UAF ICE ARCH

SPRING 2012

<u>DESIGN PACKAGE</u>

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PREPARED FOR FALL 2011 ASCE UAF ICE ARCH DESIGN COMPETITION

PROPOSAL SUBMITTED NOVEMBER 30, 2011

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1.0 DESIGN PROPOSAL

This document is to propose a conceptual outline for the design and construction of an ice arch to commemorate UAF Engineer's Week in the spring of 2012.

1.1 DESIGN CONCEPT

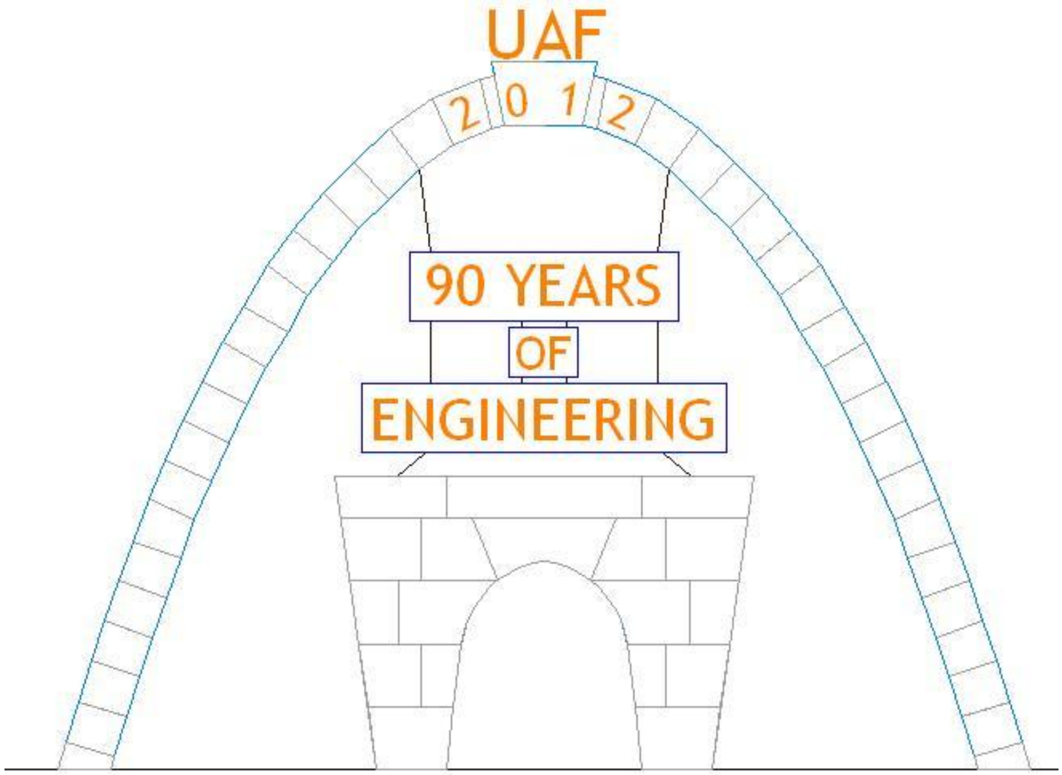
The proposed ice arch structure complexwill be located in the center of the Circle of Flags and will consist of

1) a large ice arch in the shape of an inverted catenary
2)anice wall placed underneath the large arch with a small arch section in its middle
3) a set of boards displaying the words "90 YEARS OF ENGINEERING"
3) aboundary formed by ropes connecting six barrier posts about the arch

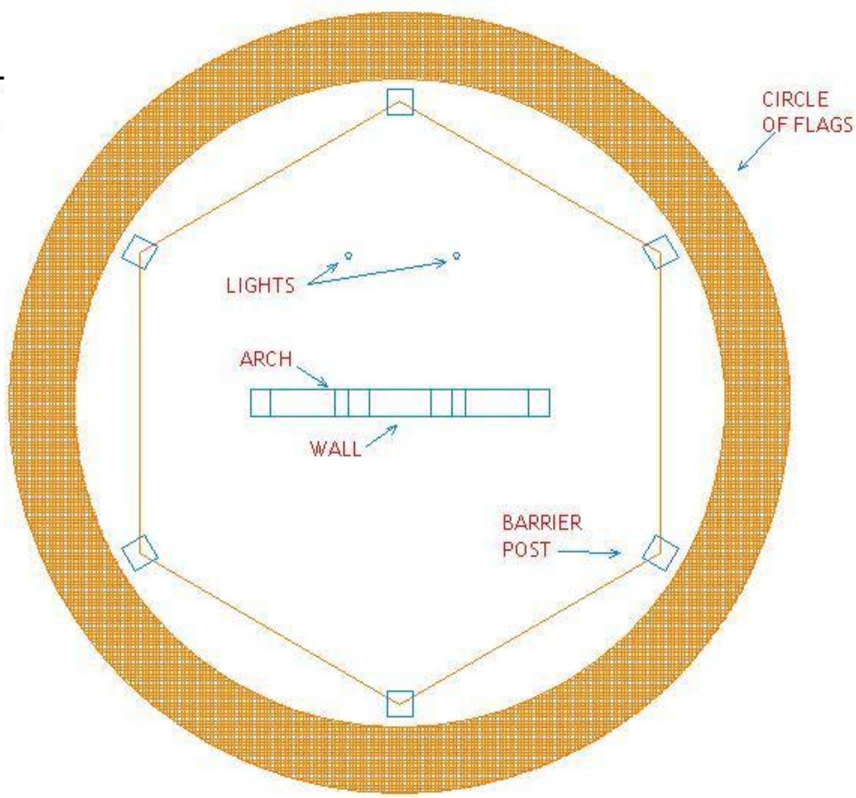
The arch and wall will be aligned approximately parallel to the west face of the Duckering Building, i.e the spine of the arch and wall will be run approximately north-south. The complex will face west, away from the Duckering Building, and this document will use "front" to refer to the west face of the arch. The board display with the engineering inscription will hang between the arch and wall, facing the front.

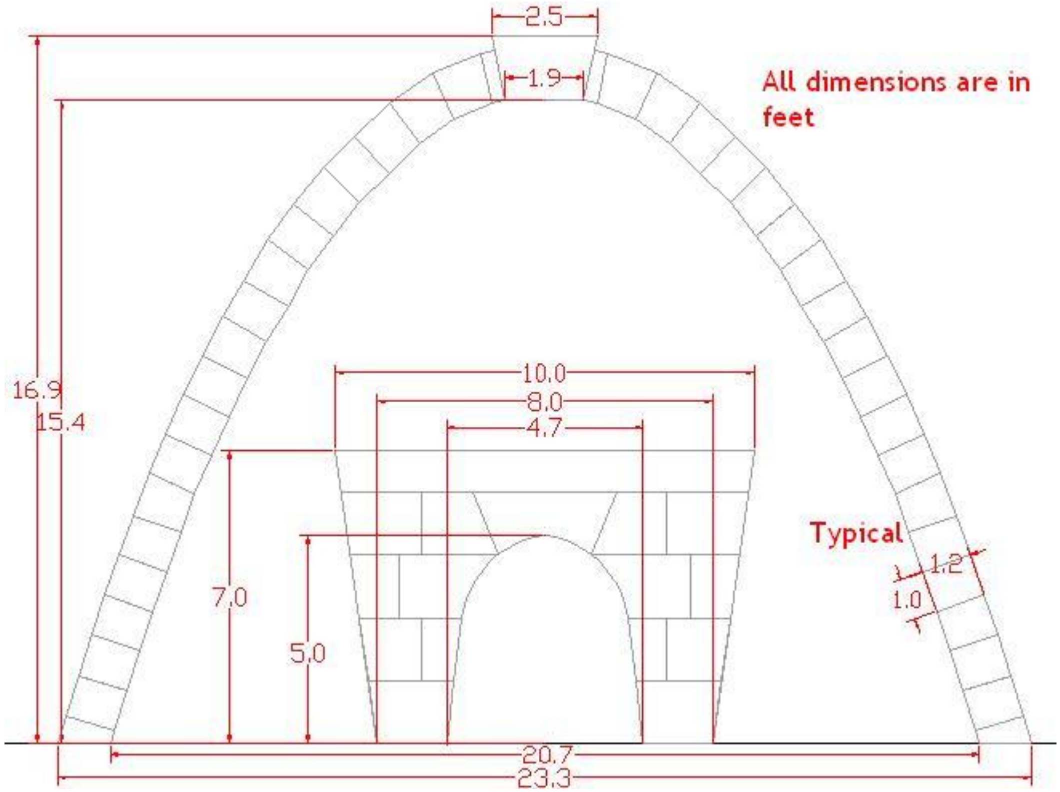
Two separate forms of lighting will be used to light the arch - two floodlights placed on the ground, and an LED rope running through the center of the arch, inside the ice blocks. One of the floodlights will be aimed at the uppermost suspended board, the other at the lowermost suspended board.

1.2 ILLUSTRATIONS


UAF
2012
90 YEARS
OF
ENGINEERING

PLAN VIEW


CIRCLE OF FLAGS
LIGHTS
ARCH
WALL
BARRIER POST



1.3 METHOD OF CONSTRUCTION

Order of construction shall be barrier, ice wall, ice arch, and lighting.

Both the arch and the wall will be constructed on timber frame false work structures.Two levels of scaffolding on either side of the arch will be incorporated into the construction, and block-and-tackle devices will be used where appropriate to hoist the ice blocks up.

While the false work necessary for the small arch will be minimal, the design and construction of the false work for the large arch will be a significant undertaking. The general form shall be as described below.

1) A post and beam structure surrounding the lower arch
2) A system of angled stud walls made of 2" x 6" studs centered on the arch spine
3) A front and back layer of plywood attached to the stud walls, cut to the shape of the arch, with 3 inch notches aligned radially every 8 inches
4) A locking system of plywood pieces placed radially in the notches along the plywood supporting elements, to support the actual ice blocks with a minimum of surface freezing

The false work will incorporate wedges in the junction between the stud walls and the supporting post and beam structure, with bolts connecting the two structures at points other than the wedges. This will allow the false work to be set free by knocking the wedges loose, at which point the upper part of the timber structure will drop slightly, but will still retain its integrity and be ready for safe disassembly.

The ice used for the arch will be frozen in layers in separate molds. Each of the 3 slabs and 2 keystones will have its own mold, which will allow the water to freeze to a closely determined dimension. The rest of the blocks will be cut to size from large ice beams, which will be made using five large rectangular molds 2.0 feet wide by 1.5 feet deep by 10.0 feet long in which water will be frozen over a period of days. These molds will be placed in the worksite for freezing and water added in layers no thicker than 1.5 inches per 24 hour period. The blocks will then be cut to precise shapes using bow saws and further shaped with rasps and scrapers.

Water will be added to the molds in layers, or lifts. The construction team will use a standard equation for ice formation in a plane

to determine the time required to freeze a layer of water and thereby determine the ideal thickness of the layers of water for the weather conditions, assuming a 9% vertical expansion of the water during freezing. Past experience has suggested adding 0.25 – 0.5 inches of water per 12 hour period for temperatures around -40 degrees Fahrenheit.

The assembly of the blocks will consist of lifting each block onto the scaffolding, followed by the unique shaping of each block to its particular position, with a minimum contact surface area for each block of 75% of its total surface area for the joint in question. Once shaping is satisfactory, final placing of each block will be done after wetting both contacting surfaces. The blocks of the large arch will have the hole drilled for the LED rope BEFORE final placement. Once all blocks are placed and the entire arch has frozen for 24 – 36 hours, the false work will be carefully removed following a predetermined method chosen by its designer.

A white rope will be passed through a longitudinal groove along the middle of the keystone's top surface, and will traverse down the spine of the arch to the middle of the third full block from the apex, where a hole drilled through the arch perpendicularly will allow the rope to pass to the inside. The ends of this rope will be attachment points for the board display.

1.4 SAFETY AND PERMITTING

The appropriate Codes and Safety offices of UAF Facilities Services will be contacted for approval of all stages of the project and no construction will be undertaken until all permits have been obtained and safety plans approved. In addition to scaffolding, safety measures to be enforced during construction of both the arch and the wall will include appropriate safety training for all personnel, site protection barriers, and cold weather injury prevention. The construction manager will oversee the enforcement of all safety measures and will maintain a safe worksite by expelling any personnel engaging in unsafe behavior from the site until corrective actions are taken.

2.0 DESIGN SPECIFICATIONS

The large arch, central to the arch complex and the centerpiece of this design,will have the shape ofan inverted catenary, defined along the spine of the arch by the equation

The inner dimensions of the archwill clear 20.7 feet across and 15.4 feet high at the center, and the arch will be 1.5 feet wide and 1.2 feet thick, with thickness measured perpendicular to the curve at any point. The arch will be constructed of blocks measuring approximately 1.0 x 1.2 x 1.5 feet. Each block will have a 90 degree angle at its inner lower edge, and a slightly oblique angle at its inner upper edge, forming an asymmetrical trapezoid when viewed from the side. The dead weight of the entire arch will total approximately 4400 pounds of ice.

There will be a trapezoidal keystone, molded in blue ice, at the apex of the large arch, which will havethe school letters “UAF” molded in yellow ice mounted on its upper surface and secured by wooden pins drilled into the upper surface of the keystone and frozen in place. The number “2012”, the digits of which will each be 1.0 feet high and molded in yellow ice 2 inches thick, will be placed in a curved shape on the front of the arch apex, using a layer of water to bond the digits to the arch. All letters will be on or facing the front of the arch.

The ice wall below the large archwill be in the shape of an inverted trapezoid with ansmall arch cut out of its middle. The wall will by 8.0 feet long at its base and 10.0 feet long at its top, which will be 7.0 feet high. The arched section will be 4.7 feet wide by 5 feet high. The entire wall will be 2.0 feet thick and will be constructed of blocks measuring approximately 1.5 x 1.5 x 1.0 feet, using brick style construction in two layers front to back. Estimated dead weight is 6600 pounds.

There will be three boards suspended by nylon cord in the vertical distance between the lower surface of the large arch and the top surface of the wall. The first, suspended directly from the upper arch, will be 6.4 x 1.6 feet and will bear in 1.0 foot letters “90 YEARS”. The second, hanging from the center of the first, will be 1.5 feet square and will bear in 8 inch letters “OF”. The third, hanging from the first, attached to the second, and secured downward to the ice wall, will be 8.7 x 1.6 feet and will bear in 1.0 foot letters “ENGINEERING”. The boards will consist of two pieces each of 0.75 inch plywood, painted white. The pieces will be laminated together, with the front board containing appropriate lettering cut out of it, and the back board solid, providing a background for the letters. The letters will thus give the illusion of being inlaid, which will be aesthetically completed by painting the letter spaces red.

The four bases where the arch and wall contact the ground will be surrounded by a minimum of 0.5 feet mixed frozen material to ensure that they are bonded with the ground.

The ropes around the arch will be anchored at each of six corners by running through a 2.0 foot cubed block of ice with a 1.0 foot letter formed on the top of it. Each ice block will be sitting just inside of the ring formed by the Circle of Flags. The six letters will be C, C, M, M, E, and P, in recognition of the respective branches of Civil, Computer, Mechanical, Mining, Electrical, and Petroleum engineering, which together comprise the majority of engineering disciplines taught at the UAF College of Engineering and Mines. Each of these letters will be molded in blue ice, and when positioned will face outward, its face perpendicular to the Circle of Flags.

3.0 CONSTRUCTION MATERIALS AND COST

The major material of the actual arches is, of course, ice, which will require a great deal of water – anywhere from 1400 – 1800 gallons of it. Possible water sources include commercially supplied water, University water, and lake water. The construction team will determine the most viable water source and proceed with construction using it.

Furthermore, while this design will require no reinforcement materials and minimal specialized equipment, the construction of the arches relies heavily on false work. Hence, much of the material needed to make this project a success will be the timber required to construct the falsework.

While this proposal does not contain a final design for the false work systems in question, the following materials list should be a conservative estimate of the materials required.

TABLE 1. FALSE WORK MATERIALS

Item	Function	Quantity	Unit Price	Total Price
4'x8' 7/16" OSB				
	Large Arch Block Laying Surfaces	6	14.00	84.00
	Small Arch Block Laying Surface	1	14.00	14.00
	Shear Wall Elements	2	14.00	28.00
4" x 6" x 12' Beam	Main Supports	6	13.00	78.00
2" x 6" x 8' Stud				
	Falsework Walls	15	2.10	31.50
	Bracing	10	2.10	21.00
2" x 4" x 8' Stud	Surface Supports	10	3.10	31.00
2.5” Framing Screws (5 lbs)	Connections	2	32.00	64.00
5 inch Lag Screw (25 pack)	Major Connections	1	55.00	55.00
			TOTAL	**406.5**

TABLE 2. MOLD MATERIALS

Item	Function	Quantity	Unit Price	Total Price
4'x8' 7/16" OSB	Forms for Ice Blocks	5	14.00	70.00
2" x 4" x 8' Stud	Form Structure	20	2.10	42.00
2.5 inch Framing Screws (5 lbs)	Connections	1	32.00	32.00
Cove Base Material	Letter Molds (120 ft)	1	50.00	50.00
Plastic Liner	Keep ice from freezing to mold	3	13.00	39.00
			TOTAL	**233.00**

TABLE 3. ARCH MATERIALS

Item	Function	Quantity	Unit Price	Total Price
4' x 8' 1/2" Plywood	Anniversary Board Display	2	25.00	50.00
Spray Paint (white and red)	Coloring Boards	4	6.00	24.00
Hampton Bay LED Rope, 27 ft	Lighting Arch	2	65.00	130.00
Floodlights, Malibu set of 4	Lighting Arch	1	80.00	80.00
Nylon Rope				

	Hanging Boards (Braided White)	50 ft	10.00	10.00
	Barricading (Black Truck Rope)	150 ft	30.00	30.00
Food Coloring	Making colored ice letters	8	2.00	16.00
			TOTAL	**360.00**

Summing the totals of these three tables gives an estimated project materials cost of $999.50.

The actual budget will be finalized by the construction team once the design of the false works and other structural elements has been completed. This proposal suggests that a budget of $1300 will be completely adequate to cover any extra materials costs and possible unforeseen costs of additional items found to be required during construction.

4.0 ASCE ARTICLE DRAFT

The flagship campus of the State of Alaska, the University of Alaska-Fairbanks, got its start as the Alaska Agricultural College and School of Mines, which enrolled its first class in 1922, 90 years ago. Civil and mining engineering students were among the men in that seminal class of six, and ever since then, America's northernmost university has been recognized as an engineering institute. Engineering traditions run deep on the campus, as engineering students young and old are inspired by the challenges of cold climate development and the rich history of Alaskan engineering.

Among the most famous of these traditions is the UAF ice arch.

The concept of the ice arch embodies the uniqueness of engineering challenges in the Far North, and it is fitting that the arch shares its chief material and its design features with that ubiquitous and effective aboriginal form of shelter in northern climates, the igloo. Both use snow and ice, common materials in cold climates, to create a structure with surprising resilience and, in the case of the igloo, great effectiveness

Many stories of the first official ice arch are told on campus, but local legends aside, it is not certain when it was built, nor what inspired it. What is known is that enterprising students have been constructing these arches in the center of campus since at least the 1960's. The variety of daring and innovative designs coupled with ingenious construction methods has made the UAF ice arch a legend in college engineering circles nationwide. Since the middle of last century, many, though not all, years have seen the construction of an official ice arch at UAF during the first months of the spring semester. Over the decades, many brilliant successes, and a few disappointing but information failures, have contributed to the furthering of the legend.

Perhaps it is the fascination of building with such a primitive material as ice which endlessly lures incoming engineering students who are eager to build and make their mark on a campus known for engineering innovation. Or perhaps it is a matter of school pride, to build structures every year that defy comparison to other college projects. Or it may be a bit of both.

Whatever the motivation, the team that designed and built this year's ice arch had the drive necessary to defy freezing weather and ever-present construction hang-ups and complete a structure worthy of their university.

The team paid tribute to its forebears with an elegant design consisting of an inverted catenary framing a short wall, and fittingly incorporated a commemoration of 90 years of engineering at the campus. In further keeping with methods used in the past, the team chose to ignore the possibility of reinforcing the structure, used often in recent years, in favor of creating a pure ice arch built of ice blocks alone.

After acquiring the necessary permits, the team began constructing false works on which to lay the ice. In the meantime, they began creating artificial ice blocks by freezing layers of water into molds. Such was the dedication of the team members that they undertook this part of the project during the university's winter break, in temperatures dipping to -40 degrees Fahrenheit during the second week of January.

Once this was done, actual placement of the ice blocks began. The great difficulty of properly mating each block to its neighbor while using cold water to bond the connecting surfaces was matched by the satisfaction of watching the structure grow, a few feet at a time, toward the apex.

On February 1st, the team placed the final block, the keystone, which appropriately bears the school letters and the year, molded in colored ice. Some apprehension accompanied the subsequent removal of the false work structure, but the arch held firm. Late in the afternoon of February 2nd, the engineering department, together the the UAF vice-chancellor, dedicated the arch, and for the first time, the ice began to glow as the lights placed inside the ice and in the nearby courtyard were switched on.

The arch experienced a great deal of fanfare during Engineer Week and many students from numerous university departments expressed their admiration for the tenacity of the team and the quality of the final structure.

For many years, the engineer tradition at the university has involved the efforts of industrious students volunteering themselves above and beyond their academic obligations in order to demonstrate the value of the engineering calling to the rest of the university and the community. The spring 2012 ice arch proved to be a noble addition to that tradition.