# CE 133 / ME 180, Lab project #8

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The measurement of the tensile strength of brittle materials is a challenging experiment, as it is difficult to grip and pull in tension a specimen without the results being dominated by grip effects.

A popular test which is often employed to this purpose is the Brazilian test. In this test, a cylinder is loaded with two sets of opposing compressive forces along the cylinder's diameter, as shown in Figures 1 and 2. You can check the experiment on YouTube.


Figure 1: Brazilian test.

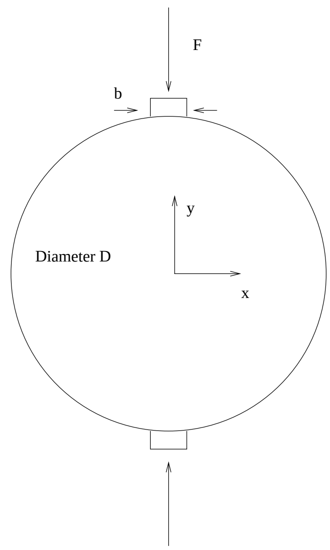


Figure 2: Geometric setup of the problem.

Use COMSOL to analyze the behaviour of a concrete specimen subjected to the Brazilian test.

1. Initialize a stationary three-dimensional mechanical problem.
2. Taking symmetry into account, construct 1/8 of the three-dimensional geometry. Consider a cylinder of length $L = 12''$ and diameter $D = 6''$, and a $0.5''$ high loading block on top with a width $b = 0.9''$. It is convenient to set the coordinate system at the center point of the cylinder. Be careful, as the loading patterns have to be centered with the cylinder, otherwise the stress distribution will not be accurate. Figure 3 shows the global disposition of the geometry.

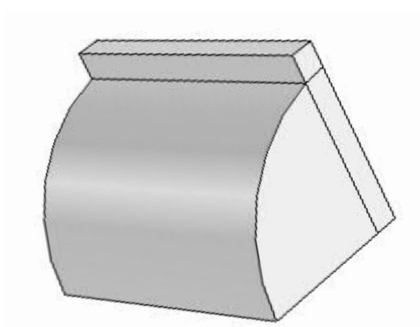

Figure 3: Geometry disposition.

3. Apply symmetry boundary conditions: prescribe zero $y$ displacement at the bottom face and zero $x$ displacements at the lateral face. Also, prescribe zero $z$ displacement at the midspan plane $z = 0$. Apply a total force of $F = 100$ lbf at the top of the block.

4. Consider the specimen as made of concrete and the loading plattens as made of structural steel. Select these materials from COMSOL's library.

5. Mesh the domain with quadratic tetrahedra and solve the problem. Note that you want a sufficiently fine mesh in order to have accurate results up to the second digit.

6. Perform the following analysis:

   - Obtain $\sigma_{xx}(0, 0, z)$ along the axis of the cylinder with two significant digits, and compare it to the theoretical plane strain result
   $$\sigma_{xx}^{th} = \frac{2f}{\pi D}$$
   Note that $f = 2F_{tot}/L$. Is the system reasonably approximated by a plane strain assumption?
   - Obtain the stress $\sigma_{xx}(0, y, 0)$ along the line $x = 0$, $z = 0$ of the central section of the cylinder, and compare it to the theoretical value in plane strain again. Explain the behaviour of $\sigma_{xx}(y)$ according to the boundary conditions.
   - Obtain a contour plot of $\sigma_{xx}(x, y, 0)$ at the central section of the cylinder, $z = 0$. By noting that the stress $\sigma_{xx}$ is orthogonal to these contour lines, discuss the state of stress of this plane.
   - Obtain the principal stress directions of the 3-d specimen and argue why this test can be used to obtain the tensile strength of a material.

7. Repeat the calculation with $b = 0.3''$ (keep everything else the same) and obtain $\sigma_{xx}(0, y, 0)$ along the line $x = 0$, $z = 0$ of the central section of the cylinder with two accurate digits. How does this curve compare to the former one (with $b = 0.9''$) from Part 6?

8. Submit a plot of $\sigma_{xx}/\sigma_{xx}^{th}$ at the center of the cylinder as a function of $b/D \in (0.05, 0.15)$. What do you observe?