ROBERT JOHN PROWSE
A Monograph

Robert J. Prowse Memorial Bridge (Prowse Family Papers, Private Collection, Concord, NH).

TranSystems & URS Corporation
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Table of Contents

Engineer Robert John Prowse (1906-1969), a native of Concord, New Hampshire, was a leading designer of highway bridges for the New Hampshire State Highway Department, the predecessor agency to the New Hampshire Department of Transportation.[1] He was active from 1934 to 1969, with interludes to serve during World War Two and to work as a consulting engineer with the firm of Steinman & Robinson during 1956-57. Prowse gained national recognition with two prize-winning bridges – the 1958 Squamscott River Bridge (Bridge No. 106/100), carrying Route 101 in Exeter, New Hampshire, and the 1961-62 Ash Street Bridge (Bridge No. 140/120) over Interstate 93 in Londonderry, New Hampshire. Both of these bridges showcased the economical and aesthetic advantages of welded steel girders. Prowse was among a number of bridge engineers nationally who advanced welding over riveting as the preferred modern technique for fabricating steel bridge members. His efforts helped to place New Hampshire at the forefront of welded bridge design.[2]

Prowse was a successful and well-respected civil engineer who worked his way up through the ranks of the State Highway Department. After joining the Bridge Division in 1934, he quickly gained the recognition of his superiors who assigned him work of progressively greater responsibility and complexity. His earliest opportunities to design important bridges were a result of New Deal programs, including the Works Progress Administration (WPA) program to rebuild New England's bridges after the Great Flood of 1936. From 1934 to 1961, Prowse was the designer of no fewer than 180 New Hampshire highway bridges (see Appendix A, Prowse Portfolio). Prowse applied his considerable skills in drawing, design, and mathematics to a wide range of projects from minor culverts to major bridges. These projects were invariably in support of the broader goal of bringing the state's highways up to higher standards in promotion of safe and efficient travel by motor vehicles. In addition to his full-time job, Prowse found time to pass along his knowledge and experience. Beginning in 1946, he taught courses in structural design in the engineering programs at New England College in Henniker, New Hampshire, and at Northeastern University, his alma mater, in Boston, Massachusetts.

In 1962, Prowse was promoted to Assistant State Bridge Engineer, and in January 1969 he became State Bridge Engineer. As a senior official, Prowse had significant administrative responsibilities. He supervised the staff of the Bridge Division, oversaw the work of consultant engineers, reviewed contracts, and developed design and construction specifications. Construction activity was at historically high levels as the State Highway Department worked to complete the interstate highway system, and Prowse's primary goal was to ensure that the state received good value for millions of dollars spent on bridge improvements. During his tenure as Assistant State Bridge Engineer and State Bridge Engineer, the Bridge Division designed and

[1] New Hampshire established the position of State Highway Engineer in 1905. This office was officially reorganized as the New Hampshire State Department of Highways in 1915 and as the New Hampshire Department of Public Works and Highways in 1950. It became the New Hampshire Department of Transportation (NHDOT) in 1986. For the purposes of this monograph, it will simply be referred to as the State Highway Department, which was how it was often referred to in period literature.

[2] For in-depth technical background on these and other of Prowse's bridges, see James L. Garvin and Preservation Company (Ken Story), New Hampshire Bridge 111/115, F. E. Everett Turnpike Bridge No. 13 (Merrill's Marauders Bridge), N.H. State No. 585, New Hampshire Property Documentation, Concord, N.H.: New Hampshire Division of Historical Resources (NHDHR), 2005; James L. Garvin, "Ash Street Bridge" (Robert J. Prowse Memorial Bridge), Bridge No. 140/120, New Hampshire Division of Historical Resources Form No. LON0116, Concord, N.H., NHDHR, 2002.

oversaw the construction of approximately 400 bridges.[3] Prowse retired and passed away following a brief illness in December 1969.

Recurring Themes in Robert J. Prowse's Career

A Culture of Engineering: Technical Standards and Incremental Innovation

An important theme that weaves its way through Robert J. Prowse's professional life is participation in a culture of engineering that emphasized the development and application of standards and specifications to guide technical decision making and inform the development of transportation policy. A corollary to this theme is that technological progress was achieved through incremental innovation. Prowse's significant achievements were never his alone, but always framed by this larger picture of how they advanced broader professional goals. Through one man's life, light is shed on a generation of engineers who collectively made important contributions to the development of New Hampshire's transportation systems but were rarely acknowledged outside of a close circle of associates.

Many engineers, Prowse perhaps among them, would deny their influence, insisting, for instance, that they were merely carrying out the orders of others. Presented with a particular technical problem, they would say they were simply offering solutions and carrying them out. The reality, however, was much more complex in historical perspective. In fact, engineers were often the ones identifying particular problems and presenting options to others – politicians, for instance. The crucial problem in the transportation field in the mid-twentieth century was not so much how to build improved roads and bridges, but how to fund them and give political legitimacy to a nationwide program of improvements that reached its pinnacle with the interstate highway program. Engineers played a crucial role. The data they provided and the technical know-how they exhibited provided politicians and, ultimately, the public with the confidence to support policies that emphasized highway improvements over all other forms of transportation. Prowse nor or any of his colleagues would have been able to accomplish as much as they did without this unprecedented level of funding and political support.[4]

Prowse, like most engineers, was an active member of professional societies. He was a contributor of technical data, especially on the topic of welded steel bridges, and as a senior official of the State Highway Department he also represented New Hampshire's interests through his presence in the American Association of State Highway Officials (AASHO), the American Society of Civil Engineers (ASCE), and the Society of Professional Engineers.[5] By the mid-twentieth century, these organizations wielded considerable influence since lawmakers sought out their advice when crafting transportation policy. Their members represented all facets of the engineering profession working in government agencies, universities, and the private sector.

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[3] Federal Highway Administration, National Bridge Inventory Data, Bridges by Year Built, Available on-line < <http://www.fhwa.dot.gov/bridge/structyr.cfm> [17 June 2009].

[4] For a broader study of highway policy and the role engineers played shaping it, see Bruce E. Seely, *Building the American Highway System, Engineers as Policymakers* (Philadelphia: Temple University Press, 1987).

[5] Prowse was a Registered Professional Engineer in New Hampshire and Pennsylvania; a member of the New Hampshire Society of Professional Engineers; a Fellow of the American Society of Civil Engineers; a member of the National Society of Professional Engineers, and a Member of the New Hampshire Good Roads Association. "Robert J. Prowse," Obituary, *Concord Daily Monitor*, 22 December 1969, p. 21.

Through their publications, conferences, and cooperative efforts, they provided conduits for the sharing of research and new technical information from state to state, as well as mobilization of the profession to support specific government policies. They lobbied for highway funding, established qualifications to practice engineering, and promoted a professional culture that valued technical objectivity as a source of influence.

As an employee of the State Highway Department, Prowse worked within an environment shaped by professional engineering culture and judged by its ability to meet established goals. One of the key tenets was that the state highway system should meet minimum standards of design and quality of construction. The specifications for achieving these goals were written down in New Hampshire's official *Specifications for Highway and Bridge Construction*, first published in 1927 and revised for progressively higher standards every few years.[6] The State Highway Department also published *Instructions to Engineers* (1937), a manual that, among other items, laid out a consistent approach to the preparation of bridge drawings with standard symbols, abbreviations, and procedures.[7] State highway agencies everywhere were wedded to this approach because it provided for predictable outcomes, controlled costs, held engineers and contractors accountable, and ensured that the public's investment in improved roads and bridges could be technologically, financially, and, ultimately, politically justified.

Adherence to specifications and standards was reinforced by administrative procedures of the federal Bureau of Public Roads (BPR, predecessor agency to the Federal Highway Administration). The BPR required that specifications cooperatively developed with the American Association of State Highway Officials (AASHO) and the American Society for Testing Materials (ASTM) be used on all state highway projects receiving federal aid. This accounted for the majority of New Hampshire's primary highway projects and all of its interstate highway projects. As time passed New Hampshire's *Specifications* were increasingly modeled upon the AASHO *Specifications* and frequently referenced them. The specifications were not so tightly written that all of New Hampshire's highway bridges looked like those of other states; federal officials had realized since the inception of the Federal Aid Highway program in 1916 that the states would not accept such tight control and that variances needed to be allowed for differences in climate, geography, character of travel, and even the individual preferences of state engineers. This allowed Prowse, and other bridge engineers of New Hampshire's Bridge Division, to develop their own tendencies but within a circumscribed range. Prowse's career eventually was marked by a long-term specialization in the design of welded steel bridges that, while not unique to New Hampshire, were nonetheless highly characteristic of the preferences of its bridge engineers.

Designing with Drawings

Robert Prowse's work products were principally drawings, the first stage in bringing a bridge into existence. These drawings are a visual form of communication that served to show Prowse and his co-engineers what their ideas looked like, that the design met the required specifications

[6]Updated editions of the Specifications were published in 1931, 1935, 1938, 1941, 1948, 1954, and 1960. State of New Hampshire, State Highway Department, Specifications for Highway and Bridge Construction and Reconstruction (Concord, First Ed., 1927). Titles of later editions vary with year.

[7] State of New Hampshire Highway Department, *Instructions to Engineers* (Concord, 1 February 1937).

and standards, and, when complete, to show contractors all of the information they would need to build a bridge. Bridge design requires an ability to determine the various ways that geography, materials, costs, and other factors control design. These conditions establish parameters for what is technically possible. They also help designers to form a vision in their “mind’s eye.” The systematic transfer of this vision on to paper is the key first step to producing a finished design. The information conveyed in the drawings is overwhelmingly visual, except for notes and charts that specify materials or other details. Bridge drawings are not numerical, except for dimensions, although they are supported by mathematical calculations, sometimes very complex and presented graphically (Figure 1), to determine if parts of the bridge are proportioned correctly for the optimum use of materials and the required degree of safety.[8]

Prowse had all of the necessary aptitude and skill to be an excellent bridge designer. He had a fine drawing hand, an excellent sense of proportion and scale, the ability to fit an immense amount of information into a single drawing in a logical and clear fashion, the vision to see how a bridge would fit within its physical environment, and an understanding of applied mathematics. All of this comes through in his drawings, plan sheets, and graphic analyses, and it allowed him to undertake some very challenging designs. These designs often took the form of statically indeterminate rigid frame and continuous steel stringer bridges, both of which offered the opportunity to make use of beams with shallow, arched soffits while achieving a high degree of

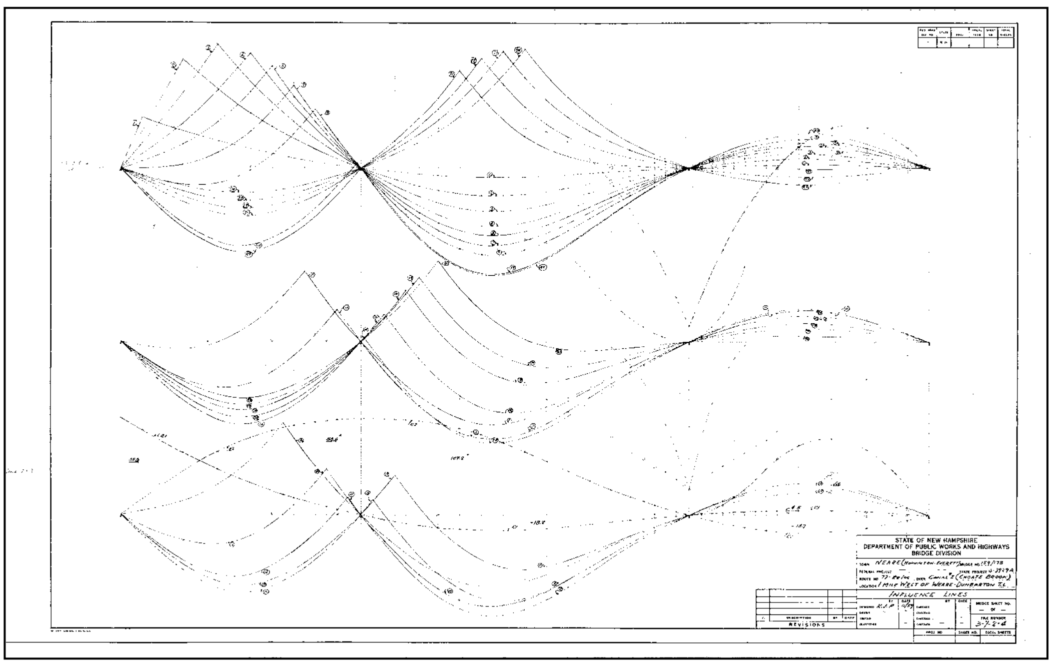

Figure 1. Influence lines for New Hampshire Bridge No. 159/178 in Weare (Route 77 over Canal No. 2) (1959), by R. J. Prowse. Prowse developed a talent for graphic analysis of the moments (stresses) in continuous stringer bridges. The graphics were often works of art in and of themselves. New Hampshire Dept. of Transportation.

[8] For insights into the importance of non-verbal forms of communication in engineering, Eugene S. Ferguson, *Engineering and the Mind’s Eye* (Cambridge: MIT Press, 1992).

economy of material. The best of Prowse's bridges exhibit graceful, simple lines that to the untrained eye belie a high-degree of engineering accomplishment.

Early Life, Influences, and Education

Robert (Bob) John Prowse was born in Concord on 4 September 1906. He was the eldest of four surviving children of John T. (Jack) and Ruth Prowse (Figure 2). Robert Prowse's grandfather was a Cornish quarryman (stone cutter) who immigrated to America in 1875. The Prowse family moved to the North End neighborhood of Concord about 1881. Jack Prowse, Robert's father, established a grocery store and raised his family in the same neighborhood. The grocery, which remained in business and was operated by Robert's brother Edwin after their father's death in 1937, was a neighborhood fixture for more than 50 years.[9]

Robert Prowse was educated in local schools. Family recollections are that he was an active child who enjoyed sports and outdoor activities.[10] He showed an early aptitude for drawing, modeling, and solving puzzles and games. As a young adult, Prowse was described as 6'1" in height with fair complexion, brown hair, and blue eyes.[11]

Figure 2. Robert Prowse (second from right) and His Family, Circa 1923. (All photographs from Prowse Family Papers, Private Collection, Concord, NH unless otherwise noted.)

[9] "John Prowse, Ex-Alderman, Dies In Woods," *Concord Daily Monitor*, 30 November 1937; Ancestry.com. *New York Passenger Lists,* 1820-1957, (Robert Prowse, 1875); "Prowse Family Tree," Prowse Family Papers, private collection, Concord, New Hampshire; Ancestry.com. U.S., Bureau of the Census, Concord, New Hampshire, 1880 p. 158; 1900 p. 266; 1910 p. 69; Jack Prowse died while on a hunting trip in November 1937.

[10] Prowse grew up playing baseball for the Sunset League in White Park, only a few blocks from his home. His father, Jack Prowse, was one of the founders of the Sunset League in 1909 and became a star player. It is the oldest after-supper amateur baseball league in the United States. "Robert Prowse Chosen Coach," *Concord Daily* Monitor, 22 May 1952; Sunset League Historical Marker.

[11] Ancestry.com. *Border Crossings: From Canada to U.S., 1895-1956*, (Robert J. Prowse, 30 June 1933).

Figure 3. Graduation from Northeastern,

In 1924 Prowse was admitted to the Engineering School at Northeastern University in Boston. The school was known for its cooperative plan offering upper classmen the opportunity to take "Engineering Practice," working for one of the many firms or public agencies having a cooperative agreement with Northeastern. When they graduated, engineering students already had worked 72 weeks in their chosen profession. The program was geared toward young men of moderate means who could pay for their tuition and other school expenses while receiving college engineering training and practical experience. From 1925 to 1928, Prowse participated in the Northeastern cooperative plan as an employee with the Engineering Department of the City of Newton, Massachusetts. He served as a rodman and transitman in a survey party headed by Albert Morse, Chief of Party. The work consisted of surveying properties for tax assessment, furnishing line and grade for streets, water and sewer lines, and other city projects.[12] Prowse graduated in 1928 (Figure 3). His senior thesis was *The Design of a Swing Drawbridge over Fort Point Channel, Congress Street, Boston, Massachusetts*.[13] His extracurricular activities included playing the violin in the school orchestra, appearing in a musical comedy production his senior year, and writing for the school newspaper. He also played for the Northeastern varsity baseball team for two seasons.[14]

In the years after college, Prowse continued his education by taking correspondence courses from the Wilson Engineering Corporation of Cambridge, Massachusetts. This popular form of education was a pathway to self-betterment and career advancement. It built on, or reinforced, the knowledge he had gained in college, although a college degree was not required to take the courses. His personal papers include samples of correspondence coursework and tests, which he

[12] Robert John Prowse, Military Personnel Record, Application for Commission or Warrant, U.S. Naval Reserve, 1943.

[13] Prowse's thesis, as a student project based on a current problem in engineering, did not resemble the bridge as built. The Congress Street Bridge, a Strauss-trunnion bascule, was built in 1930 by the City of Boston, Department of Public Works. Historic American Engineering Record, Congress Street Bascule Bridge, HAER No. MA-38, 1984.

[14]The school of engineering was established in 1909 with little equipment and a registration of eight pupils. Fifteen years later, when Prowse entered its halls, Northeastern's engineering program had grown to include over a thousand students. Northeastern University (Boston, MA), *Course Catalog, School of Engineering, 1924-1925,* pp. 18-19, 23; Samuel Nelson Dickinson, *Boston Register and Business Directory* (Boston, 1921), p. 632; Northeastern University Yearbook, *The Cauldron, 1928.* A drawing in Robert Prowse's engineering notebook in the family collection in Huddleston, Va., is suggestive that the Concrete Steel Company employed Prowse as a draftsman preparing shop drawings or samples for customers. [Robert J. Prowse] *Concrete Reinforcing Bars*. Drawing adopted from Boston Warehouse Standard, Concrete Steel Co., 11 April 1927. Bridge Division, New Hampshire Highway Department, 15 January 1938). Several of Prowse's college textbooks, inscribed by Prowse, remain on the reference shelf at the NHDOT Bridge Division. These texts confirm a traditional civil engineer education and include L. B. Johnson, C. W. Bryan, and F. E. Turneaure, *The Theory and Practice of Modern Framed Structures*, 9th ed. (New York: John Wiley & Sons, 1910) and the classic Thomas E. French, *A Manual of Engineering Drawing for Students and Draftsmen*, 3rd ed. (New York, McGraw Hill, 1924). Other books inscribed by Prowse include the classic series of books by Hool & Kinne (1943 ed.); Charles Spofford's *The Theory of Continuous Structures and Arches* (1943 ed.); Thomas Clark Shedd, *Structural Design in Steel* (1934); and Raymond D. Douglass and Douglas P. Adams, *Elements of Nomography* (1947).

typically passed with flying colors. Between 1930 and 1935, Prowse enrolled in at least three correspondence courses – Structural Engineering, Structural Steel Designing, and Reinforced Concrete Engineering. The curriculum included basic problems in statics and the design of typical details, such as riveted steel-truss connections.[15]

Early Engineering Career, 1928-1942

Concrete Steel Company, Boston, Massachusetts (1928)

From June 1928 to November 1928, Prowse was employed as an engineer by the Concrete Steel Company of Boston, Massachusetts. The firm was a supplier of reinforcing steel for concrete structures. Prowse prepared plans for the proper placing and setting of the reinforcing bars. He worked on plans for reinforced-concrete bridges in New Hampshire and Vermont, as well as parts of the Boston & Main Railroad's North Station Terminal in Boston and the Sears Roebuck Building in Boston's Back Bay neighborhood. He also prepared plans for a 40' x 100' swimming pool at the residence of Robert Choate in Springfield, Massachusetts.[16]

Hamilton Bridge Company, Hamilton, Ontario (1928-1932)

Robert Prowse married hometown girlfriend, Doris Lillian Robinson, in Concord on 6 July 1929. In December 1928, he had accepted a position as a structural engineer with the Hamilton Bridge Company, in Hamilton, Ontario, Canada. He and Doris moved to Hamilton where their daughter, Joan, was born in 1931. Prowse retained close ties with his family in Concord. In fact, he was enumerated on the 1930 United States census during a visit with his parents.[17]

The Hamilton Bridge Company was a fabricator of steel bridges and steel work associated with office buildings and skyscrapers, mostly to markets in Canada. Established in 1863, the firm had supplied many of the bridges on the transcontinental Canadian Pacific and Canadian National Railways from Nova Scotia to British Columbia. In 1931, the company completed work on the Canadian Bank of Commerce Building in Toronto, considered one of the finest skyscrapers in Canada at the time. Prowse prepared some of the structural details for the skyscraper. He also prepared shop drawings for the Royal York Hotel in Montreal, a storage building for the Canada Cement Company also in Montreal, and roof details for the Medical Arts Building at McMaster's University in Hamilton, and for several vertical-lift bridges over the Welland Canal in Ontario.[18]

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[15] [Robert J. Prowse] Notebook, Prowse Family Papers, private collection, Concord, New Hampshire.
[16] Robert John Prowse, Military Personnel Record, Application for Commission or Warrant, U.S. Naval Reserve, 1943.
[17] "Prowses Wed Thirty Years," *Concord Daily Monitor*, 27 September 1930; "Prowse Family Tree," Prowse Family Papers, private collection, Concord, New Hampshire; Ancestry.com. U.S., Bureau of the Census, Concord, New Hampshire, 1930, enumeration district 7-14, p. 67.
[18] Business and History – Bridge & Tank Company of Canada Limited, reprinted from Industrial Canada, Centennial Issue, May 1967, Western Libraries, University of Western Ontario. Available on-line <www.lib.uwo.ca/programs/companyinformationcanada/ccc-bridge.htm> [June 11, 2009]; Chris Madsen, "Industrial Hamilton's Contribution to the Naval War," The Northern Mariner, Vol. XVI, No. 1 (January 2006), pp. 21-52; Robert John Prowse, Military Personnel Record, Application for Commission or Warrant, U.S. Naval Reserve, 1943.

For any young engineer who wanted to go into a career of designing structural steel, the Hamilton Bridge Company was a distinguished choice, and it seems probable that Prowse felt fortunate to find a job during the Great Depression, even if it meant moving away from his native New Hampshire. Among family papers are a series of drawings prepared by Prowse for the Hamilton Bridge Company. These drawings are typical journeyman's work. They include a series of riveted column splices as well as some welded T- and I-beam connections, which are of interest because they demonstrate that Prowse was exposed to welding during the early 1930s well before the technique had become standard practice for fabricating structural components.[19]

In February 1932, Prowse was laid off from the Hamilton Bridge Company due to lack of sufficient work. He and his young family returned home to Concord, New Hampshire, where Prowse assisted his father with miscellaneous jobs at the family grocery store while presumably looking for full-time employment in the midst of the Great Depression. In February 1933, he trademarked "Lok-Tite Puzzle" with the State of New Hampshire.[20] Perhaps he had dreams of creating a sideline in the manufacture of these imaginative, wood jigsaw puzzles. Throughout his life, Prowse enjoyed creating customized puzzles for family and friends. He was good with his hands, applying deftness and creativity to many aspects of his personal life and work. He often combined his love of drawing, calligraphy, and poetry into greeting cards that became treasured keepsakes. Tragically, his wife, Doris, died from a burst appendix on 13 May 1933 in Concord. Robert's parents took over the care of their granddaughter, Joan.[21]

Following Doris's death, Prowse's sister, Clara, introduced him to her vivacious friend, Mildred (Milly) Veino. Milly and Clara were nurses at the Margaret Pillsbury General Hospital in Concord. Robert and Milly were married in New York City on 1 June 1934. A son, John James, was born in Concord four years later.[22]

New Hampshire State Highway Department (1933-1942)

Robert Prowse began working for the State Highway Department in the Highway Division in September 1933. He became a member of its "corps" of engineers, a group that took pride in an already impressive record of achievement as a statewide road and bridge-building organization. The department, which traced its origins to 1905 and the appointment of New Hampshire's first State Highway Engineer Arthur W. Dean, had grown from what was initially the work of one man to an organization that employed upwards of 2,000 full-time by the mid-1930s. Originally established to gather data on New Hampshire roads and to offer technical and financial

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[19] [Robert J. Prowse], Notebook, private collection, Concord, N.H.

[20] NH, Secretary of State, Trademark Registration, 14 February 1933, Prowse Family Papers, private collection, Concord, N.H.

[21] H.A.Manning Co., *Manning's Concord and Hopkinton (NH) Directory for the year beginning October 1933* (Springfield, Massachusetts: H.A. Manning Co., 1933), 212; Prowse Family Tree; Personal communication, Joyce Prowse, 2 May 2009; Henry H. Austin, *History, Boscawen-Webster : Fifty Years, 1883-1933* (Penacook, New Hampshire: W. B. Ranney Co., 1933), 252.

[22]Prowse Family Tree, Prowse Family Papers, private collection, Concord, New Hampshire; Personal Communication, Joyce Prowse, 2 May 2009). Bob and Milly began married life in a house in the North End of Concord, but by 1937 had moved to Pembroke not far from Concord. (H.A.Manning Co., *Manning's Concord and Hopkinton (NH) Directory for the year beginning October 1933* (Springfield, Massachusetts: H.A. Manning Co., 1933), 212; H.A. Manning Co., *Manning's Concord and Pembroke (NH) Directory for the year beginning January 1935* (Springfield, Massachusetts: H.A. Manning Co., 1935), 217-218; H.A. Manning Co., *Manning's Concord and Pembroke (NH) Directory for the year beginning January 1937* (Springfield, Massachusetts: H.A. Manning Co 1937), 228.

assistance to town road supervisors, the department was transformed during the 1910s into an organization with ever-growing direct responsibilities for the construction of New Hampshire's trunk-line system, the nucleus of today's primary highway system (U.S. and N.H. numbered routes). Funding for the State Highway Department was provided through vehicle registration fees, and beginning in 1916 aid from the federal government. Since federal-aid appropriations grew faster than the state's ability to match them, a one-cent per gallon gas tax was imposed in 1923 and progressively increased to four cents per gallon in 1928. With a dedicated and growing source of revenues, the late 1920s and early 1930s were a "golden age" in road and bridge construction. During the late-1920s, the Bridge Division was designing an average of 25 to 30 new bridges each year. In 1930, the State Highway Department proudly reported that New Hampshire's trunk-line system of 1,517 miles was "complete," meaning that the roads have been provided with hard surfaces and bridges capable of carrying 15-ton trucks. [23]

Prowse was quickly steeped in the State Highway Department's engineering culture with strong sense of dedication to purpose. This culture promoted the idea that it provided materially to the growth of New Hampshire's economy and the improvement of the everyday life of its citizens through the development of a modern highway system. The engineers were the vital repository of technical knowledge and objective advice on how to best spend millions of dollars on the construction and maintenance of roads and bridges. This role was never more vital to the state's economic health than during the Great Depression because the State Highway Department was one of the few established agencies in a good position to direct large-scale statewide projects that provided economic stimulus and work relief to New Hampshire's unemployed. In late 1932, the Legislature augmented the department's budget with a special appropriation of nearly one million dollars for an unemployment relief construction program during the harsh winter months. Beginning in early 1933 and continuing through 1940, a series of federal New Deal programs also directed millions of dollars in special funding to the State Highway Department, supplementing already hefty regular federal-aid payments. Prowse worked on numerous projects funded through these appropriations, including the 1933 National Recovery Act (NRA), the 1936 Works Progress Administration (WPA), and the 1936 federal Railroad Grade Crossing elimination program. New state laws were also passed to relieve cash-strapped town and city governments of their responsibilities for numerous roads and bridges, transferring these responsibilities to the State Highway Department.[24]

Prowse's first year of work for the State Highway Department was in the Road Division, where he worked surveying and preparing contract plans for state highways. He was head of a survey party that conducted a reconnaissance survey for the route of the Daniel Webster Highway (State Route 3) from Pittsburgh to the Canadian line. [25]

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[23] F. A. Gardner, "New Hampshire's Highway System," *New Hampshire Highways*, Vol. 4, No. 8 (November-December 1926); John W. Childs, "State Highway Bridge Program 1929*, New Hampshire Highways*, (December 1929), pp. 4-5.; James Garvin, "New Hampshire Good Roads Association 100th Anniversary Series: Part I: The Trunk Line Road System," *New Hampshire Highways* (January/February 2004), pp. 25-29; Donald B. Harriott, "History of the New Hampshire Highway Department, *New Hampshire Highways*, Vol. 9, No. 7 (October 1931), pp. 1-6.; *New Hampshire Highways*, Vol. 23, No. 10, March 1969, p. 10).

[24] "New Hampshire Highway History," Typescript on file at NHDOT Planning, Concord, New Hampshire, ca.1957; Untitled typescript [Thirtieth anniversary of road building in New Hampshire], on file at NHDOT Planning, ca. 1935.]

[25] Robert John Prowse, Military Personnel Record, Application for Commission or Warrant, U.S. Naval Reserve, 1943.

In August 1934, Prowse transferred to the Bridge Division. The leaders of the Bridge Division were State Bridge Engineer John W. Childs and Assistant State Bridge Engineer Harold E. Langley.[26] Both men had joined the department during the 1910s. They had shaped the bridge program along lines that promoted then-current trends in modern highway bridge design, moving it away from the days of pin-connected metal trusses and timber bridges to reinforced-concrete and steel girder bridges. They assisted with New Hampshire's *Specifications for Construction and Reconstruction of Roads and Bridges*, first published in 1927 and revised in 1931. The *Specifications* covered topics ranging from the design of riveted connections to procedures for mixing and pouring concrete. All bridge designers were required to have a working knowledge of the *Specifications*. In addition to his statewide duties, Childs served on the American Association of State Highway Officials (AASHO) committee that developed national *Specifications for Highway Bridges*, published in 1935. AASHO specifications were incorporated into and referenced by later editions of New Hampshire's state specifications. Throughout his career, Prowse kept notebooks that helped him record important pieces of technical data that supported application of the *Specifications*, from how to determine the weights of materials to the area and spacing of reinforcing steel in concrete slab decks. In later years, Prowse would assist with updating the *Specifications* to reflect advances in practice.[27]

Figure 4. Working for the NH Highway Department, 1938.

It was an exciting time to be a young, talented engineer, and Prowse took full advantage. He reported to work in the State Highway Department's central office, which was located in a suite of rooms in the Patriot Building at the corner of North Main and Park Streets until 1939 when it moved into the newly completed State House Annex in downtown Concord (Figure

[26] John W. Childs was a native of New Hampshire and a graduate in engineering from Dartmouth College. He began his career as a transit man for the State Highway Department by 1910 (U.S., Bureau of the Census, Henniker Twp., Merrimack Co., NH, 1910 p. 180). In the next decade he married, started a family, and moved to Concord where he moved up the organizational ladder of the State Highway Department, becoming the State Bridge Engineer in 1925 (U.S., Bureau of the Census, Concord City, NH, 1920 p. 263). Harold E. Langley was also a native of New Hampshire. He was born in 1896, the son of Edward (a marine engineer) and Edith Langley (U.S., Bureau of the Census, Durham town, Strafford Co., NH, 1900 p. 157). Following graduation from the Massachusetts Institute of Technology, Langley began working for the state as a "resident engineer" in 1919. He was named Assistant State Bridge Engineer three years later. In 1942 Harold E. Langley took over from John W. Childs as State Bridge Engineer (*Portsmouth Herald*, 22 September 1961 p. 14).

[27] State of New Hampshire State Highway Department, *Specifications for Highway and Bridge Construction and Reconstruction* (Concord, 1927, 1931, 1935, 1938, 1941, 1948, 1954, 1960). Title varies with year. Prowse's engineering notebook illustrates the variety of topics in which a designer needed to be familiar. Included within its pages are charts, diagrams, and drawings, many drawn by Prowse, on such topics as bridge bearings (n.d.); various shapes of reinforcing bars and instructions for detailing them on plan sheets (1938); sectional areas of steel reinforcing bars in deck slabs (1953), radiographic testing of welds (1963), minimum depth of steel beams for uniform loads (n.d.), moments for reinforced-concrete deck slab on steel stringers (n.d.), maximum reactions and moments on various lengths of span for various truck design loads (1955), minimum area of waterway beneath a bridge based on maximum water flows (n.d.), sight distances for passing cars (1946, 1949); calibration of lifting jacks (1966); locating the neutral axis on reinforced-concrete beams (1940); design of flashboards (1935); bridge railing details (1946, 1950, 1960); check list for preparing bridge plans (1959); job descriptions in the Bridge Division (1963); regulations regarding vertical and site clearances over railroads (1956), etc. [Robert J. Prowse], Engineering Notebook, private collection, Huddleston, Va.

4). Bridge design took place in a third-floor drafting room.[28] At each drafting table, the engineers had the tools of the trade – T-squares, triangles, compasses, scales, pencils, erasers, and, of course, a slide rule. Work was organized with more-experienced engineers overseeing the less-experienced engineers with a total of about a dozen engineers employed in bridge design. A typical project might begin with a design concept, usually in the form of sketches and calculations developed by a senior engineer. The design was supported by survey information, detailed notes on the lay of the land where the bridge was to be built, and any other special considerations, such as the need for an aesthetic design to fit the setting. Once there was agreed upon direction, the project was assigned to a designer. For any large or complex project, the designer was a senior engineer, but small, less complex culverts and bridges, or components of larger projects, were often assigned to less-experienced engineers. The earliest plan sheets to bear Prowse's initials confirm this approach to the on-the-job training of younger engineers. Prowse's earliest known design assignment was a 1934 plan to add a sidewalk to the Winnisquam Lake Bridge in the towns of Belmont and Tilton (see p. A-16).[29]

The designer's responsibilities included calculating loads, determining quantities and dimensions, and insuring that the design met the appropriate standards and specifications. As the design became progressively refined, the information was systematically transferred to plan sheets (drawings). Depending on the size and complexity of the project, the number of sheets ranged from one to several dozen or more. Each sheet was recorded with the initials of the designer and the drawer, who was often a junior engineer. In Prowse's first few years in the Bridge Division, his initials often appear as the drawer of other engineers' designs. This was considered an appropriate way for less-experienced engineers to gain experience, demonstrate their competency, and learn the senior engineers' preferred methods.

Once the drawings were complete, another engineer would be assigned to check them for accuracy and completeness. This included independently re-running load calculations, reviewing dimensions and quantities, and checking that they met standards and specifications. Prowse also checked drawings. Invariably, all of the Bridge Division's plan sets made reference to then-current published AASHO and state specifications. Completed plan sets were sent for another layer of review, first for the signature of the State Bridge Engineer, then to the State Highway Commissioner. For federal-aid projects, the signature of an engineer from the Bureau of Public Roads (BPR) was also required. The federal engineer checked that the plans met BPR and AASHO guidelines and was eligible for federal funding. Once all signatures were applied, the project could be advertised for bid and contracted.

As Prowse gained experience with this process, he was given more complex and challenging assignments. The Great Flood of 1936 provided him with the opportunity to design one of his earliest bridges, a steel truss. The flood wiped out dozens of bridges and washed out miles of roadway. The loss of bridges was so great that the federal government provided the New England states a special appropriation for flood bridge replacement under the Works Progress Administration. In assisting this effort, Prowse designed a replacement span for the North

[28] The Bridge Division relocated to the New Hampshire Department of Transportation Building in Concord Heights in 1964. *Annual Report, State of New Hampshire Department of Public Works and Highways* (Concord, 1964), p. 5. James L. Garvin, written communication with authors, August 2009.
[29] NHDOT, Plan No. T3, 1934.

Thetford Road Bridge (Bridge No. 052/153) over the Connecticut River at Lyme. The design was for a conventional riveted, Warren, through-truss – a heavier, more flood-resistant version of the span that was lost.[30] Following the flood, Prowse also designed a temporary suspension footbridge with a clear span of greater than 400' across the Merrimack River at Manchester. The bridge served until dismantled in 1938.[31]

Prowse's development as a bridge designer was fostered by the Bridge Division's senior engineers and observation of the types of bridges that they were designing from the mid-1930s to early 1940s. A review of the Bridge Division's work reveals a full-range of "ordinary" bridge types, mostly of reinforced-concrete or steel. Prowse designed or assisted with the design of reinforced-concrete box culverts, slabs, T-beams, and arches, and of steel truss, stringer, and girder-floorbeam bridges. This wide-ranging experience provided Prowse with the necessary tools to handle almost any aspect of bridge design from the foundations to the railings. Most of these bridges were standard fare, but there were some that were less ordinary, and, in retrospect, likely shaped Prowse's growing interest in rigid frames, welded girders, and statically indeterminate designs.

State Bridge Engineer John W. Childs, who served from 1925 until his untimely death at the age of 54 in 1942, was an early influence on Prowse. Childs was noteworthy for the extensive use of rigid-frame bridges on the state highway system. New Hampshire built no fewer than 80 rigid-frame bridges from 1929 to 1940 with Prowse designing several of them.[32]

The basic engineering principle behind the rigid frame is that the top member (deck slab) is integral with the legs in supporting the loads. Rigid frames could be built of either reinforced-concrete or steel, although reinforced-concrete was the usual choice. One of the rigid frame's advantages is that it reduces the mass of the abutments and thus costly work in the ground. It is also an economical use of materials, and it works well in settings with limited vertical clearance, such as overpasses. Rigid frame bridges have an intrinsic, shallow arch profile, often looking like an upside down "U", because of the material required at the knees where the top and legs meet and where the stresses (moments) are the greatest (in fact, it's not uncommon for rigid frames to be misidentified as arches by laymen).

Rigid-frame bridges were considered to have "extreme adaptability to architectural expression as compared with ordinary types of construction...," according to Arthur G. Hayden of the Westchester County (NY) Park Commission.[33] Hayden is credited with introducing the bridge for Westchester's pioneering parkway system, which he helped to develop starting in the early 1920s. The rigid-frame technology originated in Europe during the last part of the nineteenth century, but it was Hayden who popularized the bridge type through technical articles, an influential 1931 textbook *The Rigid Frame Bridge,* and many handsome bridges. Beginning in the early 1930s, rigid-frame bridges were employed throughout the country for bridges in parks, along parkways, and even some major highways. The bridge type, however, found limited use in the development of statewide highway systems in most states, in part because of the advanced

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[30]James L. Garvin, "100th Anniversary Series Part II: High Water: Rebuilding Bridges after the Floods of 1927 and 1936," *New Hampshire Highways* (March/April 2004), pp. 26-31; *Raging Rivers and the WPA, New Hampshire* (October 1936).
[31]Robert John Prowse, Military Personnel Record, Application for Commission or Warrant, U.S. Naval Reserve, 1943.
[32] New Hampshire State Highway Department, *Annual Reports*, 1929-1940.
[33] Arthur G. Hayden, *The Rigid Frame Bridge* (New York, John Wiley & Sons, 1931), p. vii.

engineering required to analyze the statically indeterminate frames in the 1920s and 1930s. New Hampshire was an exception, and Child's willingness to adopt the design showed confidence in his staff's ability to carry out this challenging work.

The Bridge Division began designing reinforced-concrete, rigid-frame bridges in about 1929. The earliest of these bridges were less than 25'-long, really little more than larger culverts, but by the mid-1930s, the state bridge engineers were designing multiple-span examples with individual span lengths of up to 50'.[34] In 1938, Prowse was assigned the design of the Contoocook River Bridge (Bridge No. 155/084) in the village of White's Mills in the Town of Jaffrey (see p. A-22). The 33'-long rigid-frame bridge was neatly detailed and featured a masonry-faced, concrete balustrade. More impressive was Prowse's design of the 1940 Route 12 Bridge (Bridge No. 081/129) over the South Ashuelot River in Troy, a four-span, 188-ft.-long, rigid frame bridge with a restrained Moderne-styling.

During 1935, Prowse assisted bridge designer R. D. Field with the Dartmouth College Road Bridge (Bridge No. 092/121) over the Ashuelot River in Gilsum (see p. A-17). This four-ribbed, steel rigid-frame bridge was singular among the bridges designed by the Bridge Division during the 1930s. Not only was it steel instead of reinforced concrete, but it featured unusual, haunched girders that were formed by longitudinally splitting the web of wide-flange beams, bending the lower flanges into a curve, and then filling the "gore" or gap that had been formed with fillet-welded steel plate. The tapered, welded legs of the rigid frame were formed in the same manner. The haunched horizontal girders were riveted to the vertical legs. This bridge was likely Prowse's first practical experience with welded bridge girders, and the method of forming the girders bears striking resemblance to the method he would use in his later bridges. It also illustrated a tendency within the Bridge Division's to occasionally stretch itself by trying out a progressive design.[35]

A contemporary bridge may have influenced Prowse's later designs of continuous girder bridges with haunches at each point of support, fabricated by simple means. This was the 1935 Route 10 Bridge (Bridge No. 152/181) over the Ashuelot River in Winchester. Designed by G. R. Whittum (with the plans checked by R. D. Field), this bridge achieved its haunched sections by cutting the bottom flanges from the girders, bending the flanges down in a graceful curved, and riveting a steel gore in the gap thus created. Though using traditional riveting instead of the welding employed on the Gilsum rigid frame, this bridge presaged the fabrication technique that Prowse was later to employ on his Merrill's Marauders Bridge (1952) in Merrimack.[36]

Another bridge that was something out of the ordinary was Prowse's design of the 1936 County Farm Road Bridge (Bridge No. 089/100) over Partridge Brook in Westmoreland (see pp. A-19 and A-20). The six-span, 144'-long bridge was a composite timber and concrete slab with a nail-laminated, 2" x 6", wood sub-deck keyed to a 4.5" to 6.5"-deep concrete overlay. The design was likely suggested by the experiments of J. F. Seiler, an engineer with the American Wood

[34] New Hampshire State Highway Department, *Sixth Annual Report* (Concord, 1929), p. 89.
[35] NHDOT, Plan No. T19 (1935). Prowse assisted Field with the drawings and was the designer of the substructure, deck, and railings.)
[36] Thanks to James L. Garvin of the New Hampshire Division of Historical Resources for bringing this bridge to the authors' attention and providing appropriate verbiage for this paragraph. See also, NHDHR Inventory Form, Bridge No. 152/181, prepared by Lisa Mausolf, NHDOT, Nov. 11, 2008.

Figure 5: Atkinson Depot Bridge (Bridge No. 105/030), Plaistow (NHDOT, Historic American Engineering Record Documentation).

Preservers' Association. Seiler's published the idea in the November 1933 issue of *Wood Preservation* magazine. The first known use was for the approach spans of a 1934 bascule bridge over Old Tampa Bay in Tampa, Florida. The design had the advantage of adapting readily available materials to short spans designed for rural roads with low traffic volumes, although long-term maintenance and labor-intensive construction methods eventually relegated it to limited use in New Hampshire and other states that attempted it.[37]

Two of Prowse's bridges in particular presaged the continuous steel designs for which he would become best known in the 1950s and 1960s. The 1937 Town Road 9 Bridge over Catsbane Brook in Chesterfield is probably Prowse's first attempt at a continuous-design, steel stringer bridge. The three-span, 80'-long bridge featured 18"-deep, wide-flange beams made continuous with riveted splice plates. The span lengths were modest, even by 1930s standards, but the statically indeterminate design showed that Prowse and his supervisors were willing to test him with increasingly more difficult assignments. This was followed by Prowse's far more impressive 1939 Atkinson Depot Bridge (Bridge No. 105/030) in Plaistow (Figure 5, see p. A-23), constructed under the auspices of the Railroad Grade Crossing elimination federal New Deal program. The beams of this ten-span 514'-long bridge were fabricated by combining rolled sections with riveted haunched girders to create variable-depth beams. The rolled sections were wide-flange beams spliced to the haunched riveted plate girders over the piers, creating variable-depth girders of more than 50' span by very economical means.[38]

In each of the above cases, Prowse's rigid frames and continuous steel stringers relied on recent advances in the analysis of statically indeterminate structures. The engineering definition of statically indeterminate is that the reactions from loads are greater in number than the number of

[37] Lichtenstein Consulting Engineers, Delaware's Historic Bridges (Dover, Delaware: 2000), pp. 199-200.
[38] Garvin (2005), p. 11.

independent conditions of equilibrium. This condition is challenging to analyze because it requires the use of theoretical approximations as compared to a statically determinate design where the designer is able to solve for each of the reactions. In the days before computers the calculations to support a reasonably accurate analysis of a statically indeterminate design could take weeks to perform by hand. Despite the complications, the attractiveness of using statically indeterminate designs was strong. They could result in significant cost savings in materials, fabrication, and erection costs. Continuous designs, which are a subset of statically indeterminate structures, also had the considerable advantage of reducing the number of expansion joints, an area of high maintenance in bridge decks due to moisture-related deterioration and the impact of moving vehicles. A continuous-design bridge has fewer expansion joints than a similarly proportioned, statically determinate, non-continuous (simple) design.

For nearly a half century from the 1870s to 1920s, most American professional bridge engineers were taught to avoid statically indeterminate designs. This attitude was changing just as Prowse entered the profession but it still took many years for the engineering profession to develop agreed upon procedures to arrive at reliable solutions. The change was based on advances in engineering research, often conducted at universities. Professor Charles M. Spofford of the Massachusetts Institute of Technology was an early American specialist in statically indeterminate designs. The third edition of his textbook, *The Theory of Structures* (1928), was the first authoritative college-level text to offer simplified methods of calculating the stresses and elastic behavior of statically indeterminate structures using graphic analysis. New Hampshire Assistant State Bridge Engineer Harold E. Langley, an M.I.T. graduate, was a widely recognized expert in the field. He was selected as one of the engineers to revise the second edition of Hoole and Kinne's classic textbook *Movable and Long-Span Steel Bridges* (1924,1943), which included a lengthy, updated section on continuous bridges. Langley gained national recognition in the 1930s for his steel arch designs, including the Chesterfield Bridge over the Connecticut River, which won the American Institute of Steel Construction's award for the most beautiful steel bridge in 1937. There is little doubt that Langley was an important influence in Prowse's development.[39]

Another significant milestone in the development of statically indeterminate continuous designs was the publication of Professor Hardy Cross's "Analysis of Continuous Frames by Distributing Fixed End Moments" in 1932. Cross taught and researched at the University of Illinois, and many engineers cite his work as their first introduction to a practical procedure for analyzing statically indeterminate structures. That Cross's work had the imprimatur of the American Society of Civil Engineers was a significant factor in its acceptance. Potential applications of these advances were discussed at length in engineering journals and at conferences, such as the American Association of State Highway Officials (AASHO), attended by the senior bridge engineers of the federal Bureau of Public Roads and state highway agencies across the country, which in turn incorporated those findings into their design guidelines and specifications.[40]

[39] George A. Hool and W. S. Kinne, eds. *Movable and Long-Span Steel Bridges*. 2nd Ed. Revised by R. R. Zipprodt and H. E. Langley (New York: McGraw-Hill, 1943); "New Hampshire Engineers," *New Hampshire Engineering*, Third Quarter (1953), pp. 7-8. Garvin (2005), p. 10.
[40] Leonard K. Eaton, *Hardy Cross, American Engineer* (Urbana, Illinois: University of Illinois Press, 2006).

New Hampshire's Bridge Division placed these innovative design concepts into practice with the 1934-35 Connecticut River Bridge between Littleton, New Hampshire, and Waterford Vermont, which was being completed just as Prowse joined the division. This bridge no doubt engendered excitement because it represented a new method of analysis and design that offered the ability in multi-span bridges to use steel beams of shallower depth to span greater distances, thus a savings in material and costs. The design also had the ability to be erected with little or no falsework, an important advantage in New Hampshire where construction seasons were short and spring freshets a threat to falsework. Successful experiences prompted more frequent use of continuous girder designs by Prowse and his colleagues, leading to such bridges as Prowse's 1939 Atkinson Depot Bridge. This was a textbook example of how New Hampshire's engineers transferred and built upon successful advances in knowledge promoted through dialogue at the national level. Prowse's observation of, and firsthand experiences with, this approach early in his career likely influenced his desire to participate and make his own significant contributions.[41]

Service in World War Two, 1942-46

Figure 6. Lt. Robert Prowse, 1943-1946.

During 1941 the State Highway Department began feeling the impacts of war. The move to a wartime footing was first noticed early in the year when the federal government ordered that federal-aid allotments be spent only on roads designated by the U.S. War Department as having strategic importance.[42] Another direct impact of the war was a growing shortage of construction materials, particularly steel, which was requisitioned for use by wartime industries. In February 1942, Robert J. Prowse prepared drawings for "standard" timber-truss bridges, several of which were built during the war years due to the unavailability of steel or concrete.[43]

In late 1941, the department's engineers began leaving to do their part in the war effort. In April 1942, Prowse, his wife, Milly, and son, John, moved to Pittsburgh where he took a job doing wartime work with the Engineering Division of Koppers Incorporated. Koppers was an internationally known designer and manufacturer of coke ovens and by-products equipment for the steel and chemical industries. Prowse worked in the Structural Department at Koppers designing industrial buildings to expand plant capacity to meet wartime demands. Prowse designed reinforced-concrete buildings for the production of benzene (derived from coal tar and an important component in synthetic rubber) at the Henry Kaiser coke plant in San Bernadino, California; the Columbia Steel Company coke plant in Provo, Utah; and the Republic Steel coke plant in Cleveland, Ohio. He also designed quenching stations for the Provo and Cleveland coke

[41] Garvin (2005), pp. 9-11.

[42] In general, this meant the U.S.-numbered arterial highways or roads that connected to military bases, sources of raw material, or manufacturing centers.

[43] "New Hampshire Highway History," typescript in the NHDOT Planning Office, ca. 1957; New Hampshire State Highway Department, *Annual Reports*, 1942-43.

plants. For the Inland Steel coke plant at Indiana Harbor, Indiana, Prowse designed a quenching station and a "booster and exhauster" building. For the Lone Star Steel Company in Daingerfield, Texas, he designed a reinforced-concrete screening station and a sulfate storage building.[44]

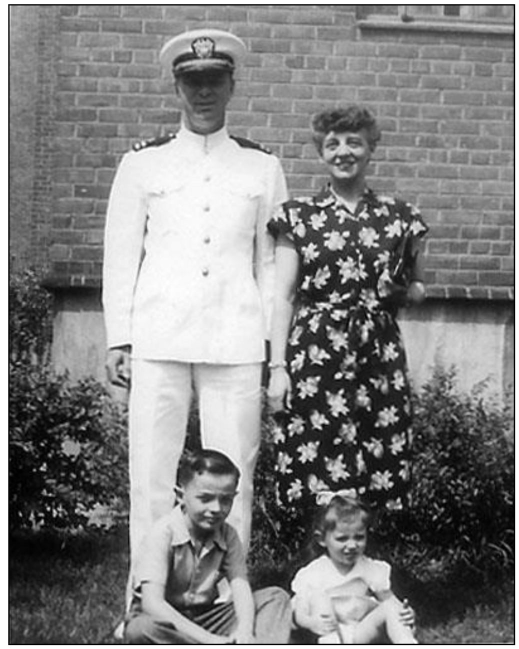

Figure 7. Robert & Milly Prowse with John & Katy in Brooklyn, circa 1945.

While in Pittsburgh, Prowse took graduate courses in structural design at the Carnegie Institute of Technology (now Carnegie Mellon University). He matriculated at Carnegie in 1942 and 1943. Carnegie mainly offered evening courses to men and women who worked during the day. It had a graduate program with a full range of courses in structural engineering. Prowse took courses in indeterminate structures and advanced strength of materials, reflecting his interest in developing a high-level of expertise in structural design.[45] On 6 August 1943, Milly gave birth to their daughter, Kathryn (Katy), in Pittsburgh.[46]

Prowse wanted to serve in the military but his first attempt to enlist in 1942 was deferred due to poor eyesight (Prowse wore glasses and attributed his less-than-perfect eyesight to long working hours under poor artificial light). He reapplied in October 1943 and was accepted into the US Naval Reserve. He reported to the US Naval Training School in Princeton, New Jersey, in December 1943. In February 1944, he graduated with the rank of lieutenant and was assigned to the New York Navy Yard in Brooklyn as an engineering specialist. Milly and the children joined him in Brooklyn (Figure 7).

Prowse worked on the modification of the *USS Brooklyn* and the reconstruction of the *USS Franklin*. The *Brooklyn* was a light cruiser, commissioned in 1936, that saw action in the North Atlantic and Mediterranean theaters from 1942 to late 1944. In December 1944, she reported to the New York Navy Yard for an extensive overhaul and refitting, returning to service in May 1945. Prowse went to sea on the *Brooklyn* for her post-repair sea trial, and this would be his only sea duty. The *Franklin* arrived at the Navy Yard in April 1945 after severe damage from a dive bomber attack near the Japanese mainland in March. The *Franklin* became known as the most severely damaged aircraft carrier to survive the war. She was repaired but never returned to active duty. Prowse's superior at the Naval Yard was the Superintendant of Hulls, so it is likely that Prowse assisted with the steel hull repairs, which, per then-current shipyard practice, would

[44] John J. McKetta and William Aaron Cunningham, *Encyclopedia of Chemical Processing and Design* (CRC Press, 1974).
[45] Robert John Prowse, Military Personnel Record, Application for Commission or Warrant, U.S. Naval Reserve, 1943.
[46] *New Hampshire Highways*, Vol. 23, No. 10, March 1969, p. 10; Personal communication, Jennie Benford, 28 May 2009); Carnegie Institute of Technology, Evening Courses in Engineering, 1941-42; Carnegie Institute of Technology, Engineering, Science and Management War Training, 1942-43. Carnegie does not provide access to individual student enrollment or class records; Prowse Family Tree,

have involved significant amounts of welding. Although speculative, this experience likely played some role in the development of his expertise in welded steel bridges.[47]

Mid-Career Engineer, 1946-1961

Robert Prowse was discharged from active duty on 3 March 1946.[48] Returning to Concord and his position with the State Highway Department's Bridge Division, he entered into what were his most productive years as a bridge designer.[49] This prolific period in Prowse's career was by no coincidence overlapping with a sustained effort by New Hampshire to modernize its highway network. In 1951, the Legislature adopted a 15-year plan to reconstruct or widen approximately 3,700 miles of roadway, including some 300 bridges. Much of Prowse's work was in fulfillment of this plan to bring the state's bridges up to desirable standards based on highway classification. Prowse designed dozens of new bridges to replace old ones that were too narrow or under capacity. He also designed plans to extend or strengthen old bridges to meet updated standards.[50]

This stage of Prowse's career overlapped with the establishment of New Hampshire's toll road and interstate highway networks, placing even greater demands on the Bridge Division. Turnpike planning began with the establishment of the New Hampshire Turnpike in 1947, followed by the Spaulding and F. E. Everett turnpikes in 1953. These high-speed highways required many more bridges than a conventional highway because they were limited access, meaning that all intersecting roads or railroads had to be grade separated. A bridge per mile was a good rule of thumb for rural settings with many more bridges required in urban settings because of the numerous intersecting streets and more closely spaced interchanges. These highways also reflected "balanced design" concepts in which everything about the highway was matched to its design speed, from curvatures to sight distances. This often required deep cuts, high fills, and, correspondingly, longer and higher bridges to maintain the highway's overall design. After the passage of the Federal-Aid Highway Act of 1956 that established funding for the National System of Interstate and Defense Highways, the State Highway Department chose to meet the accelerated construction schedule by increased use of private consultant engineers to design interstate bridges. This was in part due to engineering manpower shortages within the department. Although consultants did most of the interstate bridge design, Prowse had the opportunity to design several interstate bridges, and he worked with consultants to develop their designs.[51]

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[47] Robert John Prowse, Military Personnel Record, Application for Commission or Warrant, U.S. Naval Reserve, 1943; "Robert J. Prowse," *Concord Monitor*, 20 December 1969; Prowse's personal notebook includes a section from his officer training. He copied down basic Navy commands, procedures, and regulations in preparation for quizzes. [Robert J. Prowse], Notebook, private collection, Concord, N.H.; Joseph A. Springer, *Inferno: The Epic Life and Death Struggle of the USS Franklin in World War II* (Zenith Press, 2007). He would have seen welding in extensive use but it is not known if he, for instance, prepared designs or supervised welding crews.

[48] Certificate of Satisfactory Service for Lieutenant Robert John Prowse, US Navy Department, 8 March 1946.

[49] In 1946 Prowse moved his family to a house in Contoocook. A few years after his mother's death in 1950, he and Milly moved back into the family home in Concord's North End. He lived there for the remainder of his life. H.A.Manning Co., *Manning's Concord and the village of Penacook (NH) Directory for the year beginning May 1953* (Springfield, Massachusetts: H.A. Manning Co., 1953), p. 232.

[50] New Hampshire State Highway Department, *Highway Needs in New Hampshire* (Concord, 1948). Malcolm J. Chase, "Planning Our Highways," *New Hampshire Engineering,* Third Quarter 1952, pp. 3-5, 10. Minimum tolerable standards established for rural primary highways were 28' curb-to-curb roadway widths and 20-ton truck design loads.

[51] New Hampshire State Highway Department, *Highway Needs in New Hampshire* (Concord, 1948), pp. 43-47; *Annual Report,*

Figure 8. Prowse Discussing Design of a Floating Stage with Harold W. Langley (l) and John O. Morton (r), October 1950.

Prowse's designs of the post-war years were a continuation and refinement of trends that had taken hold prior to the war. For instance, the 1951 Bloods Brook Bridge (Bridge No. 049/064) on Route 12A in Lebanon (see p. A-28) was similar to the reinforced-concrete, rigid-frame bridges designed by the Bridge Division during the 1930s. If it differed from earlier bridges, it was that it lacked any pretention to architectural adornment, such as a stylized balustrade, relying instead on the intrinsic, shallow-arched soffit and tapered legs of the rigid-frame design for a cleanliness of line.[52]

Prowse was in tune with post-war aesthetics that "form followed function" and that a beautiful bridge was one that expressed itself in a desire for minimum materials, resulting in less weight, less cost, and less visual mass. Prowse's expertise in statically indeterminate structures meshed well with this aesthetic, since the primary purpose of mastering the theory, and the effort expended in the analysis that supported it, was to determine an economical use of material, ultimately arriving at a bridge that was simple to construct and easy to maintain.[53]

In the mid-1950s, Prowse's worked with State Bridge Engineer Harold E. Langley updating the Bridge Division's approach to designing bridges for heavier semi-trailer trucks (Figure 8). This coincided with Prowse's promotion to Chief of Bridge Design in late 1955. The expansion of the

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New Hampshire Department of Public Works and Highways (Concord, 1952), p. 5; Jack Scanlon, "Go Toll, Go Free," *New England Construction* (June 1954, pp. 40-42, 111.

[52] NHDOT, Bridge Plan. No. 3-2-4-11, 1952.

[53] David P. Billington, *The Tower and the Bridge: The New Art of Structural Engineering* (Princeton, New Jersey: Princeton University Press, 1983), pp. 266-76. Prowse did design a handful of bridges with architectural embellishment in the 1950s, such as the Route 101 Bridge over Route 85 in Exeter, a reinforced-concrete rigid-frame with Moderne-styling, but this was more the exception than the rule.

trucking industry and the introduction of semi-trailers was an area of concern for bridge engineers because of the wear-and-tear of trucks on bridge decks as well as safety concerns related to under-capacity or narrow bridges. The typical approach to bridge design, as had been developed by AASHO in 1931, was to design bridges for a "theoretical" truck of a certain weight, typically 10-ton or 15-ton in the 1930s, but new heavier truck designs were required by the 1950s. During 1955, Prowse developed a series of tables and graphs for designing bridges of various lengths and materials for the H-20, S-16 (or HS-20) design load rated for a semi-truck with a gross-vehicle weight of 36 tons.[54]

Welded Steel Bridges

Prowse found a perfect expression for post-war engineering ideals in the design of variable-depth, welded steel girder bridges, marrying his prior experiences with welding and statically indeterminate design. These welded girder bridges would become Prowse's "hallmark."

In 1952, Prowse was the designing engineer for the F. E. Everett Turnpike Bridge No. 13 (State Bridge No. 111/115) over the Souhegan River in Merrimack, also known as the Merrill's Marauders Bridge (see pp. A-32 and A-33). This was the first bridge in New Hampshire, and among the earliest in the nation, to make use of shaped welded girders with curved haunches. The three-span, 224'-long bridge featured twelve steel stringers placed on 8' centers, with each stringer being a composite of rolled wide-flange members with welded plate-girder haunches above the two piers. The haunches, in a technique similar to that used with the 1935 Dartmouth College Road Bridge in Gilsum, were fabricated by cutting the lower flanges of rolled sections and curving them to form the soffit. The gaps or "gores" thus formed were filled with steel plates shop-welded to the severed webs. The ends of the haunches on the central span of the bridge were attached to the adjacent rolled sections by field splices of high-strength bolts, themselves a relatively new technology, which, like welding, was challenging the long-reigning supremacy of riveting.[55]

Merrill's Marauders Bridge was a transformative work for Prowse, establishing the precedent for his later award-winning designs. The key technological refinement was the use of welding to fabricate the curved haunches of the girders. This offered Prowse the ability to proportion the beam to best approximate its true structural form with the greatest depth where the stresses were greatest, and the shallowest depth where the stresses were least. This, in particular, appealed to a designer like Prowse who apparently enjoyed the challenge of translating a complicated design idea on to paper. The curve of the beam could be designed to follow the lines of influence (moments) determined through graphic analysis (See Figure 1). A bonus was that from an aesthetic viewpoint, a long, deep beam could be fabricated by welding that was not visually disrupted by clusters of rivets and gusset plates.

Prowse was not the only highway bridge designer enthusiastic about the possibilities of welded steel bridges in the post-war years. States on the leading edge of welded design included

[54] FHWA, America's Highways, 1776-1976 (Washington, D.C., 1976), p. 432; [Robert J. Prowse], Engineering Notebook, private collection, Huddleston, Va.

[55] For extended discussion of the technical background of these bridges, refer to Garvin (2002) and Garvin (2005).

Connecticut, New York, and Kansas, which reported successful welded steel bridges during the 1940s. By 1955, at least 22 states reported that they had used welded beams. Welding was slowly but surely overtaking riveting as the preferred method of fabricating structural steel components. In part, this was an effect of the thousands of wartime workers who had been trained in welding in shipyards, aircraft plants, and other factories. This created a pool of experienced welders that had not existed prior to the war. No less transformative was the growing body of data from university and government labs demonstrating the effectiveness of welding. This was complemented by the development of standards and specifications by professional organizations like the American Welding Society. This gave Prowse the tools he needed to justify the use of welding from the cost, constructability, and safety perspectives. Prowse was a student of this data, and his Merrill's Marauders Bridge reflected an understanding of then-current ideas about the appropriate use of welding in structural design. Welding was almost always described as being more cost-effective than riveting because of the use of less labor and the ability to form up the beams without having to use heavy equipment to punch holes. Prowse was no doubt aware of these results and hoping to duplicate them in New Hampshire when he undertook the design of the Merrill's Marauders Bridge. Although there were precedents to this design in a few other states, Prowse's design still placed New Hampshire's well ahead of most states.

Given the importance of welding to Prowse's career achievements, it is appropriate to offer some background on the history of welding. The adoption of welding was one of the most important refinements in structural steel design during the twentieth century, but it took many decades to replace the long-customary method of fabricating beams using rivets. Traditionally, when bridge builders wanted beams of greater depth than the available rolled sections, they had turned to built-up riveted beams.[56] The technique of building up beams by riveting plates, angles, and channels had been used by the railroads prior to the Civil War. Of course, welding was not unknown; it had been done for centuries by blacksmiths heating and hammering together metal parts, but its use for connecting structural members did not begin until the early twentieth century and the development of arc-welding where an electric current provides the welding heat. The arc-welding technology saw its earliest structural application in steel-frame building construction starting in the late 1910s. The Westinghouse Electric Company of Pittsburgh was a leading promoter of the technology, and Westinghouse is usually credited with building the nation's first weld-connected truss bridge at its Chicopee Falls, Massachusetts, plant in 1927-28, and the nation's first welded plate girder bridge at its East Pittsburgh, Pennsylvania, plant in 1928.[57]

The application of welding to bridges, particularly for truss connections and minor repairs in the field, spread during the 1930s. Some bridges, like New Hampshire's 1935 Dartmouth College Road Bridge, explored the possibilities of fabricating shaped beams, but it was not until the 1940s that American engineers and contractors began thinking seriously about fabricating large beams and girders under controlled shop conditions. These beams found limited acceptance

[56] Beam depth is determined by the length of span, beam spacing, and design load – the longer the span, wider the spacing, and/or the heavier the load, the deeper the required beam given similar properties to the material. Prior to the development of rolled, wide-flange beams in 1908, the practical span limits of a rolled beam were usually well under 50 ft. Even with wide-flange beams, span lengths of about 80 ft. are rarely exceeded.
[57] Gilbert D. Fish, *Arc-Welded Steel Frame Structures* (New York: McGraw-Hill, 1933).

Figure 9. Tremont Street over the Contoocook River in Boscawen.
State Bridge No. 131/035 (Photograph taken by Patrick Harshbarger).

immediately before and after World War II, particularly with promotion by the James F. Lincoln Arc Welding Foundation and the American Welding Society, which published its first edition of the *Welding Handbook* in 1942. New Hampshire's *Specifications* (1941) reflected the tentative acceptance of welding by bridge engineers when it required that the "heating of steel" be undertaken "only by permission of the bridge engineer." [58]

In states that did not move early to adopt welding, engineers either held on conservatively to tried-and-true riveting or expressed legitimate concerns that welding did not have enough of a track record to prove its long-term practicality. The viability of welded connections under high stresses was a matter of some concern, as was the lack of convenient methods for inspecting welds and repairing defective welds. These concerns were not unjustified; fatigue cracks have been a problem with some welded girder bridges over the years, and it took some time to develop convenient procedures for inspecting welds with radiography.[59] A significant step forward in the campaign to promote welding was the collaborative work of the federal Bureau of Public Roads (BPR) and the American Society for Testing Materials (ASTM) to develop specifications for structural steel alloys best suited to welding. These steels – identified by the ASTM designations A373 introduced in 1954 and A36 introduced in 1960 – had high yield points and rapidly expanded the scope and volume of welded structures. Prowse's later bridges made use of these new steels.[60]

58 State of New Hampshire Highway Department, *Specifications for Highway and Bridge Construction* (Concord, 1 May 1941), p. 172.

59 In the past 30 years, fatigue cracks, especially in butt-welded splices, have been an area of major concern for bridge designers and inspectors. Bridges have developed them in various parts of the country, occasionally requiring emergency repairs. A large body of research deals with this topic and methods to inspect and retrofit splices. NHDOT reports that it has not been a problem with New Hampshire's bridges. American Iron and Steel Institute, *Steel Bridge Construction: Myths and Realities* (2007), pp. 18-19.

60 American Welding Society, *Welding Handbook* (1942); James G. Clark, ed. *Comparative Bridge Designs* (Cleveland: James F.

In 1953 on the heels of the completion of the Merrill's Marauders Bridge, Prowse designed the Contoocook River Bridge (Bridge No. 131/035) on Tremont Street in Boscawen (Figure 9, also see p. A-34). The three-span, continuous, steel-stringer bridge was similar to Merrill's Marauders Bridge, but at 264' from abutment to abutment was 40' longer. The Contoocook River Bridge, like the earlier Merrill's Marauders, achieved continuity of the beams by using high-strength bolts for the field splices, but original plans prepared by Prowse show that his intention was to make the Tremont Street Bridge a fully welded bridge.[61]

The Contoocook River Bridge exhibited other refinements that make it an important touchstone in the evolution of Prowse's engineering legacy. One was the use of reinforced-concrete "hammerhead" piers, a single-stem pier with a flared, hammer-shaped cap that came into prevalent use during the 1950s and made use of higher-strength concretes. Prowse gave the hammerheads a curved profile, similar in proportion to the curve of the girders, thus subtly joining in composition the steel superstructure and the reinforced-concrete substructure. He would frequently return to hammerhead piers in future bridge designs. Another significant detail was Prowse's decision to place the web stiffeners of the girders on the inside faces of the outer haunches for improved appearance. This simple decision removed visual clutter from the curved haunches and any hint of disruption from the line of the beam's curved lower flange.[62]

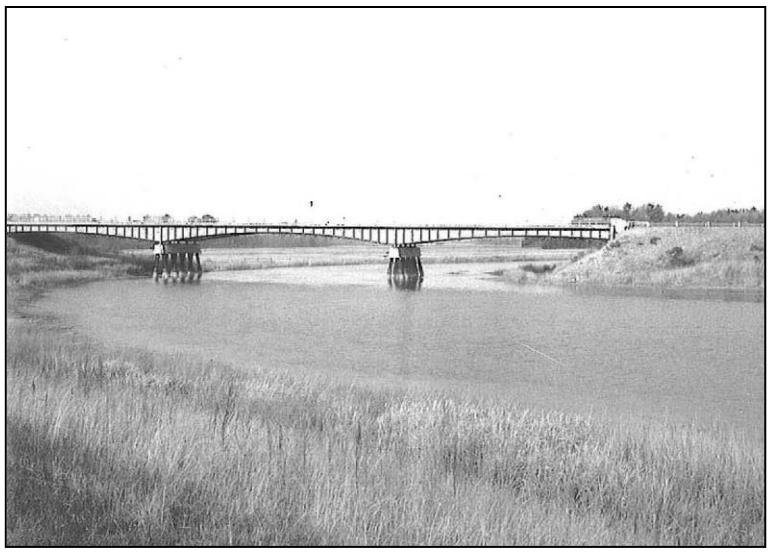

Figure 10. Squamscott River Bridge (Bridge No. 106/100) between Exeter and Stratham. Source: NHDOT Bridge Card.

The 1957 Cold River Bridge (Bridge No. 082/065) carrying Route 12 in Walpole (see p. A-38) represented the next stage in the evolution of Prowse's welded girder designs. There Prowse used beams that were welded end to end, with no splicing in of rolled sections nor use of high-strength bolts to achieve splices. This allowed Prowse to extend the curve of the soffit for a smoother transition between the straight and curved sections of the haunched beams resulting in more pleasing lines.

Lincoln Arc Welding Foundation, 1954); James G. Clark, ed., *Welded Interstate Highway Bridges* (Cleveland: James F. Lincoln Arc Welding Foundation, 1959.]

[61] See Plan Sheets 1 and 10 of NHDOT, Bridge No. 131/035, Plan No. 3-3-3-13. The plans do not record why high-strength bolts were substituted for welds at the beam splices. Likely reasons are constructability issues and contractor preferences. Thanks to James L. Garvin of the NHDHR for pointing out this detail.

[62] NHDOT, Bridge Plan No. 3-3-3-13, 1953.

Figure 11. Canal No. 2 Bridge on N.H. Route 77 in Weare (Photograph taken by Patrick Harshbarger).

Similar to the 1957 Cold River Bridge was Prowse's 1958 Squamscott River Bridge (Bridge No. 106/100) carrying Route 101 between Exeter and Stratham (Figure 10, see pp. A-41 and A-42). At 306' long, the bridge was Prowse's longest three-span, continuous welded stringer design to date, and it achieved him a third honorable mention and a $1,000 award in a design competition sponsored by the James F. Lincoln Arc Welding Foundation. Qualifying entries were required to meet the general specifications of bridges for the National Interstate and Defense Highway System as established by AASHO as well as the "Standard Specifications for Welded Highway and Railway Bridges" of the American Welding Society. Prowse noted that "span lengths such as those in this design are beyond the limits of the standard rolled sections, yet the average weight per foot of girder is substantially less than the heaviest 36" WF [wide flange] section …This economical use of material makes it possible to utilize the welding procedures to effect a more functional design and at the same time to impart simply pleasing lines to the structure … Erection costs can be held to a minimum by shipping each girder in three parts, enabling the erector to place all sections without erection of falsework."[63] The bridge's superstructure was composed of five lines of variable-section continuous plate girders, with a maximum depth of 8' at the piers and a minimum depth of 3' at mid-span. The change in depth was achieved through a shallow curving of the lower-flange of the beams, thus achieving the "pleasing lines" that Prowse admired.

The Squamscott River Bridge well represented the advances that Prowse and his colleagues in the Bridge Division had made in the design of indeterminate, continuous, welded steel girder bridges, and the award from the Lincoln Arc Welding Foundation gave national recognition to their efforts. The bridge was featured in the 1960 edition of the foundation's publication, *Welded Interstate Highway Bridges*. This book emphasized the economic and aesthetic advantages of welding as illustrated by best-practice examples from around the United States as part of the foundation's campaign to persuade engineers to adopt welding in place of riveting and bolting.

[63] James G. Clark, ed., *Welded Interstate Highway Bridges* (Cleveland, Ohio: James F. Lincoln Welding Foundation, 1960), pp. 7-8;

The inclusion of Prowse's Squamscott River Bridge placed New Hampshire at the forefront of these trends.[64]

In 1959, Prowse designed an even longer example of the three-span design, a 448'-long bridge to carry the relocation of Route 77 over Canal No. 2 in Weare (Bridge No. 159/178) (Figure 11, also see pp. A-46 and A-47). At the haunches, the all-welded beams measured 74" deep, only 2" deeper than the 1952-53 Merrill's Marauders Bridge, but nearly twice as long made possible in part by the use of the new A373 high-strength steel for welding. The Route 77 Bridge further exhibited Prowse's skill as a designer as he deftly handled site conditions that required it to be built with a thirty-degree skew and a four-degree vertical slope to maintain a smooth transition with the approach roadways. In 1960, Prowse completed the design of three more three-span continuous, welded, steel-stringer bridges to carry a relocation of US 202/9 in Hopkinton. These three nearly identical bridges measured 278', 312', and 312' long.[65]

In late 1958 or early 1959, Prowse turned his attention to designing a welded steel rigid-frame bridge. This challenge did not have any immediate application to a project in New Hampshire, so it was probably suggested by a competition announced in September 1958 by the American Bridge Company, a division of United States Steel. The competition was to design "a more imaginative and effective use of steel in the design of highway overpasses" for the interstate highway system. All entries were to conform to AASHO standards to carry a two-lane overpass over a four-lane interstate highway. American Bridge received three hundred entries from 264 professional engineers and thirty-six college engineering students. A panel of six engineers judged the entries on the basis of originality of design, utilization of the properties of steel, economy, and appearance.[66]

Prowse was awarded an honorable mention and a prize of $1,000 for his welded rigid-frame design concept. Writing several years later about the three-span rigid-frame design, Prowse stated that, "For some time this writer has felt that the use of a series of short spans smacks of expediency, overstandardization, and unwarrented [sic] haste in trying to 'get the job out'." His design was for a continuous, all-welded frame having a central span of 150', end spans of 45', and a vertical clearance of 25'. For safety, the central span provided a clear, unobstructed crossing of a four-lane, median-divided highway with no piers in or immediately adjacent to the travel portioned of the roadway.[67]

In early 1960, Deputy Commissioner Robert H. Whitaker requested that consulting engineers Clarkeson Engineering Company check into the feasibility of adapting Prowse's award-winning rigid-frame design to an actual site along Interstate 93. Clarkeson recommended a location in Londonderry where Ash Street would cross the four-lane, limited-access interstate. In executing Prowse's design concept, Clarkeson composed a bridge of five, parallel steel rigid frames

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[64] Ibid.; "Robert J. Prowse," *Concord Monitor*, 20 December 1969; Garvin 2005, pp. 16-17; "Exeter Bypass Officially Opens Sept. 1," *Portsmouth Herald*, 25 August 1960, p. 8; Garvin, N.H. Historic Property Documentation, NHDOT Bridge 111/115 (Merrill's Marauders Bridge), pp. 16-17.
[65] NHDOT, Bridge Plan Nos. 3-5-1-1 (Tamworth, 1955) 3-5-4-16 (Walpole, 1957); 3-6-2-1 (Exeter-Stratham, 1958); 3-7-2-14 (Weare, 1959); 3-7-2-5 (Hopkinton, 1960); 3-7-3-4 (Hopkinton, 1960); 3-7-3-8 (Hopkinton, 1960).
[66] "Welded Structures Dominate Bridge Competition," *Welding Engineer* (December 1959), p. 50.
[67] Robert J. Prowse, "All-Welded Frame Type Stringer Span Design Proved by Model Tests," *Modern Welded Structures,* Volume I (Cleveland: James F. Lincoln Arc Welding Foundation, 1963), pp. 103-05; Robert Prowse $1000 Winner For Arch Plans," Unattributed newspaper clipping, 22 October 1959; Garvin 2005, pp. 17-18; Garvin 2005, pp. 17-18.

supporting a composite concrete deck. The bridge had a center span of 146’ flanked by side spans of 35’, thus closely matching the proportions in Prowse’s original design concept. The Ash Street Bridge (Bridge No. 140/120) (see p. A-48) was reportedly the first welded steel rigid-frame overpass built on the interstate highway system in the United States, although not the first of its type having been preceded by at least two welded rigid-frame pedestrian bridges: the 1954 Garrison School Bridge in Kansas City, Missouri, and the 1960 Cemetery Access Bridge in Milwaukee, Wisconsin.[68]

In August 1963, United States Steel took out a full-page ad in *Civil Engineering*, a magazine aimed at the engineering profession, to promote its role in awarding Prowse for the design concept of the Ash Street Bridge. The ad, which featured a photo of Prowse and the bridge, commended Prowse for combining “beauty and safety in an economical bridge.” The ad also provided one of the few instances of Prowse being quoted directly on what he had tried to achieve in his design:

> “Few highway departments have funds to invest in looks alone, but today’s better steels and design concepts are making aesthetically pleasing structures quite economical. Take the new Ash Street Bridge in Londonderry. One look at the long fabricated center span suggests increased costs. In fact, the price of fabricated steel was about 13% per ton over conventional beam construction. But continuous welded-plate girder, rigid-frame design reduced steel requirements in three ways: continuous design cut weight per foot, welding eliminated various angles and details, and fabricated girders permitted the use of thinner flange material.
>
> Besides, by eliminating the center pier, we saved $6,000 to $8,000, and probably duplicated this saving on side abutments. By minimizing abutment size, we have greatly reduced future maintenance problems – particularly those arising from today’s road salts and freezing and thawing cycles which often produce malignant sores which have to be cleaned out by jack hammer.” [69]

In 1964, the Ash Street Bridge won an award from the American Institute of Steel Construction for its outstanding aesthetic design. This award, given annually from 1928 to 1973, was intended to stimulate “a deep and lasting interest in improved bridge design” with winners receiving a stainless-steel plaque and engraved certificate.[70]

Prowse continued to investigate the possibilities of welded rigid-frame bridges, although he never had the opportunity to see another one to actual completion. In 1963, he published an article in *Modern Welded Structures* describing a refinement in the design. It was what he termed a “portal ring,” resulting in the removal of an oval-shaped portion of the web at the frame leg. Prowse believe that it would simplify field splices and facilitate shipping and erection. Due to the

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[68] Both of these bridges won awards as the most beautiful bridges in their class from the American Institute of Steel Construction. *American Institute of Steel Construction Prize Bridges, 1928-1973* (1973); Garvin 2005, pp. 17-18; “Sleek, Sturdy Roads to Scenery, New Hampshire’s Highways,” *Engineering News-Record* (7 November 1963), pp. 32-36; New Hampshire Division of Historical Resources, Individual Inventory Form, Ash Street Bridge (Robert J. Prowse Memorial Bridge), Bridge No. 140/120 (2002).

[69] United States Steel Ad, *Civil Engineering* (August 1963), p. 121.

[70] American Institute of Steel Construction, Prize Bridges, 1928-1973.

unusual shape and size of the structure, Prowse checked his design by building model beams out of cardboard and plexiglass. He tested them on a Begg's Deformeter, a devise developed by Professor George E. Beggs of Princeton University, to measure deflection under varying conditions of loading. In the article, Prowse concluded that "this design is basically a departure from the solid web, in the leg region, to meet the design objectives." [71] Today, steel rigid-frame bridges are sometimes designed without solid-web legs confirming the practicality of Prowse's "portal ring" innovation.

Structural Engineering Instructor (ca. 1946-1960)

After his return to the New Hampshire Highway Department in 1946, Robert Prowse taught advanced and basic engineering evening courses on a part-time basis in the Graduate Division of Northeastern University, his alma mater. According to a 1952 course description, the curriculum emphasized "the practical application of theory to design of reinforce concrete, steel and timber structures." Prowse also conducted evening courses in structural theory and design at New England College in Henniker, New Hampshire, from 1951 until 1959. Henniker was established in 1946 for the purpose of offering a college education to men and women returning from service in World War II. [72]

Mackinac Straits Bridge (1956-67)

In March 1956, Robert Prowse took a leave of absence from the State Highway Department to work with consulting engineers Steinman & Robinson of New York City as a Project Engineer. Headed by David B. Steinman, the noted designer of long-span suspension bridges, the firm was engaged in the design and construction supervision of the famed Mackinac Straits Bridge connecting the upper and lower peninsulas of Michigan. In January 1956 Ray M. Boynton, a long-time associate of David B. Steinman, gave a lecture on the Mackinac Straits Bridge project to personnel from the State Highway Department. Shortly thereafter, Prowse requested a leave-of-absence.[73] While working for Steinman & Robinson, Prowse assisted in the design of the Mackinac Straits Bridge and several other structures.[74]

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[71] All-Welded Frame Type Stringer Span Design Proved by Model Tests," *Modern Welded Structures,* Volume I (Cleveland: James F. Lincoln Arc Welding Foundation, 1963), p. 105.

[72] *New Hampshire Engineer*, First Quarter (1952), n.p.] (*New Hampshire Highways*, "Robert J. Prowse Receives Bridge Engineer Appointment," Vol. 23, No. 10, March 1969, p. 10; "Robert Prowse $1000 Winner For Arch Plans," Unattributed newspaper clipping, 22 October 1959; Graduating class sizes in engineering at New England College were typically between 10 and 20 graduates. *New England College Yearbooks*, 1951-1960.

[73] Photograph of event in Prowse Family Papers; Ray M. Boynton was a graduate in civil engineering from the University of Maine, and he had worked for Steinman since 1928. Henry Petroski, *Engineers of Dreams: Great Builders and the Spanning of America* (New York: Alfred A. Knopf, 1995), pp. 364-66).

[74] *Concord Daily Monitor*, "Robert J. Prowse," 20 December 1969; *New Hampshire Highways*, "Robert J. Prowse Receives Bridge Engineer Appointment," Vol. 23, No. 10, March 1969, p. 10; The exact circumstances of Prowse's engagement with Steinman are not documented, but the Department was having significant difficulties retaining experienced engineers due to low levels of pay in comparison to other states and private consulting firms. A combination of pay and the prestige of working on the Mackinac Straits Bridge may have attracted Prowse. *Annual Report, State of New Hampshire Department of Public Works and Highways* (Concord, 1956), p. 6.

The main span of the Mackinac Straits Bridge is an 8,614'-long (from anchorage to anchorage) suspension bridge with a center span of 3,800'. When built, the bridge was second in clear-span length to the 1933-37 Golden Gate Bridge, which has a center span of 4,200' but overall length of about 2,000' less. Overall, the Mackinac Straits Bridge, including approach roadways and approach spans, measures nearly seven miles long. The bridge was a massive project engaging more than 350 engineers and over 10,000 workers over the course of a four-year construction schedule from 1954 to 1958. In addition to assisting with the Mackinac Straits Bridge, Prowse consulted on other bridges for Steinman including the Rumsey Street Bridge in Seneca Falls, New York.[75] Prowse's personal papers do not include any engineering notes on the Mackinac Straits Bridge, but they do include a whimsical poem entitled, "The Big Mac – Not the Burger but the Bridge." (Figure 12).

THE BIG MAC-
NOT THE BURGER-
BUT THE BRIDGE

Spanning blue and crystal waters
Gleaming golden in the sun
Cables shining just beyond the northern ridge
If you want to see St. Ignace,
And you don't know how to swim,
Take the Big Mac - not the Burger -
But the Bridge.

Watch 'er shine,
Spanning Michigan from Huron,
Watch 'er shine.
Seven miles of road that you're on all the time
Like some royalty beyond the northern ridge.
That's my Bridge

Oh, watch 'er shine
Worth a hundred million dollars and she's mine.
She's a great big pill to swaller
But she's fine.
Just beyond the northern ridge -
It's my Big Mac.
That's my Bridge.

If you want to get away
To where the green is ever green,
Camping out up on some lone pine ridge,
Well, I've got to look at 'er,
It's tucked way within the woods,
Take the Big Mac - not the Burger -
But the Bridge.

Watch 'er shine,
Spanning Michigan from Huron,
Watch 'er shine.
Seven miles of road that you're on all the time,
Like some royalty beyond the northern ridge.

Oh, watch 'er shine.
Worth a hundred million dollars and she's mine.
She's a great big pill to swaller,
But she's fine.
Just beyond the northern ridge
It's my Big Mac
That's my Bridge.

Spend a dollar then go over,
In your truck, in your Land Rover.
That's my Big Mac,
That's my Big Mac.
It's my Bridge

Figure 12. Mackinac Bridge Poem by Robert Prowse.

Old Man of the Mountains (1958)

In 1958 Robert Prowse was part of a team of highway department and state parks personnel that prevented the *Old Man of the Mountains*, the famed rock formation at Franconia Notch and the official emblem for the State of New Hampshire, from imminent collapse. In 1954 a study by University of New Hampshire

[75] Ray M. Boynton, who apparently recruited Prowse, was in charge of the design of the Mackinac Straits Bridge substructure and towers, so there is some likelihood that Prowse was assisting Boynton with this part of the landmark bridge's design. The David B. Steinman records at the New York State Library do not include correspondence with Prowse or details related to the hiring practices or operations of the firm, which was renamed Steinman, Boynton, Gronquist & London in 1962. The Steinman firm was absorbed into Parsons Brinckerhoff in 1988. "Seneca Falls Bridge Plan Voted," *Syracuse Herald-Journal* (November 27, 1956), p. 2, column 2; William Ratigan, *Highways over Broad Waters: Life and Times of David B. Steinman* (Grand Rapids, Michigan: William B. Erdmans Publishing Co., 1959), p. 298.

engineers determined that a fissure in the "forehead boulder" had widened enough to destabilize the rocky profile. Some earlier attempts at stabilization, including driving steel spikes had not arrested the movement. Prowse was the chief design engineer for a combination of large turnbuckles, steel rods, U-bolts, and clevis pins that were custom designed to delay the inevitable collapse. His solution, as shown in original drawings (see pp. A-43, A-44, and A-45), which, incidentally, were like everything else conforming to AASHO and State Highway Department specifications, was to "post-tension" the rock formation by the strategic placement of tie bars. At the ends of the tie bars were clevises attached to U-shaped anchorages or eye bolts driven into the rock. The tie bars had turnbuckles that were tightened after jacking the bars into position using a system of cables. To provide a firm connection, concrete was placed at selected locations in the cracks between the boulders. This design forestalled the collapse of the rock face for 45 years.[76]

Figure 13. Prowse in the Bridge Engineering Division, 1961.

Senior Engineer, 1962-69

Assistant State Bridge Engineer (1962-68)

In 1962, Robert J. Prowse was promoted to Assistant State Bridge Engineer (Figure 13).[77] Prowse's day-to-day responsibilities shifted from that of a designer to that of an administrator, although he clearly continued to play a very influential role in design. This was a pressure-filled time for the department's engineers as they pushed forward to complete the interstate highway system within the 15-year schedule contemplated by federal legislation in 1956. Most states, including New Hampshire, had found that it took several years to gear up for the interstate program, and that the traveling public's appetite for the new highways was greater than the pace at which they could be built. By the early 1960s, intense political pressure was building as Congressional committees inquired into the slow pace of progress, symbolized on the ground by many miles of disconnected interstate. New Hampshire, with the head start given by its turnpike system, was able to advance more quickly than most states, but Interstate 89 and Interstate 93 were far from complete in 1962. The section of Interstate 89 from New London to Grantham opened on schedule in 1968, and the section of Interstate 93 near Woodstock opened in 1974, some three years behind the original completion date.[78]

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[76] The Old Man of the Mountains had been a well-known tourist attraction since the mid-nineteenth century. It became the official state emblem in 1945. "How Long Will The Old Man Last?" Granite State Vacationer, 23 June 1972; NHDOT, Plan No. 3-6-2-5 (1958). Prowse also had an illustrated talk on the Old Man of the Mountains. "Brentwood Historical Society," Portsmouth Herald, 12 November 1963, p. 23.
[77] *Concord Daily Monitor,* "2 Veteran Engineers Retire From Service," 8 December 1969, p. 9.
[78] "Opening Dates of New Hampshire Interstate System," typescript in the NHDOT Planning Office, ca. 1975; Bruce D. Zimmerman, "The Granite State Looks to Its Highways," *Public Works* (June 1959), pp. 131-33; Sleek, Sturdy Roads to Scenery, New Hampshire's Highways," *Engineering News-Record* (7 November 1963), pp. 32-36.

As an administrator, Prowse was no doubt keenly aware of engineering manpower shortages. This was not an issue unique to New Hampshire, but a long-term challenge to state highway departments throughout the United States. Simply put, universities were not graduating enough civil engineers to fill the need. In part this was because students were being attracted to other fields of engineering, including nuclear, aerospace, computer, electrical, and chemical, which offered many exciting new possibilities. State highway departments were further burdened by low pay scales and rarely were able to compete with the salaries offered by private industry. A complicating factor was the aging of the departments' senior engineers. New Hampshire, like most states, had hired many engineers in the 1910s and 1920s, and these men reached retirement age in the late 1950s to 1960s. The Bridge Division was a case in point with state bridge engineers Harold E. Langley retiring in 1961 and Robert Prowse retiring in 1969.[79]

The State Highway Department looked to address manpower shortages by developing cooperative programs and internships with universities in an attempt to attract graduates, as well as adopting new labor-saving technologies such as computers. Prowse was involved in the application of computers to cut down on the time that bridge engineers spent calculating loads and quantities. In December 1962, Prowse participated in a panel session at the 9th Annual New Hampshire Highway Conference on the topic of "The Use of Electronic Computers in Highway Engineering." During the 1960s, main-frame computers were used to calculate the moments in statically indeterminate structures and to calculate the quantities of materials, particularly in earth excavations. These were time-consuming calculations to do by hand, sometimes taking weeks. A computer, once programmed, could complete these same calculations in a matter of hours using punch cards. The State Highway Department rented computer time from the State Liquor Commission, which had acquired New Hampshire state government's first IBM computer sometime in the early 1960s. The State Highway Department purchased its own computer from RCA in 1966.[80]

Another aspect of Prowse's administrative responsibilities was coordinating with the federal Bureau of Public Roads (BPR) and representing the state at national meetings, particularly the American Association of State Highway Officials (AASHO) that developed national technical guidelines and policies for highways. The relationship of the State Highway Department to AASHO was an especially critical one since BPR engineers approved state plans for federal aid based on AASHO guidelines. One of Prowse's duties was to help ensure that New Hampshire's bridges met federal technical requirements. For example, a 1963 memorandum in Prowse's notebook summarizes the topic of bridge railings, noting that the Bridge Division and the BPR agreed that New Hampshire would no longer use various types of stone, concrete, and wire-rope bridge railings in preference to tubular steel railings.[81]

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[79] Engineering manpower shortages were chronic at the Department and identified as a critical challenge as early as 1947. *Twenty-Fifth Annual Report of the State Highway Department of New Hampshire* (Concord, 1947), p. 27; *Annual Report of the State of New Hampshire Department of Public Works and Highways* (Concord, 1964), p.6; Review of Department of Public Works and Highways: Suggested Staffing Patterns (1959) in Archives Miscellany, Box 043013, New Hampshire State Archives, Concord.

[80] Carol Howard. Interview. May 6, 2009. Ms. Howard, who now works at the New Hampshire State Archives, began working in the State Highway Department's computer room in 1967. She recalls that Prowse was a frequent user of the computer; "Highway Conference," *Portsmouth Herald*, 1 December 1962, p. 10.

[81] State of New Hampshire, Inter-department Communication, January 18, 1963 in R. J. Prowse, Notebook, private collection, Huddleston, Va.

Although administration consumed most of Prowse's time, he did occasionally become directly involved in the design of a bridge and entered his initials on the drawings as the bridge designer. In July 1962, he designed the general plan of the Route 106 Bridge (Bridge No. 160/178) over US Route 202/9 in Concord (see p. A-49), another of his handsome, three-span continuous, welded steel girder bridges. In November 1966, he did likewise for the Baker River Bridge (Bridge No. 117/143) carrying Route 3A/25 in Plymouth (see p. A-50). In both instances, Prowse designed and drew the general plan sheet but left detail sheets to be designed and drawn by other engineers. In 1967, Prowse assisted in the design of another long-span, welded steel girder bridge over the Connecticut River (Bridge No. 065/134), this time on Route 12/103 between Claremont, New Hampshire and Ascutney, Vermont (see p. A-51). Departing from the three-span units typical of Prowse's prior designs, this bridge had a single, four-span continuous unit with center span lengths of 180' and side span lengths of 156'. The 180' spans are the longest welded, steel-girder spans known to have been designed by Prowse.

During the mid-1960s, Prowse developed an interest in orthotropic, steel-deck bridges. Orthotropic bridges utilize steel deck plate as both the top flange of steel stringers and as the underlay for the roadway's wearing surface. The deck and the stringers are integrated by welding the lower edges of the deck to the top edges of the stringers, integrating them into a single unit that acts in concert to carry loads. The orthotropic technology developed in Europe after World War II and became a "hot" topic of conversation and investigation amongst American engineers in the 1960s. The first major orthotropic-deck bridge in the United States was the Poplar Street Bridge over the Mississippi River at St. Louis, Missouri, constructed in 1965-66.

Prowse's orthotropic design was a natural outgrowth of his long-term fascination with welding technology and statically indeterminate structures. In 1965, Prowse published an article in *Modern Welded Structures* detailing his investigations of a proposed 650'-long, welded orthotropic plate deck bridge. These investigations may have been completed with some thought that they could be applied to the Connecticut River Bridge at Claremont-Ascutney, since the continuous-design stringer and span lengths were nearly identical to the bridge that was eventually built with a conventional deck. Prowse concluded that an orthotropic deck bridge could offer cost savings over a conventional design if the contractor following a specific construction sequence in which the deck units were fabricated making "optimum use of shop cutting and welding techniques" requiring high-speed automatic welding machines. To illustrate the design, Prowse built an elaborate cardboard model with breakaway sections. Although Prowse's investigation did not result in the construction of any orthotropic-deck bridges in New Hampshire, it did represent the ultimate progression of his thinking on the design and fabrication of welded bridges.[82]

[82] Robert J. Prowse, "Slim Trim Welded Bridge Deck Has Strength and Durability," *Modern Welded Structures*, Volume II (Cleveland: James F. Lincoln Arch Welding Foundation, 1965), pp. C-7 to C-13; Garvin (2005), pp. 19-20. Prowse's model remained on display in the NHDOT building for many years.

State Bridge Engineer (1969)

In January 1969, Robert J. Prowse was named the fourth State Bridge Engineer of New Hampshire by State Highway Commissioner Robert H. Whitaker. He replaced Bernard H. Langley (no relation to Harold Langley) who was promoted to Assistant Chief Engineer of the State Highway Department. Later that same year, on 1 December 1969, Prowse retired citing ill health as the reason. Three weeks later, on 20 December, Prowse passed away following a brief illness associated with a diagnosis of cancer. One can only speculate what he might have accomplished given a longer life than 63 years.[83]

During Prowse's brief tenure as State Bridge Engineer, two important bridge projects were seen to completion. The first was the opening of the Connecticut River Bridge at Claremont-Ascutney in September 1969, a bridge that Prowse co-designed. The second was the opening of the new Amoskeag Bridge over the Merrimack River at Manchester, designed by consulting engineers Fay Spofford & Thorndike.[84]

Near the end of his career, Prowse had also been developing an idea for an improvement in bridge roller bearings. This idea was presented posthumously as an article in *Modern Welded Structures, Vol. III* (1970) describing an expansion bearing that was more compact and lighter weight than conventional bearings.[85]

In March 1973, Robert J. Prowse was honored posthumously for his service to the State of New Hampshire by a legislative act to change the name of the award-winning Ash Street Bridge in Londonderry to the Robert J. Prowse Memorial Bridge. A commemorative bronze plaque was attached to the bridge railing at a ceremony held on 30 October 1973 (Figure 14).[86]

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[83] *New Hampshire Highways*, "Robert J. Prowse Receives Bridge Engineer Appointment," Vol. 23, No. 10, March 1969, p. 10.

[84] A sidebar to this story is that both bridges were built on sites that were identified as having archaeological sensitivity. Efforts to recover artifacts prior to construction were among the first applications of Section 106 of the National Historic Preservation Act of 1966 by the State Highway Department in fulfillment of its federal-aid obligations. The Amoskeag Bridge, in particular, was controversial since it resulted in the destruction of the Smyth site, an area rich with prehistoric artifacts and the location of Governor Frederick Smyth's mansion. Thaddeus M. Piotrowski, *The Indian Heritage of New Hampshire and Northern New England* (Jefferson, North Carolina: McFarland, Reprint ed., 2002), pp. 3-4. These archaeological projects were symbolic of a sea change in American highway policy that Prowse glimpsed, if only briefly. By the late-1960s, state highway departments across the nation were confronted with the "freeway revolt," a diffuse movement whose members opposed specific highway improvements for a variety of reasons including social, ecological, cultural, technological, and economic grounds. At the national level, Congress responded passing laws reining in the independence of highway officials to choose new highway alignments and complete projects, especially through urban neighborhoods or environmentally sensitive areas. Section 4(f) of the U.S. Department of Transportation Act of 1966, Section 106 of the National Historic Preservation Act of 1966, the National Environmental Policy Act of 1969, the Clean Air Amendments of 1970, and the Noise Control Act of 1972 required highway officials to consider the impacts of their projects in ways that would have been unthinkable in earlier decades. As a result, almost every aspect of highway construction procedures changed because of the new environmental regulations, transforming the federalist system of highway administration in ways that continue to guide New Hampshire Department of Transportation activities to this very day, including the preparation of this monograph as mitigation for alterations to the historic Merrill's Marauders Bridge. Mark H. Rose and Bruce E. Seely, "Getting the Interstate System Built: Road Engineers and the Implementation of Public Policy, 1955-1985," *Journal of Policy History*, vol. 2, no. 1 (1990), pp. 25-55.

[85] "Bridge Roller Bearing Has Simplified Design," *Modern Welded Structures, Vol. III* (Cleveland: James F. Lincoln Arc Welding Foundation, 1970), pp. D-8 to D-9.

[86] Chapter 27, "An Act Changing the Name of the Ash Street Bridge in the Town of Londonderry to the Robert J. Prowse Memorial Bridge," *Laws Passed January Session, 1973* (Concord, N.H.: State of New Hampshire, 1973); "Bridge Designer Honored At Dedication Ceremonies," *Manchester (N.H.) Union Leader*, 31 October 1973 p.38.

Figure 14. Dedication of the Robert J. Prowse Memorial Bridge, 1973.

Conclusion

Robert J. Prowse was an extraordinarily talented and gifted bridge designer who made significant contributions to the development of New Hampshire's highway system. Most engineers prefer to be known by their works, not their words. Prowse's body of work speaks volumes. In a career that spanned four decades, Prowse personally designed at least 180 bridges and was the administrator overseeing the design of more than 400 bridges. A life-long employee of the State Highway Department, he worked within an organization that historically tempered technological progress with an emphasis on controlling costs and adherence to specifications and standards. In the development of welded steel bridges, Prowse more than fulfilled the State Highway Department's mandate to provide economical, efficient, and safe bridges. Taking full advantage of advances in welding technology, he created bridges that were recognized by his peers as among the most beautiful bridges in the United States. His welded girder bridges, in particular, met the highest aesthetic ideals of the time with designs that emphasized function over ornamentation, lightness over heaviness, and economy over excessiveness. These bridges placed New Hampshire at the forefront of the application of welded girder technology, which became the dominant technology for the fabrication of steel bridge members in the latter half of the twentieth century.[87]

[87] The two dominant superstructure materials of the last half of the twentieth century were steel and prestressed concrete. New Hampshire remains a "steel bridge" state. According to National Bridge Inventory data, New Hampshire has 1,428 steel bridges

Acknowledgments

This monograph owes much of its character and detail to the care and consideration that members of the Prowse family gave to their collection of papers, photographs, and memorabilia. Special thanks are given to John J. Prowse, deceased, the son of Robert J. Prowse. John Prowse had a long and distinguished military career after graduating from The Citadel, The Military College of South Carolina, and earning a master's degree in language arts from San Francisco State College. In 1967 he brought his family back home to the Old North End neighborhood of Concord. In 1992 he became a curator/archivist for the U.S. Department of the Interior Museum Services. He cataloged papers from Ellis Island, The Longfellow House in Cambridge, and Theodore Roosevelt's Sagamore Hill home. John Prowse also brought his talents to bear on the organization of his own family's records. Heartfelt thanks are also extended to John's wife, Joyce Prowse, and his sister, Kathryn Willoughby, who granted access to the Prowse family papers and shared their stories. A special thank you also to Jeffrey Prowse who generously shared his grandfather's engineering notebook.

The staff of the New Hampshire Department of Transportation was welcoming and provided access to Robert Prowse's bridge records and plans. Joyce McKay of the Bureau of Environment provided administrative support. Jill Cunningham of the Bureau of Environment helped the team find their way around the building, made introductions, and scanned several graphics. David E. Powelson, P.E., and Robin L. Brown of the Bureau of Bridge Design and Karen Gola of the Bureau of Bridge Maintenance and their staffs gave invaluable support, including scanning Prowse's drawings.

James Garvin of the New Hampshire Division of Historical Resources shared his extensive knowledge of New Hampshire bridges and provided important insights.

A number of repositories provided useful information regarding the education and teaching career of Robert J. Prowse. These included the Carnegie Mellon University Archives, Pittsburgh, Pennsylvania (with special thanks to Jennie Benford who produced a lot of information in a short amount of time); The Northeastern University Archives & Special Collections, Boston, Massachusetts; and the New England College Library, Henniker, New Hampshire. The National Archives in College Park, Maryland provided information on activities at the New York Navy Yard where Robert J. Prowse was stationed during the Second World War. All photographs of Robert J. Prowse are courtesy of the Prowse family, Prowse Family Papers, Private Collection, Concord, New Hampshire. Bridge Photographs were taken by Patrick Harshbarger in May 2009.

Opportunities for Further Research

Prowse's success was built on a foundation established by his predecessors in the Bridge Division, and he carried that progressive tradition forward. Further research into the background and careers of bridge engineers John W. Childs, Harold E. Langley, and G. R. Whittum, among others, would add to this interesting chapter in the state's transportation history. These engineers

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and 843 bridges of other materials, including 149 prestressed-concrete bridges (Federal Highway Administration, Dec. 2008).

are worthy of historical study, and perhaps monographs, although it would be extremely fortunate to find as rich a collection of primary source materials as was available for the Prowse monograph.

The primary limitation to placing Prowse's legacy more fully within a larger national context is that the history of mid-twentieth-century bridge technology is a relatively new field of inquiry. There is yet to be a synthesis of the data, and most data that is available is in the form of state-by-state inventories and compliance studies. Very few of these studies have focused more than briefly on the topic of post-1945 bridge technology, let alone welded girders. Advances in welding technology and shop practice played a significant role in Prowse's designs, but no historians have yet to undertake a study of those practices to determine, for example, the changes that made the curved girder feasible. This is an important area of study that could use a nation-wide context for the birth of a technology that is still current today.[88]

The ability to compare Prowse's legacy with that of other state bridge engineers is also limited for similar reasons. While it is clear that New Hampshire was among the earlier states to apply continuous-design principles to highway bridges, and among the very few states that were quick to take advantage of haunched welded girders, it is currently difficult to make direct and specific comparisons and connections with what was happening in other states.[89] The Prowse monograph is a case study that will advance the national context but more studies will be needed before a fuller picture emerges. Key questions include, what were there factors that led some states and their engineers to develop particular technologies? What made one state's bridge division progressive and another's conservative in the application of the new technologies? Who were the significant engineers in advancing successful technologies, like welded girders and prestressed-concrete beams? These are important avenues for exploring the nature of technological change and its impact on the built environment. These studies may even have practical lessons. They will broaden the understanding of older bridges, which today's engineers must maintain and inspect. They may also suggest ways in which inherited tendencies (both realized and unrealized) continue to shape the work products of state bridge organizations. In some cases, insights into how and why earlier engineers chose to do what they did can even be of great importance (for example, Minnesota's I-35W bridge disaster and its causes rooted in the history of the design and inspection of that bridge's gusset plates).

A specific area of Robert Prowse's career that could use further research is his work with Steinman & Robinson on the Mackinac Straits Bridge. There is the possibility that some records or plans exist with the Mackinac Bridge Authority that would shed light on his contributions to the Big Mac's (not the burger's) design.

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[88] Thanks to James L. Garvin, NHDHR, for his willingness to exchange thoughts on this subject. Personal Communication, Aug. 2009.

[89] Lichtenstein Consulting Engineers, "Historic Context for Bridge-Building Technology in Michigan, 1956-1965", Michigan Department of Transportation, Lansing, Michigan, 2007; "Bridge-Building Technology in Ohio, 1951-1960," Ohio Department of Transportation, Columbus, 2004; "Historic Context for Bridge-Building Technology in Georgia, 1956-1965," Georgia Department of Transportation, Atlanta, Georgia, 2007; "Historic Context for Bridge-Building Technology in North Carolina," North Carolina Department of Transportation, Raleigh, 2004; "Historic Context for Bridge-Building in South Carolina," South Carolina Department of Transportation, Columbia, 2006.

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