Project Number: MDS-SV04

The Physical and Social Impact of Truss Bridges

An Interactive Qualifying Project Report
Submitted to the Faculty
Of the
Worcester Polytechnic Institute
In partial fulfillment of the requirements for the
Degree of Bachelor of Science

By

____
John Schreiner

____
Gary B. DeBlois

____
Benjamin Cooper

Date: January 11th, 2005

____
Professor M. David Samson, Advisor

Authorship Page

The work was evenly divided throughout this report. Ben volunteered to redesign the website for Old Sturbridge Village. This entailed the creation of images, layout and accompanying text. Gary was in charge of most of the photography at and away from Old Sturbridge Village. John and Gary were also heavily involved in the research done at Old Sturbridge Village.

John and Gary each took a section to write individually and worked together on the rest of the report. John completed the section on modernization while Gary completed the write up about Ithiel Town. The technical and historical sections on covered bridges were revised and edited together by John and Gary. With the exception of section 7, which was covered by Ben, the entirety of the report was written in collaboration between John and Gary. John and Gary were also responsible for all proofreading and editing of the final copy of the report.

Acknowledgements

We would like to thank Dr. Larkin and Professor Samson for their guidance and support during this project. We would also like to thank the staffs of Old Sturbridge Village and the Gordon Library at WPI without whose support this project would not have been possible.

Abstract

The purpose of this project was to take technical research done on the “Vermont Bridge” at Old Sturbridge Village and transform it into a tourist friendly explanation of how bridges function. Efforts were focused on ideas for the implementation of a model and redesigned website to illustrate the details of the “Vermont Bridge”.

Table of Contents

Table of Figures

1.0 Purpose

The purpose of this project was to relate the technology of the covered truss bridge and to show how it serves as an example of a modernizing society. This was done by examining a variety of truss bridges with the primary focus being on the Vermont Covered Bridge at Old Sturbridge Village and explaining the ways in which it functions as well as its impact on society in the nineteenth century.

2.0 Literature Review

There were two sources which provided most of the primary research material for this project: the research library at Old Sturbridge Village and WPI's Gordon Library. Both facilities provided many books on the construction and design of covered bridges as well as their relationship to society in general. The works provided by these libraries presented much information which proved invaluable to this project.

The research library at Old Sturbridge Village proved to be an invaluable tool in obtaining material directly pertaining to the design of covered bridges and their history. Much of the material, though, pertained to specific bridges found throughout New England, and appeared to be mostly a cataloging of information such as bridge location, dates of construction, type of design, etc… This information was useful in the sense that it provided background on the numbers and types of bridges being built during certain periods, which one could correlate to the longevity of certain designs. The research library also provided a number of books relating directly to the design and construction of wooden bridges. The works of Sloane, Condit, and Allen in particular provided clear references on the procedures, materials, and know-how needed in the manufacture of these bridges. The research library also contained a jewel among its shelves: an original volume of Haupt's *General Theory of Bridge Construction* which outlines the trigonometric methods of truss analysis that he helped to pioneer.

The Gordon Library at WPI also provided two very helpful tomes: Calhoun's *The Intelligence of a People* and Stilgoe's *Common Landscape of America*. Both of these books explored in depth the psyche of the American people during the nineteenth century and how they adapted to a changing world and in what ways they helped to shape that changing world. Calhoun does a good job of exploring some the evolutionary changes of the bridges of this time and how these changes highlighted the innovative ways people were changing. Stilgoe's book mainly explores the way in which the American landscape was changing and how the people adjusted to such changes. He explores the events which prompt America's road and bridge building eras and how society adjusted to the events happening around it.

3.0 Bridges: An Introduction

In the early nineteenth century the country was expanding quickly due to advances in technology and transportation. Tiring of the appalling conditions of the roads, America embarked on a series of turnpike building eras which saw the countryside woven together by a series of well-graded, long distance roads. The need for bridges became apparent as these new roads would eventually need to cross over the many rivers, streams, and tributaries found throughout the land.

3.1 Types of Bridges

The three most common types of bridges in use today are the beam bridge, the arch bridge, and the suspension bridge. These bridges differ in construction and functionality, from the relatively simple beam bridge to the more complex suspension bridge. The increase of the length of the spans of these bridges is directly proportional to the increase in complexity of each successive type, with the simple beam bridge spanning the shortest distances to the more complex suspension bridge, whose spans can be hundreds or even thousands of feet long.

The simplest of the bridges, the beam bridge, is used to span short distances and is shown in Figure 3.1. Its construction consists of a flat surface, called the deck, laid horizontally and placed between two abutments. Abutments, essentially, are what support bridges on either end. These can range from beam bridges simply resting on the banks of a river to the giant concrete and steel towers of modern suspension bridges buried deep in the ground. Burying the abutments allows the earth to dissipate most of the tensile forces. In the simplest of beam bridges, the deck rests on two abutments, one at each end of the bridge. Although the beam bridge is simple to design and construct, it can support only relatively small loads. Since the beam bridge lacks a supporting truss, it has nothing, save the bridge itself, over which to distribute the load. In this sense, the bridge is limited in the amount of loading it can support by the materials out of which it is constructed. A beam bridge constructed from a hardwood, such as oak for instance, could support greater loads than a bridge constructed out of a softer wood, such as pine. Beam bridges are therefore often augmented with a truss system.

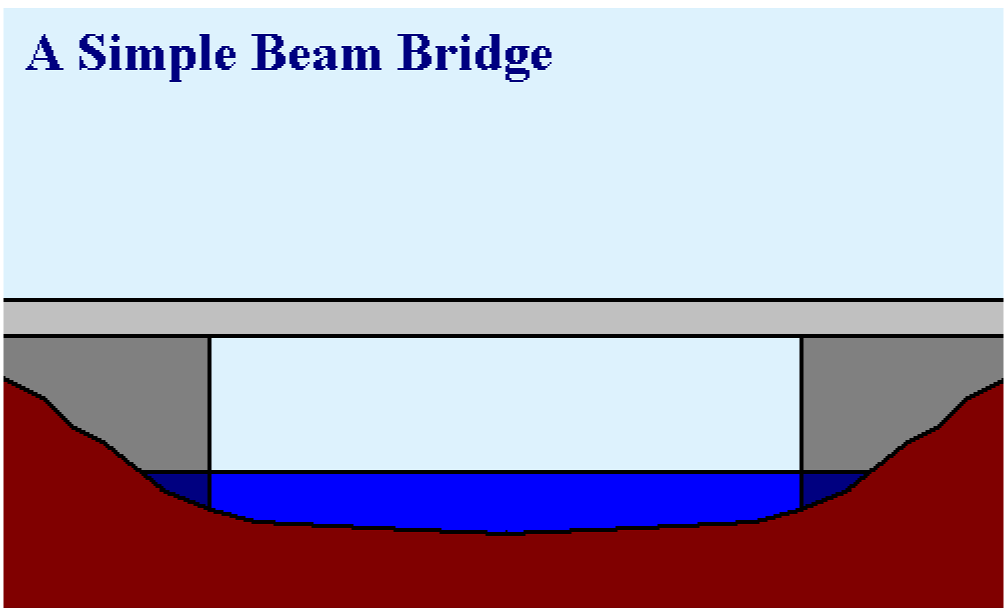


Figure 3.1 The Simple Beam Bridge

A truss system, shown in Figure 3.2, is comprised of a network of rigid beams which distribute the load on the bridge throughout the entire network of trusses. A majority of covered bridges, including the "Vermont Bridge" at Old Sturbridge Village, employ a truss system for added support.

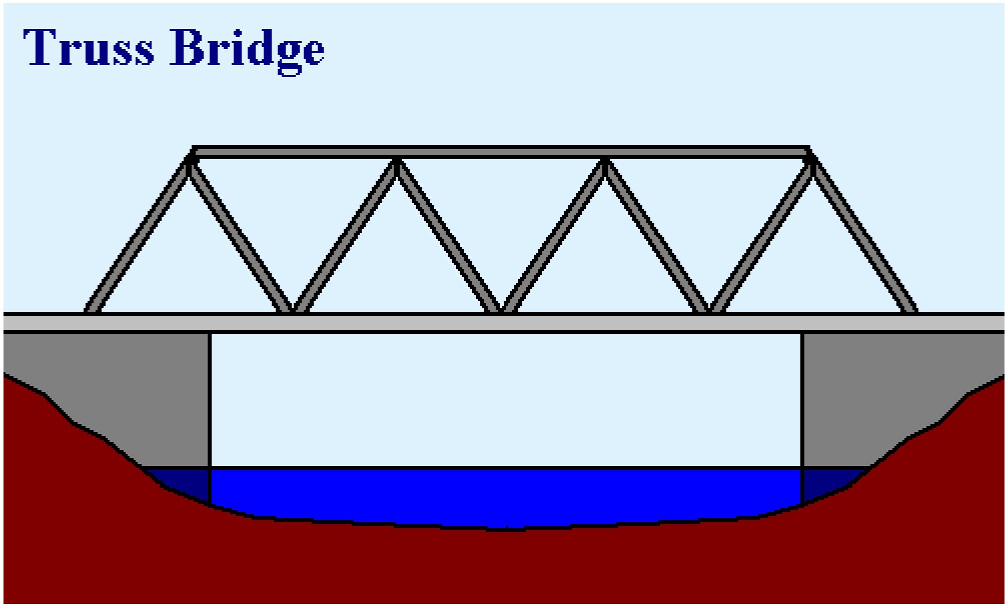


Figure 3.2 The Simple Truss Bridge

The design and construction of an arch bridge is much more complex than that of a beam bridge. The arch bridge is similar to the beam bridge in that it commonly rests on just two abutments. However, it differs greatly in the shape and design of its deck. In an arch bridge, the bottom of the deck is angled in a manner that allows all the weight to be distributed evenly throughout the arch out to the abutments, instead of straight down in the center as in the beam bridge as shown in Figure 3.3. Distributing the load throughout the entire arch ensures that no one section of the bridge is overstressed or completely responsible for the overall security of the bridge. This enables the arch bridge to be built with a greater span, as well as to support greater loads for the same number of abutments as the beam bridge.

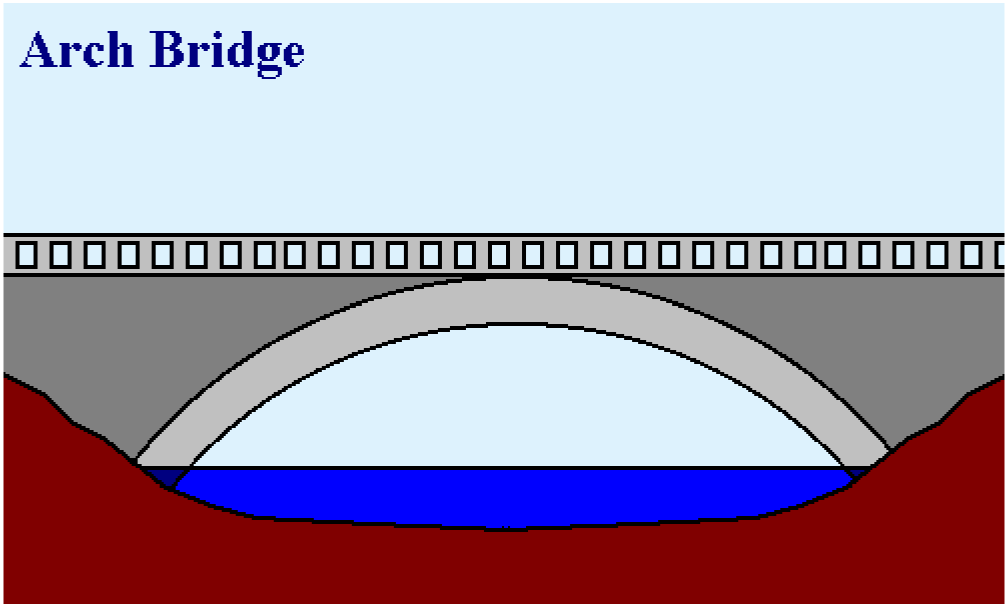


Figure 3.3 The Arch Bridge

Suspension bridges are by far the most complex in terms of design and construction. Like all bridges the suspension bridge, shown in Figure 3.4, rests its deck on its abutments. The major difference is that the suspension bridge also suspends the deck of the bridge from cables which extend from one end of the bridge to the other. At each end of the bridge the cables are attached at the ends to massive stone or concrete anchorages and in the middle they are attached to towers which enable the cables to be draped over the huge distances that the bridge can traverse. These cables allow all the weight put on the bridge to be dispersed out to the anchorages.[1]

[1] NOVA article on suspension bridges. (no author). Retrieved November 18, 2004, from http://www.pbs.org/wgbh/nova/bridge/meetsusp.html

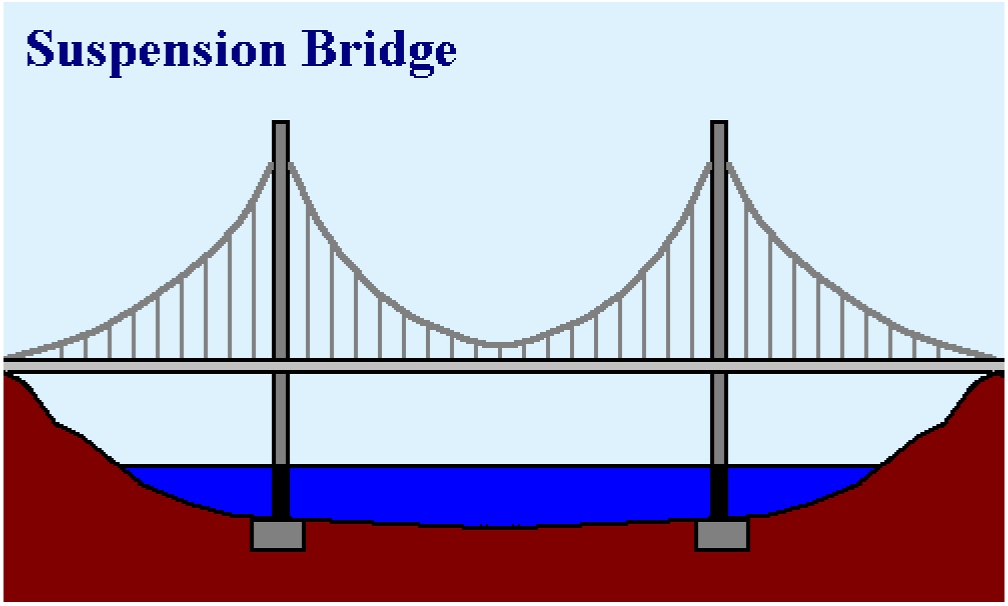


Figure 3.4 The Suspension Bridge

Suspension bridges can span distances far greater than either the beam or arch bridges. Japan's Akashi Kaikyo bridge, for instance, measures a staggering 3,911m –over two and a half miles long![2]

Figure 3.5 Japan's Akashi Kaikyo Bridge

[2] Introduction to Akashi Kaikyo Bridge, Honshu-Shikoku Bridge Authority. Retrieved November 18, 2004, from http://www.hsba.go.jp/bridge/e-akasi.htm

3.2 Physical Terminology

In order to understand how bridges function one must first be familiar with the concepts of compression and tension. These concepts can best be illustrated by considering a coiled spring. As outside forces press the spring together as shown in Figure 3.6, it becomes compressed. In reaction to this, the spring attempts to exert a force against the applied compressive forces so that it may revert to its natural state. The opposite of compression, tension, is illustrated in Figure 3.7. As the spring is pulled apart, the spring material is stretched out and placed under strain. While under this strain, it again exerts a force opposite to that of the applied force and attempts to revert back to its un-stretched state. In this situation, the spring is said to be in tension. These concepts are vital in the explanation of how bridges function.

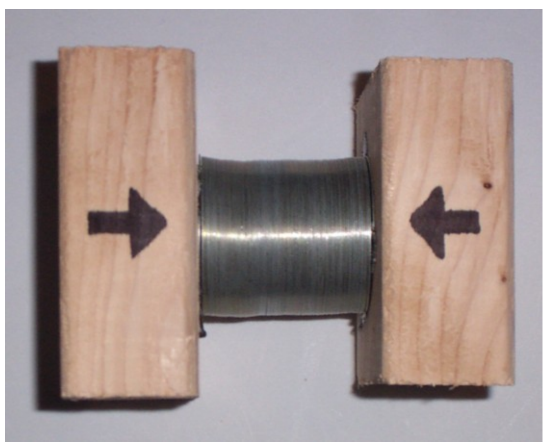


Figure 3.6 A Spring in Compression

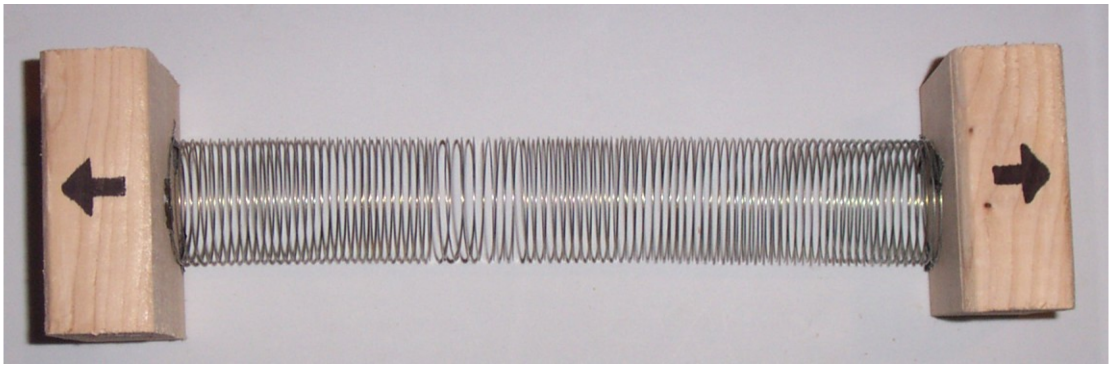


Figure 3.7 A Spring in Tension

Another important concept that must be grasped is tensile strength. Tensile strength can best be thought of as a measure of how much a material can be pulled apart before it breaks. Different materials have different tensile strengths. For example, steel is extremely strong and has a very high tensile strength whereas Silly Putty® is very weak and has an extremely low tensile strength.

3.3 Function and Physical Characteristics of Bridges

When examining how tension and compression are exhibited in bridges, the basic beam bridge is the simplest to consider. As an object crosses the bridge its weight pushes down on it. This causes the surface of the bridge immediately under the load to be in both tension and compression. The top portion of the deck is under compression, while the bottom portion is under tension as illustrated in Figure 3.8. The rest of the bridge before and after the load placement will be in tension. These forces at first will cause the deck to bend downward. If the bridge undergoes too much bending it will fail, causing the bridge to break. When designing a bridge, it is therefore important to choose materials that will be able to withstand a desired load so that it does not fail prematurely.

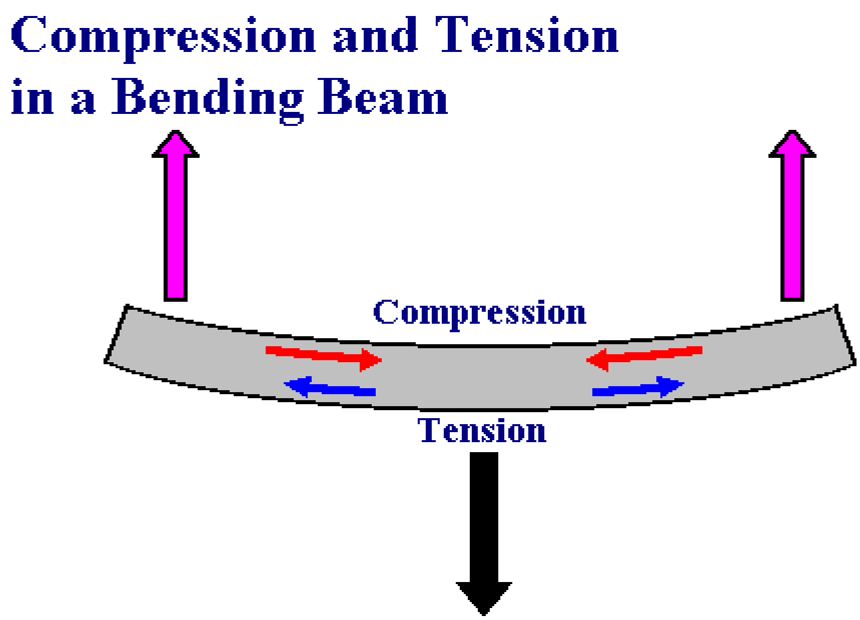


Figure 3.8 This demonstrates how the bridge deck undergoes tension and compression.

Simple beam bridges bend very easily because all the weight is being dispersed to the abutments via its deck. Truss systems were eventually added to beam bridges in order to better distribute the tensile and compressive forces and thus increase the maximum loading a bridge could withstand. The forces of tension and compression are handled independently by parts of the network as shown in Figure 3.9.

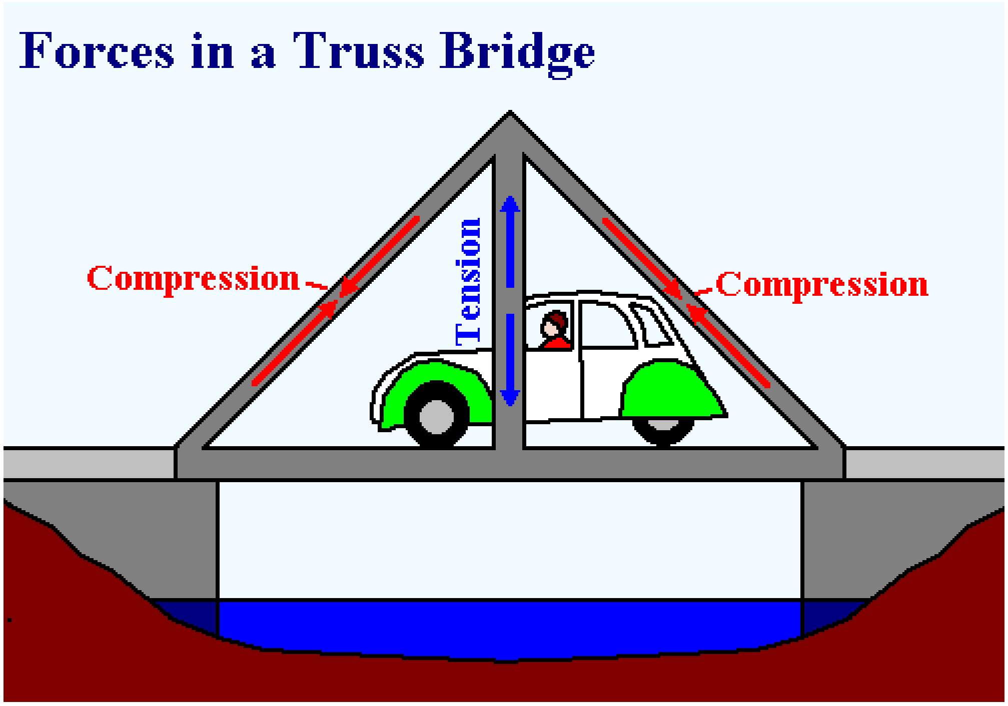


Figure 3.9 Forces in a Truss Bridge

Although the beam and arch bridges serve the same purpose they are much different in design. The arch bridge uses an "arch" to help distribute the weight of the object crossing it as shown in Figure 3.10. When weight is on the bridge it squeezes and the forces are carried outward along the arch to each end. The support of the abutments is necessary to hold together the arch bridge. There are no tensile forces acting on the bridge, instead the entire bridge is under compression. Because there are no tensile forces, it is able to withstand greater loadings without failure. This enables arch bridges to span greater distances than basic beam bridges.

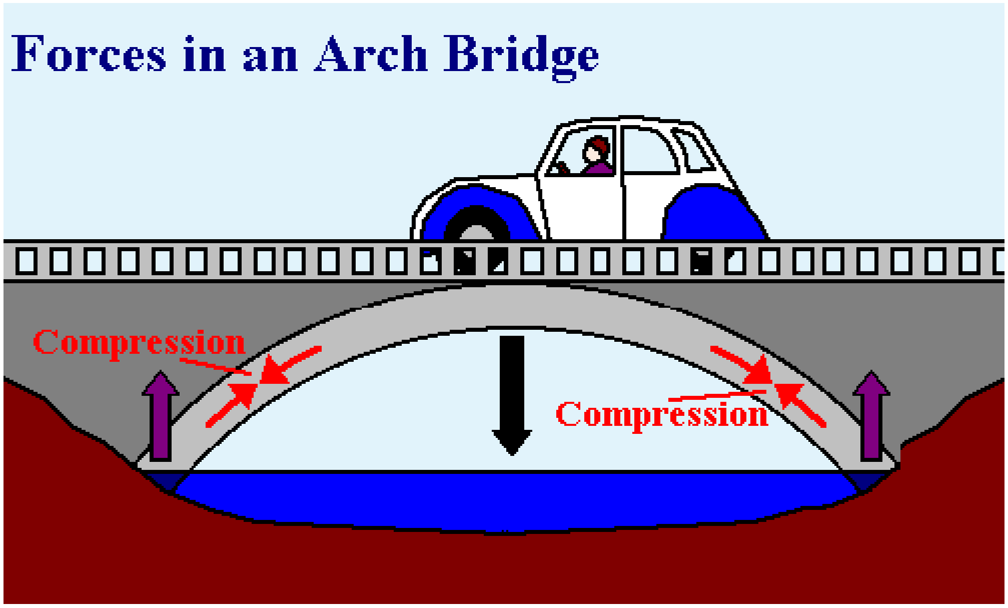


Figure 3.10 Distributed Loading in an Arch Bridge

Of the three basic bridges, suspension bridges are by far the most complex engineered, but in turn have the greatest strength and span of the three. When the bridge is placed under loading, the cables, which span the length of the bridge, are placed under tension. The cables are attached at the abutments and draped over the towers, causing the abutments and towers to be placed under compression. By using this system of cables and towers, suspension bridges are able to be built with huge spans and support massive loads which were previously unthinkable with the arch and beam bridges.

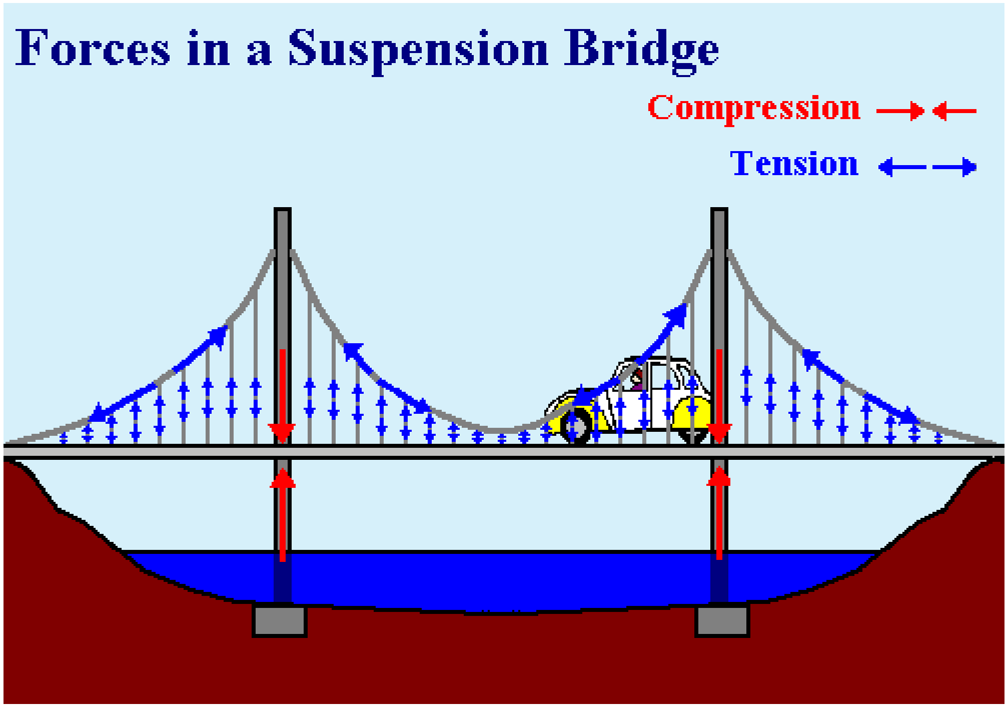


Figure 3.11 Forces in a Suspension Bridge

3.4 The Town Lattice

In 1820, Ithiel Town patented the lattice truss design that would change the face of modern bridge building. In the early nineteenth century most bridges were built as basic beam bridges using gigantic wooden timbers in their construction. Town's design not only created a sturdier bridge but also eliminated the need for these hard to find pieces of lumber. His design allowed the use of smaller milled pieces of wood that were readily available. He took the idea of the simple truss and made it into a "lattice" truss work. This took the extra strength provided by a simple truss and multiplied it. In this model, the tensile and compressive forces are divided throughout the lattice truss work and therefore are distributed efficiently to the abutments. Not only did this decrease the cost of building bridges, but the design was superior to those which preceded it. This lattice created an immensely strong bridge that could withstand almost any amount of weight necessary in its day.

Figure 3.12 The Town Lattice Truss

Another important advantage of Town's design was the lack of mortise and tenon joints. Up until the introduction of Town's lattice, mortise and tenon joints were the preferred method used to join timbers in bridge building. These joints are made by cutting one part out of a board and cutting its opposite counterpart from another so that they fit together like pieces of a jigsaw puzzle as illustrated in Figure 3.13. This created a problem because the skinniest, or weakest, part of the lumber was used in connecting the other pieces. In the Town design, solid members were used at the joints in order to avoid the weaknesses of mortise and tenon joints. In addition to strengthening the original design, using these solid members simplified the construction of the bridge so that most anybody with a rudimentary knowledge of carpentry could oversee one's construction.

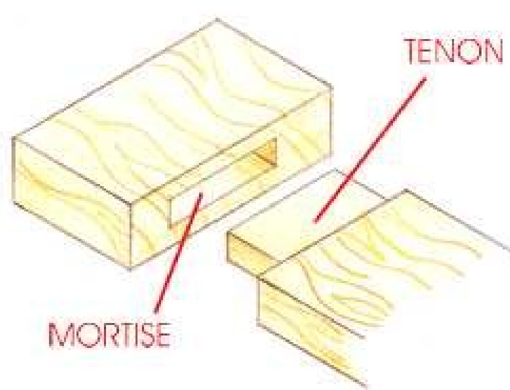


Figure 3.13 The Mortise and Tenon Joint

3.5 Covered Bridges

Common opinion is that bridges are covered to make them more aesthetically pleasing, and while this is true to a certain extent, there are many more reasons why they are covered. As noted by one astute New England farmer when asked why bridges were covered, he replied, "Why did our grandmothers wear petticoats? To protect their underpinning. Why did they cover bridges? Likewise."[3] The most important reason for covering bridges is to protect their components from the elements. The lifespan of a bridge can be increased dramatically by keeping rain, sun and snow off of its joints and surfaces. If water gets into the joints it will gradually rot the wood and lead to the bridge's failure. Likewise, if water freezes inside the joints it will cause cracking as it turns to ice. This can easily lead to the bridge's failure.

[3] Allen p. 1

4.0 History of Early American Truss Bridges

This section will consider the history of American truss bridges. This span will include, but not be limited to, the development of early bridges, the designers of these bridges, and the impact on society caused by these bridges. The focus of this will be centered on the Vermont Bridge at Old Sturbridge Village and its designer, Ithiel Town.

4.1 Evolution of Bridges

As stated by author Richard Allen, a bridge is "simply…a structure erected to furnish a roadway over a depression or obstacle."[4] When confronted with a narrow crossing, the earliest bridge builder would most likely find a tree on one bank and simply fell it across to the other. This early type of bridge became known as a *stringer bridge*.[5] The stringer bridge was quite simply nothing more than a log felled across a gap or stream over which passage was possible. Besides being crude, the stringer bridge provided only a narrow walkway for traffic, barely enough for a man, and could not accommodate any sort of vehicle or animal traffic. Such a bridge could not be built very long as the length of its span was limited by whatever timber happened to be growing in the immediate vicinity.

The stringer bridge, crude as it was, would eventually evolve into the simplest of truss bridges, but not before undergoing a series of changes. The most logical improvement was to simply split the log in half lengthwise which provided the traveler

---

[4] Allen p. 6
[5] Allen p. 6

better footing. A further refinement saw the stringers separated to allow for short logs to be placed across them providing a wider walkway.[6]

The stringer bridge and its refinements worked well enough so long as the gap or stream to be crossed was short; however, problems arose with this type of bridge when the distance became greater. The longer the bridge had to be, the more it was prone to sag and slip its abutments or crack in the middle. One of the first solutions developed to counteract this problem was to add supports, known as "piles," to the midpoint of the bridge. This type of bridge building became known as the pile-and-beam style. The first major span to be built in the Americas was just such a bridge and was constructed in 1662 over the Charles River in Cambridge, Massachusetts. The span of the bridge was only about fifteen to twenty feet long and had hand-driven piles.[7]

Two other bridge forms had been available as solutions by the late eighteenth and early nineteenth centuries: the floating span and pontoon bridge. The floating span was very rudimentary in design and construction: it was built out of wood planking and meant to rest directly on the surface of whatever body of water was being spanned. The major disadvantage of using this bridge was that it would rapidly begin to decay and sink. To keep the bridge usable, new planking kept being added over the old, making an ever-thicker span which could at times become as thick as the water was deep. The pontoon bridge is a direct offshoot of the floating span. Like the floating span, the pontoon bridge was built out of wood planking, but instead of resting directly on the water's surface, it lay on a series of small, rowboat-like pontoons placed on the water.[8] Despite this simple innovation, the pontoon bridge was still susceptible to rapid decay as it still lay directly

---

[6] Allen p. 6
[7] Condit p. 76
[8] Condit pp. 76-77

on the water's surface. Though it had the advantages of being simple to build and easily disassembled if the need arose, it was really only a temporary solution to a long term problem.

The problem of trying to figure out a way of making longer spans that could counteract sag lead to the development of the earliest simple truss design: the *kingpost*.[9] Early builders began by adding braces to the undersides of a stringer, allowing them to rest on the abutments and angling them to meet in the center. A horizontal member was added to the bottom of the braces to close the open end; later, a center post was added to rest between the vertex of the braces and the center point of the lower horizontal member. It was this arrangement that gave rise to the first triangular system of beams called a *truss*.[10]

The kingpost was simple to construct and most any American carpenter could construct one in a hurry as he was already accustomed to building them in his barns and houses.[11] Though the kingpost worked well enough for short spans, it was not ideal for longer crossings. The next iteration in truss design saw the apex of the kingpost replaced with a horizontal member, which allowed the base to become longer. The "better half of a royal family"[12] became known as the *queenpost* and was capable of spanning wider distances than the kingpost.

---

[9] Allen p. 7
[10] Allen p. 7
[11] Sloane pp. 46-47
[12] Allen p. 8

4.2 The Earliest Bridge Truss Systems

Using a network of trusses to support a bridge is a relatively new innovation in bridge building. Truss systems were first developed in Europe during the sixteenth century by Palladio and Da Vinci.[13] The remains of bridges before this period are almost nonexistent as very few of these early bridges were built in this time. Because European builders generally eschewed the use of wood when building bridges, the majority of remaining bridges are of the stone arch design, although there is evidence of decayed simple wooden bridges.

Given the preference of Europeans for working with stone over wood, the techniques of Palladio and Da Vinci did not initially come into widespread use in Europe. However, by the mid-eighteenth century, Palladio's works had been translated into English and the style began to gain in popularity in England. Despite this gain in popularity, wooden trusses were still seen as something of a novelty; since "sizeable, workable wood [was] scarce," and stone arches already in widespread use throughout Europe, there was no need to replace them with simple wooden bridges.[14]

Although England's Colonies had a virtually limitless supply of workable lumber, applications in truss building remained alien outside of being found in barns and houses. Early settlers considered truss bridges to be nothing more than "fool-hardy" [15] experiments as the custom at the time was to either ford creeks or, when available, take a ferry. A lack of skilled and knowledgeable laborers on the frontier also meant that most bridges a traveler might encounter would be of simple, rudimentary design.

---

[13] Tyrrel p. 121
[14] Allen p. 19
[15] Pancoast, et al. p. 4

It was not until the late eighteenth century that truss framing started to see widespread use in America. The early decades of the nineteenth century saw the introduction of many innovative wooden truss designs produced mostly through a process of trial and error. One of the first major bridges to debut in this time made use of the already existing kingposts design. The Burr Arch, named after its designer Theodore Burr, was a multiple kingpost bridge which had a wooden arch added for extra support. Patented in 1804, Burr's bridge could be built in lengths in excess of 250 feet without the use of additional supports.

The most significant design to be produced in this period was the lattice truss of Connecticut native Ithiel Town. First patented in 1820 and again with improvements in 1835, Town's lattice truss did away with the kingposts of earlier designs and instead relied upon webbing comprised of a number crisscrossing diagonal members.[16] Town's bridge was lighter and stronger than previous designs and was easy to construct. He was widely successful in marketing his bridge during the period between 1820 and 1840 as America was embarking on its great turnpike building era.

Two other significant designs to be produced during this time were the Long and Howe trusses. The truss of Colonel Stephen H. Long, patented in 1830, was comprised of a series crossed members held upright between posts.[17] Simple in design, Long's truss was reliable in use but needed to be improved upon. Those improvements came in 1846 when a Massachusetts millwright named William Howe augmented Long's design by adding vertical tension rods made from iron. Positioned between the braces, these rods could be loosened or tightened as the bridge aged depending on how it warped. If these

[16] Condit p. 90
[17] Sloane p. 102

rods failed, they could easily be replaced. Such an improvement saw many to consider Howe's bridge to be one of the most "modern" of the time.[18]

4.3 Truss Bridges as a Sign of Progress

Though New England is a region characterized by rough terrain comprised of rock-strewn landscapes, lakes, rivers, forests, and mountains, its people are able to enjoy a high degree of mobility today that was difficult, if not downright impossible, to achieve two hundred years ago. Poor roads and bridges remained the bane of many a would-be traveler, and those who attempted to use them often did so with great difficulty. It wasn't until the early nineteenth century when new methods of road and bridge construction were developed that allowed people to navigate the terrain with both speed and efficiency.

During Colonial times, most of New England's population was situated on farms and in small, inland communities. These small communities were often isolated as New England was traversed only by a poor network of dirt and gravel roads. Although coastal shipping was the preferred means of moving produce to market, most New England farmers lived out of easy reach of such methods.[19] Instead, they were forced to transport their goods overland on roads that were so hard and rutted they could well shake a wagon apart. As noted by Parks, the roads were so poor that an Englishman traveling by stage from Boston to Newport wrote in 1797

[18] Sloane p. 102
[19] Calhoun pp. 291-291

> Very often we surprised a family of pigs taking a bath in a gully of sufficient compass to admit a coach. As often such chasms were filled by piles of stones that, at a distance, looked like Indian tumuli. I found there were two evils to be dreaded in New England traveling –a clayey soil in wet weather, which, unqualified with gravel, made the road a canal; and a sandy one in summer, which might emphatically be called an enormous insect preserve.

Transportation through waterways was more desirable than traveling overland given the extremely poor quality of roads and scarcity of bridges. Instead of bridges, most people relied on fords or ferries when crossing rivers, but ferries were not always available and finding a ford could mean detours and hours or even days of delay.[20]

By the late eighteenth century, overland travel began increasing considerably. As inland settlements became more fully entrenched, farmers were able to begin producing more goods than they consumed. Braving the roads with wagons in the summer and sleds in the winter, ever increasing numbers of farmers were able to bring their produce to the major markets of Boston and Portsmouth and the surrounding areas. The Revolutionary War also saw a great increase in road traffic. Having returned from the War, many a New England farmer gained a greater appreciation for the roads, realizing that there was a wider world beyond the confines of the farm. Further growth in overland transportation came as a result of a series of European wars in the period between 1793 and 1815. At this time, farmers still relied primarily on oversees markets for their goods. Foreign demand for American goods was so great that even those farmers who lived in the remotest parts of New England were turning great profits. [21]

Despite the profits they were turning, the costs of transporting goods to market were still high and many people began to wonder why they must continue to suffer the

---

[20] Calhoun p. 291
[21] Parks n.p.

appalling condition of the roads. At the time, towns had local control over the roads in their vicinity and were charged with their maintenance and upkeep. Many municipalities were apathetical to the condition of the road beyond their immediate borders and so they mostly remained in disrepair.[22] Most states had a number of laws governing how towns should maintain their strip of road; however, in practice, most such laws were unenforceable, particularly among newer or more sparsely settled areas as they lacked the resources necessary to provide for the road's upkeep.[23] The states would need to look elsewhere for an answer to this problem.

Prior to, and in the years immediately following the Revolution, most roads appeared by chance and not by design. Such roads usually began as a footpath or a way through a farmer's field and were usually of very poor quality.[24] People gave very little thought to the condition of the roads beyond the immediate confines of their village and commerce within the states suffered as a result. Despite the setbacks caused by poor roads, Americans were leery of allowing the federal government to construct an interstate system of improved roads, their reasoning being that such a vast highway network could be abused by the government. As a compromise to "federal highways," turnpike companies were chartered in the early nineteenth century to construct a series of direct, long distance toll roads from which they hoped to turn a profit.[25] Although privately owned, the turnpike companies had to build roads which conformed to specific standards set by public commissioners and to charge no more than established rates of toll.[26] The new turnpikes were both safer and smoother which allowed for a great increase in

[22] Stilgoe p. 131
[23] Parks n.p.
[24] Stilgoe p. 128
[25] Stilgoe p. 131
[26] Parks n.p.

overland traffic along them. In response, many inns, stables, corrals, and wooden bridges were constructed along the routes of the turnpikes in order to accommodate weary travelers.[27]

As cities expanded, it became not only necessary, but also "desirable," to bridge rivers to accommodate the burgeoning population and allow for highway construction.[28] Early bridges were limited to two basic forms, unceremoniously dubbed "short" and "long." Short bridges were used mostly to cross short, difficult rivers where fording proved impractical. These bridges usually took the form of the simple pile-and-beam style. The original Anglo-Saxon settlers most likely learned the art in England, where it was originally learned centuries ago from Roman occupiers. This style of bridge consisted of a pair of pillars called piles to be driven into the ground on either end of the proposed bridge site with simple wooden beams laid in between. The first major span built in the American colonies was one such bridge built in 1662 over the Charles River in Cambridge, Massachusetts. The span measured 15 to 20 feet in length and had hand driven piles. Its relatively simple design and the ready availability of lumber meant that this was the mostly widely used design during the Colonial period.[29] When faced with marshlands or the mouth of a river, long bridges were employed. A long bridge usually took the form of the floating span or pontoon bridge. For a time, these bridges were adequate for the simple purpose of ferrying people from one side of an obstacle to another; however, since the length of these bridges was limited to whatever force a simple horizontal beam could withstand, they soon proved to be inferior in the face of

[27] Stilgoe p. 23
[28] Calhoun p. 294
[29] Condit p. 76

ever increasing traffic.[30] It was not long before it became apparent that these simple bridges could not accommodate the new, expanding America.

Around the turn of the eighteenth and nineteenth centuries, Americans began experimenting with designs for spans which were longer than the pile-and-beam style utilized in past decades. Two of the simpler designs to come out of this era, which proved at best to be only temporary structures, were the floating span and pontoon bridge. A floating span is just that: a wooden span built across a lake or other body of water. The major disadvantage to using this design was that since the span rested directly on the water, it was prone to decaying very quickly and would actually begin to sink. The most common method of correcting this was to keep adding new layers to the bridge. These new layers would eventually sink as well and still more new layers would be added. It was not unheard of to have a floating span that would be as thick as the body of water it was resting on was deep! Pontoon bridges were similar to floating spans except whereas the floating span rested directly on the water, the deck of a pontoon bridge rested upon a series of small rowboat-like pontoons in the water and were similarly susceptible to the ravages of decay. The disadvantages of these bridges made it clear to bridge builders that more sophisticated bridge building techniques were needed in order to accommodate the ever increasing traffic on America's roadways. For this reason American builders turned to truss framing to build their bridges.[31]

Even though by the mid-eighteenth century truss framing had developed to a certain degree in Europe[32], Americans needed to look no further than their own backyards for experience. For decades, trusses had been used in barn construction prior to their

[30] Calhoun p. 292
[31] Condit pp. 76-77
[32] Condit p. 77

incorporation in bridge building. Indeed, many of the early truss bridges were essentially barns erected over rivers![33] Still, even though trusses allowed bridges to be built longer and support greater loads, they were still vulnerable to weathering. In 1785 a 365 foot bridge was erected by Enoch Hale over the Connecticut River at Bellows Falls, Vermont. Hale's bridge was essentially just a simple trussed arch that called for the joints to be boxed in to protect them against the elements. Though not a true covered bridge, it would become the forerunner to the modern covered bridges we know today.[34, 35]

The design of the first truly covered bridge didn't come to fruition until twelve years later when Charles W. Peale was granted the patent on January 21, 1797.[36] Peale had been contracted to build a bridge over the Schuylkill and the original design called for the bridge to be built open to the weather. That was the plan until one of Peale's stockholders, Judge Richard Peters, heard of it and decided that the bridge should be covered at the sides and have a roof added.[37] The bridge would in this way be protected from the elements which would increase its longevity and preserve the investment.

In the early nineteenth century, bridging a river with wood posed certain technical challenges. Although the existing king- and queenpost trust designs of this time were adequate for short spans, they were not suited to spanning larger rivers. A kingpost or queenpost truss built on the same scope as Hale's bridge would buckle and collapse beneath its own weight without the use of many additional supports. Wood employed in such a way was simply not strong enough to support so large a span. Iron might have been considered as an alternative to wood, but prior to 1840 was mostly consigned in the

---

33 Sloane pp.46-47
34 Sloane pp. 81-83
35 Condit p. 77
36 Sloane p. 80
37 Sloane pp. 80-81

form of beams for smaller bridges.[38] In order for builders to continue relying upon wood, new innovations in truss framing would need to be developed, which would allow a bridge to support itself over larger distances.

Two major solutions to the problem of spanning rivers with wood would eventually emerge which relied heavily on the carpentry skills honed throughout the Colonial period in house-, barn-, and shipbuilding: the Burr arch and Town lattice. Theodore Burr's arch bridge was essentially a multiple kingpost truss built from wooden beams and support by built-in arch segments. Burr's arch truss had several disadvantages: its weight and costs were high and it also required a sizable amount of specialized labor. It was also very time-consuming to construct. Despite these disadvantages, the Burr arch became a commonly found bridge in the mid-Atlantic United States.

Although Burr's arch became popular elsewhere, the design that would ultimately become the favorite among bridge builders, especially in New England, was Town's lattice truss. Patented in 1820 by Connecticut native Ithiel Town, the Town lattice truss is interesting in that it has two distinct advantages over earlier truss designs: first, Town's lattice did away with the kingposts and arches of earlier designs and relied solely upon a network of crisscrossing members which in effect formed a webbing of many small triangular supports. The second advantage was that it was easy to erect as its construction was simple and was built from common sizes of lumber, requiring few bolts or metal rods. The uniformity of timber sizes and easy construction meant that even an inexperienced carpenter could erect a Town lattice in a short time with a minimum of expense.[39] Though Town's lattice appeared fragile in construction, it has proved to be a

---

[38] Edwards n.p.
[39] Condit p. 90

resilient design as demonstrated by the large number of them still existing in New England today.

Though not mathematically designed for strength, Town's lattice truss could be easily analyzed for maximum efficiency. Bridge designers began to realize that bridges could be built both cheaper and more secure if the exact stresses and strains placed on a bridge could be analyzed mathematically. Previous bridge builders relied on treatises from France or Great Britain for rules governing the building of bridges; however, these treatises made certain assumptions about bridge construction that often times forced builders to build far more massive structures with far more material than was required for safety's sake.[40] The old European method of building bridges left them *statically indeterminate*. That is, it was impossible to analyze a bridge mathematically and come up with a definite solution as to how much force a bridge could ultimately withstand.

It was not until 1840 when two American engineers, working independently, discovered a means of bridge analysis that allowed bridges to become *statically determinate* by breaking down the network of trusses into a triangular arrangement of beams. The new methods would allow any engineer with a rudimentary understanding of calculus to precisely calculate the stresses and strains upon any given beam of a truss. The first of these men, Herman Haupt, was a West Point trained engineer who was not only able to present a trigonometric method of analysis, but also provided approximations for determining stresses in statically indeterminate bridges. The second and decidedly less sophisticated of these engineers was Squire Whipple of New York. Having neither a college education nor any specialized training, Whipple, a railroad engineer by trade, was able to produce a first-of-its-kind handbook on the design of truss bridges. Like Haupt,

[40] Calhoun p. 298

Whipple was able to analyze trusses by considering them as series of triangular schemes, out of which the exact stresses and strains in any beam could be obtained.[41] The "ruthlessly simple"[42] methods developed by Haupt and Whipple gave American bridge builders their greatest advantage over their European counterparts: by reducing a bridge to a statically determinate form, it would be possible to calculate the exact amount of material needed to construct any given bridge. Such a procedure was an economic boon for Americans. In the 1870's Americans were competing against European bridge builders for contracts to build bridges in newly modernizing Japan. As Japan is a country where raw material is relatively scarce and very expensive, many contracts were awarded to American builders due to their ability to provide exact figures for material costs.[43]

Today we take for granted the ease of travel afforded us by the bridges which dot our roadways, but their effect on the landscape is immeasurable. The introduction of Town's lattice and other trusses, which were cheap to build and quick to assemble, meant that even the most isolated New England community could construct a bridge with relative ease. These trusses, coupled with the new turnpikes, allowed the people of New England to move about as never before and increased the speed at which their goods could be brought not only to major local markets, but to the oversees markets of Europe as well. Town's innovative use of traditional materials and building techniques, along with the discovery of advanced analytical methods, made his lattice the most popular bridge form of the time and helped play a part, as Parks notes, in contributing to a "quickening pulse in the economic and social life" of New England.

[41] Calhoun pp. 297-298
[42] Calhoun p. 298
[43] Calhoun p. 299

4.4 Ithiel Town

Ithiel Town was not just an engineer; he was an innovator with an eye for the future and an appreciation for the past. Town's fascination for architecture and engineering was apparent at an early age. His first job was as a house carpenter in his home town of Thompson, CT. His interest in building soon led him to Boston where he apprenticed under architect Asher Benjamin.[44] Town decided to move back to Connecticut in 1810 and was almost instantly successful as an architect. In 1812, he was hired to design the Center Church in New Haven.[45] This church was his first major architectural project and was a huge success. From this point on Town's reputation would precede him.

His next major accomplishment was the patent of a bridge design that would become the "universal design for covered wooden bridges."[46] This truss design was structurally superior to prior bridges as Town designed it to account for the "tension strength" of the timbers and the "thrust strain" placed upon certain members.[47] It also had the added advantage of being easier to manufacture. Most bridges before this had to be built by highly skilled carpenters and used huge timbers that were difficult to obtain. Town's design required easily obtainable sizes of lumber and could be built by men with even moderate carpentry skills. This patent quickly became very popular and remained a lucrative source of income for Town for many years.

The notoriety of this bridge did not happen by chance. Although Town had a great appreciation for antiquity he was also many years ahead of his time. He did not

---

[44] Condit p. 90
[45] Searles, n.p.
[46] Searles, n.p.
[47] Calhoun p. 296

build these bridges; he successfully marketed his design throughout the country. Town's bridge style was used in over a dozen states spanning the country from Connecticut to Georgia to California. Author Herbert Congdon used these words to describe the manner in which Town was able to market his bridges, "…they seem to have been built by the mile and sold by the yard."[48]

Town differed from most bridge builders of his time in the fact that he did not actually build his bridges; he sold the rights to his design for others to build.[49] This saved Town an immense amount of time. Instead of spending years building a single bridge, he was able to sell his patent to multiple customers in the same timeframe. Town was known as a sort of promoter. He would show up at the site of a new bridge to wine and dine the directors of the project.[50] Town also used pamphlets about his bridge throughout the country to advertise it. If asked to use the design, Town would usually charge a dollar of every foot in length of the bridge. For example, if a two hundred and fifty foot bridge was built with Town's design the cost would be two hundred and fifty dollars. Town also had agents who would nose about riverbanks to see if his design was used without his permission. If this was the case the bridge's builder would usually be charged double the original rate.[51] Town was able to amass a small fortune through the steady stream of royalties from this patent.

The immense sale of the Town Lattice was not purely the result of a superior design. The Town lattice was patented in 1820, right in the middle of New England's first major period of road building known as the Turnpike Era. Over thirty seven hundred

---

[48] Congdon p. 15
[49] Sloane pp. 101-102
[50] Allen p. 16
[51] Allen p. 16

miles of toll roads were built in New England during this era by local corporations.[52] This led to a massive need for bridges in the area and Town's was not only the most sound structurally but it was the easiest to build. The beginning of the railroad boom began in the late 1820's and increased the need for sturdy bridges on a national level. Roger Newton wrote, "Practically every section of the Eastern seaboard from Newfoundland to the Carolinas began to benefit by this remarkable device, to which the rapid spread of railroads also owed much."[53] Not only did Town design a great bridge, but his timing was impeccable. His design worked hand in hand with the great transportation explosion of the early nineteenth century.

[52] Parks, n.p.
[53] Newton p. 19

5.0 Critique of Original Report

The E-term IQP[*] report attempted to present an introduction to the history and physics behind truss bridges. Although informative, it managed to present the information haphazardly, in many instances repeating itself or providing unclear physical explanations which oftentimes left non-technically inclined readers confused and asking themselves, “What did I just read?” In order to get a non-engineer’s opinion of the report, the group surveyed various people who had no prior engineering background. Persons surveyed ranged from blue collar, middle aged people to college students studying topics such as elementary education and nursing. Their opinions gave valuable feedback and added direction to the future report.

There were several major issues with the original report. First was the use of unnecessary technical terminology. There are several terms which must be known to understand how bridges function, such as tension, compression, and tensile strength. Expressions such as bending moment, shear force, normal force, and cross sectional area tended to confuse the average reader, instead of laying down a simple foundation, as they were not clearly articulated. The second problem with the report was the order in which topics were discussed. For example, tension and compression were used to describe the engineering of the beam and arch bridges before the terms had even been defined. Doing this took away from the entire section because the readers were not able to get a clear understanding of the information. The third problem with the old IQP was that some of the examples used were unclear and confusing. A perfect example of this is the use of a pencil at the edge of a table to illustrate an applied moment.

---

[*] Courcy, Roy and Wixon. (2004). History and Physics: The Covered Bridge at Old Sturbridge Village. Interactive Qualifying Project, Worcester Polytechnic Institute.

These problems have been addressed and solved in the current report. The section on the functionality of bridges has been rewritten in its entirety so as to be presented in a much more easily understood format. Also, much of the complex technical terminology has been modified or removed as it would be better left to readers with a more advanced knowledge of engineering. By changing these two aspects of the report, the average person who does not have engineering knowledge will be able to obtain a much better understanding of the information presented. To address the third major issue, some new examples have been created. For example, to illustrate tension and compression, a spring was photographed while it was being compressed or pulled apart.

Outside of these problems, the old report did an excellent job laying down the groundwork for the future report. Section five of the original report gave an excellent historical background on bridges that was used and expounded upon in the current report. The suggestions given were also helpful in generating the new report. A website complete with new images and text was created to contribute to Old Sturbridge Village's webpage as suggested in the previous report.

6.0 Facts about the Vermont Bridge at Old Sturbridge Village

How does the Vermont bridge work? The Vermont Bridge is a Town lattice truss design. This means that the lattice truss work is designed in such a way as to distribute the loading so that the bridge experiences only vertical forces which meant that the abutments do not experience any horizontal or diagonal loading, creating one of the most successful and efficient bridge designs of the nineteenth century.

Why is the Vermont Bridge covered? Covered bridges, such as the Vermont Bridge, were thought to have been covered for a variety reasons. Privacy for trysting lovers, keeping pedestrian traffic dry, and added support for the bridge were a couple of common reasons people believed these bridges were covered, but the most significant reason for covering these bridges was far more simpler: protection from the elements. Keeping a bridge dry from the snow and rain allowed it to survive much longer than other uncovered bridges of the time.

Why was the Vermont Bridge built? In 1869, a large storm caused the Stickney Brook to flood and created a new estuary. It chose a path through Dummerston, Vermont by the Taft Tavern causing a problem for the locals. In 1970 it was decided that a bridge would need to be built using Ithiel Town's lattice truss design. Originally called the Taft Bridge, the Vermont Bridge was built to allow crossing of this subsidiary of the Stickney Brook.

Who invented the style used to build the Vermont Bridge? Ithiel Town created the lattice truss design in the early nineteenth century and was granted a patent for this design in 1820. Town was a "super salesman" who was widely successful in marketing his bridge as evidenced by the large number of Town bridges still in existence today.

What did the Vermont Bridge mean to society? This bridge, as well many throughout the United States, simplified transportation. Bridges in this era were not just crossing rivers and streams; they were connecting communities that were previously separated and allowed for cities to grow and expand. Not only did this make traveling easier for the average traveler, but it increased the economy by allowing business transactions to traverse towns and counties which could not be reached via coastal shipping.

7.0 Covered Bridge Website for Old Sturbridge Village

After visiting the Old Sturbridge Village website's section on the Vermont Bridge, it was decided that an update was necessary. The section of the website pertaining to the waterwheel had an excellent layout. This is the layout that would be imitated in creating a new section for bridges.

7.1 The Website Images and Layout

It was decided that a layout very similar to the waterwheel portion of Old Sturbridge Village's website would be used in updating the Vermont Bridge section. The basic layout was drawn on paper and then the source code from the waterwheel section was used to convey this layout from paper to computer. For purposes of conformity, the background and style of the waterwheel section were used in the new webpage.

The website was organized into two sections: covered and uncovered bridges, which were further divided into subsections. These subsections were each dedicated to more specific topics such as bridge type and style. The first bridge type explained was the simple beam bridge. This was used to introduce the reader to the most straightforward bridge style as well as tension and compression. The next section was a long beam bridge comprised of two short beam bridges and a platform connecting the two. This was chosen because it was a building block to larger bridges. Next were the Kingpost and Queenpost styles. These show how diagonal and vertical segments help support a bridge when a load is applied to it. The following section discussed and illustrated various truss systems, including the Town lattice. The final part of this block is the modern suspension bridge. Although this bridge type was not prevalent during the timeframe of Old Sturbridge Village, it is a significant advancement in the evolution of bridges and worth mentioning.

The next section entailed several subsections which described and illustrated multiple covered bridges. The first subsection explained in detail the Town lattice structure. The following subsection gives an explanation as to why bridge builders used the Town lattice instead of other methods and why they were covered. The final subsection of this block discusses Old Sturbridge Village's Vermont Bridge, including both photographs and historical facts.

7.2 The Interactive Bridge Model

To begin, a virtual model of the bridge was built in Visual Basic. It was done in Visual Basic because of familiarity with the language and accessibility via any Windows platform. Once a working model of the bridge was obtained, it would be transferred to another language such as Java or Flash so that it could be easily placed on a website.

To start off with, a simple beam bridge was created. It was comprised of a single line segment between two supporting cliffs. The next step was to implement gravity. This was accomplished by adding a mass variable to the line segment. When the program ran the bridge fell straight down. After adding the code so that the bridge would be blocked by the cliffs, the bridge stood where it was as expected.

Now that there was a bridge the next object to create was the car. For simplicity the car was represented by a circle. Luckily there was a built-in function to place the car at the mouse pointer. This was a problem because the car needed to be at the location on the bridge corresponding to the location of the mouse, not simply at the point of the mouse. So after a few more lines of code the car followed along the ground and bridge wherever the mouse went.

With the current model, the bridge was never in tension or compression. This was because it was not changing length at all. The two supporting cliffs pinned the bridge line segment in. A way to make the bridge be flexible needed to be found. A bending bridge was approximated as a series of small interconnecting bridges to solve this problem. The line segment was broken into ten sub-divisions and made so that the ends of each of the sub-divisions were connected to the ends of the next sub-division. This way the ends of the bridge could remain fixed and allow the middle to sink in when the car was driving over it.

When the program ran this time, the middle of the bridge sank down a little due to its own weight. This was realistic and showed that the material properties such as density of the bridge determine a maximum length. If the bridge was longer than it sank more. In real life, if a material were stretched too much then eventually it would snap. However this simulation was created to show how bridges work, not how they break. Because of this reasoning, code was not added to make the bridge break when it was stretched too far. Instead the mass of the bridge was lowered so that it would not sink very much but enough to show that it was lower than the cliffs.

Next was to drive the car over the bridge. As the car drove over the bridge, the bridge sank down as expected. However, once the car was removed the bridge did not spring back into place. That is exactly what was missing: spring. In addition to the force of gravity working on the bridge there were also the internal forces of the bridge of the bridge itself. More code was added so that each line segment acted as a spring. When the segment was stretched or shortened it would work on pulling itself back to its original length.

The simulation was run again to see how it would react. When the car drove over the bridge, the bridge would sink faster and faster instead of returning to its original form. After some debugging, the simulation was run again. This time the bridge returned to its original shape. However the bridge seemed a little blocky. To correct this, the number of line segments the bridge is comprised of was increased. The more line segments, the more realistic the simulation but also the slower the program ran. A real bridge would have a line segment for each atom in the bridge, so that would be unreasonable to simulate. It was decided through trial and error that a bridge comprised of several hundred line segments would suffice. This was enough so that it appeared continuous but did not overwhelm the computer running the simulation.

Once the action of the car moving over the bridge was satisfactory, it was time to move on to the next step. The whole point of the simulation was to demonstrate the concepts of tension and compression. Since the line segments appear continuous one cannot differentiate between one stretching out and another shortening. It was decided that a good graphical way to represent tension and compression would be to colorize the segments according to how much they were stretched. An un-stretched segment would remain black. The more that the segment was stretched the bluer it became. The more that it was shortened the redder it became.

After the simple beam simulation was acceptable work began on other kinds of bridges. More complicated bridges can be thought of as several simple bridges stuck together. The kingpost bridge was next to be constructed, so a function was called to create a beam across the cliffs, one in the center, and diagonal beams to connect the end points. After drawing the beam segments, the simulation was run and the middle and diagonal sections of the bridge sank to the bottom of the screen. This is because the beams were not connected to each other. Code was added that connected each new beam to any previous beam created where they overlap.

Downloading a separate program for each type of bridge would create a major inconvenience, so buttons were added to the side of the program to select which type of bridge would be simulated. The type of bridge would need to be selected, and the program would run. The car would be on the floor level of the bridge corresponding to the horizontal position of the mouse pointer. As the bridge sank due to the weight of the car on the bridge and the bridge itself, the car would sink with it.

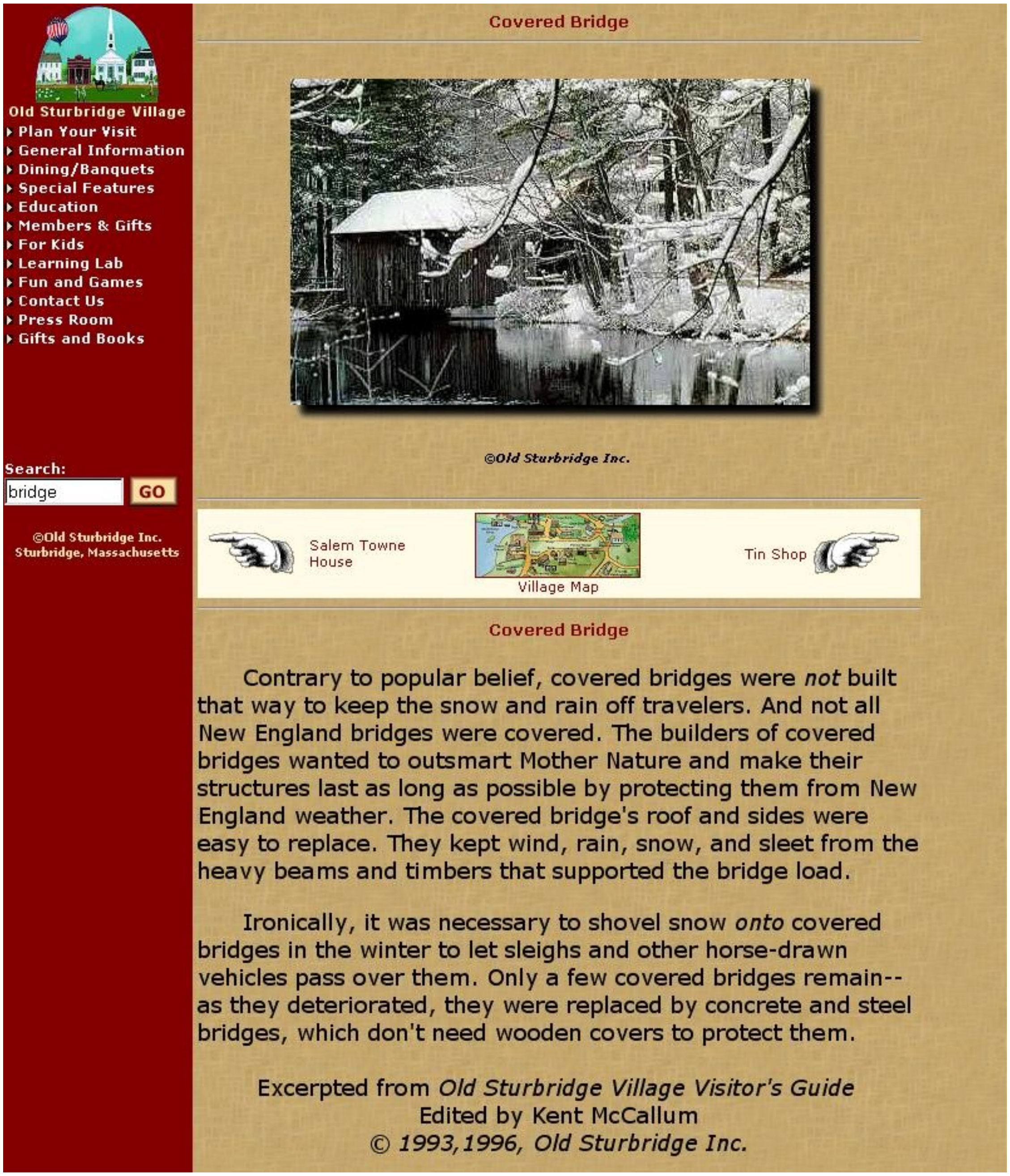
After adding the capability to choose the bridge type, the simulation was run again. The simple bridge type was chosen and it performed as expected. Next, the kingpost beam bridge simulation was run and proceeded to fail. This problem was partially corrected by changing the manner in which the beams were connected in the program. With this correction in place, the model would work as long as the load was continuously moving across the bridge. There were still problems if the car remained on one side of the bridge for a long time, but for normal conditions this solved the problem. For other types of bridges, such as the queen post and Town Lattice, all that needed to be done was to enter in where the beams were. All of the connections between the beams were automatically made due to the way that the simulation was programmed. The regions that are in tension and compression are shown in correlation to the load moving across the bridge.

The last block of the website is comprised of only one section: the interactive model. This is where the program that I've been discussing is located. It will allow users to learn the basics of how a bridge works. Since they're interacting instead of being lectured to, they are more likely to retain the information and want to learn more. They can easily experiment with how changing the location of the beams changes the performance of the bridge.

After all of this work, however, the interactive program does not perform as I had hoped. The user will have to install the program in order to use it. I wanted to have it be embedded into the website so that they would just use it from there. Although it is possible to do this, I do not possess the technical abilities to implement it. Another limitation is that I used one-dimensional line segments. This means that for even the simple beam bridge they are not seeing the whole picture. All that they see is the beam in tension stretching out from gravity. However it is actually only the bottom surface of the beam that is in tension while the top is in compression. If I had used a two-dimensional beam instead of a one-dimensional beam then the user would be able to see this and learn much more about strain in a material. Since I was not able to get the interactive website operational, I removed the link from the final copy of the new website.

7.3 A View of the Website

The following section is a compilation of images juxtaposing the current OSV website on covered bridges with the proposed redesigned site.



Covered Bridge

Old Sturbridge Village
- Plan Your Visit
- General Information
- Dining/Banquets
- Special Features
- Education
- Members & Gifts
- For Kids
- Learning Lab
- Fun and Games
- Contact Us
- Press Room
- Gifts and Books

Search: bridge GO

©Old Sturbridge Inc.
Sturbridge, Massachusetts

©Old Sturbridge Inc.

Salem Towne House

Village Map

Tin Shop

Covered Bridge

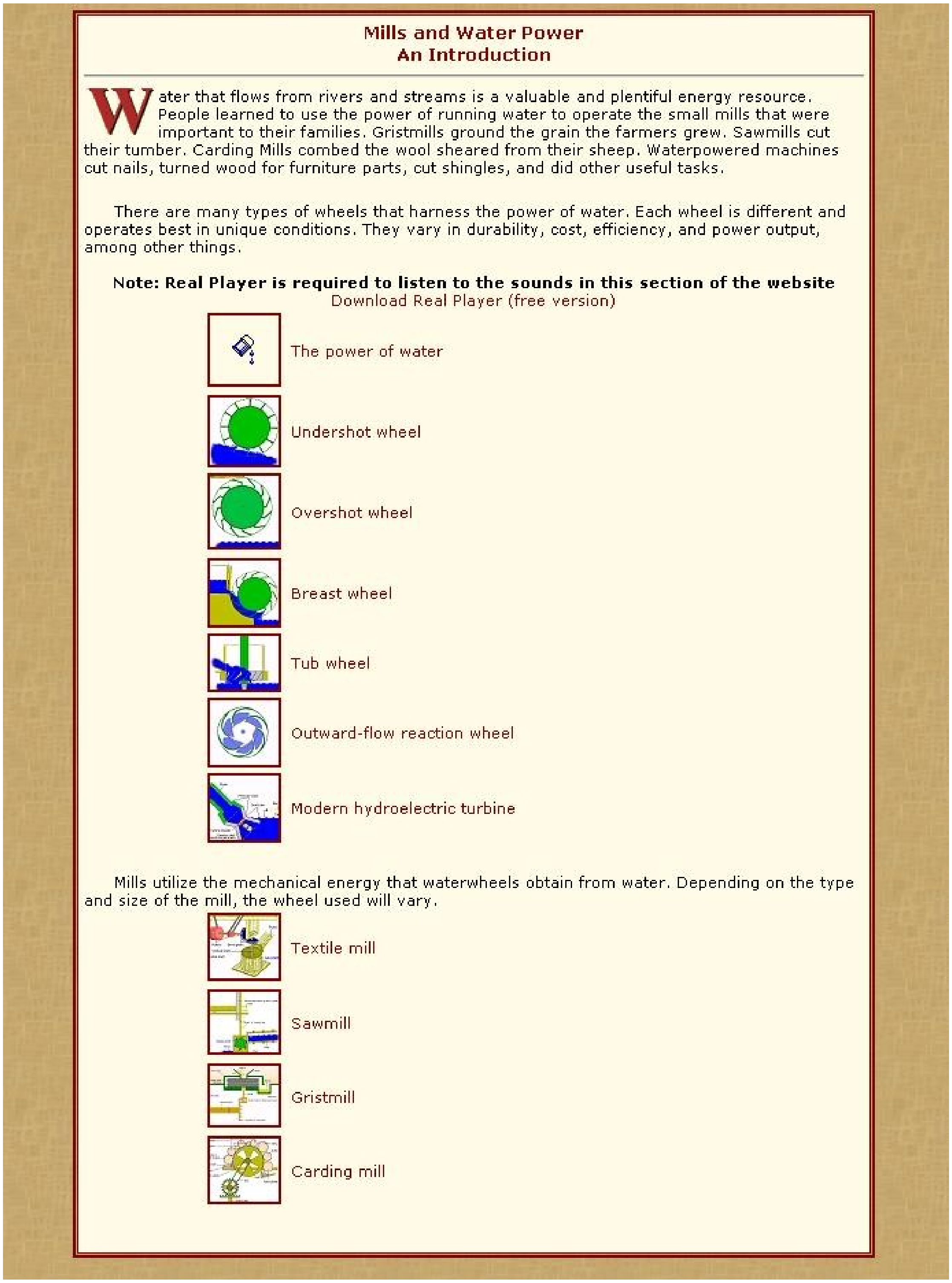
Contrary to popular belief, covered bridges were *not* built that way to keep the snow and rain off travelers. And not all New England bridges were covered. The builders of covered bridges wanted to outsmart Mother Nature and make their structures last as long as possible by protecting them from New England weather. The covered bridge's roof and sides were easy to replace. They kept wind, rain, snow, and sleet from the heavy beams and timbers that supported the bridge load.

Ironically, it was necessary to shovel snow *onto* covered bridges in the winter to let sleighs and other horse-drawn vehicles pass over them. Only a few covered bridges remain--as they deteriorated, they were replaced by concrete and steel bridges, which don't need wooden covers to protect them.

Excerpted from *Old Sturbridge Village Visitor's Guide*
Edited by Kent McCallum
© *1993,1996, Old Sturbridge Inc.*

http://www.osv.org/tour/bridge.htm

Figure 7.1 The current OSV webpage on the covered bridge.



http://www.osv.org/education/WaterPower/index.html

Figure 7.2 Waterwheel example on OSV website. The design and layout were emulated in the redesign.

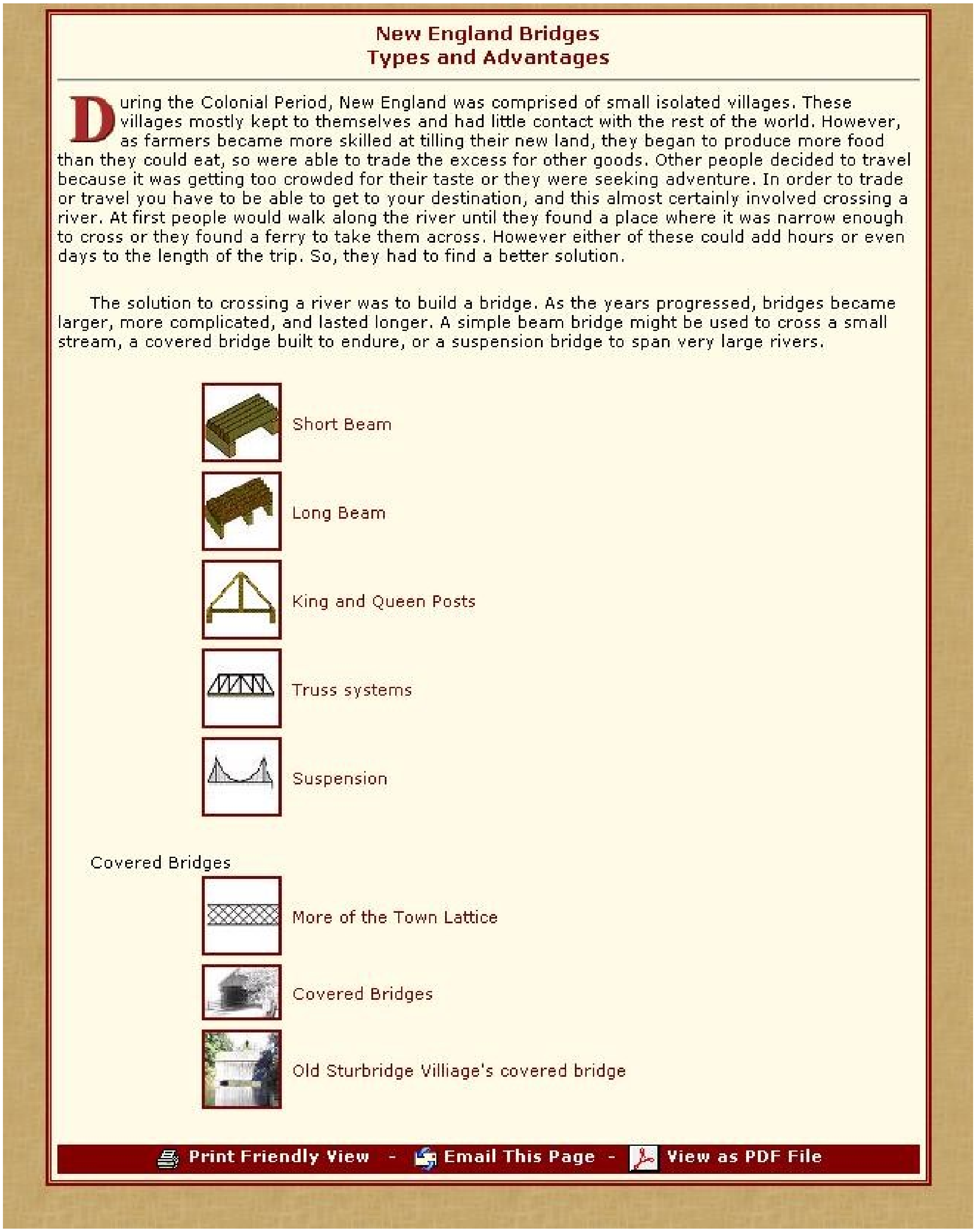
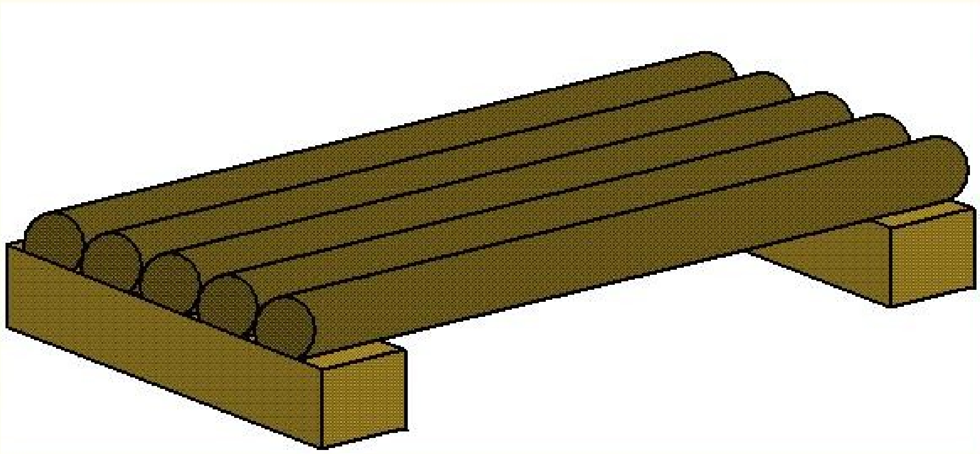


Figure 7.3 Redesigned main page

Short Beam Bridge

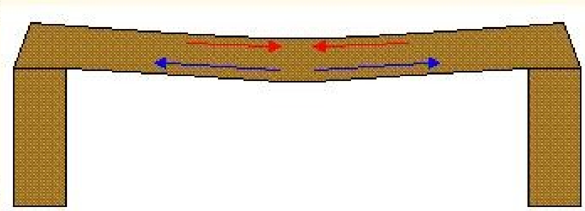
<<Prev New England Bridges Index Next>>



Early bridges of American history were log beam bridges. These were simply a tree laid down accross an obstacle such as a stream or valley. These bridges were not intended to last very long, support much weight or span long distances. They were instead intended for only a few trips across the obstacle, not caring what happened to the bridge in the future or the inefficiency of having to continually make new bridges. These bridges often rotted away or rolled into the stream unnoticed.

As time went on the bridges became more permanent. Instead of a single log they were comprised of multiple logs laying next to each other. These logs would then be tied together so that they could not roll apart. This helped prevent the bridge from falling into the stream, allowed more than one person to cross at a time, and heavier payloads such as a horse and cart. An example of a multiple log bridge is shown above.

If there is a large river to cross then it is difficult to build a simple bridge such as this. First of all the span is limited to the height of the trees in the area. Since the trees only grow so tall, you bridge can only be that long.



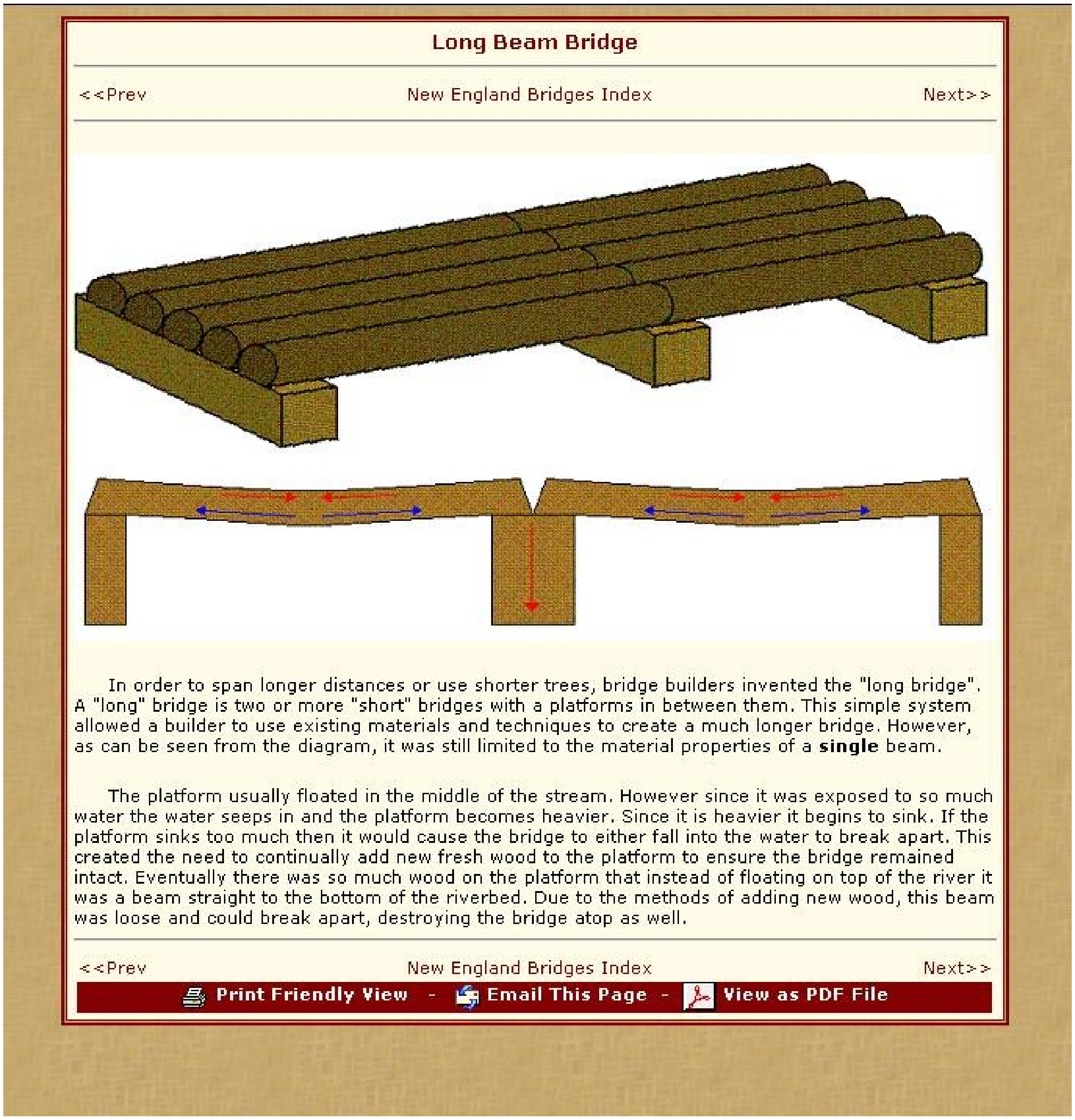
Secondly there are material properties of the tree to consider. As the length of the span increases, the bridge starts to sag in the middle. This sag causes the bottom surface of the log to stretch, also known as be in tension. Since the size of the log remains the same and the bottom of the log is stretched out, to compensate the top of the bridge has to shorten, known as being in compression.

In addition to the weight of the bridge itself there is the weight of the travelers. If this weight is too large then the bridge will fail in one of two ways. The first would be buckling. If an object is under too much compression then it will buckle. This means that the bridge would go from being almost flat to being almost a semi-circle. This would shorten the span of the bridge and it would most likely fall into the water below. The second and more common way for a bridge to fail however is the bridge being in too much tension. If an object is being stretched out too much then it will snap. The bridge will start to form small cracks. The bridge is weaker at the cracks because it isn't as thick there anymore. Since it is weaker then it cannot support as much and the cracks grow until the bridge breaks in half.

<<Prev New England Bridges Index Next>>

Print Friendly View - Email This Page - View as PDF File

Figure 7.4 New webpage outlining the simple beam bridge.



Long Beam Bridge

<<Prev New England Bridges Index Next>>

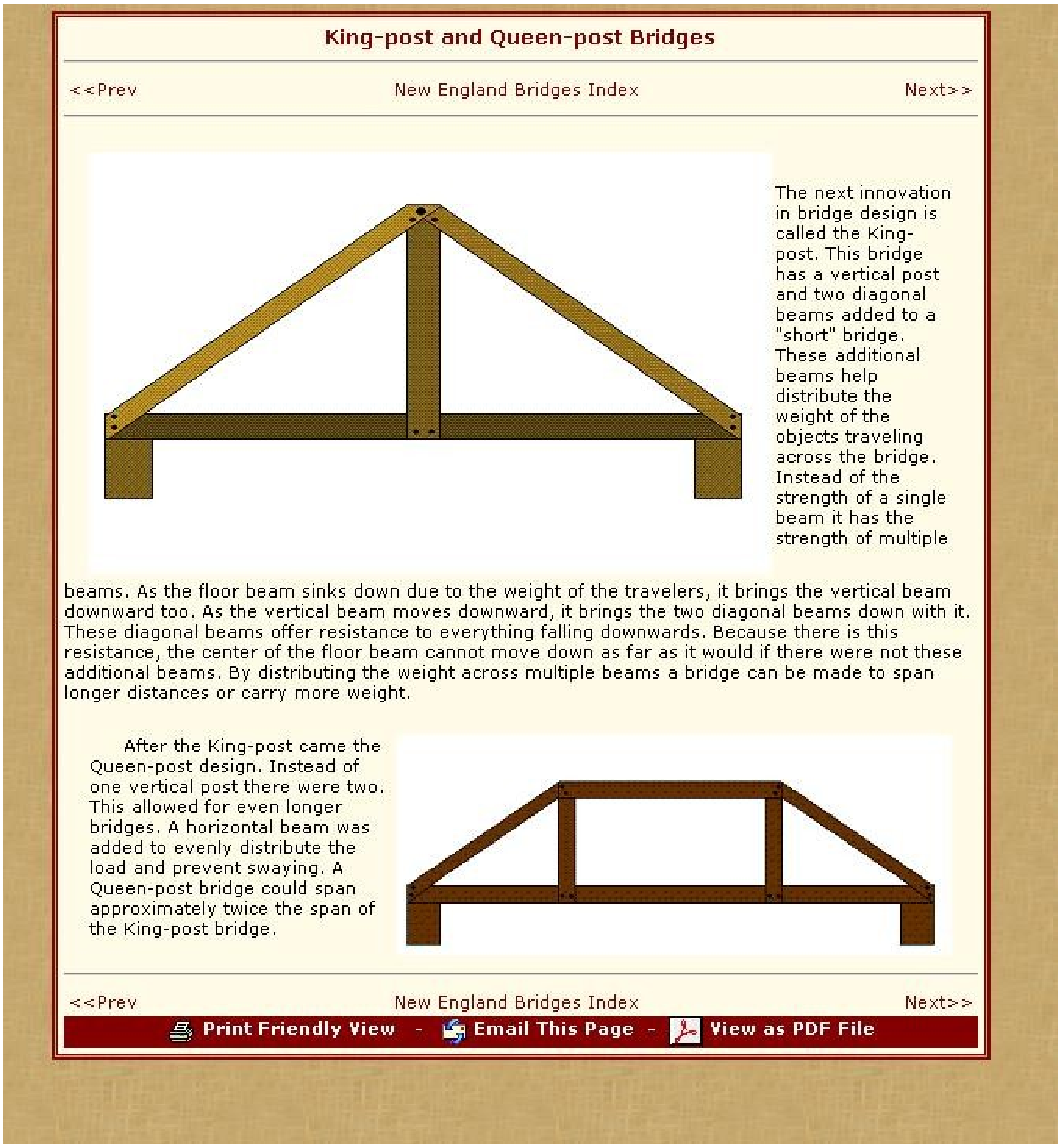
In order to span longer distances or use shorter trees, bridge builders invented the "long bridge". A "long" bridge is two or more "short" bridges with a platforms in between them. This simple system allowed a builder to use existing materials and techniques to create a much longer bridge. However, as can be seen from the diagram, it was still limited to the material properties of a **single** beam.

The platform usually floated in the middle of the stream. However since it was exposed to so much water the water seeps in and the platform becomes heavier. Since it is heavier it begins to sink. If the platform sinks too much then it would cause the bridge to either fall into the water to break apart. This created the need to continually add new fresh wood to the platform to ensure the bridge remained intact. Eventually there was so much wood on the platform that instead of floating on top of the river it was a beam straight to the bottom of the riverbed. Due to the methods of adding new wood, this beam was loose and could break apart, destroying the bridge atop as well.

<<Prev New England Bridges Index Next>>

Print Friendly View - Email This Page - View as PDF File

Figure 7.5 New webpage explaining the long bridge.



King-post and Queen-post Bridges

<<Prev New England Bridges Index Next>>

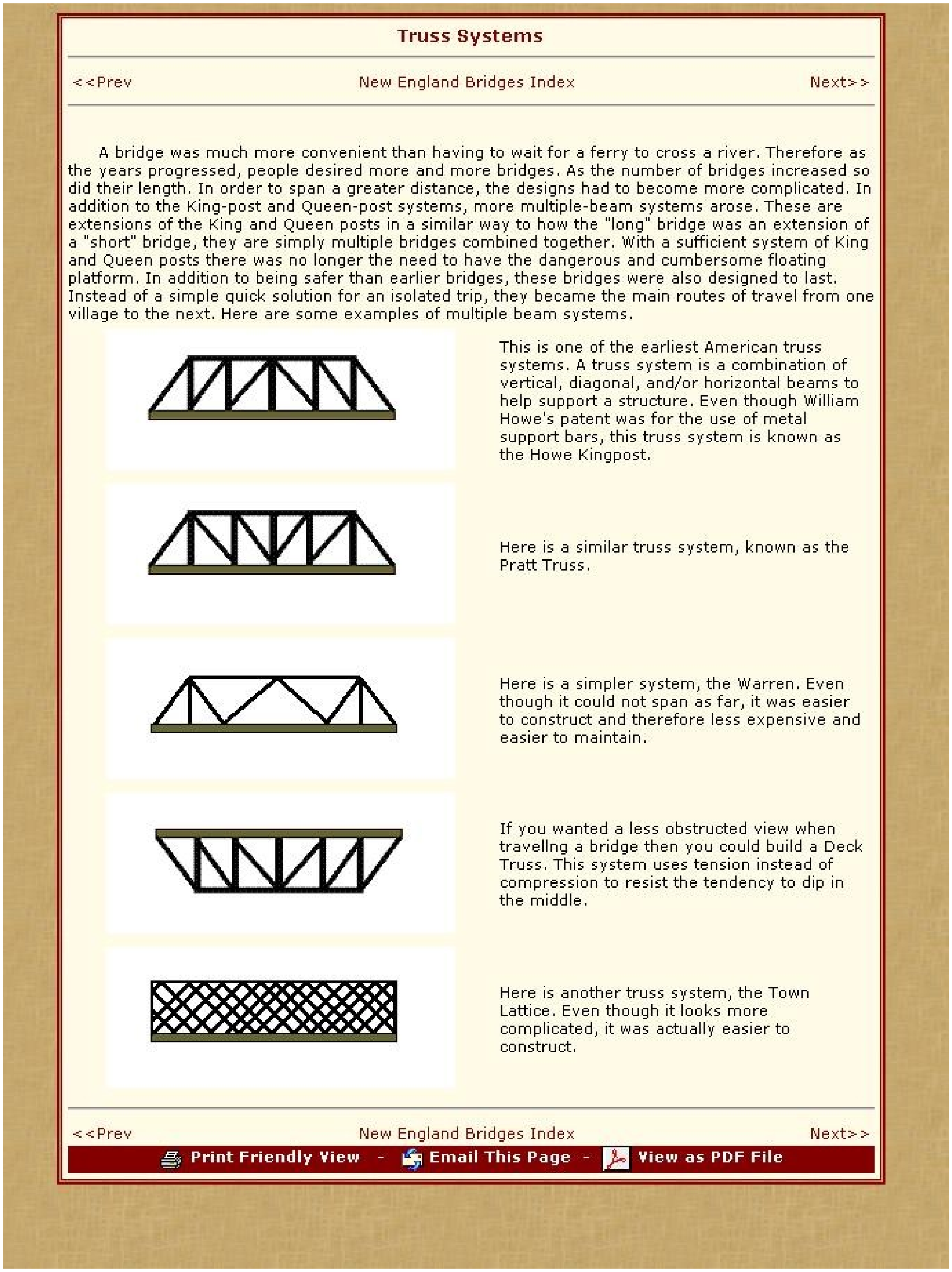
The next innovation in bridge design is called the King-post. This bridge has a vertical post and two diagonal beams added to a "short" bridge. These additional beams help distribute the weight of the objects traveling across the bridge. Instead of the strength of a single beam it has the strength of multiple beams. As the floor beam sinks down due to the weight of the travelers, it brings the vertical beam downward too. As the vertical beam moves downward, it brings the two diagonal beams down with it. These diagonal beams offer resistance to everything falling downwards. Because there is this resistance, the center of the floor beam cannot move down as far as it would if there were not these additional beams. By distributing the weight across multiple beams a bridge can be made to span longer distances or carry more weight.

After the King-post came the Queen-post design. Instead of one vertical post there were two. This allowed for even longer bridges. A horizontal beam was added to evenly distribute the load and prevent swaying. A Queen-post bridge could span approximately twice the span of the King-post bridge.

<<Prev New England Bridges Index Next>>

Print Friendly View - Email This Page - View as PDF File

Figure 7.6 New page describing the king- and queenposts.



Truss Systems

<<Prev New England Bridges Index Next>>

A bridge was much more convenient than having to wait for a ferry to cross a river. Therefore as the years progressed, people desired more and more bridges. As the number of bridges increased so did their length. In order to span a greater distance, the designs had to become more complicated. In addition to the King-post and Queen-post systems, more multiple-beam systems arose. These are extensions of the King and Queen posts in a similar way to how the "long" bridge was an extension of a "short" bridge, they are simply multiple bridges combined together. With a sufficient system of King and Queen posts there was no longer the need to have the dangerous and cumbersome floating platform. In addition to being safer than earlier bridges, these bridges were also designed to last. Instead of a simple quick solution for an isolated trip, they became the main routes of travel from one village to the next. Here are some examples of multiple beam systems.

This is one of the earliest American truss systems. A truss system is a combination of vertical, diagonal, and/or horizontal beams to help support a structure. Even though William Howe's patent was for the use of metal support bars, this truss system is known as the Howe Kingpost.

Here is a similar truss system, known as the Pratt Truss.

Here is a simpler system, the Warren. Even though it could not span as far, it was easier to construct and therefore less expensive and easier to maintain.

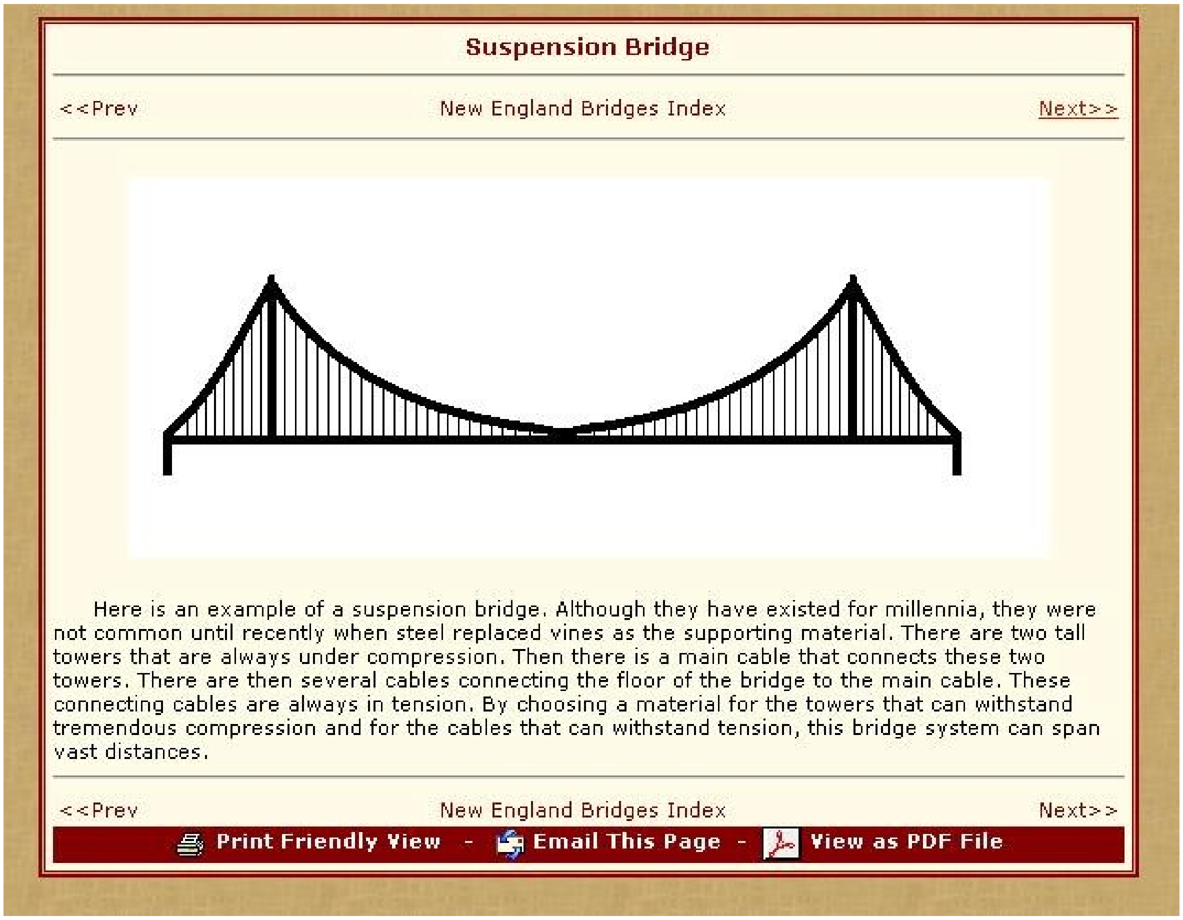
If you wanted a less obstructed view when travellng a bridge then you could build a Deck Truss. This system uses tension instead of compression to resist the tendency to dip in the middle.

Here is another truss system, the Town Lattice. Even though it looks more complicated, it was actually easier to construct.

<<Prev New England Bridges Index Next>>

Print Friendly View - Email This Page - View as PDF File

Figure 7.7 Various truss designs are explained for visitors to the OSV website.



Suspension Bridge

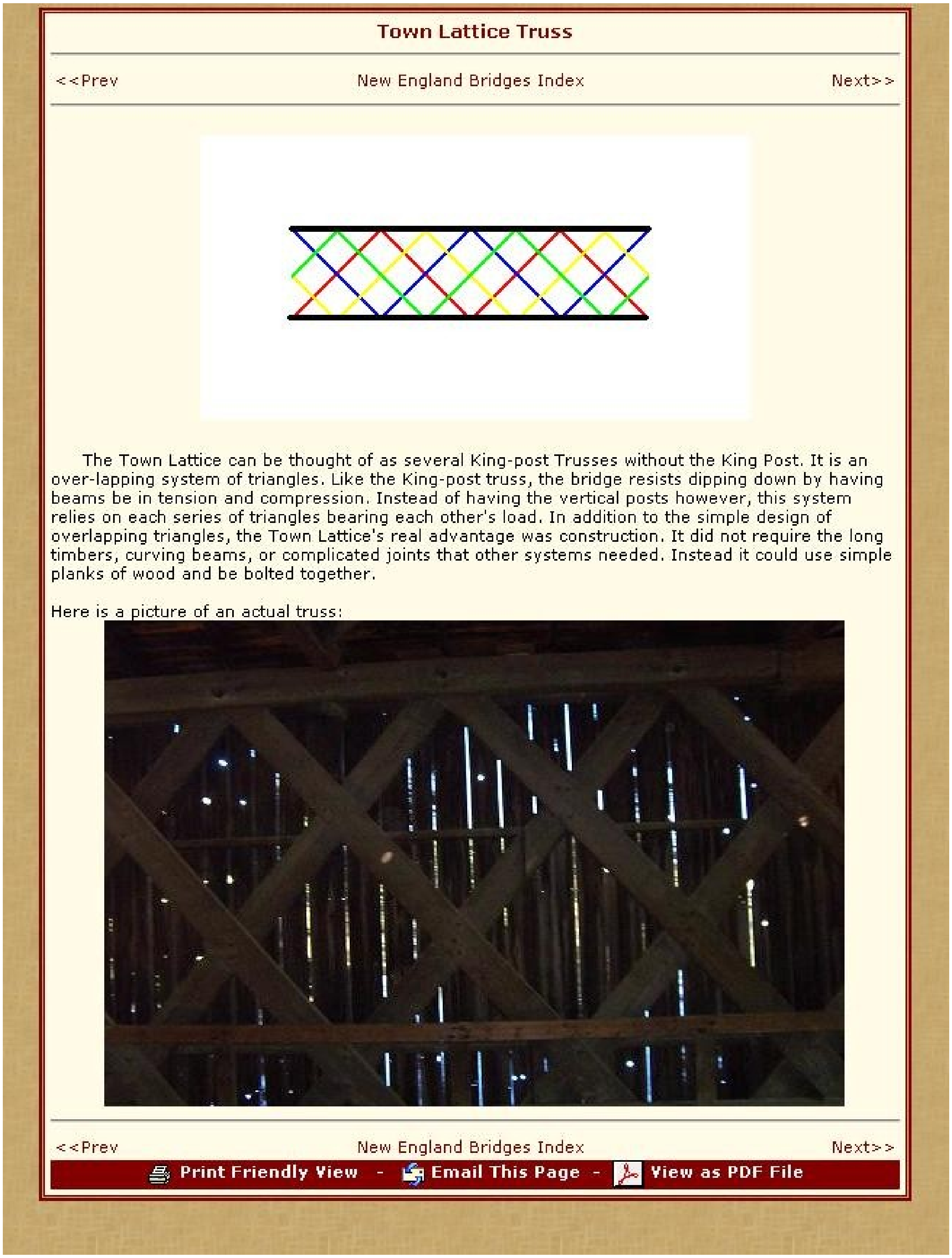
<<Prev New England Bridges Index Next>>

Here is an example of a suspension bridge. Although they have existed for millennia, they were not common until recently when steel replaced vines as the supporting material. There are two tall towers that are always under compression. Then there is a main cable that connects these two towers. There are then several cables connecting the floor of the bridge to the main cable. These connecting cables are always in tension. By choosing a material for the towers that can withstand tremendous compression and for the cables that can withstand tension, this bridge system can span vast distances.

<<Prev New England Bridges Index Next>>

Print Friendly View - Email This Page - View as PDF File

Figure 7.8 Explanation of the suspension bridge.



Town Lattice Truss

<<Prev New England Bridges Index Next>>

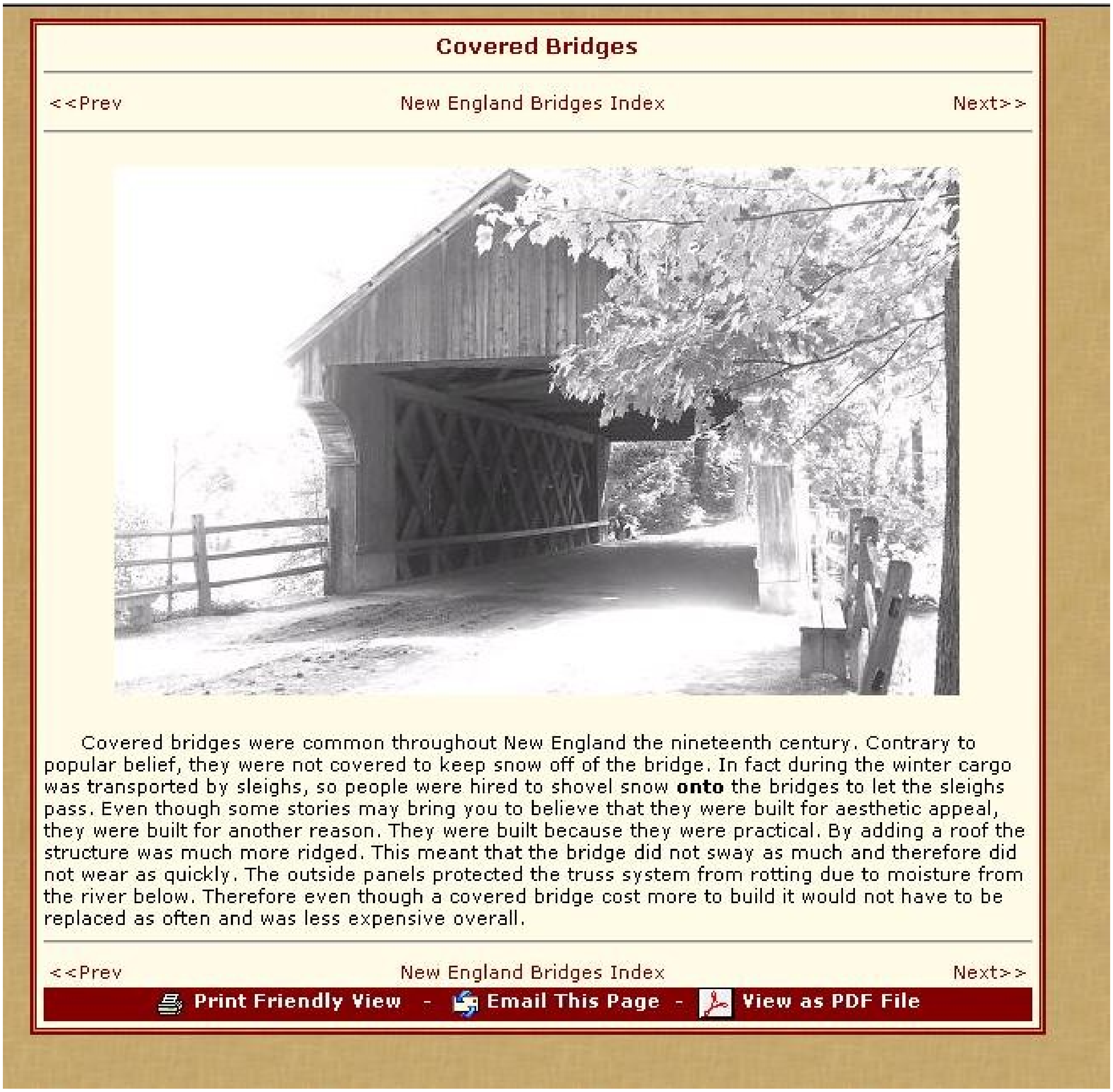
The Town Lattice can be thought of as several King-post Trusses without the King Post. It is an over-lapping system of triangles. Like the King-post truss, the bridge resists dipping down by having beams be in tension and compression. Instead of having the vertical posts however, this system relies on each series of triangles bearing each other's load. In addition to the simple design of overlapping triangles, the Town Lattice's real advantage was construction. It did not require the long timbers, curving beams, or complicated joints that other systems needed. Instead it could use simple planks of wood and be bolted together.

Here is a picture of an actual truss:

<<Prev New England Bridges Index Next>>

Print Friendly View - Email This Page - View as PDF File

Figure 7.9 The Town Lattice Truss



Covered Bridges

<<Prev New England Bridges Index Next>>

Covered bridges were common throughout New England the nineteenth century. Contrary to popular belief, they were not covered to keep snow off of the bridge. In fact during the winter cargo was transported by sleighs, so people were hired to shovel snow **onto** the bridges to let the sleighs pass. Even though some stories may bring you to believe that they were built for aesthetic appeal, they were built for another reason. They were built because they were practical. By adding a roof the structure was much more ridged. This meant that the bridge did not sway as much and therefore did not wear as quickly. The outside panels protected the truss system from rotting due to moisture from the river below. Therefore even though a covered bridge cost more to build it would not have to be replaced as often and was less expensive overall.

<<Prev New England Bridges Index Next>>

Print Friendly View - Email This Page - View as PDF File

Figure 7.10 Reasons why bridges were covered.

8.0 Model Suggestions

In the previous report, two ideas for models were explained. The first was a computerized model using a program called West Point Bridge Builder. This would enable Old Sturbridge Visitors to see where tension and compression occurred throughout the bridge. It was decided that this plan of action had two serious drawbacks. The purchase and upkeep of computers would be very costly for Old Sturbridge Village. Also, young children and adults who were not computer literate would not receive a full appreciation for this model. It was decided that this idea should not be exercised at this time.

The second concept discussed in the old report was to build small models of several bridge designs that could be subjected to loads to show how each design would react. This idea had several advantages. It would be an excellent physical representation of the way bridges support their loads, and also be easily understood by people of any age. In addition to this, its initial costs of production and maintenance would be much less than that of several computers. The problem that was discovered with this model is that it would be extremely difficult to build these models accurately while maintaining the durability necessary for everyday use. This idea was eliminated from the scope of possible models.

The model idea created in the new report would involve fifteen to twenty foot long working models of different bridge types. These models would be used at Old Sturbridge Village for people to walk across and test each bridge. This would allow for visitors to not only see how each bridge type reacts to certain loads, but to also feel how each bridge reacts. People would easily understand the importance of a truss system by using this model. There would be moderate initial costs with this model, but maintenance costs would be very low. This concept would have been used with completion of this report, but neither the manpower nor the funds could be procured in the allowable timeframe.

9.0 Conclusion

The purpose of this project was to explore the physical properties and social implications of covered truss bridges, produce a website for Old Sturbridge Village which better explained them to the public, as well as to revise previous work completed on this subject. Through research conducted at the libraries of Old Sturbridge Village and Worcester Polytechnic Institute, as well as through conducting personal surveys, the group was able to piece together its research to produce a snapshot of what these bridges meant to nineteenth century society.

The physics of these bridges were simple enough to be intuitively understood by their designers despite the lack of mathematical methods of analysis in the early nineteenth century, yet reliable enough to allow them to be built on a grand scale throughout the country. The impact these bridges had on the small towns of New England, such as the fictional Old Sturbridge Village, was enormous. The economies, societies, people, and even civil policy of the region were all affected to some degree. As even remote villages found themselves more easily connected to the wider world, merchants, producers, manufacturers and travelers all benefited from the easier travel afforded by these bridges.

Another objective of this project to was to redesign Old Sturbridge Village's website on covered bridges. The goal of the group in this was to produce an interactive demonstration for users so that they could see how the bridges worked. Ideally, when one visited the site, their cursor would act as a "load" when dragged across a model of a bridge. The bridge would then react accordingly, indicating which members were in either tension or compression. In practice, however, this type of web editing proved to be beyond us in technical ability. Although the interactive website could not be completed, a major reconstruction of the Old Sturbridge Village website on the Vermont Covered Bridge is proposed. A redesigned website has been created which lists the various types and histories of covered bridges and links them to their own individual sections along with accompanying image upgrades.

The final objective of this project was to revise the text and images of the previous IQP completed on this topic. As a precursor to revision, approximately a dozen individuals, who had no prior engineering background, were asked to read portions of the previous report and fill out a survey questionnaire about the types of things they found confusing. The most common response received was that the information contained in the previous report and the examples used to illustrate various concepts were not explained well and that the writing was choppy and jumped around too much. The group therefore decided to furnish all new examples and rewrite the sections explaining many of the concepts. The end result is that the group feels its examples do a better job at explaining key concepts and that the text is easier to read.

10.0 References

Allen, Richard Sanders, Covered Bridges of the Northeast (Brattleboro, VT: Stephen Greene Press, 1957).

Calhoun, Daniel Hovey, The Intelligence of a People (Princeton: Princeton University Press, 1973).

Condit, Carl W. American Building Art: The Nineteenth Century (New York: Oxford University Press, 1960).

Congdon, Herbert Wheaton. The Covered Bridge: An Old American Landmark (New York: Alfred A. Knopf, 1946).

Edwards, Llewellyn N. A Record of History and Evolution of Early American Bridges (Orono, ME: University Press, 1959).

Haupt, Herman, General Theory of Bridge Construction (New York: D. Appleton & Company, 1853).

Introduction to Akashi Kaikyo Bridge, Honshu-Shikoku Bridge Authority. Retrieved November 18, 2004, from http://www.hsba.go.jp/bridge/e-akasi.htm

Jakeman, Adelbert M. Old Covered Bridges (Brattleboro, VT: Stephen Greene Press, 1935).

Liscombe, R. W. (1991). A "new era in my life": Ithiel Town abroad. Journal of the *Society of Architectural Historians L*: 5-17.

Newton, Roger Hale. Town & Davis Architects. (New York: Columbia University Press, 1942).

NOVA article on suspension bridges. (no author). Retrieved November 18, 2004, from http://www.pbs.org/wgbh/nova/bridge/meetsusp.html

Pancoast, Hazel, & Chalmers. Covered Bridges to Yesterday. (Newark, OH: Chalmers Lowell Pancoast, 1959).

Parks, Roger N. Road and Travel in Early New England (Sturbridge, Mass.: Old Sturbridge Village, 1967).

Searles, Priscilla. (2004, February 2). Business and civic award winners for the ages. *The New Haven Enterprise Hall of Fame*. Retrieved November 7, 2004 from http://www.conntact.com/archive_index/archive_pages/4806_Business_New_Haven.html

Sloane, Eric, American Barns & Covered Bridges (New York: Wilfred Funk, Inc., 1954).

Stilgoe, John R. Common Landscape of America: 1580 to 1845 (New Haven, CT: Yale University Press, 1982).

Tyrrell, Henry Grattan. History of Bridge Engineering. (Chicago: G.B. Williams Co. Printers, 1911).