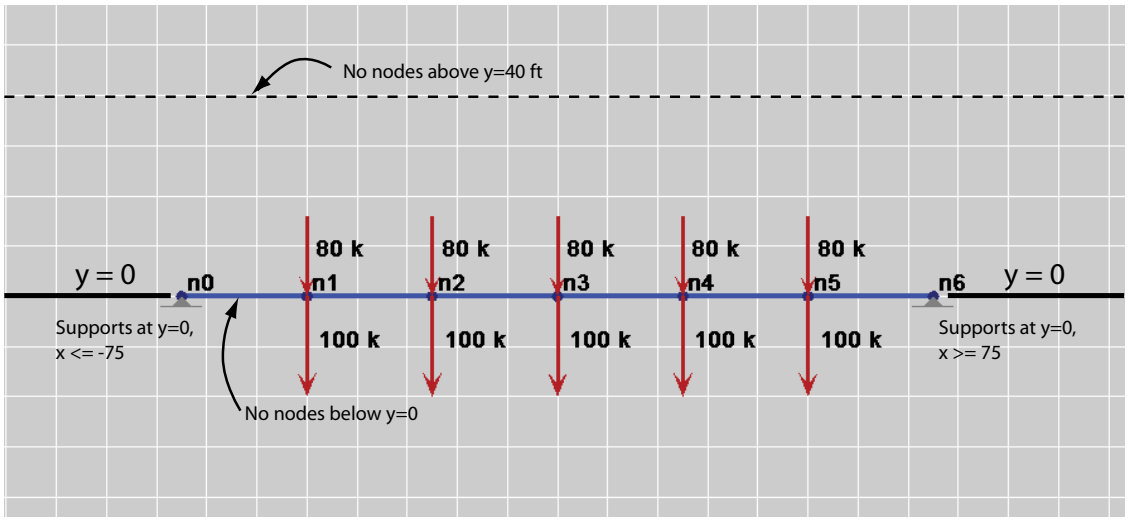
HOMEWORK 13: DIGITAL BRIDGE PROJECT

OVERVIEW

In this assignment, you will develop a design for an Arcade model using design constraints and performance criteria. In addition, you will create a poster in the form of a PDF file that graphically explains your structural strategy. The performance criteria concern strength, stiffness, and redundancy; the design objective is to minimize the self weight of the model. The figure below shows the portion of the model defined in the starting file, plus annotation describing some of the constraints.



The model and constraints represent a bridge crossing a river where the structure may not project into the area below the deck in order to preserve space for navigation. There is also a 40-foot height limit.

Nodes *n0* through *n6* and their associated loads represent the trajectory of the bridge deck and the loads that the deck would impose on the bridge superstructure. You are designing a model of the superstructure that would go on one side of the bridge, carrying half of the dead and live load from the deck.

You can get the file *hw-13-start.rcd* from the following folder on Classes:

```
Arch324-Martini-SP09\homework_files\hw_13
```

The project is to be done in teams of two. The team assignments are posted on the course web site.

MODEL TESTING DEMONSTRATION

The class meeting on Wednesday, April 22 will be devoted to testing a select set of structural models (6 to 10 models) to discuss common patterns of behavior and design approach. Remaining models will be tested and scored outside of class time.

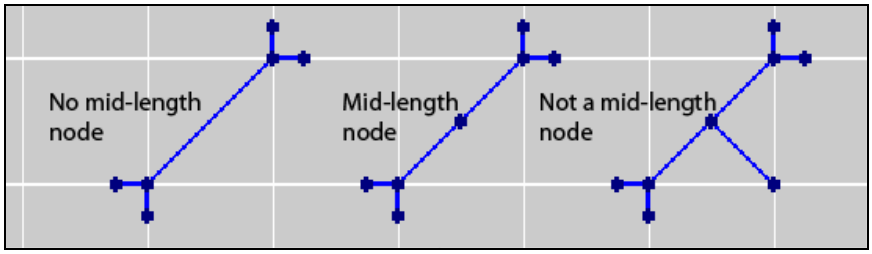
RULES FOR CREATING AND MODIFYING THE MODEL

In creating your design, you will add nodes, elements, and supports to the model from the start file according to the following rules:

- **Nodes**.
  - Nodes *n0* through *n6* included in the start file must be completely unchanged.
  - No nodes may have a y-coordinate less than zero.
  - No nodes may have a y-coordinate greater than 40 feet.

- **Elements**:
  - Use only **Truss-2** elements (which model yielding and fracture).
    Be very careful: **do not to use Truss-1 elements** by mistake. Truss-1 elements model elastic behavior only, and so are effectively indestructible.
  - You are limited to four member sizes
    - Heavy member Area = 28.3 in^2 (HSS 16x16x1/2)
    - Medium member: Area = 20.9 in^2 (HSS 12x12x1/2)
    - Light member: Area = 16.4 in^2 (HSS 8x8x1/2)
    - Tension-only member Area = 8.0 in^2 (3" diameter cable).

    Any tension-only member must include a *mid-length node* to ensure that it does not work in compression. A mid-length node is a node that connects to exactly two elements, which are oriented in-line in the undeformed configuration. As shown in the figure below:



    (See *Tips and Advice* below for efficient ways to deal with mid-length nodes.)

  - You must use the steel material defined for the truss-2 elements and not change its properties.
  - You may place no more than one element between any pair of nodes.
  - The six horizontal elements connecting *n0* through *n6* must be included in the model, although their sizes may be modified.

- **Supports**: Supports may be added only to the left of *n0* and the right of *n6*. This is equivalent to the following constraints on the coordinates of nodes that have supports:
  - $y = 0$ and $x \leq -75$ ft.
  - $y = 0$ and $x \geq 75$ ft

No other aspects of the model may be changed (e.g. loads, etc.)

DESIGN CRITERIA AND OBJECTIVES

There are three performance criteria for the model:

- **Stiffness**: Under full dead and live service load, the deflection at midspan should not exceed L/500, where L is the 150-foot clear span of the structure.

- **Strength**: Under an overload of 1.2 times the dead load and 1.6 times the live load, no member should exceed the yield stress of 50 ksi (note this criteria is unrealistic since it neglects buckling.) The strength analysis must account for the fact that live load may be unevenly distributed.

- **Redundancy**: The structure should have *single-member redundancy*, meaning that any member can be removed from the overloaded structure without causing complete collapse. During the load sequence, I will use the bomb tool to remove a member from your structure (I may do this several times to test the effect of removing different members).

LOAD SEQUENCE

The load sequence is defined in four stages, as follows:

1. **Service full**: dead load, plus live load at all points.
2. **Overload full**: dead load, plus live load on all five points.
3. **Overload left**: dead load, plus live load on the two leftmost points.
4. **Overload right**: dead load, plus live load on the three rightmost points.

Check deflections during stage 1, full service loads.

POSTER

The project includes an 8.5x11 inch poster that should do the following:

- Include a diagram that uses line thickness to show the designation of each member, using a very thick line for the Heavy member, and successively thinner lines for the Medium, Light, and Tension-only members.
- Explain the strategy for redundancy graphically and verbally.
- Organize the page for quick comprehension of the project.

SCORING

- **Self Weight:**
  Your score for the weight will be calculated as follows:

$$\frac{70 - (\text{self weight in kips})}{2}$$

  The less your model weighs, the more points you get.

- **Redundancy**
  If your model passes the series of single-member redundancy tests, you will receive an additional 10 points. Passing means that all six horizontal elements connecting nodes *n0* through *n6* remain unbroken, even though there may be significant yielding and deflection throughout the structure.

- **Stiffness:**

4.00 in < deflection	0 points
3.60 in < deflection ≤ 4.00 in	2 points
deflection ≤ 3.60 in	4 points

- **Strength:**
  If the model goes through the entire load sequence without any member yielding, you will receive an additional 6 points. (See *Tips and Advice* below for effective ways to detect yielding).

- **Poster:**
  You will receive a maximum of 10 points for a poster that meets the criteria explained above.

TIPS AND ADVICE

- **Hiding the loads**. To better see all the elements, at times you may want to stop the display of the applied loads as follows:
  - Click *Settings* > *Graphic* > *Forces*, uncheck *Display forces.*

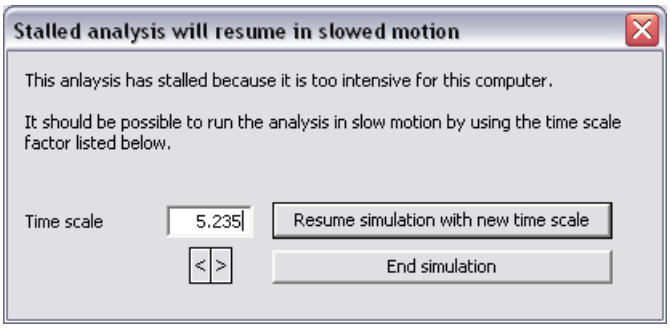
- **Making yielding more visible**. The start file is set to display the elements in Axial-depth mode, where the thickness of the member is proportional to the axial force, and the color indicates tension or compression. In this mode, yielding is indicated by a change to a paler shade of either red or blue, which can be hard to see in some cases. Yielding is more visible when you switch to in the Uniform width mode as follows:
  - Click *Settings* > *Graphic* > *Truss-2*, then click *Uniform width*.

  In this mode, yielding is indicated by rendering the element in yellow.

- **Mid-length nodes**. Mid-length nodes can be inserted by first laying out the member as normal and then using the *Subdivide Element* tool to split the element into two parts: Click *Build* > *Subdivide Element*, and then click anywhere on an element to split it into two equal pieces.

  It is better not to do this subdivision too early, since it makes it difficult to modify the geometry of the structure. It is best to set the geometry, making sure that the member in question in fact never goes into compression under any load (including when other members are removed) and then to subdivide the element and test the model again.

- **If your model goes in slow motion**: During a simulation, you may get the following dialog box:



  This occurs when Arcade is unable to run the model in real time (i.e. so that events happen at the same speed they would in real life). This condition can result from a computationally large model (i.e. with many nodes and elements), or a busy computer (running many other programs at the same time). In this case, the program sets the *Time Scale* property so that the model runs in slow motion, a time scale of 3 means that the model runs at three-times slow motion.

  If the time scale sets to a very large number, your model will run extremely slowly. In this case, click *Settings* > *Numeric…* and reset the Time Scale to a reasonable value. For this project, any model should be able to run at a time scale of 2 or less on a computer that is reasonably new and not overloaded.

WHAT TO SUBMIT

- **Arcade file**:
  - Submit the Arcade file describing your design to the appropriate submit directory for *hw_13* on Classes.
  - Type the names of both team members in the *Notes* slot in the upper window (Click *Settings > Notes* to see this window).
  - You can submit the file to the folder of just one team member, rather than both. Make sure that the names of both members are typed in the file.

- **Poster**:
  - **PDF file**:
    - Submit the PDF file of the poster to the same folder as the Arcade file.
  - **Hard Copy**:
    - Submit a hard copy of the poster to the normal homework boxes. Make sure the poster includes the names of both team members.
    - On the poster, underline the name of team member whose folder includes the Arcade file and poster file.