
Historic Jack Arch Bridges of New Hampshire

Inventory and Significance Study



Old NH Route 11 Bridge over Merry Meeting River, New Durham, NH, built 1926. NH Highway Department photo, 1941

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1.0 INTRODUCTION

This report was compiled by Historic Documentation Company, Inc. (HDC) for Hoyle Tanner and Associates, Inc. (HTA) to meet cultural resource permitting requirements set forth by the NHDOT Cultural Resource Committee (Committee).

The purpose of this report is to compile data and information regarding New Hampshire's Historic Jack Arch bridges to enable the state's cultural resource managers to make informed decisions regarding the management of these significant and endangered properties.

The jack arch bridge in its various forms has played an important role in the development of the primary and secondary road systems in the United States from the late 19th century up until roughly World War II. In New Hampshire, the jack arch bridge was embraced by the New Hampshire Highway Department about 1920 when standardized plans were drawn to facilitate the uniform, economical and rapid construction of the bridge type by the state and local municipalities. As a result, over 100 bridges of the type are estimated to have been built in New Hampshire. Thirty-seven have been identified as remaining, of which ten are "red-listed" due to structural deficiencies and will soon require major repairs, replacement, or bypassing. Many of the remaining 27 bridges have functional or structural deficiencies to some degree and will be, in all likelihood, slated for replacement within the next decade or two. It is therefore imperative that a full understanding of the history and application of this bridge type in New Hampshire be obtained.

To that end, this report begins an organized process of gathering and analyzing data and historical information pertaining to the development and use of the jack arch bridge type in New Hampshire. General information on the development of the bridge type has been gathered through historical literature research; information specific to New Hampshire's jack arch has been derived primarily by examining plans and records in the NHDOT Bridge Design Section, studying prior reports and inspecting bridges in the field.

The results of the data gathering are presented in two tables. Table 1 is a listing of the known existing jack arch bridges and is believed to be complete although more jack arch bridges that have been mis-categorized in the bridge records may turn up. Table 2 is a listing of bridges no longer extant, plus those currently approved for replacement; it is not a complete list and for the most part includes only the jack arch bridges still existing at the time of the 1982 Statewide Historic Bridge Inventory. A cursory examination of the older bridge plans on file and old bridge cards for bridges replaced indicates there were many more jack arch bridges built than the 81 listed in the two tables. The intent of the lists was to gather sufficient information about the jack arch bridges that were built in New Hampshire to understand the variations in design and identify the important character defining features. The study found 37 existing jack arch bridges and 44 bridges previously replaced or now approved for replacement.

2.0 HISTORICAL DEVELOPMENT OF THE JACK ARCH BRIDGE TYPE

2.1 ORIGIN OF THE "JACK ARCH" FLOOR SYSTEM

The so-called¹ jack-arch concrete floor system that was commonly used to encase short-span steel beam or stringer bridges in New Hampshire during the first half of the twentieth century has its origins in mid-to-late nineteenth-century fireproof mill and factory construction. The idea of encasing iron I-beams in *beton* for strong, economical and fireproof building construction was studied by American engineer W.E. Ward in the early 1870s.² Ward conducted tests on what he called "composite beams" and determined "that a system of iron beams reinforced with beton can be made to sustain weights many times greater than the iron beams alone" and that "it affords a perfect defense against the interior destruction of buildings by fire."³

During the 1870s and perhaps earlier, various types of arched masonry floor systems incorporating I-beams and concrete were employed for fireproof building and factory construction. The arches were formed with flat or corrugated sheet metal, brick, or wood formwork that rested on or were hung from the bottom flanges of the beams and then filled with concrete. When the beams were widely spaced and the arches shallow or "flat," the concrete was typically reinforced with expanded metal or woven wire and reinforcing bars. The Roebling Arch-Floor System is one example that was widely used (Figure 2.1).⁴

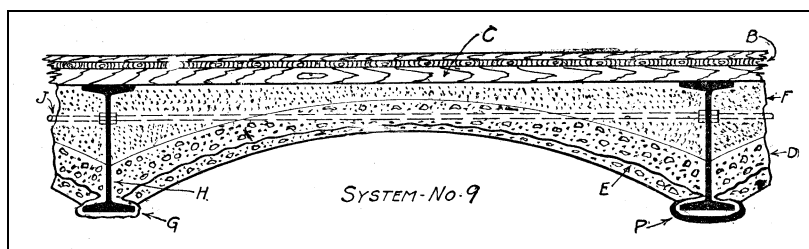


Figure 2.1: Roebling Arch-floor System for fireproof factory construction (Tucker 1908, p. 75).

In factory construction the arched concrete floor was adopted because of its low cost and fireproof characteristics and was cast around the I-beams to prevent them from melting and collapsing during a fire. The I-beams were designed to carry the entire live and dead floor load, and often the load of formwork used in forming the floor as well. They were therefore not designed as composite-beam construction, although they functioned as such. The arched concrete floor slabs, cast between and around the beams, constituted a series of short and wide parallel arches with a width-to-span ratio commonly of 10:1 or greater. The arches at the edges of the slab functioned as tied arches, their thrust restrained by lateral steel rods interconnecting the beams at or near the bottom flange.

2.2 APPLICATION OF THE JACK ARCH TO BRIDGES

The first use of the beam and arched concrete floor system for bridges has not been determined but may date to the 1870s or earlier. The Berlin Iron Bridge Company claimed in their 1889 catalog that bridges of the type had been in service for more than fifteen years.⁵ In his 1876 treatise on "Iron Highway Bridges" Alfred P. Boller states that a "very excellent floor is one made with brick arches turned between the beams, and laid in cement mortar, very similar to the ordinary fireproof floor."⁶ Boller provides a drawing of the floor system but does not state if a bridge of the type was constructed (Figure 2.2).

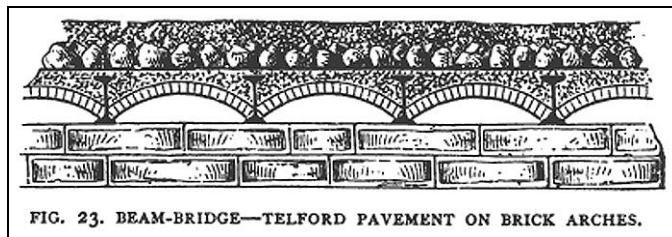


Figure 2.2: design for jack arch bridge floor, 1876 (Boller 1879, p. 76).

In 1896 the Boston & Albany Railroad used transverse I-beam jack arch floors on overhead through plate girder highway bridges in the Newton, Massachusetts grade crossing elimination project.⁷ The roadway was carried on brick arches with concrete fill that afforded both resistance to fire and corrosion from locomotive exhaust. Steel sheet forms, left in place, were used to form the arches carrying the sidewalks (Figure 2.3). The steel forms were cheaper than the brickwork and were not subjected to the locomotive exhaust.

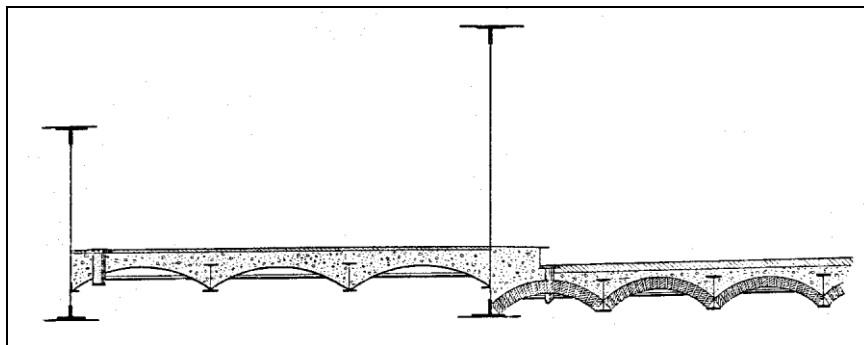


Figure 2.3: Jack arch highway bridge, over railroad tracks, 1896 (Chamberlain 1898, p. 63).

In 1898, F.W. Patterson, Allegheny County [Pennsylvania] Engineer, built an I-beam jack-arch floor highway bridge near Pittsburgh (Figure 2.4). The Pittsburgh bridge had a span of 28' and incorporated "expanded metal arches sprung between and imbedding I-beam girders."⁸ The design used rolled steel beams, 18" fascia beams and 20" intermediate beams, and concrete encasement placed over arched wood forms that were removed after the concrete had set. The concrete was technically reinforced concrete due to the embedded expanded sheet metal, a feature seldom seen in the simple short span jack arch highway bridges built in great numbers by state and local road building crews in the ensuing decades.

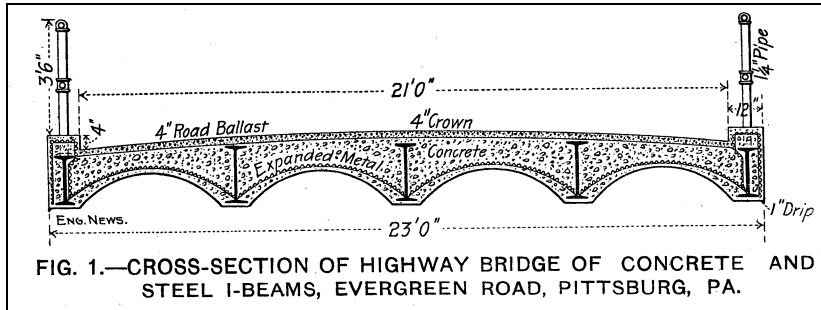


Figure 2.4: Jack arch highway bridge, Pittsburgh, 1898 (*Engineering News*, 1899, p. 50).

In *Road Making and Maintenance* (1900), Thomas Aitken describes and depicts a highway bridge "formed of cast iron beams and jack arching" using "masonry arches springing from the lower flanges of the beams."⁹ Over the arches, presumably of brick, concrete was placed to fully encase the beams. The beams were joined transversely with iron tie-rods 1-1/2" to 3" in diameter spaced 5 to 8 feet apart (Figure 2.5). The extent to which cast iron beams were used for jack arch bridges was not determined.

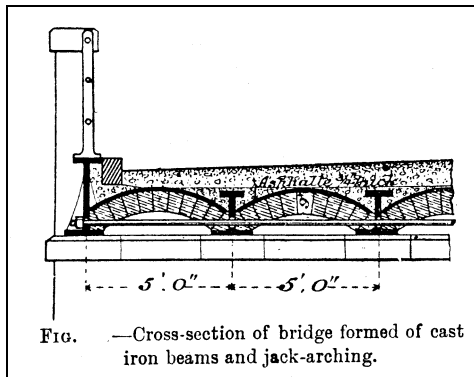


Figure 2.5: Design for jack arch highway bridge using cast iron I-beams (Aiken, 1900, p. 86).

The extent to which simple jack arch bridges were built during the first decade or two of the 20th century is not apparent from a search of the engineering literature. Applications of the beam and concrete arch floor system that are mentioned are typically those in which the technology was used in a notable manner for its economy, rigidity or fire resistance.

The Weybosset Bridge in Providence Rhode Island, 132.5 feet wide and known as the "widest bridge in the world," was an example of an exceptionally large-scale use of the jack arch floor system. The downtown bridge was "subject to very heavy and concentrated travel, including both highway and trolley cars" and a project objective was to achieve "a substantial floor at a reasonable cost."¹⁰ The complicated floor system covered over 3/4 of an acre and consisted of concrete filled brick arches turned between 10" stringers carried on 24" floor beams carried on 42" main girders (Figure 2.6).

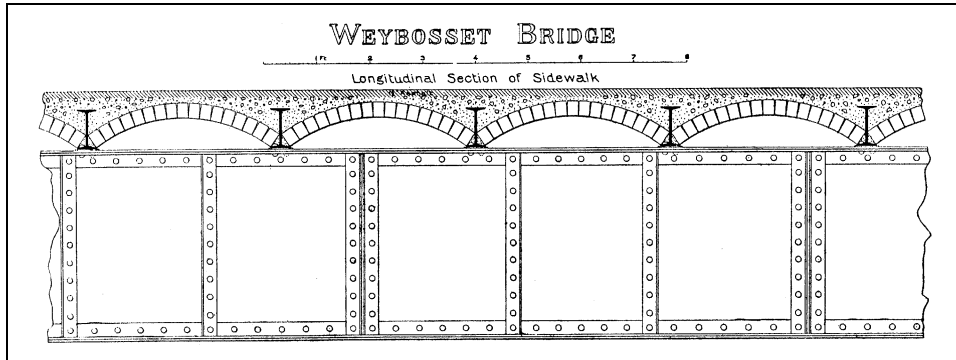


Figure 2.6: Jack arch girder and floor beam system, 1900, Providence, RI. (Bullock, 1901, p. 75).

Another example of the uncommon use of the jack arch floor system is given by Milo S. Ketchum in his 1908 book *The Design of Highway Bridges of Steel, Timber and Concrete*. In his discussion on the use of solid floors for rigidity, Ketchum provides a drawing for a jack arch deck on a riveted through truss highway bridge (Figure 2.7).¹¹ It is not stated if a bridge was built based on the design, but the level of detail suggests it was taken from actual plans.

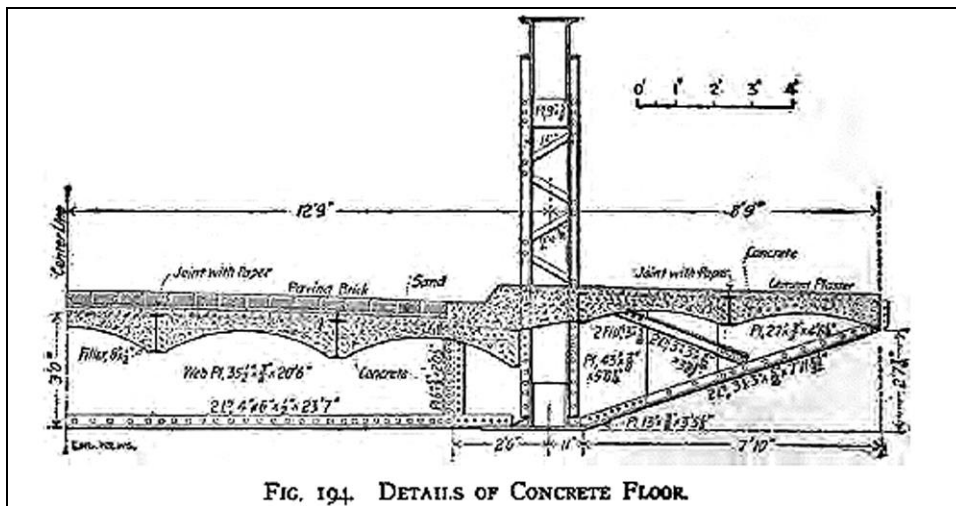


FIG. 194. DETAILS OF CONCRETE FLOOR.

Figure 2.7: Design for jack arch deck on thru-truss highway bridge. (Ketchum 1908, p. 278).

The use of the solid jack arch concrete floors for railroad overpass bridges grew with the increase in grade crossing elimination projects in cities during the early 20th century. In addition to being fireproof and corrosion resistant, the great strength of the solid floors assured the owners and users of safety and a long service life as highway loading continued to increase. In 1909, the Delaware and Lackawanna Railroad, a leader in the use of structural concrete, installed a jack arch deck on a very large 109' span thru plate girder highway overpass in Jersey City as part of their massive grade elimination project in that city (Figure 2.8).¹²

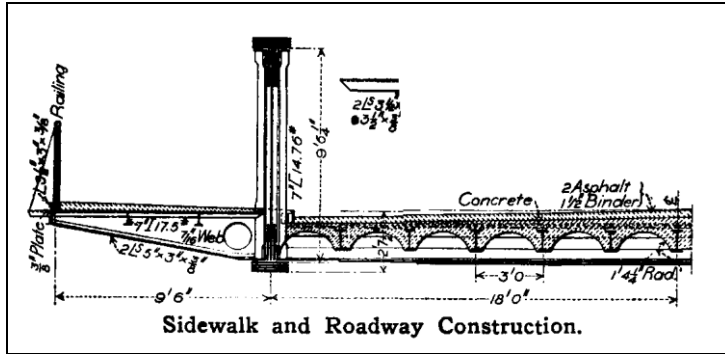


Figure 2.8: Plate girder railroad overpass, Jersey City, 1909. (*Engineering Record*, May 21, 1910, p. 662).

2.3 ENGINEERING CHARACTERISTICS

During the first decade of the 20th century the engineering properties of reinforced concrete became understood. Short-span reinforced concrete arch, beam and slab bridges were built in great numbers for use on America's rapidly developing secondary and rural road system. The all-concrete bridge could be significantly less costly than one incorporating steel beams and offered what was believed to be a fully maintenance-free and perhaps permanent structure. However, concrete bridges were fabricated entirely in the field and every step of the process required careful attention because once it was completed errors and omissions were forever hidden from view. The making of strong concrete demanded pure materials of high quality, accurately proportioned, mixed, and placed. The steel reinforcement had to be precisely placed and secured in order to support the intended loads. In rural areas, there were few knowledgeable and experienced concrete contractors suitable for the task.

Although seldom discussed in the engineering literature, jack arch bridges were also being built in increasing numbers during the early 20th century. They competed directly with shot-span reinforced concrete bridges for many good reasons. The jack arch bridge did not require falsework placed at risk in the watercourse for its construction. Instead the beams could be set in place across the abutments with a gin-pole or simple derrick and then used to support the concrete forms of wood or corrugated metal. In the view of town road agents or highway superintendents who lacked engineering training, steel girders encased in concrete were intuitively a stronger and more foolproof method of construction than reinforced concrete bridges. Jack arch bridges were far less subject to defects in construction due to improper placement of the reinforcing bars or errors in the mixing and placing of the concrete. They could be properly built with one knowledgeable supervisor and a small crew of unskilled laborers. Cast around the steel beams, the arched floor protected the steel from damage and corrosion, just as it protected the beam from fire in factory floor construction. The encasement provided a smoother underside to the bridge (than bare steel stringers) that would not catch and trap ice or floating debris during flooding. The jack arch bridge offered a larger waterway opening than a concrete arch bridge and required less costly abutments. It was also perfectly suited as a replacement for old wood stringer bridges carried on stone abutments: a simple concrete bridge seat could be cast on the existing abutments to provide a solid and level bearing for the new steel stringers. Used steel stringers could be employed and readily had at a discount, whereas no such savings was possible for reinforcing bar. One or more of these factors might tip the scale in favor of a jack arch bridge the logical and most economical choice over other bridge types.

The following discussion of jack arch floors for bridges is given by Melville B. Wells in *Steel Bridge Designing* (1913):

Concrete arches may be used between the stringers, and arches of corrugated steel or of other material may be used to support the concrete while it is setting. The construction is apt to give a heavy floor, and, when the material is at hand, the use of cinder concrete is advisable. The lateral thrust of the arches must be provided for in some way, so that the stringers may not spread and the arches fail. This type of construction is not used to any extent at present.

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But based on the dates of construction of many jack arch bridges in New Hampshire and other states, use of the bridge type was becoming more common during the 1910s. In 1915 Charles M. Spofford, MIT Professor of Civil Engineering and principal of Fay, Spofford and Thorndike Consulting Engineers, wrote a comprehensive paper entitled "Highway Bridge Floors" in which he discussed the various characteristics of each type. He states "concrete and reinforced concrete floors and brick arch floors, while durable and rigid, are very heavy, and in consequence impose an unnecessarily heavy load upon the permanent structure."¹⁴ Not exactly an endorsement, but he notes that in the case of concrete jack arch bridges, where the beams and deck are bonded as together as a unit, "the continuity is marked" and for bridges called upon to carry heavy impact loads such as street cars, continuity provides better load distribution. Within a decade the weight and speed of autos and trucks would dramatically increase and heavy solid bridge decks would make more sense.

In designing jack arch bridges for the City of Philadelphia, chief engineer Mr. Webster considered "somewhat arbitrarily" the effect of both composite action and continuity of the "solid floor to distribute a concentrated load over several adjacent beams."¹⁵ For example, for a jack arch bridge with beams 4 feet on center, the beam immediately under a concentrated load would carry and estimated 40% of the load. This is the only mention found in the literature of an engineer assigning a "value" to the continuity and composite action in jack arches and it is unknown to what degree other engineers may have similarly considered it in their design calculations. It appears that in the vast majority of cases, the bridges were designed as simple span steel stringer bridges with a concrete deck, albeit a heavier deck which was then compensated for in the sizing of the stringers.

Bridges with jack-arch-floor bridges continued to grow in popularity with state highway department engineers through the 1920s and 1930s. Although not Astate-of-the-art@ from an engineering standpoint, they were a cost-effective solution to the great need for short-span high-capacity bridges. An estimated 1300 jack arch bridges were built in New York State alone. In New Hampshire, state engineer Harold E. Langley, embraced the jack arch bridge and was responsible for the design of many of the earliest bridge of the type. He is believed to have prepared the Highway Department's standard designs for jack arch bridges in the early 1920s. The fact that these bridges have proven capable of carrying much greater loads than intended in their design and have been in service for 90 years or longer, thus far outperforming their reinforced-concrete counterparts, is testimony to the utility of their design.

3.0 JACK ARCH BRIDGES IN NEW HAMPSHIRE

3.1 EARLY DESIGN AND APPLICATION

The question of who first introduced the jack arch bridge to the state's roadway system and when and where it was built has yet to be answered. Bridge companies that were doing business in the state, such as the Berlin Iron Bridge Company of Berlin, Connecticut and the United Construction Company of Albany, New York, are known to have been building the bridge type in the late 19th century. As previously mentioned, the Berlin Iron Bridge Company claimed to be building the type as early as 1874.

If the jack arch was not introduced by a bridge company, then John W. Storrs, New Hampshire's first State Highway Engineer (1903 to 1905) is a good candidate. Storrs was an engineer with the Boston and Maine Railroad during the 1890s and he undoubtedly was familiar or perhaps even designed bridges with concrete arch floors. As mentioned above, the Boston & Albany Railroad built a highway overpass bridge with a jack arch floor system in 1896 as part of their grade crossing elimination project in Newton, Massachusetts. A paper on the project was presented at the February 1898 meeting of the Boston Society of Civil Engineers that Storrs may have attended or read in the conference proceedings.

One of the earliest jack-arch bridges in New Hampshire, for which the construction date is reliable, is the Fremont Bridge (NH Bridge No. 096/095) over the Exeter River built in 1912. John W. Storrs designed it in his capacity as a consulting engineer (see Figure 3.1). The Fremont Bridge consists of two 20' spans supported by 15" I-beams on 2'-9" centers.

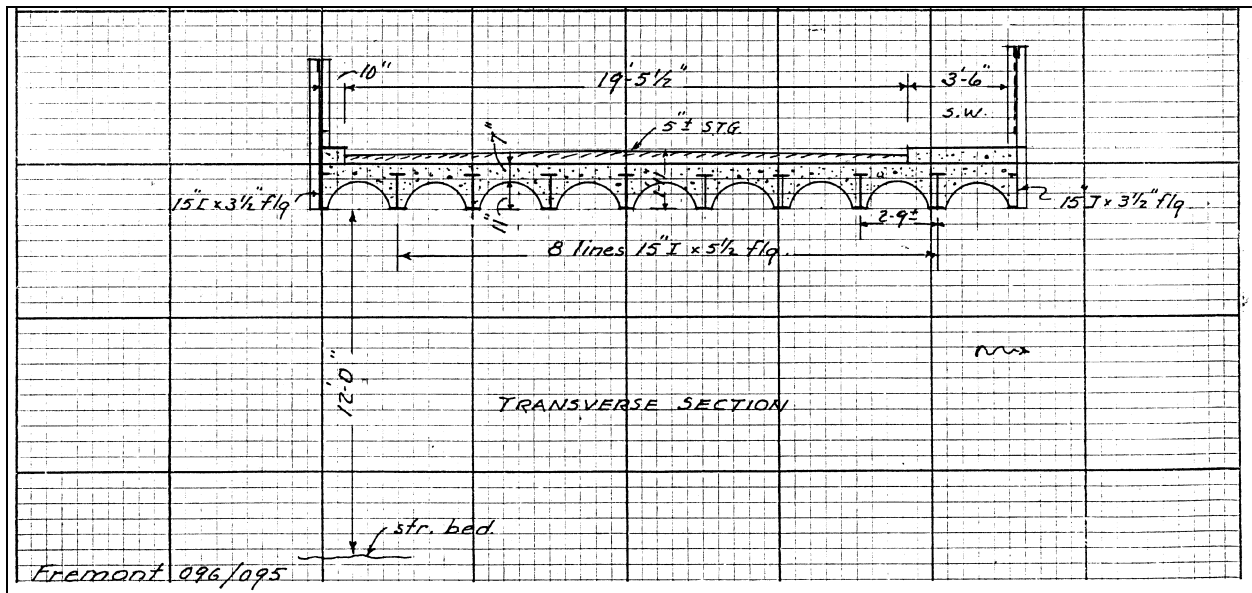
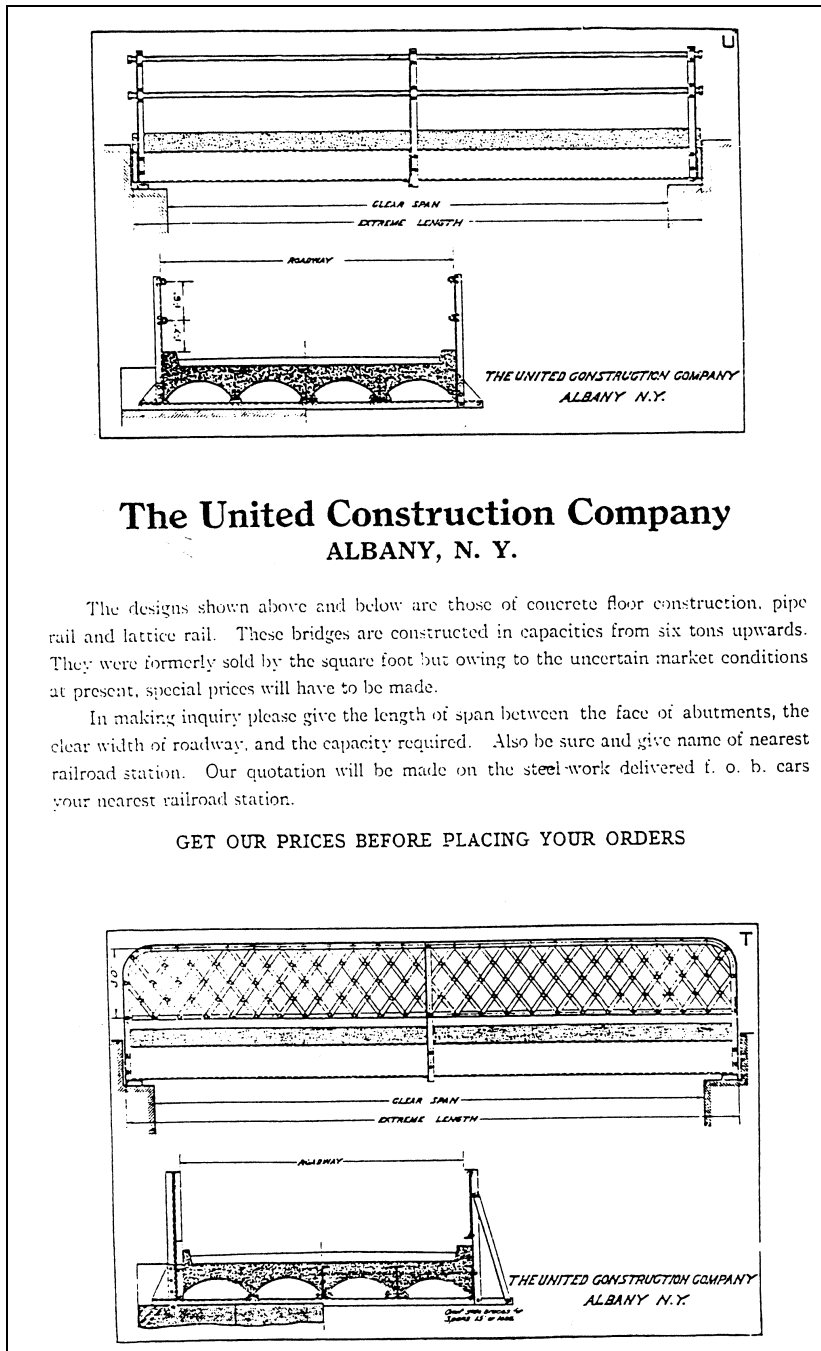


Figure 3.1: Jack arch highway bridge, Fremont, NH, Bridge No. 096/095, designed by John W. Storrs, 1912. (NH DOT Bridge files).

In 1915, the United Construction Company of Albany, New York, published a catalog of bridge designs that included a jack arch bridge with two types of railings (see Figure 3.2).



The United Construction Company ALBANY, N. Y.

The designs shown above and below are those of concrete floor construction, pipe rail and lattice rail. These bridges are constructed in capacities from six tons upwards. They were formerly sold by the square foot but owing to the uncertain market conditions at present, special prices will have to be made.

In making inquiry please give the length of span between the face of abutments, the clear width of roadway, and the capacity required. Also be sure and give name of nearest railroad station. Our quotation will be made on the steel-work delivered f. o. b. cars your nearest railroad station.

GET OUR PRICES BEFORE PLACING YOUR ORDERS

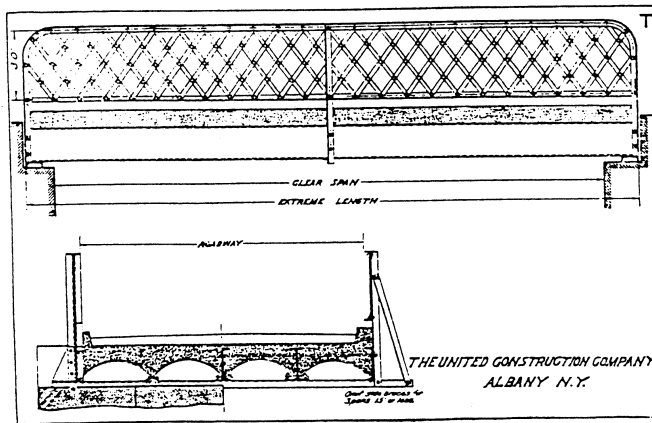


Figure 3.2: Jack arch highway bridge, from United Construction Company Catalog, 1915.

In 1916 the first of the two beam and jack-arch-floor bridges built in Enfield Village was erected to carry Main Street over the Mascoma River (Enfield 081/154). Replaced in 2003, it was notable as one of only a few multi-span jack arch bridges built in New Hampshire. Also designed by John W. Storrs, it was also unusual for its relatively long individual spans of 34 feet making it one of the longest jack arch bridges in overall length built in New Hampshire.

In 1918 the engineering firm of Storrs and Storrs of Concord, New Hampshire, formed by John W. Storrs and his son Edward, published a bridge design handbook that included a drawing and specifications for a jack-arch bridge under the name "Steel I-Beams with Concrete Arch Floors" (see Figure 3.3).¹⁶

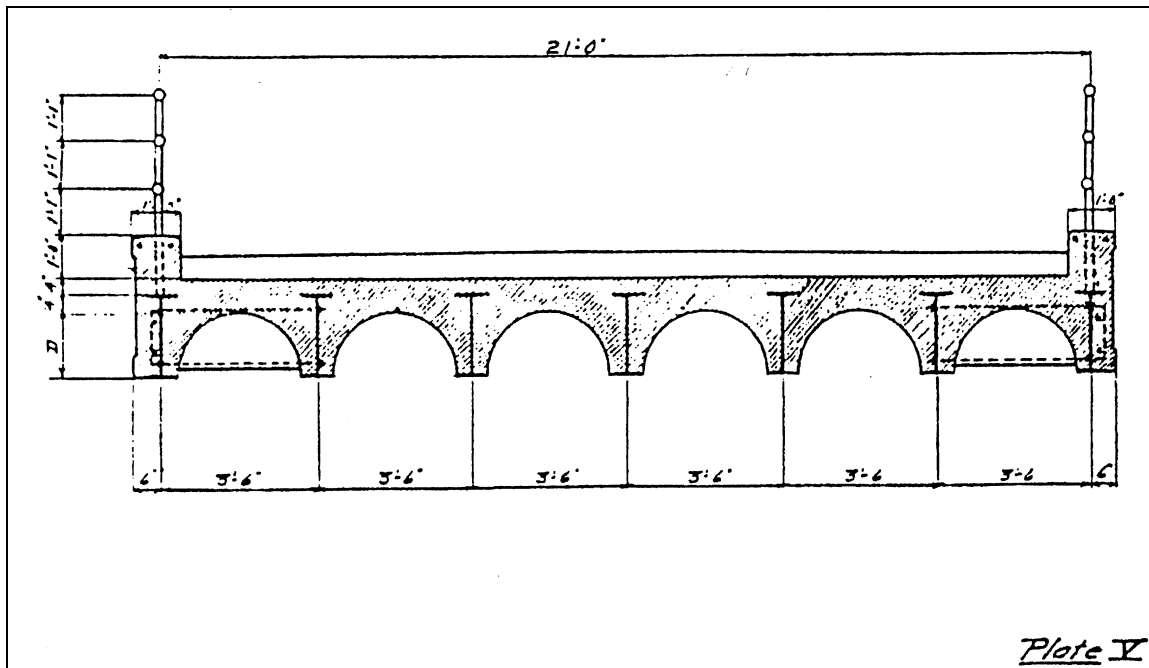


Figure 3.3: Jack arch highway bridge (Storrs and Storrs, 1918, p. 20).

The Storrs handbook provided a table that specified the size and weight of the I-beam to use for jack arch span lengths from 12 to 30 feet in 2-foot intervals. A 20-foot span for example, required using an 18" I-beam with a weight of 48 pounds per foot. A paragraph of instructions was also given:

These bridges are designed with a capacity for carrying twelve-ton trucks. The wearing surface may be two inches of tar, concrete, or asphalt, or six inches of gravel. The two outside I-beams on each side of the bridge are held in position by two ½" diameter yoke rods passing through the webs of the beams. The bottom rod should be encased in concrete, making a small crossbeam. These should be spaced not over 10 feet apart. The yokes should also be placed at the abutments and the crossbeams should run the full width of the bridge at these points. Two ½" diameter rods are required in the top of each curb; also two rods of the same size further down on the outside of the bridge. The latter should be held in place by the yoke rods mentioned above.¹⁷

By the early 1920s the New Hampshire's State Highway Department was designing jack arch bridges "in house" using its own engineers; unfortunately the earliest plans examined for this study do not include the designer's name. One example is the plan for the "Middleton Bridge 1921 State Aid" (Figure 3.4). No name appears on the drawings and the bridge is no longer extant. Further research would be needed to determine its location, when it was replaced and who might have been the designing engineer. The Middleton Bridge design followed the earlier designs of Storrs and United Construction that used metal forms resting on or at the level of the bottom flanges without fully encasing their underside. The fascia beams were not encased and wood railings were supported by channel posts bolted to the outside of the fascia beams (Figures 3.4 and 3.5).

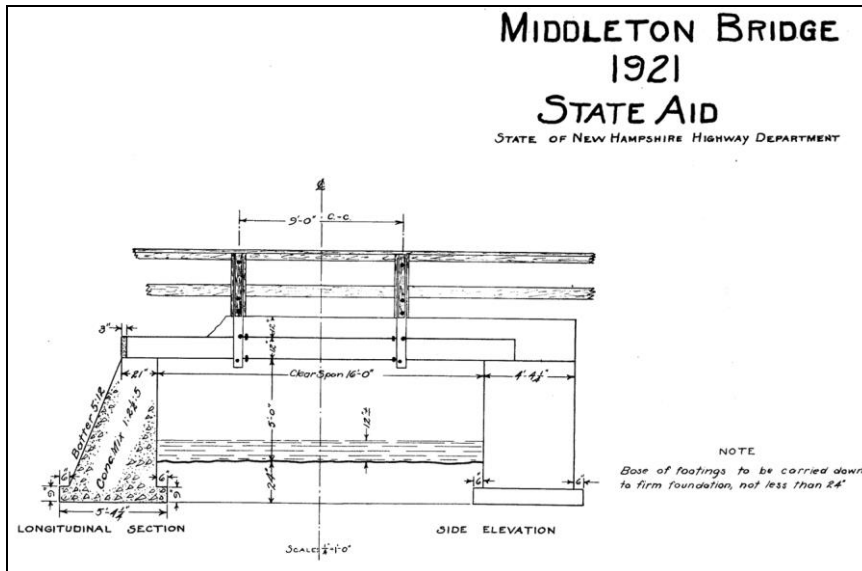


Figure 3.4: Middleton Bridge 1921 State Aid (NHHD Plan C-16).

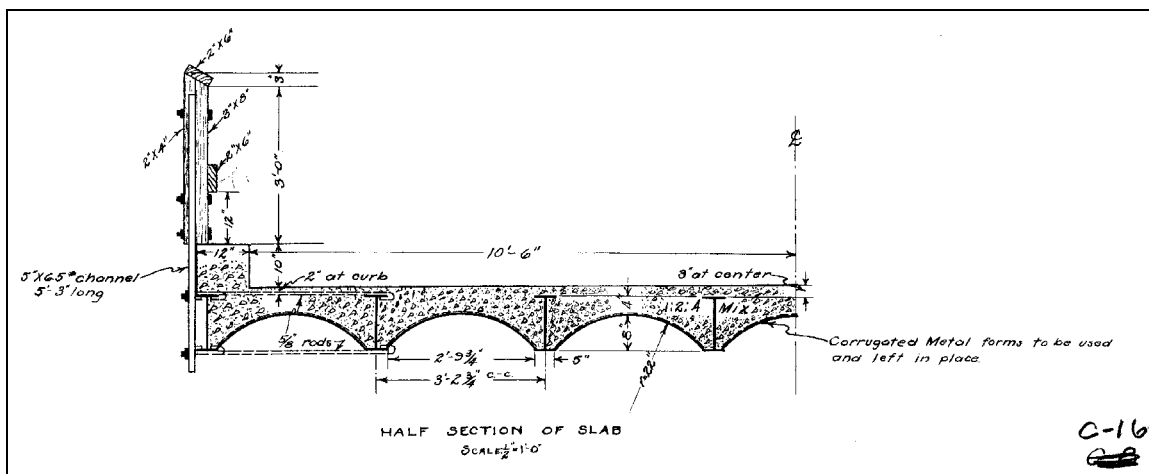


Figure 3.5: Middleton Bridge 1921 State Aid (NHHD Plan C-16).

Steel girder bridges with transverse floor beams encased with a jack-arch floor system were also built early on by the highway department. One example is Lebanon 165/109 over Stony Creek, built in 1921. In that case, the 15" floor beams are set 2" above the bottom flange of the 28" girders, allowing the arch forms to be supported by the girders. The top of the concrete roadway curbing came up flush with the top flange of the girder (see Figure 3.4).

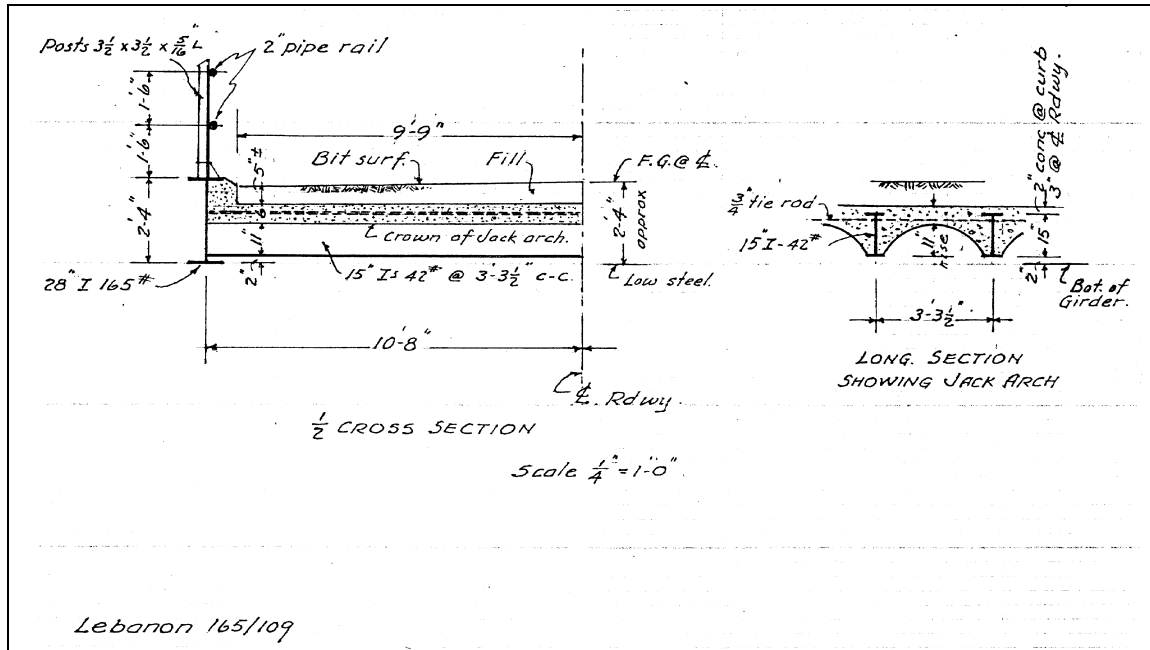


Figure 3.4: Lebanon 165/109 [1921], a girder and floorbeam bridge with jack arch floor system, also called a jack arch bridge with transverse arch (NHHD).

Standard designs for "Steel I-Beam Concrete Arch Bridges," dated July 9, 1921, and July 3, 1923, were incorporated into the Department's *Standard Structures* design book published in 1925 (see Figures 3.5, 3.6, and 3.7). The 1921 drawings depict the use of arched wood forms or corrugated metal forms to fully encase the bottom flange of the beams. Mesh reinforcement, referred to as Abeam wrapper, was crimped around the bottom flange to reinforce and anchor the 2-inch thick concrete cover.

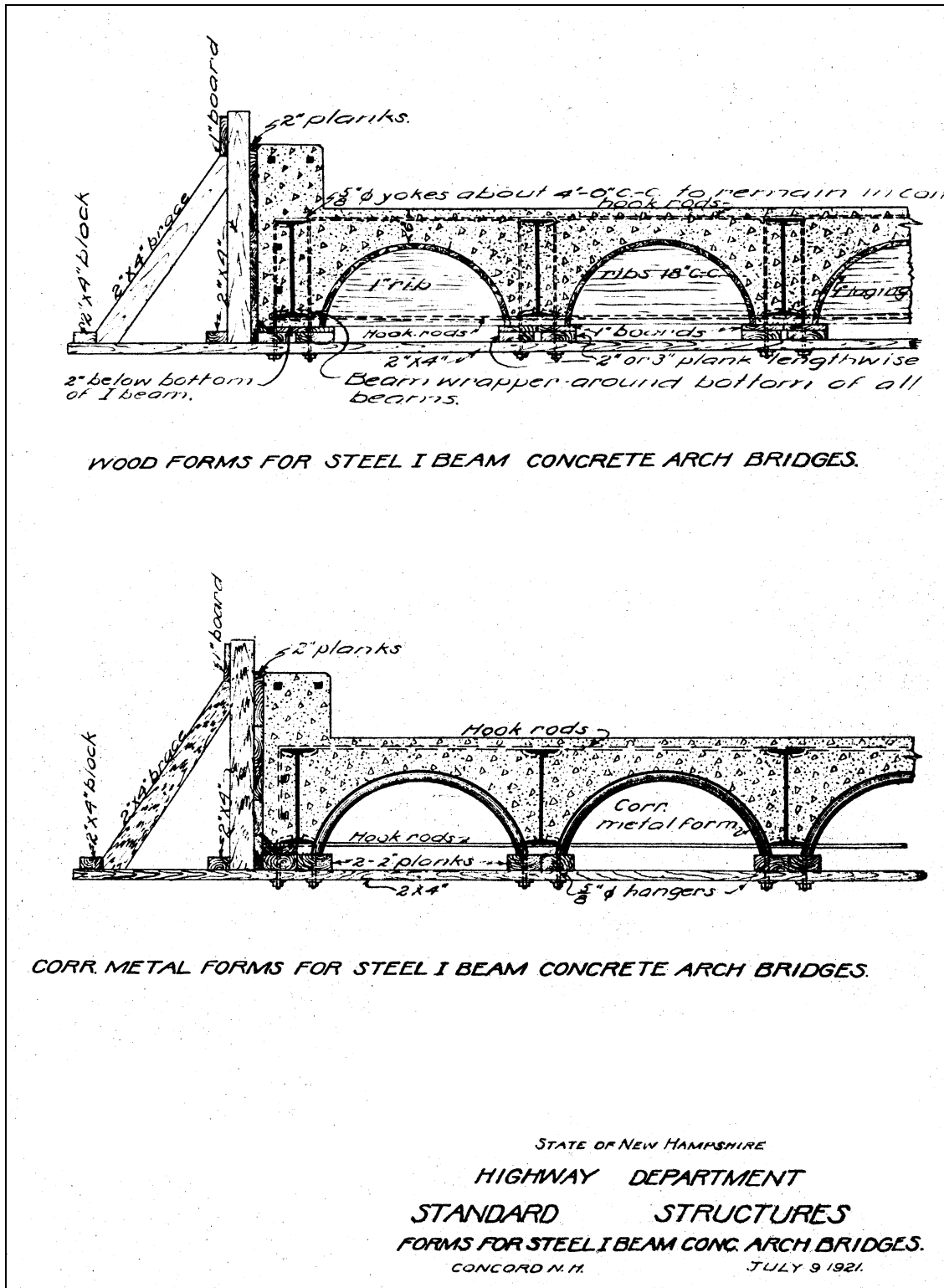


Figure 3.5: NHHD Standard Plans for "Forms for Steel I-Beam Concrete Arch Bridges" 1921 (NHDOT).

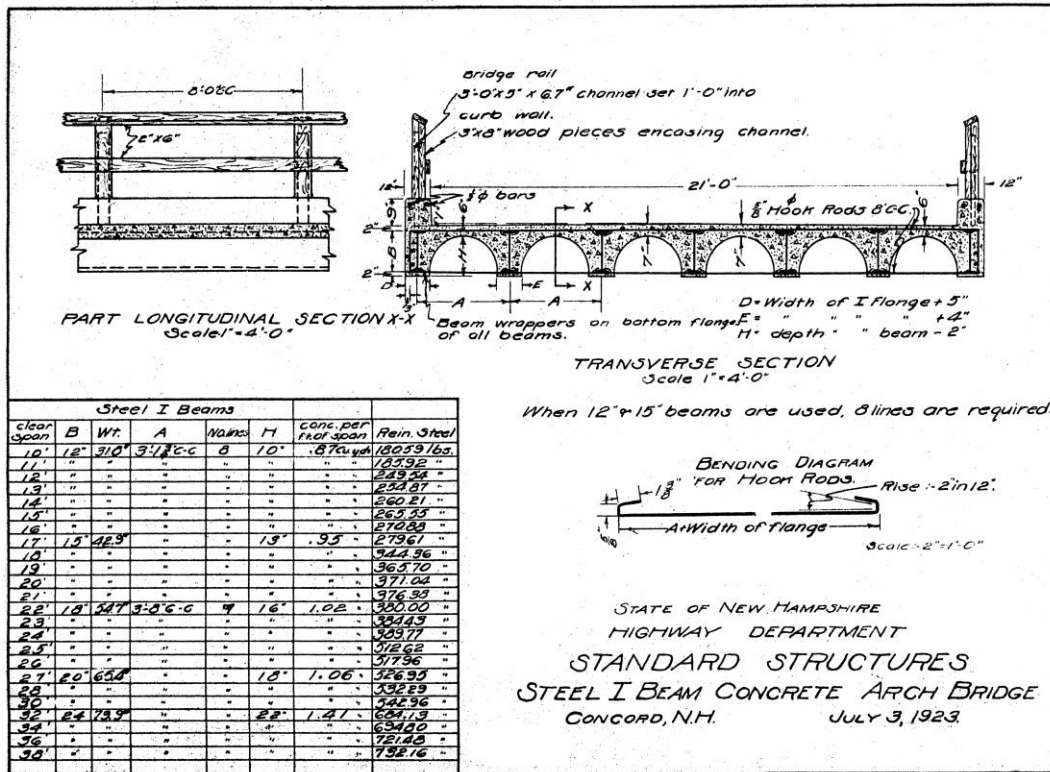


Figure 3.6: NHHH Standard Plans for "Steel I-Beam Concrete Arch Bridge" 1923 (NHDOT).

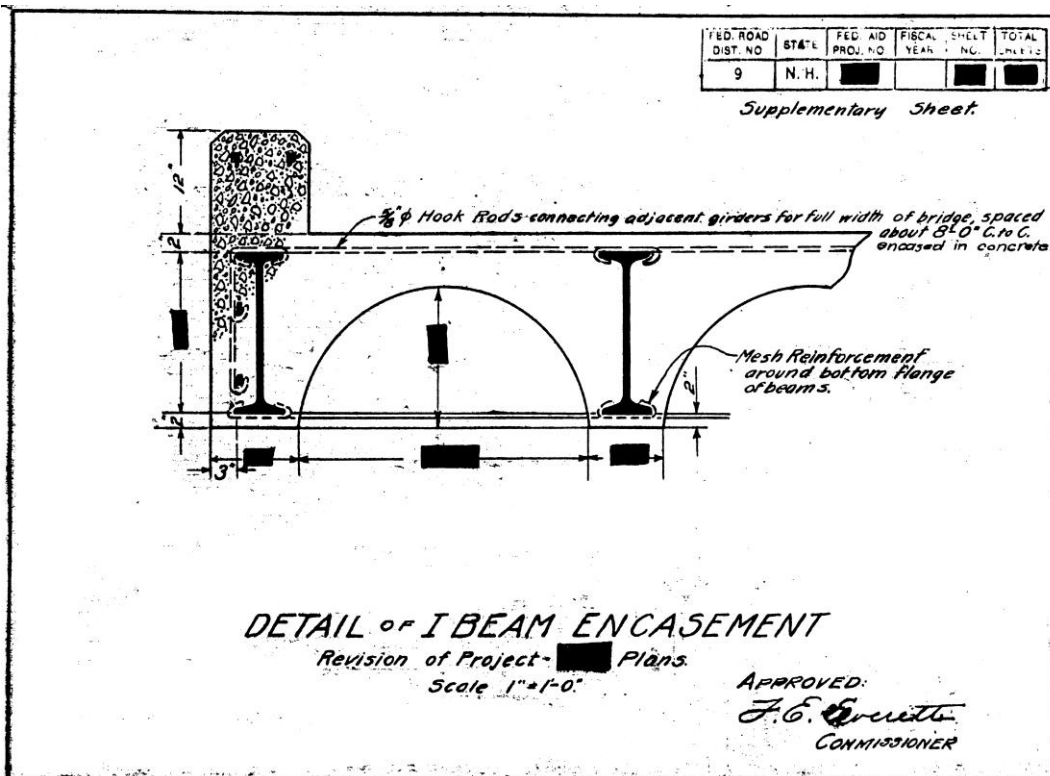


Figure 3.7: NHHH Standard detail for jack-arch concrete encasement for bridges built with Federal Aid, circa 1924 (NHDOT).

A random examination of early bridge plans at NHDOT indicates that a large number of jack arch bridges were probably designed by Harold E. Langley. His name appears on several bridge drawings from 1923 including Alton 096/287, Goffstown 053/119, and Hampton Falls 094/142, among others.

New Durham 199/054, built 1926, carries Old Route 11 over Merrymeeting River and is an example of one of many jack arches bridges designed by Harold E. Langley during the 1920s for the New Hampshire Highway Department (NHHD). It was constructed in 1926 by the NHHD work force at a cost of \$4,349.72 under the State Aid Bridge account. A clip from the drawings (Figure 3.8) lists those involved in preparing the drawings.

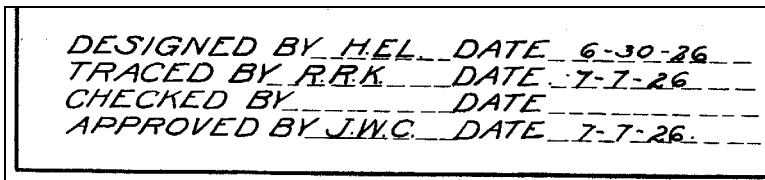


Figure 3.8: New Durham 199/054 [1926]. Designers block, NHHD Plan E-39.

The plans were traced by Ralph R. Kenny, and approved by John Warren Childs. Bridges that were designed by other engineers or designers within the Highway Department were often checked by Langley. Childs was State Bridge Engineer from 1925 to 1942; Langley was second to occupy the position, from 1942 to 1961.

Located on Route 11, now bypassed and called Old Route 11, the New Durham bridge was wider and heavier than typical jack arch bridges built by towns on secondary roads. Designed for H-15 loading, it used 9 lines of 18" deep I-beams (see Figure 3.9).

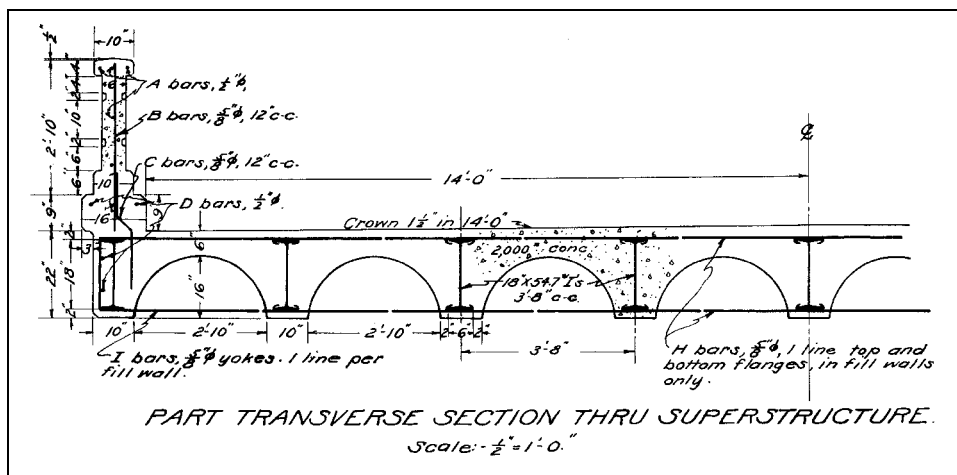


Figure 3.9: New Durham 199/054 [1926]. Section detail, NHHD Plan E-39.

The fascia beams and bottom flanges were fully encased with concrete to insure a long service life. It was finished with solid concrete parapet railings with decorative panels and a sidewalk. Further details of the solid railings are given in Section 3.3.5 below. Jack arches built on a low budget by town road crews or others, often omitted the encasement of the lower flange that required more costly suspended formwork. The same was true for the encasement of the fascia beams, which was done primarily to protect the steel from corrosion. Note the 1-inch bituminous wearing course applied directly to the concrete deck.

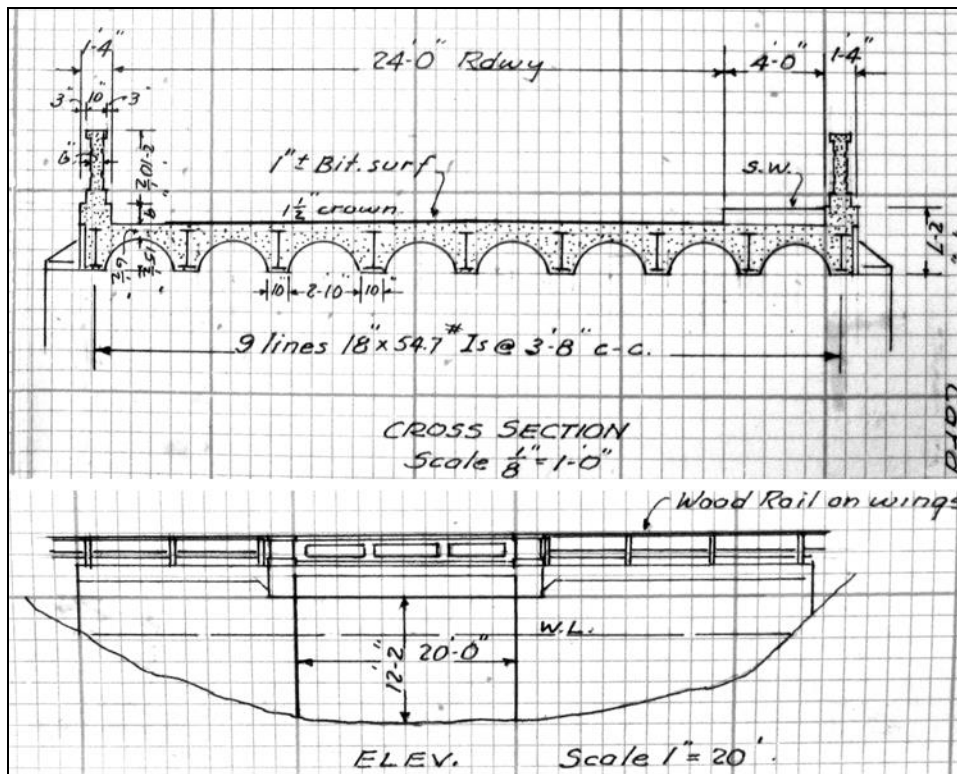


Figure 3.9: New Durham 199/054 [1926]. Field sketch from Bridge Card, 1941.

Another example of an NHHD-designed bridge from the mid-1920s is Tamworth 095/162, carrying NH Route 113 over the Chocura River, built 1925. The plans for this bridge were not examined, but the bridge is very similar to New Durham 199/054 and may have also been designed by Langley (see Figures 3.10, 3.11, 3.12). Note the 15" I-beams and the 9" gravel roadbed.

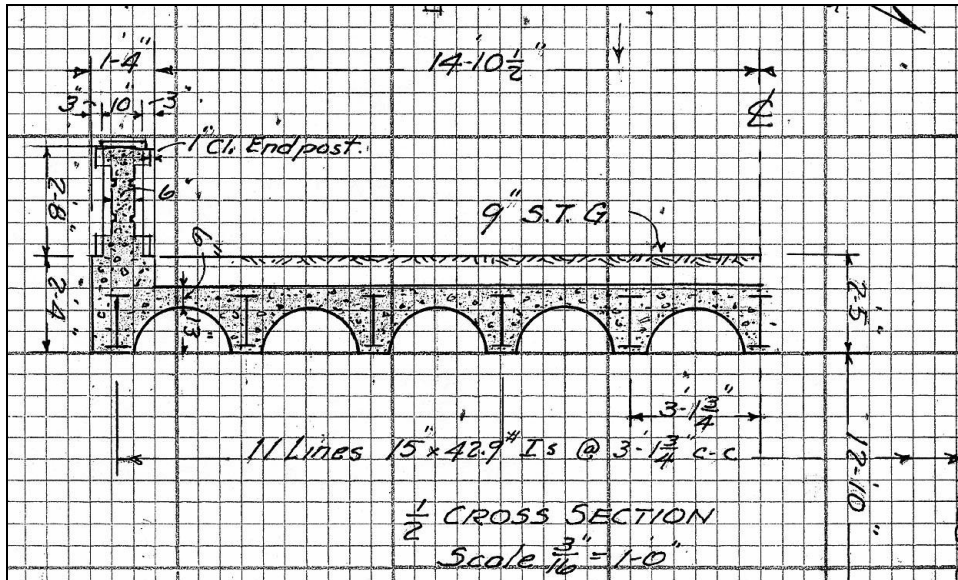


Figure 3.10: Tamworth 095/162 [1925]. Solid concrete parapet railing with paneling. Bridge built by NHHD work force at a cost of \$4,349.72. Field sketch from Bridge Card, 1941.



Figure 3.11: Tamworth 095/162 [1925]. Photo from bridge card, 1941



Figure 3.12: Tamworth 095/162 [1925]. Photo from bridge card, 1941

3.2 NH JACK ARCH BRIDGE INVENTORY

A goal of this report is to begin the gathering and analysis of available data and historical information pertaining to the development and use of the jack arch bridge type in New Hampshire. Information in this section has been gathered by examining the records in the NHDOT Bridge Design Section.

Tables 1 and 2 compile data gathered from the NHDOT Bridge Summary database and the Bridge Cards; the cards resulted from a field survey and inventory of the bridges in the state done by the highway department from roughly 1940 to 1942. Cards were not found for all bridges and in those cases information in the Bridge Inspection File was used. A select number of plans were also examined and any additional information added to the tables.

The results of the data gathering are presented in two tables. Table 1 is a listing of the known existing jack arch bridges and is believed to be complete although more jack arch bridges that have been incorrectly categorized in the bridge records may turn up. Table 2 is a listing of bridges no longer extant or plus those currently approved for replacement; it is not a complete list and for the most part includes only the jack arch bridges still existing at the time of the 1982 Statewide Historic Bridge Inventory. A cursory examination of the older bridge plans on file and old bridge cards for bridges replaced indicates there were many more jack arch bridges built than the 81 listed in the two tables. The intent of the lists was to gather sufficient information about the jack arch bridges that were built in New Hampshire to understand the variations in design and identify the important character defining features.

In 1990, the NHDOT compiled a list of 33 jack arch bridges dating from 1912 to 1940 for review by the Historic Bridge Inventory Committee, which was made up of representatives of the NHSHP, NHDOT and FHWA. Seven unaltered bridges were considered in detail for National Register eligibility using a point scoring system; none achieved the necessary score for eligibility. Since that time the NHSHP has for the most part abandoned the point system method as unreliable and required that jack arch bridges be reevaluated on an individual basis.

In 2009, L.B. Driermeyer of Preservation Company prepared an NHDHR Individual Inventory Form for Farmington Bridge 060/144, a jack arch bridge built in 1925. The form provided information on the approximate number, ownership and size of jack arch bridges remaining at that time:

- 48 extant jack arch bridges dating from 1900 to 1970, 5 predate 1920, 20 date 1920 to 1939, 6 date 1940 or later;
- NH municipalities own two-thirds of the bridges, 13 are on DOT Red listed;
- Spans range 12 to 33 feet; widths range 17 to 43 feet.

This study finds 37 existing jack arch bridges and 44 bridges previously replaced (demolished) or approved for replacement. The difference between the Driermeyer number of existing bridges and the 37 found in this study is due to two bridges being miscategorized and the remaining being bridges slated for replacement.

Before perusing the data in Table 1 please read the Notes at the end of the table.

3.2.1 Table 1 – Existing Jack Arch Bridges

TABLE 1: EXISTING JACK ARCH BRIDGES						
Town	Bridge No.	Year ¹	Carrying/ Over	Span	Width	As-Built Notes ²
Acworth (SR) (2010 Photos)	113/064	1915	NH123A over Bowers Brook	17'	27.3'	- 9 lines 12" IBs 3'-2" o.c. - low 9" rise arch - wood rail on pipe posts
Alton (2010 Photos)	096/287	1923	NH 11 over West Alton Brook	22'	35.9'	- 8 lines 15" IBs 3'-2" o.c. - 13" rise arch with diaphragms - wood rails on encased channel posts ⁴ - Built by NHHD SAB 1923 Plans C-50 - Harold E. Langley, designer
Andover (IB-C) ³	041/110	1920?	Bypassed Historic over Blackwater River	40'	23.1	- 7 lines 24" IBs 3'-8" o.c. - 20" rise semi-circular arch - wood forms left in place - cable rail on wood posts
Berlin	232/066	1931?	Hillside Ave over Dead River	16'	43'	Bridge Card not found ⁵
Charlestown (MR) (2010 Photos)	142/101	1940?	Borough Rd over Clay Brook	15'	21.7'	Bridge Card not found - 22 lines 8" IBs 12" o.c. - 2-1/2" arch rise - 1-rail pipe railing in 1981 photo
Chester (MR)	147/100	1920? 1972	Fremont Rd over Towle Brook	19'	23'	Bridge Card not found - 6 lines 12" IBs 3'-5" o.c. - steel forms left in place, 1979 photo - 2-rail pipe railing, 1979 photo - widened in 1972
Chichester (IB-C)	130/100	1931	Main St over Sanders Brook	15'	33.8'	- 8 lines 10" IBs 3'-1" and 2'-8" o.c. - low 6" rise arch - steel forms left in place
Concord	140/113	1875? 2008	Commercial St over Wattanummon Brook	28'	30.4'	- 10 lines 8.5" IBs 3' o.c. - 12" rise arch - steel forms left in place - on stone abutments - alterations 2008
Deerfield (MR)	139/127	1930	Blakes Hill Rd over Lamprey River	19'	20.9'	- 8 lines 15" IBs 3'-2" o.c. - 12" rise arch - steel forms left in place - wood rails on encased channel posts
Dublin (MR) (2010 Photos)	085/103	1938? 1914	Charcoal Rd over Charcoal Brook	22'	22.8'	1914 on Bridge Card - 6 lines 15" IBs 3'-8" o.c. - 10" rise arch - steel forms left in place - wood rails on encased channel posts

TABLE 1: EXISTING JACK ARCH BRIDGES						
Town	Bridge No.	Year ¹	Carrying/ Over	Span	Width	As-Built Notes ²
Effingham (MR)	097/088	1930?	Drake Rd over Wilkinson Brook	22'	17.6'	Bridge Card not found - 7 lines 10" IBs 34" o.c. - low 5" rise arch
Franklin (IB-C) (2010 Photos)	159/117	1922	US 3, NH 11 over Winnepesaukee River	3@ 45.5'	50.8'	- 145' overall - 12 lines 26" IBs 4' o.c. - solid concrete paneled parapet railings - John Storrs, cons. eng - NH Cement Const. Co., contractor
Freedom	185/067	1922	Maple Street over Cold Brook	24'	29.5'	- 8 lines 15" IBs 3'-2" o.c. - 10" rise arch - steel forms left in place - on stone abutments - 4 rail pipe railing on concrete posts - Built by NHHD SAB 1921
Fremont (IB-C)	086/055	1930?	Sandown Rd over Exeter River overflow	22'	24.3'	- 6 lines 12" IBs 3'-2" o.c. - 7" rise arch - wood rails on encased channel posts
Gilford	126/101	1931? 1979	NH 11B over Gunstock River	26'	30.9'	- 7 lines 18" IBs 3'-8" o.c. - 16" rise semi-circular arch - wood rails on encased channel posts - widened in 1979
Goffstown (IB-C) (2010 Photos)	053/119	1923	Parker Station Rd over Gorham Pond Brook	20'	25'	- 9 lines 15" IBs 3'-2" o.c. - 13" rise arch with diaphragms - wood rails on encased channel posts - Built by NHHD SAB 1923 Plans C-60 - Harold E. Langley, designer
Grafton	159/049	1930?	Slab City Rd over Smith Brook	24'	17.7'	Bridge Card not found - 6 lines 18" IBs 3'-6" o.c. - 16" rise arch - steel forms left in place - 3" steel angle railings and posts
Hampton Falls	094/142	1923 1981	NH 88 over Taylor River	21'	35.4'	- 8 lines 18" IBs 3'-3" o.c. - 15" rise arch - fully encased IBs, wood form removed - solid concrete parapet railings - Built by NHHD SAB 1923 Plans C-61 - Harold E. Langley, designer - not built per plans - alterations 1981
Hill	175/109	1924?	Old NH 3A over Lower Mill Brook	33'	27.1'	Bridge Card and Bridge File not found

TABLE 1: EXISTING JACK ARCH BRIDGES						
Town	Bridge No.	Year ¹	Carrying/ Over	Span	Width	As-Built Notes ²
Jefferson	140/097	1900? 1940 1979	US 2 over Priscilla Brook	13'	47.5'	- 7 lines 10"? IBs 31" o.c. - low 5" rise - on stone abutments - wood rails on encased channel posts - jack arch probably NHHD 1940 - widened in 1979
Jefferson (IB-C) Closed	166/058	1939	Carter's Cut Rd over Israel River	2 1-28' 1-38'	14.7'	- Transverse jack arch span 38' span- - 73" overall - Flat slab imbedded I-beams, 28' span - 15 transverse IBs ?" 20" o.c. carried on two side IBs 27", 14'-8" o.c. - low 5" rise arch - 1 line 3x8" wood railing on angle posts
Landaff	082/150	1920?	King Hill Rd over Mill Brook	23'	20.6'	Bridge Card not found - wood 2x4 forms removed - flanges exposed - solid conc. parapet railing 1979 photos
Madison	163/048	1900, 1967	NH 153 over Purity Pond Brook	27'	35.0'	Bridge Card and Bridge File not found
Merrimack (MR)	116/137	1940?	McGaw Bridge Rd over Baboosic River	30'	31.2'	Bridge Card not found - 9 lines 20"? IBs 47" o.c. - flanges and outside beams exposed - 16" rise arch - wood 2x4 forms in place - 3 rail pipe railing on pipe posts
Milton	064/167	1930	Hopper St over Salmon Falls River	24'	22.7'	- 7 lines 18"? IBs 3'-9" o.c. - 17" rise semi-circular arch - steel forms left in place - solid concrete paneled parapet railings - Built by NHHD "Inter State Bridge"
Nelson (2010 Photos)	073/098	1940? 1998	Murdough Hill Rd over Brook	21'	22.3'	Bridge Card not found - 6 lines 15" IBs 3'-2" o.c. - 12" rise arch
New Durham (IB-C) (2010 Photos)	199/054	1926	Old NH 11 over Merrymeeting River	24'	30.7'	- 9 lines 18" IBs 3'-8" o.c. - 16" rise arch - solid concrete paneled parapet railings - wood railings on wings - Built by NHHD SAB 1926 plans E-39 - Harold E. Langley, designer

TABLE 1: EXISTING JACK ARCH BRIDGES						
Town	Bridge No.	Year ¹	Carrying/ Over	Span	Width	As-Built Notes ²
Ossipiee (MR)	133/237	1940?	Thurley Rd over Dan Hole River	20'	17.8'	Bridge Card not found - 5 lines 12" IBs 3'-8" o.c. - 9" rise arch - wood forms marks evident
Peterborough (MR) (2010 Photos)	132/134	1940?	Slab Road over Otter Brook	26'	19.5'	Bridge Card not found - 7 lines 18" IBs 3'-2" o.c. - 11" rise arch - 2 rail pipe rail on pipe posts
Plymouth	076/136	1919? 1981	Yeaton Rd over Spencer Brook	24'	27'	Bridge Card and Bridge File not found
Randolph (MR)	140/067	1935 1970	Durand Rd over Carlton Brook	21'	30.6'	- 9 lines 15" IBs 3'-8" o.c. - 12" rise arch - 2 rail pipe rail on pipe posts, u.s. side - wood rails on wood posts (encased channel?), d.s. side - widened 1970
Raymond	172/149	1950?	Stingy River Rd over Pawtuckaway River	16'	16.5'	Bridge Card not found - 6 lines 10" IBs 3'-2" o.c. - 2 rail pipe railings in place - outside beams exposed - wood forms in place - original example on stone abutments
Salem	115/097	1900? 1959	Bridge St over Spicket River	29'	35.3'	- 6 lines 18" IBs 4'-3" o.c. - 13" rise arch - flanges exposed - forms in place - 2 rail pipe rail on pipe posts - widened 1959
Stratham	073/114	1929 1955	NH 33 WB over Mill Brook	12'	53'	- 12 lines 10" IBs 2'-8" o.c. - interesting needs study - rebuilt 1955 'flat slab + old jack arches' - Built by NHHD F.A. 226-C
Tamworth	095/162	1925	NH 113 over Chocorua River	22'	30.9'	- 11 lines 15" IBs 3'-2" o.c. - 13" rise arch - fully encased IBs, - on old stone abutments - solid concrete paneled parapet railings - wood railings on wings - Built by NHHD SAB 1925 plans D-35 - Cost \$3376.32

TABLE 1: EXISTING JACK ARCH BRIDGES						
Town	Bridge No.	Year ¹	Carrying/ Over	Span	Width	As-Built Notes ²
Warren (MR)	120/058	1930?	Fish Hatchery Rd over Patch Brook	33'	23.3'	Bridge Card not found - 7 lines 18" IBs 3'-8" o.c. - 18" rise semi-circular arch - full encasement w/ wire mesh reinforcement. - wood forms marks evident - wood rails on wood posts
Westmoreland (IB-C)	124/061	1932?	Hatt Rd over Partridge Brook	24'	20.1	Bridge Card not found - 7 lines 12" IBs 3'-4" o.c. - 10" rise arch - channel top rail, pipe mid-rail on angle posts present in 1980 inspection

NOTES:

(SR) = State Redlist

(MR) = Municipal Redlist

¹ First date is from the NHDOT Bridge Summary for which the source is unknown. A question mark after the date means the date does not agree with the Bridge Card because the Bridge Card is missing, the date field on the Card is blank, or the date field reads "no data."

² Information on I-beams and railings is taken from the 1940-42 Bridge Cards

³ IB-C means the bridge is classified in NHDOT Bridge Summary as an I-Beam stringer bridge with Concrete deck, which is technically correct, but not sub-classified as a jack arch.

⁴ This railing has a 2"x6" wood top and side rail attached to wood encased 3"x5" steel channel posts driven or imbedded and is known as Standard Design 12-A

⁵ If Bridge Card not found, then information is from Bridge File (Inspection file) and/or from project field survey.

3.2.2 Table 2 – Jack Arch Bridges Replaced or To Be Replaced

TABLE 2: JACK ARCH BRIDGES REPLACED OR TO BE REPLACED							
Town	Bridge No.	Year	Carrying/ Over	Span	Width	Notes	Demo Date
Bath	131/145	1972 1923	Dodge Rd over Pettyboro Brook	23'	23.9	Designed by "C.L.P." checked by Harold E. Langley	?
Bristol	103/062	1923	NH 104 over Newfound River	53'11"	?		?
Bristol	097/075	?	NH 3a over Newfound River	64'	39.5'	New NEBT	1999
Charlestown	154/065	?	Old Claremont Rd over Clay brook	20'	25.7'		2002?
Chinchester	150/154	?	Kelly's Corner Rd over Sanborn Brook	28'	28'	New TS-P;	1991
Derry	053/097	?	Maple St over Hornes Brook	37'	29.5'	New PVS	1998
Derry	088/124	1935	Pond Rd over Beaver Brook	22'	30.4'	New PVS	2001
Derry	056/088	1935	Florence St over Shields Brook	19'	27.9'	Municipal Redlist DOE 5/13/2009: Eligible	2009?
Derry	066/092	1935	South Ave over Shields Brook	20'	36.7'	Form 2009; Eligible 8/2009	Going
Enfield	083/156	1922	Shaker Hill Road over Mascoma River	81"	43.3'	DOE 11/10/1998	2003
Enfield	081/154	1916	Main St over Mascoma River	111'	43.3'	New NEBT	2003
Farmington	060/144	1930	Bay Rd over Cochecho River	14'	23.3'	DOE 5/09: Not Eligible	Going
Fremont	096/095	1912	Sandown Rd over Exeter River	48'	31.6'	New PVS; Early NH Jack Arch	1998
Goffstown	137/107	1930	Henry Bridge Rd over Harry Brook	25'	23.6'	** IB-C [Files sent to archives]	2008
Grafton	151/073	?	Prescott Hill Rd over Smith River	42'	32.3'	New PVS	1997
Harts Location	256/069	1939	US 303 over Stony brook	22'	28.6'	Deck replaced 2003 with prestressed voided slabs	2003
Lancaster	173/090	?	Garland Rd over Otter Brook	28'	26.5'	New CS	1992

Town	Bridge No.	Year	Carrying/ Over	Span	Width	Notes	Demo Date
Lebanon	165/109	1921	Riverside Drive over Stony Brook	40'	27.8'	Transverse axis New CRF-P	1997
Merrimack	089/038	1930	Thornton Rd. over Pennichunk Brook	24'	20'	Deck replaced	2001
Middleton	082/109	1925	Ridge Road over Jones Brook	21'	22'	- Harold E. Langley, designer - Plans C-64	2000
Milford	122/126	?	Lincoln Street over Great Brook	45'	32.6	New PVS	1992
Milton	081/159	1920	Lebanon St over Salmon Falls River	33'	32.5'	New CS;	1998
Newbury	120/078	1936	Village Rd over Andrew Brook	34'	23.2'	** IB-C; Municipal Redlist DOE 8/2009 Not Eligible	Going
New Ipswich	no brg number?	?	?	?	?	Bridges closed since 19xx DOE – in progress? [see Hengen form]	
Newmarket	112/098	1931	Packers Falls Rd over Piscassic River	31'	37.6'	New IB-C	1997
Orford	116/089	1930	Town Rd #79 over Jacobs Brook	38'	15.8'	New PVS	2006
Peterborough	055/112	1940	Wilder Rd over Nubanusit Brook	60'	29.2'	New IB-C	2004
Peterborough	084/090	1940	Elm St. over Nubanusit Brook	41'	29.2'		2003
Peterborough	135/136	1940	Gulf Rd over Otter Brook	38'	24.5'	New PVS	2006
Peterborough	133/136	1940	Gulf Rd over Otter Brook	17'	20.5'		2003
Randolph	040/044	?	Valley Rd over Israel River	50'	32.6'	New IB-C	1986
Raymond	160/094	1917	Prescott Rd over Lamprey River	?	?	Transverse axis United Construction Company HAER NH-16, 1989	1990
Rindge	155/073	?	Old NH 119 over Old Mill Tail Race	10' *	22'	* 2 -10' spans, 28'-2" overall	?
Salem	113/070	1935, 1955	Lawrence Rd over Spicket River	64'	32.3'	Municipal Redlist DOE 3/25/09	Going
Stratford	123/104	1940	Bog Rd over Stratford Bog Brook	54'	26.2'	Transverse axis New PVS	1998

TABLE 2: JACK ARCH BRIDGES REPLACED OR TO BE REPLACED							
Town	Bridge No.	Year	Carrying/Over	Span	Width	Notes	Demo Date
Stratford	126/111	1930	Eagan Rd over Stratford Bog Brook	25'	14.5'		2002
Sunappe	097/100	1910	North Rd over Sugar River	25'	16.3'	New TB	2004
Sunappe	108/099	1920	High Street over Sugar River	27'	27.1'	New TS	2006
Sunappe	111/099	1920	Main St over Sugar River	30'	32'	New TS	1992
Sunappe	122/163	1920	Cooper St over Otter Pond Outlet	28'	20'	New TB	2006
Tuftonboro	145/070	1921	NH 109 over Melvin River	30'	30.7'	New PVS	1992
Westmoreland	158/123	1930	Old Mill Brook Rd over Mill Brook	34'	18'	New CS	2005
Winchester	133/163	1940?	Old Westport Rd over Wheelock Brook	27'	16'	New IB-C on existing conc. abutments	1982
Wolfeboro	100/112	1900	NH 109 over Smith River	31'	66.7'	New PVS	1995

Note: This table represents an initial compilation of data and is incomplete. A cursory examination of the early bridge plans on file at DOT indicates there are many more jack arch bridges that were built and are no longer extant than listed above.

3.3 JACK ARCH BRIDGE CHARACTERISTICS

3.3.1 Date of Construction and Period of Significance

Of the 81 Jack Arch Bridges tabulated (37 Existing, 44 demolished or approved for replacement) fifteen of the bridges have Bridge Cards with construction dates assigned to them. Those dates are considered most likely accurate. The dates range from 1914 to 1939 as listed below. Of those fifteen, eight were built by the NHHD and the dates are considered accurate. Plans are noted on the cards as "On File" for five of the NHHD bridges. One bridge, Franklin 159/117 was designed by John Storrs; a commemorative plaque on the bridge states the date as 1922.

Dates of NH Jack Arch Bridges

1914	1929
1915	1930 (2)
1922 (2)	1931
1923 (3)	1935
1925	1939
1926	

For the 22 bridges listed in the Tables with a question mark in the date column, there was no reliable source for the date found in the bridge files. Historical research and/or field examination of these bridges would be necessary in order to establish the actual dates or an estimated date based on information analysis. Six of those bridges are assigned the date 1940. While it is true that many of the local bridges that were destroyed in the 1938 hurricane were not considered fully completed until 1940, no information directly linking those bridges to the hurricane has been found in the files that were examined. One bridge is dated 1875, and three are dated 1900. These dates may pertain to earlier bridges that preceded the existing jack arch bridges, as suggested by the stone abutments carrying the 1875 bridge and one of the 1900 bridges (see Figure 3.13).

The Period of Significance for New Hampshire Jack Arch bridges at this point in the research can be considered to span the complete range of reliable construction dates listed above from 1912 to 1939 (Storr's Freemont 096/095, demolished, was built 1912). If new information establishes earlier or later dates for the bridge type, the period of significance should be adjusted accordingly.



Figure 3.13: Jefferson 140/097 under construction. 1940 Bridge Card photo. The bridge replaced an earlier bridge on stone abutments that were encased by the new concrete abutments. The Bridge Summary lists bridge date 1900, presumably referring to the preceding bridge.

3.3.2 Size Characteristics

Most jack arch bridges are single span and the length of the span and the overall width are the dimensions of interest since they determine the beam sizing and spacing. For the rare multi-span bridges of the type the number of spans and resulting overall length of the bridge is also of interest since it reflects the magnitude of the undertaking or perhaps indicates a new road system was built.

Unlike most bridge types where the length of the span is typically a measure of the cost or engineering importance relative to other bridges of the same type, it is of less importance for jack arch bridges. They are very short span bridges meant to replace wood beam spans or compete with reinforced concrete bridges, so their significance lies not in how big they are but rather how cheaply they could be constructed.

Table 1 provides the following data on the range of dimensions of existing jack arch bridges:

Span: 12.0' to 45.5'

Width: 14.7' to 53.0'

Multi-spans: Only one 2-span (Jefferson 166/058) and one 3-span (Franklin 159/117).

Overall length of multi-spans: Jefferson 166/058 is 73' overall; Franklin is 145' overall.

3.3.3 Arch Characteristics

Arch Axis

Of the 81 Jack Arch Bridges tabulated, 77 are I-beam stringer bridges with the beams running longitudinally. Four of the bridges are girder and floorbeam bridges with the floorbeams carrying the jack arch floor system transversely. An example is Lebanon 165/109, built by the NHHD in 1921, (see Figure 3.4). Technically, these are not jack arch bridges according to the common definition of the type. As previously discussed in Section 2.2, the jack arch floor system can function as a simple bridge span or be a separate floor system carried by another bridge type, such as a truss or girder span. For this study, they are included in the jack arch bridge-type category, but they should also be included in any study of girder and floorbeams bridges with the overlap noted.

Arch Shape

Arch shape is determined by the ratio of the distance between the spring points of the arch and the rise of the arch. The spring point is determined by two factors: the spacing of the I-beam stringers and whether the arch springs from the corner of the web and the bottom flange – generally the case when metal forms are used, or if it springs from a point 1 or 2 inches out and down from the edges of the bottom flange – the case when wood forms or another method was used to fully encase the bottom flange. The rise is the vertical distance from the spring line to the highest point of the arch curve. If the distances are equal then the ratio is 1:1 and the arch is semicircular.

There is a wide variation of jack arch shapes depending on the spacing on the stringers ranging from very flat segmental-arch shapes to semi-circular shapes. The type of forms used can also dictate the shape. Corrugated galvanized steel sheets and wood formwork can be arched to most any shape, whereas galvanized culvert pipe split lengthwise creates a semi-circular form and arch.

The variations in the beam spacing and the method of forming the arches is not of any engineering or design significance. The variations are instead notable because they reflect the vernacular nature of jack arch bridges built by local road agents using the materials readily at hand or most economically obtained. Bridges built by the NHHD are more consistent in the use of wood forms to fully encase the stringers. Longer span bridges require deeper stringers and therefore have arches with a greater rise.

Arch Formwork

Wood forms and steel forms of various types were used as noted above, depending on who was designing and building the bridge and the materials they were familiar with or could be readily obtained most economically.

Corrugated galvanized steel sheets were used in widths of 24" and 36" cut to the necessary length to arch between the beams while allowing roughly 12" of concrete over the top of the forms and 3" or more cover over the top beam flange (Figure 3.14). The forms were often left in place and are now either rusted and falling away or completely missing (Figures 3.15, 3.16).

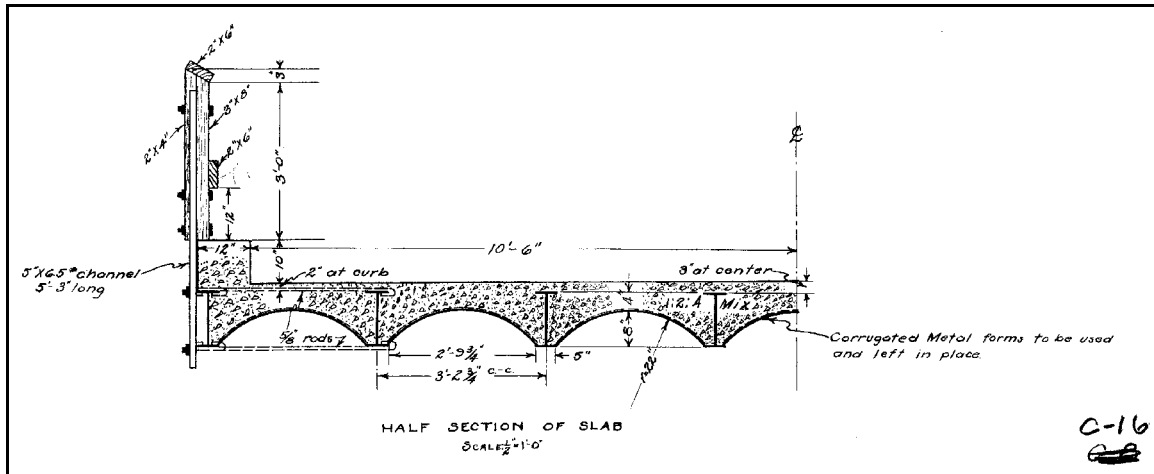


Figure 3.14: Middleton 1923 State Aid Bridge. Detail of metal forms left in place and hook-type beam tie-rods.



Figure 3.15: Acworth 113/064. Corrugated galvanized steel sheet forms left in place, severely corroded and falling away. Survey Photo July 2010.



Figure 3.16: Peterborough 132/134. The brown portion of the arch at right is a piece of completely rusted corrugated metal form; the gray area of the arches is exposed concrete where the other form sections have fallen away. Note different shape arch at the outside beams. Survey Photo July 2010.

Flat (non-corrugated) galvanized metal sheet cut in approximately 4-foot lengths was used on at least one bridge, Charlestown 142/101 (Figure 3.17). The floor has small closely spaced stringers with only 2-1/2 inches of rise to the arches.



Figure 3.17: Charlestown 142/101. Non-corrugated galvanized forms. Survey Photo July 2010.

Wood forms were custom built for a particular bridge and then left in place in some cases (Figure 3.18). In other instances the forms were removed to be used for another bridge. Forms were typically oiled to release them from the concrete, leaving wood-grain form marks behind (Figure 3.19). In at least one case, tarpaper was applied over the forms as a release liner (Figure 3.20).



Figure 3.18: Raymond 172/149. Wood forms left in place. Note the hangar bolts supporting the wood cross beam members that support the forms and that diaphragms were not formed to encase beam tie rods as shown in Figure 3.19. Survey Photo July 2010.



Figure 3.19: Nelson 073/098. Note wood forms marks, exposed bottom flanges and hook-type beam tie-rods. Survey Photo July 2010.



Figure 3.20: Alton 096/287. Tarpaper used between the forms and the concrete shown still adhering to the arches. Note hangar bolts for the forms and concrete diaphragms between the arches encasing the beam tie-rods. Survey Photo July 2010.

Diaphragms were used to encase the beam tie-rods and provide lateral bracing and increased rigidity to longer span jack arch bridges (Figure 3.21). Several bridges designed by Harold Langley with this feature survive; Goffstown 053/119 for example, survives in remarkable condition suggesting that the diaphragms greatly reduce racking of the floor and prevent the cracking and breakdown of the concrete seen on other jack arch floors that lack the stiffness afforded by the diaphragm bracing (Figures 3.22, 3.23).

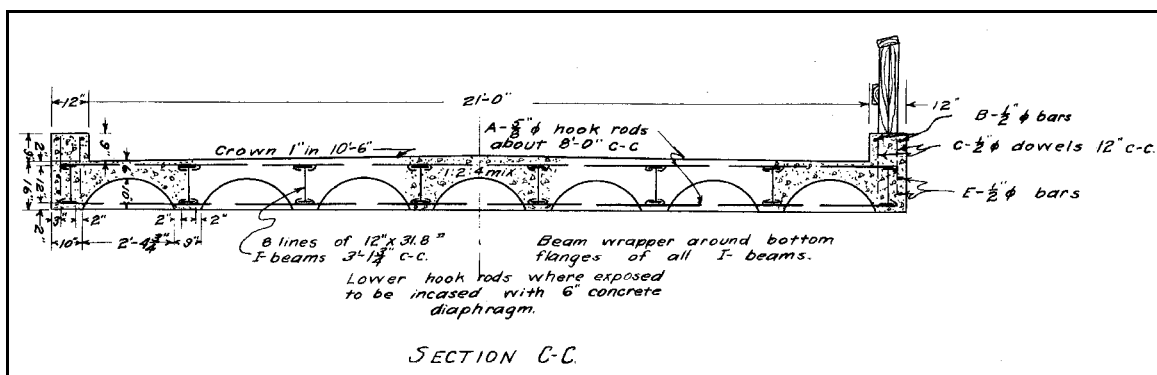


Figure 3.21: Hampton Falls 094/142 [1923]. Note diaphragms specified on plans prepared by Harold Langley (NHHD Plan C-61).



Figure 3.22: Goffstown 053/119 [1923]. Designed by Harold Langley. Survey Photo July 2010.



Figure 3.23: Goffstown 053/119 [1923]. Designed by Harold Langley. Survey Photo July 2010.

3.3.4 Abutment Types

Abutments used for jack arch bridges are of three types: standard-design concrete abutments designed with the design of the bridge; existing stone abutments from the previous bridge at the site; and existing stone abutments modified with reinforced concrete in some way such as the addition of new bridge seats, partial concrete encasement, or full concrete encasement. Examples of each are shown on Figures 3.24, 3.25, 3.26.

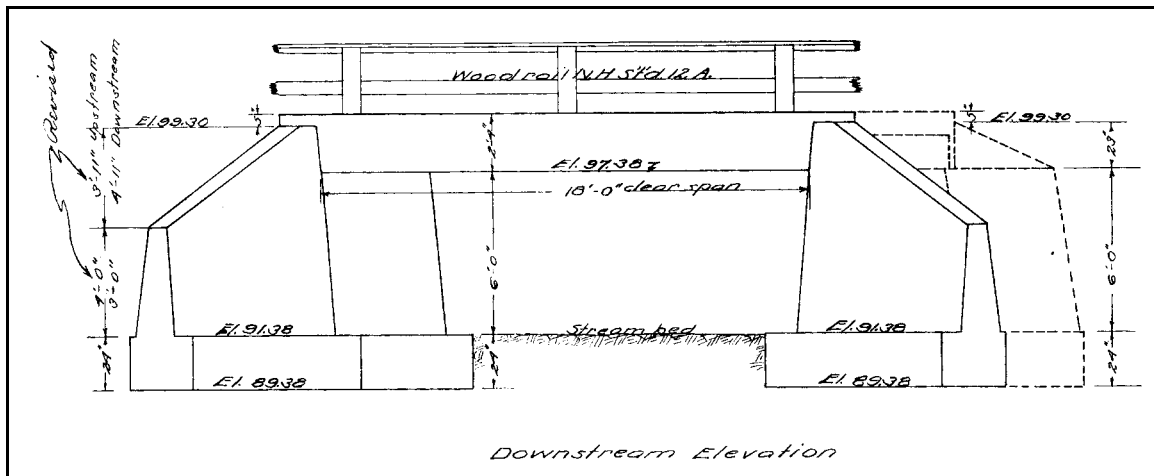


Figure 3.24: Goffstown 053/119 [1923], designed by H.E. Langley. Standard bevel wing type concrete abutments as used on a variety of bridge types (NHHD Plan C-60).



Figure 3.25: Raymond 172/149. Existing stone abutments carrying retrofitted jack arch bridge. Survey Photo July 2010.

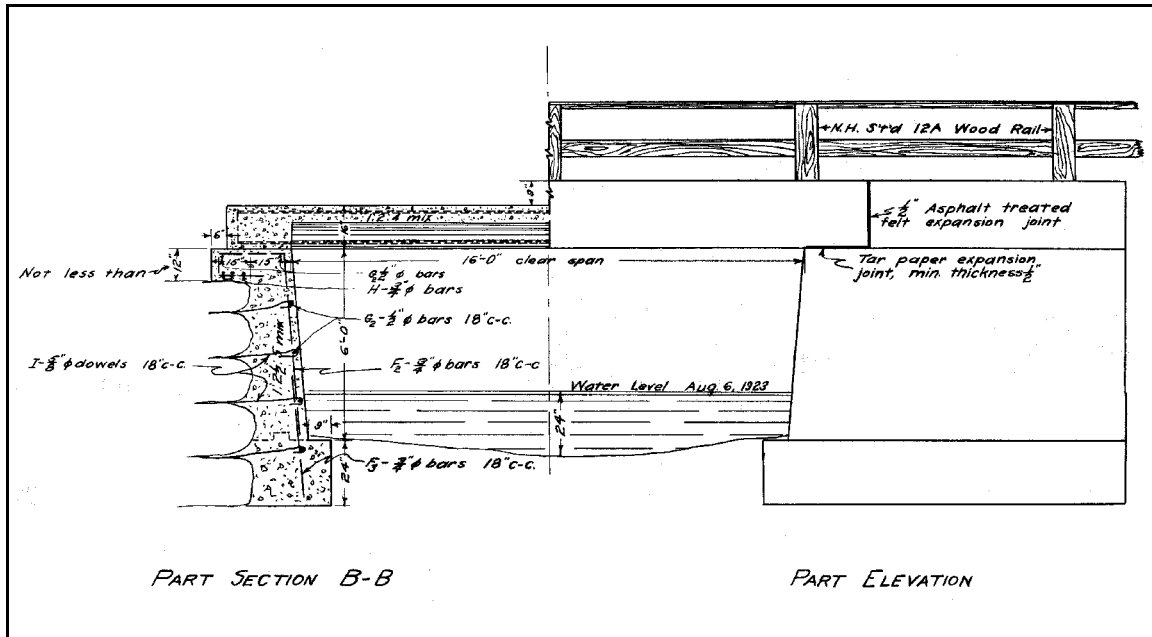


Figure 3.26: Hampton Falls 094/142, 1923, designed by H.E. Langley. Existing stone abutment with reinforced concrete encasement (NHHD Plan C-61).

3.3.5 Railing Types

Steel Lattice Railing

Lattice railing and pipe railing are apparently the oldest railing types used on jack arch bridges. More expensive than simple pipe railing, lattice railing was more suited to urban settings or bridges with sidewalks as it was both decorative and offered protection for small children. John Storrs used lattice railing on Freemont Bridge 096/095, built in 1912 and demolished in 1998 (Figure 3.1). United Construction Company shows lattice railing in their 1915 company advertisement (Figure 3.2). At this point of the study, there are no known examples of lattice railing in place on the remaining jack arch bridges.

Steel Pipe Railings

Steel pipe railings consisting of one, two or three lines of pipe rails joined to pipe posts with cast iron fittings, was a widely used railing type on early jack arch bridges of the 1910s and 1920s. United Construction Company depicts pipe railing in their 1915 company advertisement (Figure 3.2). The Storrs and Storrs 1918 bridge design handbook (Figure 3.3.) shows 3 lines of pipe rail interconnected to pipe posts of the same size (generally 2" or 2-1/2" pipe) with 3-way (tee) or 4-way (cross) cast fittings. The posts are shown set into the concrete curbs, suggesting the railings were preassembled, braced into position and cast in place.

A one-rail example is still in service on Charlestown 142/101 (Figure 3.27). The bridge is dated

1940 in the Bridge Summary, but the Bridge Card is missing so the date is uncertain. Chester 147/100, 1920? can be seen with two-rail pipe railings in the 1979 and 1984 photos contained in the bridge inspection files. Those railings are believed to still be in place. Merrimack 116/137 was equipped with three-rail pipe railings, one of which may still be in place behind modern W-beam guardrail.



Figure 3.27:Charlestown 142/101 [1940]. Surviving one-rail pipe railing. Photo July 2010.



Figure 3.28: Peterborough 132/134 [1940?]. Surviving two-rail pipe railing. Survey Photo July 2010.

Pipe Railings on Non-pipe Posts

Railings consisting of pipe rails carried on other types of posts were also used on jack arch bridges. The use of steel angle posts and wood posts bolted to the outside of the bridge were stronger than pipe posts and allowed long continuous lengths of pipe to be bolted to the inside face creating a smooth snag-free rub rail.

The 1915 United Construction Company advertisement (Figure 3.2) shows two lines of continuous pipe railing bolted to angle posts in turn bolted to the outside stringers or the concrete fascia. According to the 1980 bridge inspection report, Westmoreland 124/061 was then equipped with steel angle posts with a pipe rail at the mid-point and steel angle for the top rail.

One known example of a jack arch bridge with pipe rails cast into concrete posts is Freedom 185/067. The bridge is located in a village setting subject to frequent foot traffic and was built with four closely spaced rails (Figure 3.29).



Figure 3.29: Freedom Bridge 185/067 [1922]. Steel pipe railing on concrete posts. Photo from Bridge Card, 1940. NHHD bridge inspectors shown at work.

Steel cable on wood posts

This type of railing, or guardrail, consisted of two lines of steel cable on wood posts. The upper half of the posts are shown painted white in the available photographs. Several bridges were identified with this type of railing including Andover 041/110, 1920? and Chichester 130/100, 1931 (see Figure 4.5).

The size and type of post, round or square and means of attachment is not stated or evident from the bridge card sketches and photos. It is also not apparent from the available information if these railings were originally built with cable guardrails or if they were added later. No examples are known to remain in service on jack arch bridges

Wood Rails on wood-encased steel channel posts,

This railing was part of the NHHD 1923 Standard Design for Steel I-Beam Concrete Arch Bridge (jack arch) as shown on Figure 3.30. The railing posts consisted of 3"x5"x6.7 p.l.f. steel channel set 1 foot deep into the curb wall on 8-foot centers. The posts were then encased with 3"x8" wood boards to a finished height of 33". The means of construction and attachment, nails and/or bolts, is not specified, but in photos (as shown below) through-bolts appear to be seen. Two 2"x6" wood board rails were attached to the posts: the top rail was mounted across the top of the posts at an angle to shed water; the mid-rail or "rub-rail" was mounted on the inside at about the midpoint. At some point this railing became known as "NH Standard 12A" which is all that is noted on many of the bridge cards.

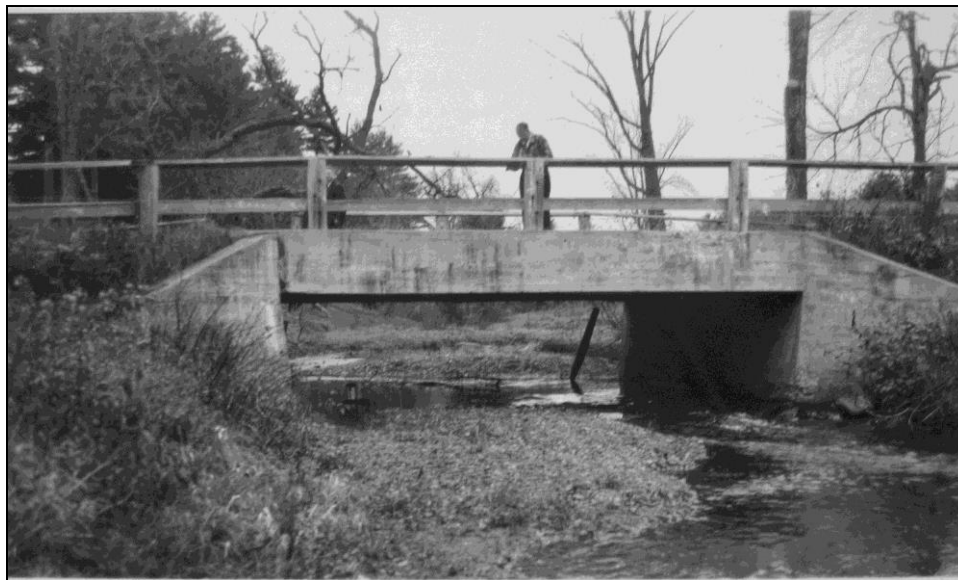


Figure 3.30: Bath 131/145 [1923]. Demolished. Wood bridge railing, NH Standard 12A, shown in photo from Bridge Card, 1941, prepared by Wendell H. Piper. Piper prepared most of the 1940-1942 bridge cards examined; H.B. Pratt also prepared some. All of the NHHD personnel involved in the fieldwork and card preparation have not been determined. Many of the photos on the cards show NHHD bridge inspectors at work, as above, but their identities also have not been determined.

Solid Concrete Parapet Railings

The data gathered to date indicates that solid concrete parapet railings were used on several jack arch bridges designed and built by the NHHD from 1923 to 1930. The railings were more expensive than other railing types, requiring more skilled formwork as well as heavier outside stringers to carry the additional dead load. Franklin Bridge 159/117, designed by John Storrs and built in 1922, is one example of use of concrete parapet railings on a jack arch bridge built by a town or city.

When used in a prominent location, concrete parapet bridge railings were often given some decorative treatment, typically by applying moldings to the inside of the forms to create the appearance of "paneling" (see Figure 3.9, 3.31, 3.32). On less important bridges the concrete might be left flat and capped with a simple coping as in the case of Hampton Falls 094/142, shown in Figure 3.33.

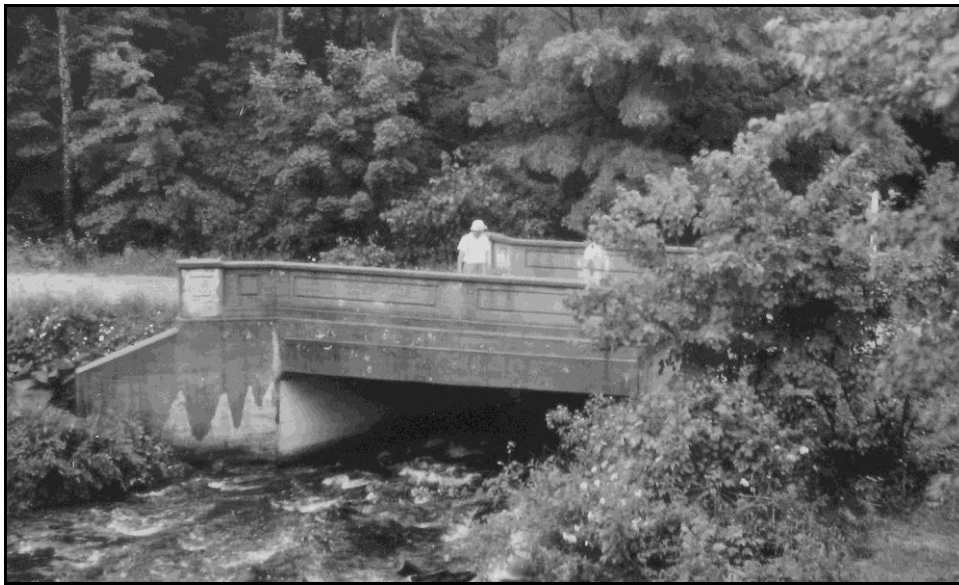


Figure 3.31: Milton 064/167 [1930]. Solid concrete parapet railing with embossed paneling. Photo from Bridge Card, 1940. NHHD bridge inspectors shown at work.

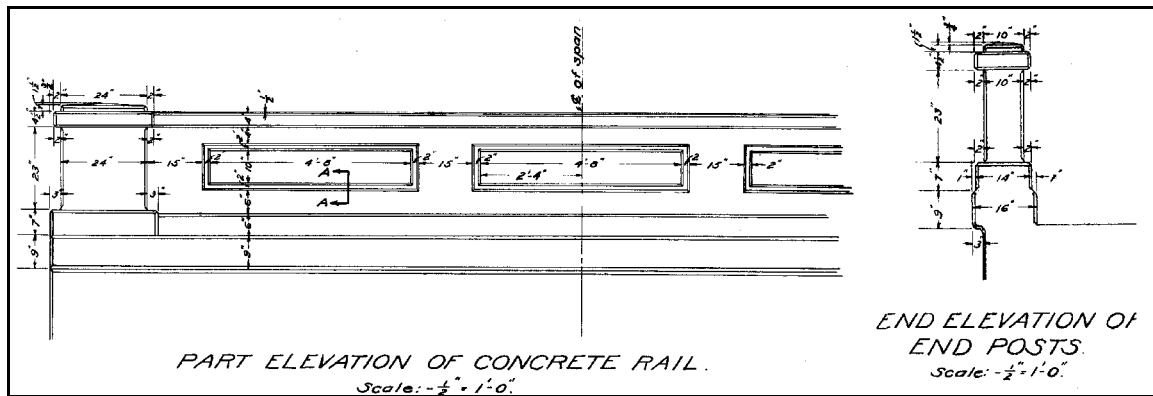


Figure 3.32: New Durham 199/054 [1926]. Details of paneled concrete parapet railing. NHHD Plan E-39.

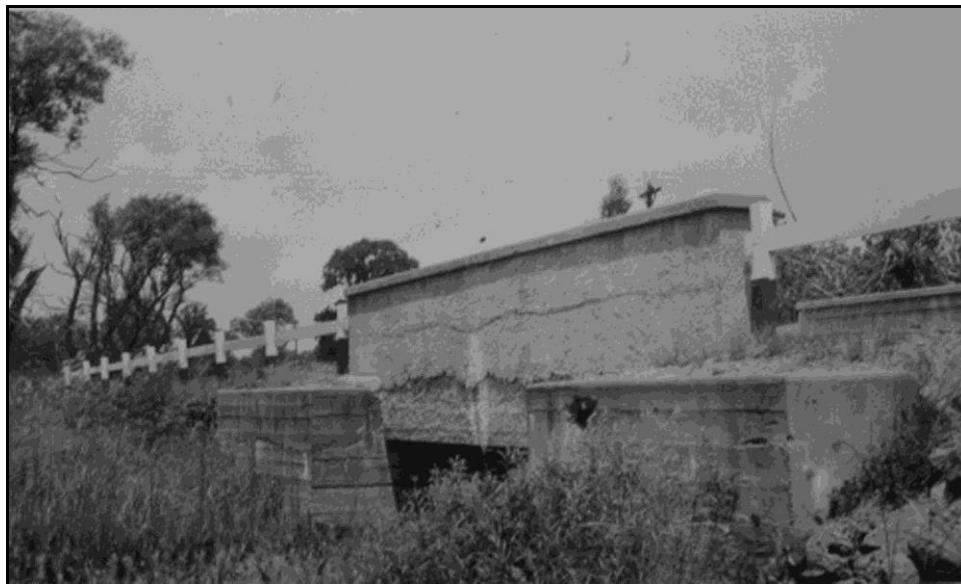


Figure 3.33: Hampton Falls 094/142 [1923]. Plain solid concrete parapet with coping. Photo from Bridge Card, 1942.

4.0 HISTORIC SIGNIFICANCE

4.1 SIGNIFICANCE DISCUSSION

The jack arch bridge in its various forms has played an important role in the development of the primary and secondary road systems in the United States from the late 19th century up until World War II. In New Hampshire, the bridge type was embraced by the New Hampshire Highway Department about 1920 and standardized plans were prepared to enable the uniform, economical and rapid construction of the bridges by the state and local municipalities. As a result, over 100 jack arch bridges are estimated to have been built in New Hampshire. Thirty-seven have been identified as remaining, ten of which are "red-listed" due to structural deficiencies and will soon require major repairs, replacement, or bypassing. Most of the remaining 27 bridges have functional or structural issues or deficiencies to some degree and will be slated for replacement in all likelihood within the next decade or two.

The jack arch bridge in New Hampshire will therefore continue to disappear and those remaining will become increasingly rare examples of a once common bridge type, a consideration when determining historical significance.

The degree of historical importance of the jack arch bridge for its role in the development of New Hampshire's state and local highway system is a question that remains subject to analysis based on the individual bridge. Jack arch bridges designed and built in the 1920s by the NHHD for state highways certainly played an important role in the economical and efficient expansion of that system. Jack arch bridges designed and built by municipalities may or may not have played a significant role in the local transportation network; specific historical research will continue to be required to fully answer that question.

The architectural and engineering significance of the jack arch bridge has always met with a variety of opinions. The historical research conducted for this report shows the bridge type to be essentially vernacular in origin. It was not an invention to which a specific engineer or engineers have staked claim. Architectural considerations, as they are typically applied to bridges, have had no role in defining the bridge type other than in the occasional simple decorative detail that may appear in the railing design, and those were made by engineers, not architects. The bridge is simple by design and subject to the most basic structural analysis as long as the deck is considered as an independent slab and the composite action and continuity that exists is disregarded.

A measure of historical engineering significance can be assigned to the refinement and definition of the bridge type by state highway engineers during the early 20th century. In particular, the development of standardized plans by Harold E. Langley and possibly other engineers in the NHHD marked a transition of the jack arch from its vernacular form into a defined and accepted bridge type. Other state highway departments also developed standard jack arch designs about the same time, placing the NHHD's designs within the broader context of a national property type.

4.2 INTEGRITY CONSIDERATIONS

Jack arch bridges in general retain a high degree of integrity of their primary character-defining feature, which is the concrete arched deck. The type is defined by the arch floor system and it is the integrity of the floor system that is of greatest importance. The other features of the bridge, the railings and abutments take on varying degrees of importance depending on the individual bridge and their integrity or lack of it may add or detract from the overall design integrity of the bridge.

4.2.1 Alterations

Railings

Except in a few cases original railings have been replaced with modern W-beam guardrail. Bridges with sidewalks have been fitted with incompatible railings such as chain link wire fencing on Concord 140/113. Original railings on other bridges have been replaced with steel balustrade railings such as New Durham 199/054 for which no historical precedent exists, but nonetheless are aesthetically pleasing and convey a sense of the importance to the bridge that the original railings may have conveyed (see Figures 4.1, 4.2).



Figure 4.1: New Durham 199/054 [1926]. Original bridge railing. Photo from bridge card, 1941, south elevation.



Figure 4.2: New Durham 199/054 [1926]. New steel balustrade-type bridge railing. Survey photo, 2010, south elevation.

Widening

Jack arch bridges are easily widened and as noted in the table, widening was a common improvement. In some cases an additional stringer was added to carry a narrow reinforced concrete slab for a sidewalk or roadway extension. In other cases greater widening has been accomplished with the addition of reinforced concrete slab spans to one or both sides of the jack arch, Alton 096/287 and Chichester 130/100, being examples (Figures 4.3, 4.4).



Figure 4.3: Alton 096/287. Widened with a reinforced concrete slab deck extensions. Survey Photo July 2010.



Figure 4.4: Chichester 130/100, widened both sides. Survey Photo July 2010

4.2.2 Setting

The bridge setting generally plays little role in determination of the loss of integrity; changes around bridges are accepted and unless the bridge is a contributing feature of a historic district, setting is generally not a primary consideration. On the other hand, when the setting retains great integrity from the time of the original construction, Raymond 172/149 being a prime example (see Figure 3.25), then setting will raise the overall significance and integrity of the property.

Examples of how setting affects the overall impression of the bridge are given in the following "before and after" photos of Chichester 130/100 and New Durham 199/054 (Figures 4.5 – 4.8).

4.2.3 Structural Deterioration

In some cases deterioration of the concrete arch encasement of the beams is so severe that the concrete is falling away in large pieces from the encased beams (Figure 4.5). This is usually accompanied by longitudinal and/or transverse cracking that has led to rusting of the I-beams. Rust expands with immense force, further fracturing and dislodging the concrete covering. When the deterioration has reached a point that the structural integrity of the beams and floor is lost and beyond all reasonable repair, then the integrity of original design can be considered greatly diminished or lost.



Figure 4.5: Chichester 130/100 [1931]. Photo from Bridge Card, 1941. Compare setting to today in photo below. Note steel cable guardrail.



Figure 4.6: Chichester 130/100 [1931]. Survey photo, July 2010.



Figure 4.7: New Durham 199/054 [1926]. Photo from bridge card, 1941.



Figure 4.8: New Durham 199/054 [1926]. Survey photo, July 2010.



Figure 4.5: Newbury 120/078 [1936?]. Severe cracking and spalling of concrete encasement and rusting of I-beams. RMC Photo April 2009.

4.3 ELIGIBILITY CONSIDERATIONS

The primary character-defining feature of jack arch bridges is the arched concrete deck and the features associated with the deck such as forms left in place. All other features including the concrete abutments and railings are features that are characteristic of other bridge types and not associated in any specific way to jack arch bridges. The absence of integrity in these secondary features therefore should not determine the integrity of a jack arch bridge that otherwise retains structural integrity of the I-beam and concrete arch floor. However, the presence of other original secondary features does enhance the overall significance of the property and should be considered when integrity of the jack arch is present. In some cases the prominent location of the bridge may have dictated specialized railings such as the paneled concrete parapet type, and when such features are present and retain individual integrity, they should be considered a primary character-defining feature.

In the case where a professional structural engineer has determined that the structural integrity of the jack arch floor system has been compromised, a study of the feasibility of making repairs in-kind should be required.

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6.0 NOTES

¹ The term jack-arch is usually associated with masonry construction and refers to a flat arch. J.A.L. Waddell, the noted bridge engineer and historian, defines a jack-arch in his treatise *Bridge Engineering*, as an arch limited in thickness to one brick (Waddell 1916:1897). Webster's dictionary defines jack as anything smaller than the usual of its kind. The term is widely used today in carpentry to describe any timber that has been cut shorter than the other timbers answering the same purpose; as, jack-rafter, or jack-studding (Siegele 1946:177). Russell Sturgis's 1902 edition of *A Dictionary of Architecture and Building* defines jack as an adjective meaning inferior or secondary and states that terms compounded with jack are often coined on occasion to explain the idea of smaller size or secondary position, and this extemporaneously by men unfamiliar with the refinements of the language. Few of the many terms so produced are of permanent interest.

² W.E. Ward. "Beton in Combination with iron as a Building Material." *Journal of the Franklin Institute*, 83 (August 1883): 97.

³ Ward, 1883, pp. 100, 107.

⁴ For a discussion of fireproof floor systems see: Frank E. Kidder, *Architects and Builders Handbook*, 1892, and Edward A. Tucker, "Steel Construction" in *Cyclopedia of Architecture, Carpentry and Building, Volume 5*, 1908.

⁵ As cited in Lovett Bridge Historic American Engineering Report MA-133, 1994.

⁶ Boller, Alfred Pancoast. *Practical Treatise on the Construction of Iron Highway Bridges for the use of Town Committees*. New York: John Wiley & Sons, 1879. Boller's treatise was copyrighted in 1876; the first edition appeared in 1879.

⁷ W.G.S. Chamberlain. "Abolition of the Grade Crossings on the Main Line of the Boston and Albany Railroad in Newton, Mass., Part III, Bridges over Railroad Tracks." *Journal of the Association of Engineering Societies*, 21 (August 1898):62-67.

⁸ *Engineering News*. "Concrete and Expanded Metal Highway Bridge Construction in Allegheny County, Pa." *Engineering News* 41 (January 26, 1899):50.

⁹ Thomas Aitken, *Road Making and Maintenance: A Practical Treatise for Engineers, Surveyors, and Others*. Philadelphia: J.B. Lippincott Company, 1900, p. 86.

¹⁰ William D. Bullock, "Economy and Strength of Brick and Concrete Arches for Floor Systems of Highway Bridges." *Journal of the Association of Engineering Societies*, 26 (February 1901):73-83.

¹¹ Milo S. Ketchum, *The Design of Highway Bridges of Steel, Timber and Concrete*. New York: McGraw-Hill Book Co., 1908, p. 278.

¹² *The Engineering Record*. "A 109 Ft. Concrete-Floor Plate Girder Bridge." *The Engineering Record* 61 (May 21, 1910):662-663.

¹³ Wells, 1913:70

¹⁴ Charles M. Spofford, "Highway Bridge Floors," *Proceedings of the Engineers Society of Western Pennsylvania* 31 (1915): 768.

¹⁵ Spofford, 1915, p. 771.

¹⁶ Storrs and Storrs, 1918, pp. 20-21.

¹⁷ John W. Storrs and Edward D. Storrs. *A Handbook for the use of those interested in the construction of Short Span Bridges* (Concord, NH: 1918):21.