LAB 6: DESIGN FOR BLAST

Objectives:

- Understand the influence of mass, stiffness, strength, and ductility on the blast response of a wall structure.

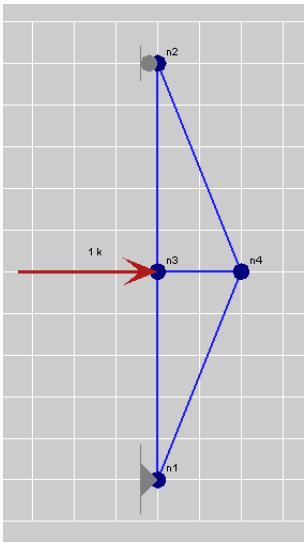
Getting Started

Copy the following file to your computer:

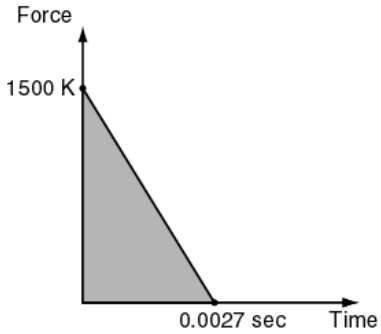
```
G:\arch721-Martini-F06\labs\lab-06\lab-06.rcd
```

- Download the newest version of Arcade and start it up.
- Open the file and view the model.

The file describes a vertical truss that supports a 20-foot tall glass curtain wall with the following characteristics:



- The material properties have been set so that the self weight of the structure is neglected.
- The model has been configured so that effectively all of the mass is concentrated at node n3. That mass weighs 2 kips.
- All elements are modeled with Truss-2 elements, which account for yielding and fracture.
- The blast load is based on a charge of 20 lb of TNT at a distance of 20 feet, which leads to the following horizontal impulse load applied at *n3*, assuming the supporting trusses are spaced at 20 feet in plan.



Design objectives:

The key measures of performance for the wall structure under blast load are the maximum resisting force, and the maximum displacement. If the resisting force is too large, the structure may break the supports that attach it to the main structure (like the window in the video presented in lecture); if the displacement is too large, this structure may slip off the roller connection at the top. In preliminary design, assume the following targets for the engineering performance of the wall support structure:

- The maximum total resisting force (the sum of the horizontal reactions) should be less than 100 kips.
- The maximum horizontal displacement at mid height should be less than 4 inches.

Assume that for visual reasons, the architect wants to build the structure using 5-inch diameter round steel pipe. We'll consider three sizes:

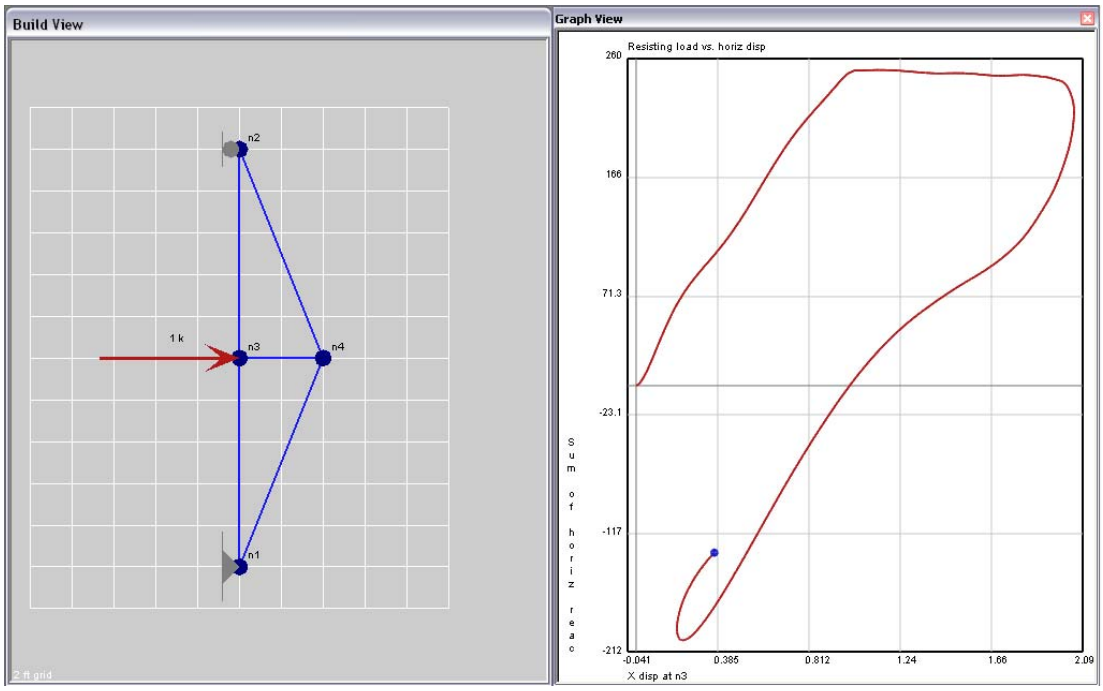
- **Heavy**: Area = 6.6 in^2
- **Medium**: Area = 4.2 in^2
- **Light**: Area = 2.6 in^2

The following steps examine the question of whether the performance criteria can be met within these constraints.

PRELIMINARY INVESTIGATION:

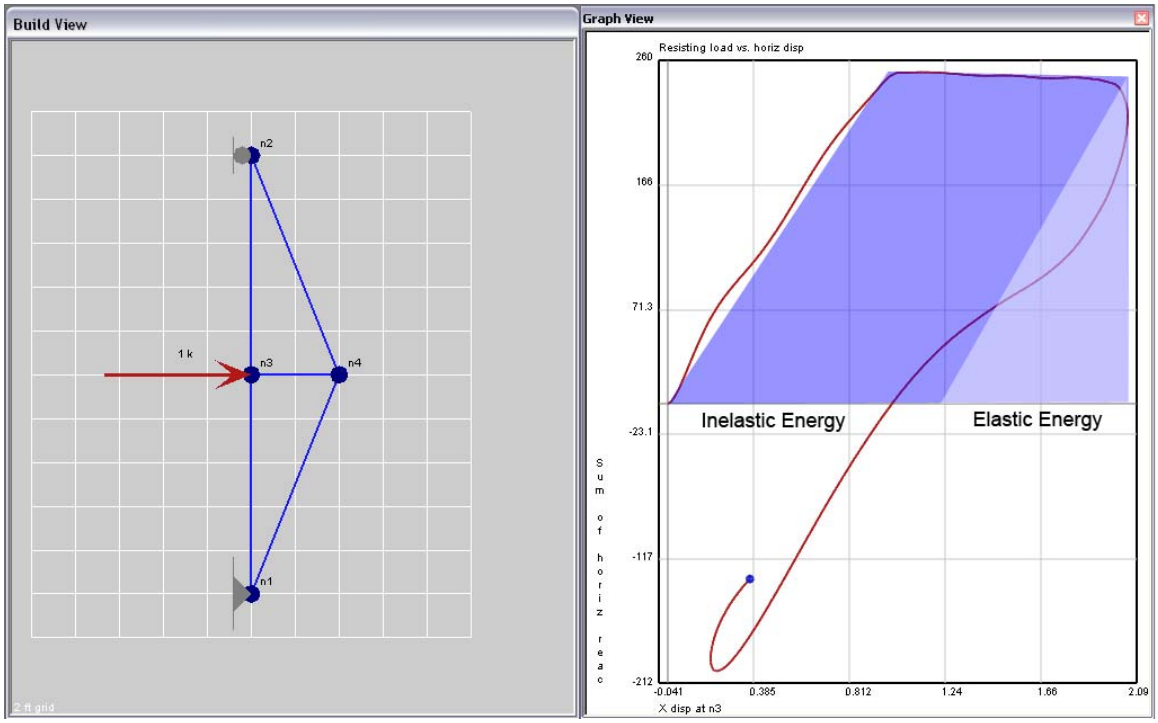
- **Calculate the kinetic energy induced by the blast: E_k**(by hand, on the checksheet)**:**
  - Calculate the impulse I as the area under the force-vs-time graph (i.e. the load history).
  - Calculate the change in velocity using the relationship $I = m\Delta v$, where *m* is the calculated as the 2-kip weight of the mass divided by the acceleration of gravity ($386 in/sec^2$).
  - Calculate the kinetic energy: $E_k = (1/2)mv^2$.
- **Do a preliminary Arcade analysis to calculate energy absorbed by the structure:** The initial Arcade model has all members set to the heavy section.
  - Run the analysis, the results should look similar to the results below:

    Note that this model is run in extreme slow motion, with a time scale of 200 (meaning 200 times slow motion). The time scale can be set by clicking *Settings > Numeric*.



- Estimate the energy absorbed by the structure by calculating the area under the curve at the peak displacement.

  This area is the area of the trapezoid which includes both the elastic energy and the inelastic energy labeled on the graph. The inelastic energy is dissipated by damage to structural material, the elastic energy is returned, causing the large rebound of the structure in the direction opposite the blast pressure.



- Right-click at key points on the curve to get approximate dimensions of the trapezoid, then calculate the area.

  This area is represents the energy absorbed by the structure, E_s

- Compare the energy absorbed by the structure (Es) with the kinetic energy induced by the blast (E_k) by calculating the percentage difference with respect to E_k.

  In theory, these two quantities are exactly equal. In practice, they may be off by 10% or so because of the approximation in calculating the area, and because this structural model has more than one degree of freedom.

Design exploration:

The analysis above reveals that the structure does not meet the performance criteria, since the resisting force is well above 100 kips. Through trial and error, try to modify the structure to meet the criteria, by modifying only the following properties:

- **Member sizes**: Any of the members may be assigned the heavy, medium, or light section properties defined on page 2 of this handout.
- **X coordinate of node *n4***: The depth of the truss can be modified by setting the x-coordinate of node *n4* to any value greater than zero.

Design conclusion:

Based on your preliminary analysis and design exploration, briefly describe your conclusion on the question of whether the performance criteria can be met within the constraints described.