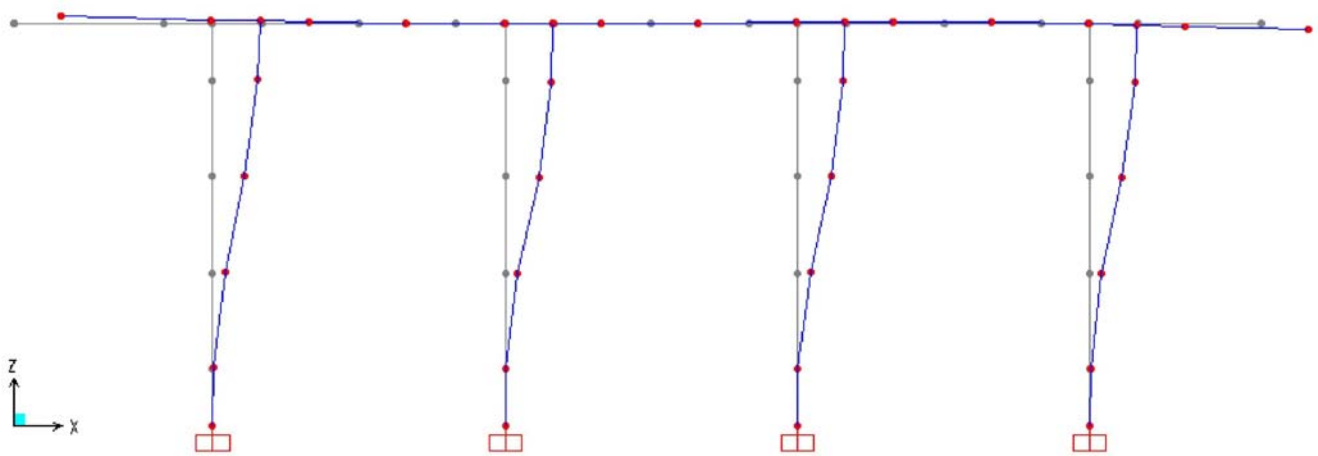
EARTHQUAKE ANALYSIS

with

SAP2000



Prepared by

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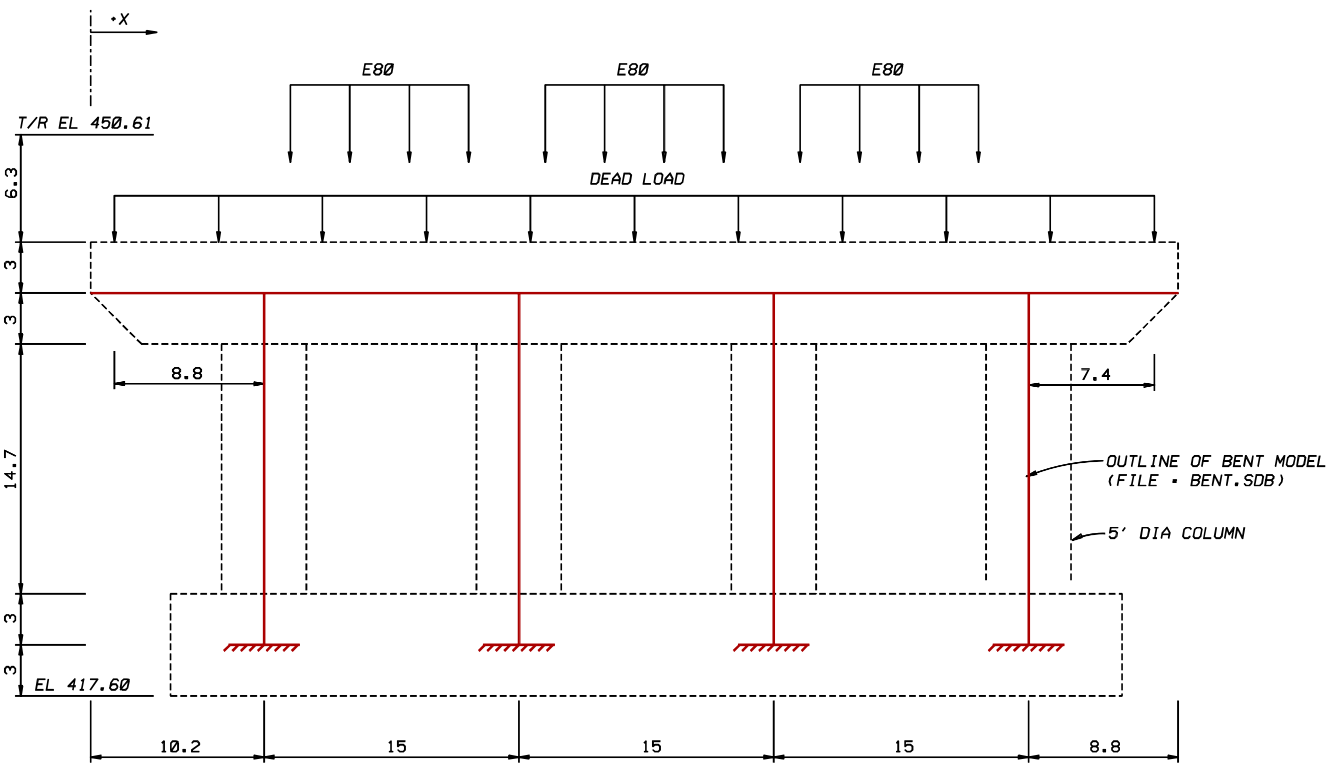
EARTHQUAKE ANALYSIS EXAMPLE

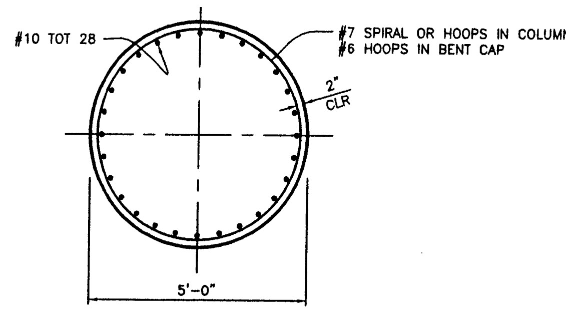
The earthquake analysis capabilities of SAP2000 are demonstrated using a railroad bridge bent designed in accordance with the AREMA Manual for Railway Engineering.



Prepare finite element model

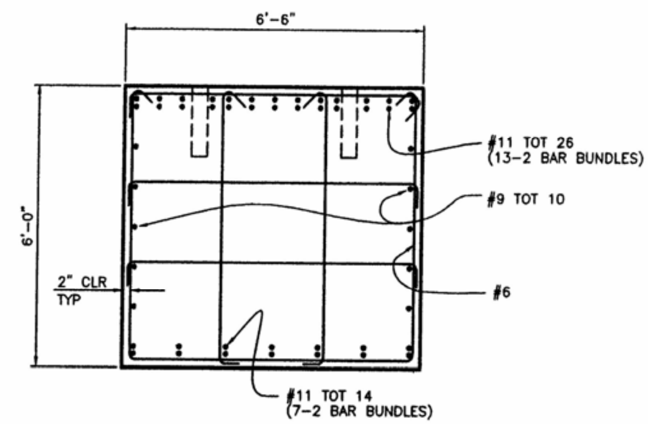
- Column properties:

  5’ diameter
  Assume $I_e = 0.35\ I_g$
  Use $I_e = 10\ I_g$ for stiffness in joint areas



- Bent cap properties:

  6.5’ wide x 6’ deep
  Assume $I_e = 0.75\ I_g$
  Use $I_e = 10\ I_g$ for stiffness in joint areas



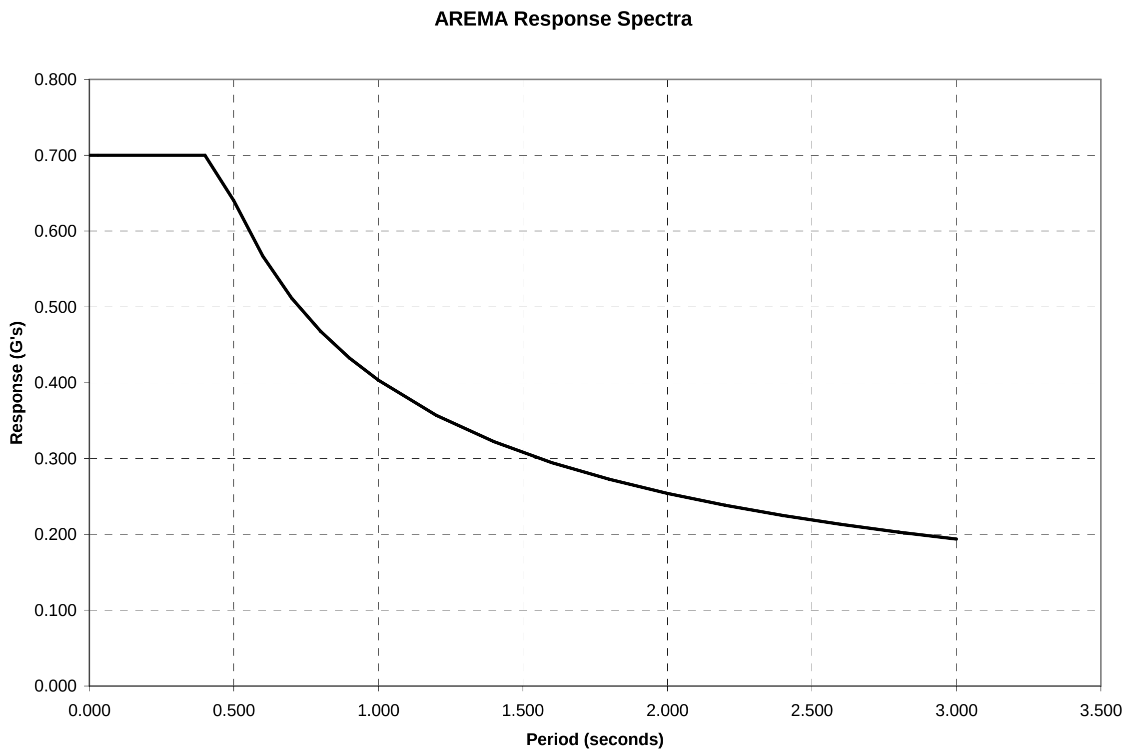
- Dead loads:

  Superstructure load = 2418 kips/61.2 ft = 39.5 kips/ft

Response spectrum analysis

Response spectrum analysis is performed to verify that the column design is adequate.

Period (sec)	Response (G's)
0.001	0.700
0.030	0.700
0.087	0.700
0.100	0.700
0.200	0.700
0.300	0.700
0.400	0.700
0.500	0.640
0.600	0.567
0.700	0.511
0.800	0.468
0.900	0.433
1.000	0.403
1.200	0.357
1.400	0.322
1.600	0.295
1.800	0.272
2.000	0.254
2.200	0.238
2.400	0.225
2.600	0.213
2.800	0.203
3.000	0.194



- Input steps

1. Define mass

    a. Select menu item: *Define > Mass Source*
    b. Select mass definition option: *From Loads*
    c. Add load case: *Dead (with multiplier of 1)*

    Note: The dead load is automatically divided by gravity.

2. Define Response Spectrum Function

    a. Select menu item: *Define > Functions > Response Spectrum*
    b. Choose function type: *Spectrum from File*
    c. Click: *Add New Function*
    d. Type function name: AREMA
    e. Select option: *Period vs. value*
    f. Browse to and select “spectra.txt” file
    g. Click: *Display graph*

3. Define Modal Analysis Case

   a. Select menu item: *Define > Analysis Cases*
   b. Select case: *MODAL*
   c. Click: *Modify/Show Case*
   d. Enter maximum number of modes = 2

4. Define Response Spectra Analysis Case

   a. Select menu item: *Define > Analysis Cases*
   b. Click: *Add New Case*
   c. Type case name = AREMA
   d. Select analysis case type: *Response Spectrum*
   e. Select loads applied from AREMA function
   f. Enter Scale Factor = 32.2 (response values in G’s)
   g. Click: *Add*

5. Define Load Combination

    a. Select menu item: *Define > Combinations*
    b. Click: *Add New Combo*
    c. Select DEAD and AREMA cases
    d. Click: *Add*

    Note: Response spectrum will automatically give +/- values

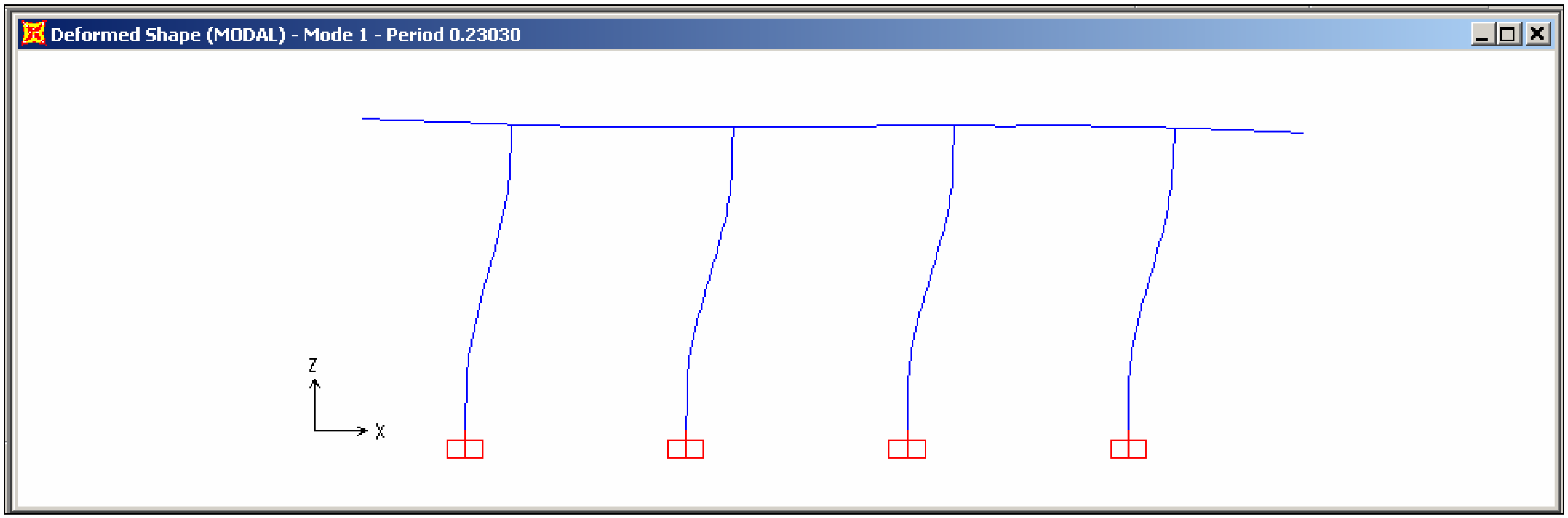
6. Perform Response Spectrum Analysis

    a. Select menu item: *Analyze > Run Analysis*
    b. Click: *Run Now*

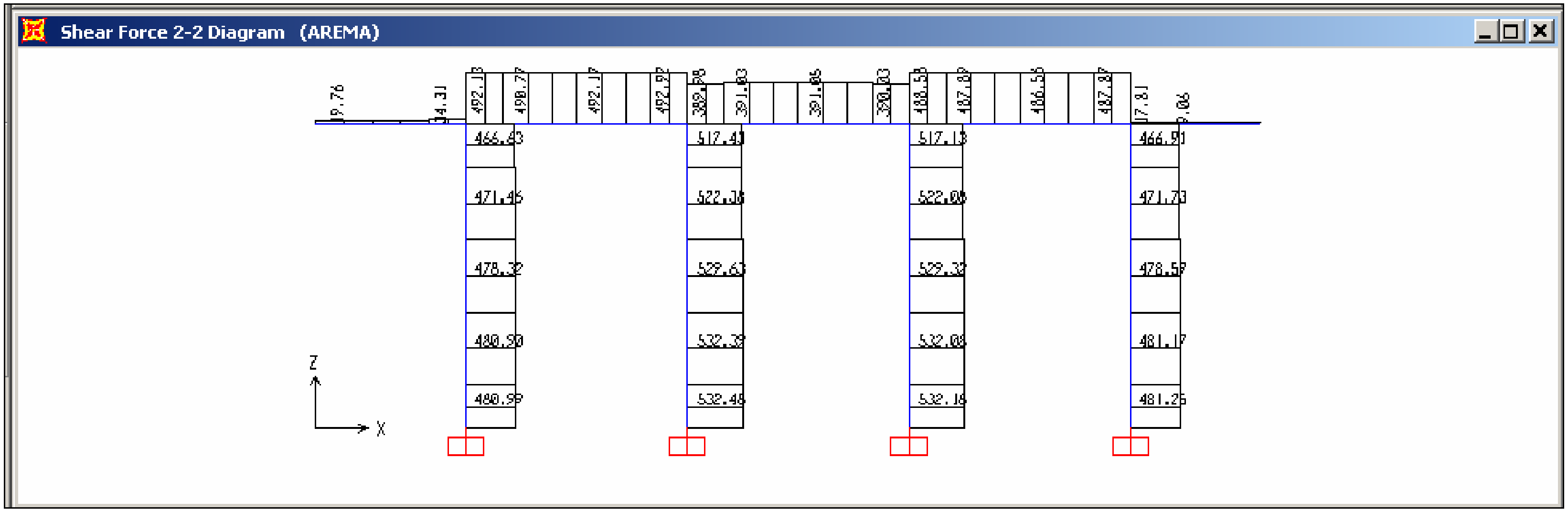
- Verify results

1. Display results graphically

   a. Select menu item: *Display > Deformed Shape*



b. Select menu item: *Display > Show Forces/Stresses*



2. Display results in tabular form

   a. Select menu item: *Display > Show Tables*
   b. Select output to verify
   c. Select analysis cases to verify

Joint Reactions

File View Options Format

Units: As Noted — Joint Reactions

Joint Text	OutputCase Text	CaseType Text	StepType Text	U1 Kip	U2 Kip	U3 Kip	R1 Kip-ft	R2 Kip-ft	R3 Kip-ft
101	DEAD	LinStatic		-10.316	0	834.134	0	-81.1603	0
101	AREMA	LinRespSpec	Max	480.988	0	520.814	0	5099.7767	0
201	DEAD	LinStatic		2.817	0	684.529	0	27.9762	0
201	AREMA	LinRespSpec	Max	532.483	0	104.167	0	5526.7034	0
301	DEAD	LinStatic		2.111	0	705.054	0	21.9008	0
301	AREMA	LinRespSpec	Max	532.176	0	99.318	0	5523.5348	0
401	DEAD	LinStatic		5.388	0	741.227	0	49.0556	0
401	AREMA	LinRespSpec	Max	481.254	0	508.889	0	5100.1768	0

Record: 1 of 8 — Done

3. Verification computations

a. Verify: dead load reaction = total weight

$$Weight = 0.15\left(\frac{\pi(5)^2}{4}\times 14.7\times 4+6.5\times 6\times 64\right)+2418 = 2965.6\ \ kips$$

$$Dead\ load\ reaction = 834.1+684.5+705.1+741.2 = 2964.9\ \ kips$$

b. Verify: total mass = total dead load / gravity

Mass = 92.1 (Export joint masses to Excel and sum)
Weight / Gravity = 2964.9 / 32.2 = 92.1

c. Verify: modal participating mass ratio > 90%

Ratio = 97% for mode 1

d. Verify: response spectra base shear = response x weight

Base shear = 481 + 532 + 532 + 481 = 2026 kips
Response for period = 0.247 sec = 0.7 G
0.7 x (2965 – 173 / 2) = 2015 kips (within 1%)

e. Verify: structure period $T = 2\pi\sqrt{\frac{W}{gK}}$

K = 40 kips / 0.0006 ft = 66667 k/ft (from unit load case)
T = 2 x 3.1416 x [2965 / (32.2 x 66667)]$^{1/2}$ = 0.23 sec
(within 6% of SAP2000 analysis)

- Check column design

1. Verify that column reinforcement is defined

   a. Select menu item: *Define > Frame Sections*
   b. Select property: *COL*
   c. Click: *Modify/Show Property*
   d. Click: *Concrete Reinforcement*

2. Analyze column

   a. Select menu item: *Options > Preferences > Concrete Frame Design*
   b. Select design code: *AASHTO*
   c. Select menu item: *Design > Concrete Frame Design > Select Design Combos*
   d. Remove all generated combos and add COMB1
   e. Select column members to design

f. Select menu item: *Design > Concrete Frame Design > Start Design/Check of Structure*
g. Select menu item: *Design > Concrete Frame Design > Display Design Info*
h. Select: *Column P-M-M Interaction Ratio*
i. Right click on member with max ratio
j. Click: *Details*