Creating a High-Tech Totem Pole

An Interactive Qualifying Project
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfilment of the requirements for the
degree of Bachelor of Science

by
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Date:
March 5, 2016

Report Submitted to:

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This report represents work of WPI undergraduate students submitted to the faculty as evidence of a degree requirement. WPI routinely publishes these reports on its web site without editorial or peer review. For more information about the projects program at WPI, see http://www.wpi.edu/Academics/Projects.

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Abstract

The purpose of this project was to study the feasibility of using concrete instead of glass as material for an outdoor sculpture that can be illuminated from within. In our prototype translucency of concrete was achieved by adding acrylic rod and fishing line to the concrete mixture.

Our prototype, an eight foot tall totem pole, was exhibited at an art show, where we studied the public's reaction to high-tech art.

Chapter 1: Totem Poles

Inspiration for the High-Tech Totem

Wendy Wacko, a landscape artist in the Canadian Rockies (Wacko, n.d.), dreams of creating a totem pole as large as the famous Haida Totems (Bedford, 1998). Wacko envisions this totem being made of a material not only durable enough to withstand the environment of the Canadian Rockies, but also translucent and lit from within so that the totem can be transformed as day changes to night. Wacko proposes using glass as a material. The team was inspired by her ideas. Different possibilities were investigated and the findings are presented in this paper.

Northwest Coast Native American Culture

There were 30 Native American tribes in northwestern North America, each with an average of 8000 members, before European Colonization occurred in 1774 (Miller, 2014). Off the coast of British Columbia, Canada, is a set of islands called Haida Gwaii, home to the Haida tribe. Mythology was an essential part of the Haida culture. Family history was preserved through oral tradition and the carving of totem poles (Halpin, 1981).

Mythology was expressed on totem poles in the form of crests and symbols, which represented the power that the family held within the tribe (Halpin, 1981). In Figure 1, an eagle is represented on the top of a Haida totem pole. As stated by Ruth Schiffmann, every animal and person carved on a totem had a specific meaning.

> "An eagle was used to portray power, courage, and wisdom. The raven showed curiosity, deception, and trickery. A fox symbolized cunning, agility, and wildness, while a frog

expressed peacefulness, adaptability, and hidden beauty. Human figures were used, too, like the watchman at the top of a totem pole put there to look over the village. Each tribe or clan spoke a different language and carved in a different style. For that reason, each totem pole portrayed the unique identity of the tribe it came from" (Schiffmann, 2009).

Figure 1: Haida Totem Pole. From Lions Lookout Park, White Rock, British Columbia, Canada (Mabel, 2013). Retrieved from http://commons.wikimedia.org/wiki/File:White_Rock,_BC_-_Haida_totem_pole_01.jpg

Traditional Totem Pole Design

Totem poles made by the Northwestern Coast tribes were primarily created from western red cedar trees because of the wood's malleability and abundance in the area (Indigenous Foundations, 2009). Red cedar is known for its height and durability (Meier, 2014). Totems made from red cedar can last about one hundred years before they disintegrate (Indigenous Foundations, 2009). This tree is considered a softwood because red cedar is a conifer or cone bearing tree, a type of wood which is generally used as structural lumber in homes (American Hardwoods, 2007).

To create the totem poles, red cedar trees were cut down and stripped of their bark (Dearborn, 2002). Tribe members applied their skills to work on various sections of the totem pole. The wood was carved using chisels, stone blades, adzes (a hand tool for shaping wood), bones, antlers, shells, and wooden tools (Adz, 2015). Colors used to paint totem poles came from earth pigments. The most common colors were black and red, as they were most available to the tribes of the Northwest Coast. To create black, salmon eggs were mixed with charred wood or bone. Red was created by mixing salmon eggs with crushed rocks that contained iron. However, colors such as blue, blue-green, white, and yellow were also used. The pigments were bound by mixing salmon eggs with various materials, then applied using porcupine-hair brushes (Schiffmann, 2009).

Figure 2 shows a replica of a round totem pole based on the three typical colors: black, red, and white. Only general measurements were available from all sources cited on totem poles. Totems can range from 3-18 m tall or approximately 10-59 ft (Indigenous Foundations 2009).

Figure 2: Replica Totem Pole. From The University of British Columbia, Museum of Anthropology in Vancouver, Canada (Leoboudv, 2012). Retrieved from http://commons.wikimedia.org/wiki/File:Haida_replica_totem_pole_(UBC_Museum).jpg

Chapter 2: Art and its Impact

Defining Art in Public Spaces

Public art is not restricted to any specific medium, form, style, or subject matter. It can be large or small, realistic or abstract, contrasting to the environment or similar to the surroundings. It can be in the form of a mural, sculpture, or structure (Encyclopedia of Art, n.d.). Public art is defined as follows by Encyclopedia of Art:

> Public art is an umbrella term which includes any work of art purchased with public funds, or which comes into the public domain (by donation, or by public display, etc.) irrespective of where it is situated in the community, or who sees it (Encyclopedia of Art, n.d.).

There are two categories of public art, transient and permanent. Transient art is temporary; it only lasts as long as the environment for it persists (Coutts, 2008), such as ice sculptures which will melt when seasons change. Haida totem poles, as well as the one proposed by Wendy Wacko (6), are considered permanent art because totems remain in the same location for an extended period of time.

Outdoor venues with public art have experienced decreased crime rates. This was the case in New York City, where government representative Henry Stern redesigned Bryant Park with the addition of sculptures. Before the redesign, drug dealers and violent criminals frequented the park. Afterward, the park became a cultural destination for New Yorkers and tourists alike (Sussman, 2013). Elizabeth Strong-Cuevas said the following about this topic,

> "Art in public spaces has a civilizing affect on a community; it promotes good behavior, whereas dilapidated and deteriorated public areas tend to invite vandalism and become havens for illegal activities." (Sussman, 2013)

The installation of public art serves the community. Artists can represent the culture of the area and reaffirm what the public is feeling (Sussman, 2013). According to Sussman, public art should neither discourage any group, nor insult the cultures of the local people. Ultimately, public art can bring a community together, while passing down culture and ideals to future generations (Sussman, 2013).

Visual Art in Worcester

In Worcester, Massachusetts, the mission of the Public Art Working Group (PAWG) is to enrich the culture and aesthetics of the city by installing public art. Current projects undertaken by the PAWG include mapping out public art in Worcester, finding new locations for public art installations, commissioning large-scale public art, and involving local artists in creating public art. This is represented in Figure 3 (Worcestermass.org, 2015).

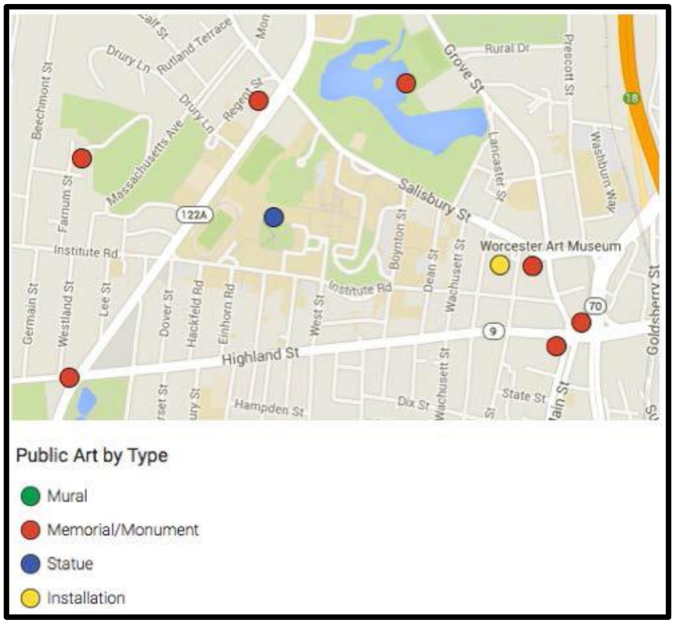


Figure 3: Public Art Catalogue around Worcester Polytechnic Institute. From Public Art Working Group (Worcestermass.org, 2015). Retrieved from http://www.worcestermass.org/arts-culture-entertainment/public-art

Also in Worcester is the Worcester Art Museum (WAM). One relevant art structure located there is The Carved Column (Figure 4). The Mayan culture adopted limestone as a primary material for sculptures. The column is 69 in. tall and originally stood in a Mayan courtyard as "public testimony to [Mayan] divine authority" (~850 AD). Most Mayan structures commemorate rulers by demonstrating their power, or successes over a lifetime (Worcester Art Museum, 1994).

Figure 4: The Carved Column (~850 AD). From Worcester Art Museum, Worcester, Massachusetts (Worcester Art Museum, 2014). Photo by Dan Sanderson.

There are several venues where art is displayed free of charge to the public in Worcester. One such organization, ArtsWorcester, exhibits and promotes new and local contemporary artists, amateur and professional. Their visual art exhibits include solo and small group shows, as well as the annual college show.

Another organization, the Sprinkler Factory, is a subdivision of the Worcester Art Museum. This converted warehouse is now used for functions such as art exhibits, classes, and work spaces for local artists of Worcester. The project advisor, Professor Servaitus, arranged to have the totem displayed at an art exhibit at the Sprinkler Factory with Luis Fraire, the curator of the art show.

WPI has integrated public art on campus. Figure 5 is a light display by Stephen Knapp at night. The display can be seen hanging from Gordon Library during the daytime in Figure 6. This piece relates to Wendy Wacko's idea for a translucent totem pole (6) because this exhibit changes in appearance drastically from day to night.

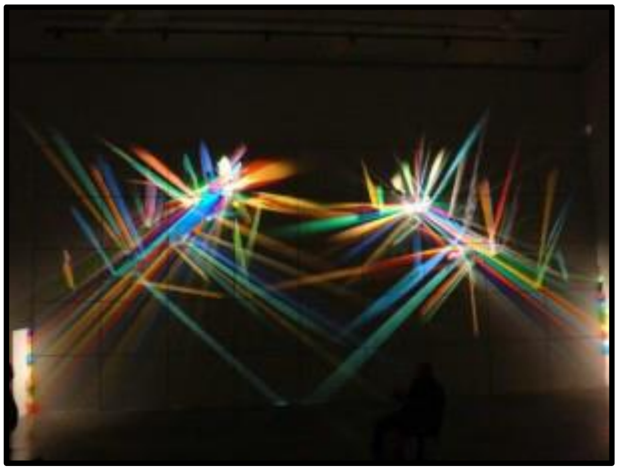


Figure 5: Lightpainting: Night. From Gordon C. Library, Worcester Polytechnic Institute (The Daily Herd, 2014). Retrieved from http://wp.wpi.edu/dailyherd/2014/05/05/lightpainting/

Figure 6: Lightpainting: Day. From Gordon C. Library, Worcester Polytechnic Institute (2/18/2015). Photo taken by Dave Hazel.

Figures 7 and 8 display two bronze statues of Gompei the Goat, the mascot of Worcester Polytechnic Institute. The Proud Goat was donated by the class of 2009, and the Charging Goat was donated by the class of 2013. The Proud Goat stands on edge of the quadrangle closest to the Bartlett Center at WPI. The Charging Goat is adjacent to Park Avenue Parking Garage on WPI's campus. Although the statues are prominently displayed, their locations and lack of seating prevent them from serving as impromptu meeting places. Erecting the totem in an open location with access to seating would be more conducive to student gatherings.

Figure 7: Proud Goat. Quadrangle, Worcester Polytechnic Institute (3/22/2015).

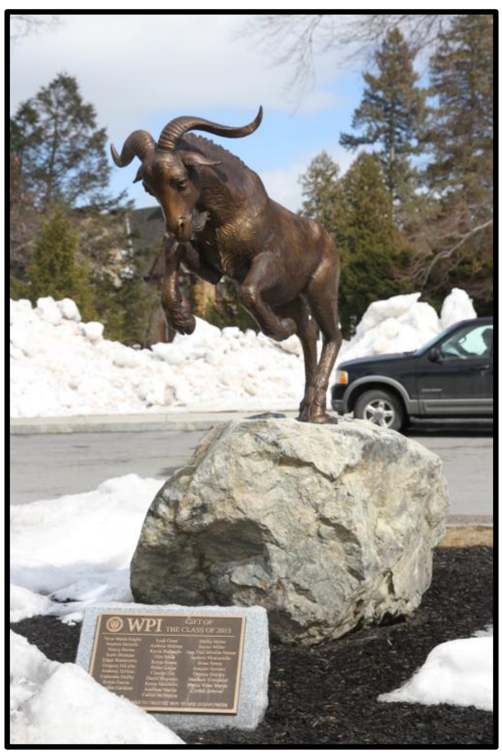


Figure 8: Charging Goat. Parking Circle, Worcester Polytechnic Institute (3/22/2015). Photo by Dan Sanderson.

MemorySpace (Figure 9) is a work of public art in Fuller Laboratories at WPI. WPI students worked in conjunction with artist Deborah Aschheim as part of the Artist in Residence program. Together, they created artwork based on how the neural networks of the brain perceive and transmit information. LEDs show how information travels within the pathways. Components such as live video, camera feeds, and sound bytes were installed to represent networks of memory.

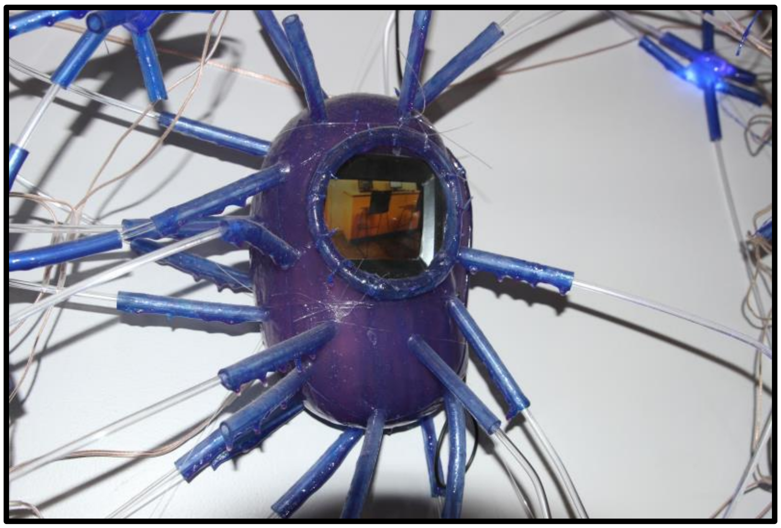


Figure 9: MemorySpace by Deborah Aschheim Fuller Laboratories, Worcester Polytechnic Institute (3/22/2015). Photo by Dan Sanderson.

The Influence of Technology on Art

Technology is giving artists more ways to express thoughts and ideas. For example, artist David Hockney successfully creates art that is seen as innovative by creating paintings on an iPad, which he considers a new medium (Hockney, 2015). Graphics tablets that translate real-world pen strokes directly into a digital medium have become increasingly popular among amateurs and professionals alike, creating art which exists purely in the digital space. Similarly, motor technology and complex gear assemblies have allowed kinetic sculptures to become prominent in contemporary art. Figure 10 shows an example of a kinetic sculpture created by Theo Jansen. His pieces are designed to walk on beaches using the power of the wind. These sculptures draw upon organic life as inspiration.

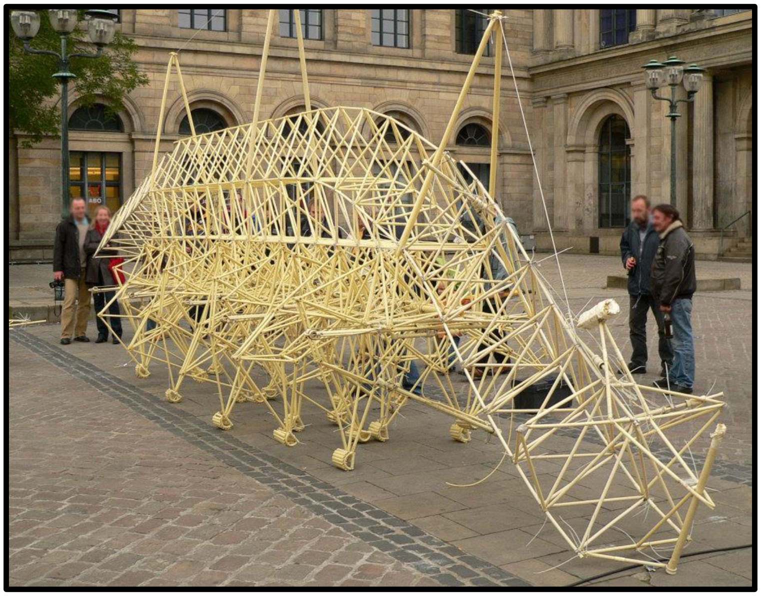


Figure 10: A Strandbeest created by Theo Jansen. From Hannover, Germany in 2007 (Wikimedia Commons). http://de.wikipedia.org/wiki/Strandbeest

3D printed art has become more prominent and commercialized. For example, mathematical models can be physically represented in the real world (Ault, 2015). The use of 3D printers, despite the illusion of automation, still requires skilled artists to manage the technical, theoretical and design requirements.

In addition to providing new techniques and materials, technology has also facilitated access to inspiration, as well as the distribution of artworks. For example, the internet helps to distribute and display art. Web sites allow artists to upload photos of their artwork, regardless of medium. People are able to view artwork, provide feedback, and add suggestions for improvement. Through the internet, people worldwide now have access to a free and evergrowing library of art, as artists share their work in a way that would never have been possible with traditional museums or printed media.

Impact on Totem

Inspired by research of ancient and contemporary art, the team wanted to combine both historical and modern features in the High-Tech Totem. The materials for the sculpture were selected based on durability, as the art piece would be created for placement in a permanent outdoor environment. Since the Mayan column (11) lasted over one thousand years, the team felt that concrete, a limestone compound, was the best choice of primary material for this project. The totem includes strong influences from Native American culture. The totem was designed with a small color palette as an homage to the traditional pigments used by the Haida people. In order to incorporate modern technology into the totem, the “carved” features were created using a 3D printer. Lighting was added to illuminate the embedded translucent apertures of the totem. These ideas will be explain in detail in Chapter 3: .

The public works of art on the WPI campus accurately reflect and promote the innovation of art and technology. The totem was intended to be a representation of WPI culture. Creating a totem using modern materials and incorporating contemporary culture would allow the WPI community to relate to the historic totem tradition. The installation of the totem would also provide the social benefits of public art previously described (10).

Chapter 3: High-Tech Totem Materials

What is Concrete?

Concrete is made with three primary ingredients: cement, water, and aggregate. Cement is a dust composed of hydraulic calcium silicate, created when limestone is fired in a kiln and then crushed. Aggregate is used to fill space and add structural support to concrete. Aggregate is divided into two categories, coarse and fine. Coarse aggregate is made of crushed stone and gravel that is larger than .2 in. Coarse aggregate is primarily in the size range of .375 in. to 1.5 in. Fine aggregate is made with sand or crushed stone that is smaller than .2 in. The size of the aggregate is based on the average dimensions of the aggregate particles (Kerkhoff, 2002). Water reacts with cement and hardens it. During this hydration process, cement particles begin to bind to other particles or surfaces. This process, known as curing, lasts until there are no longer any dehydrated particles of cement. Concrete is at its optimal strength to curing ratio after approxiametly 28 days. (Kerkhoff, 2002).

History of Concrete

The origin of concrete dates back to 6500 BC, with Nabataean or Bedouin traders in parts of Syria and Jordan. In 3000 BC, the Egyptians also used concrete for building the Pyramids. By 200 BC, the Romans built their famous structures such as the Pantheon, the Colosseum, the Roman Baths and aqueducts using concrete made with volcanic sand, lime, and water. In 1793, John Smeaton, a renowned English Civil Engineer, used concrete to rebuild the Eddystone

Lighthouse in Cornwall, England. In 1824, Joseph Aspdin, a mason who became a cement manufacturer, developed a process using chalk and clay to create Portland Cement. He later refined his method using limestone and clay (Gromicko, 2015).

Concrete was fundamental in creating modern architecture. Examples of concrete structures include the Hoover Dam, which was created using 3,250,000 cu yds of concrete. The Burj Khalifa in Dubai, U.A.E., as of 2011, was the tallest building in the world. It was created using reinforced concrete. The building was made with 431,600 cu yds of concrete and 61,000 tons of steel reinforcements. The structure stands 2,717 ft tall. Both of these structures are monuments to the diversity and strength of concrete (Gromicko, 2015).

Today concrete is inexpensive, accessible and customizable, making it the most widely used building material all over the world. The most common cement used for concrete is Portland Cement (Kerkhoff, 2002). When mixed, cured, and used correctly, concrete can sustain compressive forces of up to 7000 PSI (pounds of force per square inch). With air entrainment, or air pockets collected in the concrete, it can last through many freezing and thawing cycles as well. (Kerkhoff, 2002).

Concrete has the advantages of costing .0181-.0272 USD / lb (Appendix A.1). It has a density of .0506-.0723 lb / cu in. It also has a moldability rating of 3-4 according to Granta. This means that it has an average to good moldability on a scale of one being impractical and five being excellent. Its durability to fresh water, UV radiation, and sunlight is excellent. Concrete also has an excellent resistance to industrial and rural atmosphere. Its resistance to wear is normal. Concrete has an average resistance to frost. To avoid deterioration, a coating can be put on the concrete after it has cured that would diminish these lapses in resistance (Granta, 2014).

For reference, hardwood, specifically oak, is comparable to the western red cedar that was used for totems by the Haida tribes. Hardwood is .299-.331 USD / lb (Appendix A.2). Its frost resistance is average. Its moldability is 2-3. Its durability is limited in its resistance to fresh water. Its resistance to UV radiation is good. Wear is inevitable. It has a density of .0238-.0253 lb / cu in. It is seen that hardwood has wear properties similar to concrete (Granta, 2014).

Professor Tahar El-Korchi, department head of the Civil and Environmental Engineering program at WPI, recommended using concrete as a material for creating the totem due to its suitable pourability, inexpensive cost, and ability to withstand environmental conditions. Professor El-Korchi also granted the team access to the concrete lab on WPI's campus, located in Kaven Hall. Therefore, concrete the most viable option for this project.

Autoclaved aerated concrete was considered for creating the totem pole. Autoclaved aerated concrete is less dense than standard concrete. It has a cost of .0272-.0363 USD / lb (Appendix A.3). It has a density of .0145-.0325 lb / cu in. It has equal moldability, frost resistance, and UV radiation as standard concrete. It has the same acceptable fresh water resistance, but less wear resistance than standard concrete. Autoclaved aerated concrete is created by using a foaming mixing agent during the creation of the concrete. It can be sculpted using woodworking tools. This allows for greater possibilities in sculpting the concrete, but it also makes a protective coating a necessity because it is more prone to wear than standard concrete. (Granta, 2014). For the aforementioned reasons, as well as its lack of availability, autoclaved aerated concrete was rejected.

The concrete used for the totem pole was a standard mix consisting of Quikrete Portland Cement. This concrete was chosen largely due to availability. Quikrete Portland Cement is a prefabricated material consisting of hydraulic compounds, calcium silicates and magnesium oxide. Quickrete only requires the addition of water and aggregate followed by curing time before taking on the form of concrete.

Light transmitting materials

Acrylic is a clear translucent material, a derivative of plexiglass known for its light weight and resistance to high impact stress (Acrylic Rod, 2014). Typical industrial diameter sizes of acrylic rod range from .19 in. to 7.87 in. (Perspex & Acrylic Index, 2015). In order to balance the amount of light transmitted and integrity of the concrete structure, diameter sizes one in., .5 in., .375 in., and .25 in. were chosen. These rods were purchased in lengths of four ft., four ft., 10 in., and 10 in., respectively, from various sources through the Amazon Corporation. This material was chosen for the totem pole in order to transmit light from within the concrete structure. Varying sizes were chosen to add to the aesthetic of the totem pole.

Along with acrylic, fishing line was used to help transmit light from the light source within the structure. Fishing line is a nylon based material that has high resistance to shear and strain forces. Fishing line is categorized by gauge, which represents the thickness of the fishing line. The highest gauge and thus thickest clear nylon monofilament fishing line was chosen to best transmit light. For use in the totem, 200 yds. of 80 gauge fishing line was purchased from a local Dick's Sporting Goods®.

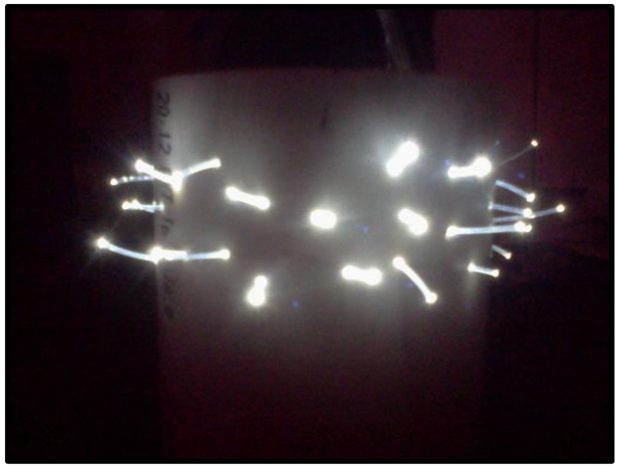


Figure 11: Acrylic Rod Test (9//12/2014). Photo by Dan Sanderson.

3D Printed Sculpture

Choosing red for the 3D printed objects emulated the small color palette of traditional Haida totem poles (8), while also representing the color scheme of WPI. The team chose to model various features for the totem pole by using a computer aided design program called SolidWorks. From these models, the team was able to generate 3D objects. To do this, the team worked with Joseph St. Germain, a laboratory manager within WPI's Robotics Engineering Department. 3D printed structures require a material known as filament. This material can be, but is not limited to, Polylactic Acid (PLA), Acrylonitrile Butadiene Styrene (ABS), Polyvinyl Acetate (PVA), Polycarbonate (PC), or High Impact Polystyrene (HIPS) (3D Printer Filament Comparison, 2015). The robotics lab printer, a Makerbot Replicator 2 Desktop 3D Printer, uses .0688 in. diameter PLA plastic (MakerBot, 2014). The Makerbot Replicator 2 works by heating a spool of filament and then moving a printhead through three dimensional space to create extremely thin layers of plastic, a method known as Fused Filament Fabrication. These 3D printed objects were mounted onto the totem pole with an epoxy to further enhance the high-tech medium of art.

Glass in the Prototype

The IQP team initially chose crushed glass as an aggregate for concrete because it is more resistant to environmental conditions such as rain, ultraviolet rays, heat, and cold. In order to ensure the structural integrity of the concrete, the glass must have relatively uniform-sized shards and irregular shape and must be greater in size or equivalent to .125” conventional aggregate. The type of glass that best matches these qualities is a variant of soda-lime glass. The variant is obtained when soda-lime glass is tempered. The definition of tempering is heating and cooling the glass so that its outer surface is in compression and inner surface is in tension. This strengthens the glass to a level above untempered glass, producing predictable breaking patterns of pieces with blunt edges when enough force is applied. (Pfaender, 1996).

Tempered soda-lime glass is commonly used in windows, glass bottles, containers, lamp bulbs, and mirrors. This is an accessible type of glass; it can easily be found at recycling facilities. (Granta, 2014).

Chapter 4: Construction of the Totem

Testing with Prototypes

After seeing embedded glass in the surface of stone counter tops and in concrete floors, the IQP team was inspired to use glass as an aggregate to transform concrete from an opaque to translucent material. A 60 lb bag of Quikrete Portland Cement (21) was purchased from Lowe's©. The cement was mixed with crushed glass from recycled bottles collected for use in small-scale prototype testing.

Stone course aggregate was replaced in the mix design with a proportional amount of glass aggregate. To accomplish this, sieves of size .375 in. were used to separate the glasses into two concentrations, greater than .375 in. and less than .375 in. The amounts of water and cement used were unchanged. The coarse aggregate weight was altered due to the different weight of tempered glass. The absolute volume method for determining the fine aggregate proportions was altered due to the change in the coarse aggregate absolute volume.

- Density of tempered glass was determined by dividing the mass of tempered glass by its volume as measured in a laboratory setting. The result was 155 lb / cu ft

Course Aggregate (CA) = 155 lb / cu ft * 27 cu ft * .55 = 2287 lb

- Absolute volume method

Water: 5.37 cu ft

Cement: 3.103 cu ft

Course Aggregate (CA): 2287 lb / (2.21 (Specific gravity of silica glass) * 62.4 lb / cu ft) = 16.58 cu ft

27 cu ft - (16.58 + 3.103 + 5.37) cu ft = 2.03 cu ft

Fine Aggregate (FA): 2 cu ft * 2.68 (specific gravity of fine aggregate) * 62.4 lb / cu ft = 335 lb

Water: 10%

Cement: 17%

Course Aggregate (CA): 64%

Fine Aggregate (FA) : 10%

(Kerkhoff, 2002)

The glass-concrete mixture was mixed and set in three 2x2x1 in., solid cubes and three 3x6 in. solid cylinders. The amount of glass aggregate was increased in the last of the 3x6 in. cylinders so that it had a significantly larger proportion of volumetric glass than the first two cylinders. After allowing the mix to settle in the casts, the sides were tapped with a rubber mallet to remove as many air bubbles from the concrete as possible. The vibrations from the mallet dissipated the air that was trapped when the concrete was poured. This ensured that the concrete would be non-air-entrained: it would have few to no air pockets left in the concrete mixture once it had dried in its mold. The concrete was left to dry for 24 hours before being moved into a curing room with 200% relative humidity. The concrete did not need to be fully cured for the standard 28 days because the strength of the concrete had no impact on the translucency testing.

The glass embedded into the concrete mixture would hypothetically allow light to pass through the concrete by refracting the light through the individual pieces of glass, and through the thin layer of concrete between the glass pieces. Although light intensity would be reduced due to the concrete in between the glass, enough light would be transmitted to classify the material as translucent.

The three aforementioned cubes were used to test translucency. The first was a pure concrete control, the second was a glass-concrete mixture, and the third was embedded with fishing line. After these molds had settled, they were taken into a dark room. A light source of 120 lumens was placed on one side of each mold. The transmitted light was subjectively measured. Both the concrete control and the glass-concrete mixture failed to transmit light. However, the mold embedded with fishing line had light shine through as seen in Figure 12.

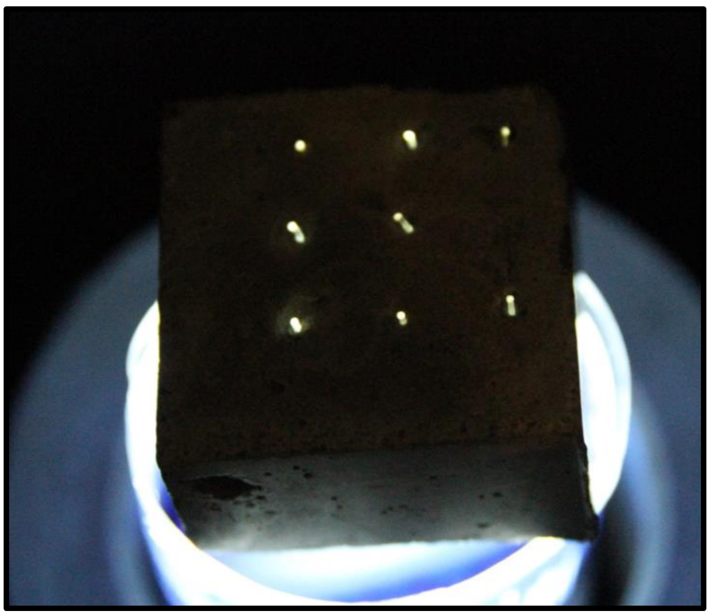


Figure 12: Fishing Line Embedded Concrete. From Worcester Polytechnic Institute (9//12/2014). Photo by Dan Sanderson.

Upon review of the results of this testing, it was obvious that the glass-concrete mixture did not test as expected, and therefore was the principle reason to reject glass as an aggregate.

A similar light transmitting test was conducted on an eight in. tall by two in. diameter cylindrical mold made of concrete embedded with fishing line, and a .375 in. diameter piece of acrylic, which was cut to one in. long. Pink tissue paper was placed inside to give color to the light. Although fishing line alone worked effectively, the combination of fishing line and acrylic rod embedded together allows for a greater amount of light to pass through in varying sizes as shown in Figure 13. The success of this prototype inspired the final design for the actual totem.

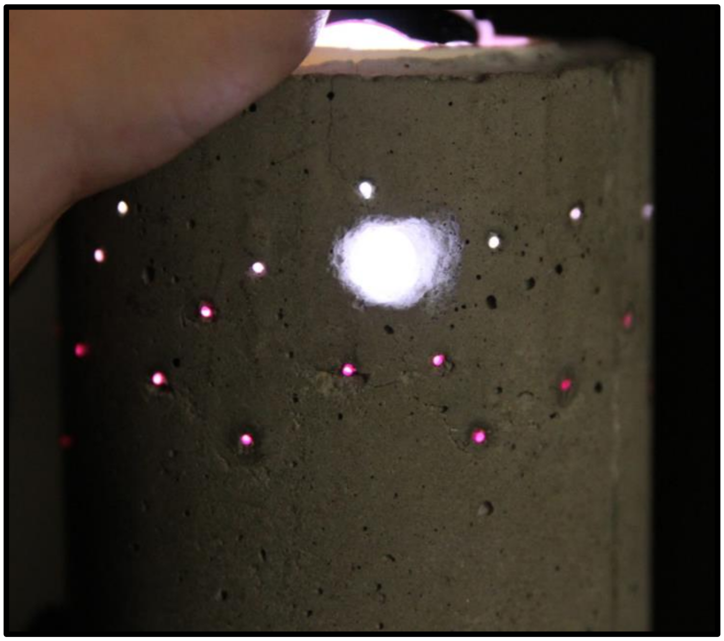


Figure 13: Fishing Line and Acrylic Embedded Concrete Tube with Pink Tissue Paper Filter. From Worcester Polytechnic Institute (11/28/2014). Photo by Dan Sanderson.

Using the prototypes, the team tested 3D printing PLA filament. Miniature black lettering was printed and an epoxy was used to adhere the letters to the prototype. The design generated was aesthetically pleasing and easy to implement.

Totem Parameters

Upon completion of the prototype experiments, the team made several decisions regarding the structure of the totem pole. The totem would be cast into four cylindrical concrete sections, each of two ft in diameter, to be placed on top of each other to give the totem a height of eight ft. An important consideration was to make the totem sections hollow, which reduced the amount of concrete necessary for a full-size totem and thereby reduced the weight of the structure. This also created an opportunity to use an internal light source to shine through the acrylic rod and fishing line embedded into the concrete.

Mold Preparation

Sonotube was used to create the molds. Sonotube is a common construction material for creating concrete cylinders. The Sonotubes, originally 12 ft long, were each cut into four two ft sections. The outer Sonotube had a 24 in. diameter, while the inner Sonotube had a 20 in. diameter. Four .75 in. plywood boards were cut into 3x3ft platforms. Blocks of wood were then placed on the corners and center of the plywood to make a raised platform. This would support the weight of the concrete, while also making it easier to move with a pallet jack for storage. Then a 2 ft section of each Sonotube was placed concentrically on the wooden platforms. These sections were held onto the platforms with wooden blocks screwed into the platform, as seen in Figure 14.

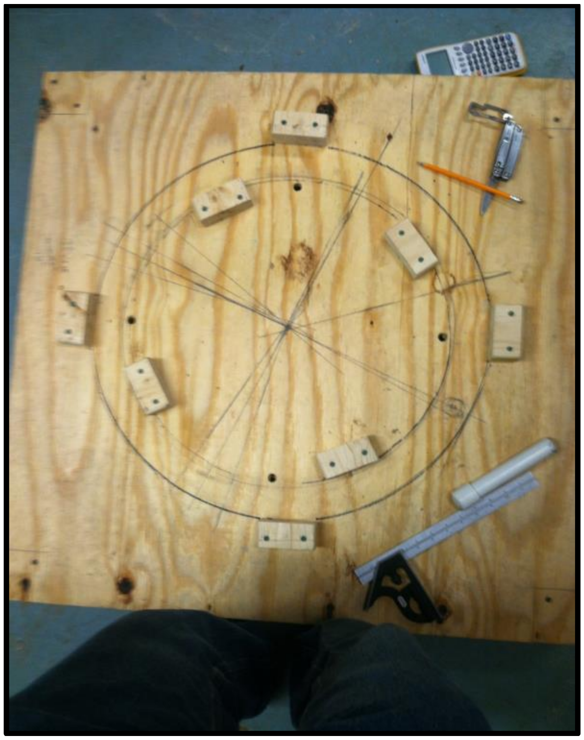


Figure 14: Raised Wooden Platform with Measured Sonotube Placement. (3/8/15)

After securing the Sonotubes, acrylic rods of varying diameters were cut with a bandsaw to a length of two in. each and were sanded by hand using 100 and 400 grit sandpaper to remove the grooves and discoloration from the cutting process. Fishing line filament was cut to 2.5 in. lengths. By drilling a hole through the inner Sonotube, it was possible to insert an acrylic rod into that hole such that it would be flush against the wall of the outer Sonotube. Holes were drilled through both Sonotubes and fishing line was threaded through the holes. The acrylic rods and fishing line were secured using hot glue as an adhesive.

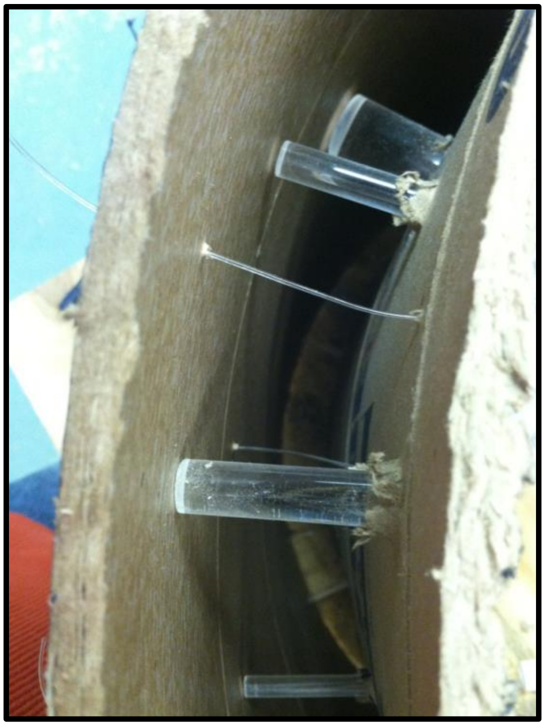


Figure 15: Acrylic Rod between Inner and Outer Sonotubes. (3/10/15)

Steel rod was cut into 12, one ft long, .5 in. thick segments. .75 in. diameter PVC was purchased to house these steel rods and act as a reinforcement. Four sleeves made from these PVC pipes were placed in the top and bottom of the sections of the Totem. The bottom sleeves were cut to six in. and adhered to the plywood with hot glue. The top sleeves had four holes drilled through them at equal intervals around the sleeve. Wire was threaded through the holes that suspended the sleeve over the mold while concrete was poured. Sleeves were not placed on the plywood on the bottom section of the totem base, nor on the top of the uppermost section.

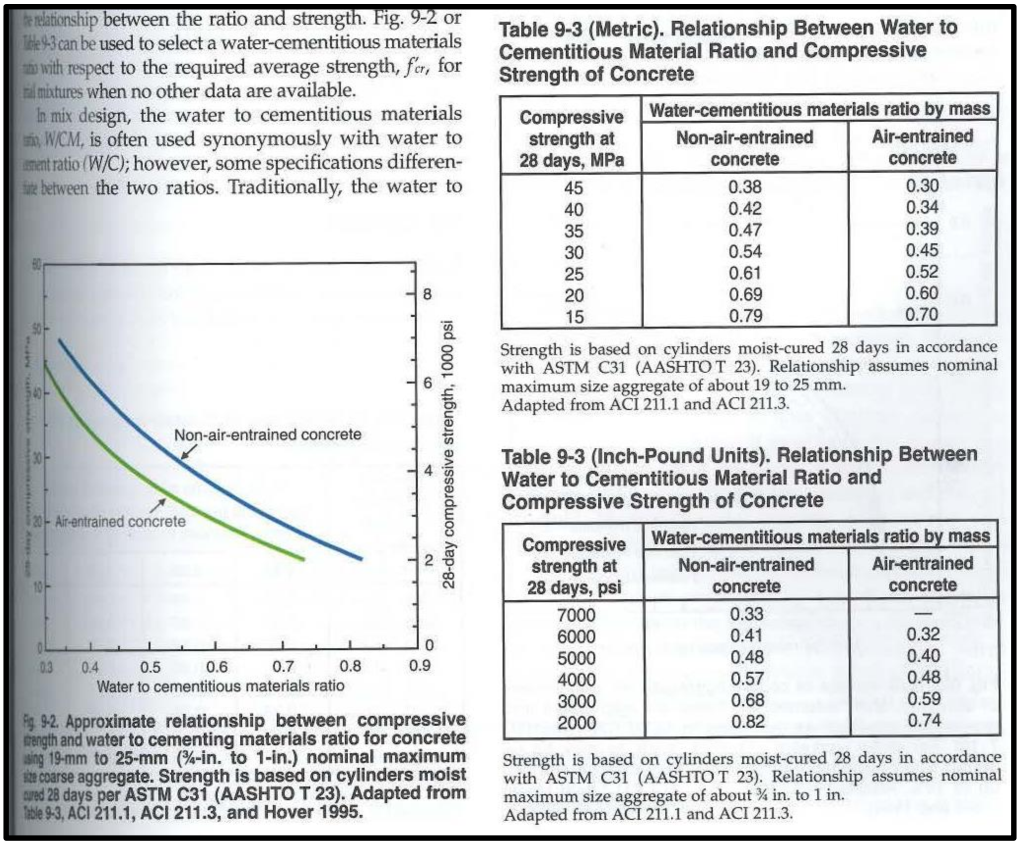
The PVC was capped off with slip PVC caps. Once the concrete had dried the PVC was cut flush to the totem sections. The PVC acted as a sleeve for the .5 in. steel rod so that the sections of concrete could be fitted together.

Concrete Mixture Calculations

The proportions of the cement, water, and aggregate in a batch of concrete is based on the exposure to rain, wind, hot and cold temperatures, chemicals, the desired strength of the concrete, and the concrete's effective workability (its relative viscosity and ability to fill a volume). The Totem was designed to withstand the climate of Worcester, MA. In the past five years, Worcester's average temperatures have ranged from 17.8°F to 77.5°F (U.S. Climate Data, 2015).

The concrete mixture for the totem was non-air-entrained. The water-cementitious ratio (mass of water divided by mass of concrete) was chosen to be .48. With a water-cementitious ratio of .48, the compressive strength of the resulting concrete would be 5000 PSI. The ratio was then readjusted to .55 to increase the workability of the concrete (Figure 16).

The standard concrete mix that was chosen for the final mold would yield a theoretical compressive strength of approximately 4800 PSI. The sections of the totem would produce a maximum of approximately 22 PSI at the very base of the structure (Figure 16, Table 9-3).



relationship between the ratio and strength. Fig. 9-2 or Table 9-3 can be used to select a water-cementitious materials ratio with respect to the required average strength, f'_{cr}, for trial mixtures when no other data are available.

In mix design, the water to cementitious materials ratio, W/CM, is often used synonymously with water to cement ratio (W/C); however, some specifications differentiate between the two ratios. Traditionally, the water to

Fig. 9-2. Approximate relationship between compressive strength and water to cementing materials ratio for concrete using 19-mm to 25-mm (¾-in. to 1-in.) nominal maximum size coarse aggregate. Strength is based on cylinders moist cured 28 days per ASTM C31 (AASHTO T 23). Adapted from Table 9-3, ACI 211.1, ACI 211.3, and Hover 1995.

Table 9-3 (Metric). Relationship Between Water to Cementitious Material Ratio and Compressive Strength of Concrete

Compressive strength at 28 days, MPa	Water-cementitious materials ratio by mass	
	Non-air-entrained concrete	Air-entrained concrete
45	0.38	0.30
40	0.42	0.34
35	0.47	0.39
30	0.54	0.45
25	0.61	0.52
20	0.69	0.60
15	0.79	0.70

Strength is based on cylinders moist-cured 28 days in accordance with ASTM C31 (AASHTO T 23). Relationship assumes nominal maximum size aggregate of about 19 to 25 mm.
Adapted from ACI 211.1 and ACI 211.3.

Table 9-3 (Inch-Pound Units). Relationship Between Water to Cementitious Material Ratio and Compressive Strength of Concrete

Compressive strength at 28 days, psi	Water-cementitious materials ratio by mass	
	Non-air-entrained concrete	Air-entrained concrete
7000	0.33	—
6000	0.41	0.32
5000	0.48	0.40
4000	0.57	0.48
3000	0.68	0.59
2000	0.82	0.74

Strength is based on cylinders moist-cured 28 days in accordance with ASTM C31 (AASHTO T 23). Relationship assumes nominal maximum size aggregate of about ¾ in. to 1 in.
Adapted from ACI 211.1 and ACI 211.3.

Figure 16: Water Cementitious Relationships. From Design and Control of Concrete Mixtures, Portland Cement Association. (2014)

The fine aggregate used for the totem pole concrete had a fineness modulus of 2.80. Fineness modulus is determined from the percentage of aggregate that is caught when the aggregate is passed through a series of sieves. Using the fineness modulus with a maximum coarse aggregate size of .5 in. the volume of coarse aggregate per unit volume of concrete is .55. The proportion of fine aggregate is determined by the following method:

- Using a half inch maximum size aggregate in a non-air-entrained concrete (1-2% entrapped air): the pounds of water needed for a 1 cu yd of concrete is 335 lb.
- By dividing the water content of 325 lb by the water-cementitious ratio of .55 generated 610 lb of cement.

335 lb / .55 =610 lb.

- Using the 2.8 fineness modulus of fine aggregate and translating that to .55 coarse aggregate per unit volume of concrete with a 100 lb / cu ft weight for the average coarse aggregate a value of 1485 lb of coarse aggregate (CA) was obtained.

100 lb / cu ft * 27 cu ft / cu yd * .55 = 1485 lb of concrete

- Calculating the absolute volume of the ingredients per 1 cu yd of concrete by dividing the weight per cu yd of the ingredients by the density of water and then summing the volumes and subtracting from 1 cu yd. The remaining volume in the mixture can be converted into a poundage of fine aggregate.

water: 335 lb / 62.4 lb / cu ft = 5.37 cu ft

cement: 610 lb / (3.15(specific gravity of cement) *62.4 lb / cu ft) = 3.103

Coarse Aggregate: 1486 lb / (2.68 (specific gravity of coarse aggregate) * 62.4 lb / cu ft) = 8.88

27 cu ft - (5.37 + 3.103 + 8.88) cu ft = 9.65 cu ft

Fine Aggregate = 9.65 cu ft * 2.68 (specific gravity of fine aggregate) *62.4 lb / cu ft = 1589 lb

- Adding the weights of the ingredients and dividing them by the individual ingredient a percent proportion of each ingredients in 1 lb was obtained.

Water: 8%

Cement: 15%

Coarse Aggregate: 37%

Fine Aggregate (FA): 40%

(Kerkhoff, 2002)

The above proportions were determined using the absolute volume method for a concrete mixture design. The design used stone as the coarse aggregate (Kerkhoff, 2002).

Additional mix info in Appendix B.

Concrete Pouring and Curing

Concrete was created in two cu. ft. batches. The process began with the collection of the materials. The coarse aggregate and fine aggregate were added to a concrete mixer according to the calculations. The aggregates were blended. .333 of the Portland Cement was added to the mixer with .375 of the water. Water, cement and aggregates were blended (Figure 17). The rest of the Portland Cement and water were added. The mixer was run for three minutes. The concrete was transferred by wheelbarrow from the mixer to the Sonotube sections. Scoops were used to pour the concrete into the mold. This was done carefully so that the aggregates and cement paste would not dislodge any of the acrylic or fishing line. While the concrete was poured, a mallet and an agitator were used to spread the concrete and make it non-air-entrained. The mold was then covered with plastic wrap (Figure 18). This process was applied to each of the four sections (Figure 19).

Figure 17: Concrete Mixing. From Kaven Hall, Worcester Polytechnic Institute (3/11/2015). Photo by Dan Sanderson.

Figure 18: Plastic Covering Mold. From Kaven Hall, Worcester Polytechnic Institute (3/11/2015). Photo by Dan Sanderson.

Figure 19: Four Concrete Sections. From Kaven Hall, Worcester Polytechnic Institute (3/11/2015). Photo by Dan Sanderson.

Unfortunately, there was not enough space in the curing room to store the four sections, so the totem pieces were left in open air with the plastic covering. After one week, the plastic was removed and the team began to peel off the Sonotube mold from both the inside and outside.

Polishing Totem Sections

After all the Sonotube had been peeled from the concrete, the team began the process of polishing the surface of the concrete to make a smooth and aesthetically appealing surface. First, the team used files, chisels and a dremel with a diamond file attachment to remove concrete that had seeped in-between the Sonotube casing and the acrylic rods. The removal of this concrete was necessary to get the light transmission that was desired. The process was time consuming and unfortunately marred the surface of some of the acrylic rods. The Dermal was the most efficient tool and would chip away the concrete but would then quickly gouge the surface of the acrylic. Very fine control of the tool was need by the team to successfully clean the surface of the acrylic.

After cleaning the acrylic rod surfaces so that light could pass through, the team cut the excess fishing line that stuck out form the surface of the concrete. Then the team sanded the surface of the totem. This made the totem smooth and removed several sharp surfaces that otherwise could have harmed viewers if they were to interact with the Totem.

Light Source System

The team created a light source consisting of 16 LED light bulbs with corresponding sockets mounted on an eight foot piece of square wood approximately 2x2 in. The bulbs were 60W equivalent (8.5W) LEDs that had a rating of 800 lumen. LED bulbs give off less heat, draw less power, and are more environmentally friendly than incandescent bulbs. The mounts were secured in crisscross patterns of four at a starting height of one foot and then consecutive rings of mounts every two ft. This layout established uniform lighting, as lights point in four different directions of the totem from the middle of every section. The mounts were wired in parallel so that the voltage would be the same across all light bulbs. The wiring was connected to a standard American 120V three prong outlet connector.

Figure 20: Internal Lighting Fixture. (3/12/15) Photo by Brian Baggaley

Creating the 3D Models

Several possibilities were considered in designing the features of the totem pole. These included wax casting, carving, and 3D printing.

Initially, the team thought about incorporating the totem pole features into the concrete mold. The first process considered was wax casting, where wax is poured over an existing object to form a mold. However, this process would require casting around an existing totem pole, which was not feasible. The second possibility discussed was to create the concrete cylinders at a thicker diameter and then carve the outside surface of the concrete down to the desired shapes.

Although these are more traditional and artistic methods, none of the team members had any experience in either wax casting or sculpting. Without the expertise of a skilled artisan, these methods had higher risk of damage and cracks in the concrete walls, as well as concerns for structural stability. Therefore, the team decided against these techniques and opted for a more attainable high-tech choice for the totem features.

The chosen method of adding dimension and shape to the totem pole was to 3D print parts, then attach them to the concrete pole. This option was feasible, since the materials were readily available at WPI. Additionally, Joseph St. Germain (23) is a subject-matter expert with respect to 3D printing.

The original 3D printed designs included the WPI logo, the school's mascot, Gompei the Goat, the WPI Two Towers icon, and small symbols representing a collection of WPI majors. After discussion with Luis Fraire, the Sprinkler Factory Gallery Manager, the WPI logo was replaced to further fit the theme of the gallery exhibit, "Red". Instead of the WPI logo the word for the color red, written in the language of the Haida people was created. Translated, "red" is "Sgíidang" in the Haida language (Haida Language, 2014). The team had limited access to the 3D printer due to time-sharing constraints from multiple departments. Therefore, it was decided that only the goat head, the two towers, and Sgíidang would be featured on the totem pole at the Sprinkler Factory exhibit.

The models for the 3D printed features of the totem were created in computer aided design software. The parts were designed to be able to fit on the print bed of the 3D printer. The dimensions were to be no larger than 5.9x5.9in. The letters for Sgíidang were made with the font creator in the Creo parametric software. The models were scaled proportionally to have the same height. The Two Towers were created by using a reference image in the Solidworks program and tracing the shape of the towers into simplified logos. The Goat model was created in two separate parts so that its total size could be larger than the 5.9 in. restriction allowed with one print. The parts were then saved as STL files so that they could be read by the 3D printer software and created.

Transporting the Totem

The Mungovan Movers Company transported the four sections of the totem to the Sprinkler Factory, where it would be assembled for display at the spring art exhibition. The construction of the totem pole was done in sections, which were each two ft. tall with an outer diameter of 24 in. and an inner diameter of 20 in. (29). The weight of these sections was approximately 300 pounds each. By building the totem in sections, it was easier to transport than an eight foot tall, 1200 pound solid object.

Erecting the Totem

The Totem team began assembling the sections by hand with the assistance of four other individuals (Acknowledgments). The totem sections were aligned with the ones below using the steel rod in the PVC sleeves (31). This was done to secure the sections. This way the sections could only be separated by moving the top section up and off of the metal rods. While stacking the third section, one of the PVC sleeves did not properly align with one of the sleeves in the section below. For this reason, there were only three steel rods between the second and third section. It was decided that the last section of the totem would be omitted for the art show at the Sprinkler Factory, since it was too difficult to lift overhead by hand. If the assemblers had attempted to lift the fourth section they would be putting themselves in a dangerous position that was deemed unnecessary and irresponsible by the team members. The fourth section would have also added to the likelihood of the totem toppling do to the higher center of gravity, creating a further unsafe situation that the public would be exposed to.

Next, the lighting source was installed inside the totem (38). Then the outer surface of the totem was sanded further as the surface became marked in the transportation. The 3D printed models were added to the surface of the totem using a two part epoxy. Red gift wrap tissue paper was placed around the inside of the totem so that viewing through the acrylic would create a red color, similar to the prototype (Figure 13).

Chapter 5: RED: Material. Symbol. Emotion. Temperature.

Presentation of the Totem

Figure 21: Postcard invitation for the opening of RED

The totem pole was displayed at “RED: Material. Symbol. Emotion. Temperature.” in the art gallery at the Sprinkler Factory. The team worked with Luis Fraire to get the totem installed and assembled for the exhibit on opening night held on April 11, 2015 from 5:00pm - 9:00pm. Thirty-five other artists were represented at the show. These artists responded to the theme of the color red for this show. In addition, lectures were given on the subject matter at an event called Art after Dark. See Appendix C for press release and advertisement.

Figures 21-25 show a combination of art and technology in a number of the works on display at the Sprinkler Factory. Figure 21 shows the interactive art that used electric motors and markers to create patterns on paper. A realistic recreation of the surface of Mars was presented using plaster and 3D printing and acrylic painting as can be seen in Figure 22. There were additional works that were done in the digital field with 3D animations, videos, and audio. Examples of these works are presented in Figures 23-25.

Figure 22: Motorized Pen, Sprinkler Factory (4/11/2015). Photo by Dan Sanderson.

Figure 23: Surface of Mars, Sprinkler Factory (4/11/2015). Photo by Dan Sanderson.

Figure 24: Visual Force Sensor Mats and Projections, Sprinkler Factory (4/11/015).

Figure 25: 3D RED Animation, Sprinkler Factory (4/11/2015).

Figure 26: Animation of realistic, Sprinkler Factory (4/11/2015).

At the opening reception for the RED show, the totem was received with praise by the community and artists present. Approximately 400 individuals attended the opening ceremony according to the assistant curator. Figure 26 shows the totem erected at the art exhibit, while Figure 27 displays how the light shines through the fishing line and acrylic rod as evening approached. Figure 28 shows a simulated representation of how the totem would have appeared with the final section included.

Figure 27: High-Tech Totem Pole, Sprinkler Factory (4/11/2015).

Figure 28: High-Tech Totem Pole in Darkness, Sprinkler Factory (4/11/2015).

Figure 29: Totem Pole with Fourth Section Attached, Sprinkler Factory (4/11/2015). Modified photo by Dan Sanderson.

Art Show Feedback

The team was given significant feedback from attendees at the RED exhibit. Several individuals were fascinated to see that engineering students had collaborated to produce a piece of artwork that was on display. Below is a list of quotes by attendees of the RED show in reference to the WPI totem. The comments are thought provoking and provide potential direction for further iterations of the Totem and ways the embedded acrylic could benefit architecture.

"I think they should do this with bridges."

"I'm waiting for it to do something."

"The light shining through the two towers looks really cool."

"Are we going to add anything to the totem over the next few weeks?"

"Art should come from the heart. The totem pole is too logical and from your heads."

"What does it do?"

"I like things that aren't like anything I've seen before."

"The fishing line lights remind me of star patterns, like constellations in the concrete."

Attendees asked questions about the Totem as well as about the Haida tribe. Showing that public art can help to grow interest in its subject matter.

"Where is the Haida tribe from?"

"Why the Haida tribe?"

"Is there a Native American population in Worcester?"

"What does 'SGIIDANG' mean?"

"Why isn't it made out of wood?"

"Why isn't it made entirely of concrete?"

Some of the questions asked were related to the creation and technology of the totem. These questions could help to express WPI's connection to art as well as its connection to the Sprinkler Factory.

"Is it one piece?"

"How did you get it to line up?"

"What materials were used?"

"How did you drill it?"

"How much concrete did it take?"

"Was this Sonotube filled with concrete?"

"How did you get it here?"

"Why is the cord coming out of the bottom and not the top?"

"What font did you print in?"

"How did you get those acrylic rods in? How can you buy acrylic rod?"

"Is the top sealed?"

"Can the 3D printing be customized in future renditions?"

Some people asked questions not about the totem pole, but of the team members' feelings. Allowing for the community to learn about the members of WPI in a more intimate way.

What year are you? What engineering are you studying?

What does this mean to you? Are you here for other reasons?

"What did you learn from the project?"

"Do you have an emotional attachment to the art?

The group realized they felt pride in building the totem. The team believed that the totem was a manifestation of both technology and art, combining elements of artistic expression with logical forethought. This IQP acknowledges the unity between art and education building upon the pillars of the WPI motto "Lehr und Kunst", which can be translated to "learning and skilled art." (Worcester Polytechnic Institute, Tech Bible, 2015)

WPI President Laurie Leshin was invited to the RED exhibit to see the totem. During President Leshin's visit, the team discussed different aspects of creating the totem and its future at WPI. She expressed a keen interest in having the totem as a permanent fixture at WPI. Details regarding the new WPI art committee were discussed. This committee could handle any future exhibitions, as well as the storage and placement of the totem. President Leshin praised the team for their work on the project and looked forward to the benefits that it would bring to WPI, both as a meeting place and public art piece.

Figure 30: President Leshin & the Totem Team, Sprinkler Factory (4/18/2015)

Chapter 6: Project Analysis

Cost analysis

The cost of materials for the Totem pole totaled $694.34, as detailed in Appendix D. The two most expensive individual costs were for the lighting and the Sonotubes. The lighting cost totaled $147.36. The positioning of lights could have been altered to three LEDs instead of four per section which would have reduced the cost by approximately $37. However, this small savings may have potentially had a negative impact on illumination. If the Sonotubes had been obtained from a construction site, rather than ordered through the WPI CEE department, the cost would have been reduced by as much as $269, a significant savings of 39%

Recommendations on how to Improve

Artistic recommendations include planning the positioning of the acrylic and fishing line in order to depict an image in the concrete. The viewers at the art show felt that an artistic design formed by a pattern in the lights would be interesting. The team's recommendation for Wendy Wacko would be to incorporate a human or animal pattern to represent the theme of the Haida people and their culture. A similar idea could be applied to the WPI-centric totem. For example, the motto "Lehr und Kunst" would make an excellent design choice to represent the WPI community. Any such pattern would likely require additional fishing line to enhance the image with more light points, thereby reducing blank space. An additional benefit of the fishing line is that it creates a transition from day to night lighting as the small light from the fibers is not noticeable in daylight, but becomes more obvious as ambient lighting fades. Adding too much additional acrylic could harm the integrity of the structure, as well as detract from the other symbolic features of the totem. It is important to maintain a balance between acrylic rods, symbolic features, and concrete so no component overwhelms any other.

Possible considerations for the symbolic features on the surface of the totem include making larger 3D printed carvings, created in the same way that the goat head was designed and assembled. Other ideas mentioned include an expansion of the 3D color palette or using color dyes on the concrete to complement the 3D printed design.

Some viewers at the art show felt that the 3D features of the totem were incongruent. Alternatively, machined cast molds for concrete could be poured into and attached to the surface of the totem using concrete anchors. This method would allow for larger features than the 3D printing, which was limited by bed size. The molds would allow for less material to be used than a solid version using the same material. While the concrete features would be more uniform and traditional, they would not exemplify the high-tech component of 3D printed features.

The team researched the possibility of using translucent concrete to follow Wendy's idea/schematic. The leader in translucent concrete production is a Hungarian concrete company called LiTraCon. LiTraCon embeds concrete with fine fiber optics. Using optical fibers in the creation of the structure would allow light from the center to show through these fibers (Al-Azzawi 2006). LiTraCon's special formula results in light being able to pass through the concrete leaving sharp shadows on the concrete when the light source is obstructed as in Figure 30. The concrete has comparable strength to standard concrete recipes. The fiber optics in the concrete act as an aggregate and bind the cement together, allowing for load bearing capabilities

(LiTraCon, 2015). However, the prohibitive costs of light transmitting concrete ruled out this option as impractical and extremely expensive. In a future rendition, WPI could possibly fund a new totem made from this translucent concrete. Alternatively, an MQP could be created that researches the creation of translucent concrete from a more technical aspect.

Figure 31: Ein Haus fuers Leben 01. From LiTraCon (LiTraCon, 2014).

Difficulties Encountered

The creation of the High Tech Totem, similar to many other projects, encountered challenges to the completion of the project. Technical issues, lack of budget, and team dynamics were among some of the issues that were overcome.

During the process to create acrylic-embedded concrete, the team placed the acrylic flush to the mold and then poured concrete inside, causing some faces of the acrylic to be covered with concrete. This meant that the concrete had to be scoured away from the acrylic surfaces for light to pass through, which could potentially damage the concrete. The recommendations provided in the report would be an alternate method for this process. Holes could be drilled on both inner and outer Sonotubes. Acrylic rods would be inserted to protrude from both sides of the mold, and then concrete would be poured. Once the concrete hardened, the acrylic rods would be cut down and sanded flush to the surface resulting in a more precise finish against the concrete. This oversight was due to the lack of artistic experience and forethought and due to time constraints that prevented testing. The time spent correcting this mistake, however, was more detrimental to the project than was worth the gains it as an upwards of six hours was spent uncovering acrylic from the concrete.

Transportation of the totem was another issue that was encountered by the team due to a lack of foresight. Although the totem was separated into sections so that it would be easier to transport and the raised platforms for use with pallet jacks helped, long distance transportation was the crux of the process. Lack of proper equipment prevented the team from being able to move the sections of the totem. A moving company was needed to transport the totem sections to the Sprinkler Factory. At the Sprinkler Factory another issue was encountered. The service elevator that would have allowed for ease of access to the studio area was out of operation. This required the moving company to pull the concrete sections on dollies up a long ramp. Having experience with moving and project planning could have prevented this tedious and expensive process.

Assembly of the totem was another hurdle that the team encountered. Miscommunication between Fraire and the team resulted in a loss of time after it was discovered that there was no support beams capable of acting as a fixed point for a pulley system. Without the ability to hoist the section and a lack of elevator or time to move lifting equipment, the totem needed to be assembled by hand. This resulted in the inability of the team to attach the final section of the totem. Better communication skills and fail-safe plans would have saved time and allowed for the completion of the full sculpture.

Communication was an issue between the team and Wacko. This lack of communication was present on both sides as many of the original emails from the team went without response. The team also began to send messages less frequently to Wacko. Had a better line of communication been established the totem team could have received more artistic insight form Wacko. In return the team could have provided their scientific and problem solving abilities to Wacko. This exchange of knowledge would have allowed for a more complete answer to the original proposal.

Team dynamics also prevented the project from being completed in an efficient manner. A lack of leadership prevented tasks from being completed on time. This issue resulted in separation in the team that prevented cohesion. Attendance to events was an issue for all members of the team. This furthered the separation in the team so that work was not spread equally. Work was also not communicated well, preventing members of the group from learning and contributing to problems that arose.

A lack of experience was another large detriment to the team. Sufficient background in construction was lacking. The large focus on concrete and construction for this project led to a significant amount of research alongside trial and error. Lack of time management experience made the project run against last minute deadlines that could have otherwise been avoided. With background in project work the team could have functioned more coherently and produced a better final product.

Chapter 7: Personal Reflections

Daniel Sanderson

The High-Tech Totem IQP was an experience that requires a lot of self-reflection. As a contributor to the project, I served a pivotal role in producing the final product. With technical skills and experience with building and constructing, I had the best grasp on how to create a concrete mixture and how to make the totem a reality. I took charge in emailing the team and setting up meetings which put me in the role of leader by the other members of the team. As a leader, I was not able to motivate others into completing tasks and did not communicate necessary tasks well. This meant that deadlines were missed and the project suffered. I also began doing work individually and did not communicate my procedures or findings well to the group. I believe this resulted in a separation that made the group require information only I was familiar with. This slowed work by the other members which meant I was picking up the slack of individual work resulting in a cyclic pattern as the result of my inability to communicate information. This failure cost time and hurt the quality of the IQP.

From this project I gained a breath of knowledge in the civil engineering field and learned about the importance of team cohesion. In the future I will take the knowledge gained from this experience to modify my behavior in teams to be more inclusive. I believe this will allow for more growth by all members of the team.

David Rubenstein

This IQP was a significant experience. Who comes out of their IQP as a gallery published artist? I learned a lot about how to work with concrete during this project. I also learned more about how organize writing an extremely long paper, something that before IQP I hadn't had to do before. With all the upsides of this project, there were also significant problems as well. First among these is the team did not communicate nearly as well as we should have. We had weekly meetings, when we should have had at least two meetings a week if not more. Also, not every team member was at every meeting. There were some team members who I barely saw at any point during the project. When we had major deadlines, we should have been much harder on ourselves to enforce them and get them done. I also think that we allowed the delegation of work to become uneven as the project wore on, with much more being asked of some of the team members than others. As a robotics major with a significant focus in computer science, my talents did not lend themselves well to physically constructing a structure.

Max Kinney

When I first saw this IQP, it was explained to me that the project would consist of researching materials with which a totem pole of the given specifications could be created. We were then to forward our findings to artist Wendy Wacko so that she could construct her art. Unfortunately, whenever we contacted Wendy, her responses were very delayed, and soon the concept of helping to create a work of art had become detached from the project. With advising Wendy no longer the goal of the project, the new goal became to work as a group to create a proof of concept with our findings.

There were many difficulties that came with this project in addition to Wendy's absence. The project was not completed in the time frame we had hoped for, leading to several difficulties. The additional workload that new terms provided lead to a significant decrease in teamwork. For me personally, I had heavy course work and could not dedicate time to a project that had completely removed itself from the aspects that had my interest. I stopped communication for longer than was reasonable. However it also proved rather difficult to get involved again when it became clear that I was still obligated to contribute to this project. I had to follow up several times on my messages to get involved again, and then once solid communication had happened there was another issue. The team had been making significant progress on the project without sharing the progress. This made it initially difficult to resume contributing to the project.

Brian Baggaley

The High-Tech Totem IQP has taught me many lessons. The first is that no project truly turns out exactly as expected. I feel as though this was particularly true for constructing the totem pole. Originally, the goal for this project was to research totem poles made by the Haida Native American tribe to assist Wendy Wacko in creating an artistic totem pole as an homage to existing totem poles. The piece was originally to be displayed in the Canadian Rockies. However, we were not able to establish stable communication with Wendy Wacko, which is the first instance of communication problems that would continue to hinder this project. Near the end of the first term, the team began to speculate on crafting an ice sculpture to display in winter for the Worcester Art Museum. This idea had potential, but we took action too late, as the art museum needed matters like this at least two months in advance. Thus, at the start of C term, our team was focused on establishing some proof of concept that a translucent effect could be produced in a concrete totem pole. It was at this point that it became clear the team was distanced from one another. Information was lost, attendance to meetings was inconsistent. I feel as though the information recorded in my meeting minutes also suffered, along with the delayed time it took to send the minutes out to everyone.

That being said, I also know that I have learned from this project. Planning is a crucial part of accomplishing goals, Moreover, I did not know anything about concrete or art in Worcester prior to this project. Although I am an electrical engineer, I have always had a tremendous appreciation for art. The Sprinkler Factory, to me, was an experience I won't soon forget. Not only was I exposed to unique styles and creative ideas, I was part of it. And I believe that working on this totem was a step in the right direction towards appreciating all that Worcester has to offer.

Chapter 8: Future of the High-tech Totem

Vision for the High-Tech Totem

The team has additional recommendations for the WPI art committee designated for future teams to oversee further development and display of this project. One suggestion is to add a solar panel to the top of the totem. This would allow the totem to be a fixture of new-age energy, as well as its own self-sustaining light source. Another suggestion would be to request that WPI department heads and their students submit 3D collaborations for the totem representing each respective major. This way, each major could choose a design to accurately represent their field of study. Another proposal would be for WPI to hold a school-wide contest each year to select a 3D design to add to the totem for each graduating class. The team recommends the use of an electric motor hoist to assemble the concrete sections in an outdoor environment.

The team recommends the WPI art committee contact or future project team contact ArtsWorcester, who expressed an interest in exhibiting the totem in their 12th Annual College Show. As there was a prohibitive limit to weight on art shown the Totem could not be shown at the event (ArtsWorcester, 2016).

Campus Installation

The placement of the high-tech totem involved finding a location where the eight foot art piece would fit. One area where the team considered placing the totem was on the quadrangle in the center of the main WPI campus. This location, although prominent and frequented, already contained two identifiable pieces of public art, WPI's statue of Gompei the Goat (Chapter 2, page 12) and the heraldic Seal in the center of the quad, with brick pathways containing names of WPI alumni. Another suggestion was attaching the totem to the side of one of the lecture or residence halls, but this would restrict a full 360 degree view. None of these options seemed to provide a unique location.

The proposed final location for the totem pole is at Gateway Park. Gateway Park is a WPI-owned, master-planned 12 acre park, located near three major highways, Route 70, 190, and 290. WPI aims to expand the complex in partnership with the business community to develop research and commercial facilities (Worcester Polytechnic Institute, Gateway Park, 2015). Since Gateway Park currently has no fixtures of public art, this would be a fresh location for the totem to be viewed from all possible angles without competition. Erected beside the parking garage, the totem could be viewed from different vantage points, offering various perspectives other than ground level. It would be recommended that the Totem be placed in the Gateway Park field with a path leading to it and a seating area. Along the path and around the seating, ground lights could be used to illuminate the area and alleviate safety concerns, without overwhelming the totem's lights.

Figure 32: High-Tech Totem at Gateway Park. From image of 50 Prescott and Totem at RED art Exhibit. Original retrieved from http://www.kelleher-sadowsky.com/wp-content/uploads/2014/12/50-Prescott-Street-Worcester-MA.jpg

The team believed that the totem would improve the area of Gateway Park and become a recognizable landmark for the Worcester community.

Future Project Work

The art director at the Sprinkler Factory, Luis Fraire, proposed the following idea to the team: assemble a pathway of several totems spanning the distance from the WPI campus, past the Worcester Art Museum to Gateway Park. Effectively, these totems could act as artistic streetlights, keeping the area safe while adding more culture and beauty to the surroundings. Each totem could have a separate theme submitted by a local artist in the community. Each artist could create their own totem, representing the culture of Worcester. This would require both communication and collaboration between the WPI art committee, ArtsWorcester, the Sprinkler Factory, PAWG, and the City of Worcester for approval to undergo such a large scale project of this nature. In doing so, WPI would become an epicenter of artistic and cultural activity, while integrating the lives of students with local artists and other members of the community.

A new Major Qualifying Project (MQP) or succession of MQP's would be the most feasible way to have a future iteration of the High Tech Totem become a known part of the community. By having this project be an MQP the teams will have more experience, more budget, and more technical skills needed to incorporate a highly functional totem into the area around campus. Fraire's idea could become a reality. Totems that provide light like a street lamp, are a meeting place with seating and a good atmosphere, and tell the story of WPI's culture and history or the culture and history of all of Worcester could become a fixture for the area and a mark of pride for WPI.

Closing Remarks

The High-Tech Totem team believe that further refinement of the totem pole design will allow for its successful construction and its installation will result in the first piece of public art to serve as a gathering and meeting point for students at WPI. By incorporating elements of WPI's culture, while also implementing technology into its design, the totem will connect and stimulate the WPI community. This installation would also improve the aesthetics of Gateway Park. The team would like the totem to attain the same notoriety as the Proud Goat statue. In 50 years, the hope is that the totem will be well-known by everyone and still standing on the WPI campus with improvements that future project groups have added to the structure.

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Appendix A

Values are estimates provided by Granta, Material Science. No warranty is given for the accuracy of this data.

A.1

Concrete (normal (Portland cement))

General information

Designation

Normal (Portland Cement) Concrete

Typical uses

General civil engineering construction, where there is little exposure to sulfates in soil or groundwater.

Composition overview

Composition (summary)

.6:1:2:4 Water:OPC:Fine:Coarse

Base	Other

Composition detail (metals, ceramics and glasses)

Al2O3 (alumina)	0.59			%	
CaO (calcia)	8.55			%	
Fe2O3 (ferric oxide)	0.43			%	
H2O (water)	7.9			%	
MgO (magnesia)	0.33			%	
SiO2 (silica)	81.7			%	
Other oxide	0.49			%	

Price

Price	* 0.0181		-	0.0272	USD/lb

Physical properties

Density	0.0795	-	0.0939	lb/in^3	
Porosity (closed)	0			%	
Porosity (open)	0.1	-	0.15	%	

Mechanical properties

Young's modulus	2.18	-	3.63	10^6 psi	
Yield strength (elastic limit)		0.145	-	0.174	ksi
Tensile strength	0.16	-	0.189	ksi	
Elongation	* 0	-	0.01	% strain	
Compressive strength	* 1.93		-	4.35	ksi
Flexural modulus	* 2.18		-	3.63	10^6 psi
Flexural strength (modulus of rupture)		0.247	-	0.348	ksi
Shear modulus	* 0.943		-	1.58	10^6 psi
Bulk modulus	* 1.03		-	1.73	10^6 psi
Poisson's ratio	0.1	-	0.2		
Shape factor	3				
Hardness - Vickers	* 5.7	-	6.3	HV	
Fatigue strength at 10^7 cycles	* 0.0783		-	0.122	ksi
Mechanical loss coefficient (tan delta)		0.01	-	0.03	

Impact & fracture properties

Fracture toughness	0.319	-	0.41	ksi.in^0.5

Thermal properties

Melting point	1.71e3	-	2.19e3	°F

Maximum service temperature		896	-	950	°F	
Minimum service temperature		256	-	238	°F	
Thermal conductivity	0.404	-	1.5	BTU.ft/hr.ft^2.°F		
Specific heat capacity	0.199	-	0.251	BTU/lb.°F		
Thermal expansion coefficient	2.78	-	6.67	µstrain/°F		
Latent heat of fusion	* 305		-	344	BTU/lb	

Electrical properties

Electrical resistivity		1.85e12	-	1.85e13	µohm.cm	
Dielectric constant (relative permittivity)		* 8	-	12		
Dissipation factor (dielectric loss tangent)		* 0.001		-	0.01	
Dielectric strength (dielectric breakdown)		20.3	-	45.7	V/mil	

Optical properties

Color	Gray
Transparency	Opaque

Durability

Water (fresh)	Excellent
Water (salt)	Acceptable
Weak acids	Limited use
Strong acids	Unacceptable
Weak alkalis	Acceptable
Strong alkalis	Unacceptable
Organic solvents	Excellent
Oxidation at 500C	Excellent
UV radiation (sunlight)	Excellent
Halogens	Limited use
Metals	Limited use
Flammability	Non-flammable

Primary production energy, CO_2 and water

Embodied energy, primary production	430	-	559	BTU/lb		
CO_2 footprint, primary production	0.0903	-	0.0998	lb/lb		
Water usage	* 89.4		-	98.8	in^3/lb	

Processing energy & CO_2 footprint

Grinding energy (per unit wt removed)		* 886		-	980	BTU/lb
Grinding CO_2 (per unit wt removed)		* 0.155		-	0.171	lb/lb

Recycling and end of life

Recycle	True					
Embodied energy, recycling		* 326		-	360	BTU/lb
CO_2 footprint, recycling		* 0.0631		-	0.0698	lb/lb
Recycle fraction in current supply	13	-	14.4	%		
Downcycle	True					
Combust for energy recovery	False					
Landfill	True					
Biodegrade	False					

Notes

Warning

Attacked by sulfates.

Other notes

Air cured. Wider ranges on values are generally 7 day-28 day values.

Links

ProcessUniverse

Producers

Reference

Shape

Values marked * are estimates.

No warranty is given for the accuracy of this data

A.2

Hardwood (oak) parallel to the grain

Description

The material

Hardwoods come from broad leave, deciduous, trees such as oak, ash, elm, sycamore, mahogany. Although most hardwoods are harder than softwoods, there are exceptions: balsa, for instance, is a hardwood. Wood must be seasoned before it is used. Seasoning is the process of drying the natural moisture out of the raw timber to make it dimensionally stable, allowing its use without shrinking or warping. In air-seasoning the wood is dried naturally in covered but open-sided structure. In kiln-drying the wood is artificially dried in an oven or kiln. Modern kilns are so designed that an accurate control of moisture is achieved.

Wood has been used for construction and to make products since the earliest recorded time. The ancient Egyptians used it for furniture, sculpture and coffins before 2500 BC. The Greeks at the peak of their empire (700 BC) and the Romans at the peak of theirs (around 0 AD) made elaborate buildings, bridges, boats, chariots and weapons of wood, and established the craft of furniture making that is still with us today. More diversity of use appeared in Mediaeval times, with the use of wood for large-scale building, and mechanisms such as pumps, windmills, even clocks, so that, right up to end of the 17th century, wood was the principal material of engineering. Since then cast iron, steel and concrete have displaced it in some of its uses, but timber continues to be used on a massive scale, particularly in housing and small commercial buildings.

Composition (summary)

Cellulose/Hemicellulose/Lignin/12%H2O

General properties

Density		0.0238	-	0.0253	lb/in^3	
Price	* 0.299		-	0.331	USD/lb	

Material form that data applies to

Bulk	True
Sheet	True

Building system

Superstructure	True
Enclosure	True
Interiors	True
Services	False

Mechanical properties

Young's modulus		1.91	-	2.02	10^6 psi	
Shear modulus	* 0.131		-	0.16	10^6 psi	
Bulk modulus	* 0.194		-	0.218	10^6 psi	
Bending modulus		0.0725	-	0.435	10^6 psi	
Poisson's ratio		0.37	-	0.48		
Yield strength (elastic limit)		6.24	-	7.98	ksi	
Tensile strength		16	-	20.3	ksi	
Compressive strength		7.11	-	10.2	ksi	
Bending strength		0.435	-	1.16	ksi	
Elongation	* 1.99		-	2.43	% strain	
Hardness - Vickers		* 6	-	8.58	HV	
Fatigue strength at 10^7 cycles		* 4.06		-	4.93	ksi
Fracture toughness		5.92	-	7.28	ksi.in^0.5	
Mechanical loss coefficient (tan delta)		0.007	-	0.01		

Thermal and combustion properties

Thermal conductor or insulator?	Good insulator			
Thermal resistivity	2.5	-	3.03	m.°C/W
Thermal expansion coefficient	* 1.11	-	6.11	µstrain/°F
Specific heat capacity	0.396	-	0.408	BTU/lb.°F
Glass temperature	170	-	215	°F
Maximum service temperature	242	-	278	°F
Flammability	Flammable			
Emissivity	0.81	-	0.9	

Hygro-thermal properties

Water absorption	12	-	30	%
Frost resistance	Good			

Electrical properties

Electrical conductor or insulator?	Poor insulator			
Electrical resistivity	* 6e13	-	2e14	µohm.cm
Dielectric constant (relative permittivity)	7.5	-	9.1	
Dissipation factor (dielectric loss tangent)	0.06	-	0.07	
Dielectric strength (dielectric breakdown)	* 10.2	-	15.2	V/mil

Optical properties

Natural color

Brown

Transparency	Opaque			
Transmissivity	0			%

Acoustic properties

Sound absorption	Average
Sound isolation	Average

Processability (scale 1 = impractical to 5 = excellent)

Moldability	2	-	3
Machinability	5		

Durability

Water (fresh)	Limited use
Water (salt)	Limited use
Weak acids	Limited use
Strong acids	Unacceptable
Weak alkalis	Acceptable
Strong alkalis	Unacceptable
Organic solvents	Acceptable
UV radiation (sunlight)	Good
Wear resistance	Unacceptable
Industrial atmosphere	Limited use
Rural atmosphere	Limited use
Marine atmosphere	Limited use

Primary material production: energy and CO2

Embodied energy, primary production	* 1.06e3	-	1.18e3	kcal/lb
CO2 footprint, primary production	* 0.841	-	0.93	lb/lb
Water Usage	* 79.7	-	88.1	gal(US)/lb

Material processing: energy

Coarse machining energy (per unit wt removed)	* 132	-	146	kcal/lb
Fine machining energy (per unit wt removed)	* 862	-	952	kcal/lb
Grinding energy (per unit wt removed)	* 1.67e3	-	1.85e3	kcal/lb

Material processing: CO2 footprint

Coarse machining CO2 (per unit wt removed)	* 0.0917	-	0.101	lb/lb
Fine machining CO2 (per unit wt removed)	* 0.597	-	0.659	lb/lb
Grinding CO2 (per unit wt removed)	* 1.16	-	1.28	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	False				
Recycle fraction in current supply	8	-	10	%	
Downcycle	True				
Combust for energy recovery	True				
Heat of combustion (net)	* 2.14e3	-	2.31e3	kcal/lb	
Combustion CO_2	* 1.69	-	1.78	lb/lb	
Landfill	True				
Biodegrade	True				
A renewable resource?	True				

Supporting information

Design guidelines

Wood offers a remarkable combination of properties. It is light, and, parallel to the grain, it is stiff, strong and tough - as good, per unit weight, as any man-made material. It is cheap, it is renewable, and the fossil-fuel energy needed to cultivate and harvest it is outweighed by the energy it captures from the sun during growth. It is easily machined, carved and joined, and - when laminated - it can be molded to complex shapes. And it is aesthetically pleasing, warm both in color and feel, and with associations of craftsmanship and quality.

Technical notes

The values for the mechanical properties given for woods require explanation. Wood-science laboratories measure the mean properties of high-quality "clear" wood samples: small specimens with no knots or other defects; the data for woods in the Level 3 CES database is of this type. This is not, however, the data needed for design. All engineering materials have some variability in quality and properties. To allow for this design handbooks list "allowables" - property values that will be met or exceeded by, say, 99% of all samples (meaning the mean value minus 2.33 standard deviations). Natural materials like wood show greater variability than man-made materials like steel, with the result that the allowable values for mechanical properties may be only 50% of the mean. There is a second problem: structures made of wood are much larger than the wood-science test samples. They contain knots, shakes and sloping grain, all of which degrade properties. To deal with this the wood is "stress-graded" by visual inspection or by automated methods, assigning each piece a stress grading G between 0 and 100: a grading of G means that properties are further knocked down by the factor G/100. Finally, in building construction, there is the usual requirement of sound practice - an overall safety factor, typically 2.25. The result is that the permitted stress for design may be as low as 20% of the value quoted in wood-science tabulations.
The data in this record is for oak of medium density, and lists wood-science ranges for the properties of clear wood samples.

Typical uses

Flooring; stairways, furniture; handles; veneer; sculpture, wooden ware; sash; doors; general millwork; framing- but these are just a few. Almost every load-bearing and decorative object has, at one time or another, been made from wood.

Related standards

BS 565 (1963)
BS 881 (1955)
BS 569 (1955)
BS 1860: Part 1 (1956)
CP 112 (1967)
CSI/CSC Masterformat Section Numbers:
06 10 00 ROUGH CARPENTRY
06 14 00 Treated Wood Foundations
06 16 00 Sheathing
06 12 00 Structural Panels
06 15 00 Wood Decking
06 17 00 Shop-Fabricated Structural Wood
06 17 53 Shop-Fabricated Wood Trusses
06 17 33 Wood I-Joists

Links

Reference
ProcessUniverse

Producers
Values marked * are estimates.
No warranty is given for the accuracy of this data

A.3

Autoclaved aerated concrete (AAC)

Description

The material
Autoclaved aerated concrete (AAC) is a foamed or cellular concrete produced by adding a foaming agent to the concrete mix in order to entrap air bubbles during the curing process, which involves steam heating ("autoclaving"). The resultant low density product is used to make lightweight buildings, structures and decorations. The strength of the concrete can be improved by the addition of fibers, but the values quoted here are for unreinforced concrete.
Composition (summary)
0.6:1:0:4 Water:OPC:Fine:Coarse
Mix constituents and proportions are varied to produce widely ranging properties.

General properties

Density		0.0145	-	0.0325	lb/in^3	
Price	* 0.0272		-	0.0363	USD/lb	

Material form that data applies to

Bulk	True

Building system

Superstructure	True
Enclosure	True
Interiors	False
Services	False

Mechanical properties

Young's modulus		1.74	-	2.61	10^6 psi	
Shear modulus	* 0.74		-	1.1	10^6 psi	
Bulk modulus	* 0.914		-	1.38	10^6 psi	
Bending modulus	* 1.74		-	2.61	10^6 psi	
Poisson's ratio		0.17	-	0.2		
Yield strength (elastic limit)		* 0.087		-	0.16	ksi
Tensile strength	* 0.087		-	0.16	ksi	
Compressive strength		0.174	-	0.271	ksi	
Bending strength		0.102	-	0.189	ksi	
Elongation		0			% strain	
Hardness - Vickers		* 0.36		-	0.56	HV
Fatigue strength at 10^7 cycles		* 0.0435		-	0.102	ksi
Fracture toughness	* 0.0364		-	0.0546	ksi.in^0.5	
Mechanical loss coefficient (tan delta)		0.01	-	0.03		

Thermal and combustion properties

Thermal conductor or insulator?		Poor insulator			
Thermal resistivity		1.25	-	1.43	m.°C/W
Thermal expansion coefficient		3.89	-	6.67	µstrain/°F
Specific heat capacity	* 0.205		-	0.263	BTU/lb.°F
Melting point		1.71e3	-	2.19e3	°F
Maximum service temperature		392	-	572	°F
Flammability		Non-flammable			
Emissivity		0.63	-	0.97	

Hygro-thermal properties

Water vapor permeability	6.01e-12	-	2.8e-11	kg/s.m.Pa
Frost resistance	Average			

Electrical properties

Electrical conductor or insulator?	Poor insulator				
Electrical resistivity	3.16e11	-	3.16e12	μohm.cm	
Dielectric constant (relative permittivity)	* 8	-	12		
Dissipation factor (dielectric loss tangent)	* 0.001		-	0.01	
Dielectric strength (dielectric breakdown)	* 12.7		-	50.8	V/mil

Optical properties

Natural color

Gray

Transparency	Opaque	
Transmissivity	0	%

Acoustic properties

Sound absorption	Good
Sound isolation	Average

Processability (scale 1 = impractical to 5 = excellent)

Moldability	3	-	4
Machinability	4	-	5

Durability

Water (fresh)	Acceptable
Water (salt)	Acceptable
Weak acids	Limited use
Strong acids	Unacceptable
Weak alkalis	Acceptable
Strong alkalis	Unacceptable
Organic solvents	Excellent
UV radiation (sunlight)	Excellent
Wear resistance	Unacceptable
Industrial atmosphere	Limited use
Rural atmosphere	Acceptable
Marine atmosphere	Limited use

Primary material production: energy and CO2

Embodied energy, primary production	108	-	141	kcal/lb
CO2 footprint, primary production	0.0903	-	0.0998	lb/lb
Water Usage	* 1.71	-	1.89	gal(US)/lb

Material processing: energy

Grinding energy (per unit wt removed)	* 103	-	114	kcal/lb

Material processing: CO2 footprint

Grinding CO2 (per unit wt removed)	* 0.0712	-	0.0787	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	True				
Embodied energy, recycling	* 82.1		-	90.8	kcal/lb
CO2 footprint, recycling	* 0.0631		-	0.0698	lb/lb
Recycle fraction in current supply	13	-	14.4	%	
Downcycle	True				
Combust for energy recovery	False				
Landfill	True				
Biodegrade	False				
A renewable resource?	False				

Supporting information

Design guidelines

Autoclaved Aerated Concrete (AAC) is light colored and contains many small air bubbles that contribute to the material's insulating properties. AAC can be sculpted with wood working tools but, being soft, it is rarely used in an exposed condition, but requires surface protection. AAC is load-bearing, insulating and capable of being 'sculpted', giving it potential as an environmentally responsible building material.

Technical notes

AAC has good compressive strength, allowing its use as a load-bearing material in structures up to 3 storeys high. Entire buildings can be made in AAC including walls, floors and roofing. Lintels, floor slabs and roofing panels require steel reinforcement to give structural adequacy. AAC has reasonably good insulation qualities and its low thermal mass gives energy efficiency. It provides good sound insulation, is suited for fire-rated applications but its porosity allows it to take up water if exposed. There are a number of proprietary finishes based on acrylic polymers, which, when mixed with sand and cement, provide a durable and water resistant coating.

The quoted properties are for unreinforced concrete. However, in practice, they are significantly improved by the addition of fibers.

Typical uses

Concrete blocks, lightweight tilt-up panels, foamed concrete floor screeds, sound and thermal insulation, geotechnical and ornamental concrete applications - e.g. column heads

Tradenames

LiteBuilt, Hebel, Ytong

Related standards

CSI/CSC Masterformat Section Numbers:

03 00 00 CONCRETE

Further reading

The Australian Government web site www.greenhouse.gov.au carries useful information on AAC.

Links

Reference

ProcessUniverse

Producers

Values marked * are estimates.

No warranty is given for the accuracy of this data

Appendix B

Mix Date		28-Jan-15	
w/c		0.55	
silica fume(%C)		0%	
Slump		5-6 "	
Air		4.00%	
Course Aggregate Properties			
Sp.Gr.		2.67	
Max Agg Size(in)		.5 in	
Dry U.W.(lb)		100	
M.C.(%)		0.00%	
Absorption(%)		1.00%	
Fine Aggregate Properties			
Sp. Gr.		2.65	
F.M.		2.8	
Absorption(%)		2.00%	
M.C. (%)		0.00%	
Mix Design Calculations			
Water (T9.5), lbs		325	
Cement		590.91	
Silica Fume		0.00	
CA Vol% (T9.4)		60.00%	
CA wt dry		1,620.00	
Volume Calculations			
Cement Sp. Gr.			
Vol Water (cf)		5.21	
Vol Cement (cf)		3.01	
Vol Silica Fume		0.00	
Vol C.A. (cf)		9.72	
Vol Air (cf)		1.08	
Subtotol Vol (cf)		19.02	
Vol F.A. (cf)		7.98	
Wt F.A.(dry), lbs		1,319.90	Laboratory Mix
Corrected Weights			8
Cement (lbs)		590.91	175.08
Silica Fume		0.00	0.00
CA (lbs)		1,620.00	480.00
FA (lbs)		1,319.90	391.08

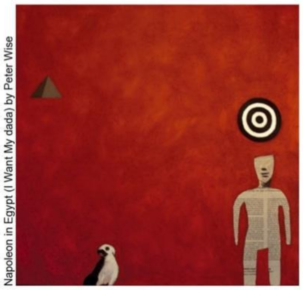
Water		367.60	108.92
AEA(oz/100 # cwt)		2.5	0.74
AEA (ml)		436.83	129.43
H2O Added (lb)			0.00
WR (Oz/100# cwt)		0	0.00
WR (ml)		0.00	0.00

Appendix C

For immediate release: April 2015
RED: Material. Symbol. Emotion.Temperature.
The Sprinkler Factory
38 Harlow St
Worcester, MA 01605
info@sprinklerfactory.com
sprinklerfactory.com
Opening Reception: April 11th 5-9pm (Saturday) 2015
RED: Material. Symbol. Emotion. Temperature. brings together 35 Worcester area artists who offer perspectives and interpretations on the subject of red. This exhibition explores the many intriguing aspects associated with this most primal color. Passion, vitality, danger, aggression, heat, rebellion, dominance, charity, abundance and intensity are but a few facets of this multidimensional subject.
The artists of the RED exhibition represent the color in a myriad of creative and unexpected ways. The visitor can experience red through video, sculpture, installation, photography, painting, collage, illustration, fabric, glass, ice, sound and interactive art. Join us as we celebrate red in this most diverse, reactive and innovative group exhibition!
Participating Artists:
Lisa Barthelson http://www.lisabarthelson.com/
Scott Boilard
John Buron http://www.johnburon.com/
Brian Burris http://www.burrisworks.com/
Stephanie Chubbuck http://www.stephaniechubbuck.com/
Donna Dufault http://www.erbphoto.com/
Veronica Fish http://www.veronicafish.portfoliobox.me/
Luis Fraire http://luisantoniofraire.com/
Tim Furman http://www.millionsofimages.com/
John Garton
Anne Greene
Ruth Hemenway
Tim Johnson
Melba Juez-Perrone http://www.melbajuezperrone.com/
Nicholas Kantarelis http://www.nicholaskantarelis.com/
Catherine Kirsch http://www.catherinekirsch.com/

Amy Klausmeyer https://moonlightconfetti.wordpress.com/
Jeanne Kowal
Joanna Matuck http://www.joannamatuckstudios.com/
Michelle May
Lauren Monroe http://www.worcesterthinktank.com/
Kim Noonan
Victor Pacheco http://www.vicpacheco.com/
John Pagano http://johnpagano.info/
Paul Puiia http://www.paulpuiia.com/
Elaine Pusateri Cowan
Rainer Reichel
Brian Riach
Emily Sandagata http://emilysandagata.viewbook.com/
Robb Sandagata http://www.rsandagata.com/
Mark Spencer http://www.markspencerstudio.com/
Susan Swinand http://www.swinand.com/
Marguerite White http://margueritetwhite.com/
Peter Wise http://www.peterwiseart.com/
WPI Totem Project
GALLERY HOURS:
April 12th 1-4pm (Sunday)
April 17th 4-8pm (Friday)
April 18th 1-4pm (Saturday)
April 19th 1-4pm (Sunday)
April 24th 4-8pm (Friday)
April 25th 1-4pm (Saturday)
April 26th 1-4pm (Sunday)
CLOSING RECEPTION:
May 2nd 5-9pm (Saturday)
SPECIAL EVENTS:
Slow Art Day
April 11th (Saturday Morning)
10:00-10:30am Meet in the gallery
10:30-11:30am Look at art slowly
11:30-12:00pm Discuss the experience
Slow Art Day is the global all-volunteer event with a simple mission: help more people discover for themselves the joy of looking
at and loving art. More info: http://www.slowartday.com/
ART AFTER DARK (talk & discussion series with Birgit Strähle)
April 17th 8-9pm (Friday) Sources of Red – Facts, Legends, and Secret Recipes
*guests are invited for a pre-talk reception at 7:30pm
April 24th 8-9pm (Friday) A Journey Through Cultural History – The Many Meanings of Red
*guests are invited for a pre-talk reception at 7:30pm
All events are FREE and OPEN to the PUBLIC

RED: Material. Symbol. Emotion. Temperature.



Napoleon in Egypt (I Want My dada) by Peter Wise

OPENING RECEPTION:
April 11th 5-9pm (Saturday)

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April 17th 4-8pm (Friday)
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April 19th 1-4pm (Sunday)
April 24th 4-8pm (Friday)
April 25th 1-4pm (Saturday)
April 26th 1-4pm (Sunday)

CLOSING RECEPTION:
May 2nd 5-9pm (Saturday)

Visit: sprinklerfactory.com
for details on special events
throughout the month of April

Lisa Barthelson • Scott Boilard • John Buron • Brian Burris • Stephanie Chubbuck • Donna Dufault
Veronica Fish • Luis Fraire • Tim Furman • John Garton • Anne Greene • Ruth Hemenway • Tim Johnson
Melba Juez-Perrone • Nicholas Kantarelis • Catherine Kirsch • Amy Klausmeyer • Jeanne Kowal
Joanna Matuck • Michelle May • Lauren Monroe • Kim Noonan • Victor Pacheco • John Pagano
Paul Puiia • Elaine Pusateri Cowan • Rainer Reichel • Brian Riach • Emily Sandagata • Robb Sandagata
Mark Spencer • Susan Swinand • Marguerite White • Peter Wise • WPI Totem Project

Sprinkler Factory
38 Harlow St
Worcester Ma

Closing Reception

Saturday May 2nd 5-9pm

RED: Material. Symbol. Emotion. Temperature.

Barthelson
Boilard
Buron
Burris
Chubbuck
Dufault
Fish
Fraire
Furman
Garton
Greene
Hemenway
Johnson
Juez-Perrone
Kantarelis
Kirsch
Klausmeyer
Kowal
Matuck
May
Monroe
Noonan
Pacheco
Pagano
Puiia
Pusateri Cowan
Reichel
Riach
E Sandagata
R Sandagata
Spencer
Swinand
White
Wise
Totem Project

Sprinkler Factory
38 Harlow St Worcester Ma

Appendix D

Bill of Materials

Material	Company	Quantity	Unit Cost	Total Cost
Educational Acrylic Friction Rod, 3/8" Diam, 10" length (bundle of 5)	Amazon.com LLC	1	10.68	10.68
Acrylic Round Rod, Transparent Clear, Meets UL 94HB, 1/2" Diam, 4' length	Amazon.com LLC	1	21.81	21.81
Acrylic Round Rod, Transparent Clear, Meets UL 94HB, 1" Diam, 4' length	Amazon.com LLC	1	27.23	27.23
Plastruct Acrylic Rod 1/4" (10) PLS90294	The BT Group	3	7.84	23.52
Ande 80lb Monofilament Line 200yd	Dick's Sporting	1	13.8	13.80
2-3-96 multi-purpose stud	Lowes	2	2.1	4.20
3/4-IN x 5-FT SCH40 PVC	Lowes	3	2.28	6.84
2-2-8 Premium Furring STR	Lowes	2	1.92	3.84
10 Ct 3/4-IN SCH-40 CAP	Lowes	2	3.33	6.66
OSI 60W (8.5W) LED A19 NA	Lowes	16	5.98	95.68
Phenolic W/one leg Hickey	Lowes	16	3.23	51.68
50-lb all purpose sand	Lowes	1	2.72	2.72
94-lb Portland Cement	Lowes	1	9.84	9.84
Dremel Carbide Cutter	Lowes	1	11.97	11.97
Dremel 3/32 - IN DMTaper	Lowes	1	7.58	7.58

1 1/2 - INx2 -FT PVC SCH40	Lowes	1	3.31	3.31
3 - IN x 2 - FT PVC DWv CELLC	Lowes	1	6.28	6.28
HM 28 - IN Wire Pigtail STA	Lowes	1	0.98	0.98
400 Grit Sandpaper (4 pack)	Home Depot	1	1.5	1.50
100 Grit Sandpaper (3 pack)	Home Depot	1	3.97	3.97
Dremel 3/32"Diamond Taper Wheel	Home Depot	2	8.46	16.92
2x4 -96"Premium Fir Stud	Home Depot	8	2.98	23.84
2.2 LB Red PLA Filament	SAIN3	1	38.99	38.99
50 lb quikrete gravel	Home Depot	10	3.15	31.50
Glass Bottles	Recycled	12	0.00	0.00
Purchased through WPI CEE Dept.				
24"x12' Sonotube	A.H. Harris	1	159	159
20"x12' Sonotube	A.H. Harris	1	110	110
FINAL COST SPENT BY TEAM				694.34

Acknowledgments

The High-Tech Totem team would like to thank the following for their help with the High-Tech Totem Pole project.

Professor Brigitte Servatius

Professor Tahar El-Korchi

Wendy Wacko

Russ Lang and the CEE department

Luis Fraire and the Sprinkler Factory Group

A.H. Harris

All others who assisted with the creation of the Totem and its assembly including Nick McMahon, Jake Zagorsky, and Kevin Lee.