-strength bolts rather than riveted connections for field assembly. Research engineers and industry lobbyists pushed for the adoption of national standards that recognized the more advanced European bridge designs, such as those incorporating steel plate, orthotropic, and composite-beam deck systems.

Steel bridges made up the largest percentage of bridges constructed during this period with 127 structures. The majority of these were steel stringer/multi-beam or girder bridges with single spans, although eight of the bridges had three or more spans (Table E-3). The steel through truss had become almost obsolete after the war; however, one such structure was built in 1949 over Otter Creek in Wallingford town.

TABLE E-3

WORLD WAR II STEEL BRIDGES IN VERMONT

BRIDGE TYPE	TOTAL BUILT 1945-1955	SPAN RANGE (ft)
Steel Stringer/Multi-beam or Girder	116	24 to 399
Steel Girder and Floorbeam System	5	70 to 826
Steel Thru Truss	1	131
Double Bascule Bridge	1	261
Steel Culvert (Multi-plate arch)	4	20 to 37

Advances in welding technology, in particular automated welding machinery that produced uniform high-quality welds, led to the use of all-welded plate girders that required significantly less steel for a given span and therefore cost less. Welded girders did not have rivet holes that reduced the strength of the web and flange plates, and welding eliminated the angles that are necessary to join the web and flange together at a right angle with rivets. A continuous weld joining the web and flange is stronger than a riveted joint. Welding also revived a very early form of the plate girder called the box girder that reappeared in a new light-weight welded version. A box-girder bridge constructed of wrought-iron plates was first built in England in the 1850s, but the form saw little later usage. The structural behavior of the welded box girder lent itself to curved construction and was applied to arches and later to tightly curved deck-girder designs that found efficient application supporting elevated access ramps. Welding also reduced the weight and material used in the built-up members of the floor and post systems of large trusses. The earlier development of lightweight, welded, open-grid decking was combined with high-strength steel tension members to set new records for continuous trusses.

Ten continuous steel bridges were constructed in Vermont in the decade after the war. Most structures were welded, but at least one, Bridge VT100-25 carrying VT Route 100 over the Deerfield River, still used rivets. The four-span, continuous deck girder bridge planned for a new crossing of VT Route 105 over the Missisquoi River at Sheldon Junction required 950,000 pounds of steel for the superstructure.[41] After a second round of bidding, Marston Construction Company of Somerville, Massachusetts, was awarded the $215,924 contract.[42]

The war-induced structural steel shortage persisted throughout the world well into the 1950s, making modern reinforced-concrete designs like rigid-frames, which had been in use since before World War II, and prestressed concrete an option for short- to medium-span bridges. In Vermont very few of these structures were constructed, the commission leaning more toward steel structures for these spans. One possible reason for the preference of steel was the damaging effects of salt and other chlorides on concrete bridges. Only two concrete rigid frame bridges were built in the state in 1950 and 1973, with spans of 30’ and 45’.

Although reinforced concrete was extensively used for short to medium spans, steel prevailed for long spans, and as the postwar nation embarked on the building of thousands of new roads, parkways, turnpikes, and thruways – many of which were incorporated into the interstate highway system – the plate girder was called back into service.

Postwar Bridge Construction in Vermont

The Department of Highways had made some progress with postwar bridge construction by November 1948, with 114 bridges on state and state-aid highways either completed or underway[43]; however, a resurvey of bridges in the state was needed to adjust the 10-year construction program that had been planned before the war. The State Highway Board survey found that 1,054 new bridges were needed: 200 on town highways, 157 on the state-aid system, and 697 on the state highway system.[44] From 1951 to 1952, 79 bridges were constructed or repaired on state aid highways at a total cost of $529,693.[45]

Despite the surge in bridge building following World War II, the Department of Highways still experienced construction problems caused by inflated prices, a shortage of materials, and a lack of skilled engineers and construction experts, many of whom had enlisted during the war and had not returned to the highway department.[46] Shortages of steel and concrete continued to hamper bridge construction nationwide into the 1950s.

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[41] “State Highway Board Finds Bids Too High,” *Burlington Free Press*, April 27, 1946, 2.
[42] “State Awards Bids on Sheldon Road Project,” *Burlington Free Press*, July 3, 1946, 2.
[43] Vermont State Highway Board, *Fourteenth Biennial Report* (1946-1948), 27.
[44] Vermont State Highway Board, *Fourteenth Biennial Report* (1946-1948), 12-13.
[45] Vermont State Highway Board, *Sixteenth Biennial Report* (1950-1952), 29.
[46] “Twenty Highway Projects Read Soon As Federal Act Operative,” *Burlington Free Press*, August 18, 1945, 2.

In April 1947 the State Highway Board purchased five Bailey bridges from the War Department. These portable, pre-fabricated bridges, which were single-lane and 150' long, were purchased for use in emergencies and were immediately installed at several locations. One of the bridges was installed across the Connecticut River between Bloomfield, Vermont, and North Stratford, New Hampshire, as a temporary bridge until a new bridge could be constructed. A second bridge was placed across the Lamoille River in Wolcott next to a closed covered bridge.[47] Although those bridges are not extant in those locations, at least five other Bailey bridges are currently in service: C3004-33, C3017-19, C3039-18, VT15A-1, and US2-88.[48]

After the war the Department of Highways began a program to replace deficient bridges, most of which had been built in the late nineteenth and early twentieth centuries and had a legal gross load limit of 10 tons.[49] Many of these were covered bridges. The program began in 1944, but very few, if any, bridges had been replaced by 1948. In 1949 the legislature authorized a state bond issue of $2.8 million to replace "weak, unsafe and deficient" bridges on the state highway system.[50] The first five bridges replaced under the program were two drawbridges over Lake Champlain on U.S. Route 2 between Alburgh and North Hero and Grand Isle and North Hero, two covered bridges on VT Route 15 over the Lamoille River in Cambridge, and the VT 30 Holland Bridge over the West River in Townshend (Figure 1).[51] Once these were completed, 12 more bridges were slated for replacement (Table E-4). In some cases, such as the Miller Bridge in Sudbury, the covered bridge was merely bypassed with a new road alignment and bridge (Figure 2).

TABLE E-4

DEFICIENT BRIDGES APPROVED FOR REPLACEMENT UNDER STATE BOND ISSUE

ROUTE	TOWN	BRIDGE	ESTIMATED COST ($)
U.S. 5	St. Johnsbury	Crooked Bridge	350,000.00
VT 8	Readsboro	High Bridge	300,000.00
VT F10	Sudbury	Miller Bridge	118,852.83
VT 12B	Craftsbury	Black River Bridge	30,000.00
VT 30	Dummerston	Taft Bridge	45718.80
VT 109	Belvidere	Rattling Brook Bridge	54,566.32
VT 113	Thetford	Post Mills Bridge	65,000.00
VT 113A	Thetford	Fish Rod Factory Bridge	50,000.00
VT 118	Montgomery	Combstock Bridge	55,000.00
VT 118	Montgomery	Gutter Bridge	45,000.00
VT 118	Montgomery	Levis Bridge	48,000.00
VT 118	Berkshire	East Berkshire Bridge	196,071.24

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[47] "Highway Department Buys Bailey Bridges For Temporary and Emergency Use," *Burlington Free Press*, April 8, 1947, 3.

[48] The bridge numbers listed are a combination of the route number and bridge number: US2-88 indicates bridge number 88 on U.S. Route 2. VTrans continues to use Mabey bridges today as temporary bridges over small streams.

[49] Vermont State Highway Board, *Thirteenth Biennial Report* (1944-1946), 17.

[50] Vermont State Highway Board, *Fifteenth Biennial Report* (1948-1950), 11-12.

[51] Vermont State Highway Board, *Fifteenth Biennial Report* (1948-1950), 11-12.

FIGURE 1: Replacement of Covered Bridges in Cambridge, 1950 (Vermont State Highway Board 1948-1950)

The Grand Isle to North Hero drawbridge, constructed in 1886, was considered hazardous; restricted load limits were posted on the bridge in 1939. In 1942 a gasoline truck fell through the bridge floor.[52] Discussions regarding replacement of the bridge started in 1943. Officials worried about maintaining navigation below the bridge, and the initial application to the War Department in 1943 was for construction of a moveable bridge (bascule). Approval was obtained the next year from the War Department. A new application for a fixed bridge in the same location with a 79-foot clear span was submitted in May 1945. A.D. Bishop, the bridge engineer for the Vermont Department of Highways, prepared a report on the bridge projects and the effect of fixed-span bridges on navigation. Bishop concluded that fixed spans would not restrict existing navigation at either site but would restrict sailboats with high masts.[53] The report was made public in November 1945 by Governor Mortimer R. Proctor in advance of public hearings requested by him to gauge public sentiment on the type of bridges to be constructed.

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[52] "To Open Bids on New Drawbridge for Islands Soon," *Burlington Free Press*, June 13, 1950, 3.

[53] "Governor Proctor Has An Open Mind On Matter of Type of Bridges Constructed in Grand Isle Co.," *Burlington Free Press*, November 1, 1945, 12.

Statewide, Vermont
County and State

Metal Truss, Masonry and Concrete Bridges of Vermont, 1820-1978
Name of multiple listing (if applicable)

FIGURE 2: New Road Alignment Bypassing the Miller Bridge in Sudbury (Vermont State Highway Board 1950-1952)

The public overwhelmingly disapproved of fixed spans for both sites, fearing that it would hamper navigation of pleasure boats that were seen as vital to the recreation-based economy of Grand Isle; locals viewed the island as "potentially one of the finest recreation areas in Eastern America."[54] In response to public sentiment, the Department of Highways compromised by proposing a bascule bridge at the Grand Isle-North Hero crossing but keeping the fixed span at North Hero-Alburgh.[55]

The contract to construct a seven-span steel beam superstructure for the North Hero-Alburgh Bridge was awarded in October 1949 to the American Bridge Company of New York for $218,700.[56] Construction of the substructure and abutments for the bridge was contracted to the Marston Construction Company, Inc. of Somerville, Massachusetts, for $593,654.90.[57] By February 1950 work on the North Hero-Alburgh Bridge was underway.[58] In 1950 the Lambert Construction Company of White River Junction, Vermont, was awarded the $975,174 bid to construct the new bascule bridge from Grand Isle to North Hero, which was designed by the Department of Highways bridge division.[59]

Since the amendment of Public Act No. 263 in 1912, which states that "any town or corporation, owning or controlling a draw bridge and the abutments thereto in the state of Vermont, shall convey to the state of Vermont all their rights, title and interest" in the drawbridge to be maintained by the state toll-free, the Toll Bridge Commissioners have worked to "free" toll bridges across the Connecticut River.[60] By 1943 seven bridges over the Connecticut River had been freed. The Springfield Terminal Railway Company-owned Cheshire Bridge on VT Route 11 between Springfield, Vermont, and Charlestown, New Hampshire, was the last toll bridge that concerned the Commission.[61]

BRIDGE AND HIGHWAY MODERNIZATION, 1952-1978

The decade of the 1950s was marked by unprecedented bridge-building activity across the nation. The largest demand was for more efficient and economic designs for short- and medium-span bridges, but bridges of every size and type were being constructed at a rapid pace. State highway departments were gradually beginning to experiment with the newer bridge types that were being used successfully in Europe.

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[54] "Fixed Span Opposed," *Burlington Free Press*, January 25, 1946, 6.

[55] "Fixed Span Opposed," *Burlington Free Press*, January 25, 1946, 6.

[56] "House Passes Gas Tax Bill by 193-22 Vote," *Burlington Free Press*, March 24, 1949, 26.

[57] "House Passes Gas Tax Bill by 193-22 Vote," *Burlington Free Press*, March 24, 1949, 26.

[58] "No Hold-up Foreseen in State's '49-50 Federal-Aid Road Program," *Burlington Free Press*, February 6, 1950, 11.

[59] "Vermont Firm Given Contract to Build N. Hero Drawbridge," *Burlington Free Press*, July 29, 1950, 2.

[60] Vermont General Assembly, *Acts and Resolves Passed by the General Assembly of the State of Vermont at the Twenty-Second Biennial Session 1912* (Montpelier: Capital City Press, 1913), 337.

[61] Vermont State Highway Board, *Seventeenth Biennial Report* (1952-1954), 13.

Steel beam and girder bridges, using rolled H-beam shapes, and welded plate girders for longer spans remained the workhorse for the highway bridge designer, but the practical span limits were soon reached. The technology of steel beam and girder bridges advanced greatly following World War II and into the 1960s in four main areas: composite beam design, the application of welding for the fabrication of plate girders, use of high-strength steels, and the use of orthotropic deck systems.

In the 1950s a total of 194 bridges with spans over 20’ were constructed in Vermont, both as replacement bridges and new structures. The majority of bridges (149) were constructed of steel, with the shortest 20’ long and the longest 826’ long. Of these, 132 bridges were steel rolled-beam structures. Other steel bridge types constructed include steel girder (6) and double-leaf bascule (1). Thirty-four of the 194 bridges were built of concrete, the majority of which were concrete slab or T-beam structures. One concrete rigid-frame bridge was built in 1950 on VT Route 106 near Woodstock, which is the earliest example of this type built in the state. Seven continuous steel girder bridges were constructed during this period as well as three prestressed concrete slab and stringer bridges. Of the seven steel girder bridges, three were rolled beam structures ranging from 305’ to 458’ long. Twin continuous plate girders, each 258’ long, were constructed for the I-91 Brattleboro bypass. One three-span continuous welded girder bridge was built over the Saxtons River in 1954.

Construction on bypass routes began as early as 1940 to relieve urban congestion on busy highways. One of the largest bypass projects undertaken by the state in the 1950s was the Brattleboro bypass, an approximately 4-mile-long project that included two interchanges and 11 structures, of which seven passed over highways. Twin three-span continuous plate girder bridges with a long span of 98’ required extensive earthwork to minimize steep slopes (Figure 3). The bridge is still in use today and crosses Broad Brook.[62]

To bring bridges in line with the modern highway standards adopted in the mid-1930s, the Department of Highways adopted a bridge widening program. In 1946 the state highway system had 640 bridges with spans shorter than 20’ that needed to be widened. Fifty-five bridges with over 20-foot spans also had to be widened. The total cost of the program was over $4.2 million.[63] In Plymouth Town, Windsor County, 12 concrete slab and T-beam bridges on VT Route 100 were widened in 1946.[64] In 1949 widening of the Works and Locke bridges on U.S. Route 2 between St. Johnsbury and East St. Johnsbury was contracted for $74,000. That same year, widening of the Lester Bridge on U.S. Route 7 between Rutland and Pittsford Mills was also planned, at a cost of $52,000.[65] The program did not continue until 1952, when several concrete bridges were widened and their concrete parapets replaced with cable guard rails.[66] An additional 10 bridges were widened on VT Route 108 in

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[62] Vermont State Highway Board, *Nineteenth Biennial Report* (1956-1958), 28.

[63] Vermont State Highway Board, *Thirteenth Biennial Report* (1944-1946), 19.

[64] Vermont State Highway Board, *Fourteenth Biennial Report* (1946-1948), 51.

[65] “House Passes Gas Tax bill by 193-22 Vote,” *Burlington Free Press* March 24, 1949, 2.

[66] Vermont State Highway Board, *Seventeenth Biennial Report* (1952-1954), 17.

FIGURE 3: Construction of Twin Bridges over Broad Brook on the Brattleboro Bypass (Vermont State Highway Board 1956-1958)

Stowe, U.S. Route 7 in New Haven, VT Route 12 between Barnard and Bethel and Woodstock to Barnard, VT Route 106 in Woodstock, U.S. Route 2 in St. Johnsbury and Marshfield, and U.S. Route 5 in Burke.[67] Seventeen additional bridges, four of which were steel, were widened from July 1956 to November 1958.[68] Fifteen were widened between 1958 and 1960.[69] Nonetheless, during the 1962-1964 biennium a total of 814 bridges on state highways were still found in need of widening.[70]

INTERSTATES/CONTROLLED ACCESS HIGHWAYS

A total of 343 miles of interstate highways were designated by the Vermont Department of Highways in 1965. According to the Fifty Billion Dollar Program proposed by President Eisenhower, the interstate system was expected to consist of a minimum of four lanes to allow the free flow of traffic. Building this limited-access, grade-separated interstate highway system required tens of thousands of short-, medium-, and long-span bridges to carry it over water obstacles and through cities. Thousands more short-span bridges were required to carry intersecting roads over the new, usually divided, highways. Between 1960 and 1978, 269 bridges were constructed as part of the interstate system in Vermont (Table E-5). Thirty of these structures are steel and concrete culverts. The majority of these bridges (232) were constructed of steel. Steel girder bridges [Type 302] were the most predominant type constructed, with 142 in the system compared with only 80 continuous steel girder bridges.

TABLE E-5

INTERSTATE BRIDGES IN VERMONT

BRIDGE TYPE	NO. OF BRIDGES	STRUCTURE LENGTH (ft)
Concrete T-Beam [Type 104]	2	32
Concrete Culvert [Type 119]	28	20 to 27
Steel Girder [Type 302]	142	69 to 846
Steel Girder and Floorbeam [Type 303]	1	187
Steel Deck Truss [Type 309]	2	851
Steel Culvert [Type 319]	2	20 and 26
Steel Continuous Girder or Stringer [Type 402]	80	123 to 1,059
Steel Continuous Girder and Floorbeam [Type 403]	4	429 to 563
Steel Rigid Frame [Type 407]	2	150
Steel Deck Truss [Type 409]	1	1,016
Prestressed Concrete Girder [Type 502]	2	80 to 92
Prestressed Continuous Concrete Tee-Beam [Type 604]	2	127 to 142

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[67] Vermont State Highway Board, *Eighteenth Biennial Report* (1954-1956), 67-71.

[68] Vermont State Highway Board, *Nineteenth Biennial Report* (1956-1958), 75-80.

[69] Vermont State Highway Board, *Twentieth Biennial Report* (1958-1960), 14-21.

[70] Vermont State Highway Board, *Twenty-Second Biennial Report* (1962-1964), 9.

All of these structures, which were funded by the Federal Aid Highway Act of 1954, had to meet interstate standards. The interstate in Vermont was to be "designed and constructed to the Interstate standards adopted in 1945....In general, minimum widths (of right-of-way) of about 200' in urban areas and 300' in rural areas...are suggested."[71]

Bridges constructed for the interstate system proved to be the longest spans in the state. In 1960 a five-span, 1,016-foot, haunched steel deck truss bridge was constructed for I-91 over VT Route 30 and is the only one of its type in the state. Twin continuous welded plate girder bridges with 1,016-foot spans were constructed over the Winooski River in 1962. The White River Bridge, built in 1967, was the longest bridge in the state at that time, measuring 1,198'.[72] Two steel deck truss bridges, each 851' long, were also built in 1965 for I-91, over the Green Mountain Railroad and the Williams River.

MODERNIZATION OF THE STATE HIGHWAY SYSTEM: BRIDGES

While the interstate was being constructed, work continued on replacement of structurally deficient bridges in the early 1960s. By June 1962 almost half of the bridges in the state highway system were either structurally deficient or needed widening. Progress was slow; only 108 of these bridges were included for repair/replacement in the 14-year construction program. Clearly more funding was needed to address these issues.

In the early 1960s the Bridge Division of the Vermont Department of Highways began researching ways to minimize disintegration of concrete, which is made worse by road salts and the freeze/thaw cycle. Concrete curbs were replaced with granite to alleviate disintegration, and water repellants were applied to bridge surfaces. To reduce the severity of the freeze/thaw cycle, the Bridge Division and the Bureau of Public Roads began experimenting with spraying urethane foam on the underside of bridge decks for insulation. Sensors would record the temperatures of the deck to test the efficacy of the method.[73]

Prior legislation assisted towns in repairing and replacing state-aid bridges within their jurisdictions, but very little funding was provided for the repair of bridges on town roads. The proliferation of heavy truck traffic on these roads and the serious condition of their bridges prompted the enactment of Act 202, which set aside 10 percent of the Town Highway Fund to improve bridges. The yearly allotment of funds, $293,000, was not always enough to cover the needed repairs: in the first year $117,000 was spent on one bridge in Castleton.[74] In 1978 the legislature appropriated over $2.3 million out of a budget surplus to the town highway bridge program, which funded the repair or replacement of 110 bridges.[75]

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[71] Vermont State Highway Board, *Seventeenth Biennial Report* (1952-1954), 49.

[72] "State's Longest Bridge To Be Built in Hartford," *Burlington Free Press*, July 26, 1965, 30.

[73] Vermont State Highway Board, *Twenty-first Biennial Report* (1960-1962), 16.

[74] Vermont State Highway Board, *Twenty-first Biennial Report* (1960-1962), 16.

[75] Vermont State Highway Board, *Twenty-Ninth Biennial Report* (1976-1978), 56.

A total of 406 long structures (bridges) were built from 1960 to 1969 in Vermont, and 366 long structures were built in the 1970s, according to the most recent Structures, Inventory and Appraisal data provided by the Vermont Agency of Transportation (VTrans) (Table E-6). Steel rolled beam structures continued to be the most common bridge type constructed in the state in both decades. The number of continuous steel girder bridges increased dramatically from eight structures in the 1950s to 67 in the 1960s and 72 in the 1970s.

TABLE E-6

TYPES OF BRIDGES BUILT IN THE 1960s AND 1970s

	NO. OF BRIDGES	
BRIDGE TYPE	1960s	1970s
Concrete, Simple Spans		
Slab	3	42
Stringer/multi-beam or Girder	0	1
Tee Beam	1	4
Frame	0	1
Culvert	2	42
Steel		
Stringer/multi-beam or Girder	234	150
Girder and Floorbeam	5	2
Deck Truss	2	0
Steel, continuous		
Stringer/multi-beam or Girder	67	72
Girder and Floorbeam	6	2
Rigid Frame	0	6
Deck Truss	1	0
Prestressed Concrete		
Slab	6	20
Stringer/multi-beam or Girder	0	3
Tee Beam	1	3
Box Beam	5	1
Channel Beam	4	1
Prestressed Concrete, Continuous		
Tee Beam	3	0
Stringer/multi-beam or Girder	0	1
Timber		
Stringer/multi-beam or Girder	1	1
Thru Truss	1	0
TOTAL	342	352

BRIDGE INSPECTION

The collapse of a 1,750-foot suspension bridge that extended 80’ above the Ohio River between Point Pleasant, West Virginia, and Gallipolis, Ohio, in 1967 proved to be a watershed event in twentieth-century bridge history. The failure of the 40-year-old “Silver Bridge”—so called because it was painted silver—occurred at the evening rush hour when the span was fully loaded with traffic. The eyebar suspension bridge’s unusual design, lauded as the first of its type in the United States by the *Engineering News-Record*, consisted of a through truss suspended from a string of eyebars that formed the top chord of the truss and the suspension “chain.”[76] When one of the suspension eyebars broke, the entire structure flipped over and hung momentarily by the other eyebar system while 57 vehicles and their occupants were dumped into the river’s swift and cold December waters, and then collapsed down on top of the victims. Forty-six people died in what was the worst highway bridge disaster in U.S. history. From the investigation that followed came a national policy of bridge inspection through the Federal Highway Act of 1968. This ultimately led to the creation of the National

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[76] Wilson Ballard, “An Eyebar Suspension Span for the Ohio River,” *Engineering News Record* 102(25-1929):997-1001; Vermont State Highway Board, *Twenty-fourth Biennial Report* (1966-1968), 58; West Virginia Department of Transportation, Silver Bridge (Charleston: West Virginia Department of Transportation, 2017).

Bridge Inventory, which identifies bridges in critical need of repair or replacement. Vermont began inspecting bridges almost immediately, hiring a consultant to inspect bridges on the interstate, arterial, and primary highway systems. An assistant maintenance engineer for bridges was also hired to oversee the bridge inspection program.[77]

By December 1968 the consultant had completed cursory inspections of all bridges that had not previously been inspected and detailed inspections of a few select bridges. Detailed inspections of the remaining bridges were conducted by Bridge Division personnel under the direction of the assistant maintenance engineer.[78] On December 31, 1970, the Federal-Aid Highway Act was enacted, which established uniform national standards for bridge inspections and designated funding for replacement of deficient bridges.[79] The law required states to perform periodic inspections on federal-aid highway bridges longer than 20'. By July 1, 1972, all 718 bridges in the federal-aid highway system in Vermont had been inventoried and inspected.[80] Bridges on federal-aid highways were then inspected every two years, with the total number of bridges inspected rising to 1,310 by July 1978.[81]

The bridge inspections required by the highway act brought to light the poor condition of bridges across the nation and in Vermont. In 1976, 76 bridges were considered to be deficient and in need of replacement. Replacement of these bridges was funded under the Special Bridge Replacement Program administered by the FHWA.[82] The number of deficient bridges was reduced to 54 bridges by 1978.[83]

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[77] Vermont State Highway Board, *Twenty-Fourth Biennial Report* (1966-1968), 58.
[78] Vermont State Highway Board, *Twenty-Fifth Biennial Report* (1968-1970), 50.
[79] Federal Highway Administration, *Your Guide to Federal Highway Administration Programs* (Denver: U.S. Department of Transportation, 1976).
[80] Vermont State Highway Board, *Twenty-Sixth Biennial Report* (1970-1972), 48.
[81] Vermont State Highway Board, *Twenty-Ninth Biennial Report* (1976-1978), 36.
[82] Vermont State Highway Board, *Twenty-Seventh Biennial Report* (1974-1976), 109.
[83] Vermont State Highway Board, *Twenty-Ninth Biennial Report* (1976-1978), 36.

III. VERMONT BRIDGE ENGINEERS AND CONTRACTORS

The following section is a list of engineers compiled from the previous MPDF, *Metal Truss, Masonry, and Concrete Bridges in Vermont,* and additional engineers and contractors identified through supplemental research. The engineers are divided by bridge material. Written histories of each firm for which information was available appear at the end of each section.

STEEL AND IRON BRIDGES

STEEL TRUSS BRIDGES

- American Bridge Company
- Berlin Construction Company
- Berlin Iron Bridge Company
- Bethlehem Steel Company
- Boston Bridge Works
- M.J. Burlington, Jr.
- Canton Bridge Company
- J.E. Cashman, Inc. (see Contractors, below)
- Groton Bridge Company
- Kittredge Bridge Company
- Lackawanna Bridge Works
- McClintic-Marshall Company
- National Bridge and Iron Works
- Henry L. Norton
- Palmer Steel Company
- Pittsburgh-Des Moines Steel Company
- Standard Engineering and Contracting Co.
- John W. Storrs/Storrs and Storrs
- Vermont Construction Company

American Bridge Company

American Bridge Co. presents a classic example of the monopolistic practices of big business at the turn of the century. J.P. Morgan, the capitalist's capitalist, incorporated American Bridge in 1900. The company lasted barely a year as an independent entity because the United States Steel Co. bought most of the stock of the new firm and operated it as a subsidiary. In its first year American Bridge purchased 24 companies representing fully one-half of the nation's fabricating capacity at the time. Eight of the purchased firms were in New York, and they operated under the umbrella organization known as Empire Bridge Co., a subsidiary of American Bridge. Another subsidiary, American Bridge Co. of New York, was responsible for all sales and contracts. American Bridge Co. of New York also took charge of construction, unless another building firm won the job in its own right and simply ordered the steel from American. American Bridge opened a new fabricating plant in Ambridge, Pennsylvania, in 1903, and began decommissioning the older plants of the purchased firms. The new plant was by far the largest in the country, three times bigger than the prior record-holder.

Until a major corporate reorganization in 1914, much of American Bridge's work in Vermont came through United Construction Co., a nominally independent contracting firm based in Albany, New York. After 1914 the number of joint contracts between the two firms diminished, although later examples exist, notably the "Power Plant" bridge built in 1926 in Essex Junction.

American Bridge pursued a policy of total market dominance, bidding on any work in any state as long as it involved steel bridges. Its massive resources and national scope drastically altered the competitive situation in the nation's bridge industry. Innovative designs had already lost much of their marketing appeal in the late nineteenth century because of several well-publicized disasters that led engineers to rely on the simple, tried-and-true truss patterns. American Bridge was the final knell for non-standard trusses because even if an innovative design had some intrinsic appeal, the economic position of American Bridge would usually win anyway. The smaller firms that started in business waged their competition along economic lines, attempting to underbid American while offering essentially the same product. The smaller firms generally did not compete nationwide, only in their home regions.

Vermont's bridges illustrate clearly the success of American Bridge. The state was remote from most of the nation's bridge makers, who were concentrated in the Midwest, but American could afford to absorb the additional transportation costs to do business in Vermont. Only Berlin Construction Co. was able to compete with American in Vermont; its Connecticut plant was about the same distance from the state as American's fabricating facilities in New York. After the New York plants closed down, the extra transportation from Ambridge was hardly an obstacle to American's continued presence in Vermont. American Bridge is still in business today as the nation's largest structural fabricator.[84]

Berlin Construction Company

When American Bridge Co. acquired Berlin Iron Bridge Co., the officers of the Berlin firm left to start their own concern, capitalizing on their extensive contacts in the New England market. In 1902 the new company, Berlin Construction Co., built fabrication shops in the Village of Kensington, in the Town of Berlin, some 4 miles from the site of their former plant. Until World War II Berlin Construction played a significant role in the regional bridge market, selling numerous spans throughout Connecticut, western Massachusetts, and Vermont. Harry Collings (see H.L. Norton, below) ran a Berlin Construction sales office in Springfield, Massachusetts, covering much of northern New England. In Vermont and Connecticut, Berlin Construction constituted the principal competition to American Bridge, the national leader in the field. After the war Berlin Construction turned more to structural fabrication and construction for buildings. Still in business today under the name Berlin Steel Construction Co., the firm no longer makes bridges.[85]

Berlin Iron Bridge Company

Berlin Iron Bridge Co. was formed in 1883 from the Corrugated Metal Co., which had produced shutters, shingles, and roofs of rolled iron. The firm had moved into fabrication of structural iron, such as roof trusses, as a corollary to its main business, and found the structural work accounting for an increasing portion of sales.

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[84] Victor C. Darnell, *Directory of American Bridge Building Companies, 1840-1900* (Washington, D.C.: Society for Industrial Archeology, 1984), 77-61, 85-86; R.A. Ta1bot, *American Bridge Company, History and Organization* (Pittsburgh: privately published, 1975): 16-18.

[85] Darnell, *Directory*, 3; Matthew Roth, "Connecticut: An Inventory of Historic Engineering and Industrial Site" (Washington, D.C.: Historic American Engineering Record, 1981), 69-70.

In the late 1870s Corrugated Metal acquired the rights to William Douglas's recent patent for a parabolic truss, and bridge work soon become the firm's sole pursuit, as reflected in the 1883 name change. Berlin Iron Bridge built hundreds of its distinctive parabolic, or lenticular, trusses in the 1880s and 1890s, and grew to become the largest structural fabricator in New England. The firm also built a smaller number of bridges in more standard configurations, such as Pratt and Warren trusses and plate-girder spans. The distinctive Berlin lenticular truss was sold to communities as far away as San Antonio, Texas, but the great majority of sales were in the Northeast. When American Bridge Co. was formed in 1900, Berlin Iron Bridge Co. was one of its initial acquisitions. American Bridge dismantled the East Berlin factories and moved the buildings to a new plant in Pennsylvania.[86]

Bethlehem Steel Company

Bethlehem Steel Co. originated in northeastern Pennsylvania as a producer of rails. By the early 1890s, having failed to achieve success in the very competitive rail market, Bethlehem turned to heavy forgings that went into ordnance. The chief engineer, John Fritz, urged the company to diversify into production of structural steel, but his suggestions went unheeded until the early years of the twentieth century, when Charles Schwab was brought in from U.S. Steel to run Bethlehem. Schwab not only devoted substantial capacity at the home plant, in Bethlehem, Pennsylvania, to structural fabrication, but also opened a new plant in Buffalo, New York, that performed structural work as part of its activities. Bethlehem expended its structural capacity in 1922 with the acquisition of Lackawanna Bridge Works, another Buffalo-area fabricator. Bethlehem is still in business as a steel producer.[87]

Boston Bridge Works

D.H. Andrews founded Boston Bridge Works in 1876. In the late nineteenth century this firm ranked second in New England to Berlin Iron Bridge Co. in structural fabrication capacity. The two firms did not often compete directly because Berlin built mostly highway bridges and Boston Bridge built mostly for railroads. Boston Bridge's market was truly national in scope, numbering many western railroads among its customers. Movable bridges were a specialty, and its products also included railroad turntables and roof trusses. Boston Bridge escaped absorption into American Bridge Co., and even grew by about 50 percent in fabrication capacity during the early years of competition with American Bridge. The firm lasted until 1930.[88]

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[86] Darnell, *Directory*, 3-5; Victor C. Darnell, "Lenticular Bridges from East Berlin, Connecticut," *Directory, The Journal of the Society for Industrial Archeology* 5 (1979):19-32; Roth, 69-69.

[87] Heather Rudge Interview with Thomas E. Leary, Curator, Buffalo and Erie County Historical Society, September 1985.

[88] Darnell, *Directory*, 22-23; *Boston Directory*, 1876-1931 (Boston: Tufts Digital Collections and Archives, Tufts University, 1876-1931, available at http://dca.lib.tufts.edu/features/bostonstreets/people/directories.html).

Canton Bridge Company

Canton Bridge Co., of Canton, Ohio, began business in 1876 but apparently did not pursue work outside its immediate region until after a new infusion of capital pursuant to the firm’s incorporation in 1891. Like other Midwestern bridge builders, Canton must have found Vermont to be a difficult business environment: remote and sparsely populated. It was also much easier for the major bridge firms in New England and eastern New York to work in Vermont. Two Canton bridges remain in Vermont, one that probably dates from ca. 1900 and one from 1914.[89] In 1929 the firm was absorbed by the Masillon Steel Co., also of Ohio.[90]

Groton Bridge and Manufacturing Company/Groton Bridge Company

This firm was founded in 1877 as the Groton Iron Bridge Company, in Groton, New York. The product lines expanded to include punches, straightening machinery (both used in bridge fabrication), and woodworking machinery, and in 1887 the company added “Manufacturing” to its name to reflect the change. In the 1890s and 1890s, Groton vied primarily with Berlin Iron Bridge for contracts to build highway bridges near towns in Vermont. The two firms were large enough to offer the most competitive pricing for bridge, and both were approximately equidistant from Vermont. Groton Bridge and Manufacturing was one of the firms acquired by American Bridge Co. upon its founding in 1900. The former owners of Groton bought their company back a year later and operated at about two-thirds of former capacity under the name of Groton Bridge Co.[91]

Kittredge Bridge Company

Kittredge Bridge Co. was a construction firm based in Concord, New Hampshire, headed by Arthur H. Kittredge. Kittredge ran the bridge department for the Colburn Construction Co., also of Concord, before beginning his own firm in the early 1920s. It appears that Kittredge may have taken over the Colburn business and changed its name. Kittredge Bridge, like so many others, benefited from the enormous demand of the 1928-30 reconstruction program, winning a contract to construct a span fabricated by American Bridge Co. The firm, also like many others, did not survive the 1930s.[92]

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[89] One of these bridges is the East Thetford Bridge, a three-span Pratt truss bridge built in 1896. The origin/location of the referenced 1914 bridge could not be determined. McCullough cites that iron bridges of unknown design were sold by the Canton Bridge Company to the towns of Northfield, Benson, Chester, and Corinth (McCullough, 330).

[90] Darnell, *Directory*, 48; *The Ohio Historic Bridge Inventory, Evaluation and Preservation Plan* (Columbus: Ohio Department of Transportation, 1983), 222.

[91] Darnell, *Directory*, 38, 79, 85.

[92] *Concord City Directory*, 1915-1935 (St. Johnsbury, VT: on file, St. Johnsbury Athenaeum).

Lackawanna Bridge Works

Known variously as Lackawanna Bridge Works, Lackawanna Steel Construction, and Lackawanna Steel, this company operated in the early twentieth century in the Buffalo, New York, area. The firm originated in Scranton, Pennsylvania, in the 1840s as an iron smelter, and in the 1870s it added the Bessemer process to produce steel rails. In 1901 William Scranton, then head of Lackawanna, moved the company to West Seneca, New York, outside Buffalo, in response to the entreaties of Buffalo promoters who wanted to establish heavy industry in their region. (Part of West Seneca was incorporated in 1911 as the new town of Lackawanna, reflecting the influence of the steel producer.) Bethlehem Steel, which also had major facilities in the Buffalo area, bought Lackawanna in 1922. The only Lackawanna bridge in this study bears the date 1922[93], so that bridge represents the company's final year of independent operation.

McClintic-Marshall Company

This firm, based in Pennsylvania, was started around 1901 by former executives of companies absorbed by American Bridge Co. in 1900. Several new firms, notably Berlin Construction Co., were started at that time as executives from formerly independent bridge companies either left American Bridge or were let go as a consequence of consolidating operations. McClintic-Marshall's ambitious marketing plan included the opening of regional offices throughout the country in the attempt to challenge the national role of American Bridge. The firm had achieved a foothold in northern New England by the mid-1920s (they built at least one bridge in Vermont before the 1927 flood, the Route 100 span in Harrisville), just in time to benefit from the enormous amount of rebuilding work after the 1927 flood. Bethlehem Steel absorbed McClintic-Marshall in 1930.[94]

National Bridge and Iron Works

This firm, established in 1860 by the Boston partnership of Blodgett and Curry, was among the first independent bridge fabricators in the country. Before the late 1860s design and fabrication of truss bridges had fallen exclusively to the railroads. C.H. Parker served as consulting engineer to the firm, and his patented design for a curved-chord truss was the basis for much of National Bridge's business. Like any new industrial sector, the independent bridge makers experienced considerable uncertainty in their early years, and most of the companies had only the most ephemeral of tenures in the trade, including National Bridge. It was out of business by 1875. The firm was highly significant, however, for its association with Parker, who went on to develop the curved-chord variation of the standard Pratt truss. Known as the Parker truss, this pattern was widely used for long-span highway bridges until the very end of the truss-bridge era. Parker's early career is almost wholly undocumented

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[93] The Warren pony truss Mountainside Road Bridge over the Ottauquechee River in Windsor County was constructed in 1922 and realigned in 1961. See James Baughn and contributors, Bridgehunter.com, Historic and Notable Bridges of the U.S. (accessed 2018 at https://bridgehunter.com/category/location/vt/page3/).

[94] Heather Rudge interview with Donald C. Jackson, National Museum of American History, September 1985.

with standing structures, making the ca. 1870 Parker Patent span over the Ottauquechee River on VT 12 in Woodstock by National Bridge a civil engineering landmark of national importance.

Henry L. Norton

Henry L. Horton was a West Springfield resident who learned the bridge business in the 1890s, while in the employ of R.H. Hawkins Iron Works (see Vermont Construction Co., below). Around 1900 Norton set up a competing firm, Norton and Collins Co., with partner Harry Collins. The business did not last more than a few years, and for several more years Norton operated on his own before opening the bronze foundry that occupied him for the rest of his life. Collins went on to run the Springfield sales office of Berlin Construction Co. It is unlikely that Norton produced more than several dozen bridges; only one standing structure in Vermont is known to be his work. The lone Norton bridge, in Cavendish, was archaic even in its day, especially in its use of pinned connections.[95]

Palmer Steel Company

Palmer Steel Co. was active as a bridge-builder in the mid- and late 1920s, fortuitous timing because it coincided with the great post-flood reconstruction program in Vermont. It is unclear in the available records whether Palmer fabricated its own steel or simply ordered fabricated stock and took charge of erecting the structures. In 1924 Palmer Steel shared a Springfield address with one of the firms descended from R.F. Hawkins Iron Works, suggesting that Palmer may have been involved with this major fabricating concern. Palmer Steel did not survive the Depression.[96]

Pittsburgh-Des Moines Steel Company

This firm appears to have begun around 1901, the first year it advertised in national trade journals. Pittsburgh-Des Moines specialized in water towers, but its experience translated well to bridge work (a relatively minor portion of the business) because water tower trestles consisted of built-up girders or rolled I-sections whose fabrication and construction were fundamentally similar to bridge building. The firm apparently made some attempt to market bridges in New England in the mid-1920s, and sold at least one bridge in Vermont before the 1927 flood. Its other Vermont bridge, the Missisquoi River Bridge in Richford, was part of the post-flood reconstruction program.[97]

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[95] Norton obituary, *Springfield Dally Republican*, March 23, 1932; *Springfield City Directory*, 1903 (H.A. Manning; Burlington, VT: on file, Bailey-Howe Library, University of Vermont).

[96] *Springfield City Directory*, 1920-1935.

[97] Mary B. Hotaling, "Missisisquoi River Bridge," National Register of Historic Places nomination, accessed online at https://npgallery.nps.gov/pdfhost/docs/NRHP/Text/90001494.pdf.

Standard Engineering and Contracting Company

This Toledo, Ohio, firm lasted about 20 years after its incorporation in 1910. It was one of a half-dozen fabricators that made Toledo a center of bridge construction in this period. Standard's chief engineer, Claude Ramsey, had worked for one of Toledo's largest producers, Wincoop and McGormley, before joining Standard. Standard apparently made limited sales in the eastern states, and only a single example of the firm's work was constructed in Vermont, the North Williston Bridge.[98]

John W. Storrs/Storrs and Storrs

John W. Storrs was born in Montpelier but his family moved to Concord, New Hampshire, in the early l870s, when Storrs was a boy, and he spent the rest of his life there. Storrs started his long career in structural engineering in the 1890s, as a bridge engineer for the Boston and Maine Railroad. In 1903 he began simultaneously to serve as the state engineer for Carroll, Coos and Grafton counties, New Hampshire. Storrs and his son, Edward D., opened their own engineering consulting firm in 1906, a firm that designed several of the notable bridges in Vermont, such as the steel arch over Quechee Gorge, the masonry arch bridge in Barre, and the Route 119 bridge over the Connecticut River in Brattleboro. The busy father-son team also ran the Ford Foundry in Concord, John as president and Edward as superintendent.[99]

Vermont Construction Company

Vermont's only significant nineteenth-century bridge fabricator, Vermont Construction Co., was a subsidiary of R.F. Hawkins Iron Works of Springfield, Massachusetts. Hawkins Iron Works could trace its origin to the very beginning of the bridge-building business in the United States, through an unbroken chain of succession (including 10 differently named firms) to the 1838 company founded by William Howe to make and market his patented truss. In 1862 Richard Fenner Hawkins joined the firm, then known as Harris, Briggs and Co. In the same year he married a niece of William Howe, solidifying his position in the company because the Howes still held some interest in it. In 1867 Hawkins became a partner; several more managing partnerships formed and dissolved over the next 10 years until Hawkins regained sole control in 1877, renaming the company R.F. Hawkins Iron Works. By that time the Springfield shops also produced boilers, standpipes, building materials, and railroad equipment, and the principal market area had broadened to include the Midwest and Canada. Perhaps as a means to enhance competitiveness in the northern markets, Hawkins set up the Vermont Construction Co. at St. Albans in 1889. Judging from directory listings, the Vermont subsidiary appears only to have participated in the bridge building portion of Hawkins's business. Vermont Construction changed its name

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[98] *Ohio Preservation Plan*, 221; Toledo City Directory, 1915-1935, courtesy David Simmons, Ohio Historic Preservation Office. The North Williston Bridge was a Pennsylvania through truss that was built in 1925 over the Winooski River and replaced in 1993.

[99] "Concord's 150th Anniversary," *Granite Monthly* 47 (May-June 1915); E.D. Storrs and J. W. Storrs, *A Handbook for the Use of Those Interested in the Construction of Short Span Bridges* (Concord, NH: Storrs and Storrs, 1918); *Concord City Directory*, 1911.

to New England Bridge Works in 1901, perhaps reflecting a change in ownership. As a result of the altered competitive situation after the formation of American Bridge Co. in 1900, and the real limitations of the sparsely settled northern market, New England Construction went into decline and by the 1920s was out of business as a bridge-builder.

Only two bridges in this study are known to have been built by Vermont Construction; with dates of 1889[100] and 1900, they represent the endpoints in time of the firm's activity under that name. Some of the spans for which no maker is known may represent the work of Vermont Construction, but even so, it appears that the company did not figure prominently in the construction of bridges in its home state.[101]

BEAM, GIRDER, AND RIGID-FRAME BRIDGES

Blauvelt Engineering Company

Blauvelt Engineering Co. was established by Harold A. Blauvelt and a partner in 1950. At that time the company was Brown and Blauvelt Consulting Engineers, based in New York City. In 1958 the partnership dissolved and the firm continued under its current name. The firm specialized in major bridge, highway and turnpike projects in the Northeast, including reconstruction of the Grand Central Parkway, Croton Reservoir Bridge north of New York City, and the I-91 Lyndon Bridges, which received the American Institute of Steel's Award of Merit, among others.[102]

CONCRETE BRIDGES

H.J. Burrington, Jr.
Walter M. Denman
Fred Dudley
Joseph Feeley
H.L. Hauser Building Company
McIntosh and Crandall
Gerald B. Owens
Harold B. Perry
Frank Sinclair
W.S. Teachout

H. J. Burrington, Jr.

Burrington's principal business was consulting work as a civil engineer. His career continued from about 1910 to 1950, and he was based in Bennington for the entire period. Since the Bennington area (like much of Vermont)

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[100] This is believed to be the Foundry Bridge, built in 1889 in Tunbridge, Vermont, which was listed in the National Register by Robert McCullough in 2006. The nomination states that the Foundry Bridge is the last extant bridge in the state fabricated by the Vermont Construction Company.

[101] Darnell, *Directory*, 25-26; "R.F. Hawkins Iron Works," *Progressive Springfield* 1(2-January 1891):89-90; Hawkins obituary, *Springfield Daily Republican*, March 6, 1913.

[102] "Harold A. Blauvelt," *The New York Times*, December 19, 2004. Accessed online at https://www.nytimes.com/2004/12/19/classified/paid-notice-deaths-blauvelt-harold-a.html.

had relatively infrequent need for professional engineering, Burrington also pursued related activities. Around 1920 he ran a construction company with E.L. Lambert, and Lambert & Burrington in turn made a sideline of selling bulk building materials such as lime, cement, and plaster. Bridges apparently constituted a small portion of Burrington's activity. Only one reinforced-concrete bridge is known to have been built by his firm. After the 1927 flood, when the massive reconstruction program provided opportunities for many firms that did not normally pursue bridge construction, Burrington sub-contracted to Berlin Construction Co., probably for work on abutments.[103]

Walter M. Denman

Walter M. Denman was a consulting engineer based in Springfield, Massachusetts. It is unknown when he began practicing, but accounts of his work in newspapers and engineering journals appear as early as 1908. In that year he designed the 60', shallow-pointed arch Melrose Bridge in West Brattleboro, which was similar to the patented Luten arch designs. He wrote an article in 1911 on Luten arch bridges and their advantages. Denman continued to design concrete bridges and was fairly prominent in the industry, presenting a paper, "Construction Problems in Reinforced Concrete Bridges," to the 1910 annual convention of the National Association of Cement Users.[104]

Fred Dudley

In 1917 Fred Dudley was appointed county supervisor of highways for Orange County, Vermont. Before that time he had served as civil engineer designing roads and bridges in the county. The same year he was appointed, he presented a paper, "Concrete in Small Highway Bridges," to the Vermont Society of Engineers, presumably as a member.[105]

Joseph Feeley

Rutland city engineer Joseph Feeley designed a barrel-vaulted concrete arch bridge for the town in 1921. Feeley may have designed four additional concrete arch bridges for the town.[106]

H.L. Hauser Building Company

Hauser was a Boston contracting firm specializing in reinforced concrete construction. The firm advertised its specialty as foundations for buildings, machinery and tanks. Its participation in Vermont bridge building was tied directly to the extraordinary needs of the reconstruction program following the 1927 flood. The great

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[103] *Bennington Directory*, 1916-1946 (H.A. Manning; Burlington: on file, Bailey Howe Library, University of Vermont).

[104] McCullough, 177 and 337; "Proceedings of the National Association of Cement Users," *Good Roads* 42:41.

[105] McCullough, 181 and 338; "Mr. Dudley Appointed," *Montpelier Evening Argus*, May 16, 1917, page 5.

[106] McCullough, 189 and 340.

number of bridges taxed the capabilities of the firms that built most of the state's bridges before the flood, opening opportunities for other fabricators. One of these was Bethlehem Steel, whose only bridges in Vermont went up between 1920 and 1930. Bethlehem relied on New England construction firms for sub-structural and erection work, and Hauser was one of the regional sub-contractors to work with Bethlehem.[107]

McIntosh and Crandall

This Burlington-based company was a partnership between Herbert M. McIntosh and Frank H. Crandall. Early in the twentieth century, both worked for the city of Burlington, McIntosh as the city engineer and surveyor and Crandall as the superintendent of the water supply system. By 1916 they had left the city's employ to operate their own consulting engineering firm, advertising their specialties as road, sewer, and water works design. The firm designed one bridge in the survey, the concrete arch carrying Park Street in Springfield.[108]

Gerald B. Owens

Owens ran an eponymously named construction company in Springfield, Massachusetts, during the first third of the twentieth century. Bridges were apparently not a specialty, but familiarity with concrete construction enabled Owens to bid on bridges of that material. The only example in the survey of the company's work is the open-spandrel reinforced-concrete arch in Windsor.[109]

Harold B. Perry

Harold Perry was educated at the Brattleboro Academy and trained as a highway engineer in Massachusetts, New Hampshire, and New York before becoming an engineer in Brattleboro. In 1915 he designed two reinforced concrete bridges in Alburgh, both of which had distinctive railings with open panels. Perry eventually became a draftsman and inspector at the Vermont Department of Transportation.[110]

Frank Sinclair

Frank Sinclair, a charter member of the Vermont Society of Engineers, graduated from the University of Vermont in 1882 and began working for a number of railroad companies. Sinclair was one of the investors and operators of the Vermont Construction Company and at one time was an agent for the Pittsburgh Bridge

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[107] *Boston Directory*, 1925-1930.

[108] *Burlington City Directory*, 1902-1930 (L.P. Waite, H.A. Manning; Burlington, VT: on file, Bailey-Howe Library, University of Vermont).

[109] *Springfield City Directory*, 1905-1935.

[110] McCullough, 181.

Company. In 1904 he became city engineer for Burlington, Vermont. Bridges known to have been designed by Sinclair include Montpelier's Rialto Bridge (1915).[111]

W.S. Teachout

William S. Teachout was a concrete contractor and built Vermont's first concrete arch bridge for highway use in 1902 in the Town of Essex, where he based his business. It is unknown whether Teachout constructed any other bridges. Anecdotal evidence suggests that he may have become the chief clerk of the Vermont State Automobile Department by the late 1910s.[112]

Harry Leslie Walker

A New York-based architect, Walker was responsible for the design of the "Marble Bridge" in Proctor. It is his only known bridge work. Walker is best known for his participation on the team that designed the first public housing project in New York City, the Williamsburg Houses on Bushwick Avenue in Brooklyn, which went up in 1937.[113]

J.R. Worcester and Company

Joseph R. Worcester worked as chief engineer for Boston Bridge Works in the late nineteenth century, before opening his own civil engineering consulting firm in the same city. His prominent commissions included the Quincy Market cold-storage facility and the Louis Prang Co. Factory. Worcester also designed the 1905 arched steel bridge across the Connecticut River at Bellows Falls (demolished). The only example of his work In this survey is another steel arch over the Connecticut, the 1928 bridge at Wells River. The fabricator was Boston Bridge Works, Worcester's erstwhile employer.[114]

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[111] McCullough, 90-91; Glenn A. Knoblock, *Historic Iron and Steel Bridges in Maine, New Hampshire and Vermont* (Jefferson, NC: McFarland, 2012), 61.

[112] McCullough, 176; "Vermont Truck Men Object to Motor Truck Bill," *Automobile Trade Journal* 23:161A, Chilton Company, 1919.

[113] Norval White and Elliot Willensky, *A.I.A. Guide to New York City*, revised edition (New York: Collier Books, 1978), 467.

[114] Darnell, *Directory*, 76; Boston City Directory, 1895-1925; Henry G. Tyrrell, *History of Bridge Engineering* (Chicago: by the author, 1911), 354.

MASONRY BRIDGES

Joseph Barton/Oliver and Joseph Valley [granite bridges near Barton]
Thomas Chappell & E.L. Grimes
James Otis Follett*
Col. William Fuller
F.D. Giddings
Levi Gould
J. Mattison
Frederick R. Patch
Frank Sinclair
Percy Smith
John W. Storrs/Storrs Bridge Engineers, Concord, NH†
Harry Leslie Walker†
Engineers from various railroad companies, including Vermont Valley Railroad, Fitchburg Railroad, and the Vermont Division of the Portland and Ogdensburgh Railroad

* See Section I, Early Bridges in Vermont, page E-4. † See Steel and Truss Bridges, page E-39.

Joseph Barton/Oliver and Joseph Valley

Joseph Barton and the Valley brothers were prominent stone masons in the Orleans area, then called Barton's Landing. More than a dozen granite slab bridges were built in the Barton's Landing area alone. Four of these bridges can be attributed to Barton, constructed between 1895 and 1901.[115]

Thomas Chappell & E.L. Grimes

Chappell and Grimes designed the stone arch Coburn Bridge in Pittsford and both had offices in Rutland in the late 1890s. Chappell was appointed chief engineer of the Rutland and Ogdensburg and Lake Champlain Railroads in 1899. After a short career in Rutland, Grimes moved to Troy, becoming the chief engineer of that city's water works system in 1903. The Coburn Bridge is the only known bridge designed by Grimes.[116]

Col. William Fuller

Col. William Fuller built the Route 7 Bridge over the Neshobe River in 1868 in the Town of Brandon, Vermont. No other bridges have been credited to Fuller.[117]

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[115] McCullough 96-97.

[116] McCullough, 81; "Active Workers in the Association," *Fire and Water Engineering* 40:352.

[117] McCullough, 77.

F.D. Giddings

F.D. Giddings, a local mason in Manchester Center, constructed a granite-faced stone bridge over the West Branch of the Batten Kill River.[118]

Levi Gould/J. Mattison

In 1874 Levi Gould and A.J. Mattison constructed a stone arch bridge on Prospect Street in North Bennington, Vermont. No additional information could be found on other bridges that Gould constructed.[119]

Frederick R. Patch

Frederick R. Patch worked for the Vermont Marble Company and was a member of the Vermont Society of Engineers by 1912. Around 1890 he designed the stone arch Cotting Bridge in Pittsford. He also designed the Union Church in Proctor, Vermont. Mr. Patch was a leader in the marble industry, serving as the superintendent and chief engineer at the Vermont Marble Company and as the head of the Patch-Wegner Company.[120]

Percy Smith

Percy Smith was educated in civil engineering at Norwich University, worked as an engineer for numerous railroads and the U.S. Forest Service in 1908, became a charter member of the Vermont Society of Engineers, then started his own consulting business in Wells River. In 1913 Smith designed a masonry arch bridge in Groton.[121]

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[118] McCullough, 89-90.

[119] McCullough, 77.

[120] McCullough 81, 84; Elaine Purdy, "Fred R. Patch," *Rutland Historical Society Quarterly* 23(2-1993):18-35. Accessed online at http://www.rutlandhistory.com/documents/RHSQVol.XXIIINo.21993.pdf. The Rutland Historical Society article contains a full biography of Patch.

[121] McCullough, 90-91.

CONTRACTORS

- Bryon, Forman & Riggs
- H.J. Burrington, Jr.
- J.E. Cashman, Incorporated
- H.P. Cummings Construction Company
- J.E. Flood & J. D. Sherrill
- James Otis Follett
- Gordon & Sutton (North Adams, Massachusetts)
- Guild & Douglas (Springfield, Vermont)
- J.A. Greenleaf Company (Auburn, Maine)
- Hagan-Thibodeau Construction Company
- H.L. Hauser Building Company
- C.I. Hosmer
- Hoyt Construction Company
- Kittredge Bridge Company
- A.B. Lane
- O.W. Miller
- C.F. Newton Construction Company
- D.J. Morrison
- Eugene A. Simpson
- George H. Stebbins
- Gerald B. Owens
- United Construction Company

J.E. Cashman, Inc.

In the early twentieth century J.E. Cashman, Inc. was among the largest construction, teamster, and warehouse firms in Burlington, Vermont. The principal owner was Burlington native James E. Cashman. The company's building business primarily involved foundations and other sub-structural work, including diving and underwater construction; bridge abutments were a specialty. Cashman also rented out construction equipment, such as derricks and pile drivers, and operated two warehouses, one at the corner of College and Champlain streets and one along the railroad at the foot of King Street. Cashman acted as a sub-contractor for fabricating firms that won bridge jobs during the reconstruction following the 1927 flood. Both Berlin Construction and Bethlehem Steel used Cashman for sub-structural work.[122]

A.B. Lane

Adolph B. Lane, active in the 1920s and 1930s, controlled several businesses in his home city of Barre, including a lumber company, a water company, and a general contracting company. His construction company apparently did very little bridge work; the only known example is the contracting work for the "Power Plant Bridge" on Route 2A in Essex Junction, which Lane shared with United Construction Co. of Albany, a much larger firm. Lane's background and connections would have suggested greater participation in state road-building because

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[122] *Burlington Directory*, 1920.

two of his relatives worked for the state: Alfred W. Lane, a soils engineer for the highway department, and Gordon H. Lane, an engineer.[123]

C.F. Newton Construction Company

Cheney F. Newton, of Springfield, Massachusetts, was a carpenter who ran a small operation out of his home in the early 1920s. Later in the decade he had built his business into a medium-sized contracting company, in time to capitalize on the extensive contracts let in the aftermath of the 1927 flood. Newton was one of several independent contractors who worked on bridges fabricated by the Berlin Construction Co. The Newton firm probably built the abutments and provided erection crews for two of Berlin's flood-era bridges, both in Hyde Park, Lamoille County.[124]

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[123] *Barre City Directory*, 1920-1940 (H.A. Manning; Burlington, VT: on file, Bailey-Howe Library, University of Vermont).

[124] *Springfield City Directory*, 1920-1930.

ASSOCIATED PROPERTY TYPES

1. NAME OF PROPERTY TYPE: STEEL AND METAL TRUSS BRIDGES

2. DESCRIPTION

Steel bridges are divided into six primary subtypes:

a. simple beam spans,
b. continuous beam spans,
c. metal and steel trusses,
d. steel arch,
e. steel rigid frame, and
f. suspension.

Each subtype may also have secondary subtypes, indicated by boldface type, which are further described. Each type and subtype are followed by the National Bridge Inventory (NBI) bridge-type number, which appears in brackets; refer to Section H, Identification and Evaluation Methods, for a description of the NBI bridge categorization system and how it is applied.

a) Simple Beam Spans

Simple beam spans are supported at each end, as opposed to continuous beam spans, which have one or more intermediate supports (piers). The **Steel Stringer, Multi-beam,** or **Girder bridge [Type 302]** consists of a series of parallel steel beams spanning supports (abutments and piers), and spaced sufficiently close to one another to allow the decking, such as wood or a concrete slab, to span the distance between them while carrying the intended load. The terms *stringer*, *beam*, and *girder* commonly refer to the relative size of the beams, girders being the largest. The largest beams that are rolled are generally no more than 36 inches in depth, but are available up to 44 inches from some mills. Beyond 36 inches of depth, a riveted or welded plate girder is required. Plate girders are commonly I-sections, consisting of top and bottom horizontal flange plates and a vertical plate web. Riveted plate girders use angles to join the flanges to the web with rivets; welded plate girders have the flanges welded directly to the web with a continuous filet weld. Welded plate girder bridges have been designated a separate type in the NBI because of their different inspection requirements compared with riveted girders. A total of 609 Type 302 bridges were built in Vermont within the 1940-1978 study period.

Simple span plate girder bridges are separately classified in the NBI if they support a transverse floorbeam system, are welded, have a diaphragm bracing system, and if they have more than two girders. The **Steel Girder & Floorbeam bridge [Type 303]** commonly consists of two parallel plate girders spanning supports (abutments and piers), spaced at a distance equal to the width of the bridge. More than two girders are used in some cases. The girders support transverse cross beams, which in turn support the closely spaced longitudinal stringers that carry the deck. The North Hero-Alburgh Bridge (U.S. Route 2, Bridge No. 00005), which has two curved girders, is the most prominent example of the steel girder and floorbeam bridge type in Vermont. Fifteen other bridges of this type were built in Vermont during the study period, ranging in span from 30' to 180'. The **Steel Welded I-Girder w/Diaphragms bridge** is a modern variation of the simple span plate girder bridge without a floorbeam system (refer to Type 302, above). The deck system is carried directly on the top flange of the girders. Depending on the width of the bridge and the deck system used, the type may be constructed with **two girders [Type 324]** or with **more than two girders [Type 323]**. A diaphragm is a secondary member, usually a rolled beam of wide-flange or channel cross section, which runs transversely to join the primary I-girders together. The diaphragm acts to stiffen the primary girders and distribute loads. Neither example occurs in Vermont within the study period.

The **bascule type of moveable bridge [Type 316]** is named after the French word for teeter-totter or balance scale. It is essentially a drawbridge with the exception that the moveable span or leaf is counterweighted and rotates around trunnions, made up of axles or pins, requiring relatively little motive power to move the bridge, which is usually supplied by an electric motor operated from a vantage point on the bridge. They can also be lifted relatively quickly. This bridge design was often adopted where there was a need to maximize the channel width for ship passage. Although in use since the 1850s, they were first used *en masse* for the crossings of the Chicago River in downtown Chicago. There are several patented types of bascule bridges. The earliest is the Strauss type, named after Chicago engineer Joseph Strauss, who developed the pivoting counterweight linkage that eliminated the need for a counterweight pit and reduced the length of the bridge span tail. With the Scherzer rolling lift bascule bridge, the leaf is lifted by rolling back and upward on a curved track that is integral to the leaf. The advantage of this type of lift bridge is that it maximizes the channel width because the leaf rolls backward as well as upward. The more rare Rall type bridge, named after its inventor, Theodor Rall, rolls and lifts using a geared wheel rolling on a flat track.

Typical original railings found on simple span beam bridges include decorative concrete posts with pipe rail and balustrade sections (Rail Type 11 in the bridge inventory), decorative concrete end walls with three pipe railing in between (Rail Types 9 and 16 in the inventory), steel I-beam and steel cable railing (Rail Type 15), and concrete posts supporting steel cables (Rail Type 14). The more common replacement railing types include W-beam rail supported by steel posts (Rail Type 1 dating to the 1980s), two and three half-ellipse aluminum railing with steel posts (Rail Types 19 and 20 dating from 1969 to ca. 2005), and rectangular tubing on steel posts (post-2012).

b) Continuous Beam Spans

A continuous girder (or bridge) can be visualized as a single beam supported at three or more points along its length. Steel trusses, plate girders, and box girders can be made continuous. The structural advantage over a simple span, which is supported only at its ends, results from bending forces created in the beam over the piers, which counteract and reduce the bending forces in the center of the span. The practical advantages are economy of material, convenience of erection in that no falsework is required, and increased rigidity under traffic. When first put into use, some engineers believed that there were structural advantages to making more than three spans continuous, but it was later proven that no increase in rigidity was obtained with more than three spans.[125]

The **Steel Continuous Stringer, Multi-beam,** or **Girder bridge [Type 402]** is in most ways identical to its simple span version with the primary difference being the continuation of the structural member over one or more intermediate piers, and the resultant need for only a single bearing at the intermediate pier rather than two separate bearings [see description of Type 302, above]. Riveted, bolted, or welded butt splices of the structural members to make them structurally a continuous beam are often located not over the piers but roughly at the third points of the span, where the positive and negative bending moments cancel each other. The same can be said for the **Steel Continuous Girder & Floorbeam system bridge [Type 403]**, applied to the simple span version described above [Type 303].

As mentioned above, welded bridges are designated as separate types, which results in several additional sub-types of steel continuous girder bridges, four of which are represented in Vermont: **Steel Continuous Welded I-Girder with Diaphragms**, with either **two girders [Type 424]**, or **three or more girders [Type 423]**, and **Steel Continuous Welded I-girder bridges with Floorbeams**, with either **two girders [Type 432]** or **three or more girders [Type 433]**. Other than the differences previously discussed inherent in bridges with welded connections versus riveted connections, these bridge types do not differ significantly in design and construction from their riveted predecessors.

Continuous beam/girder bridges can be further categorized depending on the shape and construction method of the beams. Three additional continuous types are in use in Vermont: the Box beam, the Channel beam, and the welded I-girder. The **Steel Continuous Box Beam bridge [Type 405]** consists of steel plates welded together to form a rectangular or trapezoidal box. The box girder is considered a form of plate girder with two webs that are attached to the edges of the top and bottom flanges, thus forming a rectangular (or trapezoidal) section with structural and material (economic) advantages over conventional plate girders in certain applications. Box girders are usually shop fabricated and continuous, and have composite decks.[126] They are also often used in conjunction with orthotropic decks when overall structural depth needs to be kept to an absolute minimum. Wide box girders may have additional interior webs or truss framing. The **Steel Continuous Channel Beam bridge [Type 422]** has the same characteristics as a continuous I-beam bridge except the structural members are channels. Although channel beams are a less efficient structural design than I-beams, channels are less costly to manufacture and may be used to achieve a moderate cost savings in some bridge designs.

Typical railings found on continuous steel bridges include W-Beam rail supported by steel posts (ca. 1980s), rectangular tubing on steel posts (post-2012), and three half-ellipse aluminum railing with steel posts (1969-2005).

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[125] Gustav Lindenthal, “Bridges With Continuous Girders,” *Civil Engineering* (July 1932):421.

[126] Composite means that the steel structure of the bridge is fixed to the concrete structure of the deck with connectors that are embedded in the concrete. This provides increased strength to the structure.

Less common examples range from the decorative, such as the metal pipe rail with balustrade on the VT0078 Bridge over the Missisquoi River in Swanton Village, to the functional, such as an I-beam and steel cable railing on a three-span I-beam bridge in Manchester (FAS171, Bridge No. 10). In a variation of the latter railing, concrete posts instead of I-beams support the cables. Original railings combine decorative concrete posts with pipe rail and balustrade sections in between are found on the Stevens River Bridge in Barnet (VT2008, Bridge No. 11, Rail Type 11 in the bridge inventory). The Clyde River Bridge in Derby has decorative concrete end walls with three pipe railing in between, apparently original to the 1964 bridge (Rail Type 9 in the inventory).

c) Metal and Steel Trusses

Metal truss bridges consist of one or a series of spans constructed from prefabricated members, usually on the site. The members vary in size and strength necessary for each particular bridge. Many pieces of iron or steel are interconnected in a series of triangles or panels to form the bridge. Each member of the structure, depending on its position is put in either tension or compression. Bridges are identified not by their length or number of panels, but by their configuration of tension and compression members, which includes the shape of the top and bottom chords, and the placement of vertical and diagonal members.

There are a variety of truss bridges, each with their own particular characteristics. They all, however, share some common parts. Each bridge has a floor system, often made up of a combination of plate-girder floor beams, rolled I-beams, cross-bracing, and steel-grill or concrete floor. The actual floor of the system is designed to be replaced as is needed over time, without disturbing the structural members of the bridge. The bottom chord usually consists of a box girder or Channels with stay plates. Verticals and diagonals vary greatly from bridge to bridge, often utilizing paired angles, paired T-sections, I-beams and paired channels, usually braced further by lattice bars. The top chord often consists of a box girder formed of plates and angles with a latticed underside. Additional bracing varies from latticed girder struts and bars to plate-girder struts and crossed or paired angles where present railings and sidewalks vary greatly. Virtually all the Vermont bridges constructed before the 1927 flood have built up members in various combinations of plates channels and angles connected with rivets. The post-flood trusses used this technique for their top and bottom chords, but vertical and diagonal members between the chords are usually rolled I-beams that required no assembly.[127]

Steel trusses are used when the span length is greater than can be spanned economically by a plate girder bridge. Trusses are categorized as either simple span or continuous span, and by the location of the deck relative to the superstructure as either deck, through, or pony trusses. The continuous truss design, which uses one or more intermediate supports, greatly increases the possible span length over the simple span truss, and is used for both deck and through trusses and, to a much lesser degree, pony trusses.

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[127] Heather Rudge, *Metal Truss, Masonry, and Concrete Arch Bridges of Vermont*, Multiple Property Documentation Form (Montpelier: prepared for Vermont Division of Historic Preservation, December 15, 1989).

The simple-span **Steel Deck Truss [Type 309]** bridge consists of a truss with the roadway above the superstructure. Deck trusses have an important advantage over through trusses: the width between the trusses is not determined by the highway width, enabling the trusses to be spaced closer together, allowing shorter floor beam spans and significant costs savings. Deck trusses are used when sufficient clearance is available, such as afforded by high embankments on either side of the waterway to be spanned. They are also used commonly for approach spans on long bridges where under-clearance is not a concern, and in situations where economy can be achieved by reducing the number of piers required by increasing span lengths greater than possible with plate girders. Deck trusses are most commonly of the Warren type design.

The **Steel Through(or Thru)-Truss [Type 310]** consists of a truss with the roadway passing through the superstructure, resting on floor beams carried at the level of the bottom chord of the truss. Thru trusses are used for long-span applications where under-clearance is limited. The depth of the truss (vertical distance between the upper and lower chords) can be increased as required to increase span length. The Pratt truss and to a lesser extent the Warren are mostly used; for long spans with high loading, such as double decks and railroad loadings, Pratt or Warren trusses with subdivided panels, such as the Baltimore truss, may be used, but a more efficient design is provided by the K-truss.

Two basic forms of thru trusses date back to the 1840s: the Pratt and the Warren. These forms were used throughout the century, and because they adapted well to standardization of members, were built well into the twentieth century. The last half of the nineteenth century was a time of experimentation and many different trusses were developed. Often these new forms were variations on the Pratt and the Warren trusses. Eventually the Pratt and the Warren proved their versatility and desirability through adaptability to a specific site, ease of construction, durability, and greater economy in materials.

Pratt Truss

The Pratt Truss, patented in 1844 by Thomas and Caleb Pratt, offered simplified fabrication and construction because it used a limited number of different members in its webs, and the distribution of stresses could be calculated through mathematical analysis. The Pratt truss is distinguished by parallel chords with vertical members acting in compression and diagonal members acting in tension, design features that reduced the length of compression members to help prevent them from buckling. The span of the Pratt truss ranges from 25' to 150', with the pony truss used for the shorter spans and the through truss for the longer spans.

In Vermont, the Pratt was used in the construction of through and pony truss bridges. Typically, the top chord of a Pratt through truss is a box girder with a latticed underside. The bottom chord is usually made up of paired angles connected with a continuous top plate or stay plates, or two channels with top and bottom stay plates. Verticals and diagonals consist of rolled I-beams or paired angles, while top, sway and portal bracing varies greatly from bridge to bridge. The floor system consists of I-section floor beams and stringers with a concrete slab deck. The Pratt pony truss is very similar in construction but structurally simpler because of its shorter span and lighter traffic loads.

The Pratt configuration of compression and tension members were utilized in a small number of bridges that continued to be built with the same structural members, but altered the shape of the top or bottom chords, or added short lengths of bracing (sub-struts). Those found in Vermont include the Baltimore (Petit) through truss with spans between 250 and 600' and the Lenticular (Parabolic) pony truss with spans between 150' and 400'. The Baltimore truss dates from the 1870s when engineers employed by the Baltimore and Ohio Railroad designed sub-struts and sub-ties to stiffen the Pratt truss in an attempt to maximize load capacity and support the ever increasing size and weight of their locomotives and freight. Like the Pratt the Baltimore has parallel chords with the added structural members found in the diagonal webbing. The Lenticular truss is a Pratt with both the top and bottom chords parabolically curved over their entire length. Perhaps the most handsome and visually striking of all truss bridges, its name was derived from the particular lens shape it creates. It appeared in Europe in the 1850s, and by 1878 had made its way into American bridge construction. Although visually and economically attractive, its dramatic shape drove fabrication cost up, which soon ended its popularity.

Parker Truss

In the late nineteenth century C.H. Parker of Boston designed a truss using the same structural members as the Pratt but with a curved top chord, creating a pattern that found broad application, and became known as the Parker truss. Because of its arched top chord, the bridge is stronger than a regular Pratt truss while using the same amount of material. Because of its added strength, the Parker covered spans up to 200' as compared to the 150' covered by the Pratt. The Parker, however, had a higher production cost because uniformity of the curved top chord was difficult to achieve. A particular type of Parker is the camelback truss in which a segmented top chord is formed with five slopes. The camelback design was well accepted and widely used because its design allowed for greater standardization of its members, better stress distribution, and spans of up to 300' Its cost and ease of construction made it especially popular for long spans that were required to carry heavier loads Both the Parker and the camelback are found in Vermont as thru truss and pony truss bridges.

Warren Truss

The other important truss is the Warren truss, patented by two British engineers in 1848, which was widely accepted by bridge engineers in the United States. It’s simple, compact design with parallel top and bottom chords was extremely popular, and it continues to be used by bridge, engineers today. Originally, in the nineteenth and early twentieth centuries, Warren truss was made up of diagonals alternately placed in compression or tension, giving the appearance of a series of triangles. Quite often, the diagonals serving as tension members were thin eyebars. Shortly after the turn of this century it became standard practice to use stiff, heavy diagonal members exclusively. Many Warren trusses also employ stiff vertical members, or increase the number of diagonals by overlapping them, both of which increase the structure's strength and load carrying capacity. The span of the Warren truss ranges from 50' to 400', with the through truss used for the longer spans and the pony truss used for the shorter spans. Like the Pratt, the Warren truss limited the number of different members in its webs and, because of its simple structure, stress distribution could be easily calculated.

In Vermont the Warren was used in the construction of through and pony truss bridges. Typically, the top chord of a Warren through truss is a box girder with a latticed underside. The bottom chord is usually made up of a box girder or I-section angles, both with stay plates. Verticals and diagonals consist of rolled I-beams, paired angles, or I-section lattice girders, while top, sway, and portal bracing varies greatly from bridge to bridge. The floor system consists of plate-girder floor beams, or I-beam stringers and cross beams, with a concrete slab deck. The Warren pony truss is structurally simpler because of its shorter spans and lighter traffic loads. The major difference appears in the floor system with pony trusses, often having a wood plank deck.

Like the Pratt truss, the basic Warren truss was adapted to support heavier loads and longer spans by using a polygonal top chord in place of the flat chord. Those found in Vermont are of the pony truss type, and are called Warren polygonal pony trusses. This type of pony truss typically is used over a short span where traffic loads are increased.[128]

The **Steel Pony Truss [Type 380]** is primarily for short span applications where under-clearance limitations prohibit the use of a deep plate girder of similar span capability. The “pony” or “low” truss is often of the same truss design type (exclusively Pratt and Warren), except that there are no overhead members joining the two truss members. The lack of portals, upper struts, and upper lateral bracing is a result of the limited truss depth, which seldom exceeds more than 10’ but have been built 14’ deep and higher.

The **Steel Continuous Deck Truss bridge [Type 409**] functions the same as a steel deck truss but only the superstructure is supported by intermediate piers, bents, or columns. So, the truss functions as a single structure that carries the load, which means that less material can be used. For simple deck truss spans, each span has to carry the entire load, requiring more material per span that a continuous truss.

The **Steel Continuous Truss-thru bridge [Type 410]** differs significantly in design and appearance from the non-continuous version. Continuous trusses have been built of constant depth with parallel chords; with varying depth, from slight to a point closely resembling a cantilever truss with much greater depth at the supports; and in an aesthetically superior arched form with the roadway suspended through the main span. The continuous truss is usually built using the cantilever method of construction, and then rigidly joined at the center as opposed to a “suspended” or pinned span at the center, as in the case of most early cantilever truss bridges.

Metal lattice railing is most commonly used on thru and pony truss bridges. Deck truss bridges built after 1940 commonly have three-bar circular metal railing with steel posts (Bridge No. 24N and 24S on I-91) or three half-ellipse aluminum railing with steel posts (Brattleboro I-91 Haunched Desk Truss Bridge). Older deck truss bridges may have similar metal railing installed as replacements. Railing on deck trusses is usually attached to a concrete curb or parapet that is integrated into the structure of the deck.

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[128] Rudge.

d) *Steel Arch*

Steel arch bridges can be categorized as deck arches or through arches, depending on the location of the roadway in relation to the superstructure. A deck arch has the road deck above the crown of the arch; on the through arch bridge the roadway passes through the arch at the level of the springline of the arch, or at some point above the springline, in which case it is called a half-through arch. Steel arch bridges can be designed with hinges at the supports (two-hinged) and also at the crown (three-hinged) to allow the calculated limitation of undesirable stresses from temperature changes and loading, or as a fixed-arch without hinges. A tied arch is a type in which a tension member joins the ends of the arch together like a bowstring, thereby eliminating the horizontal thrust of the arch. Some consider the tied arch not to be a “true arch” because they impart no horizontal thrust component against the abutments (abutment reaction direction is another method of categorizing bridge types), and others argue that the arch ribs distribute the span loads horizontally to the ends of the ribs like any other arch where they are simply countered by a tie instead of an abutment. Several types of ribs are used for steel arch bridges: solid ribs, including the plate girder and box girder ribs; and open or braced ribs, sometimes called truss-ribs, consisting of single or double intersecting diagonal web members joining the flanges or “chords” of the rib. Through arch bridges have the roadway suspended from the arch ribs by vertical hangars of cable or structural steel construction, and in some rare cases by diagonal hangers. Two type of steel arch bridges occur in Vermont: the simple-span **Steel Arch-thru bridge [Type 312]**, and the **Steel Continuous Arch-thru bridge [Type 412]**, the latter having a deck system that is made continuous beyond the point at which the deck intersects the arch ribs.

Railing types for steel arch bridges are similar to those for steel trusses, including metal tube railing and metal lattice. Some bridges have a combination of both types, designed to provide pedestrian safety as well as vehicular safety.

e) *Steel Rigid Frame*

A rigid frame can be defined as a structure with moment-resisting joints. The simplest form of rigid frame bridge consists of a horizontal beam or girder span supported by legs (piers) at each end to which the beam is rigidly connected. As the beam (bridge deck) deflects downward under load, the legs resist the loads through torsional strains transmitted through the solid connection. Rigid frame bridges are continuous structures that have been called a hybrid of the arch and girder bridge because some of the vertical moments on the deck become horizontal thrusts in the legs that must be restrained by the abutments or leg foundations. The **Steel Continuous Rigid Frame bridge [Type 407]** is generally used for short spans, such as highway overpasses, and are usually one span and seldom consists of more than two spans. The member that rigidly connects the leg post and deck beam, sometimes called the “knee,” is often formed as a single structural component, which is obvious to the eye, and commonly has a curved bottom flange. Another type, called a slant-legged rigid frame, has legs that are tilted at an angle to reduce the length of the center span and form short continuous side-spans. There are six continuous rigid frame bridges in Vermont built between 1971 and 1976.

A three half-ellipse aluminum railing with steel I-beam posts set on a concrete curb is the most commonly used railing type on steel rigid frame bridges. The bridge that carries VT Route 207 over the Missisquoi River has a concrete parapet with the single half-ellipse aluminum railing.

f) *Suspension*

A suspension bridge consists of a girder or truss floor system suspended from two steel cables that are draped over towers and fixed at each end to the earth by structures called anchors. The towers are located at the edge of the waterway to be spanned and equipped at the top with saddles, over which the cables pass. Towers usually consist of two primary vertical structural components that are joined by bracing or connecting trusses in a wide variety of methods often designed with aesthetics in mind. The anchors, commonly a massive block of concrete, are located some distance from the towers, usually near shore. The cables hang to form a graceful inverted curve between the towers that carries the main center span. The two side spans of the roadway, between the towers and the anchors, are also suspended from the cables and are commonly one-half to one-quarter the length of the main span. Vertical cables of varying length called suspenders are attached to the main cables at regularly spaced intervals, which in turn support the floor system. The floor system can be either stiffened or unstiffened, although the vast majority of long suspension bridges are built with deep girder or truss supported roadways (called stiffening girders or stiffening trusses) to resist bending and twisting from live loads, especially wind.

The stiffening girders or trusses (and integral floor system) may be built as a simple-span structure with hinges at the towers and perhaps at the center of the main span as represented by the **Steel Suspension bridge [Type 313]**, or as a continuous structure from abutment-to-abutment classified as a **Steel Continuous Suspension bridge [Type 413].**

Small suspension bridges as used along trails do not normally have railings; unlike their larger counterparts, such as the Golden Gate Bridge. The steel cables spanning the vertical supports serve as a railing of sorts. Some trail bridges have a chain link or metal lattice installed on the sides for safety. These would not be original to the structure.

3. SIGNIFICANCE

a) *Simple Beam Spans*

The **Steel Stringer, Multi-beam, or Girder bridge [Type 302]** is the most common highway bridge type in Vermont, comprising 55 percent of the total number of bridges built between 1940 and 1978. It was the most prevalent bridge type in the United States for much of the twentieth century because of its simplicity in design, fabrication, and erection, and its low first-cost and life-cycle cost. (Concrete bridges are now the most numerous type in the United States). Rolled steel I-beams and built-up plate girders have been effectively used for simple spans since the late nineteenth century. Steel beam and girder bridges fell in usage relative to other types during World War II because of steel shortages, but the type recovered its popularity by 1950. Technological advances in the type progressed during the 1950s and 1960s with the use of welding instead of riveting, the use of alloy steels, and the combination of lightweight, steel, or composite, decks. The technical advances sometimes pertained to increasing the cost-effective span of simple-span steel beam and girder bridges but were more widely used with continuous beam and girder spans (discussed below).

The **Steel Girder & Floorbeam bridge [Type 303]** is a common U.S. bridge type but comprises only 1 percent of the total number of steel bridges built in Vermont between 1940 and 1978. Girder and floorbeam bridges comprise nearly all bridges that are commonly called plate girder bridges. This classification refers only to simple span bridges; the relatively low numbers are in part a result of the trend beginning about 1940 to design the steel girders as a single, continuous structure. The plate girder, long used by railroads for their ease of construction and rigidity, became popular for highway use, providing the benefits of deck design, which enhanced driver safety, and its suitability for applications of low vertical clearance, such as limited-access-highway overpasses.[129] Simple-span plate girders up to 150’ in length were commonly used for highway spans until the 1950s, when continuous and welded spans became more economical for spans over 100’.

The technology of plate girder bridges advanced greatly during the period 1940-1978 primarily in four areas: composite beam design, use of high-strength steels, the application of welding for the fabrication of plate girders, and the use of orthotropic deck systems. These advances led to a rapid decline in the use of this type, as did competition from prestressed concrete girder bridges that were reaching spans equivalent to the simple-span girder at a lower cost. The traditional steel riveted plate girder of the simple span type built in 1940-1978 can be considered outdated in terms of technology, and unless a particular bridge is unusually large, either in single span length or overall length, or contains other important features in the design, the type can be considered as not technologically significant.

By 1950 welded plate girders, consisting of three plates welded together at right angles to form an I-section, had come into popular usage, a result of improvements in welding methods and automated welding machinery. Previous to welding, I-section plate girders were a riveted-together assembly of three plates and four angles. The introduction of welding reduced labor and material costs while producing a stronger girder capable of greater spans. The result was that demand remained low for the conventional riveted types, which kept their cost low, which in turn prolonged their usage. As demand for welded continuous girders grew through the 1950s and 1960s, efficiencies grew in the fabrication shops, standard designs were developed, and welded girders eventually surpassed the riveted girder for short simple spans as well.

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[129] The principle design difference between a highway and railroad plate girder bridge is the railing, a design feature that is not necessary on a railroad bridge.

b) *Continuous Beam Spans*

Continuous steel girder bridges [Type 402] were developed, refined, and widely adopted within a span of a decade beginning about 1930. During the 1930s there was an increasing tendency toward the general use of continuous structures and other statically indeterminate forms. Bridge engineers in state highway departments were chiefly responsible for the adoption of the continuous beam and girder bridge forms, which offered the most economical solution for most elevated and medium span highway bridge applications. The economic depression demanded that new technologies for safety, economy, and continuous structures offer cost savings over simple span structures of between 10 to 30 percent, which covered the increased engineering cost many times over. Continuous beam and girder bridges required less structural steel and fewer expansion joints, rockers, and bolsters. Their greater rigidity reduces deflections by about 50 percent, which allows shallower concrete deck construction. Additional savings were obtained by reducing the size of the pier caps, elimination of some end floor-beams, and the opportunity to increase the economical span length of the plate girder. By 1940 the continuous plate girder deck highway bridge was widely used across the United States by state highway engineers because of its many attractive cost and engineering features, and the development in the early 1930s of a simplified engineering analysis method that reduced the math requirements. In Vermont 208 continuous girder bridges were constructed between 1936 and 1978.

The application and technology of continuous beam and girder bridges continued to advance during the 1950s and 1960s through the introduction and increasing use of welding, high-strength steel, and integral floor systems like composite concrete decks and orthotropic plate decks. These design advances led to a reduction in the cost of beam and girder bridges as well as increasing their practical span length to the point that continuous plate girder bridges largely replaced pony trusses and short-span thru-trusses in many situations.

Another advance that was adopted by Vermont engineers was the curved girder. Around 1970 curved girders were beginning to be used for continuous beam spans. The first such bridge was constructed carrying VT Route 191 over the Clyde River near Newport City. Five additional curved continuous girder bridges were built up through 1978.

c) *Metal and Steel Trusses*

The bridges included in this type are found throughout the state of Vermont. The bridges include a number of truss types, from the simple single span deck truss to the multi-span through truss, all of which reflect the development and engineering advancements made in bridge building over the last 150 years. Located in rural areas, towns, and cities, the bridges are an important part of the Vermont landscape. Because they offered the latest technology in bridge building at an affordable price, and expanded transportation routes within individual communities, metal trusses are significant at the local level. These bridges have significance at the state level because they helped to link a growing state road system which in turn increased inter-regional transport, travel, trade and commerce.

Wood trusses and covered bridges led to the truss bridges of the late 19th and early 20th centuries when new engineering and manufacturing technology introduced the use of prefabricated iron and steel members into bridge building. Manufacturers were able to produce bridge components that could carry increasingly heavy loads, meet the specific requirements of each site, and stand up to the elements with minimal upkeep.

The types of bridges found in Vermont were influenced by engineers from England as early as the 1840s, as well as engineers employed by the railroads and bridge companies later in the century. Continually evolving technology, such as the ability to calculate stress on individual bridge members, the improvement of pre-fabrication and standardization techniques, and construction methods that allowed bridges to be built more easily, are represented in Vermont's truss bridges. Much of this new technology was brought to all parts of the state by contractors representing fabricators or their own firms. Due to Vermont's remote location, the distance from bridge manufacturing centers, the mountainous terrain, and inadequate roads, companies from New England and New York had the most impact on bridge construction in the state. Among these were Connecticut's Berlin Iron Bridge Company, New York's Groton Bridge and Manufacturing Company, and the American Bridge Company, initially owned by J. P. Morgan and, later, by U.S. Steel.[130]

Pin-connected metal trusses, developed in the mid-nineteenth century, were gradually supplanted by all-riveted trusses of steel by roughly the 1930s. For short spans, the pony or low truss (without overhead members joining the two truss members) was widely used until about 1950, when alternatives in prestressed concrete and continuous welded plate girder deck bridges again supplanted the type. **Pony trusses [Type 380]**, by the very nature of their design, do not typically display the significant engineering characteristics found in other bridge types. This is because as the length of the pony truss is increased, the depth (height) of the truss also increases until a depth is reached, commonly 10', beyond which the trusses must be braced laterally overhead, resulting in a thru truss. The maximum practical length of a pony truss is generally considered 120', with good economy in the 60' to 100' range.[131]

Thru or half-thru bridges [Type 310] – those with supporting structural members above the highway, and therefore subject to damage by collision – were being discouraged by mid-century but remained in use for long span applications that could not be met by **deck truss bridges [Type 309]**. The low weight-to-span ratio of trusses has continued to make them the practical and economical choice for replacement structures on existing substructures or other situations of limited bearing capacity. The technology of trusses during the period 1942-1970 has remained essentially unchanged, with the exception of the substitution of welded connections and the use of alloy steels with special strength or corrosion resistant characteristics. The longest simple span truss in the United States is the 720' span Metropolis Bridge over the Ohio River built in 1917.

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[130] Rudge.

[131] Pony trusses were used extensively on Vermont's railroad network. The principle design difference between the highway and railroad pony truss is the presence of angles to support and stiffen the deck of a railroad bridge.

By 1960 simple span trusses were very infrequently built as main spans but continued to see use as deck approach spans. Continuous plate girder deck spans had filled the span niche that the simple truss had occupied for spans of 100’ to 250’, and the continuous truss types took the place for spans in excess of 250’ up to the practical limit of roughly 800’.

The first steel continuous truss bridge in North America was the Lachine Bridge over the St. Lawrence River built in 1888 by C. Shaler Smith. The Lachine Bridge remained the sole example of a continuous truss on the continent until the 1917 construction of the record setting twin 775' span Sciotoville Bridge over the Ohio River by Gustav Lindenthal. Other engineers quickly adopted the continuous truss and many examples soon followed. **Continuous truss bridges [Type 409]** continued to be widely used for long span applications through the entire 1940-1978 period, including the haunched steel deck truss constructed in 1960 as part of I-91 spanning VT Route 30 and the West River. In general, continuous truss bridges are very large and expensive bridges and will possess local and state significance if not national significance.

d) Steel Arch

The 1675’ Kill Van Kull Bridge at Bayonne, New Jersey, built in 1932, remained the world’s longest steel arch until the building of the 1,700’ New River Bridge in West Virginia in 1977. The tied arch and a hybrid type combining a continuous truss with a tied-arch center span came into popular use for long highway spans during the early 1940s. In the early nineteenth century the 540’ thru arch bridge at Bellows Falls, which was demolished in 1982, was the longest such bridge in the country. The Centennial Bridge over the Mississippi at Davenport, Iowa, built in 1940, together with the Chesapeake and Delaware Canal Bridge at St. Georges, Delaware, also built in 1940, really opened the era of long span tied arch bridges that had begun in 1932 with the landmark 780’ North Side Bridge over the Allegheny River at Pittsburgh. Only a small number of steel arch bridges were constructed in Vermont, most crossing the Connecticut River to New Hampshire. Between 1928 and 1938, four **steel arch thru bridges [Type 312]** were constructed across the Connecticut River in response to flooding in 1927, 1936 and 1938.[132] J.R. Worcester & Company constructed a three-hinged, 248’ bridge at Wells River, Vermont, in 1928. This was the second three-hinged design by Worcester, the Bellows Falls bridge being the first, and is the oldest steel arch bridge crossing the Connecticut River. A two-hinged arch bridge, designed by New Hampshire State Highway Department engineer John Wells, was constructed between Brattleboro and Chesterfield in 1937. The bridge won first prize from the American Institute of Steel Construction (AISC) in 1937. A year later, Mr. Wells completed a 433’ tied arch bridge between Fairlee, Vermont, and Orford, New Hampshire.[133] The Fairlee bridge also won special recognition by AISC.

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[132] McCullough, 150.

[133] McCullough, 151-152.

Steel arch bridges of the deck type were built in the United States to new record lengths where high embankments or deep gorges made the type economically advantageous. The 1,028’ Glen Canyon Bridge over the Colorado River in Arizona established the U.S. record for a hinged arch in 1958, and the Lewiston-Queenston Bridge spanning 1,000’ over Niagara Gorge set the world’s record in 1962 for a fixed or hingeless arch, and was notable for its box-section ribs constructed in segments. In Vermont two **deck arch bridges [Type 311]** were constructed in fairly modest lengths, comparatively. The Quechee Gorge Bridge over the Ottauquechee River is a 285’ three-hinge deck truss bridge that was originally built in 1911 by John Storrs as a railroad bridge, which is an unusual type for railroad bridges. The Beecher Falls deck truss arch bridge, built in 1930, is a two-hinge design and is the only steel deck truss arch bridge between Vermont and New Hampshire.

e) Steel Rigid Frame

The development and practical application of the steel rigid frame bridge occurred between 1928 and 1933, roughly coinciding with the concrete rigid frame bridge, which saw first use in 1922. The concrete rigid frame bridge found much greater use because of cost: it was far easier and cheaper to make the deck beams, legs, and abutment integral with just the addition of bent reinforcement and a continuous pour of concrete. The **Steel Continuous Rigid Frame bridge [Type 407]** was considered costly and less practical than the concrete version and found little use for highways until the development of the slant-leg continuous steel rigid frame bridge in the 1960s. By that time steel prices had eased while labor costs continued to rise, making steel bridges that could be quickly erected in any weather popular for overpasses on time-sensitive limited-access highway projects. The slant leg bridge found wide use for highway overpasses because of the additional setback of the legs from the roadway below, which offered greater protection from vehicle collisions. Six steel rigid frame bridges were constructed in Vermont from 1971 to 1976. In 1974 the I-91 Lyndon Bridges, designed by Blauvelt Engineering, received the American Institute of Steel’s Award of Merit. The trend was to provide bridges that were not only structurally sound but also aesthetically pleasing.

f) Suspension

Suspension bridges [Type 313] provide the longest spans of any bridge type (Table F-1). Until the 1970s American engineers and contractors completely dominated the design and construction of large suspension bridges. The seven largest suspension bridges were located in the United States. In Vermont no suspension bridges are in use on either highways or railroads. Prior to 1940, only major three suspension bridges had been built in the state: the 250’ Bancroft Falls Bridge (1888) in Sheldon, the 320’ Brattleboro-Chesterfield Bridge (1889), and the Sutherland Falls Bridge (ca. 1900) in Proctor, which carried a pipeline.[134] None of these bridges remain extant.

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[134] McCullough, 159-169.

TABLE F-1

STEEL SUSPENSION BRIDGES IN VERMONT

BRIDGE	LOCATION	YEAR BUILT	PRIMARY USE
Lamoille River Footbridge		2004	Not in use
Hardwick Swinging Bridge	Hardwick	Unknown	Pedestrian
Clarendon Gorge Footbridge		1974	Appalachian Trail
Deerfield Creek Bridges I & II	Green Mountain National Forest	Unknown	Pedestrian
Saxton River Bridge	Bellow Falls	Unknown	Snowmobile
Saxton River Bridge	Grafton	Unknown	Snowmobile
Saxton River Bridge	Cambridgeport	Unknown	Snowmobile
School House Road Bridge	Chester	1977	Pedestrian
Winooski Wonder Bridge	Waterbury	2015	Snowmobile
Big Branch Bridge		2010	Appalachian Trail
MacArthur Bridge		1977	Pedestrian
Creekside Trail Bridge	Starksboro	1998	Pedestrian

There are several suspension bridges in the state that carry pedestrians and recreational vehicles. Most of these bridges were built after 1970 and are associated with trail systems. Many were constructed specifically for snowmobile use by local snowmobiling associations and the statewide association, Vermont Association of Snow Travelers (VAST).

4. REGISTRATION REQUIREMENTS

The period of significance for steel bridges includes the entire period that steel bridges were built, from ca. 1870 to 1978. Bridges less than 50 years of age that meet Registration Requirements must also possess characteristics of exceptional importance to be considered National Register of Historic Places (NRHP) eligible. Bridges that meet Registration Requirements must also retain integrity of location, design, setting, materials, workmanship, feeling, and association. A bridge that is eligible only under Criterion A for its historical significance should retain its integrity of location and setting. Bridges eligible under Criterion C for engineering significance need not be in their original setting but should be in a location appropriate for the property type.

Additions such as sidewalks, guard rails, replaced decking, and new abutments are acceptable as long as the original structural system of the bridge is in place.

Specific considerations for eligibility under Criterion A

1. A large bridge establishing the first highway crossing of a major waterway at a given location.

2. A bridge that established a new highway transportation corridor and can be shown to have been the direct cause of significant development or changes in land use.

3. A bridge that was built as part of a major state highway project or bridge building initiative, which would include major post-flood bridge building programs, and possess special characteristics, associations, or integrity that distinguish it as an exceptional representative of the type.

Specific considerations for eligibility under Criterion C

1. Early well-preserved example of a type.

   Welded girder bridges, tied arch bridges, and rigid frame bridges built in Vermont prior to about 1955 may be relatively early examples of their type to warrant this consideration. To be a well-preserved example of a type, the bridge must retain its character-defining features. For steel arch bridges this includes the curved top girder or truss, suspenders, ties, bottom chord, floor system, and hinges, if part of the original design. For truss bridges the majority (over 50 percent) of major members of the truss (top chord, bottom chord, end posts, diagonals, stringers, struts, and methods of connection) must remain as original material as well as the floor system and abutments to be a well-preserved example of the type. The 50 percent rule is merely a benchmark that may change from bridge to bridge. In general, the more important the feature is to the significance of a bridge, the more detrimental its loss is to the integrity and significance of the structure.

2. Rare survivor of a once common type.

   Owing to frequent flooding, deterioration because of salt, and the growing size of automobiles and trucks in Vermont, truss bridges in the state built before 1940 are not common. Consequently, any truss bridge that retains its character-defining features would be considered a rare survivor of a once common type. In the case of multiple spans, at least one span of the original structure must remain with an identifiable truss system. The truss system should be capable of functioning, with or without structural reinforcement, but need not be in use for carrying traffic. This consideration is generally not applicable to metal bridges built after 1940 as nearly all of them remain in service in an unaltered condition. This consideration can also apply to nearly obsolete bridge types that were still being built, such as riveted steel girder bridges [Type 303] dating from after 1960. Bridge No. 37 on C3009, built in 1964, and Bridge No. 22 on C3018, built in 1972, are two such examples of riveted girder bridges that may be significant.

3. Exceptional example of work by an important engineer, architect or firm.

   Bridges designed by local, regional or national designers that have made important and recognized contributions to the field may be eligible under this consideration. Important designers known to have constructed metal and steel bridges in Vermont are found in Section E.III.

4. Innovative, specialized, or patented designs of recognized importance.

Welded girder bridges built before 1950, tied and hinged arch bridges, and rigid frame bridges built in Vermont during the study period may possess innovative or significantly specialized characteristics to warrant this consideration. Patented bridge designs or features introduced in Vermont are not known to exist from present research.

5. Large bridges of exceptional span or overall length.

Steel bridges that are the longest span length for their type in Vermont; or are of exceptional and sufficient overall length to represent a major engineering and construction effort from the state or local perspective.

Simple beam spans: Bridges over 100’ in length of welded plate girders, composite decks, or orthotropic decks dating prior to 1955 should be individually evaluated for unique characteristics. Single spans 300’ or greater. Multi-span bridges with five or more spans with the longest span at least 80’. Bridges with an overall length in excess of 400’. Girder & Floorbeam bridges over 150’ in span length. Bridges of the steel welded I-girder with diaphragms type over 150’ in span length constructed prior to 1960 should be considered as possibly possessing significant engineering characteristics.

Continuous beam spans: Main spans in excess of 200’ clear span; structures in excess of 2,000’ overall length; box beam spans exceeding 400’; continuous welded I-girder bridges with diaphragms or floorbeams with main spans greater than 150’ constructed prior to 1950 may possess significant engineering characteristics and/or be early and large examples of the type. Main spans greater than 250’ built before 1960, and 300’ built before 1970.

Trusses: Overall bridge length of 2,000’ or greater. Deck truss with main span of 200’ or greater; simple thru trusses in excess of 400’; pony trusses 150’ or greater; continuous thru-trusses 400’ or greater. Early examples of all-welded trusses (prior to 1950) and early examples of special-alloy bridges (prior to 1960) merit specific evaluation if this information is available.

Suspension, steel arch, and rigid frame bridges should be considered regardless of span length, unless they are a modern addition to an older bridge.

6. Architecturally designed bridges of recognized aesthetic importance.

Steel arch and suspension bridge designs have important scenic qualities and are the likely types to have details influenced by aesthetic considerations. Tied arches in particular are used in steep, often scenic ravines, where the smaller abutments were structurally necessary and the aesthetic qualities of the arch were also important. The evidence of an architect’s involvement in the design warrants further study.

See Table F-2 for steel bridge selection criteria.

TABLE F-2

QUANTIFIABLE STEEL BRIDGE SELECTION CRITERIA, 1940-1978 BRIDGES (CRITERION C)

TYPE CODE	TYPE NAME	QTY	CHARACTER-DEFINING FEATURES	OTHER SELECTION CRITERIA	NUMBER OF POTENTIALLY ELIGIBLE BRIDGES
	SIMPLE BEAM SPANS			>100' in length of welded plate girders, composite decks or orthotropic decks built before 1955 Single Spans >300' Multi-span bridges w/ >5 spans of 80' each >400' Overall length	
302	Steel Stringer, Multi-beam or Girder	609	Welded splice connections (if present), riveted or welded metal plate girders, its floor system and abutments and/or wingwalls, when present. Original railing if decorative.	>150' in span length; or Welded examples before 1950	7
303	Steel Girder & Floorbeam system	16	Same as Type 302, plus floor beam structure	>150' in span length; or Welded examples before 1950	1
300	Steel Other*				
	CONTINUOUS BEAM SPANS				
402	Steel Continuous Stringer, Multi-beam or Girder	151	Rolled I-beams or wide flange beams, floor beams, and original rails, piers, wingwalls and abutments	>2,000' overall length >200' main span	0 9 (6 interstate)
403	Steel Continuous Girder & Floorbeam system	11	Same as Type 402, plus floor beam structure		7
405	Steel Continuous Box Beam or Girders-multi*			>400' span length	
422	Steel Continuous Channel beam*				
400	Steel Continuous Other*				
	TRUSSES			>2,000 in total length	
309	Steel Truss-deck	2	Top and bottom chords, end posts, diagonals, floor beams, stringers, method of connections.	>200' Main span	0
310	Steel Truss-thru	1	Same as Type 309 plus struts and bracing	>400' Main span	0

TYPE CODE	TYPE NAME	QTY	CHARACTER-DEFINING FEATURES	OTHER SELECTION CRITERIA	NUMBER OF POTENTIALLY ELIGIBLE BRIDGES
316	Movable-Bascule	1	Swing span, central pier, pivot, end rests, operational machinery, and abutments, piers or wingwalls, if original.		1
409	Steel Continuous Truss-deck	1	Top and bottom chords, end posts, diagonals, floor beams, stringers, method of connections.	>400' Main span	1 (interstate)
	SUSPENSION				
313	Steel Suspension*				
413	Steel Continuous Suspension*				
	STEEL ARCH				
311	Steel Arch Deck (w/fill over top)*				
312	Steel Arch-thru*		Curved top girder or truss, suspenders, ties, struts, bottom chord and floor system		
412	Steel Continuous Arch-thru*				
	STEEL RIGID FRAME				
407	Steel Continuous Frame (Rigid)	5	Monolithic substructure and superstructure of one continuous fabric (legs integral with horizontal girders), original parapet or railing and piers, wingwalls and abutments.	Representative example of standard bridge design	5
	TOTAL	**797**			**31**

* As of 2018, no bridges of this type have been identified in Vermont.

1. NAME OF PROPERTY TYPE: CONCRETE BRIDGES

2. DESCRIPTION

Concrete bridges are divided into five primary subtypes:

a. Simple Spans,
b. Concrete Arch,
c. Continuous Beam Spans,
d. Prestressed Spans, and
e. Concrete Rigid Frame.

Each subtype may also have secondary subtypes, indicated by boldface type, which are further described. Each type and subtype is followed by the NBI bridge-type number in brackets; refer to Section H, Identification and Evaluation Methods, for a description of NBI bridge categorization system and how it is applied.

a) Simple Spans

Simple span concrete bridges, like their steel counterparts, are supported at each end, as opposed to continuous beam spans, which have one or more intermediate supports (piers). The **Concrete Slab bridge [Type 101]** is the simplest form of concrete bridge and is usually economical for short spans up to 40'. Slab bridges usually consist of a solid mass of concrete of uniform thickness generally in the range of 8" to 20" thick, reinforced with steel rods running the full length (longitudinally) of the slab. Slab bridges are cast in place by pouring the wet concrete into forms erected at the bridge site into which the steel reinforcement has been placed according to plans. The **Concrete Stringer, Multi-beam, or Girder bridge [Type 102]** consists of a series of parallel reinforced concrete beams (meaning stringers, beams, or girders), spanning supports (abutments and piers), and spaced sufficiently close to one another to allow a concrete slab deck to span the distance between them while carrying the intended load. The terms *stringer*, *beam*, and *girder* commonly refer to the relative size of the beams, girders being the largest. Because stringers, beams, and girders all function structurally as beams, these types are generally all called beam bridges. The concrete beam bridge is also cast in place in either pre-made steel or wood forms or custom formwork made on site, which allows the engineer to vary the size of the beams for a given span.

The **Concrete T-beam bridge [Type 104]** looks like a beam bridge from underneath–the important difference is its structural design, which is dictated by the method of placement of the steel reinforcement within the beam. The T-beam consists of a vertical rectangular beam with a wide top flange that is transversely reinforced. The top flanges of the T-beams are abutted to form the continuous concrete slab road surface. The T-beams are not cast in place individually but poured all at once to insure a seamless connection between the beam and "flange." T-beams are commonly used for spans in the 45' to 95' range.

Typical original railings found on concrete simple span bridges include concrete railing with rectangular opening and posts (Type 23), paneled concrete parapets (Type 24), decorative concrete posts with pipe rail and balustrade sections (Rail Type 11 in the bridge inventory), decorative concrete end walls with three pipe railing in between (Rail Types 9 and 16 in the inventory), steel I-beam and steel cable railing (Rail Type 15), and concrete posts supporting steel cables (Rail Type 14). The more common replacement railing types include W-Beam rail supported by steel posts (Rail Types 1, 2, and 4 dating to the 1980s); two, three, and four half-ellipse aluminum railing with steel posts (Rail Types 19, 20, 21, and 22 dating from 1969 to ca. 2005); and rectangular tubing on steel posts (Rail Type 6 dating to post-2012).

b) Concrete Arch

In Vermont, concrete bridges went up in the first decade of the twentieth century after the newly formed State Highway Commission began appropriating funds and supervising the construction of bridges. The Commission preferred concrete over stone because it was cheaper, and the materials and labor to construct the bridges were readily available throughout the state. By 1915, plans for concrete bridges were available from the Commission free of charge to any town that wanted them. Many of the spans found throughout Vermont were erected according to the state's specifications, which like truss bridges, brought standardization to concrete bridges.

Concrete bridges typically have round or segmental arches and range in size from a simple arch over a small stream to a series of arches spanning a large river or gorge. Like masonry bridges, the simplest bridges are located in small towns and rural areas. Most are purely functional, having no ornamentation. Many were built by the local labor force using plan supplied by the state. The larger concrete spans also used the state plans, but often were designed with some decorative detailing. Like the deck truss and masonry bridges, concrete bridges carry their traffic loads at the top of the structure, with vehicles passing over the structural members of the bridge.

The most basic and common form is the closed spandrel, in which the spandrel is solid concrete. In Vermont, this form varies greatly in style, escaping complete repetition from site to site. Many incorporate decorative details such as pilasters, parapets, recessed panels, plaques, coping, string courses, pieces of stone, and stanchions with finials. Some towns chose to use a concrete bridge as a commemorative structure as had been done previously with the masonry spans. The concrete was often finished to imitate stone with such detailing as inscribed lines creating voussoirs of the arch and raised central tablets to resemble keystones.

Far less common than the closed spandrel is the open spandrel concrete bridge, which is typically used on long spans over deep gorges. The open spandrel differs in that much of the space is left open between the ring of the arch and the floor of the roadway. This form offers substantial economy of materials in long crossings while having great potential for creative design. Often the open spandrel forms a decorative appearance with its rhythmic vertical supports, adding to its desirability. Some early bridges had decorative capitals on columns, or used arcades to support the deck. During the early twentieth century engineers began to simplify the forms, alluding to the coming forms of the modern highway bridges. Rectangular columns replaced arcades, and the main arch was reduced to paired arch ribs.[135]

c) Continuous Beam Spans

A continuous girder (or bridge) can be visualized as a single beam supported at three or more points along its length. The structural advantage over a simple span, which is supported only at its ends, results from bending forces created in the beam over the piers, which counteract and reduce the bending forces in the center of the span. The practical advantages are economy of material, convenience of erection in that no falsework is required, and increased rigidity under traffic. When first put into use, some engineers believed that there were structural advantages to making more than three spans continuous, but it was later proven that no increase in rigidity was obtained with more than three spans.

Most forms of concrete simple span bridges can be designed as continuous spans. In Vermont only one **Concrete Continuous Slab bridge [Type 201]** was constructed within the study period, on VT Route 10A over the Connecticut River Railroad (Bridge No. 00002). This bridge type is in most ways identical to its simple span version (see descriptions above); the primary difference is the continuation of the structural member over one or more intermediate piers. This difference between simple and continuous spans is visually apparent because only a single bearing is required to support a continuous girder at an intermediate pier rather than two separate bearings at each pier to support each end of the girders of a simple span bridge. Another visual cue that is apparent in some cases is the joint where the ends of continuous beams meet, which is not located over the piers but roughly at the third-points of the span where the positive and negative bending moments cancel each other.

Typical railings found on continuous concrete bridges are similar to those found on simple span bridges: paneled concrete parapets, W-Beam rail supported by steel posts, and half-ellipse aluminum railing.

d) Prestressed Spans

Prestressed concrete is concrete with stresses intentionally induced in it to counteract stresses created by loads. Concrete is weak in tension, and therefore prestressing concrete for structural uses, such as beams and girders for bridges, is accomplished by inducing compressive stresses. The most common method for prestressing concrete beams is to precisely stretch high-strength steel bars or wires that are imbedded in high-strength concrete and in some way bonded to it. The elastic properties of steel cause the bars or wires, called tendons, to try to retract to their original length, thereby inducing the desired compressive forces in the beam. There are two general methods of prestressing concrete beams: pretensioning, in which the tendons are tensioned before the concrete hardens, and posttensioning, in which the tendons are tensioned after the concrete hardens to a specific strength. A variety of techniques for prestressing concrete beams, some proprietary, have been developed and used for

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[135] Rudge.

bridge construction. Both pretensioning and posttensioning methods can be used with either cast-in-place concrete bridge construction or with precasting the prestressed members onsite or offsite in forms. The manufacture of standardized precast-pretensioned beams and girders for short span bridges of sizes that could be reasonably transported over the road from factory to bridge site evolved rapidly after World War II. Design criteria for prestressed bridges were published by the Bureau of Public Roads in the early 1950s.

Most types of simple and continuous span concrete bridges, as well as arches, can be prestressed. Very few prestressed simple spans are found in Vermont, with only two built in the first two decades of the twentieth century and one built in 1968.

The **Prestressed Concrete Slab bridge [Type 501]** may be constructed either with solid or hollow (called voided) deck slab sections designed to reduce dead weight. Thirty-one bridges of this type were constructed in Vermont between 1940 and 1978. The **Prestressed Concrete Stringer, Multi-beam, or Girder bridge [Type 502]** also occurs in the **continuous form [Type 602]**. Three Type 502 bridges were constructed in the 1970s, and only one prestressed continuous stringer bridge was constructed at the end of the study period in 1978. Prestressed beam bridges that are cast in place or precast onsite are usually rectangular in cross section and posttensioned. More common are factory precast beams, pretensioned and posttensioned, that have evolved into several standardized designs in the form of modified I-sections, with various flange shapes depending on the application. The **Prestressed Girder & Floorbeam bridge [Type 503]** may take several forms depending on age and whether the girders are cast in place or precast. The **Prestressed T-beam bridge [Type 504],** of which four were constructed during the study period, and its **continuous form [Type 604]**, three of which are found in Vermont, are in almost all cases precast members with the possible variations in the design of the T cross section depending on age and manufacturer.

Typical original railings found on prestressed concrete spans include steel I-beam and steel cable railing (Rail Type 15), concrete posts supporting steel cables (Rail Type 14), two, three and four half-ellipse aluminum railing with steel posts (Rail Types 19, 20, 21, and 22 dating from 1969 to ca. 2005), and rectangular tubing on steel posts (Rail Type 6 dating to post-2012). Replacement railings are most commonly W-beam rail supported by steel posts (Rail Types 1, 2, and 4 dating to the 1980s).

e) Concrete Rigid Frame

A rigid frame can be defined as a structure with moment-resisting joints. The simplest form of concrete rigid frame bridge consists of a horizontal beam or girder span supported by legs (piers or abutments) at each end, to which the beam is rigidly connected. As the beam (bridge deck) deflects downward under load, the legs resist the loads through torsional strains transmitted through the solid connection. Rigid frame bridges are continuous structures that have been called a hybrid of the arch and girder bridge because some of the vertical moments on the deck become horizontal thrusts in the legs that must be restrained by the abutments or leg foundations. The **Concrete Rigid Frame [Type 107]** is generally used for short spans, such as highway overpasses, and usually consists of one span with legs that also form the abutments. The concrete member that rigidly connects the leg post and deck beam, sometimes called the “knee,” is cast as a single structural component with bent reinforcing rods forming the solid connection. The absence of a joint or bearing between the deck beam and leg makes rigid frames readily apparent to the eye. Only two examples of this type exist in Vermont, built in 1950 and 1973. Both are used on Vermont state routes carrying the road over a stream and a railroad track. The 1973 bridge (VT Route 106, Bridge No 23) appears to be an updated version of the 1950 structure (VT Route 105, Bridge No. 87).

Railings found on the two rigid frame examples include a concrete post and steel bar railing (Type 12) and a Type 21 three half-ellipse aluminum railing with steel posts.

3. SIGNIFICANCE

a) *Simple Spans*

Simple span concrete bridges date from the beginning of the twentieth century and were quickly adopted by state highway departments for their low cost and ease of construction with local labor and materials. Vermont’s State Highway Commission, for example, offered standard designs for concrete slab highway bridges to towns and cities in 1915. The simple span concrete bridge has not changed significantly in terms of general design since the 1920s. The advances that have occurred have been in concrete chemistry, mixing, placement, and curing; reinforcement design and placement; and formwork. Vermont’s 428 simple span concrete bridges account for roughly 84 percent of the state’s 508 concrete bridges built before 1978.

Cast-in-place **Concrete Slab bridges [Type 101]** did not advance in technology much beyond the 1920s for the simple reason that the type is suited economically and structurally only to very short spans (less than 40’). Efficient use of materials drops off rapidly beyond about 40’, as the ratio of bridge dead load to live load increases to impractical proportions. In other words, increasingly larger amounts of expensive steel reinforcing must be added to longer span slabs just to carry the weight of the concrete itself with an ever smaller proportion of the steel working to carry the live load. Concrete slab bridges have been built in Vermont nearly every year between 1946 and 1978 with the greatest number (14) built in 1977 and the fewest built (12) in 1947. All of Vermont’s 107 concrete slab bridges are between 23’ and 38’ in length. It is apparent from the data that for very short spans (less than 40’), which is what most concrete slabs are, Vermont clearly preferred concrete over steel stringer for short spans, as simple steel stringers with less than a 40’ span only numbered 63. Main span length is not a significance factor for slab bridges built during the 1940-1978 period unless a long span was accomplished with high-strength steel reinforcement.

Reinforced **Concrete Stringer/beam/girder bridge** (beam bridges) **[Type 102]** and **T-beam bridge [Type 104]** designs immediately followed the introduction of slab bridges in the early 1900s and provided the necessary design improvements for longer concrete spans to be economical in comparison with structural steel bridges. The technology of standard reinforced cast-in-place beam and T-beam bridges did not advanced appreciably during the study period except in the areas of precasting. Precasting of conventionally reinforced concrete bridge elements was utilized primarily for viaducts, causeways, and long approaches that required a large number of identical structural components, such as pier shafts, bent caps, and deck slabs and beams, between 1920 and 1950. The development of prestressed concrete in the United States about 1950 made conventional reinforced precast structural members for bridges largely obsolete because of their much greater weight, less strength, and susceptibility to cracking during handling. Two hundred and fifty-four T-beam structures with spans of 20’ to 63’ were built from 1915 to 1971.

b) Concrete Arch

Concrete Arch bridges [Types 111 and 181] were built within a very narrow timeframe in Vermont, between 1908 and the early 1930s. The earliest known example of an unreinforced concrete arch, built in 1902 in Essex Center, is no longer extant.[136] Plans for concrete arch bridges, developed by the highway commissioner, were circulating around the state in the first decade of the nineteenth century.[137] A total of 15 concrete arch bridges remain extant as part of the highway system in Vermont (Table F-3). Most of these bridges have closed spandrels will fill-over top. Two open spandrel arch bridges were constructed in the 1930s, one a bi-state bridge.

TABLE F-3

CONCRETE ARCH BRIDGES IN VERMONT

BRIDGE TYPE	BRIDGE LOCATION	MAXIMUM SPAN (ft)	STRUCTURE LENGTH (ft)	YEAR BUILT	TOWN NAME
Concrete Arch	TR 02 FAS 106 Over Rock River	76	100	1900	Newfane
Concrete Arch	Park Street Over Black River	70	76	1900	Springfield
Concrete Arch	C30PR Over Paran River	21	25	1900	N. Bennington
Concrete Arch	C3448 Over Power Dam Canal	96	112	1909	Rockingham Bellows Falls
Concrete Arch	Former VT 108 Over Missisquoi River			1913	Enosburg Falls
Concrete Arch	VT 00009 MI Over Whetstone Brook	60	70	1914	Brattleboro
Three-Span Concrete Arch	Marble Bridge Over Otter Creek	41	164	1915	Proctor
Concrete Arch	C30WE Over New England Central RR	38	56	1916	Winooski City
Masonry /Concrete Arch	VT 00030 MI Over Flower Brook	34	48	1916	Pawlet
Concrete Arch	C3046 Over East Putney Brook	22	27	1919	Putney
Concrete Arch	Over Walloomsac River	39	39	1921	Bennington
Concrete Arch	TR 01 FAS 131 Over Mettawee River	51	51	1922	Pawlet
Concrete Arch	TR 00003 MI Over Power Dam Canal	114	124	1927	Rockingham Bellows Falls

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[136] McCullough, 172.
[137] McCullough, 176.

BRIDGE TYPE	BRIDGE LOCATION	MAXIMUM SPAN (ft)	STRUCTURE LENGTH (ft)	YEAR BUILT	TOWN NAME
Concrete Open Spandrel Arch	US 00005 MI Over Mill Brook	88	90	1930	Windsor
Concrete Open Spandrel Arch	Bridge Street Over Connecticut River (Bi-State Bridge)	107	635	1931	Bellows Falls

c) *Continuous Beam Spans*

Continuous concrete Slab, Girder and T-beam highway bridges [including **Types 201, 202, 203, and 204]** were being routinely constructed in the United States by 1920. Improvements in the mathematical analysis of continuous structures about 1930 led to further refinements in use of the form, as previously discussed under Steel Continuous Beam Spans. Continuous construction and cast-in-place concrete were a natural marriage for long bridges made of numerous repetitive short-to-medium spans, as well as approaches and viaducts. The short sections of longitudinal steel reinforcement needed only to be overlapped and “tied” together to function as a single continuous structural element once the concrete hardened around it. The labor, materials and equipment required to build simple-span concrete bridges was the same for continuous bridges.

In Vermont concrete bridges, both simple and continuous spans, make up a very small part of the overall bridges constructed during the study period (141 of the 1,113 bridges). Continuous concrete bridges were effectively not used in Vermont, as only three structures were built before 1970: one T-beam and two slab structures, one of which is a three-span continuous concrete slab structure [Type 201] constructed in 1968 over the Connecticut River in Norwich town.

d) *Prestressed Spans*

The first prestressed concrete bridge was built in the U.S. in 1949 and the type was quickly adopted during the 1950s. Vermont utilized precast/prestressed concrete slabs for a large percentage of their short span bridges throughout the study period, constructing 31 **Prestressed Concrete Slab bridges [Type 501]** between 1947 and 1977. Only three **Prestressed Concrete Stringer, Beam, or Girder bridges [Type 502]** were built during the study period, compared with 609 of the simple span steel girder bridge [Type 302]. The **Prestressed Concrete T-beam [Type 504], Prestressed Box Beam [Type 505], and Prestressed Channel Beam [Type 522]** were built in small numbers, with a total of 4, 6, and 5, of each type, respectively, constructed during the study period. Steel was clearly favored as a building material in the state.

e) *Concrete Rigid Frame*

The concrete rigid frame bridge came to fruition as a specific bridge type for use in single or occasionally two or three span applications during the 1930s. Earlier types of concrete “rigid-frames,” or simply “frame designs” as seen in viaduct construction, behaved as rigid frames and as continuous beam structures but were not specifically designed as such. The advantages of the rigid connection between the girder and the supporting "leg" were understood, but the full design potential was not utilized. Vermont constructed only two of the standard type **rigid frames [Type 107]** and none of the **continuous type [Type 207]**. These bridges are not notable for their period or size.

4. REGISTRATION REQUIREMENTS

The period of significance for concrete bridges includes the entire period that concrete bridges were constructed: ca. 1902 to 1978. Bridges less than 50 years of age that meet Registration Requirements must also possess characteristics of exceptional importance to be considered NRHP eligible.

In general, bridges meeting registration requirements should have been built before 1940, and the original core and design features should be intact. The bridges should be capable of functioning but need not be in use today for carrying traffic. The bridges may have had structural reinforcement since they were originally constructed. Where a bridge has been reinforced or widened, one side of the original structure should be intact; widened portions should be of similar construction and materials. A bridge that is eligible only under Criterion A for its historical significance should retain its integrity of location and setting. Bridges eligible under Criterion C for engineering significance need not be in their original setting but should be in a location appropriate for the property type. Owing to the nature of construction and materials, it is unlikely that bridges in this property type will have been moved to another site.

Specific considerations for eligibility under Criterion A

1. A large bridge establishing the first highway crossing of a major waterway at a given location.

2. A bridge that established a new highway transportation corridor and can be shown to have been the direct cause of significant development or changes in land use.

3. A bridge that was built as part of a major state highway project or bridge building initiative, and possesses special characteristics, associations, or integrity that distinguish it as an exceptional representative of the type.

Specific considerations for eligibility under Criterion C

1. Early well-preserved example of a type.

> Concrete arch bridges were the earliest type of concrete structures built in the state, as early as 1902. Concrete arch bridges that are well preserved will have integrity of design, workmanship, materials, feeling, association, and location. Original railings, and decorative features such as recessed panels, pilasters, coping and scoring or other finishes, should remain intact. Alterations, such as sidewalks, replaced decking, or new abutments, are acceptable as long as the character of the bridge's arch structure

remains intact. A portion of the original structure, such as the spandrels or the barrel of the arch, should be visible and intact when concrete reinforcement is used extensively.

Concrete bridges of a completely new type were introduced in Vermont during the study period and include all those in the category of Prestressed Spans, including Types 501, 502, 504, 505, 522, 602, and 604. Bridges of these types predating 1956 could be considered early examples of the type in Vermont. Bridges meeting the age requirement should be further screened for intact character-defining features that make them the best representative of the group (Table F-4).

2. Rare survivor of a once common type.

This consideration is generally not applicable to concrete bridges as most forms are still being constructed today. Exceptions would be for short conventional cast-in-place spans (less than 50’) that have been completely replaced by precast units today. The rigid frame and concrete arch bridges might warrant this consideration.

3. Exceptional example of work by an important engineer, architect, or firm.

Bridges designed by local, regional, or national designers that have made important and recognized contributions to the field may be eligible under this consideration. Important designers known to have constructed concrete bridges in Vermont are found in Section E.III.

4. Innovative, specialized, or patented designs of recognized importance.

Concrete rigid frame bridges built in Vermont during the study period may possess innovative or significantly specialized characteristics to warrant this consideration. Patented bridge designs or features introduced in Vermont are not known to exist from present research.

5. Large bridges of exceptional span or overall length.

Concrete bridges that are of the longest span length for their type in Vermont, or are of exceptional and sufficient overall length to represent a major engineering and construction effort from the state or local perspective.

Simple spans: Slab and girder spans in excess of 50’; T-beam, box beam, and channel beam spans over 70’.

Continuous spans: Slab spans in excess of 60’; girder, T-beam, and box-beam spans 100’ or longer.

Prestressed spans: Slab spans in excess of 50’; girder, T-beam, and box-beam spans 100’ or longer; channel beams in excess of 50’.

Rigid Frame bridges: spans in excess of 50’.

Arch bridges: spans in excess of 200’.

Multiple span bridges with an overall length in excess of 400’.

6. Architecturally designed bridges of recognized aesthetic importance.

Concrete bridges may possess significant architectural treatment, especially in the design of the abutments, piers, and railings, and those possessing such features should be evaluated for their aesthetic importance or association with a noted architect or firm. Concrete arch bridges from this period may have been built for aesthetic reasons and therefore should be given such consideration.

TABLE F-4

QUANTIFIABLE CONCRETE BRIDGE SELECTION CRITERIA (CRITERION C)

TYPE CODE	TYPE NAME	QTY	CHARACTER-DEFINING FEATURES	OTHER SELECTION CRITERIA	NUMBER OF POTENTIALLY ELIGIBLE BRIDGES
				Multiple Span Bridges >400’ overall	
	SIMPLE SPANS				
101	Concrete Slab	107	Slab, parapet or railing, and abutments, wingwalls, and occasionally piers.	>50’	1
102	Concrete Stringer, Multi-beam or Girder	1	Monolithic deck and girder system, parapet or railing when integrated and abutments, and floorbeams, piers and wingwalls, when present.	>50’	0
103	Concrete Girder & Floorbeam system*			>50’	
104	Concrete T-Beam	33	Slab integrated with longitudinal beams, parapet or railing when integrated, and abutments, wingwalls, or occasionally piers.	>70’	0
105	Concrete Box Beam or Girder-multi*			>70’	
106	Concrete Box Beam or Girder-single*			>70’	
122	Concrete Channel beam*			>70’	
100	Concrete Other*				
	CONTINUOUS SPANS				
201	Concrete Continuous Slab	1	Continuous slab, parapet or railing, and abutments, wingwalls, and occasionally piers.	>60’	0

TYPE CODE	TYPE NAME	QTY	CHARACTER-DEFINING FEATURES	OTHER SELECTION CRITERIA	NUMBER OF POTENTIALLY ELIGIBLE BRIDGES
202	Concrete Continuous Stringer/Multi-beam or Girder*				
203	Concrete Continuous Girder & Floorbeam system*				
204	Concrete Continuous T-Beam	1	Continuous slab integrated with longitudinal beams, parapet or railing when integrated, and abutments, wingwalls, or occasionally piers.	>100'	0
205	Concrete Continuous Box Beam or Girder-multi*				
	PRESTRESSED SPANS			Built Before 1956	
501	Prestressed Concrete Slab	31	Prestressed slab, parapet or railing, and abutments, wingwalls, and occasionally piers.	>50'	1
502	Prestressed Concrete Stringer, Multi-beam or Girder	3	Prestressed monolithic deck and girder system, parapet or railing when integrated and abutments, and floorbeams, piers and wingwalls, when present.	>100'	0
503	Prestressed Concrete Girder & Floorbeam system*			>100'	
504	Prestressed Concrete T-Beam	4	Prestressed slab integrated with longitudinal beams, parapet or railing when integrated, and abutments, wingwalls, or occasionally piers.	>100'	0
505	Prestressed Concrete Box Beam or Girders-multi	6	Prestressed slab, the box-shaped longitudinal beams, parapet or railing if integral and abutments, wingwalls, and piers when present.	>100'	0
506	Prestressed Concrete Box Beam or Girder-single*			>100'	
522	Prestressed Concrete Channel beam	5	Prestressed deck and longitudinal beams, parapet or railing when integral and abutments, wingwalls, and piers.	>50'	0
602	Prestressed Concrete Continuous Stringer, Multi-beam or Girder	1	Same as Type 502 but with continuous stringers, beams, or girders.	>100'	0

TYPE CODE	TYPE NAME	QTY	CHARACTER-DEFINING FEATURES	OTHER SELECTION CRITERIA	NUMBER OF POTENTIALLY ELIGIBLE BRIDGES
604	Prestressed Concrete Continuous T-Beam	3	Same as Type 504 but with continuous T-beams.	>100’	0
500	Prestressed Concrete Other	1			1 (box beam)
	RIGID FRAME				
107	Concrete Frame (Rigid)	2	Monolithic substructure and superstructure of one continuous fabric, and a parapet railing.	>50’	0
207	Concrete Continuous Frame (Rigid)*			>50’	0
	ARCH				
111	Concrete Arch Deck (w/fill over top)	13		>200’	0
181	Concrete Arch Deck (no fill over top)*	2		>200’	0
	TOTAL	**198**			**49**

*As of 2018, no bridges of this type have been identified in Vermont.

1. NAME OF PROPERTY TYPE: TIMBER BRIDGES

2. DESCRIPTION

Three types of timber bridges were built in Vermont between 1900 and 1978: the **Timber slab bridge [Type 701], Timber stringer, multi-beam, or girder bridges (beam bridges) [Type 702], and Timber thru truss bridge [Type 710]**.[138] The timber slab bridge consists of a series of sawn timbers of similar thickness, joined tightly to one another with lag bolts or galvanized spikes, running longitudinally across the opening spanned, and resting directly on the abutments. A second or third layer of timbers may be added to provide greater strength for a wearing surface, but the end product is a solid, slab-like wood structure. The timber beam bridge type generally consists of sawn timbers, generally deeper than they are wide, longitudinally spanning the opening but spaced some distance apart, with stringers the smallest and girders the largest. Transverse timbers rest on the beams and either form the road surface or act as floor beams for longitudinal decking. Timber beam bridges may also be constructed using manufactured girders of glue-laminated construction. Laminated timber girders are made of many smaller boards or timbers glued together to form a girder much bigger than the largest sawn timbers, and thereby allow for much greater spans.

As one would expect, most timber highway bridges have timber railings, classified as Rail Types 26 and 27 in the bridge inventory. Numerous bridges have replacement W-beam railings (Rail Type 1). Timber trestle railroad bridges generally do not having railings because there are no safety concerns for pedestrians or vehicles.

3. SIGNIFICANCE

Timber slab bridges are very rudimentary. The first timber bridge in the state was built by Enoch Hale in 1785 spanning the Connecticut River between Walpole, New Hampshire, and Bellows Falls.[139] This bridge no longer exists and only two of the same type remain in Vermont, constructed in 1919 and 1930 on county roads. The timber beam bridge has been generally considered to be the simplest and cheapest type of span, lacking any technological significance. Since timber is a natural product, the limits of the material, in terms of span length, is dictated by the availability of high-quality, large-dimension timbers, which is generally on the decline. The introduction of new wood preservation compounds (in place of heavy, highly toxic creosote), in particular the copper-chromium-arsenic compounds that came into wide usage during the 1960s (and are now being banned), have helped keep wood one of the low-cost choices for short span bridges, especially those built privately.

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[138] Most timber thru truss bridges [Type 710] are covered bridges, which occur in large numbers in Vermont. The historical significance and preservation of these structures are covered in Vermont Agency of Transportation [VTrans], Historic Covered Bridge Plan (Montpelier: VTrans, 2018, accessed at http://vtrans.vermont.gov/historic-bridges/covered-bridge-plan).

[139] McCullough, 39.

Laminated timber bridges came into widespread use in the 1950s for several reasons: the persistent postwar shortages of steel made wood an attractive alternative, wood was much cheaper than other materials, and glue-laminated beam design and manufacture blossomed during World War II and that industry was looking for new outlets.

The timber beam bridge was built in its largest numbers in 1919 and 1920 on various county roads. Examples after World War II are rarely found in Vermont; only two bridges were built, in 1960 and 1973. The 1960 timber beam bridge, located on Route C3015, has a span of 26'. The second bridge has a larger span, of 40', and is constructed of glue-laminated members (Route C3025, Bridge No. 33). The bridge consists of four glue-laminated beams with glue-laminated stiffeners placed in the center of the span. The deck and railing are also constructed of wood.

4. REGISTRATION REQUIREMENTS

The period of significance for timber bridges includes the entire period that timber bridges were constructed: ca. 1900 to 1978. Bridges less than 50 years of age that meet Registration Requirements must also possess characteristics of exceptional importance to be considered NRHP eligible. Bridges that meet Registration Requirements must also retain integrity of location, design, setting, materials, workmanship, feeling, and association.

Specific considerations for eligibility under Criterion A

1. A large bridge establishing the first highway crossing of a major waterway at a given location.

2. A bridge that established a new highway transportation corridor, and can be shown to have been the direct cause of significant development or changes in land use.

3. A bridge that was built as part of a major state highway project or bridge building initiative, or part of the Federal Interstate System, and possesses special characteristics, associations, or integrity that distinguish it as an exceptional representative of the type.

Specific considerations for eligibility under Criterion C

1. Early well-preserved example of a type.

> Timber bridges of a completely new type, glue-laminated construction, may have been introduced in Vermont during the study period. Early examples would date before 1950.

2. Innovative, specialized, or patented designs of recognized importance.

Certain types of glue-laminated bridges built in Vermont during the study period may possess innovative or significantly specialized characteristics to warrant this consideration. Patented bridge designs or features introduced in Vermont are not known to exist from present research.

3. Large bridges of exceptional span or overall length.

Single-span timber slab and timber girder bridges less than 40’ in length constructed during the 1940-1978 period are very unlikely to possess significant engineering characteristics. Bridges above 40’ in length constructed of solid timber should be individually evaluated for unique characteristics. Bridges with stringers, beams, or girders constructed of laminated members, built prior to 1960 and with spans in excess of 50’, merit specific evaluation. Multi-span timber bridges with 10 or more spans with the longest span at least 25’ may represent a significant overall length or cost and should therefore be individually evaluated.

1. NAME OF PROPERTY TYPE: MASONRY BRIDGES

2. DESCRIPTION

Masonry bridges were built throughout the 19th century and into the 20th century, but with less frequency after the 1860s when metal truss bridges were widely accepted. Lower costs in fabrication and construction, as well as government funding of many of the projects beginning in the early 20th century, ensured the dominance of the metal truss. Consequently, many of the masonry bridges constructed in the late-19th and early-20th centuries were built by towns or funded by wealthy private citizens as a monument to their town or family. These bridges, because of their location in town centers or their function as a commemorative monument for a particular family or individual, took on a more formal appearance in contrast to the rugged appearance of the masonry bridges found in the countryside. The town center bridges were built more with a sense of permanence as reflected in the finished surfaces of the exposed stones, decorative railings, ornamentation, and street lights.

Masonry bridges consist of one or a series of stone arches constructed of rubble, ashlar, or a combination of both. The ashlar can be found in a number of stone faces and cuts, including rock-faced and rough-cut, coursed or random ashlar. Fieldstone, limestone and granite are the most commonly used stones, but marble, gneiss and brick appear on some bridges as part of the structure or as ornamentation. Typically each arch is round, semicircular or segmented, or on rare occasions, horseshoe-shaped.

The rugged masonry bridges built by country artisans are usually smaller in size and are constructed of fieldstone or granite, laid whole or rough-cut into slabs, and mortared into irregular courses. The arch itself is built with coursed stone to support the structure, while a ring of solid stones typically forms the voussoirs. The spandrels, and wing walls where present, often consist of un-coursed dry rubble. Gravel or pavement overlays the whole structure to form the road surface.

Masonry bridges located in areas of heavier population have a more formal, finished appearance, and are typically much larger than the, bridges built by country artisans. The voussoirs are usually cut stones, often projecting slightly beyond the vertical plane of the surrounding spandrels. Spandrels and piers are coursed, as is the stone or brick that forms the arch of the bridge. Typically, coursed stone or concrete form the bridge embankments. Many of these masonry bridges are ornamented with keystones, parapets, stone rails, and carved stone tablets giving information such as the construction date of the bridge and names of the builder, contractor, and engineer. Unlike the truss bridges, very few of these bridges incorporate sidewalks into their designs.

Generally, the condition of masonry bridges depends on the amount of maintenance and use each span has received over the years. All masonry spans suffer the effects to varying degrees, of exposure to road salt, pollution, extreme temperature changes, and increased traffic loads. The condition of each individual bridge reflects its maintenance schedule, if any, as well as the traffic carried over the span. With the increased weight of vehicles, some bridges that were not designed to support the modern-day loads and vibrations have deteriorated.

Monumental spans typically were designed by engineers with permanence in mind. Their stones were cut with precision to create a tight fit within a particular pattern or course. With the exception of the barrel of the arch, bridges built by country artisans were not designed and constructed with the same precision, typically using random courses of stacked stones and dry rubble infill. While no less significant for their design, these bridges have deteriorated more over the years due to the settling, shifting and washing away of stone.[140]

3. SIGNIFICANCE

Masonry bridges are locally significant for a number of reasons. In addition to expanding transportation routes in rural areas and communities, these bridges reflect the construction skills of local stone masons. In many rural areas masonry bridges are found in clusters, often having the same builder. Masonry bridges in more populated areas represent the pride and permanence of the family or community that built the bridge. These bridges are significant at the state level because they helped to link a growing state road system which in turn increased inter-regional transport, travel, trade and commerce.

The masonry bridges range in size from a single arch crossing a small stream to multiple arches spanning a large river. They represent the vernacular construction styles and techniques of the country artisans, as well as the bridge builders and contractors of the monumental and commemorative masonry bridges found in Vermont's larger towns.

Unlike truss bridges, the appearance of a masonry bridge is most influenced by its location. Bridges found in the rural areas are rugged in appearance, most often using fieldstone and rubble laid randomly, except for the ring of the arch, where the stones had to be split and fitted to assure the arches stability. These bridges were most often constructed by country artisans, reflecting local craftsmanship and materials. One of Vermont's most celebrated bridge masons was James Otis Follett, a farmer from Townshend in Windham County. Follett, who was apparently self-taught, built as many as forty bridges in nearby Vermont and New Hampshire towns, primarily between 1890 and 1910.

Masonry bridges constructed by towns, and commemorative, monumental spans built by wealthy individuals had a more permanent appearance and reflected a higher level of craftsmanship than the

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[140] Rudge.

country bridges. They were typically designed by architects or engineers. Masonry arches in town centers were more formal, with finished surfaces for all the exposed stones, and designs that incorporated elements such as sidewalks, decorative railings, parapets, and street lights.

By the turn of the 20th century the state government began to oversee construction and regulate the use of roads and bridges. Because masonry bridges were labor intensive, more expensive to build, and required skilled craftsmen that were not always readily available, the government encouraged the construction of truss and concrete bridges by instituting programs that made these bridge types more widely used. Programs included structural engineering services for truss bridges and free plans for concrete bridges. In 1915, the state legislature established a bridge fund that was used to help towns pay for bridge construction. Masonry bridges were not funded because they were too expensive. As a result of limited construction after 1900, and the number of bridges lost during the flood, the masonry bridges that survive in Vermont today are very rare resources.[141]

The bridges included in this type are found throughout the state of Vermont. Both masonry slab and arch bridges are found in small numbers across the state. Many bridges were replaced by newer structures or sometimes abandoned or bypassed. Most of the known examples cited in this section remain part of the transportation system; however, many abandoned structures are still extant, which would be significant examples of this bridge type. **Masonry slab bridges [Type 801],** of which there are three known in the state, are simple, short-span structures that can have one or more total spans. In Barton Village massive granite slabs were utilized to construct a 63' long, four-span bridge, which was constructed in 1919 and remains in good condition. These bridges are relatively simple to construct. They are rare as the majority of them have been replaced with steel or concrete structures. Large bridges, such as the Barton Village Bridge, would have taken considerable skill to construct and maneuver the large stones into place.

Masonry arch bridges [Type 811] are far less commonly found that both steel and concrete structures, but they are more prevalent than slab bridges. The Vermont bridge inventory types many of the masonry arch bridges as **masonry culverts [Type 819]**. A total of 12 masonry arch bridges with one to three spans are listed in the bridge inventory for long and short span bridges. Middlebury's Battell Bridge is, according to McCullough, Vermont's best monumental stone arch bridge. Constructed in 1893 of quarry-faced limestone, the bridge carries the town's Main Street over Otter Creek.[142] Several masonry arch bridges designed by James Otis Follett still survive, including three bridges in the Townshend area: a 1910 single arch bridge in West Townshend, a granite arch bridge on VT Route 35 north of Townshend, and a

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[141] Rudge.

[142] McCullough, 82.

fieldstone arch bridge near the entrance to the Townshend State Forest.[143] One of the significant bridges that is no longer part of the transportation system is the Vermont Valley Railroad Bridge in Brattleboro, Vermont. Built in 1878, the large, granite-arch structure sits underwater in Whetstone Brook (McCullough 2005:73). McCullough noted that masonry arch bridges built by the railroads were often the "largest and structurally most ambitious" bridges being designed by railroad engineers. Like town center bridges, railroad bridges were often constructed of local granite and marble.

4. REGISTRATION REQUIREMENTS

The period of significance for masonry bridges spans the years that the structures were constructed in the state, from 1851 to 1940. Masonry bridges can be part of the vehicular road network, railroad network, or various trails, including rails to trails.

In general, to qualify for registration, the bridges should have been built before 1940 and the original core and design features should be intact. The bridges should be capable of functioning but need not be in use for carrying traffic. The bridges may have had structural reinforcement since they were originally constructed. Where a bridge has been reinforced or widened, one side of the original structure should be intact. A portion of the original structure, such as the spandrels or the barrel of the arch, should be visible and intact when concrete reinforcement is used extensively. A bridge that is eligible only under Criterion A for its historical significance should retain its integrity of location and setting. Bridges eligible under Criterion C for engineering significance need not be in their original setting but should be in a location appropriate for the property type. Owing to the nature of construction and materials, it is unlikely that bridges in this property type will have been moved to another site.

Specific considerations for eligibility under Criterion A

1. A large bridge establishing the first highway crossing of a major waterway at a given location.

2. A bridge which established a new transportation corridor, and can be shown to have been the direct cause of significant development or changes in land use.

3. A bridge that was built as part of a major state highway project or bridge building initiative, and possesses special characteristics, associations, or integrity that distinguish it as an exceptional representative of the type.

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[143] McCullough, 85-87.

Specific considerations for eligibility under Criterion C

1. Early well-preserved example of a type.

Masonry bridges, including Types 801 and 811, were some of the earliest bridges built in the state with easy access to an abundance of stone materials. Bridges that are well-preserved will have integrity of design, workmanship, materials, feeling, association, and location. If the masonry bridge is obscured through cladding material or encased within another structure, it would not be considered a well-preserved example. Alterations such as sidewalks, replaced decking, or new abutments are acceptable as long as the character of the bridge's masonry remains intact.

2. Rare survivor of a once common type.

Given the rarity of this bridge type because of replacement, demolition, or abandonment, nearly all of the masonry bridges with a moderate to high degree of integrity would be considered a rare survivor of the type. Bridges with significant alterations, including cladding with modern materials such as concrete or stucco, widening, significant changes to railing, or complete encapsulation, would preclude eligibility as a rare survivor of the type.

3. Exceptional example of work by an important mason, engineer, architect or firm.

Bridges designed by local, regional, or national designers/masons that have made important and recognized contributions to the field may be eligible under this consideration. Important designers known to have constructed masonry bridges in Vermont are found in Section E.III.

4. Important example of building practices.

Granite slab bridges built in Vermont in the late nineteenth and early twentieth centuries represent important examples of the application of the local granite industry in various parts of the state, particularly the Barton area. These bridges possess significantly specialized characteristics to warrant this consideration.

5. Architecturally designed bridges of recognized aesthetic importance.

Masonry arch bridges may certainly possess significant architectural treatment, especially in the design of the abutments, piers, and railings, and those possessing such features should be evaluated for their aesthetic importance or association with a noted architect or firm. Most of the masonry arch bridges constructed within town centers were built for aesthetic reasons and therefore should be given such consideration.

1. NAME OF PROPERTY TYPE: CULVERTS

The *Stone Highway Culverts in Vermont* MPDF outlines the significance and eligibility of stone culverts in the state.[144] The section on culverts in this MPDF addresses the significance and eligibility of all other types of culverts.

2. DESCRIPTION

The distinction between bridges and culverts has often been vague. The NBI guidelines define a bridge as having a span of 20' or greater and define culverts as:

> A structure designed hydraulically to take advantage of submergence to increase hydraulic capacity. Culverts, as distinguished from bridges, are usually covered with embankment and are composed of structural material around the entire perimeter, although some are supported on spread footings with the streambed serving as the bottom of the culvert. Culverts may qualify to be considered "bridge" length.[145]

John Henry Bateman states that others have defined culverts as:

> a drain for carrying surface water under roadways as opposed to a bridge which carries a roadway over a watercourse or ravine. Bridges also are defined as structures having separate superstructures and substructures whereas the two are combined in a culvert. Some highway organizations differentiate between culverts and bridges on the basis of the span length, 6 to 12 feet being commonly taken as the dividing line.[146]

In Vermont, a culvert is defined as a structure with a bottom, similar to Bateman's definition, regardless of its length. The NBI and Vermont bridge databases include culverts with spans of less than 20' for safety inspection reasons because they are under-road structures, even if they are not considered bridges. Vermont keeps separate inventories for structures with spans of less than 20', which are called short structures in Vermont. Culverts are also often called "buried structures" in VTrans annual reports. There

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[144] Richard M. Casella, Suzanne Jamele, and Jessica Goerold, *Stone Highway Culverts in Vermont*, Multiple Property Documentation Form (Montpelier: Manuscript on file, Vermont Department of Transportation, 2017).

[145] U.S. Department of Transportation, *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges* (Washington, DC: Office of Engineering, Bridge Division, Federal Highway Administration, U.S. Department of Transportation, 1995), viii.

[146] John Henry Bateman, *Introduction to Highway Engineering: A Textbook for Students of Civil Engineering* (New York: John Wiley & Sons, Inc., 1942), 48-49.

are a total of 1,265 short structures in the inventory. A total of 113 culverts with spans of greater than 20’ are tracked in the long structures inventory.

Culverts in Vermont are of concrete **[Types 119 and 219]**, steel **[Type 319]**, timber **[Type 719]**, masonry **[Type 819]**, and aluminum **[Type 919]** construction.

Concrete culverts may take a variety of forms; the most common for small cross-sectional areas are round, precast pipe sections. Larger capacity concrete culverts are generally box culverts, but large precast multi-sectional units forming oval or round cross-sectional shapes are also common. Concrete culverts are also differentiated if they are of “continuous” construction, which indicates there is more than one “span,” which is important for the inspector but not of consequence to the historian. Steel and aluminum culverts are usually round or oval corrugated pipe sections. Timber culverts are generally built with treated timbers, such as railroad ties, and have generally small sectional areas. Masonry culverts are generally arched, with or without a bottom, or round like typical sewer construction.

3. SIGNIFICANCE

Culverts, some which are large enough to be considered bridges, are included in the NBI and Vermont databases when they pass under highways for safety inventory reasons, as stated above. From a historical standpoint culverts with spans of less than 20’, and therefore too small to qualify as bridges, lack historical importance except in certain cases. One exception would be the earliest application of concrete and steel culverts, which date to the 1920s or earlier and are therefore not a consideration in this study.

Culverts built in the 1940-1978 period in Vermont number 1,198, or roughly 30 percent of the total 4,005 short and long structures.

4. REGISTRATION REQUIREMENTS

The period of significance for culverts includes the period in which culverts were constructed, from 1900 to 1978. Culverts less than 50 years of age that meet Registration Requirements must also possess characteristics of exceptional importance to be considered NRHP eligible. Culverts that meet Registration Requirements must also retain integrity of location, design, setting, materials, workmanship, feeling, and association.

Concrete and masonry arch bridges have been categorized as culverts in the current bridge inventory. It is important to check the inspection report and narrative bridge type field to confirm the type of structure. Those bridges that have been identified as mis-typed have been accounted for in registration requirements for concrete, steel, and masonry bridges.

Specific considerations for eligibility under Criterion A

1. A culvert that can be shown to be a contributing element of major bridge, road, or highway construction project, including association with the Good Roads movement, that is eligible for the NRHP for reasons that include the construction of the subject culvert.

2. An early culvert established as part of Vermont's range roads or turnpikes.

Specific considerations for eligibility under Criterion C

1. Innovative, specialized, or patented designs of recognized importance.

> Certain types of precast and prestressed concrete culverts built in Vermont may possess innovative or significantly specialized characteristics to warrant this consideration. Patented culvert designs or features introduced in Vermont are not known to exist from current research.

G. Geographical Data

The geographic area encompasses the entire state of Vermont.

SUMMARY OF IDENTIFICATION AND EVALUATION METHODS

GENERAL METHODS

1. Purpose

The purpose of this study is twofold: to revise and update the historic context, property types, and registration requirements for the original 1989 MPDF, *Metal Truss, Masonry, and Concrete Bridges in Vermont: 1820-1940*; and to add new historic contexts, property types, and registration requirements for highway bridges built in Vermont between 1940 and 1978. The findings of this study will be used by VTrans to evaluate historic significance and integrity of bridges in the state and nominate individual properties to the National Register. This study continues the work of the previous MPDF and begins in time roughly where that study left off. The criteria, methods, and guidelines followed in evaluating and assessing historic properties are defined in *National Register Bulletin No. 15: How to Apply the National Register Criteria for Evaluation*.[147]

2. Research

Research for this project was conducted using information from the VTrans computerized bridge database, the VTrans Library, the Vermont State Archives, and online repositories such as Newspapers.com and the University of Vermont, Landscape Change website.

METHODS FOR DETERMINING ENGINEERING SIGNIFICANCE

1. Introduction

Nearly all highway bridges in the United States are inventoried in the NBI database created and maintained by the Federal Highway Administration (FWHA). Each state is required by the FHWA to conduct periodic inspections of its bridges and report on the condition and other physical characteristics of each bridge to the FHWA for inclusion in the NBI. To fulfill this requirement, VTrans maintains a computerized database of information on each of the state's 4,004 bridges and culverts. Over 100 detailed items of information may be provided for each bridge, including several characteristics useful in analyzing a bridge's historical significance. The characteristics studied for this report include date of construction, main structure type, materials of construction, main span length, number of spans, and overall bridge length.

2. Date of Construction

This data field was used by VTrans to select the bridges from the Vermont database that date from the period 1940 to 1978. That query resulted in a total of 1,113 individual bridge and culvert database records for interpretation in this study.

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[147] National Park Service, *National Register Bulletin No. 15: How to Apply the National Register Criteria for Evaluation* (Washington, DC: U.S. Department of the Interior, 1993).

3. Main Structure Type

Vermont's bridge types are documented in the Vermont bridge database under the same categorization system used in the NBI database developed by the FHWA. The methods for recording bridges into the NBI are defined in *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges*.[148]

The Vermont database categories "Main Structure Material" and "Main Structure Type" together identify the type of each bridge with a three-digit code. The first digit of the code in the Main Structure Material field indicates the material of construction; the second and third digits in the Main Structure Type field indicate the structural design of the main span(s). There are 10 possible *Material of Construction* types, and 30 possible *Structural Design* types (Table H-1).

There are six general material types: concrete, steel, timber, masonry, aluminum or iron, and "other." There are four specialized material types: concrete continuous, steel continuous, prestressed concrete, and prestressed concrete continuous. As shown in Table H-1, eight of the 10 material types are represented by Vermont bridges built between 1940 and 1978.

The structural design type describes the design of the main span(s) as opposed to that of the approach spans. This study has limited historical analysis to the main spans, which are generally regarded as the defining element of a bridge's engineering character. Some of the structural design types are general, for example, *Suspension*; others are quite specific, such as "*Welded I-Girder with Diaphragms and more than 2 Girders*." Twenty-two of the 30 possible structural design types are represented by Vermont bridges built between 1942 and 1970 (see Table H-1).

The various bridge types in Vermont are therefore identified in the database by combining the eight material types with the 22 structural design types. For example, Concrete, with a the first digit code of 1, and Channel Beam, with a two digit code of 22, results in the bridge type Concrete Channel Beam with the three digit main structure type code of 122. Not all combinations are possible from an engineering standpoint, nor are there bridges in Vermont that represent all the combinations that are possible. Analysis of the Vermont database indicates that there are a total of 59 unique bridge types in Vermont (Table H-2).

4. Main Span Length

The length of the main spans of a bridge is often a direct measure of a bridge's level of engineering technology that is embodied in its design, materials, and construction. As a given span reaches the length limits for its particular structural design, the practical limits of engineering, materials, and construction are also often reached. As spans reach their practical limits, more factors come into play in calculating the effective cost-to-length ratio. As spans get longer, their dead weight increases, their live load weight increases, and piers and foundations become heavier and costlier.

Span length is therefore often the principal factor that governs the selection process of the structural design type of bridge that is chosen for a given site. For short and medium span requirements, several bridge types may be

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[148] U.S. Department of Transportation.

suitable and cost differences become defined by other features of the overall design. Engineers have always exerted extra effort to extend each type of bridge to its maximum span limits. This has been done not only to eliminate or reduce the costly piers required and perhaps achieve a new cost efficiency, but often simply to establish a design record. In reality, the lowest cost-to-length ratio for a bridge type is well below its maximum record span length.

Therefore, for a given structural design type, the longest spans will generally reflect an extraordinary effort in terms of engineering and cost. Great cost is often a good indicator of the importance of the bridge as a transportation corridor and the resulting large commitment of funds to the project. Bridges that are considered long span for their particular type, but not in the record setting category, may not be significant for their engineering attributes but may be for their relative cost to other bridges in their class.

5. Number of Spans and Overall Length

The number of spans of a bridge, including multiple main spans and secondary approach spans, and the overall length of the bridge are a direct measure of the bridge's overall cost. High cost or relative cost can be a useful measure of a bridge's local or state significance. High cost may be an indication that the bridge is the first bridge at that particular location, which may associate the bridge with the opening of new transportation corridors and with the initiation of new settlement/development patterns. The actual number of spans is not of any real engineering significance except in the most extreme cases, where bridges or bridge approaches have been continued for several miles as causeways or viaducts. The number of spans and overall length are factors taken into consideration for the evaluation of each bridge type and are noted when applicable in the registration requirements for each bridge type in Section F.

TABLE H-1

MAIN STRUCTURE TYPE CODES IN VERMONT DATABASE

1ST DIGIT	MATERIAL OF CONSTRUCTION	2ND & 3RD DIGITS	DESIGN CONFIGURATION
1	Concrete	01	Slab
2	Concrete Continuous	02	Stringer/Multi-beam or girder
3	Steel	03	Girder and floorbeam system
4	Steel Continuous	04	Tee beam
5	Prestressed Concrete	05	Box beam or girders-multi
6	Prestressed Concrete Continuous	06	Box beam or girders single
7	Timber	07	Frame
8	Masonry	*08	Orthotropic
9	Aluminum/ Wrought Iron/Cast Iron	09	Truss-deck
*0	Other	10	Truss-thru
		11	Arch-deck (with fill over top)
		12	Arch-thru
		*13	Suspension
		*14	Stayed girder
		*15	Movable-lift
		16	Movable-bascule
		*17	Movable-swing
		*18	Tunnel
		19	Culvert (with fill over top)
		*20	Mixed types (approach only)
		*21	Segmental box girder
		22	Channel beam
		*23	Welded I-Girder w/Diaphragms (more than 2 girders)
		*24	Welded I-Girder w/Diaphragms (2 girders)
		*32	Welded I-Girder w/Floorbeams (2 girders)
		*33	Welded I-Girder w/Floorbeams (more than 2 girders)
		80	Pony truss
		81	Arch-deck (with no fill over top)
		82	Culvert (with no fill over top)
		00	Other

*Types not represented in Vermont between 1820 and 1978.

TABLE H-2

VERMONT BRIDGES 1940-1978 MAIN STRUCTURE TYPES

	TYPE CODE	TYPE NAME
1	100	Concrete Other
2	101	Concrete Slab
3	102	Concrete Stringer, Multi-beam or Girder
4	103	Concrete Girder & Floorbeam system
5	104	Concrete T-Beam
6	105	Concrete Box Beam or Girder-multi
7	106	Concrete Box Beam or Girder-single
8	107	Concrete Frame (Rigid)
9	111	Concrete Arch Deck (w/fill over top)
10	119	Concrete Culvert (w/fill over top)
11	122	Concrete Channel beam
12	181	Concrete Arch deck (w/no fill over top)
13	182	Concrete Culvert (w/no fill over top)
14	201	Concrete Continuous Slab
15	202	Concrete Continuous Stringer/Multi-beam or Girder
16	203	Concrete Continuous Girder & Floorbeam system
17	204	Concrete Continuous T-Beam
18	205	Concrete Continuous Box Beam or Girder-multi
19	207	Concrete Continuous Frame (Rigid)
20	219	Concrete Continuous Culvert (w/fill over top)
21	282	Concrete Continuous Culvert (w/no fill over top)
22	300	Steel Other
23	302	Steel Stringer, Multi-beam or Girder
24	303	Steel Girder & Floorbeam system
24	309	Steel Truss-deck
26	310	Steel Truss-thru
27	311	Steel Arch Deck (w/fill over top)
28	312	Steel Arch-thru
29	313	Steel Suspension
30	319	Steel Culvert (w/fill over top)
31	324	Steel Welded I-Girder w/Diaphragms (2 Girders)
32	380	Steel Pony Truss
33	400	Steel Continuous Other
34	402	Steel Continuous Stringer, Multi-beam or Girder
35	403	Steel Continuous Girder & Floorbeam system
36	405	Steel Continuous Box Beam or Girders-multi
37	407	Steel Continuous Frame (Rigid)
38	410	Steel Continuous Truss-thru
39	412	Steel Continuous Arch-thru
40	413	Steel Continuous Suspension
41	422	Steel Continuous Channel beam
42	423	Steel Continuous Welded I-Girder w/Diaphragms (3+ Girders)
43	424	Steel Continuous Welded I-Girder w/Diaphragms (2 Girders)
44	432	Steel Continuous Welded I-Girder w/Floorbeams (2 Girders)
45	433	Steel Continuous Welded I-Girder w/Floorbeams (3+ Girders)

	TYPE CODE	TYPE NAME
46	500	Prestressed Concrete Other
47	501	Prestressed Concrete Slab
48	502	Prestressed Concrete Stringer, Multi-beam or Girder
49	503	Prestressed Concrete Girder & Floorbeam system
50	504	Prestressed Concrete T-Beam
51	505	Prestressed Concrete Box Beam or Girders-multi
52	506	Prestressed Concrete Box Beam or Girder-single
53	522	Prestressed Concrete Channel beam
54	602	Prestressed Concrete Continuous Stringer, Multi-beam or Girder
55	604	Prestressed Concrete Continuous T-Beam
56	701	Timber Slab
57	702	Timber Stringer, Multi-beam or Girder
58	719	Timber Culvert (w/fill over top)
59	819	Masonry Culvert (w/fill over top)

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