...I have seen that in any great undertaking it is not enough for a man to depend
simply upon himself.
~ Lone Man (Isna-la-wica) Teton Sioux

INTRODUCTION

Who is a structural engineer? What does a structural engineer do? What goes into constructing a building or bridge or for that matter any structure? These were some of the questions I had that needed to be answered before I could continue with the unit.

According to the information I acquired through the Tripod website, “A structural engineer is a person that possesses a Bachelor’s degree in Civil Engineering and a Master’s degree in Structural Engineering. A structural engineer has a number of responsibilities: The structural engineer assesses the dead loads, imposed loads, wind loads, earthquake loads, snow loads and other loads acting on the structure in accordance with the relevant Standard Specifications.” That was just the beginning of their detailed information. A structural engineer also selects the structural system to carry the loads, calculates the dimensions of beams, columns, slabs, walls, foundation, staircases, determines the grade of concrete and amount of reinforcement, prepares detailed drawings, supervises the construction, determines the proportion of cement, sand, course aggregate, water and admixture, and is responsible for the design of “buildings, bridges, stadiums, towers, tunnels, powerhouse, canals, highways, airports, harbors, etc. in association with various other engineers and specialists and does it within the relevant Standard Specifications of each job.” Whew!

The next step was to answer “What goes into building a building or bridge or for that matter any structure?” Again Tripod came to the rescue. Their answer: architectural planning (functional requirements, local bye laws, budget), finance, estimation of design loads (dead loads, imposed loads, wind loads, earthquake loads, snow/ice loads, temperature loads, secondary loads, and other loads), geotechnical investigations of the sites, analysis of building, design of building, preparation of detailed drawings, selection of good materials, construction techniques and good construction practices, quality control and quality assurance at site, and periodic maintenance. Structural Engineers also have to work with the owner, the consultants (architect, other structural engineers, electrical and mechanical engineers, interior decorator, and other specialists), the builder/contractor, and the city development authority/municipality.

Whew! This was beginning to sound more complicated that I thought. As I reread the qualifications and job descriptions I began to compare my job as a teacher with that of the structural engineer. Although structural engineering may be technically more detailed, teaching might just be the most difficult as structural engineers don’t have do all this in a room filled with children.
Historically bridges provide a means to get to the other side of an expanse that would otherwise be impossible or inconvenient to cross by other means. Very little thought is often given to the designer, builders, or actual constructions of a bridge. The convenience of having the bridge is usually taken for granted and expected in our modern society, and unless the bridge has a famous name, we often cross it without another thought. Other bridges are not literal but figurative bridges. Most of us have heard someone say, “Don’t burn your bridges,” or “We will cross that bridge when we come to it.” One “bridges the gap” in education from one subject to another or from one generation to another. Bridges have inspired artists like Van Gough and Monet, awed world travelers like Marco Polo. Marco Polo was so enamored by a bridge that had 485 carved lions that he made this notation in his diary, “Over this river there is a very fine stone bridge, so fine indeed, that is has very few equal in the world.” The bridge he was writing about is known as the Guangle Bridge or the Marco Polo Bridge, located 15 k southwest of Beijing, China on the Yongding River. Movies, such as The Bridges of Madison County and The Bridge over the River Kwai; songs, such as “Bridge over Troubled Water” and “Ode to Billie Joe;” and poems, such as “The Tay Bridge Disaster,” by William McGonagall, all tell stories about bridges. Bridges may be built with real or imaginative materials, but bridges are always used to get from one side to the other, regardless of what kind of bridge it may be.

The first bridge I encountered was a very old iron bridge that crossed the Illinois River a few miles south of my grandfather’s farm. The bridge was the quickest way to cross the river between granddad’s farm and his neighbor Fred’s farm. Fred would drive across the bridge to come up our side of the river to get my mother when they were dating. When the bridge was damaged after a dam burst up river, Fred had to park on his side of the river, walk across the bridge where my mom would meet him on our side of the river. This continued until the bridge was repaired, inspected, and considered safe for cars and trucks to use it again.

When they married, and we moved across the river to his farm, we had to drive over that bridge every time we went to town. When I began ninth grade, I started riding the bus to school in Tahlequah and had to go over it twice a day. I would hold my breath the entire way across, praying that the wooden deck would not give way. A few times we even had to walk across it. One particular spring there had been an exceptionally bad flood, and when the waters subsided, huge trees with their tangled roots were wedged against the supporting piers. Everyone had to get off the bus because the driver wasn’t sure the bridge would take the extra weight, or perhaps he just didn’t want us to get hurt if the bridge collapsed under the bus. Whatever the reason, it was terrifying to look down through the spaces between the old timbers to the river below. I walked on the larger boards spaced for cars to drive across. All I could think was how could those rickety old boards be strong enough to hold up a car, let alone a big school bus. Even knowing that the county made regular inspections and repairs did not calm my fears enough to let out a breath as I made the trips across in that big old yellow bus. The boards creaked and groaned and slapped back down as the tires pushed down one end and then the other. I don’t recall any boards actually breaking or falling off, but I was sure glad when we moved to town and we didn’t have to cross that bridge everyday.

On a recent trip to Oklahoma I drove out Oklahoma State Highway 10 to take pictures of the old bridge. It hadn’t changed very much. The deck had been replaced with new lumber, boards that went across the deck, but the timbers along the deck that once marked the one lane were gone. All the boards seemed secure as we drove across. Although it was apparent that the bridge had been repainted, we could still see the rust on parts of the structure. There was still the feeling that something might fall off into the river when a vehicle went across. It still groaned, grumbled, and rattled with the weight of each car and pickup. It is almost as though the bridge came alive and was fussing, having to carry the weight, or perhaps it was welcoming the traffic and just happy to be of service.
The crossings, this time, were not fearful or dreaded. This was a time for remembering a simpler time, the one room school, and all the happy times spent on the river. Memories of lazy summer days fishing, swimming, and having fun with my brothers in a borrowed boat came flooding back as we watched Oklahoma Park Rangers check out their boats and people paddling flat bottomed boats and canoes, floating effortless down the slow moving river. This old bridge still serves the Combs community well.

Another old iron bridge just outside Tahlequah has been cut off from the public. Once vibrant and always busy, a focal point for local picnics and access for swimming in the river, it is now abandoned, rusting away from neglect and being obscured by vines. Considered dangerous even to walk across, all access is denied. Even the one lane drive below the bridge and the paths to the river are closed, and the picnic areas are overgrown with small trees, bushes and weeds. Only the memories of those who frequented that area remain. There is a new bridge, just up river, but it is a flat concrete bridge and will never have the character of the old iron bridge.

UNIT BACKGROUND

Crossing the bridge at Combs community reminds me of all the trials one has to go through to educate a child. Teachers are architects, designers, builders, and the repair crew of bridges, too. We are constantly designing curriculum, building lessons, inspecting, changing the design to fit the area or need, re-teaching, repairing, and adding finishing touches as we teach each child we have in our classroom. Curriculums are designed with the knowledge that students can succeed if the plans are followed. Daily lessons are prepared as building blocks so they can learn and then
apply their newly gained knowledge to continue learning. The inspection process is
accomplished when we check their progress through the use of tests or assessments and we
change the design to fit the need when we re-teach. We add enthusiasm to our methods of
teaching to make learning more exciting. Diversity in presentation is a method that teachers use
to make learning more aesthetically appealing similar to the architects adding bar relief or
intricate designs to a building or bridge. Bridges are inspected and kept in good repair for the
same reasons that we constantly re-teach, monitor, and review the lessons. We want the children
that we teach to become life-long learners and to be excited about learning. Our bridges are real
and made of lasting materials, materials that can last a lifetime if constructed correctly.

It has been documented through test results that many children are lacking in problem solving
skills and listening skills. With the use of this curriculum unit I plan on building both through a
series of lessons that allow the students to draw on their own creativity and curiosity. The flow of
the lessons will depend on the student’s level of prior knowledge, and continue by researching the
history of bridges. Some of the questions that will be answered include the following: (1) Who
decides where bridges are to be built? (2) How are bridges constructed? (3) What problems are
encountered during the planning and building stages? (4) How do bridges eventually benefit or
change the surrounding areas?

Listening skills will be further enhanced through the sharing of information and actual hands-
on bridge and house construction. I have purchased eight bridge kits from K’NEX that will be
used to introduce basic construction of eight different types of bridges. The K’NEX kits consist of
precision pieces that simulate the materials used in actual bridge construction. The success of the
project will require the ability to follow both written and oral directions. Additional lessons will
include planning, designing, and building a footbridge across a wet area to connect an outdoor
classroom to the sidewalk in our outdoor science lab.

As we are also studying buildings, the architecture of building, and their structural analysis, I
will include lessons and activities that allow students to solve yet another problem in their
outdoor classroom. We have just completed and received our certification for our National
Wildlife Habitat, and I will be integrating the wildlife curriculum I wrote last year with this unit.
My students will use the design techniques of functionality, purpose, and aesthetic value to design
a series of birdhouses for the outdoor classroom. Once the designs have been submitted and
approved by the students, one or more of the designs will be chosen and sent to a professional
Martin House builder who will then construct their bird condo for Martins, and another
professional will use their single-family bird dwelling designs to make kits that the students can
assemble and add to their outdoor classroom. Once birds begin using the bird abodes, the
students can better observe the life cycle of our native bird population.

Students of all ages tend to learn best through hands-on activities. Throughout this unit
students will be encouraged to use their creativity to solve problems and their listening skills to
work with their peers to complete the projects. It has been documented that students of all ages
tend to learn best and retain what they have learned through hands-on activities. The majority of
the lessons will include a project that the students can design and build: a model or a full size
project, one they can take pride in and know that they have the skills to succeed.

SCHOOL DEMOGRAPHICS

I teach second grade at a Title 1 elementary school for the Houston Independent School
District. The children I teach are not much different from children in any second grade classroom.
Demographically it may be different, approximately 90% of our students are eligible for free or
reduced lunches and almost 85% come from homes where English is their second language, but
that is where the difference ends. I have yet to teach any child that does not like to construct
something, to have their ideas come to life, and to have their work displayed for others to admire.
Each child wants to be successful and to have their work validated by their peers, their teachers, and their parents.

**HISTORY OF BRIDGES**

The earliest bridges were natural bridges or natural accidents within nature. Naturally occurring arches were among the rock formations, trees fell across a creek or river constructed the first beam bridges, and exposed rocks used as stepping-stones were man’s first encounter with bridges. Where they did not occur naturally man soon learned to build his own bridge by cutting down trees and using them as beam bridges, placing stones where they did not occur naturally, and using vines, animal skins, and wood to construct a suspension bridge where a tree or rocks would not work. Before bridges were built, rafts were suspended between the river banks and pulled across by hand or horses.

Building bridges where they did not occur naturally made transporting goods and people across the rivers and streams easier, and progressed into building bridges that are engineering wonders of the world. Every man-made bridge has been copied from naturally occurring bridges, the suspension bridge, the beam, and the arch, or a combination of these basic types.

![Fig. 1, Suspension](image1) ![Fig. 2, Beam](image2) ![Fig. 3, Arch](image3)

The Romans built aqueducts to transport water long distances. They are a basic type of arch bridge and are considered to be architectural and engineering marvels. Remains of these aqueducts, dating as far back as 18 BC, can be found in various areas of the old Roman Empire. The Pont du Gard aqueduct, the most famous of these aqueducts, was 886 feet long and stood 155 feet tall. The top tier has a cement-lined water channel that carried the water and was part of a 31-mile long channel for transporting for water. Despite wars, weather, and man, this two tier semicircular arches still stand today and is a symbol of the brilliant architecture and craftsmanship of the era. One can find less impressive remnants of the Roman aqueducts in various regions of the old Roman Empire. One such aqueduct that we saw on our trip to Israel was very impressive, and although only a small section remains, it is a reminder of the expansive use of aqueducts in the Roman Empire. The original aqueduct transported fresh water from Mt. Carmel to the coast and was originally over ten miles long.

The oldest and perhaps the most monumental bridge, from both the engineering and aesthetic perspective, is the 132 foot-long Anji Bridge over the Xaio River in North China Plain. Designed and built by Li Chun in the late 6th century the Anji Bridge was the first segmental stone arch design bridge constructed and is over 800 years older than anything comparable in Europe. The meticulous craftsmanship of the Anji Bridge stands as a treasured work of art and although it is over 1400 years old it is still being used (Dupre 16-19). Not only is this bridge still being used, it is still very strong and is very beautiful as well. The saying “they just don’t make them like this anymore,” is an understatement when one looks at this bridge compared the ones that are being constructed today. I located a magnificent picture of this bridge when I was doing my research. Go to the web listing for en.structurae.de and check out Peter Neville Hadley’s photos. The intricate and ornate carvings on the bridge are very clear in these particular photographs. I received permission to use them but the transfer to black and white did not show the carvings as well as the color pictures.
If you want to see old bridges, then by all means visit Venice. This Italian city, known for its canals, has earned the nickname the “City of Bridges” as well. This nickname is undoubtedly due to the number of canals and the bridges needed to cross them, as there are more bridges per square mile in Venice than in any other city. The best-known bridge in Venice is the Rialto Bridge that crosses the Grand Canal. This stretch of the canal was first traversed by a pontoon bridge, then a wooden bridge. One bridge collapsed under the weight of a wedding party. After the wedding party was dunked, a simple arch bridge was designed by Antonio de Ponte and built of marble. The design conceals two rows of shops and a center roadway. The décor includes depiction of the Annunciation, the angel Gabriel, the Virgin receiving the news she is going to be the mother of Christ, and in the center a dove representing the Holy Spirit. Not everyone appreciated the architecture; even calling it a white elephant, but the way it looks has not swayed the people of Venice from their passionate appreciation of their Ponte du Rialto (Dupre 26-27).

Many early bridges were designed with shopping areas on either side of the roadway. These shops caught the travelers attention as they entered the city and again as they left. Modern malls appear to use the same concept, without the roadways of course.

Walk down a street humming or singing “London Bridge is Falling Down,” and you might catch others smiling or even humming along. From early childhood most children sing and dance to the old poem “London Bridge is Falling Down.” For me this poem always evoked a mental image of a frail bridge that collapsed, as it does at the end of the poem when children mimic the falling stones. The rhyme was actually written when the Vikings pulled the London Bridge down while it was full of Danish soldiers in 1014. London Bridge has been replaced numerous times since. Old London Bridge was built in 1209 and stood for over six hundred years. It replaced a series of timber spans that had either burned or collapsed.

The newer London Bridge, built in 1831, in actuality was sinking. The government in London decided that it needed to be replaced and put it up for sale. Robert P. McCullock purchased London Bridge in 1968 for $2.4 million and moved it to Lake Havasu City, Arizona. The reconstruction took seven years and a crew of 800 men. The original was built in one and a half years with a crew of 140 men and was built over a river. The reconstruction took place over dry land; they added the water after it was completed. London Bridge is now a bridge without a river, in a desert oasis, awaiting tourists. Had the bridge not been immortalized in the children’s poem, one wonders if it would have been just another bridge replaced in the name of progress?

London Bridge has been confused with The Tower Bridge that was completed in 1894. It has been said that Mr. McCullock thought he was buying the Tower Bridge when he purchased London Bridge. This confusion may be due to the fact that both bridges crossed the Thames, but The Tower Bridge is still in England and looks like a medieval castle. The castle towers hide the iron framework and the mechanism that raises and lowers the two bascules allowing ship traffic passage to and from the sea. The Tower Bridge was built to divert some traffic from the London Bridge and the bascules had to be included to accommodate port traffic. The bascules are still in use today allowing ocean vessels access to the port on the Thames as it has for centuries.

One bridge that appears to have been built for beauty was the Iron Bridge at Coalbrookdale in England. It was not the first iron bridge but the first large-scale cast-iron bridge (Dupre 34-35). The cast iron was designed to resemble timber bridges and it includes dovetails, mortises, wedges, and screws but no bolts. This sounds more like building a piece of furniture than building a bridge. It is difficult to imagine a bridge with dovetails and mortises but the open framework is an ironworkers dream. With all this open framework it appears to be a lightweight bridge, but it actually contains over four hundred tons of cast iron. This magnificent arch bridge contains 800 pieces of cast iron and has a span of 100 feet. All the iron was floated down the
river from the foundry in Coalbrookdale. Construction, completed in 1795, only took three months to complete. It is not only a magnificent marvel of construction and daring, this bridge was the only bridge to survive the Severn River flood of 1795. As with so many bridges this age it was closed to vehicular traffic in 1934 and is now the centerpiece of a museum that celebrates Coalbrookdale’s contribution to the iron industry. It played a big part in the innovative thinking that preceded the industrial revolution and rapid progression of engineering technology in the 19th century (Dupre 34-35).

Halfway around the world from England stands a marvelous arch bridge with a suspension deck. If you have ever watched any celebrations on New Year’s Eve, you have possibly seen the Sydney Harbor Bridge with all the fireworks and celebrations that are touted the first of the year-end celebrations. For years I promised myself that one day I would be at the celebration, but that would mean flying back to Los Angeles that same night in order to get back to work, so my husband and I did the next best thing. We went during our summer vacation. We went to Australia to see this bridge up close and personal. Watching television and viewing photographs of this bridge does not do it justice. Sydney Harbor Bridge is overwhelmingly huge and is a magnificent work of art as well as an architectural landmark. Stretching for 1650 feet over the deepest part of Sydney Harbor, the bridge connects East and West Sydney. Crossing the bridge on the deck 300 feet above the harbor in one of the eight traffic lanes and room for four rail and tram tracks and a pedestrian walkway was exciting, but getting a close-up view of the construction was mind-boggling. It was difficult to fathom the immenseness of the beams and girders that loomed overhead and cast shadows on the water below. The entire bridge emits an awesome sense of power and strength. From the deck of the bridge the structural design of the arches tower over your head and you realize you are in the midst of beauty made of steel.

After crossing the bridge we then took a boat tour of Sydney Harbor. As we came around a bend the bridge was the focal point of our cameras. It was even more beautiful from the water. The suspended deck appeared to float overhead as the boat glided under it. As our tour boat emerged from under the bridge, from beneath the massive suspended deck, all I could say was WOW! Over and over all that came to mind was WOW! As the boat moved slowly away from the bridge something caught my eye. High atop the arch there were people waving. People were actually on top of the bridge. A catwalk had been built into the bridge for repairs and was open for tourists. I had a difficult time believing that people actually paid to walk to the top of the bridge. It is an adventure for some, but it was not for me. The view from beneath the bridge and as we crossed the massive deck was sufficient for me.

Anytime you begin a discussion about suspension bridges the Brooklyn Bridge, the George Washington Bridge, the Bay Bridge, and the Golden Gate Bridge are usually in the conversation. The story behind each bridge is interesting. The Brooklyn Bridge, built in 1883 across the East River was the longest suspension bridge until 1903. With a span of 1,595 feet it was constructed of steel and granite and took 14 years to build. John Roebling, the principal engineer, died in July 1869, but he left minute detailed documents, from its two enormous granite towers to the four suspended steel cables, that had been approved in June 1869 just weeks prior to his death. His son, Washington, completed the bridge as it had been designed. Washington Roebling contracted cassion’s disease while working on the bridge. His wife acted as his assistant and carried important messages to the work site until it was completed. She was the first person to cross the completed bridge and according to news clippings she carried a rooster with her.

One summer, on the way from East Port, Maine, we traveled through New York City I did manage to get a glimpse of the Brooklyn Bridge and actually drove over the George Washington Bridge. We were on the lower level and I didn’t really get to see much of the bridge. I was not used to driving in a large city and was concentrating more on where I was heading than the history of the bridge. Since I have done some research, I wish I had been able to take more time
admiring than driving. The George Washington Bridge, with a span of 3,500 feet, was the longest suspended span bridge until 1937. Le Corbusier, author of *When Cathedrals Were White* stated, “The George Washington Bridge over the Hudson is the most beautiful bridge in the world. It is blessed. It is the only seat of grace in the disordered city. Here, finally, steel architecture seems to laugh” (Dupre 72-73). Othmar Hermann Ammann, a Swiss-born designer who had immigrated to New York in 1904, was the genius that designed it. His design was to have six lanes of traffic when it was finished, and he planned for future growth. In 1946 the bridge was increased to eight lanes by using an area left for that purpose. In 1962 a lower level was added, making fourteen lanes available. Ammann, a man of vision, had calculated the expansions into the original design. Amman eventually designed six of New York’s major bridges, the George Washington, Bayonne, Triborough, Bronx-Whitesone, Throg’s Neck, and Verrazano Narrows. Othmar Herman Ammann concluded his career with the Varazano Narrows Bridge. The need for this bridge dated back to the early 20th century. Construction of a tunnel had been one option, but it turned out to be too costly, and all that remains of the endeavor is an abandoned entrance. A suspension bridge design was submitted in 1926 by David Steinman, but once again financing kept it from becoming a reality. More than thirty years later once again the need for a new bridge was recognized. It was eventually built by Ammann & Whitney. It was Ammann’s last and perhaps the most magnificent in his career as a bridge builder.

When David Steinman was designing his suspension bridge in New York out on the West coast, over 46 million passengers were being ferried annually between San Francisco and Oakland. By 1928 the private automobile had defined the lifestyle of California. In 1930 Charles H. Purcell was hired to construct the $44 million San Francisco/Oakland Bay Bridge. Six years later the 8.4-mile long Bay Bridge, made of steel with the combination of suspension, cantilever, and truss, a tunnel, and a long viaduct was completed. Almost immediately it exceeded traffic levels that were predicted for 1950 (Dupre 78-79).

In October 1989, when I was teaching in Hempstead, an earthquake measuring 7.1 on the Richter scale shook the bridge for twenty seconds. The news that night showed the crowd running from the ballpark, the section of the Bay Bridge that had collapsed, and other damages in the area. During this 20 second earthquake, a section of the bridge collapsed impacting about 270,000 daily commuters and over $1 billion dollars was spent repairing and refitting the Bay Bridge. A new section is under construction, and according to an article in the *Houston Chronicle* in April 2005, it has not been completed yet. The new section under construction is being built stronger and the engineers are hoping it can survive any future earthquakes.

Not far from the Bay Bridge is another famous California bridge. I don’t know of anyone that can listen to “I Left My Heart in San Francisco” without having a picture of the Golden Gate Bridge enter into their thoughts. The Golden Gate is the symbol of San Francisco and possibly the most photographed suspension bridge in North America. Spanning 4,200 feet this majestic steel and concrete suspension bridge is indeed a work of epic proportions. It held the record for the longest span from its completion in 1937 until 1964 when the Varrazano Narrows Bridge was completed with a span of 4,259 feet. Even then the popularity of the Golden Gate was not diminished. Just the feat of overcoming the elements; salt spray, the strong tides, the depth of the water, strong wind currents, earthquakes, and everything else that nature can dish out makes the Golden Gate a bridge that is larger than life. The designer and chief engineer, Joseph B. Strauss invited architect, Irving F. Morrow to help with the design. After taking into consideration all the effect that the ocean, the wind, and earthquakes they made provisions for continuous maintenance. As part of the construction, air-compressors were installed at intervals across the bridge. A permanent team of 38 painters and 17 welders carry out continuous maintenance work on the bridge (Perino 83-84).
A lesser-known suspension bridge is the Lion Gate Bridge that stretches from Vancouver, British Columbia, Canada across the bay to the North. This bridge was built shortly before the Golden Gate and is a smaller version of the Golden Gate. When we were in Vancouver we were told they were designed by the same person and that the Lion Gate Bridge was built before the Golden Gate. No, it is not as impressive as nor as famous as the Golden Gate Bridge, but it does serve Vancouver as a means to cross the ship channel instead of having to rely on the ferry. When the cruise ship approached the bridge, it was spectacular; however, the view from the park overlooking the bridge brought the superior workmanship into perspective. The deck seemed to be held in mid air by tiny cables as a spider might suspend its catch of the day. These tiny looking cables were not all that small; they just look delicate from the distance. As with any suspension bridge the cables are rather large and complex. Just building a bridge over a deep bay is difficult enough but a suspension bridge looks like it would pose even more problems. Engineers solve problems such as this every time they choose where to build a bridge.

Before we complete our history of bridges, one must include a most unusual bridge, the Firth of Forth Bridge near Edinburgh, Scotland. The Forth was the first long-span railroad bridge made only of steel. Upon its completion in 1890, it broke all the records. Its span was the longest of any bridge, and it was the tallest. It also used a new design inspired by the simple cantilever (Johmann 47-48). When first built, it was the largest and tallest steel structure in the world. The double-cantilever design looks like giant dinosaurs that are following an invisible path across the inlet. Each section of the double-cantilever bridge sits on four large pads that making the illusion even more believable. Most pictures that I have reflect the enormity of the bridge as the ships passing underneath look more like toys that full size ocean going vessels. These pictures, found on the web site, Wikipedia, the free encyclopedia, give an idea just how large it is. There are houses below the bridge on the island and a full size train on the bridge.

When discussing bridges, one must always include those that are not used for cars or other motor vehicles. Footbridges in our gardens and parks are among some of the most beautiful and architecturally marvelous structures. Artists have immortalized them in their paintings, songs have been written about them, and they are the backdrops for photographs. Perhaps the best known park bridge is the wrought iron arched Bow Bridge in Central Park. It was built to evoke the romantic traditions of formal gardens in England and France. The Bow Bridge, as well as a majority of urban setting bridges, was concealed in such a way that it would not be seen until one turns a corner or goes around a curve in the pathways. Glimpses of this bridge and other similar to it can be seen from parts of the path but they were never intended to be the focal point of the parks.

This is just a taste of the history of all the wonderful bridges throughout the world. Marvelous modern designs are being designed, tested, and built around the world. Some look as though they were designed by an architect from a far away planet, built to entice imagination of other worlds. From the beginning of man’s desire to cross a river, each bridge began as the figment of imagination, an inspiration from an architect, a dream of an engineer, and the reality of all those who toiled endless days, months, and years to make it come alive. Thanks to the imagination of the bridge designers and architects bridges are beautiful as well as functional.
I have discovered that you don’t have to travel around the world looking for bridges. On my way to work I cross over ten bridges and under two. There is nothing that makes them special or unique. They are necessary to keep the flow of traffic moving. However there are other bridges in the area that are historic, and perhaps somewhat unusual, right here in our beautiful city.

Travel a few miles to the east on highway 225, through Pasadena, take the La Porte exit, and you will discover our area’s most famous bridge.

As you travel closer it seems to grow before your eyes. Golden braids, huge elongated diamonds looming overhead, a graceful arch below and you can’t stop to admire it or take pictures. Most days you can’t even slow down as the traffic pushes you across. Perhaps one of the best ways to see the bridge would be to be a passenger in a convertible or drifting slowly along the ship channel below. That way you wouldn’t have to watch out for traffic and you would be able to see the entire bridge, as it seems to engulf the entire sky.

The majority of the books I purchased about bridges as well as bridge-related websites contain information about the Fred Hartman Bridge. The Fred Hartman Bridge was built over the Houston Ship Channel between La Porte and Baytown in 1992 for approximately 117 million dollars. The uniqueness of the Hartman Bridge is not that it is a cable-stay bridge, or that it is 1,250 feet long and 440 feet high. The uniqueness is the two sets of steel-reinforced diamonds that carry two separate bridge decks to a height of 178 feet, the largest of its kind in the world, and its ability to carry 200,000 vehicles per day. Put into perspective, the double diamond towers
supporting the bridge stand as tall as a 45-story building, and the total square feet of the deck is in excess of eight acres.

When I drove over the bridge my impression was that it is a giant harp waiting for some large hand to pluck the stings that are actually part of the 618 miles of cable strands used in the construction of the bridge. Actually there are 192 separate cables, the longest is 650 feet, and more than three million cubic feet of concrete (roughly that is enough concrete to pave almost 14 miles of two-lane highway). The stats make it a very impressive bridge, the artistic value makes it beautiful, and the best part is it is just a short drive from Houston.

If you have traveled on Highway 59 through Houston you might have noticed the arch bridges that cross overhead. That is if you can take your eyes off the road long enough. The construction has this section so congested it is difficult to do anything but watch the traffic. When construction is completed, there will be six identical arch bridges stretching across this section of 59.

Each bridge has four big red balls, two at each end. Not only are the big red balls attractive but they also give the bridges a uniqueness and distinct flair. The significance of this adornment is a mystery and some think they are ugly. When I first saw the giant red balls I questioned the reason for them, but the more I see them, the more I feel they give the bridges an anchor that sets them apart from all other arch bridges anywhere.

As I took these pictures I began to appreciate the architectural aspect. They give the bridges a rather distinguished look and are whimsical at the same time.
The arches deserve a closer look as well. Driving down 59 they loom overhead but with the traffic so thick it is difficult to get a really good look at the structural essence. The best way is to exit 59 and drive through the residential area, find a parking place and walk over the bridge. They are fantastic. The arches are laterally braced by giant Xs with a circle in the center. The circle is repeated in the hanger connections.

Throughout Houston there are bridges that are usually not even thought of as bridges. When we go over a street we are traveling on a bridge, the overpasses are bridges. Some of the newer HOV lanes loom overhead as we travel around Houston. One in particular that I see every Sunday is the HOV lane over I-10 at Taylor Street Exit. The support beams are giant Y’s. Coming up to the exit you can see the V shape and as you exit the entire Y is visible. This bridge is unique and aesthetically pleasing.

Everywhere you go in and around Houston you cross bridges, everywhere, but seldom do we stop and see how they are constructed or do we notice what type of bridge we are driving over.
Sometimes it seems that they appear overnight as if being built by magic. The construction of a bridge is mysterious, but nothing magic goes on. Each step is inspected, the concrete must undergo a slump test before it is poured, and then each batch is tested for strength. The steel used has another set of tests to pass before it can be used. Each step of construction must be inspected to make sure it is being built to the correct specifications. Once the construction is completed, these bridges seldom get any recognition. They are taken for granted and only get noticed if they are out of commission or have to be replaced and once again creating a problem for commuters.

Driving around Houston looking for bridges that were different or unusual, I found more than I imagined. Just off I-10, hiding somewhat just behind some trees along the White Oak Bayou, is an old railroad bridge, and just down stream along the jogging path is a small arched footbridge that is barely visible from the street. Other old railroad bridges are located to the north of the Hogan Street overpass. Everywhere you go in and around Houston you see bridges under you, overhead, or off in the distance; they are everywhere. Other cities are known for their magnificent bridges; I wonder if Houston could be the city with the most bridges. Next step, call TX Dot and see if they have any stats on this.

CONCLUSION

At the beginning of this unit I was very much a layman when it came to construction of bridges. In the past I had enjoyed the aesthetics of bridges, the convenience of having a bridge to cross, and at times had even looked forward to crossing a bridge. I had never taken into consideration all the work that went into the actual construction: the work of the architect, the engineers, all the testing, inspections, and preliminary work that has to take place before a bridge can be built. Now architects and designer and engineers and the people who construct the bridges have my utmost respect.

Before I was just a bridge crosser, now I check out the design of the bridge to see if the engineer has included beams, arches, suspension cables, or a combination of these. I will not criticize how long it takes to build a bridge; I will simply enjoy the progress as often as possible. Where I just walked across a footbridge, I will now stop to see the beauty of the bridge, functionality will no longer be the focal point. In the future when I travel I will, without a doubt, take more pictures of bridges and strive to learn more about the history of the bridge. Bridges are built to cross, but they can be enjoyed for their beauty as well.

And when I see a bridge being constructed, I will forever remember the “Slump Test” and check to see if they happen to be conducting the test as I pass. I will feel safer knowing that there are people that are conducting stress tests, slump tests, checking for air pockets, and doing their best to make the bridges strong and safe for everyone.

LESSON PLANS

Lessons are geared toward listening and problem solving skills. All students will be expected to write a journal entry for each lesson. Vocabulary for each lesson will be included in the journal entry. I will use these journals as part of the classroom grades and the students will have a written record of their work.

A photo journal can be included in with the written record to assist retention of the materials in the lessons. Having a picture of the project stimulates discussion of the process used to complete the project.
Lesson A: Introduction to Bridges

A-1 Objective
This lesson will provide an introduction to basic designs, vocabulary, and history of bridges.

Procedure
I will use pictures of ancient bridges to identify the basic bridge types as well as using web sites and books from our classroom library to research modern bridges that have used the basic designs.

Materials
I plan on using Bridges! Amazing Structures to Design, Build & Test by Carol A Johmann and Elizabeth J. Rieth as a text for my classroom. It has a wealth of resources for teachers and students.

Vocabulary
Introduce the vocabulary in context as the lessons progress. Some of the vocabulary will be apparent when the students begin reading about bridges. Some terms will have to be explained in demonstrations and with actual work on a bridge.

Basic vocabulary: Beam, arch, suspension, cantilever, compression, tension, load, stress, stress test, slump test, concrete, cable, deck, beam, span, approach, piers, abutment, foundation, tower, anchor, hanger, concrete, cement, pontoon bridge, stone arch bridge, covered bridge, trestle, drawbridge, H-beams, trusses, cofferdam, caisson, formwork, leaf, strut.

Vocabulary list for the planning phase: Architect, contractor, structural engineer, surveyors, mapping expert, bridge designer, planning expert, soils engineer, aerial photographer, traffic and safety expert, landscape architect, environmentalist.

Vocabulary list for the building phase: bridge designer, project superintendent, foremen, inspectors (there are specialist in this area), contractor, builders (includes masons, steelworkers, carpenters, truck drivers, equipment operators, electricians).

A-2 Objective
This lesson will be basic problem solving by answering the following questions: (a.) Why was a particular bridge type used? (b.) Why was the location suitable for this bridge type? (c.) Why did the architect or designer use a particular design for the bridge that was built?

Procedure
Using Internet and classroom library the students will answer the questions within their teams and then discuss the results.

A-3 Objective
Explore how modern designers use a combination of the designs to build the magnificent bridges today.

Procedure
Although the Sydney Harbor Bridge is not new, it will be used to demonstrate how the arch and suspension design was used in the design. We will use the Fred Hartman Bridge to explore modern bridges and the problems that were encountered during and after the construction of this local bridge.
Material
We will use pictures and drawings of the bridges when identifying the major parts of the bridge.

A-4 Objective
Explore some of the reasons bridges fail.

Procedure and Material
Viewing catastrophic events using the web sites that contain film clips or looking at pictures detailing the events will be part of this lesson. Learning about tests that bridge designs and materials are put through to determine the stress and strain limits, weather factors, and the load bearing capacity of the proposed bridges will be included to help understand why some bridges fail and others will not. This lesson is not designed to scare the students but to help the student understand that bridges are not built to fail but are built to survive.

Lesson B: Problem Solving

B-1 Objective
Examine how bridges react to stress and strain.

Vocabulary
Review vocabulary from lesson A.

Procedure
Using lessons from Bridges! : Amazing Structures to Design, Build, and Test by Carol Johmann and Elizabeth Rieth, the students will use problem solving skills to learn how different bridge designs react to stress and strain.

B-2 Objective
Use a variety of classroom and kitchen materials to build bridges and test their strength.

Procedure
Follow lessons in book mentioned in E-1

B-3 Objective
Use K’NEX bridge kits to build eight different bridges.

Procedure
Follow directions in the kits.

These kits are designed so that the students can test the bridges using stress and strain methods learned from part 1 of this lesson. Examine and learn the names of the parts of the kit and how they will be used during bridge construction. Compare the parts to the actual parts of a real bridge.

Using prior knowledge of bridge design predict where the stress points would be and how much load they will be able to carry.

Material
K’NEX Kits

B-4 Objective
Each group will use a kit to build a bridge of their own design, test it for strength and complete a graph showing which bridge design is the strongest. At the completion of this lesson each team
will have tested their bridge, constructed a graph of the results, and will write a conclusion as to the desirability of the design as compared to the designs from the other groups.

**Procedure**

Each group will construct at least two different bridges in order to do a comparison chart. The comparison charts will then be used to make one large graph showing how the different designs in the *K’NEX* bridge kits compare with each other. The final step will be to come to a conclusion as to which bridge is stronger and perhaps come to some conclusion as to the most reliable type of bridge to build.

**Material**

*K’NEX* Bridge Kits

**Lesson C: Planning and Designing**

**C-1 Objective**

Learn how to design a structure for a specific purpose.

**Procedure**

Introduce or review vocabulary necessary to understand how different jobs influence the planning and designing. The specific vocabulary will include architect, engineers, surveyors, planning experts, soil engineer, aerial photographer, bridge designer, traffic and safety expert, landscape architect, environmental specialist, and laborer. Once the students are familiar to the job descriptions, they will then form groups to begin the design process.

**Enrichment**

Outside assistance will be requisitioned to assist in the design process. If a visit to a construction site is not possible, a local architect or architectural student will be consulted.

**C-2 Objective**

Design a Bridge.

**Procedure**

Using the knowledge they have acquired about the basic designs, the arch, beam, and suspension, each team will design their own bridge. One design will then be chosen for the actual construction and once that design has been reviewed by an architect we will use that design for our actual bridge.

**C-3 Objective**

Review the building phase.

**Procedure**

Questions to be answered include: What comes first? Why? Who is in charge? How does someone go about getting a bridge built? What materials will be used? How does one begin the construction?

These are difficult questions and some will be answered by using research and others by a professional bridge engineer. Once the questions have been answered and the students have their materials list, they can go to their site and make preliminary plans for the actual building of their bridge.
Lesson D: Bridge Construction

D-1 Objective
Complete the plans for the actual construction.

Procedure and Material
Assign jobs. Materials will be purchased, brought to the site, and the site prepared for construction.

D-2 Objective
Actual construction of a bridge.

Procedure
The students will follow their design and the engineer’s directions to construct their own bridge. This phase will be an enormous undertaking as my students are second graders. However, I have never underestimated just how resourceful seven and eight years olds can be when assigned a task that take them out of the classroom. After all they are the same age as the students that have just completed the National Wildlife Habitat and have been active in building a butterfly habitat and vegetable garden in our outdoor classroom for the past four years. Not the same children, but the same age as those that did the work.

Lesson E: Concrete

E-1 Objective
Examine the contents of concrete.

Vocabulary
concrete, cement, sand, slump test, stress test, rocks, pebbles, aggregates, water, air bubbles, forms.

Procedure
Students will learn the different usages for concrete. Before mixing the students will inspect the different ingredients that go into the making of concrete. They will be given a formula for mixing concrete for different usages, such as the footing for a bridge, stepping stones, and sidewalks. Instructions as how to pour or place the concrete and setting time will be included in this lesson.

Material
Concrete mix, cement, sand, aggregate, water, forms, buckets, gloves

E-2 Objective
The students will mix and pour concrete.

Procedure
Students will be expected to do the mixing and pouring of concrete to make stepping-stones for the paths in the outdoor classroom and a path in front of the school. Students will be able to add designs to their stone and place their stepping-stones in the paths.

Material
See lesson E-1

Once these lessons have been completed students of all ages should possess an understanding of why men built bridges, why specific designs are used, why a bridge is built to specific
specifications, why some bridges fail. Hopefully they will also carry with them the desire to learn more about bridges and never cease to imagine themselves as being able to design the ultimate bridge.

It is my goal to bridge the gap between problem solving skills and listening skills, not only on standardized tests, but in their every day lives. When students are successful they take that success and gain more confidence in other areas. The weight of the world is on their shoulders and we must all help them prepare for the stress and strain they will endure throughout their lifetime.

**ANNOTATED BIBLIOGRAPHY**

**Works Cited**

A history of the world’s most famous and important spans. The bibliography and web site entries are very extensive and helpful when researching bridges.

This is an anthology of the most important bridges in history. Lushly illustrated, breathtaking photography, and beautifully edited it is a valuable resource for the classroom library.

Describes different kinds of bridges, their history, dilemmas, safety, and contains activities that include the designing, building, testing, and problem solving connected with building bridges. This is an excellent resource for teachers and students as well. I would consider it the most valuable of all the resources I purchased for this unit. If you purchase only one book, this is the one to buy.


**Teacher Resources**

Collection of over 250 of the world’s greatest and most exciting buildings. Photography is superb.

Guidebook cataloguing 986 architecturally significant buildings and places of Houston. Contains brief descriptions, pictures, and map locations. Excellent book for anyone that want to experience the architectural diversity in Houston.

This is the story of the largest urban construction project ever launched in America.

The reader will discover a wide range of highly diverse buildings the stories surrounding these edifices and the events which took place in them that lend these buildings their enduring mythical auras.

Contains instructions and plans for building unconventional birdhouses whose plans are based on famous buildings. Good resource to use to show that birdhouses don’t have to be boring.

**Student Resources**

Burton, Virginia L. *Mike Mulligan and His Steam Shovel*. Boston: Houghton Mifflin, Co., 1939  
Classic story for teaching problem solving. How can you get the steam shovel out of the basement?

Describes different kinds of bridges, how they are built, and how they are used. Very good book for young children or adults the know little about different kinds of bridges.

Describes different kinds of bridges, their history, dilemmas, safety, and contains activities that include the designing, building, testing, and problem solving connected with building bridges. This is an excellent resource for teachers and students as well. I would consider it the most valuable of all the resources I purchased for this unit. If you purchase only one book, this is the one to buy.


An excellent resource for school projects and classroom studies. Contains current and historical information about bridges around the world.


Story of a boy watching a skyscraper being built on a lot neighborhood children have been using as a playground. Leads to discussions of needs, ownership, and progress.


Discusses different kinds of bridges, from train bridges to fortified castle bridges, and provides examples of each. Gives the name of the bridge, type of bridge, and the date they were built. Illustrations are unique.


Details for building a birdhouse.


Chumash Indian legend about the origin of dolphins. Hutash stretched “the rainbow bridge” from Limuw to the coast so ½ of the tribe could go to the mainland.

**Internet Sites**


Details about Tsing Ma Bridge of Hong Kong. Change the site address to wiki/List_of_bridges for more bridges of China.