

CEE 744 Structural Dynamics

Structural Dynamics Project *Dynamic Analysis of the Elizabeth Ashman Bridge*

The Elizabeth Ashman bridge is the arch shaped pedestrian bridge over Campus Drive near the Stock Pavillion on the Agriculture campus. Take an opportunity to cross it and observe the structure carefully. Look particularly at how different components are attached together or supported. Check the walk thickness (it is listed as 4" below, but may be 6").

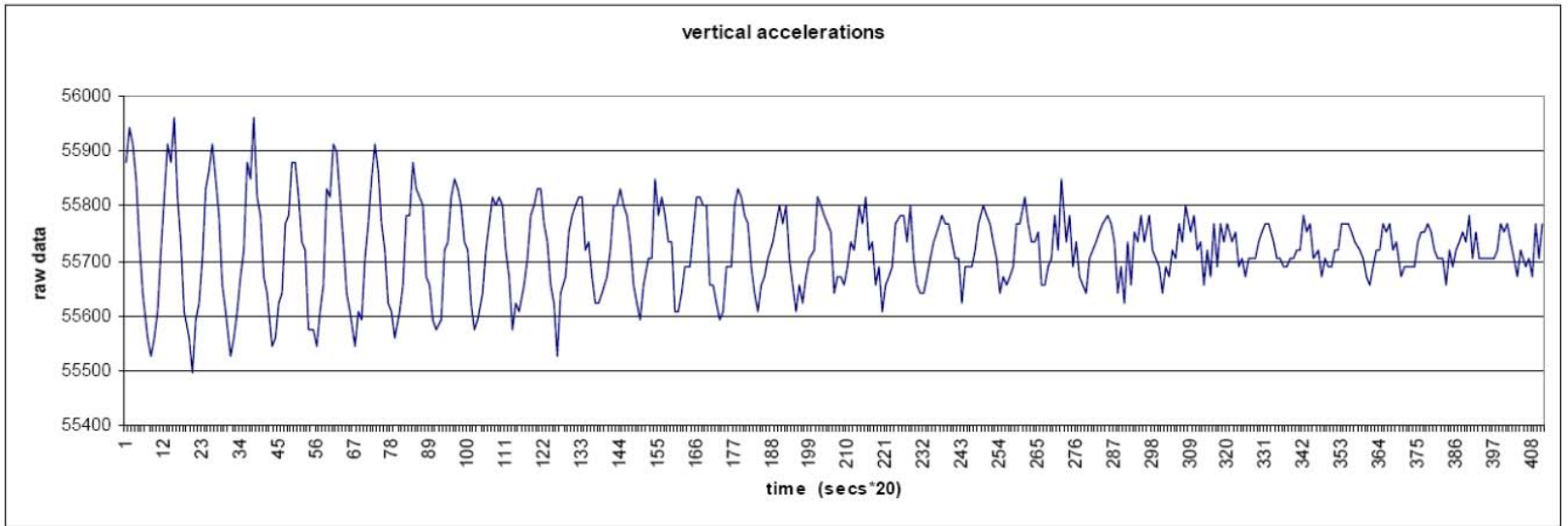
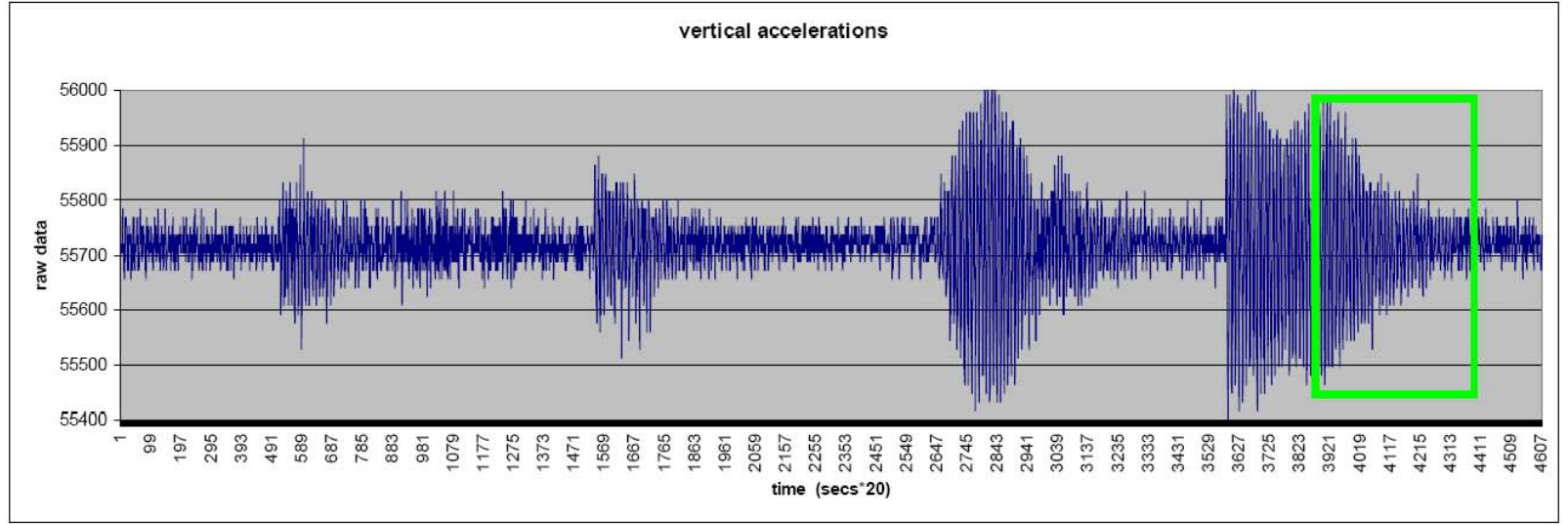
Detailed structural information on the bridge is provided on the following pages and part of a "model" for the bridge has already been prepared, for analysis in the SAP2000 program that is available through CAE, and may be downloaded from the class web site. The remainder of the structural modeling will need to be completed by you. This part of the modeling will help you develop initial familiarity with key modeling parameters for structural analysis and comfort with the use of the analysis program.

To Do:

There are 5 solution steps to complete as listed below. Be careful to complete each!

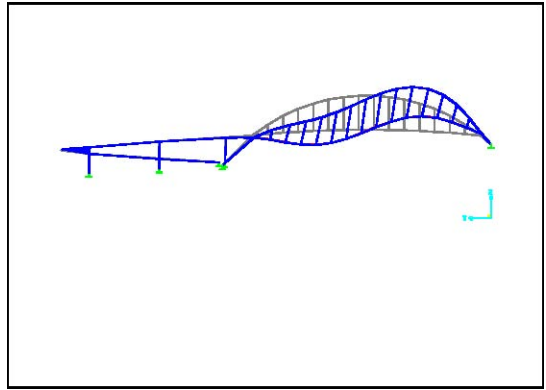
1. Find the deflections of the arch portion of the bridge at node or joint S15L and S07L when a 10k downward point load is applied at joint S15L. Also find the displacements of joint 21 on the ramp when a 10k downward load is applied at that joint. (complete by 2 April) As a check on your model building the results will be given in class.
2. Two people jogging across the bridge created the vertical acceleration records shown below. Each set of pulses is when the joggers were running, in between they stopped. Once they stopped it is as if the bridge had an initial displacement and velocity and then decayed in free vibration. Using the enlarged portion of the record estimate - **the natural period of the structure and the % damping.** (complete by 9 April)
3. Calculate the first 8 natural frequencies of the bridge system and physically describe the shape of the motion (in words, not numbers) for each of the associated mode shapes as is shown below for the first mode.

4.



Natural frequency: $f_1 = 1.85 \text{ Hz}$,

mode 1: An unsymmetric vertical displacement of the arch span with one side of the span moving upward and the other downward.



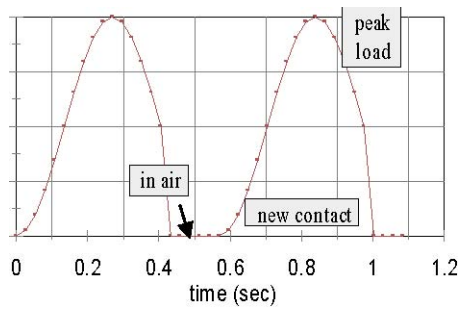
4. Solve for the displacement response of the structure under the simulated marching band load shown below. Determine the peak displacements at the ends of the cantilever beams extending from the far north column and the peak displacements at the column top.

This step in the analysis is to estimate the possible response of the bridge to a marching band crossing and marching in step. This will involve placing a dynamic vertical loading on the bridge floor and solving for the elastic response of the structure.

The bridge will be considered to be under full dead load, with a reduced uniform live load of 40 psf (160 lb. person over 4 sq. ft. of floor), and a superimposed 30 psf varying live load. The 30 psf multiplies the following variation. The assumed variation (but not amplitude) in the live load is shown below and is intended to represent the effect of stepping down and then removing weight from the floor. So, when the load variation is -1 and multiplies the varying live load of 30psf, combined with the static live load of 40 psf, the resulting live load decreases to 10psf.

dynamic load variation

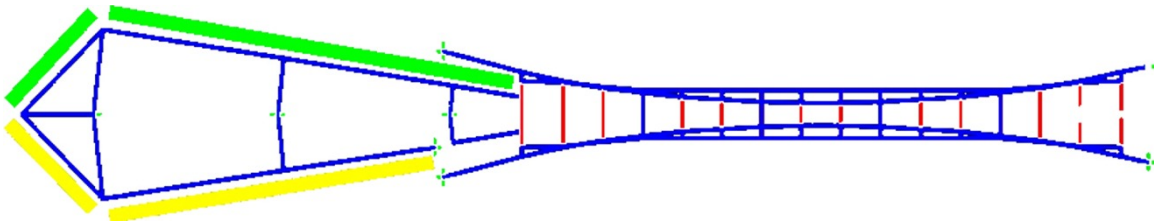
period = .542 seconds



The vertical live load (dynamic) will only be applied to half the ramp: from the arch to the turn-around. The dynamic load will be applied where you see green shading (see the Figure). Static vertical live load will be applied over the entire bridge floor. A file that provides the time variation of dynamic load, as shown above, will be on the web site

– titled “load.dat”. This time variation will have to be multiplied by the 30 psf amplitude in the SAP program. The “time history” load function option is used in SAP to define this load.

5. Calculate the peak stress in the bottom of the same column under the peak marching band effect as noted in part 3.



Submissions:

Submit the following:

- Calculated displacements at joints for #1
- Calculated period and damping for #2
- Plots of the first 5 mode shapes and listing of first 8 frequencies and mode shape descriptions for #3
- Peak displacements for #4 and calculations used to determine the stresses requested for #5

Structural Modelling Data:

Below you will find a listing of joint location information for the Ashman bridge. A partial input file of data for SAP is already placed on the class web site for downloading. Use this information to finish building the model of the bridge using SAP. **BUT** – also check the model provided and compare with the data below to make sure it is correct. This is a time taking task – but not really very difficult. I would suggest that after you look at the partial model in SAP and review the element information given below, that you walk around the Ashman bridge to get a good idea of how it all looks and goes together.

With a structure this complex, I tend to feel more comfortable preparing the model using a text processor and importing into SAP, rather than using the graphic interface. You may prefer to use graphic input and then check the data in the file that SAP creates. You can use any method that you are most comfortable with.

section	material	area – in ²	I33	I22	J
Arch1	steel	32.53	2841.50	774.03	1993.8
Arch2	steel	44.13	3843.08	1017.05	2688.0
Arch3	steel	61.47	4615.94	1505.62	4032.0
Brace1	steel	33.75	526.95	903.20	1323.0
Brace2	steel	31.22	2081.70	762.38	1728.0
Rbeam	steel	112.56	3420.86	2588.31	3046.0
Cant1	steel	25.69	1637.38	876.01	1852.2
Cant2	steel	51.75	6452.00	3522.00	6797.0
Cant3	steel	58.06	10434.00	6685.00	12338.0
Column1	steel	50.25	1392.75	1103.00	2205.0
Column2	steel	96.25	6663.00	5275.00	10653.0
Column3	steel	123.75	14195.00	11136.00	21710.0
Channel	steel	5.28	29.65	5.93	0.38
Tube	steel	2.09	2.22	1.15	2.63

Member information for Ashman bridge:

Rbeam = ramp floor, must add extra mass to simulate full mass of the concrete floor, mass (in kip-s²/ft units = 0.013975 per foot length), must add extra self dead load weight of 0.450kips/ft

Support conditions: The following nodes are fixed in all translations and all rotations:

- bottom of arch at East end (nodes T01L and T01R)
- bottom of arch at West end (nodes T18L and T18R)
- bottoms of three West end columns (5, 13, 17)
- bottom of rampway (16)

All other nodes are free in all directions and rotations.

Steel modulus is 29,000 ksi. Concrete modulus for floor shell elements is 3130 ksi.

Element locations:

- braces – (brace2 property) between: T05R & L, T08R & L, T11R & L, T14R & L; the braces at 5 and 14 are angled 22° off vertical, other wise the stiff direction is vertical.
- ramps – (Rbeam property = composite section) ramps at the West end between nodes: 9-7-14-21-23-22-15-16, and 10-8
- small arch elements – (arch1 property) between: left arch between the left nodes T01L to T02L, etc, through T13L to 1; similarly the right arch between right nodes T01R to T02R, etc, through T13R to node 2;
- larger arch elements – (arch2 property) on left side between nodes 1 and T14L, T14L and T15L, etc. through T16L and node 3; on the right side between nodes 2 and T14R, T14R and T15R, etc. through T16R and node 4;
- large arch elements – (arch3 property) on left side between node 3 and T17L, T17L to T18L, then on right side between node 4 and T17R, T17R to T18R;
- beam – (brace1 property) beams across ends of arch between nodes S02R and T02R, T02L and S02R, T02L and S02L, T17R and S22R, S22R and 9, 9 and 10, 10 and S22L, S22L and T17L;
- channels – (channel property) adjacent to floor in arch, on the left side between nodes S02L and S03L, S03L and S05L, etc. through S21L to S22L; on the right side between nodes S02R and S03R, S03R and S05R, etc. through S21R and S22R;
- hangers – (tube property) suspending the floor from the arch, on the left between nodes T03L and S03L, T04L and S05L, etc. through T16L to S21L; on the right side between nodes T03R and S03R, T04R and S05R, etc. through T16R and S21R; moment restraints are released on both ends, torsion restraint remains;
- column – (column2 property) between nodes 11 and 12, 12 and 13;
- column – (column3 property) between nodes 17 and 18, 18 and 19, and 19 to 20;
- column – (column1 property) between nodes 5 and 6;
- ramp column outrigger beams – (cant1 property) between nodes 6 and 7, 6 and 8;
- ramp column outrigger beams – (cant2 property) between nodes 11 and 14, 12 and 15;
- ramp column outrigger beams – (cant3 property) between nodes 18 and 22, 19 and 23, 20 and 21;
- shell elements, concrete material with 4” thickness, between each set of four hanger nodes on floor of arch; 15 elements,

Additional information: All arch elements have their stiff axis in the vertical direction;

brace between nodes T05R and T05L has strong axis rotated -22° from vertical, brace between nodes T14R and T14L has strong axis rotated $+22^\circ$ from vertical, other beams and braces have stiff axis vertical, the channels have their stiff axis vertical, outrigger beams have stiff axis vertical, hanger tubes have their stiff axis perpendicular to the span length, column members have stiff direction perpendicular to span of bridge.

SAP: local frame element axis directions are defined as follows (default orientation): a.) the "1" axis is along member length, pointing from the first node to the second; b.) the local 1-2 plane is taken to be vertical or parallel to global Z axis; c.) the local "2" axis is taken to have an upward (+Z) orientation unless the element is vertical, in which case the local "2" axis is taken to be horizontal along the global +X direction. d.) the local "3" axis is horizontal – in the X-Y plane. e.) coordinate angle: the angle "ang" defines element orientations different from default (above), it is angle through which the local 2 and 3 axis are rotated about the positive local 1 axis from the default orientation. The rotation for a positive "ang" value appears counterclockwise when the local +1 axis is pointed toward you.

Node locations for Ashman bridge (partial SAP input file is on web site):

JOINT 1 X=-4.12 Y=122.25 Z=74.075

2 X=4.12 Y=122.25 Z=74.075

3 X=-7.97 Y=152.5 Z=58.29

4 X=7.95 Y=152.5 Z=58.29

5 X=0 Y=175.8 Z=36.11

6 X=0 Y=175.8 Z=53.38

7 X=6 Y=175 Z=53.38

8 X=-6 Y=175 Z=53.38

9 X=3.56 Y=157.8 Z=54.54

10 X=-3.56 Y=157.8 Z=54.54

11 X=0 Y=219.2 Z=50.73

12 X=0 Y=219.2 Z=39.31

13 X=0 Y=219.2 Z=32.74

14 X=12 Y=217.6 Z=50.73

15 X=-12 Y=217.6 Z=39.31

16 X=-7 Y=179.76 Z=36.74

17 X=0 Y=265.57 Z=29.87

18 X=0 Y=265.57 Z=42.51

19 X=0 Y=265.57 Z=44.86

20 X=0 Y=265.57 Z=47.03

21 X=18 Y=263.17 Z=47.03

22 X=-18 Y=263.2 Z=42.51

23 X=0 Y=283.57 Z=44.86

S02L X=-7.12 Y=6.75 Z=54.54

S02R X=7.12 Y=6.75 Z=54.54

S03L X=-6.91 Y=17.3 Z=55.69

S03R X=6.91 Y=17.3 Z=55.69

S05L X=-5.95 Y=27.3 Z=56.46

S05R X=5.95 Y=27.3 Z=56.46

S06L X=-5 Y=37.3 Z=57.14

S06R X=5 Y=37.3 Z=57.14

S07L X=-5 Y=47.3 Z=57.69

S07R X=5 Y=47.3 Z=57.69

S09L X=-5 Y=57.3 Z=58.1

S09R X=5 Y=57.3 Z=58.1

S10L X=-5 Y=67.3 Z=58.3

S10R X=5 Y=67.3 Z=58.3

S11L X=-5 Y=77.3 Z=58.5

S11R X=5 Y=77.3 Z=58.5

S13L X=-5 Y=87.3 Z=58.5

S13R X=5 Y=87.3 Z=58.5

S14L X=-5 Y=97.3 Z=58.3

S14R X=5 Y=97.3 Z=58.3

S15L X=-5 Y=107.3 Z=58.1

S15R X=5 Y=107.3 Z=58.1
S17L X=-5 Y=117.3 Z=57.69
S17R X=5 Y=117.3 Z=57.69
S18L X=-5 Y=127.3 Z=57.14
S18R X=5 Y=127.3 Z=57.14
S19L X=-5.95 Y=137.3 Z=56.46
S19R X=5.95 Y=137.3 Z=56.46
S21L X=-6.91 Y=147.3 Z=55.69
S21R X=6.91 Y=147.3 Z=55.69
S22L X=-7.12 Y=157.8 Z=54.54
S22R X=7.12 Y=157.8 Z=54.54
T01L X=-10.15 Y=0 Z=48.71
T01R X=10.15 Y=0 Z=48.71
T02L X=-8.9 Y=6.75 Z=54.54
T02R X=8.9 Y=6.75 Z=54.54
T03L X=-7.02 Y=17.3 Z=62.04
T03R X=7.02 Y=17.3 Z=62.04
T04L X=-5.64 Y=27.3 Z=67.79
T04R X=5.64 Y=27.3 Z=67.79
T05L X=-4.51 Y=37.3 Z=72.3
T05R X=4.51 Y=37.3 Z=72.3
T06L X=-3.73 Y=47.3 Z=75.87
T06R X=3.73 Y=47.3 Z=75.87
T07L X=-3.16 Y=57.3 Z=78.46
T07R X=3.16 Y=57.3 Z=78.46
T08L X=-2.75 Y=67.3 Z=80
T08R X=2.75 Y=67.3 Z=80
T09L X=-2.5 Y=77.3 Z=80.83
T09R X=2.5 Y=77.3 Z=80.83
T10L X=-2.5 Y=87.3 Z=80.83
T10R X=2.5 Y=87.3 Z=80.83
T11L X=-2.75 Y=97.3 Z=80
T11R X=2.75 Y=97.3 Z=80
T12L X=-3.16 Y=107.3 Z=78.46
T12R X=3.16 Y=107.3 Z=78.46
T13L X=-3.73 Y=117.3 Z=75.85
T13R X=3.73 Y=117.3 Z=75.85
T14L X=-4.51 Y=127.2 Z=72.3
T14R X=4.51 Y=127.2 Z=72.3
T15L X=-5.64 Y=137.2 Z=67.78
T15R X=5.64 Y=137.2 Z=67.78
T16L X=-7.04 Y=147.2 Z=62.04
T16R X=7.04 Y=147.2 Z=62.04
T17L X=-8.9 Y=157.8 Z=54.54
T17R X=8.9 Y=157.8 Z=54.54
T18L X=-13.44 Y=177.4 Z=34.88

T18R X=13.44 Y=177.4 Z=34.88

1. Define 3 separate load cases (Define/Static load cases) including 1: DL with self weight multiplier of 1; 2: LL with the static uniform load (be sure to set the self weight multiplier to 0); and 3: dynamic live load (self weight = 0).
2. The static LL case can be achieved by defining (using the ASSIGN menu) a UNIFORM -0.040 kips/sq ft in the Z direction on the shell elements and by defining (ASSIGN) a uniform DISTRIBUTED span load of -0.40 kips/ft on the ramp beam elements (10 feet wide by 40 psf).
3. Define a second live load – the dynamic load, on the east (upper) ramp elements (R01 to R04). Use a DISTRIBUTED span load and set the value equal to 10 (floor is 10 feet wide, will multiply this by the actual psf when the dynamic load history is solved for).
4. Define a time history load function: (Define/ Time History Function Definition) that tells SAP to read in the load variation vs. time from an input file (keep this file with your SAP input data). Type in a label (anything), open the file that has the load variation information (load.dat). The file has 1 point per line. The time interval in the file is 0.0214 seconds.
5. Ask SAP to do a Time History solution (Define/Time History Cases). Use the following: give the history a name, linear analysis define 1% damping in all modes (0.01) do 2000 steps of solution the output time step = 0.0214sec (same as load) get envelopes for the “load assignment”: use your dyn load name (#3 above) for the load use your function name (#4) for the function scale factor = 0.030 for 30psf arrival time = 0
6. Create an output combination: (Define/Load Combination) giving the combination a name of your choice, make it add the static DL, the static LL, and the dynamic history cases.
7. Under Analyze/Analysis Options define Dynamic Analysis and set the parameters: include the number of modes you wish, use eigenvectors, maybe define a cutoff freq of 15.
8. For output select Analyze/Analysis Options and Generate Output. Pick node displacements for the combination named in #6. Also pick frame forces for the combination.