PRELIMINARY DESIGN PROPOSAL

FOR

UAF ICE ARCH 2014

DESIGNERS:

MARTIN GRAY

ANDY CHAMBERLAIN

PROPOSAL DATE:

11/21/2013

PREPARED IN ACCORDANCE WITH 2014 ICE ARCH RULES FOR:

FACULTY REPRESENTATIVE: DR. J. LEROY HULSEY

OWNER REPRESENTATIVE: TASK FORCE, ASSOCIATED GENERAL CONTRACTORS
CONCEPTUAL INTRODUCTION

The 2014 UAF Ice Arch project (hereinafter referred to as “The Mighty Dome”) shall consist of a reinforced ice dome 15 feet in diameter, resting on four ice columns 10 feet tall, and buttressed by Gothic-style flying buttresses of ice which themselves come to rest upon large ice blocks radial to each of the four columns. The entire structure will be freestanding and will be located in the center of the Circle of Flags on the UAF campus. The Mighty Dome will be constructed during the time period from December 2013 to February 2014, utilizing owner funds and student volunteer time.

The Mighty Dome is shown in site plan, profile view, and 3d view in the following figures. The circle in the site plan represents the Circle of Flags. Dimensions are in feet.
Mighty Dome Profile View

Mighty Dome in All its Glory
PRELIMINARY LOAD ANALYSIS

The dome component of The Mighty Dome will consist of a continuous sheet of ice, approximately four to six inches in thickness uniform across the entire dome. The lower part of the dome, where it comes into contact with the columns, will contain a continuously welded segment of rebar, which will absorb the tensile hoops stresses associated with the weight and ice creep of the dome.

A great deal of complicated force behavior is exhibited by dome structures, which is not fully understood to this day. The combination of meridional forces and hoop forces can be resolved using varying methods, none of which describe the true behavior. See “Equilibrium Analysis of Masonry Domes” by Wanda Lau (2002) for a comprehensive treatment of this subject. Final dome design and calculations will be conducted using the program and methods presented in that publication. However, we present here a conservative calculation to show that the dome will be stable when supported by the flying buttresses and columns.

The weight of the dome will be approximately 3500 – 3800 pounds. In order to show that this weight can be carried by the columns and the buttresses, we consider the dome as half of a tetrahedron, with each of four leaning triangular faces serving as the tributary area for one column and buttress. Because these faces lean on one another, the horizontal reaction forces that must be developed by the buttresses will be no greater than the cosine of the angle of lean multiplied by the force due to the weight of the individual face supported by that buttress. To determine this approximate angle of lean for the dome, we consider the location of a resultant force caused by a distributed load that increases from zero at one end (the dome crown) to a maximum at the other (the dome base). See diagram below:
TENTATIVE CONSTRUCTION PLANS

One of two methods may be used to construct The Mighty Dome. Others may of course be suggested by the build contractor.

In both cases, the flying buttresses, columns, and blocks will be frozen in molds or obtained from Ice Alaska, depending on the relative economy of these options.

For the construction of the dome component, one method would consist of building a free-standing timber framework, or falsework. It would be located between the four columns and buttresses, and its upper surface would create the shape of the dome and would be covered with plastic or canvas. The dome would then be formed on this framework by spraying water in successive layers, at the rate of \( \frac{1}{2} \) an inch or so per day. When the desired dome thickness has been reached and the support system of columns and buttresses completed, the falsework could then be lowered and removed, leaving the dome to come to bear on the support system.

A second method would consist of building a large bowl in the shape of the dome on the ground, spraying water in layers to form the dome from the outside surface inward, or from the inside surface outward. The dome could then be lifted into place and the bowl framework removed after placement.

In both cases, one or more hoops of continuous rebar would be incorporated into the spraying / freezing process. The rebar would ensure that as the ice fractures from thermal stresses or creep, it continues to behave as a relatively solid piece rather than as numerous small arches which would be susceptible to further fracture.

Other types of reinforcement could also be incorporated into the dome. For instance, if detailed calculations indicate that the spanning sections of dome between the columns, may be in danger of experiencing excessive tensile forces, than the ice can be make thicker around the lower edges of the dome and a tall hoop of welded rebar can be incorporated into the freezing. This would act as a beam between the supports to ensure that the edges of the dome do not sag and fracture.
MATERIAL LIST AND BUDGET ANALYSIS

The design team foresees minimal use of materials in creating The Mighty Dome. However, the following will be essential:

<table>
<thead>
<tr>
<th>MATERIAL / PURPOSE</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plywood (Molds and Forms)</td>
<td>$200</td>
</tr>
<tr>
<td>2 X 4 (Molds and Forms)</td>
<td>$150</td>
</tr>
<tr>
<td>2 X 6 (Structure and Forms)</td>
<td>$150</td>
</tr>
<tr>
<td>1 X 4 (Molds)</td>
<td>$25</td>
</tr>
<tr>
<td>Nails</td>
<td>$25</td>
</tr>
<tr>
<td>Bolts</td>
<td>$25</td>
</tr>
<tr>
<td>Screws</td>
<td>$25</td>
</tr>
<tr>
<td>Ice (from Ice Alaska, for large base blocks)</td>
<td>$400</td>
</tr>
<tr>
<td>Rebar (Hoops)</td>
<td>$200</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>$100</td>
</tr>
<tr>
<td>Scaffolding (2 sections, each 8 feet high)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

These costs total to $1300, which should be entirely reasonable within a design budget of $1500 after designer costs and building costs are considered.

SUMMARY

The Mighty Dome will be a challenging yet unique structure, and will be an honorable addition to the long UAF tradition of ice structure construction. While not as soaring in concept as the 1996 Hyperarch design, nor as daring as the unusually tall arches of the 1970’s and 1980’s, this arch brings its own flair for the audacious. Furthermore, it recreates an esteemed architectural style, the Gothic, the originators of which were among the greatest civil engineers of history.

The design team has deeply appreciated the opportunity to submit a proposal for the honor of the UAF Ice Arch 2014 Project. We thank you for your consideration and await your response.