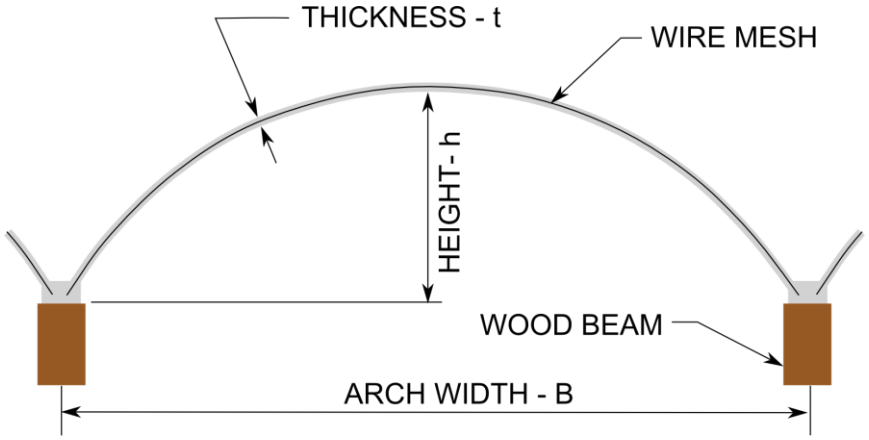
Design Problem

Barrel shell roofs have been around for almost 100 years, and were initially introduced by Anton Tedesko around WWII. During the war and after, they were used extensively for large span structures such as hangers and gymnasiums, including our own Camp Randall Memorial Sports Center, aka "the Shell". These structures use material efficiently and are relatively lightweight, inexpensive, and technically simple. These features make barrel roof shells an attractive option for impoverished regions, especially in earthquake regions where their lower mass is important.

One method for constructing barrel shells is to form the arch in the inverted position using gravity to create the shape. Each shell panel consists of a thin membrane of concrete with a wire mesh in the center of the membrane. These panels can then be lifted into position onto a framework of timber beams and connected together. Due to the complexity of the structure, it is difficult to analyze these structures using traditional methods, and Finite-Element Modeling is ideal.

In this project, you will idealize a barrel shell roof for a 20ftx20ft building. You may assume that all four walls are bearing walls. The cross section of the arches will have a catenary shape (see http://en.wikipedia.org/wiki/Catenary), which you may discretize into linear sections. They will be supported on rectangular wood beams that you may make any dimensions you wish. The cross section of the arches will look something like this:



Note that because of the Moment of Inertia of the arch section, the roof will act in two directions (as an arch in the width direction and as a beam in the length direction). You may assume perfect bond between the concrete arch and the wood beams, once in place. Because the arches will be constructed in panels on the ground, you may assume that the dead loads do not create any longitudinal stresses in the concrete. This may require different boundary conditions for dead and live load application.

You must provide the following parameters for your design:

1. The arch width (between 3'-0" and 7'-0")
2. The arch height
3. The thickness of the concrete
4. The size of the wood beams

Design Criteria

Your design must meet the following criteria:

1. The roof must withstand a uniform load of 10psf (rain load)
2. Alternatively, the roof must withstand a point load of 250 lbs over an area of 1 square foot
3. The compressive stress must not exceed 3000psi anywhere in the concrete
4. The tensile stress must not exceed 500psi anywhere in the concrete
5. The steel stress must not exceed 21 ksi
6. Wood stress must not exceed 500 psi

Properties

E_c = 3120 ksi

E_s = 29000 ksi

E_w = 1000 ksi

Unit weight of concrete+steel = 150 pcf

ν = 0.30

The steel mesh may be approximated as a steel sheet of thickness = 0.008 inches

Assume perfect bond between concrete and steel

Report

Your design report should include:

1. Provide the requested design parameters (model geometry)
2. Provide key outputs (maximum stress due to dead load and max stress due to live load, etc)
3. Document the FEM models used to carry out the design (pictures of mesh, element types, etc)
4. Provide calculations used to validate your results.