Suspension Bridges of New England

New design innovations have made the suspension bridge a rare bird. Before they all disappear from the landscape, it might be best to review and honor those that still exist.

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Despite all of the infrastructure development in New England, there are only five automotive suspension bridges in all of Massachusetts, Maine, New Hampshire and Vermont. Three of them were built in the 1930s and none have been built in over thirty-five years. Since the success of the Zakim Bridge has begun the process of replacing aging suspension bridges with cable stayed systems, it is time to look back and celebrate the suspension bridges that still grace the New England landscape.

The Claiborne Pell Bridge

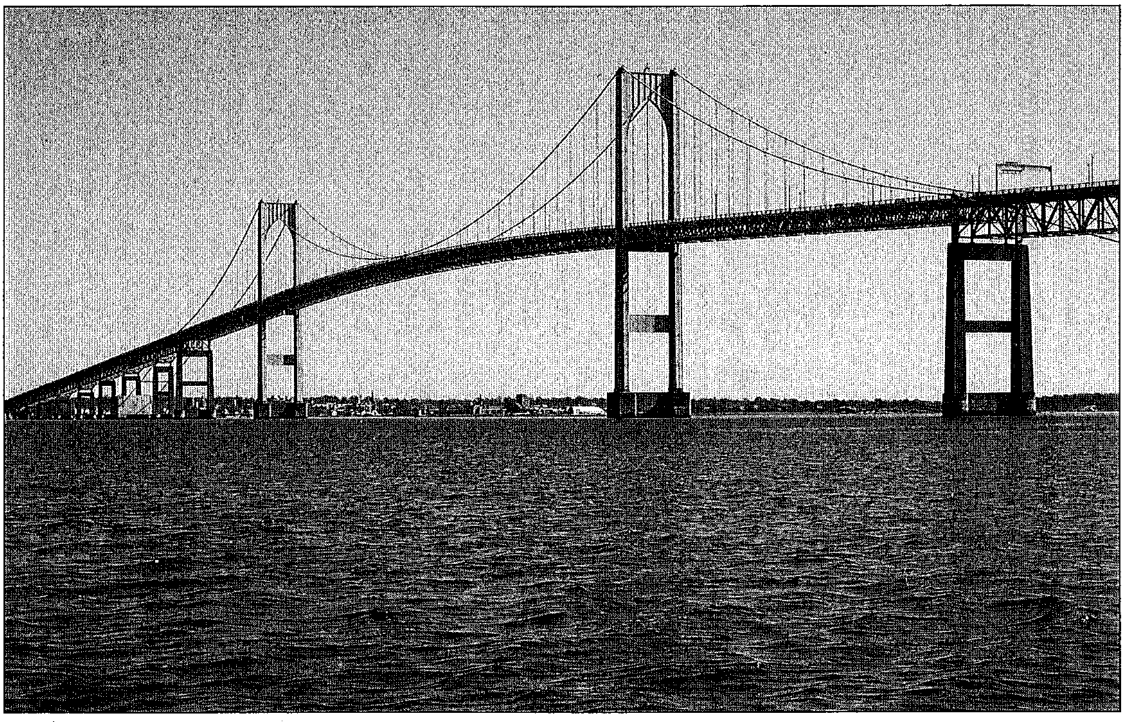
The Claiborne Pell Suspension Bridge is located in Newport, Rhode Island. It stretches a total of 11,248 feet, carrying State Route 138 across the Narragansett Bay and linking Jamestown to Newport.[1] It is the longest suspension bridge in New England, and the first to use prefabricated parallel-wire strands.

The early planning for the bridge design was initiated by the State of Rhode Island in 1934 when it sought federal aid to build bridges across the west and east passages of the Narragansett Bay. The new bridge would replace the ferry servicing the Conanicut and Aquidneck islands. The west passage was designed, and built by 1940; it was later called the Jamestown Bridge.[2]

The onset of World War II put a hold on the east passage project, and planning did not resume until 1944.[3] The newly formed Newport-Jamestown civic commission finally convinced the state legislature to approve the Newport-Jamestown Bridge Proposal in 1948.

Extensive engineering studies were then performed for the proposed crossing. There were thirty-two different studies done that evaluated possible locations of a suspension bridge, cantilever bridge, tunnel or possible bridge-tunnel combination. Factors that narrowed down the selection of location were: higher construction costs for greater water distances, extensive relocation of U.S. Navy property, disruptions to boat traffic in heavily navigated areas and strong local opposition from residents.

It was not until the mid- to late 1950s that the project gained momentum. The Rhode Island Turnpike and Bridge Authority



Claiborne Pell Bridge, Rhode Island.

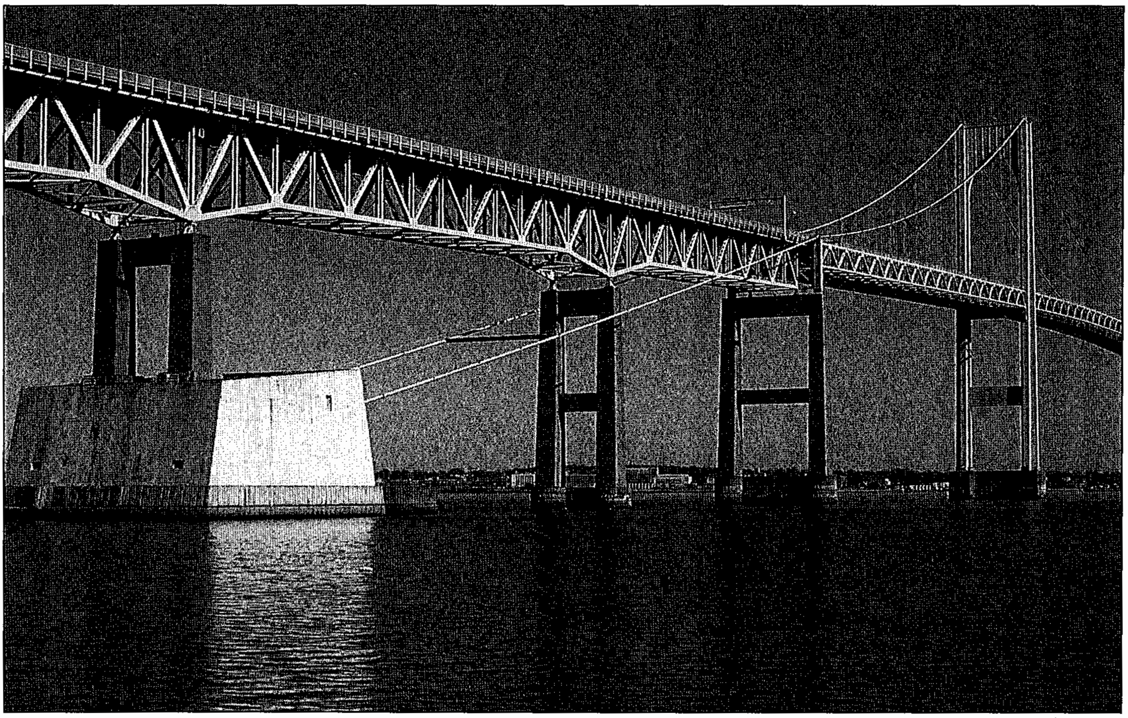
(RITBA) was created in 1954. This organization would eventually finance, build and maintain the proposed east passage crossing and its immediate approaches. The Rhode Island Department of Public Works included the east passage in its plans for a statewide expressway network.

Despite the gains in support, the project was not scheduled for construction until the mid-1960s. In 1960, RITBA secured a firm to design the bridge. The chief design engineer assigned to the project was Alfred Hedefine. The firm recommended a bridge location that was a variation of the earlier proposed Taylor Point–Admiral Kalbfus Road alignment. This variation addressed the U.S. Navy's expensive relocation concerns by veering the alignment south toward Washington Street before turning west, thus avoiding the Coasters Harbor Island Naval Station altogether.

The chosen alignment would connect Taylor's Point in Jamestown to Washington Street in Newport. The next obstacle that stood in the path of the project was a statewide referendum that would give RITBA bond-selling power. It was rejected by voters in 1960, but it was finally ratified in 1964 (and later re-approved in 1965).

RITBA received final approval for the bridge location and clearances from the U.S. Army Corps of Engineers, and the U.S. Navy in 1965. Construction on the bridge started on April 5, 1966. A total of 838 steel piles were driven down to bedrock under 162 feet of water (the deepest ever attempted) to support the concrete foundation blocks. Working at this depth proved difficult for divers. Productivity initially was limited to one pile per day because divers could only stay under for thirty minutes at a time while they cut off the tops of the piles. However, a diving tank was later shipped to the site, and productivity increased significantly to fifteen piles per day.[2]

Prefabricated forms were used to build the piers. They were brought to Newport by barge because of their immense size (the largest weighing more than 400 tons and standing an astounding ten stories high). One of the world's largest floating lifters, "the Avondale Senior," was used to remove the forms from the barges and set them in place. It traveled all the way from New Orleans. The vessel was



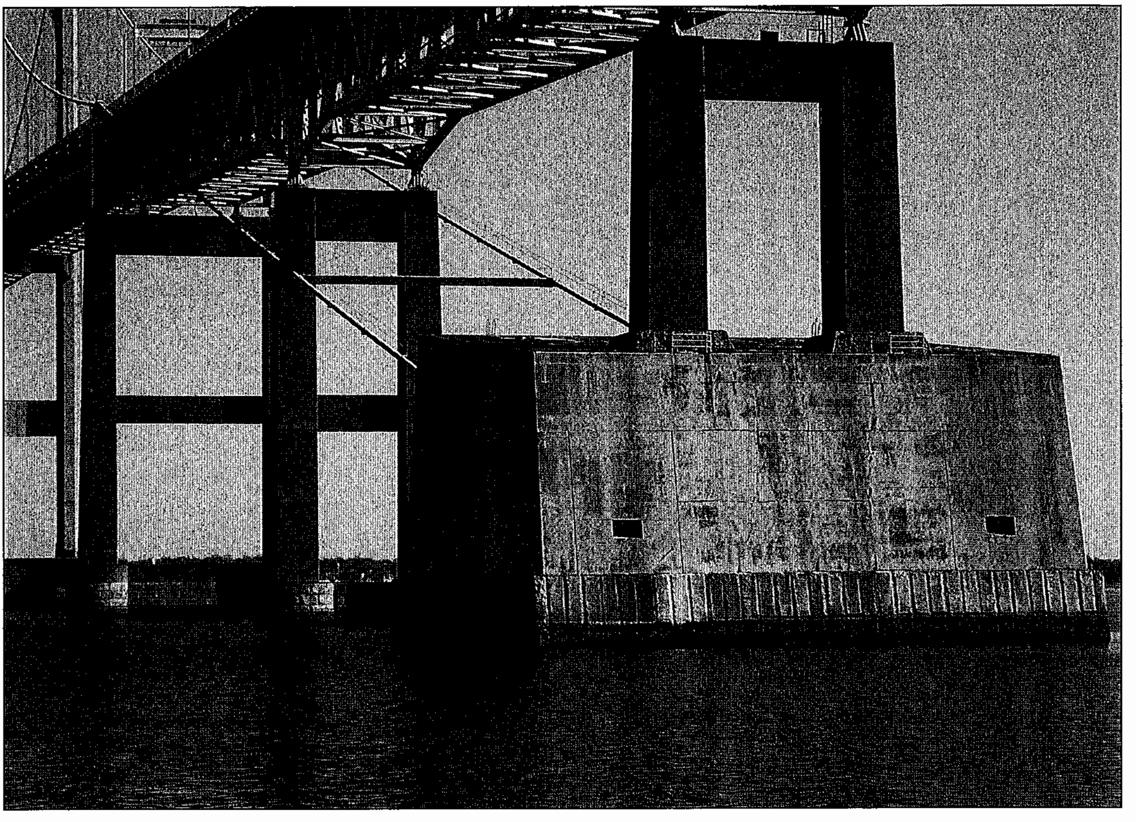
Approach spans of the Claiborne Pell Bridge.

309 feet long, and had twin booms that could handle 500 tons. During placement of the forms, two powerful storms struck Narragansett Bay. The high winds and pounding waves caused significant damage to the forms. Workers had to straighten them out before the concrete could be poured.

It took an estimated of 90,000 cubic yards of concrete to pour the piers and anchorages. This amount was the largest ever structural concrete placement under water. The tremie method was used, which resulted in reduced pressure exerted on the sides of the pier walls. The steel reinforcing used in the concrete weighed 4,000 tons. The piers were finally completed by 1967.

During the summer and fall of 1967, the 400-foot steel towers were erected. The cable steel manufacturer developed a new technique in stringing the main suspension cables using prefabricated parallel wire strands. This major innovation was used in place of the conventional cable spinning process, which involved spinning each strand wire by wire while stringing it from one anchor, over each tower and down to the other anchor. This process was repeated thousands of times for each cable. The prefabricated strands saved time and money. They were made in Pennsylvania and sent to Newport as a package. Each cable measured 15.0625 inches in diameter, and was coated with a protective plastic sheath. Once the bridge construction was complete, it opened to traffic on June 28, 1969. It was named simply "The Newport Bridge."

The over two-mile bridge consists of a 1,600-foot suspended span, 688-foot approach spans, eleven deck truss spans totaling 3,450 feet, fifteen girder spans totaling 2,524 feet, 300 feet of multi-girder spans and 2,000 feet of prestressed concrete beams. The bridges roadway carries four lanes of traffic with a total width of 48 feet over the Narragansett Bay at 225 feet above the water line. The maximum grade of roadway is 4.8 percent. The maximum gross weight for vehicles is 40 tons (80 tons with a permit). Its towers rise 400 feet above mean high water. The deck is stiffened by a lateral truss running longitudinally along the bridge that protects against failure due to lateral wind forces.[4]



Claiborne Pell Bridge abutments.

The two main suspension cables each have a 15.0625-inch diameter that supports 4,636 suspender cables on either side. Each cable contains 76 strands, and each strand has 61 wires. Each wire has a diameter of 0.2 inches, and measures 4,516 feet long. The total length of wire if laid out end to end is an astounding 8,000 miles long. The total combined weight of the cables is 2,280 tons.

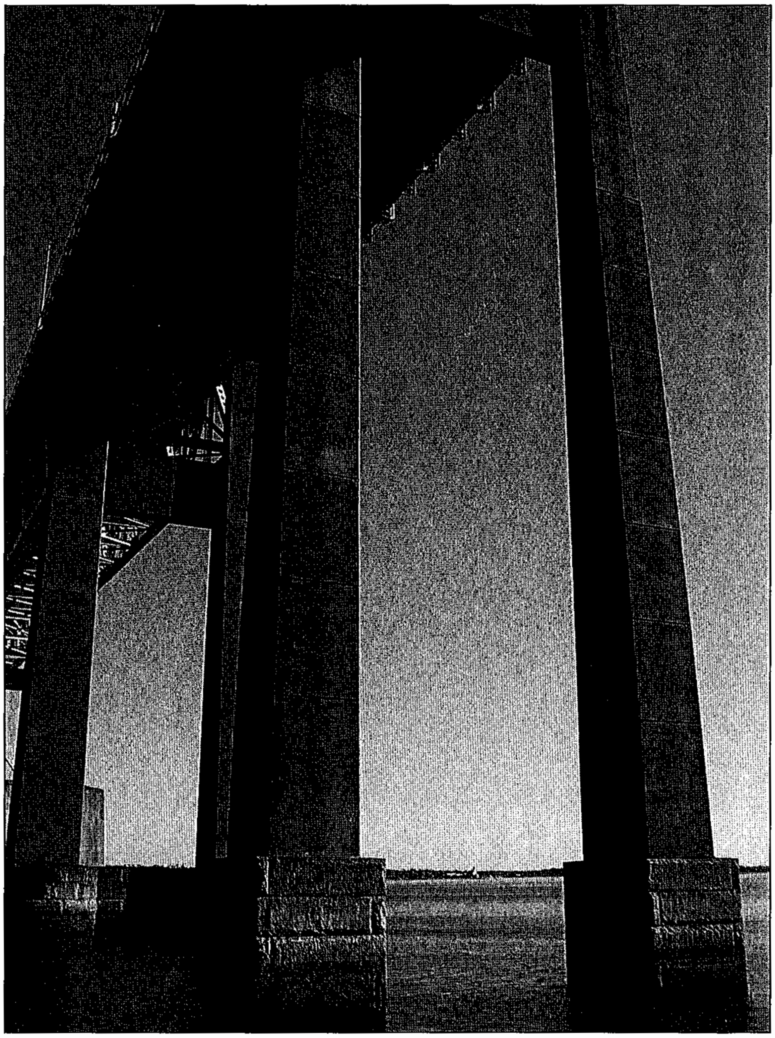
The substructure contains 136,000 cubic yards of concrete. The roadway and approaches contain an additional 17,500 cubic yards of concrete. The concrete deck is 7.5 inches deep. Once completed, the total cost of the original structure came in at $54.742 million.

The bridge's strength and reliability were tested in February 1981. A tanker carrying 50,000 barrels of oil collided with one of the main piers of the bridge. The pier suffered only a smear of grey paint. No structural damage was found whatsoever. The tanker was not so lucky — its bow was impacted ten feet. Even though the bridge sustained the blow from the tanker without damage, RITBA is conducting continued investigations for the need for pier protection. Currently, there are no fenders protecting the bridge's piers.[2]

In 1997, the bridge was rededicated and renamed in honor of retired six-term U.S. Senator Claiborne Pell of Newport. Senator Pell was the longest serving senator in Rhode Island history. He is currently serving on the Board of Governors of the National Parkinson Foundation.

RITBA places travel restrictions, and sometimes closes the bridge, when winds reach certain speeds. Travel is restricted once winds reach a sustained 50 knots coming from a North, North-East-South or South-West direction. If the winds sustain 60 knots, RITBA considers closure as a safety precaution.

The bridge receives regular maintenance and repairs. Recent repairs have been made to the concrete slab, piers, steel catwalk and other miscellaneous steel repairs. In 1997, another engineering firm was contracted by bridge's original design group to provide consultation services in the rehabilitation of 720 linear feet of reinforced concrete deck. The deteriorated concrete was removed by hydrodemolition methods, and replaced with high-performance microsilica modified concrete. Because of the cold New England weather conditions, relatively new techniques were used in the placement of the new concrete. Specifically, the adaptations of ground-thawing techniques were used to maintain pre- and post-placement temperatures to ensure quality concrete placement in the cold weather. The rehabilitation was completed in the spring of 2001.



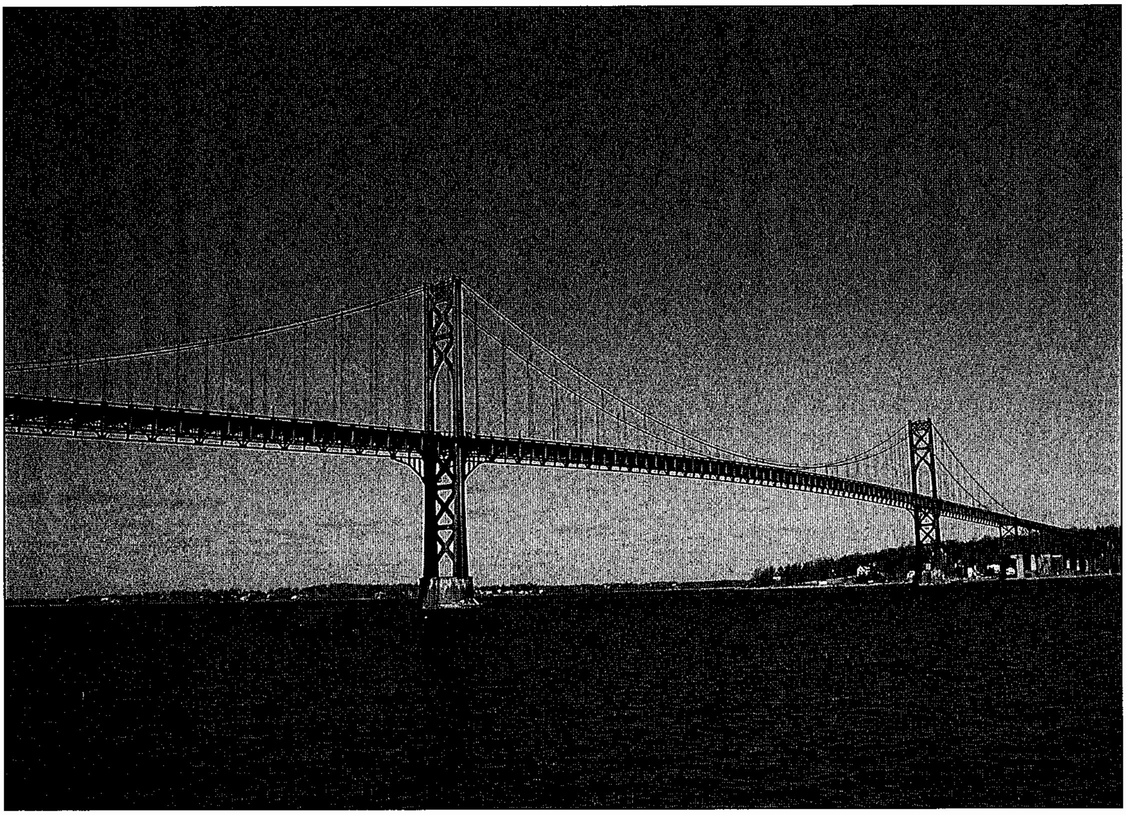
Claiborne Pell Bridge piers.

In 2003, repairs and/or replacement of deteriorated steel catwalks were performed. The concrete piers also received repair work during that time. These repairs consisted of crack repair, shallow and deep spall repair, repointing of granite facing at water piers and anchors, and cleaning and protective sealing of the anchorages. Only limited short-term lane closures were allowed for mobilization of equipment throughout the construction.[2]

The Claiborne Pell Suspension Bridge faced many challenges during its construction. Engineering innovation and creativity in design proved to be invaluable in making the crossing possible. The bridge won awards for excellence in engineering design from the New York Association of Consulting Engineers, the Consulting Engineers Council, the American Iron and Steel Institute and the American Society of Civil Engineers. Today, it carries an average of 27,000 vehicles per day.[2] The surrounding areas have benefited from the bridge over the past thirty years. The Claiborne Pell Bridge continues to encourage trade, travel and tourism by providing an efficient and aesthetically pleasing gateway over Narragansett Bay.

The Mount Hope Bridge

The Mount Hope Suspension Bridge was originally built as a private toll bridge. It carries State Route 114 over the small area of water between Mount Hope Bay and Narragansett Bay in Rhode Island and connects the towns of Bristol and Portsmouth. The bridge is stiffened with a deck truss and is gravity anchored. It is known for its stability and

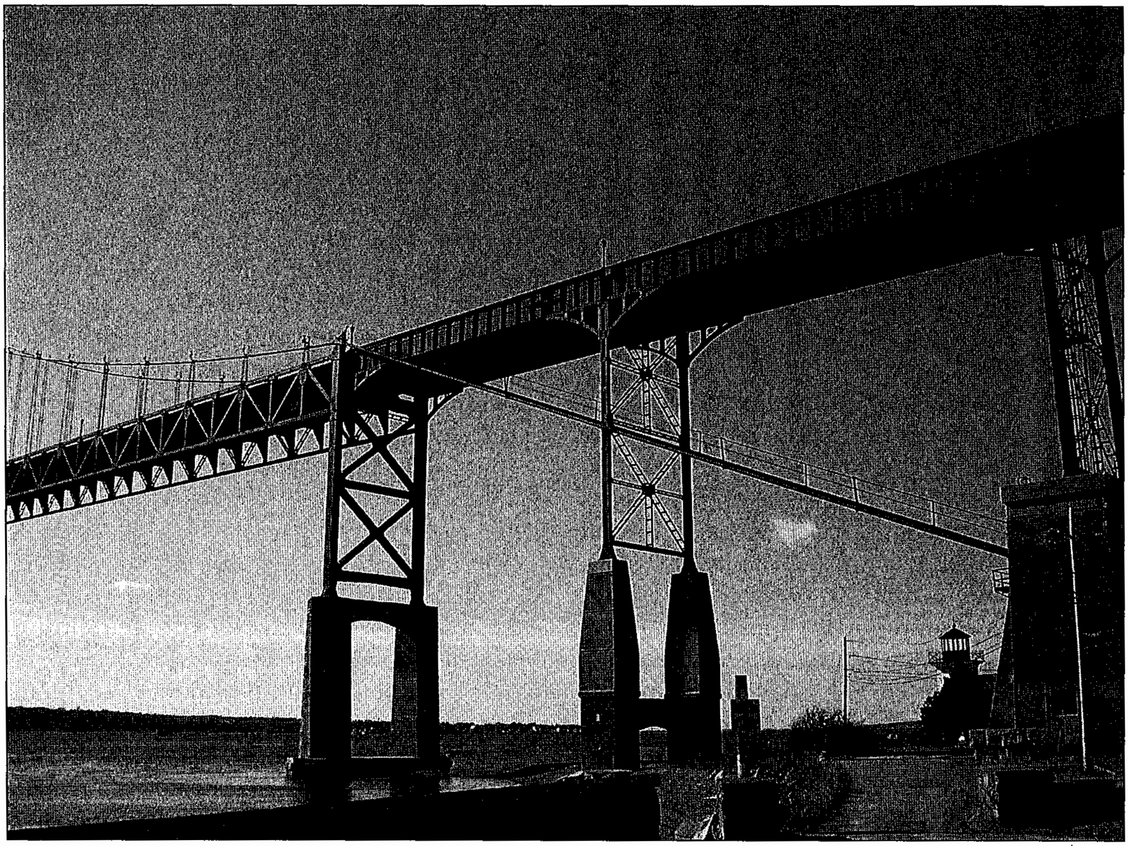


Mount Hope Bridge, Rhode Island.

strength since it has survived seventy winters and three hurricanes. It was the largest suspension bridge in New England before the construction of the Newport (Claiborne Pell) Bridge. It was also the first suspension bridge built in Rhode Island, and it was known for taking "the Island out of Rhode Island."

The site of the Mount Hope Bridge is historically significant. In 1636, Roger Williams settled the Providence Plantations to the north of the bridge area. John Clarke settled the Island of Rhode Island in 1638 to the south of the bridge. The bridge got its name from the nearby Mount Hope, which is located within the town of Bristol. Mount Hope is where the Indian attacks of 1675–76 where planned by the Wampanoag chief, King Philip. Captain Benjamin Church and his men used the ferry services that ran where the bridge now stands to gain access to the mainland in order to quell the Wampanoag uprising.[5]

The cold winters of Rhode Island would cause the waters of Bristol Harbor to freeze, thus preventing the ferries from running. This isolation was hard for the people on the island of Rhode Island (which includes Newport) to endure. Legislators from Newport County would occasionally be late to, or miss, sessions of the Rhode Island General Assembly due to the harbor freezing. A resolution sponsored by William L. Connery of Bristol in the Rhode Island General Assembly on March 9, 1920, formed a joint committee to investigate the need for a bridge linking Bristol to Portsmouth. Ultimately, the committee decided that the financial burden to build a bridge would be too great for the state to shoulder at the time. However, by the mid-1920s there was increased need for a direct link between the two cities due to the rapid influx of tourism from the west and due to the increase of vehicular traffic because of greater automobile use. The expense of building the bridge was still too high for tax payers, so the General Assembly decided to hand over building rights and ownership to a private company.



Mount Hope Bridge abutments and approach spans.

The Mount Hope Bridge Company would finance the project and operate the bridge as a private toll bridge.[6]

David B. Steinman, a well-known structural engineer, was put to the task of designing the Mount Hope Bridge in 1927.[7] He designed over 400 bridges in his lifetime. He also founded the National Society of Professional Engineers and served as its first president. Steinman was first informed of the Mount Hope Bridge project in 1926. He quickly turned in a proposal to the Rhode Island State Highway Engineer only to learn that a commission was already appointed to the task of designing the bridge. However, the state rejected the commission's proposal, and turned to Steinman, asking if he could design and build the bridge for less than $4 million. Steinman replied, "I can do better than that. I can build it for three million, and maybe I can shave that."[??] Steinman was awarded the job and completed it for $2.5 million.[6]

Excavation began in December 1927. The deck and foundation construction began in 1928. The deepest foundation was poured 54 feet below sea level. A total of 40,000 cubic yards of structural concrete were used on the project. Since the bridge marked the first time that 150-foot continuous steel girders were used, they had to be custom made. The steel spans were completed in only thirteen days. The suspension cables were constructed using the conventional cable spinning process.

During construction a problem was discovered with the suspension cables. It was only four months from opening day when the cables were declared unsafe. The problem was the result of using heat-treated steel even despite Steinman's objections. The cables were breaking and crews had to work around the clock to take down the roadway and replace the cables with new cold-drawn steel cables at a cost of an extra $1 million. The completion date was pushed four months past the dead-line. The contractor paid for the changes and construction delays. The total cost of construction was $3,897,820 million. Today, it would cost an estimated $33.7 million to erect the same bridge.

The bridge opened to traffic on October 24, 1929, only two years after construction began. The Mount Hope Bridge was purchased by the State of Rhode Island on November 1, 1955. Eventually, RITBA purchased the bridge on June 1, 1964. The bridge became toll-free on May 1, 1998.

The bridge is 6,130 feet long and consists of a 1,200-foot suspension span. The total water span is 3,000 feet. Each 150-foot girder span contains four steel girders. The bridge's roadway carries two lanes of traffic with a total width of 27 feet over 135 feet above the water. The maximum grade of roadway is 3.8 percent. The maximum gross vehicular weight is 42 tons. Its steel towers rise to 285 feet above mean high water. The deck is stiffened laterally by a deep truss running longitudinally along the bridge that protects against failure due to wind forces.

The two main suspension cables each have an 11-inch diameter. Each cable contains 2,450 wires. The total length of wire if laid out end to end is 2,620 miles long. The total loading capacity of the cables is 5,600 tons. The use of cable bents with straight backstays at the ends of the side spans were a major innovation, and resulted in an economic benefit.[8]

Recent repairs were performed on the main suspension cables. The repairs were completed in two phases from April to December 1999, and April to October 2000. The scope of work included rehabilitating the main cable by replacing the hand rope system, or conventional cable spinning method. Also new wire rope suspenders were installed at designated locations along the main of the bridge.

The main cable wire wrapping was removed and disposed of. Then 4,400 linear feet of main cable were repaired, compacted, waterproofed and rewrapped with new galvanized steel wire. The cable bands were re-caulked and repainted. New re-tensioned cable band bolts were fabricated and installed. A new "bridge necklace" lighting system was also installed.[9]

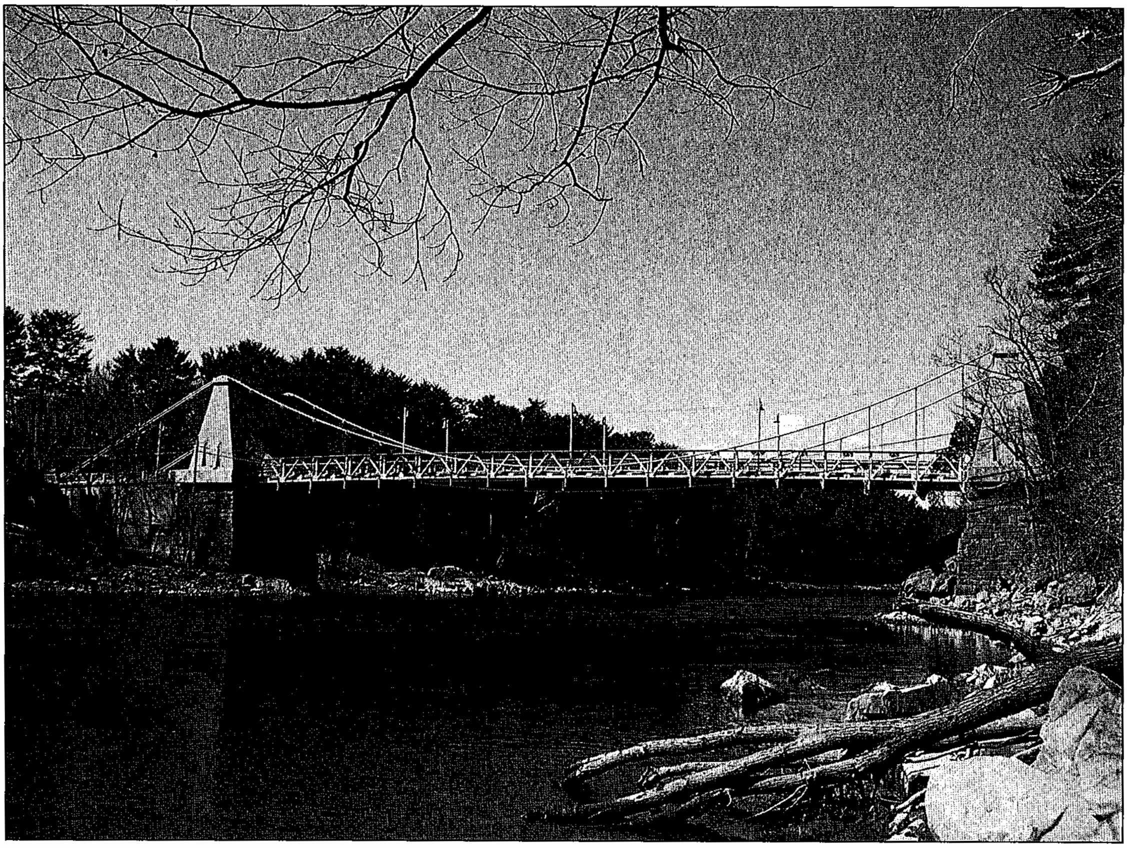
The Mount Hope Bridge is known for its beauty. Its light green tint helps the bridge blend into its surrounding environment. This color represented a significant departure from other bridges at the time, which were usually painted battleship grey or black. The design also incorporated artistic lighting, a new concept at the time. The combination of the lighting and the green hue enables the suspension cables to be clearly visible at night. Extra funding was obtained to landscape the areas adjacent to the bridge access roads. Various flowers and trees were planted to help integrate the bridge into its environment. In 1929, the Mount Hope received the Artistic Bridge of the Year Award by the American Institute of Steel Construction.[8]

The building of the Mount Hope Suspension Bridge greatly benefited the surrounding community as did the building of the Claiborne Pell Bridge. Easier access has financially boosted the Newport area due to increased tourism and trade. The Mount Hope Bridge is one of the oldest long-span suspension bridges in the United States.

The Merrimack River Chain Bridge

The Merrimack River Chain Bridge is the only standing vehicular suspension bridge in Massachusetts. It is also the site of the oldest suspension bridge in the United States. The present-day structure still stands on the original bridge's foundation. The Chain Bridge is located in Newburyport just a sort distance south of Interstate 95. The Merrimack River is separated into two channels by a small body of land known as Deer Island. The Chain Bridge carries Main Street in Newburyport across the southern channel of the Merrimack River onto Deer Island.

The crossing was originally built as a long-span timber truss bridge, known as the Essex Merrimack River Bridge. The bridge consisted of two structures that were combined to form a total length of 1,030 feet. Each structure contained one long span timber arch truss. The northern structure consisted of two abutment approach spans, three watercourse spans, three pier sections and a 113-foot timber truss arch span. The southern structure, currently known as the Chain Bridge, contained two



Merrimack River Chain Bridge, Massachusetts.

abutment approach spans and a 160-foot span timber truss arch. The southern structure was the longer of the two arch spans.[10]

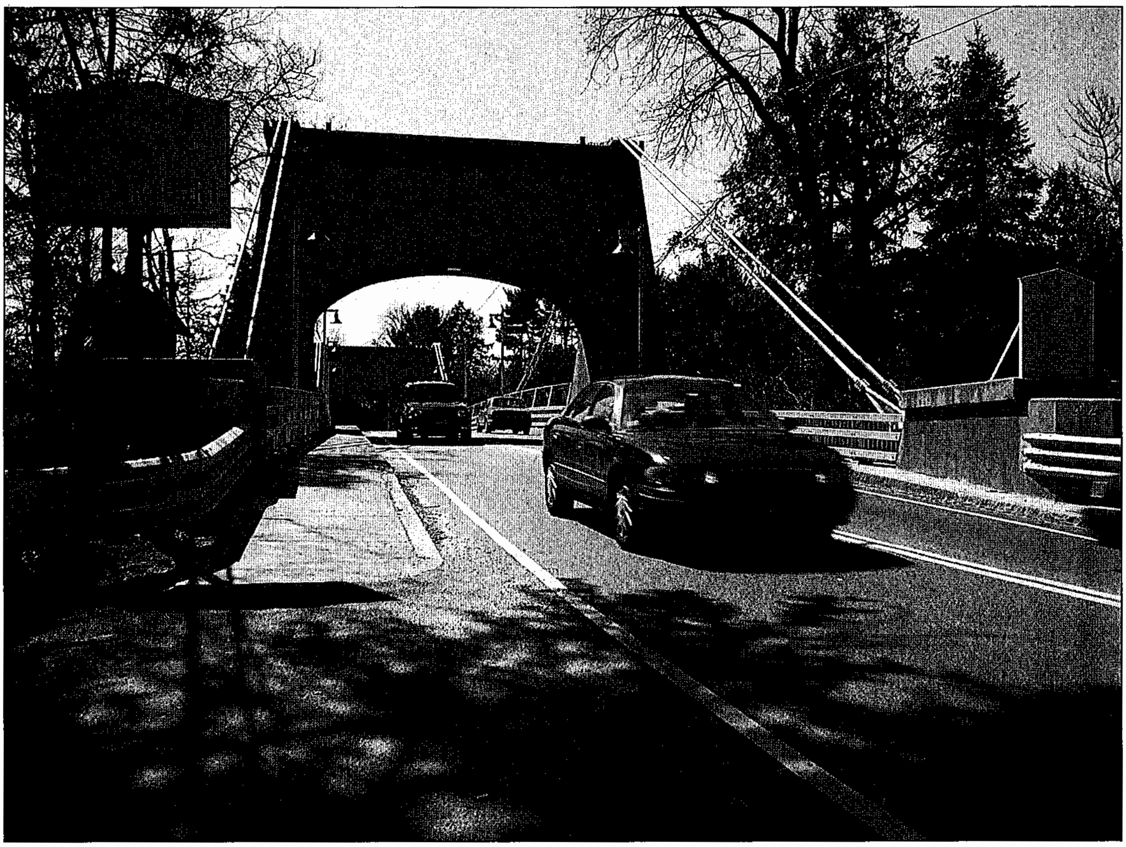
This timber truss bridge was believed to be the first of its kind in America, and the first to cross the Merrimack River. It was designed under the direction of Timothy Palmer in just seven months. The bridge was opened to traffic on November 26, 1792. This structure stood for almost two decades. However, boaters found it to be a hindrance to navigation, so the southern section of the bridge was eventually replaced with a bridge suspended by wrought iron chains in 1810.[11]

This replacement for the southern section was the original Chain Bridge. It was designed by Judge James Finley (1756-1828) of Pennsylvania, and built by John Templeman. The wooden stiffening truss provided a level and rigid roadway, which was uncharacteristic of bridges at the time. Most were not stiff and deflected significantly. The northern portion of the Essex Merrimack River Bridge was replaced with an iron bridge that was erected at a later date.

The Chain Bridge remained in service for seventeen years until 1827 when one of the supporting chains failed due to corrosion and the bridge fell into the river. It was rebuilt according to its original design in 1828 where it remained as a toll bridge until 1868. It then became a public highway.

It was rebuilt again under the authority of an 1908 act of the General Court by the County Commissioners of Essex County in 1909. The bridge was redesigned by consulting engineer George F. Swain. The county engineer Robert R. Evans also played a role in the design of the bridge. The new design took the form of the original Chain Bridge, but added some then state-of-the-art materials.

From 1909 on, the Chain Bridge has been rehabilitated a number of times. The original wooden deck was replaced in 1922, and again



Merrimack River Chain Bridge roadway.

in 1931. The hinges on the stiffening truss were rebuilt in 1935. In 1938, all of the timber decking was replaced by steel grid decking.[12]

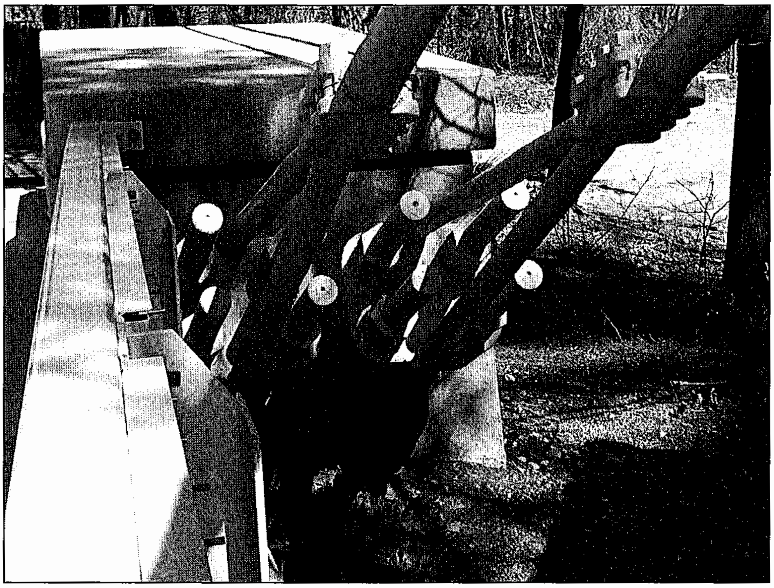
The structure now consists of a deck truss-gravity anchored suspension bridge that measures 384 feet between cable anchors (which also includes the 70-foot retained earth approaches). The suspension span is 244 feet (not including the approaches). Instead of wood, the deck truss was constructed with a 7.25-foot-high single-intersecting steel pony stiffening truss hinged at the pier ends and at the center. The roadway width is 24 feet with a 4-foot-wide timber sidewalk.

The problem of those corroding wrought iron chains was solved by using four 3.5-inch-diameter cables containing bundled steel wires. There are two cables on each side that are supported by castings and rollers situated at the top of two hollow reinforced concrete towers. The main cable ends are linked to groups of 1-inch by 5-foot steel eye bars in massive concrete anchorages. The towers stand about 34 feet above the roadway surface and are supported on the original granite piers. The granite block piers are founded on rock, but are interestingly not bonded with mortar. Instead, wooden dowels were placed in some of the larger blocks to give the blocks strength.

The suspender cables consist of 2.75-inch steel spaced approximately every 12.33 feet along the deck. They connect from the four main suspension cables and attach to the built-up steel riveted truss floor beams using saddle plate connections. The shorter suspender cables are actually steel rods connected to the floor beams, and the longer cables wrap around a circular plate connecting to the saddle plate.

In 2003, the bridge received major renovation that was estimated to cost $3.26 million (year 2000 dollars). The renovations included replacing the existing steel grid deck system with an orthotropic deck system. The floor beams and connections were repaired, along with damaged cables. The substructure was patched, and retrofitted, to meet current seismic code requirements.

A major component of the seismic retrofit consisted of providing a system that would transfer the load path around the granite piers. There were concerns that a seismic shear transfer would displace blocks along the pier walls, and cause the structure to collapse. Therefore, reinforced concrete collars were wrapped around the base of the towers. They were then connected with the anchor slabs at each approach span. This design was adopted so that the lateral shear forces would transfer directly to the anchor slabs, and away from the "shaky" granite block piers.



Merrimack River Chain Bridge cables.

Another key feature of the seismic retrofit introduced transverse restraint of the suspension cable saddle castings and rollers at the top of each tower. The concern was that a seismic event could potentially move the fixtures off the tower, thus causing the bridge to collapse.

The orthotropic deck system was installed for two reasons: it is a very lightweight deck system; and it adds protection to the floor beams from roadway surface constituents. This deck system consists of a steel deck plate longitudinally stiffened by trapezoidal-shaped steel ribs. It acts as a composite by using an extension plate to connect the existing floor beams with the steel ribs. By connecting the floor beams, added torsional stiffness to the deck system is achieved. Also, a special 0.375-inch-thick polymer concrete wearing surface was placed on top of the orthotropic steel plate deck.

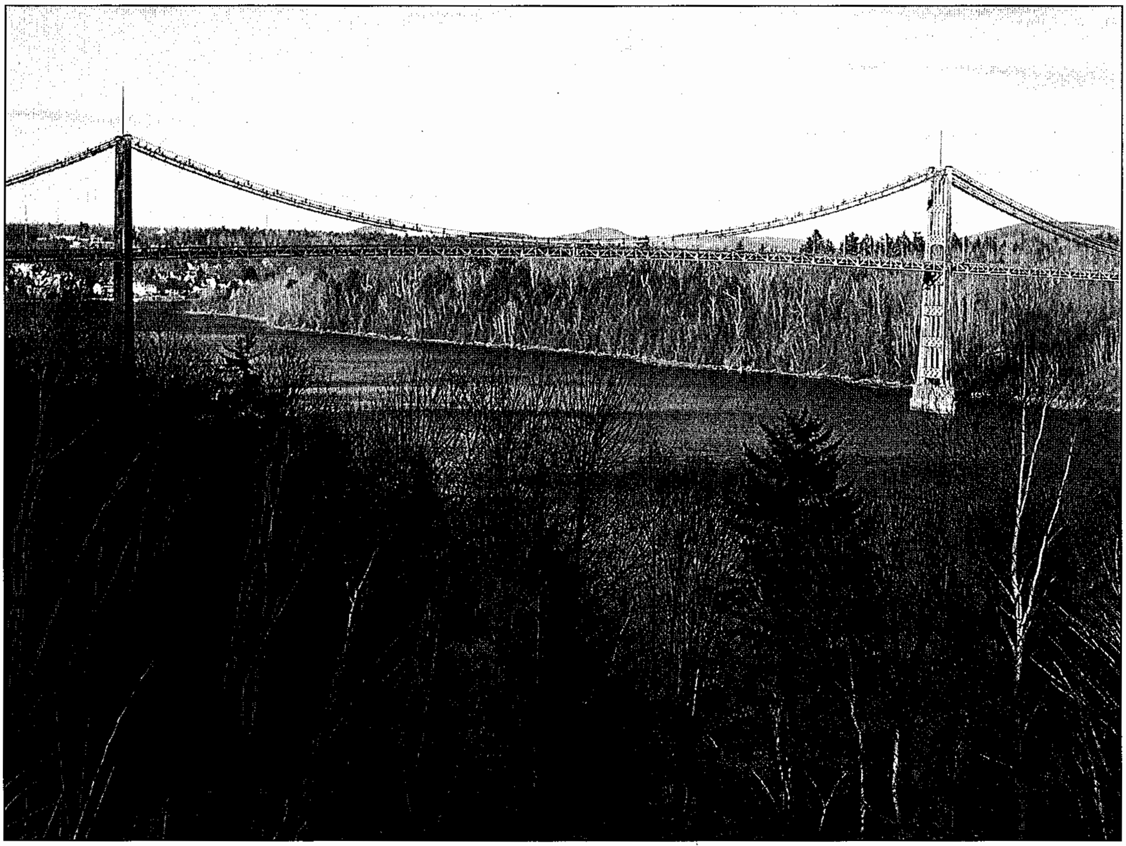
The stiffening trusses were also rehabilitated. The middle hinge on either side was removed for improved live load capacity. A cover plate was then added to the top chord in the middle four bays of the truss to prevent rotation at mid-span, reduce deflections and eliminate the need for a joint in the deck.

Other repairs included the replacement of suspender cables, cable saddle plates and hanger plate connections at a few locations along the bridge. Wingwall caps were also added, along with repairs of spalled concrete along the face of the towers. Navigational lights and roadway light posts were also added. The old x-lattice rail was replaced with crash-tested Massachusetts S3-TL4 bridge rail, which has a similar appearance to the original rail. The new rail uses a vertical post and horizontal tube rail configuration.[13]

After all renovation work was completed the bridge opened again to traffic on June 28, 2003. With all of the replacement and repair work performed on the Chain Bridge, it still maintains its unique original appearance in accordance with its historical significance. Today, it carries an average daily traffic of 23,120 vehicles.

The Waldo-Hancock Bridge

Located in Verona, Maine, the Waldo-Hancock Bridge spans the Penobscot River. Originally designed to connect the towns of Verona and Prospect, it has become a major thoroughfare for travelers on Route 1 in Maine. Up until the construction of the bridge,



Waldo-Hancock Bridge, Maine.

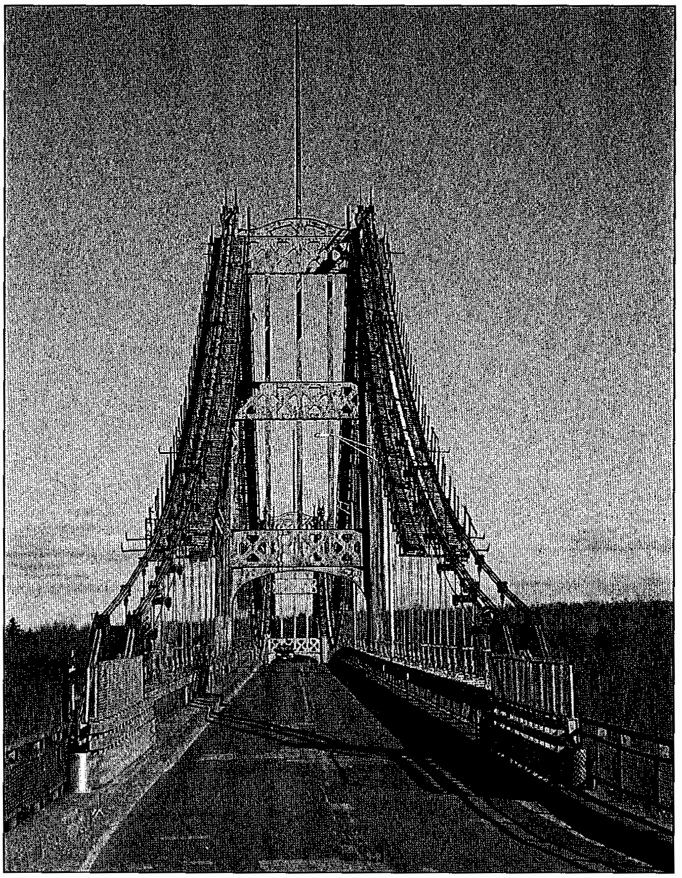
the only crossing of the Penobscot was done by ferry, which severely limited travel between the two towns.

Construction took place from 1929 until 1931. The bridge was one of several New England suspension bridges designed by David B. Steinman, whose firm also managed the construction of the bridge. The severely depressed economy forced the designer to alter designs in several ways and to stretch the budget for the bridge to an extreme. The overall cost of the bridge was roughly $850,000, leading to its nickname as "The Million Dollar Bridge." The bridge was awarded by the American Institute of Steel Construction the title of most beautiful and artistic span of all bridges constructed in 1931. It was also (for a time) the longest span in Maine. The cost was to be paid for by tolls on the bridge. Twenty-two years later, the cost was recovered and the tolls from the bridge were removed from the bridge.[14]

The Waldo-Hancock Bridge is a gravity-anchored suspension bridge with concrete abutments. Like Steinman's other suspension bridges, it has steel pylons and piers supporting the spans. The main span is 800 feet long, and the overall length including approaches is 2,040 feet. The towers reach a maximum height of 236 feet. The deck has deep stiffening trusses, although wind vibrations are still perceptible while crossing the bridge. The bridge has one lane in each direction, which has had a substantial impact on traffic patterns along the Atlantic coast route. Economic concerns led to a helical design of the cable strand system. Helical strands are capable of spanning longer distances and carrying added strength. However, splicing broken helical wires is next to impossible, and would eventually force the replacement of the span.[15]

The bridge underwent major renovations from 1959 to 1961 after engineers discovered severe cracking in the deck and slab, as well as corrosion in the steel superstructure. Work was also performed on the cable wraps after they were gouged by a passing truck.

A rehabilitation study was performed in 1988 that found that the bridge was in need of massive rehabilitation, and would cost roughly $20.6 million to restore. After debating the merits of a total replacement, a $5.3 million rehabilitation project was chosen. Early analysis reduced the load rating of the bridge from 50 to 12 tons. This reduction was due to a substantial amount of corrosion in the cable strands. The first step in the rehabilitation was to reinforce the piers in order to prevent erosion behind them. Environmental concerns slowed down this portion of the project substantially, but it was eventually completed in May 2001. A massive cable strand replacement effort began in 2002. Halfway through the project it was discovered that several helical strands in the main span had broken, and it was determined that rehabilitation was no longer an feasible option. The immediate replacement of th bridge was deemed critical.[16]



Waldo-Hancock Bridge roadway.

Traffic and economic requirements have had a huge impact on the rehabilitation and replacement efforts. Alternate crossings of the Penobscot River are forty miles away and the bridge needs to remain open to local traffic. Concerns from both towns about the economic impacts of closing the crossing have prevented a complete closure of the structure.

These problems led to emergency rehabilitation work, and an expedited replacement timetable.[17] Additional work was done in order to support the sagging spans. A highly complex and innovative load transfer procedure was performed in 2003 in order to reduce the load on the corroded cables. At an overall cost of $2.5 million, new abutments and a new cable system were linked to the entire structure via steel plates, which were welded to the original system. The new system now supports 50 percent of the dead load, and allowed the Maine Department of Transportation (DOT) to increase the load rating to 40 tons. Furthermore, the immediate need for a new bridge has increased the cost to build it, which is now estimated to be roughly $75 million.[16]

Construction has now begun on the new cable-stayed replacement, although several points of the design are still under consideration. The scenic views and historic nature of the original Waldo-Hancock Bridge have dictated that the new design replace the existing structure not only in function, but also as a landmark. In order to maintain the feel of the original structure, the piers were placed on the banks of the Penobscot River, not in the river itself. The piles for the new structure have already been placed, and the replacement bridge is being quickly built. Sadly, the old Waldo-Hancock Bridge will be demolished when construction is complete. But perhaps

Waldo-Hancock Bridge primary and secondary cable systems.

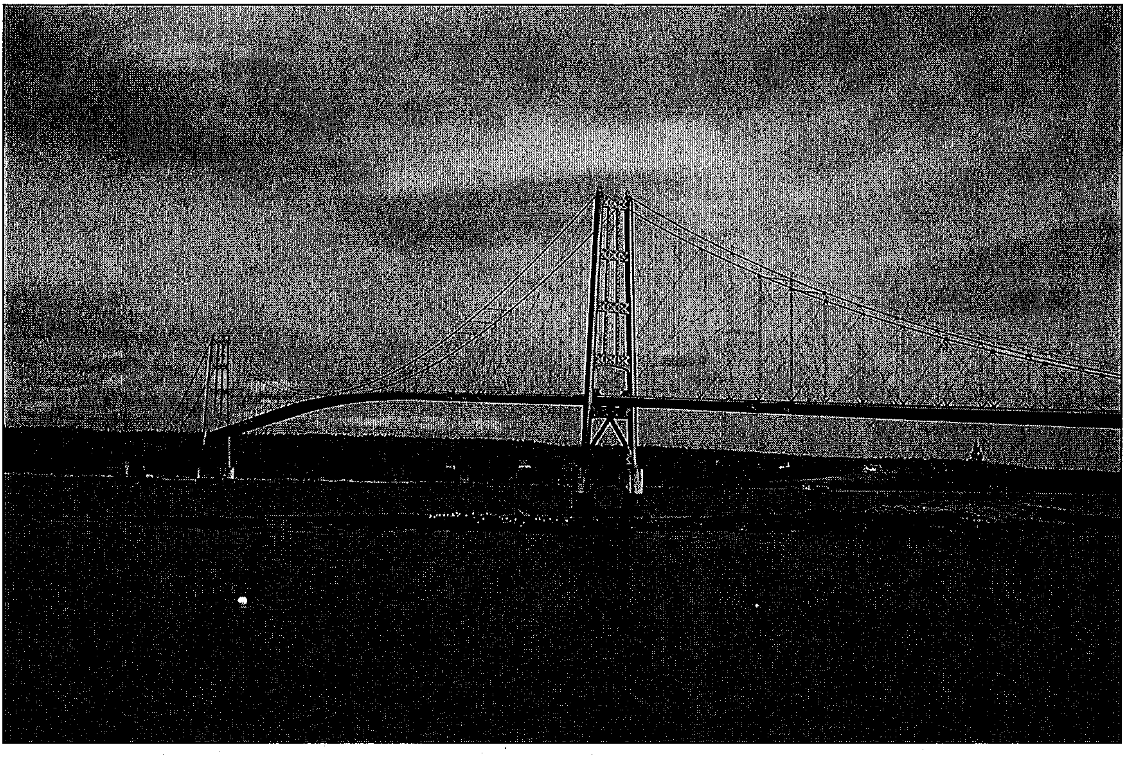
the current aspect of the Waldo-Hancock Bridge is even sadder. Severe rusting on the towers and strands is visible from far away, and the rushed rehabilitation work has completely masked the elegance of the original span. What was once an award-winning and beautifully slender span has become a hulking mess of rusted steel. While many local residents might mourn the loss of such a beautiful and historic landmark in coastal Maine, the deteriorated state of the bridge has many people eagerly awaiting the new structure that will grace the Penobscot River.

The Deer Isle Bridge

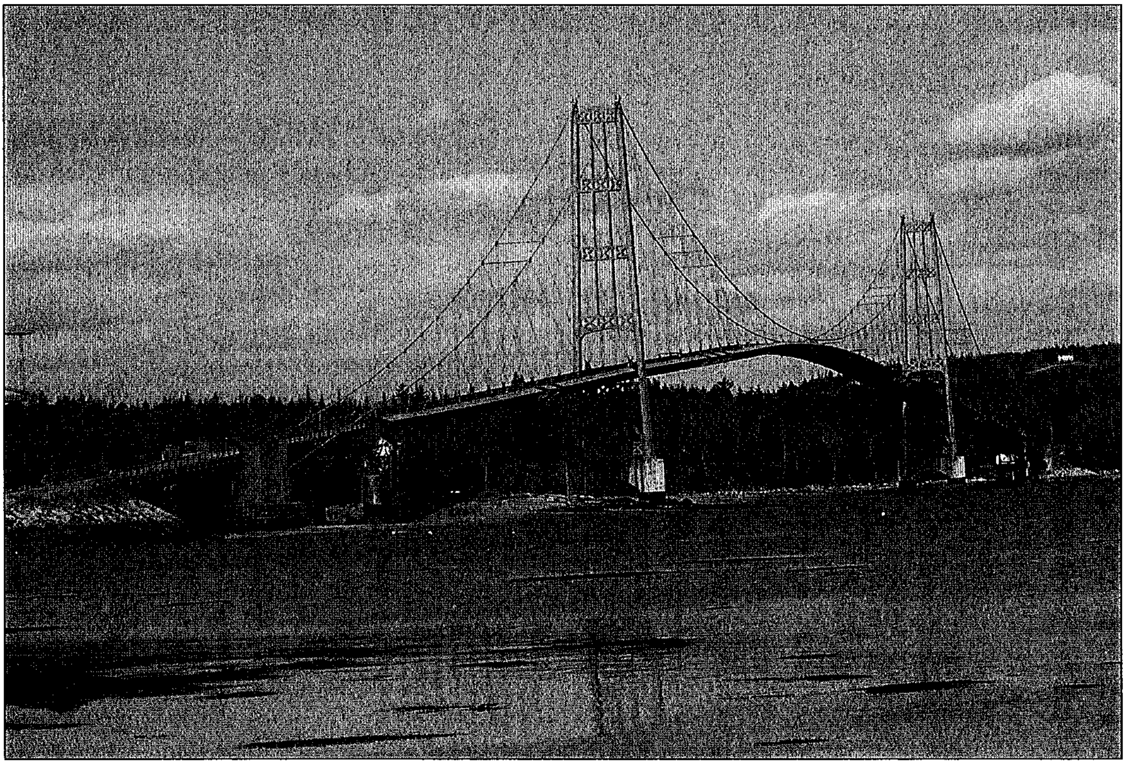
Located between Sedgwick and Deer Isle, Maine, the Deer Isle Bridge carries State Route 15 across Eggemoggin Reach. This crossing of Penobscot Bay is the primary point of entry to the sleepy resort area of Deer Isle, and is a well-known crossing for anyone visiting Acadia.

The residents of Deer Isle have led a relatively secluded life for centuries. Since the island was too small to be economically influential, bridge crossings were not considered vital. Ferry crossings were the only means of access for residents and travelers. But Deer Isle's one major export eventually helped bring about its first bridge crossing to the mainland. Deer Isle granite was highly valued because of its stability and aesthetic appeal. Demand for the stone reached all the way into New York. In the 1920s and 1930s, Deer Isle granite was extremely prized since steel and reinforced concrete construction had not yet overtaken stone as construction materials. The high cost of the granite was further exacerbated by the difficulty in obtaining it. The only access to the island was by ferry — not the most efficient system for transporting large amounts of stone. The need for better access to the island was growing rapidly.

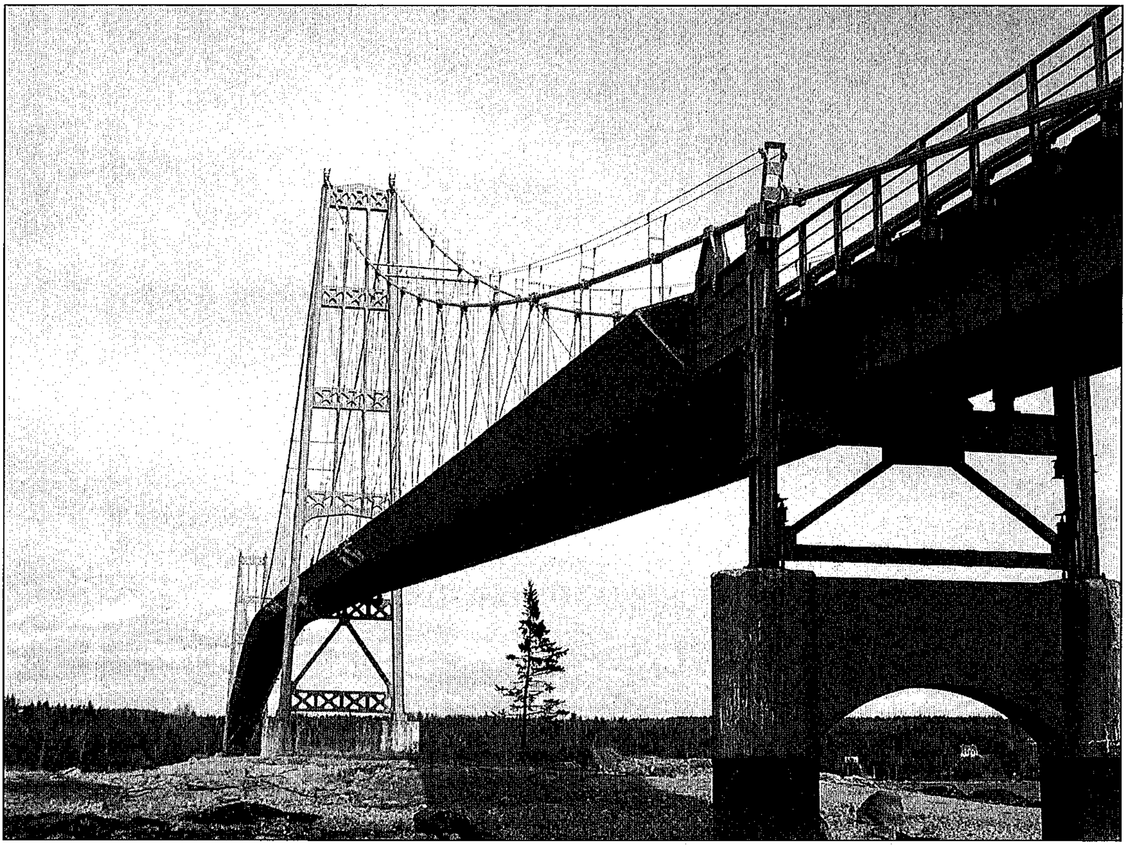
Demand for a bridge increased as the rise of automobile use in the United States heightened travelers' frustrations with the ferry crossing. This last of the three suspension bridges in New England designed by David B. Steinam's firm was constructed in 1939. The construction of the bridge was considered the most important moment in the history of the island by its residents. It was not uncommon to have several boatloads of observers floating around the newly formed piers of the bridge during construction. For residents who, for generations, had been isolated from the rest of the United States, simple and direct access to the mainland brought the promise of many changes. Hope ran high that automobile access to Deer Isle would bring additional income to the island so there would not be so much reliance on the granite trade. In the end, the bridge became a major reason why Deer Isle is a quiet and readily accessible vacation spot for many on the east coast today.[18]



Deer Isle Bridge, Maine, from the west.



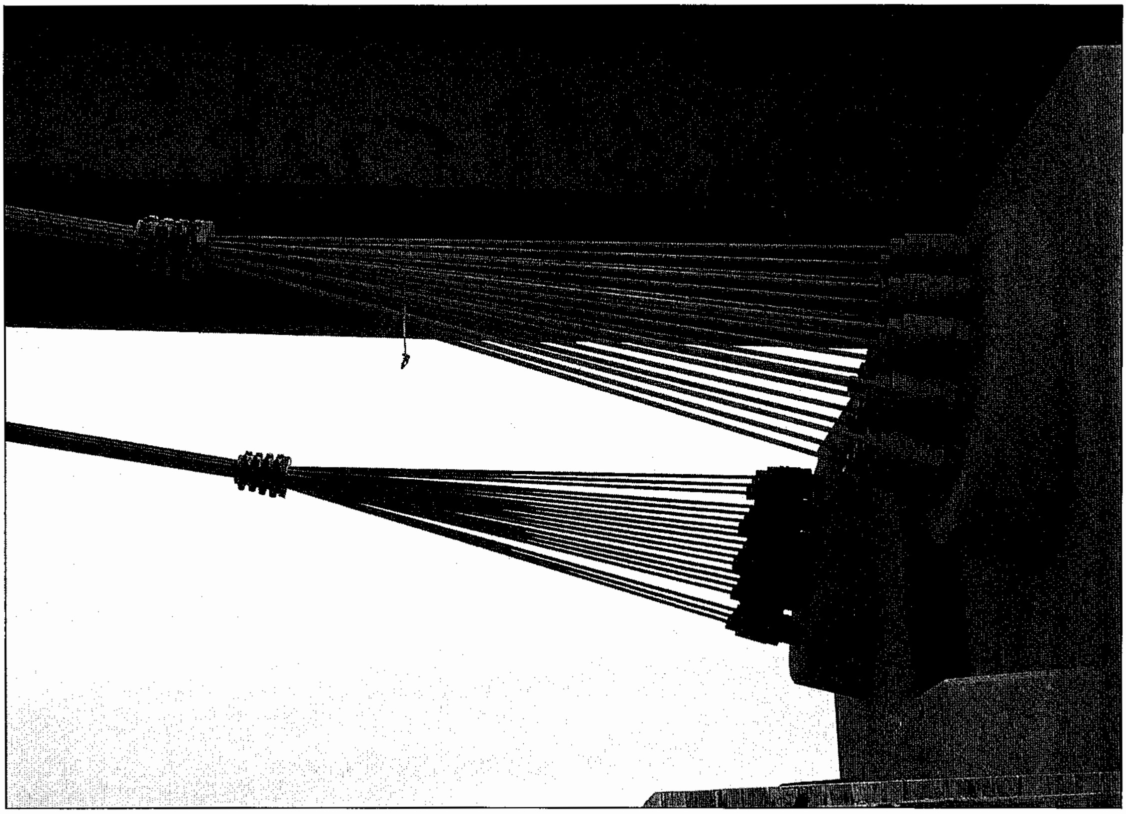
Deer Isle Bridge from the east.



Deer Isle Bridge orthotropic deck retrofit.

The Deer Isle Bridge is a gravity-anchored suspension bridge with a main span of 1,081 feet. It has steel pylons and piers and it reaches a maximum height of 210 feet. The cable system is unwrapped (meaning that there is no protective casing system and the cables themselves are exposed). Each individual cable was coated to protect against corrosion. The cables run into concrete abutments at the ends without any end casings. The bridge has a thin plate girder deck, one of several that were designed during this period. This method of deck construction led to elegant, slender designs, but also made the bridge susceptible to failure from lateral wind loads. The Tacoma Narrows Bridge is the most famous example of this type of deck design. The pitch of the Deer Isle Bridge is dramatic and it borders on parabolic when seen in elevation. The bridge has one lane in each direction.

Almost immediately after its construction travelers began to report heavy wind-induced loadings of up to 10 inches even in even moderate wind conditions. These reports led the designer/contractor to retrofit the bridge with diagonal cable stays in order to prevent major vibrations. After the Tacoma Narrows disaster, the Deer Isle Bridge was heavily monitored. A minimum spacing of 500 feet. between heavy trucks was ordered, as well as load ratings and closings in high winds. Several major wind studies were undertaken during the 1980s, with the end result being a retrofit of aerodynamic fairings to the plate girder deck in order to counteract wind forces. The bridge is now constantly monitored via wind testing mechanisms attached to the deck that were installed in 1981. These mechanisms send real-time data to research and monitoring facilities in Virginia for further analysis. Despite the retrofit, many locals still comment on uncomfortably high vibration levels during high winds, although designers claim a safety factor of 2.5 for the current bridge.[19]



Deer Isle Bridge cables.

The Deer Isle Bridge has become a significant landmark in the Maine landscape over the years. With its extreme grade and slender profile — not to mention the misadventures of crossing in high winds — it had become a local treasure. The profile of the bridge easily blended with the breathtaking landscape that it spanned. Passengers were treated to stunning views while making their crossings. Unfortunately, the retrofitted diagonal cables obscure those views now, and the graceful profile of the deck is concealed behind the aerodynamic fairings.[20]

Aside from the vibration problems, a recent rehabilitation study found the bridge to be in good condition considering its age. The unwrapped cables were very thoroughly inspected and they were rated to be in "good" condition. The lack of corrosion is most likely due to fact that the unwrapped strand system did not have the same issues that plagued the Waldo-Hancock Bridge further south where the wrapping trapped water and accelerated cable corrosion. The inspection also found moderate to heavy local corrosion in the steel superstructure, which is to be expected considering the saltwater environment of the bridge. Currently, the main issue with the bridge is substantial cracking in the deck. While there is no major spalling of the concrete yet, the deck is delaminating and it needs substantial repair. Work is scheduled to begin in 2005.[15]

Perhaps in large part due to the problems associated with the Waldo-Hancock Bridge, there is growing local sentiment to replace the bridge completely in order to avoid safety issues as well as the high cost of rehabilitation. If this movement goes forward, there might be substantial resistance from other residents who place more value on the bridge's historical significance.

NOTES — *RITBA awarded the task of designing the Claiborne Pell Bridge to Parsons, Brinckerhoff, Quade, and Douglas. The chief design engineer* *assigned to the project was Alfred Hedefine, principal engineer and also a partner at Parsons. Bethlehem Steel developed the new technique in stringing the main suspension cables using prefabricated parallel wire strands. Dupont supplied the protective plastic cable sheathing. The Maguire Group, Inc., was contracted by Parsons & Brinckerhoff to provide consultation services in the rehabilitation of the reinforced concrete deck. Design of the Mount Hope Bridge was contracted to Dr. Steinman's firm, Robinson & Steinman. The contractor was McClintic-Marshall. Cianbro carried out the repair work on the Mount Hope Bridge. The rehabilitation study for the Waldo-Hancock bridge was performed by the Parsons Transportation Group. The new cable-stayed replacement for the bridge was designed by the FIGG Engineering Group. Cianbro, Reed, and Reed is the contractor in charge of replacing the Waldo-Hancock Bridge. This article was written as part of a Masters degree program at Tufts University.*

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REFERENCES

1.www.bostonroads.com/crossings/pell-newport/.

2. www.ritba.org/newport.htm.

3. thesaltysailor.com/rhodeisland/event13.htm.

4. www.maguiregroup.com/Project%20Sheets/PELL.pdf.

5. web.bryant.edu/~history/h364proj/sprg_01/lynch/significance.htm.

6. filebox.vt.edu/users/mawagner/steinman_early_design_years.htm.

7. www.obituariestoday.com/Obituaries/ObitShow.cfm?Obituary_ID=30510&section=pin.

8. www.ritba.org/hope.htm.

9. www.cianbro.com/profile.

10. massroads.com/nbi_record.php.

11. www.state.ma.us/mhd/bridge/datasheets/chain.htm.

12. Bennett, L., & Kaminski, R., "Lower Merrimack River Bridges," *Civil Engineering Practice: Journal of the Boston Society of Civil Engineers Section/ASCE*, Vol. 15, No. 2, Fall/Winter 2000.

13. www.bridgebuildermagazine.com/rehab/chain.html.

14. www.structurae.de.

15. www.maine.gov.

16. Angelo, W.J., "Maine Cables Get Extra Support in Rare Procedure," *Engineering News Record*, Nov. 10, 2003.

17. Ciciotte, C., "Waldo-Hancock Bridge Job May Take Six Years," *Ellsworth-American*, May 25, 2000.

18. Personal phone conversation with Clayton R. Gross, local expert on Deer Isle Bridge, April 24, 2004.

19. www.tfhrc.gov.

20. Turner, H.R.B. Turner, & Huston, D.R., "Aerodynamic Design of Highway Structures," *Public Roads*, Winter 1996."