BCEE129 Final Design Project Submittal
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<u>Iconic Bridges Across New England and Beyond: When, Where, and Why</u>

Bridging Projects 2 and 7 Together

Photo Essay on the History of Important Local Bridges

Introduction: Before we jump into the history of the Bridge of Flowers specifically, we wanted to give an overview of the history of bridge design around New England and beyond. This storied history can be traced through several different landmark bridges. It is a history of new construction methods, new design techniques, and new materials. It is also a story that follows the development of the United States from a small agrarian colonial backwater into an industrial power at the forefront of engineering innovation.

One critical resource for this timeline and an excellent resource for historic bridges is the National Cooperative Highway Research Program Report (NCHRP) titled "A Context For Common Historic Bridge Types". It can be found at the following link: https://gis.penndot.gov/CRGISAttachments/Survey/A_Context_For_Common_Historic_Bridge_Types.pdf

1662 - Great Bridge to Boston
1764 - Choate Bridge, MA
1792 - Essex-Merrimac-Newburyport Bridge
1810 - Templeman Chain Bridge
1820 - The Town Lattice Truss
1829 - Carrollton Viaduct in Maryland
1840 - Howe Truss
1870 - Bessemer Process For Steel
1871 - Cleft Ridge Span, Brooklyn, NY
1890 - Shelburne-Buckland Wrought Iron Bridge
1893 - Melan Bridge, Iowa
1893 - Chicago World's Fair
1908 - Bridge of Flowers Built
1927 - Mount Hope Bridge
1931 - Charles River Rail Bridges
1939 - Deer Isle Bridge, Maine
1948 - Claiborne Pell-Newport Bridge, Rhode Island
1950 - Braga Bridge
1958 - Joseph E Muller Bridge
1997 - Zakim Bridge

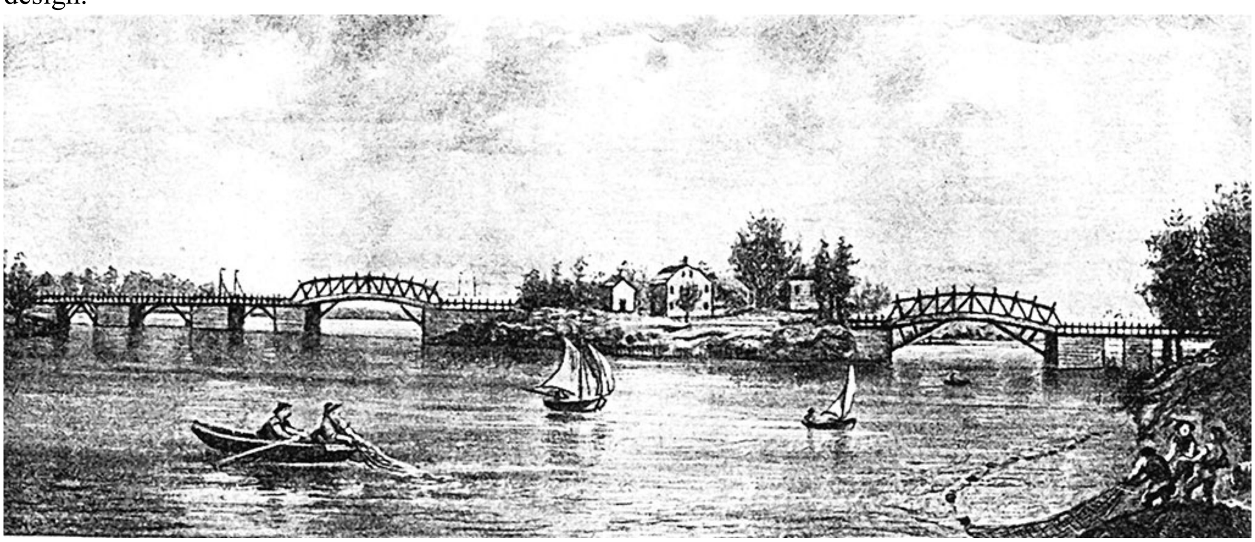
1662 - **Great Bridge to Boston -** (modern day Allston to Cambridge). This bridge represents the first major bridge in the colonies. This bridge was a timber pile bridge. The simplicity of the design can be seen in the photo below from much later in the bridge's life.

Source: http://thewestendmuseum.org/wordpress/wp-content/uploads/2013/07/1_Panel1.pdf

1764 - **Choate Bridge, MA -** This bridge is a good example of an early stone arch bridge. This is a 75 ft span bridge over the Ipswich river and is the oldest bridge in Massachusetts.

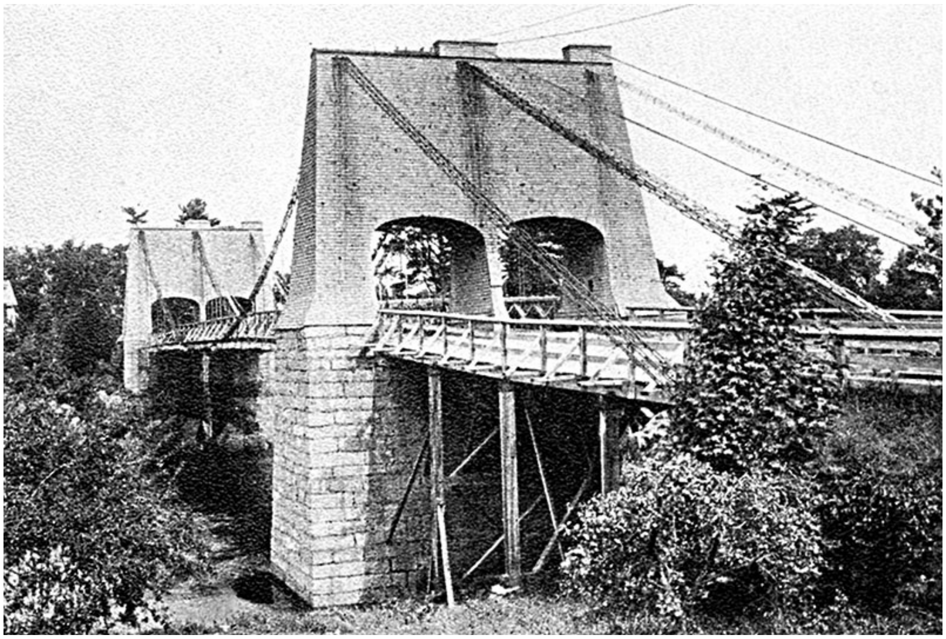
Source: https://www.loc.gov/pictures/resource/hhh.ma0636.photos.078507p/

1792 - **Essex-Merrimac-Newburyport Bridge-** This bridge was one of the first major truss bridges in the US. It used a wooden truss system adapted from another design from 16th century architect Palladio (https://www.structuremag.org/?p=117). This bridge is significant since it was the longest truss span of its time at 160 ft. Timothy Palmer also represents a very common story for engineers in the early USA. Palmer was originally a "house wright" (house builder) and the Newburyport bridge was his first bridge design.



Source: https://www.structuremag.org/wp-content/uploads/0613-hs-1.jpg

1810 - **Templeman Chain Bridge** - This bridge was a chain suspension bridge covering a 244 ft span built by John Templeman. This bridge was built to replace the 160 ft span built by Palmer for the Essex-Merrimac/Newburyport bridge because by 1810 the wooden arch bridge was decaying and needed replacement (https://www.structuremag.org/?p=117). John Templeman represents another common story in early engineering. He has worked under James Finley, the father of the suspension bridge, and then based this design off a Finley design (https://issuu.com/structuremag/docs/mar16/s/11768822).



Source: https://www.structuremag.org/wp-content/uploads/0613-hs-3.jpg

1820 - Town Lattice Truss - The Town Lattice is one of the first "true trusses" patented. It was easy and cheap to build. For example, the Cornish-Windsor Covered Bridge built in 1866 has a Town Lattice truss. In the image on the right you can see the internal truss system with the criss-crossed wooden members.

Source: NCHRP Report Figure 3-12
https://gis.penndot.gov/CRGISAttachments/Survey/A_Context_For_Common_Historic_Bridge_Types.pdf

1829 - **Carrollton Viaduct in Maryland** - While it is not in New England, the Carrollton Viaduct has an important place in the history of bridge design since it is the first stone arch railway bridge built in the US. It spans 80 ft and is still in service today.

Source: https://www.ce.jhu.edu/baltimorestructures/Index.php?location=Carrollton%20Viaduct

1840 - **First patent for Howe truss** - The Howe truss integrates iron and wood into a truss. An example of a double intersection Howe truss is a bridge over the Blackledge River in New London, Connecticut from 1907.

Source: NCHRP Report Figure 3-38
https://gis.penndot.gov/CRGISAttachments/Survey/A_Context_For_Common_Historic_Bridge_Types.pdf

1870 - Bessemer Process - The Bessemer process for steel made steel much cheaper and easily available. This means that from this point forward steel became a common material used in bridge design. A good example of this would be the Eads bridge in St Louis Missouri. The Eads bridge, finished in 1974, was the world's first steel truss bridge (https://www.stlouis-mo.gov/government/departments/planning/cultural-resources/city-landmarks/eads-bridge.cfm). The designer James Buchanan Eads is another example of a self taught engineer who innovated bridge design in the early engineering history of the USA.

Source: https://www.stlouis-mo.gov/government/departments/planning/cultural-resources/city-landmarks/eads-bridge.cfm

1871 - Cleft Ridge Span - The Cleft Ridge Span was the first concrete bridge in the US. It is a small span in Prospect Park Brooklyn NY that is used by pedestrians. It was a significant experiment at the time since concrete was a new construction material back in the 1870s. Since concrete can not carry tension, the bridge uses the same kind of compression arch seen in the Carrollton Viaduct and Choate Bridge.

Source: https://www.brownstoner.com/history/prospect-park-brooklyn-cleft-ridge-span-bridge-olmsted-vaux/

1890 - Shelburne-Buckland Wrought Iron Bridge Built

Source: https://www.loc.gov/pictures/resource/hhh.ma1414.photos.079336p/

1893 - Melan Bridge - The Melan bridge in Iowa was the first concrete reinforced bridge in the U.S. It is called the Melan bridge because it used the Melan system, first pioneered in Austria in the early 1890s.

The span was only 30 ft so it did not really need to be a reinforced concrete bridge but the span was seen as an experiment to prove reinforced concrete was an effective structural system (https://iowadot.gov/historicbridges/historic-bridges/Melan-Arch-Bridge).

Source: https://iowadot.gov/historicbridges/historic-bridges/Melan-Arch-Bridge

1893 - Chicago World's Fair - The Chicago World's fair is not directly related to bridge design structurally, but it has a major effect on aesthetics. The Chicago World's Fair hosted the "white city" and was meant to be a kind of manifesto of design from city beautiful reformers. The fair focused on promoting a Beaux Arts style that persisted well into the 1900s.

1908 - Bridge of Flowers Built

Source: https://www.bridgeofflowersmass.org/about-us

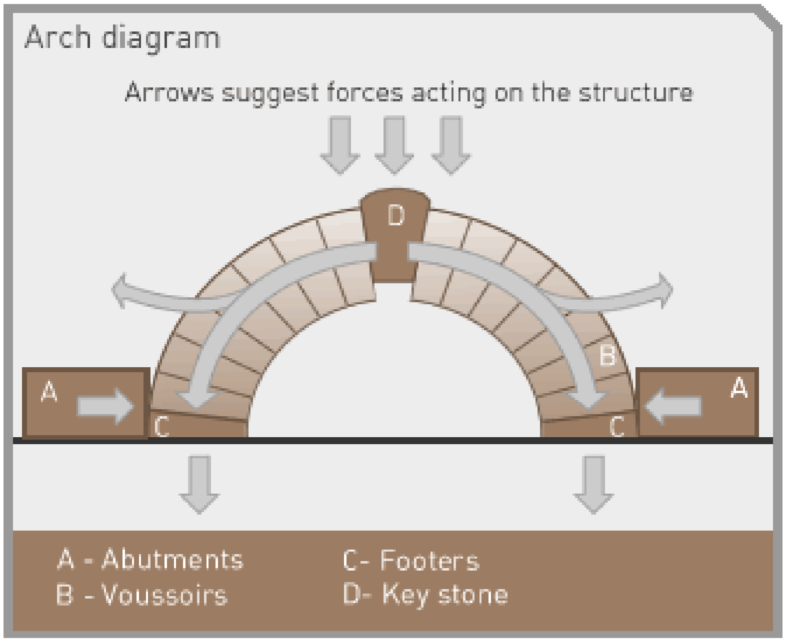
Conclusion: The bridge of flowers fits well into the history of bridge design in New England and around the US. One can trace the development of construction materials from wood, stone, and iron to steel and concrete. One can also trace the development of engineering as a discipline as the "rockstar" engineers such as Palmer, Melan, Eads, and others that worked on large projects or innovated new structural designs to other less well known figures who did excellent work but do not have the same star power. Finally one can trace the aesthetics of the bridge of flowers back to the Chicago World's Fair and the city's beautiful reformers.

Construction and Notable Examples of Each Type of Bridge
Arch Bridge - Construction of the Bridge of Flowers:

Source: https://artsfuse.org/208543/visual-arts-commentary-the-bridge-of-flowers-shelburne-falls-massachusetts/

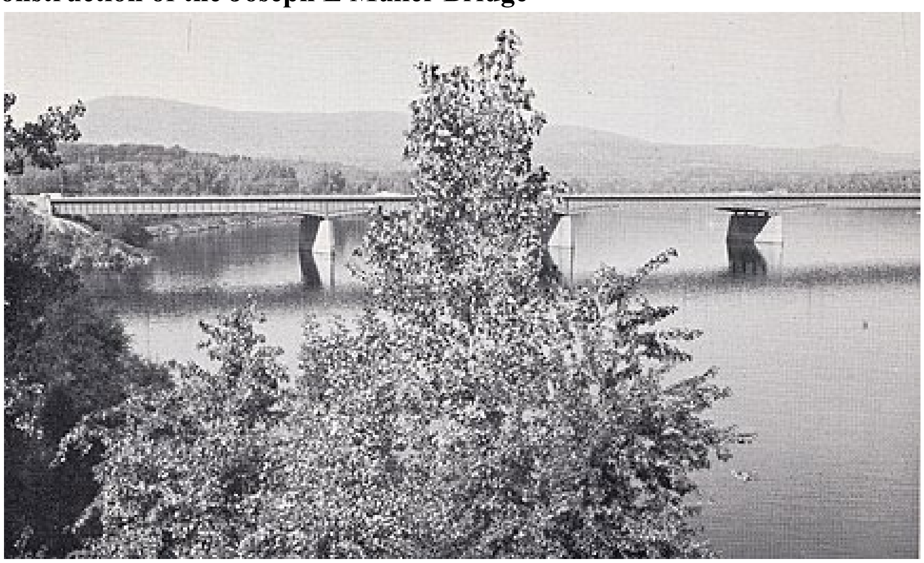
Historical Context:
Originally a steel truss bridge crossed the Deerfield River. As Shelburn and Buckland grew around the river, with the help of the trolley, the loads on the original bridge became too much, so a parallel bridge was proposed. The arch bridge was constructed in 1908 to meet the needs of the two towns, utilities also crossed the bridge and unified the towns' economies. As trolleys closed across the country, this particular one was discontinued in 1928, but the bridge remained because of a water main that traversed the bridge and connected the towns. This lack of usage led to the bridge falling in disrepair and weeds growing over the top. In 1929, local women wanted to beautify the bridge and added fertilizer and soils to help plant flowers and the greenery has flourished ever since.

Steps in construction of arch bridges:
1. Design bridge with arch and roadway placement in mind.
2. Excavate and prepare the banks of the water body by excavating to bedrock to make room for the abutments of the arch or placing concrete anchors in the water body to bear the weight of the arch and load.
3. Construct the arch, bottom-up, from both banks, using material that is good in compression. Stability is only reached when both ends meet. To temporarily support the arch, cables can be anchored into the banks or scaffolding can be used.
4. Keep the arch building to reasonable tolerances to make sure that the sides meet in the middle.
5. Connect both sides of the arch bridge at the top (with a key stone if using concrete/stone) and slowly remove the temporary bracing.
6. Build the roadway starting from the bottom of the arch. Add pavement.



Source: https://howbridgeswork.weebly.com/arc-bridge.html

Beam Bridge - Construction of the Joseph E Muller Bridge



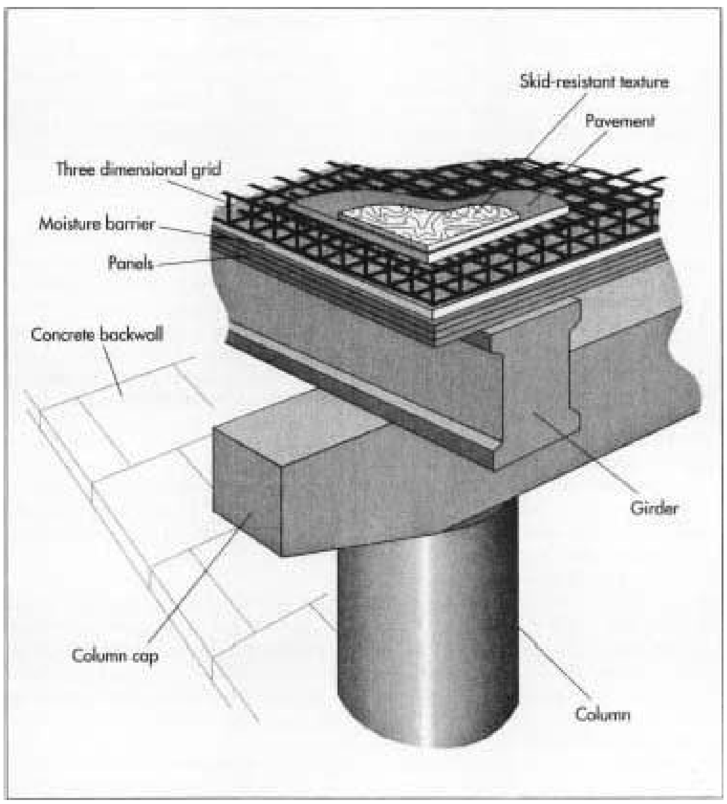
Source: https://en.wikipedia.org/wiki/Joseph_E._Muller_Bridge

Historical Context:

In 1958, a proposal arose to extend the I-91 corridor through Holyoke, MA. Due to concerns of heavier traffic and access to the interstate, a bridge crossing the Connecticut River would be required. Route 202 would be diverted over this bridge. The traffic was redirected from an older, smaller bridge crossing the river as well. Some homes were torn down, while others were uplifted and relocated to make space for the new highway. Even with the destruction and transformation, the bridge was seen as vital to connect the two towns. The highway that came through also spurred development and helped growth of businesses adjacent to this new bridge.

Steps in the construction of beam bridges:

1. Construct a cofferdam (watertight enclosure) around each location of columns in the riverbed and pump the water out. Drill foundations through the riverbed to the bedrock, while pumping clay slurry into the hole to prevent the shaft collapsing. Lower a cylindrical case of reinforcing steel rebar into the shaft, then pump concrete to the bottom of the shaft. The top of each column can be attached to the foundation after being formed and cast in place or precast and lifted into place.
2. Prepare bridge abutments on the riverbank where the end of the bridge will be. Form a concrete backwall as a retaining wall for the osil beyond the bridge. and pour it between the top of the bank and the riverbed.
3. For the bridge to rest on a pair of columns at each support point, finish the substructure by putting a reinforced concrete beam cap perpendicular to the direction of the bridge. The cap will go from the top of one column to the next.
4. Set steel or prestressed concrete girders between consecutive columns. Bolt the girders to the column caps.
5. Lay steel panels or precast concrete slabs across the girders to complete the superstructure by forming a solid platform.
6. Create a moisture barrier on top of the superstructure platform. Add a grid of reinforcing steel bars.
7. Pour concrete pavement, and add a skid-resistant texture atop the fresh concrete or score the surface.



Source: http://www.madehow.com/Volume-4/Concrete-Beam-Bridge.html

Cantilever Bridge - Construction of the Braga Bridge

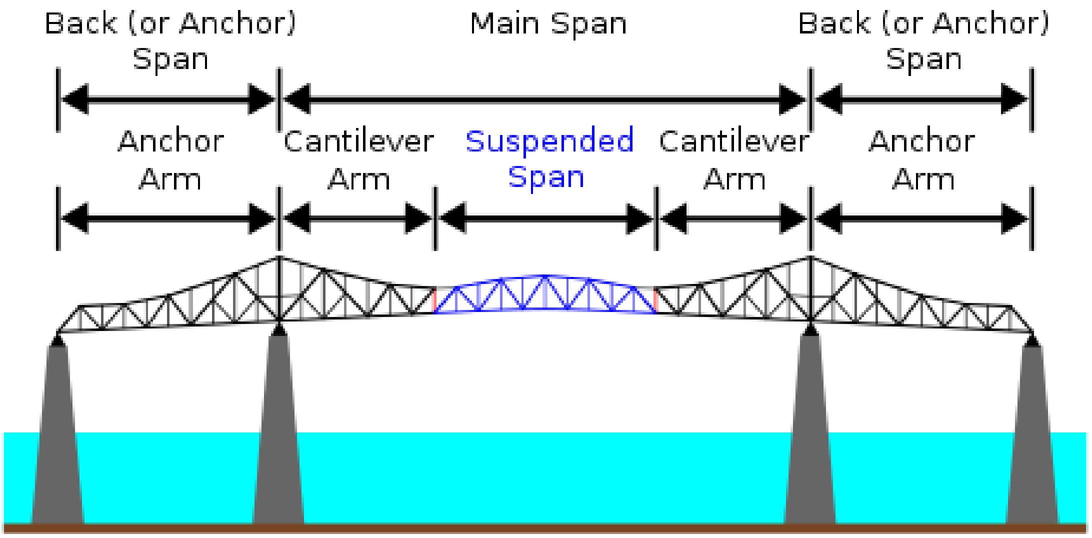
Source: http://www.bostonroads.com/crossings/braga/

Historical Context:

The Taunton River was crossed by two bridges pre-1950; one was a swing bridge that had two levels for rail and traffic. The other was a drawbridge that held only automobiles. Both of these bridges became overused and deteriorated. A new bridge was proposed, but a significant height was required to allow boats to pass through and into the busy ports. Originally, this bridge was to be located up the river further north in Somerset, leading to Wareham. As the plan progressed, the bridge was relocated to its current position, connecting Providence and New Bedford, helping both of these towns develop into large cities.

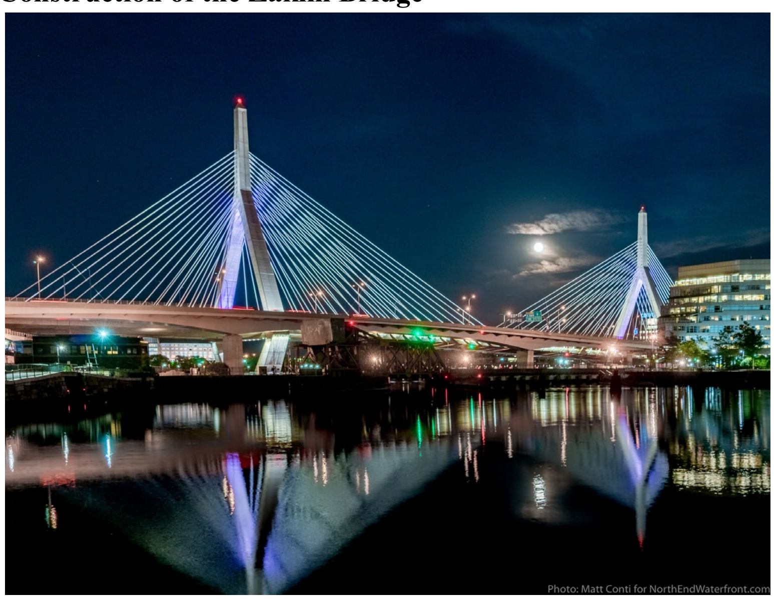
Steps in construction of cantilever bridges:

1. Measure the span distance. This can indicate if the beam should be an arch or suspension bridge, and if the cantilevers can be directly connected in a simple span or if a truss needs to be placed between them.
2. Place foundation piers for vertical support - typically, there are two equidistant from the positions to be spanned. If the bridge is short, this is not necessary.
3. Build cantilever arms (beams or girders fixed at one end only) toward the center of the span and toward the foundations at the end of the bridge. In this balanced cantilever construction, anchor arms that extend toward the center foundation. These anchor arms counterbalance the arms that extend to span the water body.
4. Construct support towers over the foundation piers to give more strength to the supports.
5. If necessary (long enough), insert a central truss bridge (built onsite or constructed offsite and dropped in place) between the projecting cantilever supports.
6. Using connecting pins, attach the projecting cantilever arms to the ends of the central truss or each other in the middle.
7. Install the roadway.



Source: https://en.wikipedia.org/wiki/Cantilever_bridge

Cable Stayed Bridge - Construction of the Zakim Bridge

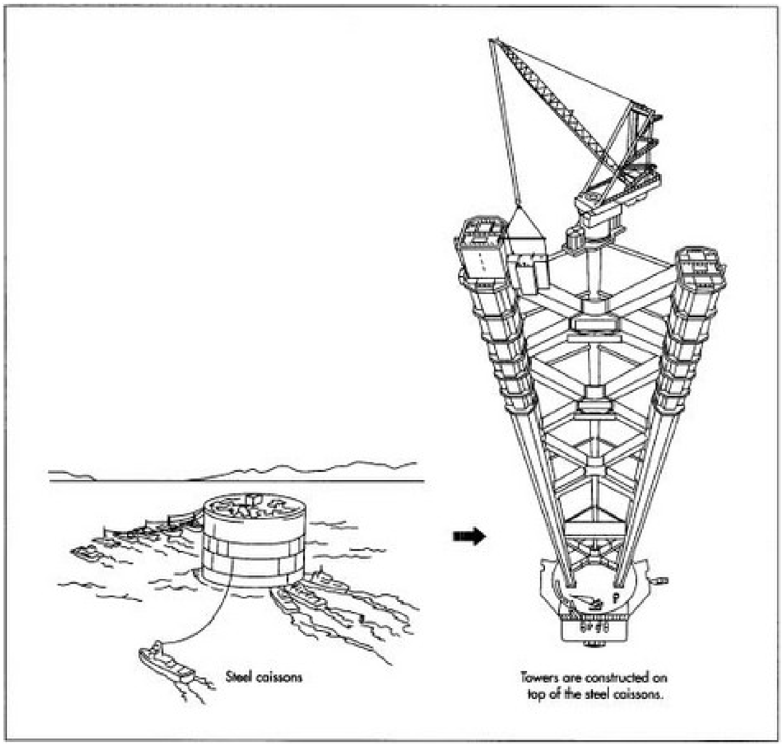


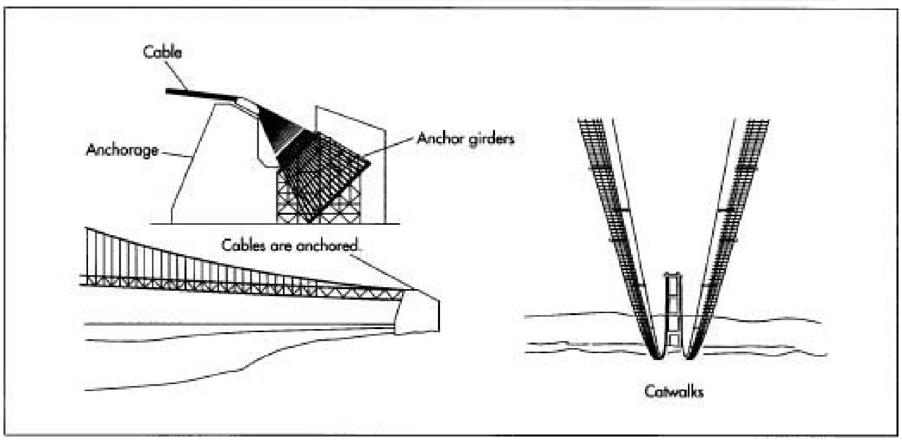
Source: https://northendwaterfront.com/2018/09/zakim-bridge-lighting-show-friday-september-21

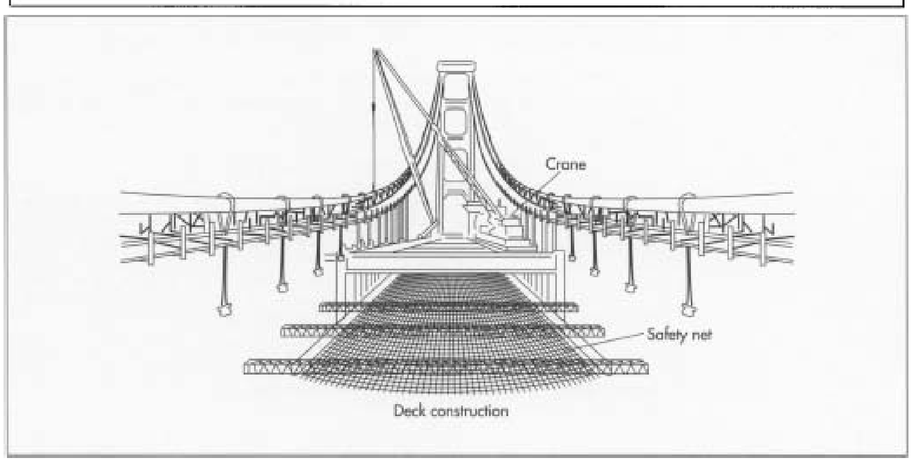
Historical Context:
A truss bridge originally spanned the Charles River at this location, but with the Central Artery Project, also known as the Big Dig, the city expected to see heavier traffic over the old bridge. A major plan was developed to design this bridge. Planners decided that an iconic bridge was needed to be a landmark in Boston. Because of its scale, it is hard to tell, but the side spans are not the same length, making the Zakim Bridge the first asymmetrical cable stayed bridge in the world. Construction started in 1997 and with many delays and difficulty arising from the entire Big Dig project, it finally opened to traffic in 2003.

Steps in construction of suspension bridges:

1. Dig down to a firm rock formation to prepare a tower foundation. If the tower will stand on land, construction is easier. If it will stand in water, lower a caisson (steel and concrete cylinder that acts as a circular dam) into the waterbed then remove the water from the caisson. Finish excavation and pour a concrete tower foundation.
2. Construction of towers can vary based on each bridge. In one example, each tower has two columns, which are each composed of 30 vertical layers or blocks (which then consist of three horizontal sections). Three sections can be lifted in place on each column to complete a layer using a crane, working layer by layer. Add diagonal bracing between the columns as necessary.
3. To construct anchorages, the structures that secure the ends of the bridge cables, massive concrete blocks are securely attached to strong rock formations. To construct the anchorages, strong eyebars (steel bars with a circular hole at one end) are fixed in the concrete blocks. A spray saddle to support the cable where the wire bundles fan out is mounted in front of each concrete anchorage.
4. A pilot line must be strung along the cable's path from one anchorage to the other across the towers. A helicopter may be used to string the pilot line. Then, a catwalk is constructed about 1m below the pilot line for workers to form the cable.
5. A large spool of wire is put at the anchorage to start spinning the cable. The wire is looped around a spinning wheel installed on the pilot line, then this process is repeated until the number of wire strands required is formed. The catwalk is used by workers to prevent any kinks and ensure the wire unwinds smoothly. Wire is cut and secured to the anchorage, then the process repeats for the next bundle. When enough bundles have been spun, radially positioned jacks are used to compress the bundles into a compact cable then wrap steel wire around it. Fasten steel clamps on the cable to anchor the vertical cables that connect the decking and the support cable.
6. Create the deck structure after vertical cables are attached to the main support cable. Keep the forces on the towers balanced constantly by building the structure in both directions from the support towers.
7. Cover the deck structure with a base layer and add pavement.



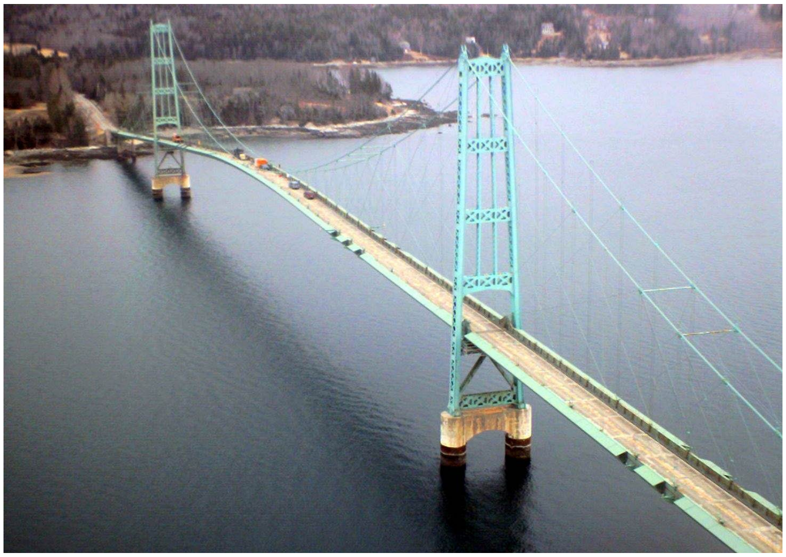




Source: http://www.madehow.com/Volume-5/Suspension-Bridge.html

Three Notable Suspension Bridges

Deer Isle Bridge
This bridge crosses the Eggemoggin Reach in Deer Isle, Maine. Constructed in 1939, it connects Deer Isle and Sedgwick with State Route 15. It is notable because it is the only vehicular connection from the Maine mainland to Little Deer Isle.



Source: https://en.wikipedia.org/wiki/Deer_Isle_Bridge

Mount Hope Bridge
The Mount Hope Bridge in Bristol, Rhode Island had a bumpy start with some serious structural problems. However, once it was structurally sound, after being constructed in 1927, it won a 1929 Artistic Bridge Award of the American Institute of Steel Construction. It crosses the Mount Hope Bay, connecting Portsmouth and Bristol. It is also notable because it was awarded a National Register of Historic Places in January 1976.

Source: http://www.ritba.org/history/

Claiborne Pell-Newport Bridge

The Claiborne Pell-Newport Bridge was built to replace a ferry service in 1948. It crosses the Narragansett Bay, connecting Newport and Jamestown. It is notable because it is the longest suspension bridge in New England.

Source: http://www.ritba.org/history/

Truss Bridge - Construction of The Charles River Rail Bridges

Source: http://www.wfrjr.com/data/bridge/Boston/CharlesRR.html

Historical Context:

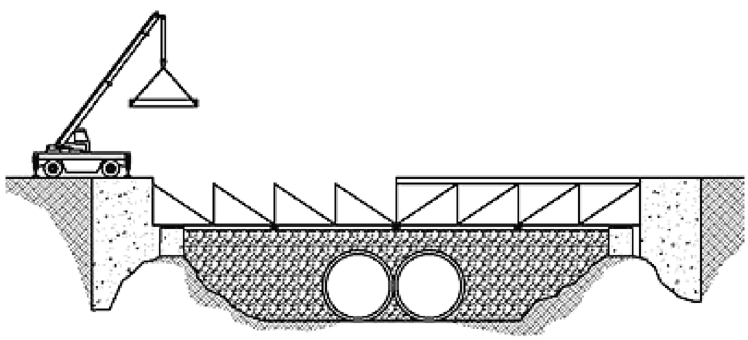
The Charles River Rail Bridges are a set of rotating swing drawbridges opened in Boston in 1931. When North Station was first built, bridges carried trains across the Charles River. However, in the early 20th century, North Station was expanded, and the Charles River was diverted to accommodate this. As is the story with many structures in Boston, filling in the shores of the river allowed for further development.

When the river shifted north, new bridges were required to connect the extended platforms to the rest of the rail network into Cambridge and beyond.

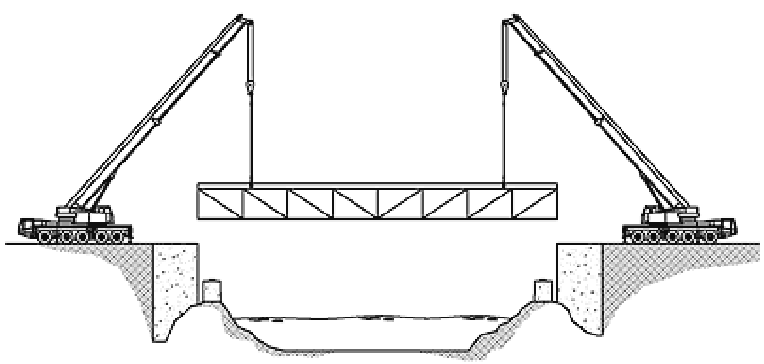
Steps in construction of truss bridges:

1. Conduct a detailed soil analysis to determine suitability for bridge and traffic loads
2. Determine if you want to design the road being at the bottom or top of the truss
    a. Road (load) at truss bottom = members under compression
    b. Road (load) at truss top = members under tension
3. Select bridge materials based on if you want members under compression or tension, and then either weld or bolt the joints
4. Pour concrete in abutments with anchor bolts firmly inserted
5. Build trusses member by member (or beforehand) based on what kind of truss design is necessary/desired (Pratt, Parker, K-Truss, Howe, Camelback, Warren, Fink, Brown, Vierendeel)

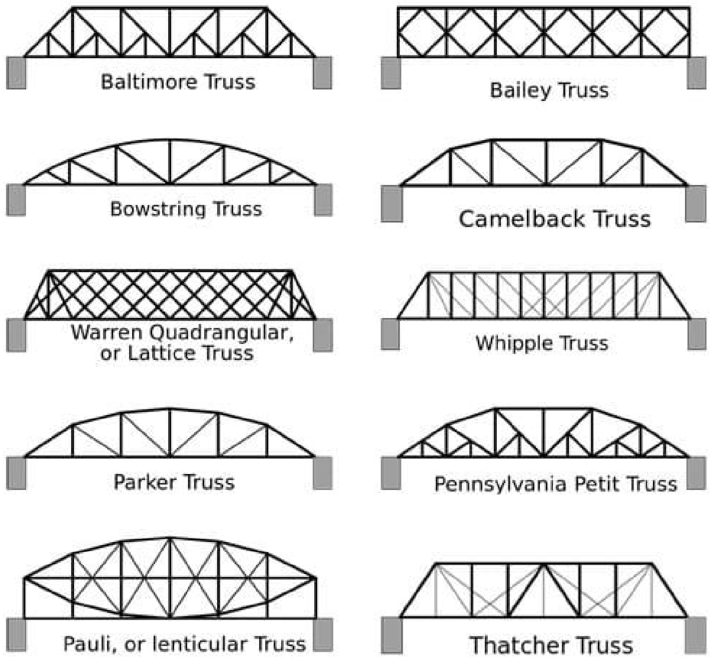
In-Situ Truss



Prefabricated Truss



Source: http://www.steel-bridges.com/tech-over-truss-bridge.html



Source: https://www.pinterest.com/pin/114138171790772983/

Timeline of Trolley History and the History of the Region

Introduction: In addition to its interesting place in bridge history around the US, the Bridge of Flowers and the trolley that originally ran over it are an integral part of the history of industrial development in the region. The trolley is also a very interesting example of the larger trends surrounding trolleys and interurbans in the US.

Trolley Timeline

1888 - Innovative trolley system installed in Richmond Virginia

Source: https://richmond.com/discover-richmond/from-the-archives-richmond-gears-up-for-street-trolleys-in/article_c9737548-ae36-5096-a6cb-f35bc0e5d2af.html

1889 - 13 mi line between Portland and Oregon City Oregon

Source: http://wst.oregontrolley.com/

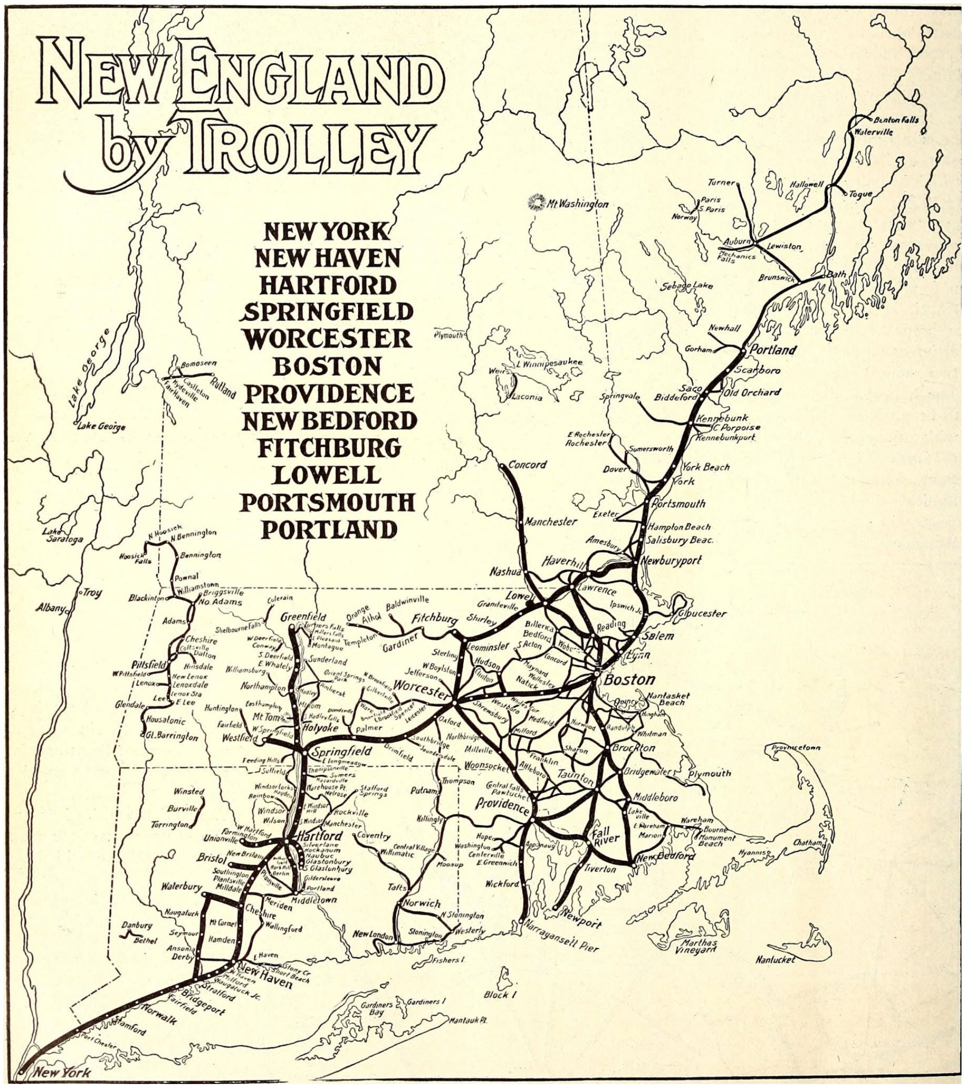
1896 - Shelburne Falls and Colrain Street Railway Company is Established

Source: https://www.sftm.org/index.shtml

1900 - Everett-Moore Syndicate owns 500 mi of track between Ohio, Michigan, and Canada

1908 - Bridge of Flowers Built

1917 - Interurban Operators have 18,000 mi of track across the US



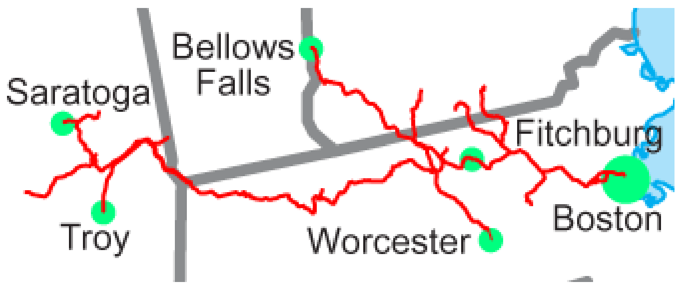
1920s - Explosion of cars across the US
1924 - Shelburne Falls and Colrain Street Railway Company is Shut Down
1950s - The final death of many streetcar companies
Sources for Timeline*:*
https://www.historynet.com/trolleys-time-when-streetcars-were-desired.htm
https://www.sftm.org/history.shtml

Colrain
1865 to 1875 - 2 cotton mills became the main industry of the town. Griswoldville was a common name given to the area since the mills were established by Joseph Griswold and his sons.

Source: http://industrialhistory.org/histories/griswold-cotton-mills/

1880 - 234 people worked at the mill in Colrain and cotton mill product was 97% of the total value of manufactured products from the town

1896 - Opening of the Shelburne Falls and Colrain Street Railway connected the town to the Fitchburg Mainline

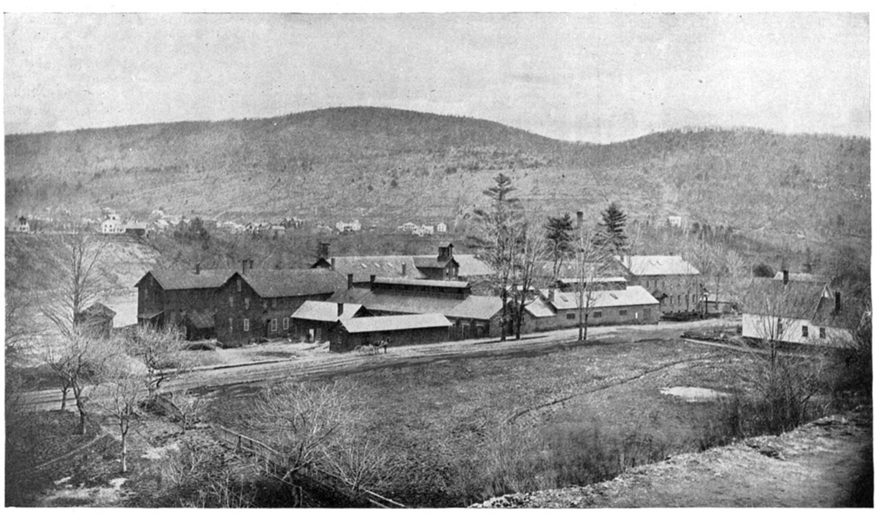


Source: https://en.wikipedia.org/wiki/Fitchburg_Railroad

1920s - One of the Mills Closed in 1920s

Shelburne Falls & Buckland

1845-65 - Mostly agricultural Shelburne is transformed by manufacturing into a small hub I.e. Cutlery, Farm Equipment, & Metal Working (Image is Lamson and Goodnow Cutlery)



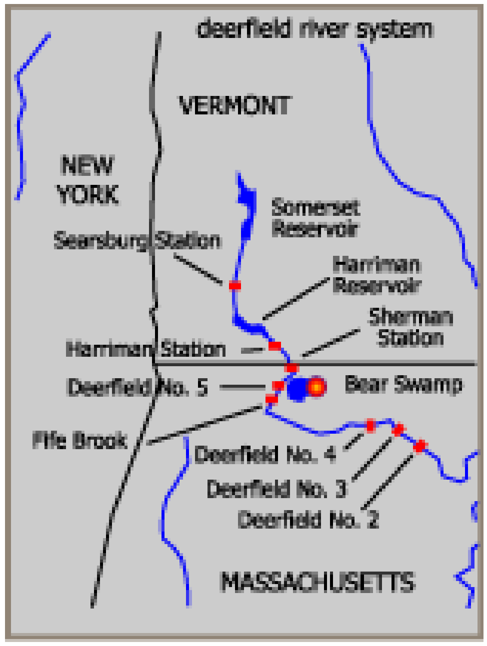
WORKS OF THE LAMSON & GOODNOW MFG. CO., SHELBURNE FALLS.

Source: http://industrialhistory.org/histories/lamson-goodnow-mfg-co-shelburne-falls/

1867 - The arrival of the Railroad in Buckland helped develop new industry I.e. Silk, Harmonicas, Pocket Cutlery

1890 - Iron Bridge across the Deerfield River to Buckland

1904-11 - Several Hydroelectric Dams built in the area



Source: http://www.negt.com/asset_deerfield.html

1908 - Concrete Bridge for Trolley from Colrain to Buckland

Post 1920s - Move to more tourism

Sources for industrial development timelines:

- https://www.sec.state.ma.us/mhc/mhcpdf/townreports/CT-Valley/col.pdf
- https://www.sec.state.ma.us/mhc/mhcpdf/townreports/CT-Valley/shl.pdf
- https://www.sec.state.ma.us/mhc/mhcpdf/townreports/CT-Valley/buc.pdf
- https://montaguearchive.org:8443/xmlui/bitstream/handle/123456789/5459/The%20Griswold%20Cotton%20Mill%20at%20Turners%20Falls%20and%20Colrain.pdf?sequence=1&isAllowed=y
- http://industrialhistory.org/histories/griswold-cotton-mills/