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The Road to Bridge Design

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Introduction

We must recognize that we do not have a work force capable of using science, technology, engineering, and mathematics. Therefore, the emphasis of my curriculum unit is on mathematics and my teaching method is to look at problem solving from an engineering viewpoint in the classroom. The focus on engineering has led me to choose civil engineering and bridge design to bring out the concepts of mathematics. However, students would not be expected to design a bridge per se but to examine the process of designing a bridge. They would look at exercises using mathematical concepts as triangles or parabolas. They would examine an aspect of bridge design for proportions and symmetry. Or they may examine a failed bridge that was due to mathematical design flaws or perhaps discover it was due to materials. They may also attempt to design their own bridge using bridge design software.

The goal of this approach is to stimulate interest in our young people which in turn would translate into a skillful work force who would have demands for high level jobs that include designing and building models, asking questions to solve a problem, analyzing and interpreting data, finding solutions, and drawing conclusions. It would provide an opportunity for students who can explore their ideas, work them out, troubleshoot problems, and feel successful no matter the outcome.

The objective for the classroom is to create an environment where students will take complete control of their projects and develop confidence to make their own decisions. This will be accomplished by the student looking at the project and making decisions about tasks that they will work on or are interested in. They may begin with their desires but through trial and error will settle on what interests them most or what they can do based on their skill set. The environment should be relaxed, busy, and engaging.

Students would work in teams. Working in teams will enable the student to decide who will accomplish which task. It will teach each student about taking ownership of a task and realize the dependence of team members on completion of it. In this process a leader should emerge who will guide direction and focus.

Teams would consist of four members and can be selected randomly or by using a behavioral tendency models such as DISC [1] . DISC categorizes individuals into four behavioral tendencies D-individuals who like to direct, Iindividuals who like to influence, S-individuals who like to serve, and C-individuals who like to comply with high standards. This or other behavior models would help individuals to regulate theirs and others strengths and weaknesses to the advantage of the team and the completion of the project by anticipating potential problems and delegating tasks to the right person. However, if a behavioral model is not available then knowing your students well would be an advantage. Students demonstrate daily proficiency in thinking, organizing, working with their hands, writing, or technology. It is easy to select a team of students that possess all the skills needed to perform an activity proficiently as a team.

Students would also decide on what area of development they would like to concentrate on. Would they prefer the design process to develop a model, the assembly process to put things together and test them, or research? And, they would be required to hypothesize on some aspect of the project to test or develop and collect data to analyze. This approach will show how engineering combines the use of science, technology, and mathematics.

Activities to support the goal would be field trips, constructing models, and using software to create designs.

Background information on bridges would be given to students for projects or activities proposed below.

Who is a Civil Engineer?

When we talk about bridges, we talk about civil engineering and at the helm of civil engineering is the civil engineer. So, what does a civil engineer do? He or she plans, designs, tests, and/or supervises projects. Projects that may include anything from buildings, dams, and roads to medical equipment and cell phones. Just about anything that improves society or the environment needs a civil engineer.

A civil engineer not only must consider normal and severe weather conditions when working on structures such as buildings or bridges, but also, the potential for natural disasters as hurricanes and earthquakes.

He or she must be adept at one or more of the disciples of science, math, chemistry, physics, and computer technology. Projects may be hands-on and involve teams of a few members to several hundred. An engineer must be able to communicate and work well with others.

Engineers are creative people who find ingenious solutions to solve society's problems or create new products such as the more recent computers. Other fields of engineering include aerospace, agriculture, chemistry, computers, electrical, industrial and mechanical.

Bridge Design

There are three basic structural elements to designing a bridge: the beam, compression members, and tension members. The beam is a simple structure that may link one piece of land to another piece of land separated by a stream, river, or any body of water. When designing a beam bridge a sketch is made showing the elements in the problem which include the geometry and the forces acting on the beam. What must be considered is the anticipated traffic on the beam. Will it be pedestrian, vehicle, or both? This is important because it may dictate the materials used in the construction. Will the beam be made of wood, concrete, or steel? Also, what will be the supporting materials needed to hold the beam in place?

Figure 1: The above beam bridge is on a trail in a park in Branford, CT and is a cross over a small stream. The sketch shows a straight bridge between two land pieces. The dashed lines show that weight on the bridge will cause it to sag and with too much weight the bridge will collapse.

Traffic on the beam will cause it to buckle downward if it is too heavy. In this case, compression members are needed to counter it. We see many bridges with thick concrete pilings under them.

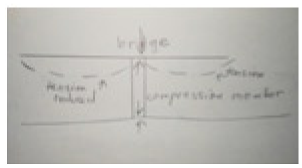

Figure 2: Pictured is a compression bridge on an interstate highway in Branford, CT. In the sketch, the arrows show where the compression forces act on the bridge. Compression is a pushing force. In this case, the concrete piling pushes down to the ground and the ground pushes up to the piling. Likewise, on the bridge, the two forces push against each other at the piling. Notice that the tension is halved.

If the bridge is long with anticipated frequent or heavy traffic tension members will be applied. These bridges will have cables pulling the beam upwards.

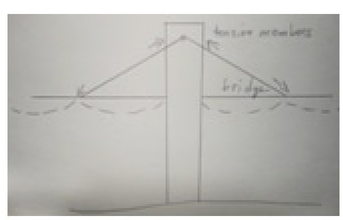

Figure 3: The sketch shows the tension forces acting on a bridge. Tension is a pulling force and the arrows show the forces pulling in opposite directions. The cables reduce the tension in half on both sides of the

compression tower. Pictured is the Pearl Harbor Memorial Bridge in New Haven, CT showing some tension members. The bridge is not a pure tension bridge. It is a cross between a cable-stayed bridge and a girder bridge called an extradosed bridge.

If forces acting on a bridge, whether it be pedestrians or vehicles, are not balanced the tension or compression forces may become too great on one side to support the weight of the bridge and may collapse. So, it becomes important to assess where the stresses are and then spread the force over a greater area or transfer it to a stronger point on the bridge. This can be accomplished by using other designs as arches, trusses, or cables that can transfer compression and tension forces. As new materials become available new bridge designs become apparent and mathematical models are used to analyze and test them.

Now, let us look at what is involved in bridge design. First, there must be a concept–a bridge. But, what kind of bridge? Who will use the bridge-cars, trucks, pedestrians? What is the traffic flow and how heavy will it be? Will it be spanning over water or another highway? What is the economic feasibility of the bridge? What is the future projection for the bridge?

Next, a model needs to be designed and constructed maybe both or either a scale model or a design model using software. The design of the bridge will depend on its use. Will the bridge be a member bridge, a tension bridge, or a suspension bridge? Or, will a new design be introduced? The model needs to be analyzed and tested for strengths and weaknesses and the weaknesses corrected if possible. And, lastly, it needs to be determined if the design meets the objectives of its purpose.

Finally, an evaluation is performed and a decision made on whether to proceed, halt, or redesign the project. Engineers are involved from inception and throughout construction.

Some Mathematics Behind the Bridge

For an example, the truss bridge is formed by the use of triangles. These bridges are used for the passage of trains over water. Each joint of the bridge must be in equilibrium which means that the two forces acting on it must be equal to zero. The directional forces are horizontal and vertical and their summations equal zero or $\Sigma H=0$ and $\Sigma V=0$. These expressions will yield two equations that can be solved for only two unknown forces. $\Sigma H=0$: $F_1 \cos\theta - F_2 \cos\theta = 0$ and $\Sigma V=0$: $- F_1 \sin\theta - F_2 \sin\theta = 0$ where θ is the angle of inclination for example 45^0 or 60^0. More complicated truss bridges may have more than two unknown forces and would need other analytical techniques such as matrices.

In addition to gravitational forces torque forces must also be balanced to zero or the bridge will rotate. Torque, is the cross product between the applied force relative to the position of an object's center of mass, $\tau = F \times d$.

Commonly, mathematical applications in bridge design include differential calculus, integral calculus and Newton's Second Law: F=mg for which F is the force, m is the mass, and g is the gravitational acceleration.

Bridge Failures

In this day and age of technology it would be almost impossible to think that a bridge could fail. But, there is a long list of failed bridges and students, if they are to successfully design a bridge, need to know how a bridge can fail. I would like to contrast two bridge failures. Also, sample websites depicting video bridge failures are suggested in activity 3.

In July 1997 the Maccabiah Bridge collapsed and killed two athletes and injured 60 others. It was a wooden pedestrian bridge constructed for the Maccabiah Games in Tel Aviv, Israel. The Games celebrate the Zionist Revolution and is also a way for the Jewish people to demonstrate their unity and athleticism. The Maccabiah Bridge spanned 60 feet long and 18 feet wide over the Yarkon River. It was built as a temporary bridge where the athletes would wait before the opening ceremonies of the games in Ramat Gan Stadium. The bridge buckled before the ceremony could begin.

An investigation ensued and the public commission deemed that the bridge failed because of poor planning and construction and found fault at all levels in the process. It was found that the engineer never submitted a plan and failed in adequately identifying the bridges intended use. It was also recognized that the engineer did not supervise the construction.

The construction company never communicated with the engineer, it used substandard materials, and the company was not authorized to build this type of structure.

Interestingly, the organization committee of the games did not communicate with the principals of the project and did not appropriately manage the athletes on the bridge.

In contrast, the Mianus River Bridge in Cos Cob, Connecticut collapsed in 1983 because of metal corrosion and fatigue.

The bridge was constructed in 1958 as part of Interstate 95 traveling southward from New York through Connecticut and northward through Massachusetts. It consisted of six lanes-three lanes that went northbound and three lanes that went southbound. The bridge was composed of four spans each weighing 500 tons. A new design called the pin and hanger was employed to connect the spans. The outline of the hanger is oval. At the top and bottom of the oval piece are two holes for metal pins, similar to rods, to go through and then kept in place with retaining bolts, keeper plates, and knots.

Ten years prior to the disaster, the bridge was resurfaced and the storm drains on the bridge were paved over. This action allowed water, stilt, and dirt to reach the hangers. Road treatment in winter which contains a fair amount of salt, the nearby salt marsh in conjunction with the tidal flow from Long Island Sound adding more salt, and harsh winters all led to the pin and hanger's corrosion. The National Safety and Transportation Board conducted an investigation. Deputy Commissioner CT DOT Carl F. Bard P.E. stated that location, heavy traffic, and environmental factors were the cause of the fatigue and rusting of the pin and hanger that caused one pin to fall off and caused the second pin and hanger to let go since it could not support the weight of the bridge alone. A one hundred foot section of the bridge collapsed and fell into the river.

It was determined that the bridge was not routinely inspected, and, that all Connecticut bridges using this system were inadequate. The disaster of the collapse of the Mianus River Bridge that sent two cars and two tractor trailers into the river killing three people could have been avoidable.

Teaching Strategies

I would accomplish teaching mathematical concepts by employing an engineering team of students to work on a project in bridge design. They would make their own decisions about what they would want to study: bridge design, bridge failure, or some component of a bridge such as symmetry. A laboratory report would be essential to the project including hypotheses and a description of the mathematical concepts employed.

A laboratory report is essential because it takes the student to the next level showing their comprehension of the initial mathematical concept(s) learned or applied. The most important element of the report is the hypothesis or problem statement. This is where students demonstrate taking mathematical concept(s) learned to the next level. For example, if a team of students successfully derived the parabolic equation of the main cable of a suspension bridge (see activity 1), then, a hypothesis may be to lengthen the span of the road and see how this effects the original equation or derive a new equations to the lengthening or contraction of the road in order to find patterns. However, students can be creative and do develop their own curious ideas.

Teachers would provide background information about design, materials, and types of bridges (see appendix 2) in group discussion. Alternatively, teachers may have students research aspects of bridges using books and/or media. Teachers would be observant of student choices and query their choices individually. Then students would report out explaining how their choice would help the team. Teachers would also assist by providing guidance and needed information in a timely manner as students are working to move the project along or by asking questions. Inquiries would consist of asking students about what they are thinking about, what they plan to accomplish it, or lead them to explore other solutions. For example, if students are working with several equations, then asking the students about relationships and patterns between equations or to another concept might lead them to a solution. The emphasis is to lead the students and not provide answers. Teachers would always be available to answer student questions and act as moderators throughout the process. Students make all decisions whether they are successful or not. The emphasis is on what they have learned during this process.

This atmosphere of team work is student driven and would enable students to learn to work together, learn from each other, work toward a common goal, and accomplish a task together in addition to learning mathematical concepts and the connection of mathematics to the real world. Other benefits would be it would teach students patience, focus, perseverance, and to enjoy or have fun in the process.

Classroom Activity 1

Objective:

Students will build a suspension bridge using a building kit and determine the standard equation of the parabola created by the main cable. Students will also complete a laboratory report and determine a hypothesis showing higher level thinking.

Procedure:

Students will work in teams as described above to build a suspension bridge.

Students will know the following:

· The main forces of the suspension bridge are tension and compression.
· The tension is supplied by the cables and the compression is supplied by the towers. The cables hold up the span or road by being attached to the towers. This causes the weight of the traffic to be transferred to the towers by the attachment of the cables to it and then to the ground by the towers.
· It is the main cables of a suspension bridge that form the parabola.
· Students should be able to define: parabolic graph, focus, directrix, vertex, axis of symmetry
· Students should know these parabolic equations:
Standard form: $y= ax^2 +bx+c$

Vertex form: $y = a(x - h)^2$ where (h, k) is the vertex

Intercept form: $y = a(x - p)(x - q)$

Students will locate the vertex of the suspension cable of the bridge they built using a kit by using a ruler and derive the value of *a* to write the parabolic equation in standard form.

Deriving the value of a : It is important to note that a parabola is formed by a locus of points that is equidistant from the focus and the directrix. The vertex is found midway from the focus to the directrix. This is useful information when the students are trying to compute *a* since *p* of the ancients conic form of a parabolic equation is the distance between the vertex and the focus or from the vertex to the directrix.

Compare the modern vertex form of the parabolic equation to the older conics form of the parabolic equation from ancient times which is $4p(y - k)=(x - h)^2$ where (h, k) is the vertex.

Show how the vertex form translates to the conics form and yields the value of *a* .

$y = a(x - h)^2 +k$

$y - k = a(x - h)^2$

$(y - k)/a = (x - h)^2$

Replace $1/a$ with $4p$ from the conics form, so $4p(y - k)=(x - h)^2$ and the vertex form becomes the conics form therefore, $1/a = 4p$ and $a = 1/4p$ where p is the distance between the vertex and the focus and is also the distance between the vertex and the directrix. Note: $2p$ is the distance between the focus and the directrix.

Sample Lesson

One way of executing this lesson using the above described teaching strategies is to first have students discuss general information about bridges during a report out with attention to covering essential topics as tension, compression, and use of cables in a suspension bridge. Have students discover that the main cable is a parabola. If basic information is not discovered by the students then it must be given.

Remind students of the three parabolic equations already studied and listed above.

Next, show students how a parabola is formed by using a locus of points from a point (focus) and a line (directrix). Inform students that the parabola is created by points equidistant from the point and the line. Note that if the line is below the point then the parabola opens upward and *a* is positive. If the line is above the point then the parabola opens downward and *a* is negative. Do not emphasize to the students that the distance

between the vertex and the focus and the vertex to the directrix are equal. This is for them to realize later when using the ancients conic form of the parabolic equation.

Provide students with more background information by introducing the ancient's conic form for the parabolic equation using the solids of their time. Hence, the conic form of the parabolic equation. The cone would be appropriate.

See if students can establish a relationship between the modern vertex form of the parabolic equation and the conic form. If not, then a hint might be appropriate. See if students will recognize the need to translate the vertex form to the conic form. If not, provide guidance or hints before having students translate the vertex form into the conic form. They should find that $1/a$ and $4p$ are equal and that p is the distance from the vertex of the cable of the bridge to the deck or road by association of the focus and directrix demonstration. This would serve as an application to the real world. Appropriate guidance may be needed.

Students can compute p measuring their bridge using a ruler or tape measure, find *a* , and write the equation in standard form.

Assessment

Laboratory Report

The most important part of the laboratory report is the hypothesis or problem statement. This is where students may become creative or express a curiosity about the suspension bridge as they are working on it. For example, students may decide to look for patterns by lengthening and contracting the main cable to see how or where it affects the parabolic equation. Also, in order to write a hypothesis students show they understand the initial mathematical concept. See appendix 1 for a sample Laboratory Report outline but any will suffice.

Classroom Activity 2

Objective:

Students will draw or construct a replica of a local bridge using a scale. They will include in a laboratory report information about the bridge regarding ratio, proportion, and symmetry as well as a hypothesis. See appendix 3 for suggestions on local bridges.

Procedure:

This activity will require a field trip to a local bridge. Students will work in teams as described above.

> Students will know how to scale using ratios and proportion and will be able to determine symmetry.
> Students will examine the bridge for symmetry, ratios, and proportion at the site.
> Students will use measurements, such as tape measure, ruler, compass, string, camera, sketch pad, and pencils to record the dynamics of the bridge and then translate the information to a scaled drawing or model the bridge by scale out of sticks or other medium back at the school.

Sample Lesson

One way of executing this lesson using the above described teaching strategies is to first have students discuss general information about bridges during a report out with attention to covering essential topics as scale, ratio, proportion, and symmetry. Have students brainstorm about what they predict what they will find when they examine the bridge they have chosen from a list of available bridges to visit provided by the teacher. Where will they predict they will find symmetry on the bridge, where will they find ratios and proportions? If basic information is not revealed by the students then the teacher would provide guidance and hints for its discovery.

Students would decide what will be taken out to the field trip such as ruler, tape measure, sketch pad, pencils, camera, or whatever they deem needed. Guidance would be needed so that nothing is left behind. At the site have students collect information and data to bring back to the classroom. Moderate and guide students so that all information necessary is recorded to avoid a second trip. It is suggested that teachers visit the site of the bridge beforehand.

At this time remind students that they need to formulate a hypothesis or problem statement and should consider this as they as taking measurements. Back at the classroom, some students will decide to work on the engineering aspect of the project and sketch a scaled detailed replica of the bridge or construct the bridge out of sticks or papier mache. Other students will begin working on the hypothesis and laboratory report. The two groups should see the need to integrate, work together, and share ideas as they complete their aspect of the project.

Assessment

Laboratory Report

A sample hypothesis or problem statement might concern changing the scale to see how ratios and proportions are affected or vice versa or perhaps determine how the bridge might look if it was not symmetrical. Students may also have discovered an attribute about the bridge that they would like to hypothesize about. See appendix 1 for a sample Laboratory Report outline but any would suffice.

Classroom Activity 3

Objective:

Students will design a virtual bridge using software. Students will produce a laboratory report that includes a prediction of an expected outcome or hypothesis.

Procedure:

Students will work in teams as described above.

Students will research bridge design, terms, and requirements for a successful bridge.
Students will familiarize themselves with the software.
Students need to be adept using computer technology.

Sample Lesson

One way of executing this lesson using the above described teaching strategies is to first have students discuss general information about bridge types as timber bridge, truss bridge, and the like noting differences and similarities that they found during their research. During student report out attention should be paid to covering essential topics as tension, compression, load, cost, design, and the mathematics involved. Students should speculate about what makes a bridge fail. Since they will be designing a bridge it is essential that they know why a bridge might fail. Here is a sample of websites that may be used to show bridge collapse found on You Tube:

· Tacoma Narrows Bridge Collapse "Gallopin' Gertie" - this video depicts a bridge oscillating in

gale winds and shows its eventual collapse. There is no commentary with this video and it is very dramatic.
· Tacoma Bridge Collapse - with commentary.
· The Silver Bridge Collapse - this video includes a narration of bridge design and a conclusion that the bridge collapse was due to poor design and materials.
· Tasman Bridge collapse - a ship collapsed this bridge.

Have students familiarize themselves with the software they will be using. For example students may use the West Point Bridge Designer 2012 (2 nd edition). This websites entails constructing a type of truss bridge. The objective is to select a type of truss bridge from an offered list and design it so that passes a load test, with minimal cost, and its structure does not fail. It also offers a contest.

Have students make predictions about the viability of their bridge before testing.

Assessment:

Laboratory Report

A sample hypothesis could be the parameters they choose and its predictable outcome. Or, they may vary one parameter and look for patterns. See appendix 1 for a sample Laboratory Report outline but any would suffice.

Appendix 1

Sample Laboratory Report

Title: Names of participants, title of experiment, date

Problem Statement: Hypothesis or problem to be solved

Independent Variable

Dependent Variable

Procedure: Steps, results

Materials

Data

Conclusion: Explain, analyze and/or interpret the results, what was learned

Validity: Reflect on what happened and possible errors

Appendix 2

Types of Bridges

There are many types of bridges and the key structural components of bridges are the beam, the arch, the truss, and the suspension bridges. The beam bridge and the truss bridge were introduced above, the arch bridge will be discussed using the example of a stone bridge, and suspension bridges employ the use of cables and are more commonly referred to as cable bridges.

I would like to focus on four bridges. Three of which are material bridges and the fourth a design bridge. The timber bridge, the stone bridge, and the steel highway bridge are material bridges and the drawbridge is a bridge of design.

There are many considerations to make when designing a bridge. First of all is function. Is the bridge needed for travelers to cross water using vehicles? Will boats need to be accommodated if the bridge is over water? Is a foot bridge needed for people to walk over a road from a parking garage to a mall or business plaza? And then there is location. Is the bridge to be built in a small city or a crowded one? Is the bridge along the coast or in the mountains? Location and function will determined the materials used. Determining the materials is important because of maintenance and the anticipated duration of the bridge. If the load (heaviness of traffic) is great then perhaps a concrete bridge would be a better selection than a timber bridge to meet the needs and its function. The size of bridge, past practices, and new ideas interplay. New technology and new products are continuously tested, manipulated, and tried. But, in the mind of all the planning is cost and public opinion. Without the public's approval a bridge may never be built. Likewise, if there are not enough resources a bridge can be put on hold or an inexpensive one will take its place. In today's world, we also have a new consideration which is emerging as a primary concern and that is of the environment. How the bridge and the materials used affect the environment is emerging as a significant concern in an ever changing climate, a more polluted and congested world, and the diminishing of useable space.

The most important consideration for timber bridges is wood preservatives to keep the wood from rotting. The preservative must be compatible with the wood used be it a softwood or a hardwood. A softwood may be harder than a hardwood. Softwoods and hardwoods are classified by their leaves or needles. Softwoods have needles and hardwoods leaves. The Forest Products Laboratory under the U.S. Department of Agriculture is continuously doing research on how wood performs and addressing the question of how wood will stand up to natural disasters. We are familiar with sawn lumber processed in saw mills. But, since the mid-1940s, the U.S. has been using glue-laminated timber called glulum which can be made from either hard or soft woods just as the sawn lumber. One of the advantages is that glulum timber can be produced in a variety of shapes and sizes. We are familiar with it in furniture that is made from processed woods.

Forty to fifty years ago timber bridges were common. But, with heavier traffic and greater volumes of traffic more durable materials and design are more desirable and trusted. Engineers site that timber is short-lived due to rotting, has high maintenance due to inspection and preservation, and is not strong enough for today's needs.

Solutions to engineers concerns have been proposed in 1989 by the Timber Bridge Initiative (TBI). The initiative provided for a training program to promote the benefits of the "modern" timber bridge. Solutions include using composites of steel and wood to reduce bridge movement, water-shedding joints and water proofing to address deterioration, and a stressed-type timber to reduce water movement between boards.

All in all, it still seems that the acceptable places for timber bridges today are in rural areas where engineers are unnecessary. These bridges would be bridges for light traffic, foot bridges, railroads, and the esthetic covered bridges, and, they would be regulated by the county instead.

When we think of a draw bridge we envision a castle with a moat and the story that went along with it. And, this is usually our first encounter with a drawbridge. It is called the bascule. We have come a long way since then primarily because our needs have changed, and, so, the function of the draw bridge. We no longer need to keep people out but to help them get across water. This would not be so complicated except we must also let ships and boats pass under it.

There are several types of draw bridges. One is the vertical lift span that that works like an elevator. The span (a section of road) rises and then lowers. Another is the retractable span that slides back and forth. A section of road moves under the bridge to let ships pass and then slides back. A third draw bridge is the swing bridge. This bridge rotates horizontally on vertical pivots and swings to the side.

However necessary, a drawbridge is costly both to operate and to maintain its moving parts. Its one drawback is that it stops the flow of traffic for a time or for more time than people care to wait.

Early bridges were made of stone. The process is called stone masonry. The advantage of stone bridges over timber bridges, in their time, was that they can bear heavy loads. And, when stone bridges were formed in an arch they could possibly bear unlimited weight. This was desirable when legions of armies marched over stone bridges in the Roman era or when tanks traversed over stone bridges in more modern times.

Stone bridges are more expensive to construct than the timber bridges and were built when the needs and the function of the bridge met. Brownstone, granite, brick, or field stone (stones found when clearing out land) were used. Design, esthetics, and cost dictated the type of stone used and how elaborate of a design the arch would be.

The only maintenance of stone bridges would be due to cracking. And, if neglected over time dirt would be allowed to settle in and the bridge could sprout growth in the form of moss, plants, bushes, or even trees.

In comparison to these smaller bridges, the steel bridge highway can be a massive project that can take a team of engineers to design it and another team of engineers to oversee its construction. More attention is given to weather conditions and the earth in its construction. Wind velocities during construction are a concern. The bridge must be stable at each point of construction. Expected wind velocities must be determined for the strength of the bridge to hold in place and not sway or crumble under the pressure or gusts of wind especially at shore points where wind can be brutal. Perhaps, not much attention was spent on natural disasters as hurricanes, tornados, earthquakes, or tsunamis years ago when the likelihood of such events could not materialize. But, today, it is a different story. Natural disasters are occurring in areas unexpectently. Determining design, materials, and the likelihood of natural disasters are becoming crucial to new bridge design.

The earth presents its own problems. The earth gives off its own pressures and surcharges. Studies of type or types of soil present in the area where the bridge is to be constructed dictates equipment and materials used. It also determines if support equipment will be needed during excavation. The condition of the soil may require the use of lagging walls and/or piles to support the construction of bridge walls. Code and specifications are more numerous and may be more complicated. All engineers must be in constant communication so that design and construction needs are met.

Appendix 3

Community New Haven and Hamden Bridges

The Pearl Harbor Bridge in New Haven, CT, commonly referred to as the "Q-Bridge", is in serious need of repair and is receiving just that attention. It is old, deteriorating, and is congested with 140,000 vehicles per day. It was designed for only 40,000 vehicles per day. The bridge will move from three lanes to five lanes and from one six lane bridge to five two lane bridges. The project will include other enhancements that will allow easy access and exit lanes onto and off the bridge. It will be longer than the original bridge because of the enhancements that also include operational and safety improvements.

The bridges design is unique because it is a first of its kind. The tension design is called an extradosed bridge. Its design is a combination of a concrete girder bridge and a cable-stayed bridge. The benefits of this type of bridge are shorter towers and less girder depth which allows for longer straight span lengths than the traditional cable-stayed bridge and girder bridge. The cables do not need tension adjustment which will reduce maintenance costs. The expected completion date is in mid-2015 and the projected cost is $417 million.

The Tomlison Bridge, also in New Haven, CT, is a vertical lift span drawbridge. It was a $120 million project that took 10 years to complete. It is the largest vertical lift span drawbridge east of the Mississippi River. The bridge is composed of four lanes that cross over the New Haven Harbor and alongside is a single-track freight train line. [2]

Some construction facts of the bridge are: The bridge is 90 feet wide and 270 feet long with six 100 feet long approach spans and two 30 feet tower spans which were erected from the water. The vertical lift spans weigh nearly 6.5 million pounds with a total load-to-move of 13 million pounds. It provides a channel with 240 feet horizontal clearance and 13 feet vertical clearance when the span is closed and it supports 17 million pounds of steel. [3]

Trowbridge in New Haven, CT is a stone arched bridge. It was named after the family that funded its construction and is located on Trowbridge Drive which is a park road in East Rock Park. It was constructed in the late 1880s and like all old bridges it shows its wear. Its stone masonry construction has moss and small plants everywhere on its surface but this bridge is not widely traveled and so it is not in deterioration.

Figure 4: Trowbridge constructed in the late 1880s.

Next to the Eli Whitney Museum in Hamden, CT is the Major A. Frederick Oberline Bridge also located at East Rock Park and dedicated to the memory of Major A. Frederick Oberline who was an eminent soldier and citizen. His commemoration is inscribed on a plaque inside the bridge.

Figure 5: The Major A. Frederick Oberline Bridge showing a lattice design.

The wood covered bridge, originally located at a different site, was washed out during a flood. Its' simple design of closely spaced diagonals and overlapping triangles made the bridge strong, economical, and easy to build. The bridge was constructed as a lattice-truss bridge so that the stresses of the bridge were evenly distributed over the triangles. In 1979, Eli Whitney VocationalTechnical High School students reconstructed the above bridge where it currently stands.

Appendix 4

Implementing State of Connecticut Common Core State Standards

Algebra: Creating and reasoning with equations.

Functions: Interpreting, analyzing, and building functions.

Modeling with Geometry: Apply geometric concepts in modeling situations.

Mathematical Practices:

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularly in repeated reasoning.

Notes

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Thank you to the seminar class for helpful suggestions.

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