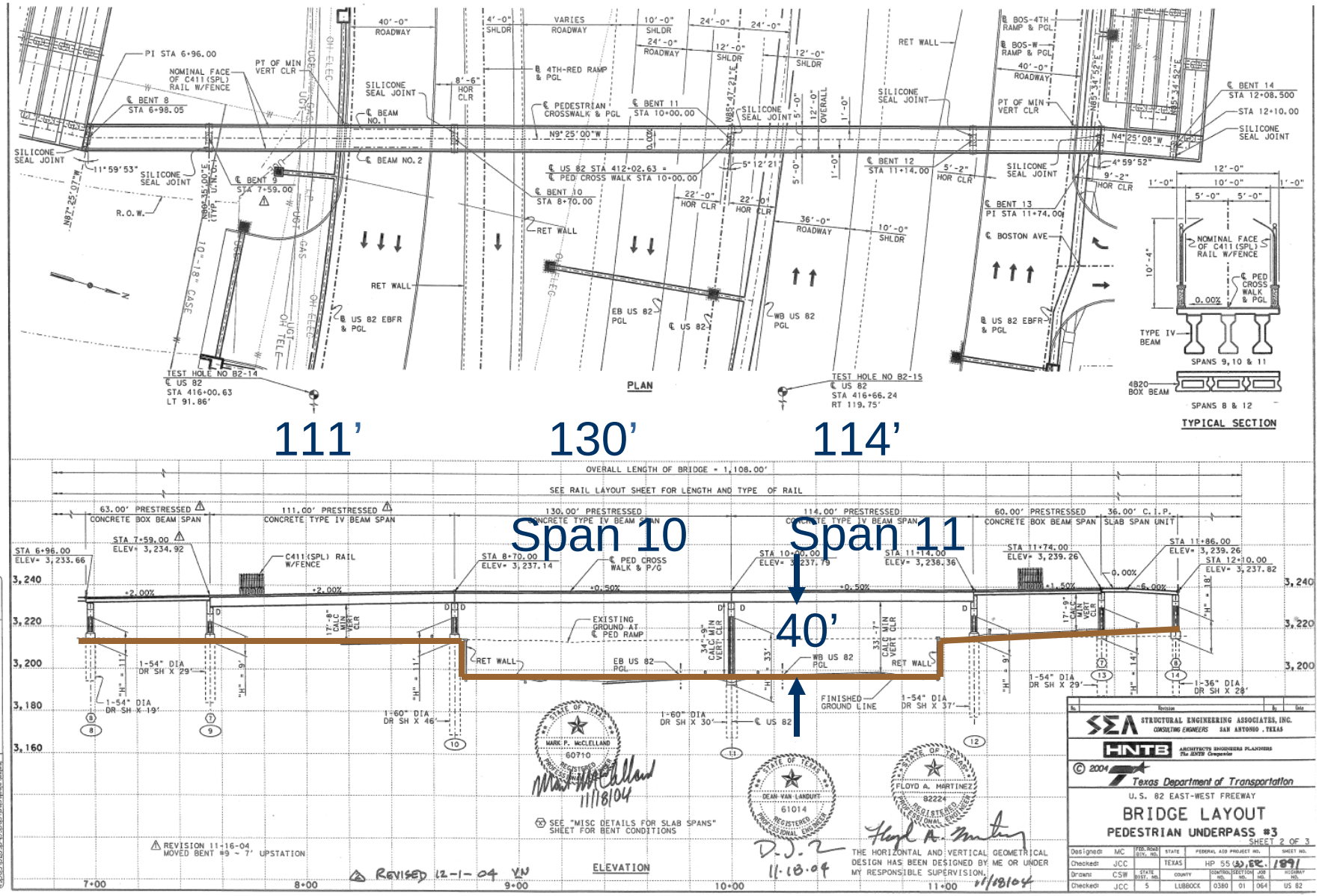
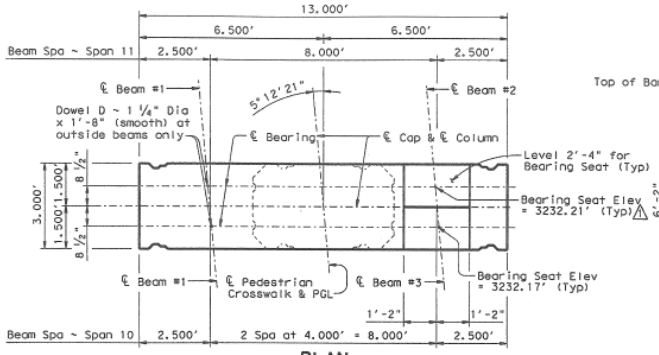
The Perfect Storm: Lateral Vibration of a TxDOT Pedestrian Bridge

Dean Van Landuyt, P.E.

TxDOT—Bridge Division

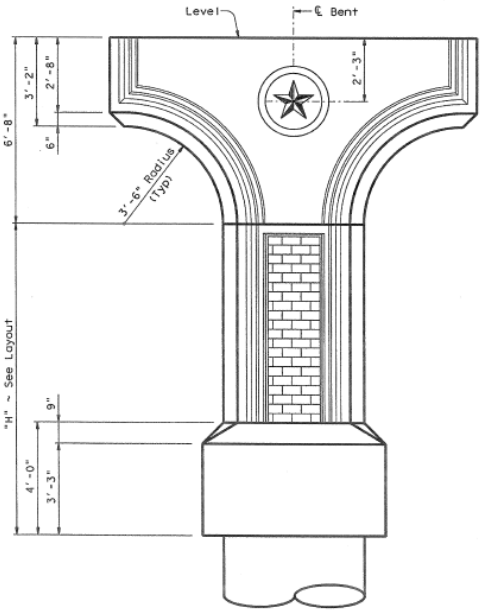

PLAN
TYPICAL SECTION
ELEVATION
111’
130’
114’
Span 10
Span 11
40’
OVERALL LENGTH OF BRIDGE = 1,108.00’
SEE RAIL LAYOUT SHEET FOR LENGTH AND TYPE OF RAIL
63.00’ PRESTRESSED CONCRETE BOX BEAM SPAN
111.00’ PRESTRESSED CONCRETE TYPE IV BEAM SPAN
130.00’ PRESTRESSED CONCRETE TYPE IV BEAM SPAN
114.00’ PRESTRESSED CONCRETE TYPE IV BEAM SPAN
60.00’ PRESTRESSED CONCRETE BOX BEAM SPAN
36.00’ C.I.P. SLAB SPAN UNIT
STRUCTURAL ENGINEERING ASSOCIATES, INC.
CONSULTING ENGINEERS SAN ANTONIO, TEXAS
HNTB
ARCHITECTS ENGINEERS PLANNERS
Texas Department of Transportation
U.S. 82 EAST-WEST FREEWAY
BRIDGE LAYOUT
PEDESTRIAN UNDERPASS #3
SHEET 2 OF 3
THE HORIZONTAL AND VERTICAL GEOMETRICAL DESIGN HAS BEEN DESIGNED BY ME OR UNDER MY RESPONSIBLE SUPERVISION.
REVISED 12-1-04
REVISION 11-16-04 MOVED BENT #9 - 7’ UPSTATION

111’
Span 10
130’
Span 11
114’

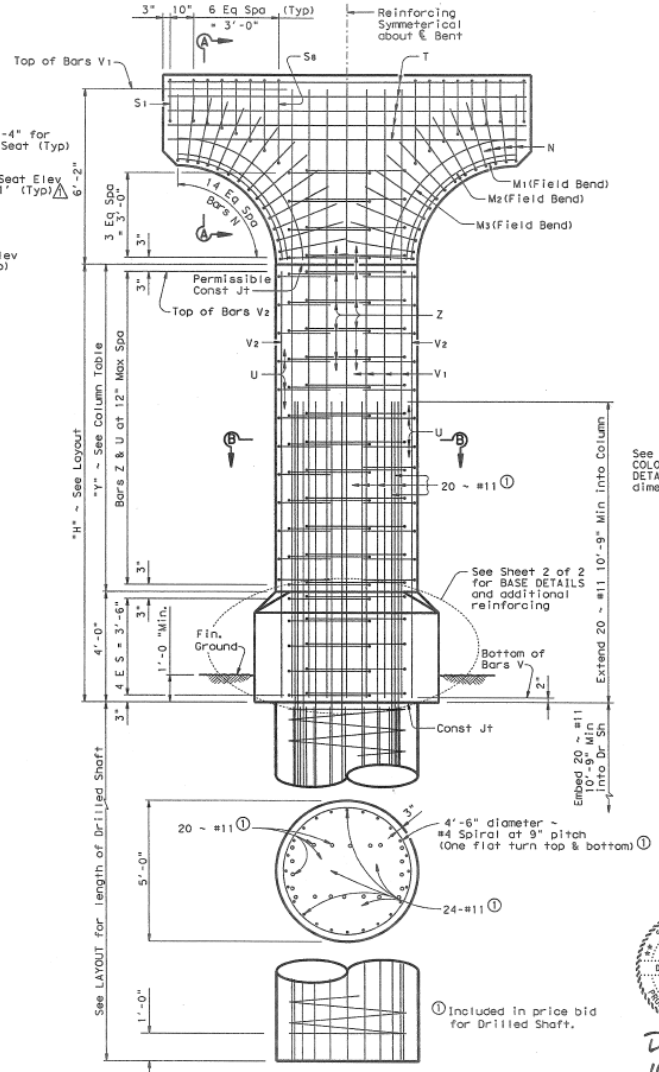


PLAN

See "TTU / SPANISH COLONIAL ARCHITECTURAL DETAILS" for information on aesthetic treatment.

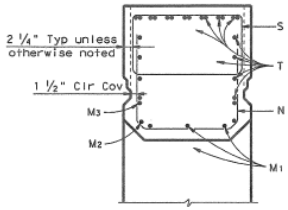


ELEVATION
(Showing Dimensions)

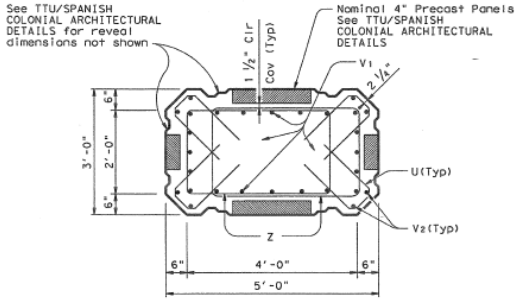


① Included in price bid for Drilled Shaft.

ELEVATION
(Showing Reinforcing)



SECTION A-A



SECTION B-B

STATE OF TEXAS
DEAN VAN LANDUYT
61014
REGISTERED PROFESSIONAL ENGINEER

D.J.-2
11.18.04

SHEET 1 OF 2

Texas Department of Transportation
Bridge Division

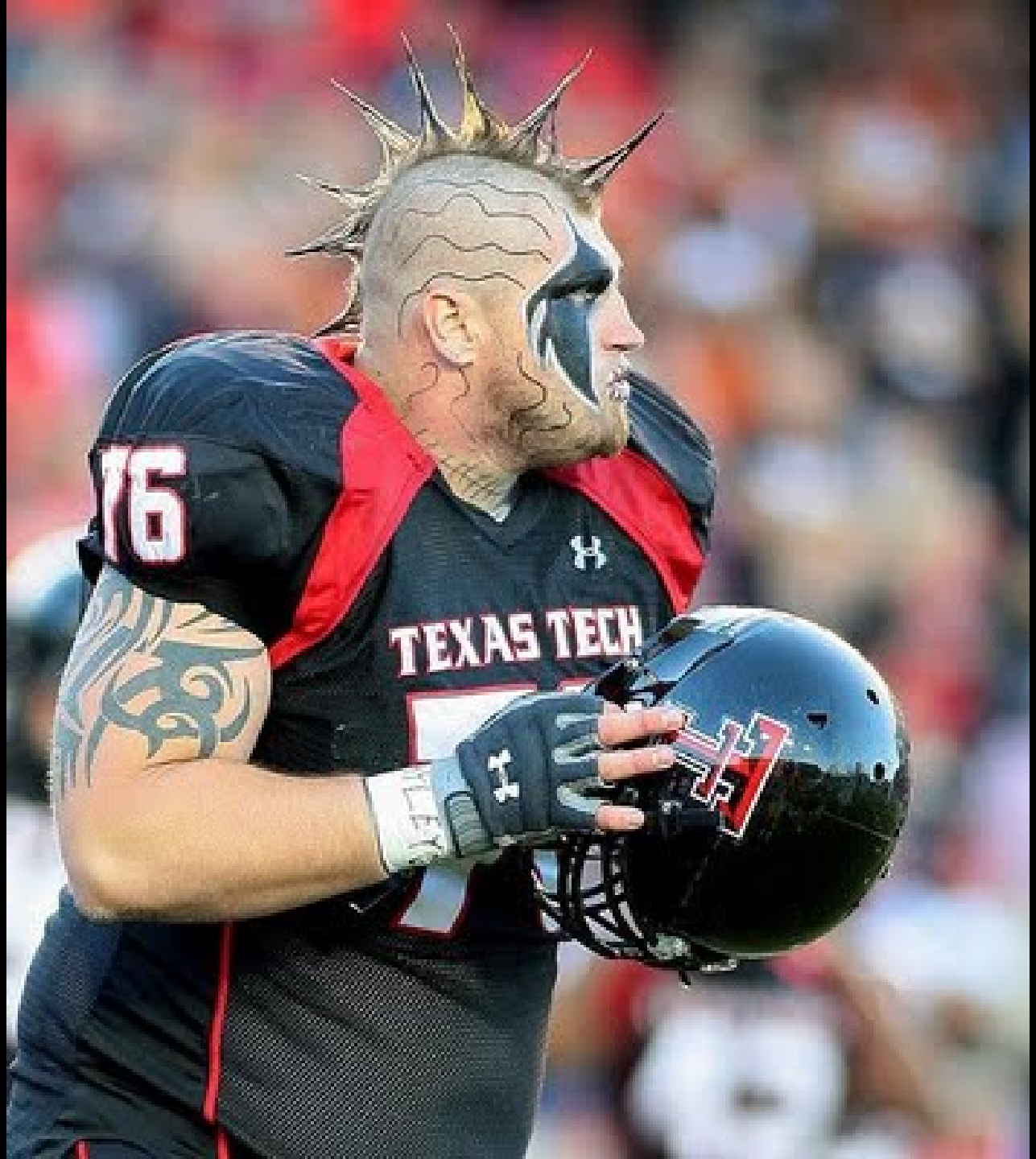
INTERIOR BENT NO. 11

PEDESTRIAN UNDERPASS #3

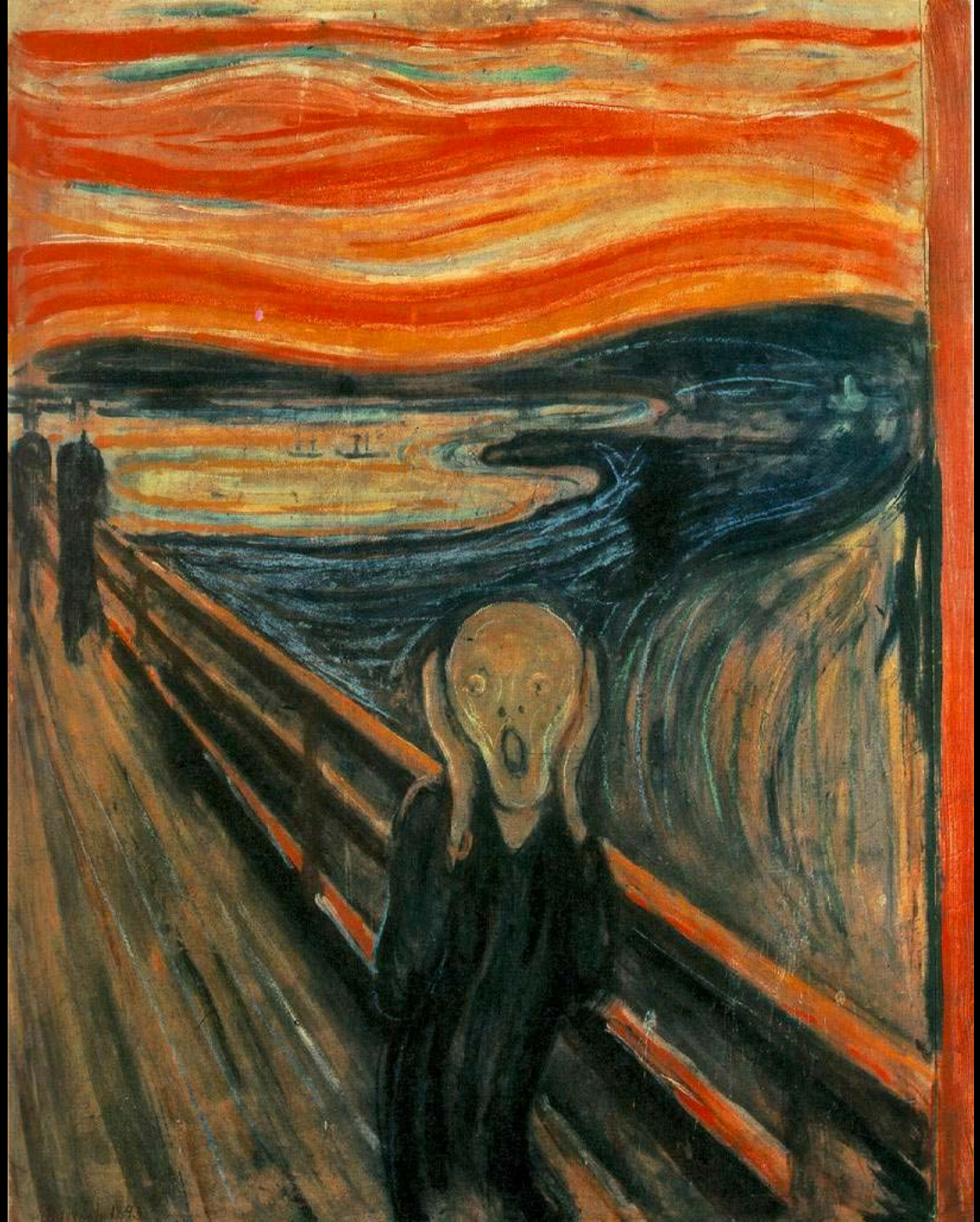
FILE: 6202sc01.dgn	DN: DVL	CK:	DW: RNP	CK: DVL
©TxDOT MAY 2004	DISTRICT	FEDERAL AID PROJECT		SHEET
REVISIONS MOVED BENT #9 AND REDESIGNED SPANS 9 & 11 TO USE SIMILAR BEAMS 11-18-04	5	HP 55(1)		1903
	COUNTY	CONTROL	SECT	JOB	HIGHWAY
	LUBBOCK	0380	01	064	US 82

⚠ REVISED 11-24-04 VN

LEVELS DISPLAYED
PATH: BRG-RPORTER-1
6202sc01.dgn


76
TEXAS TECH

TEXAS TECH
5
3
12

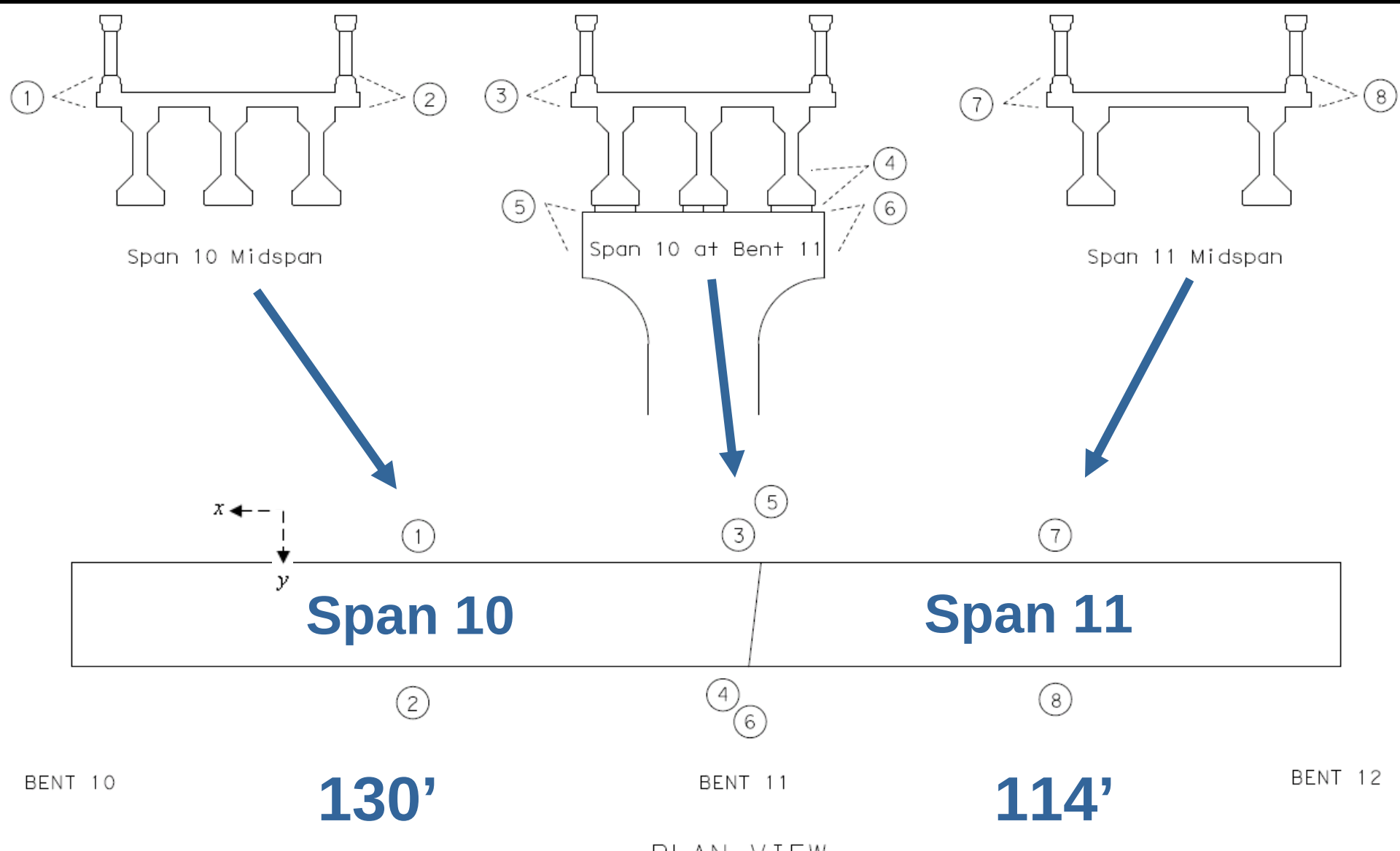


One week later...

Texas Tech - Oklahoma State

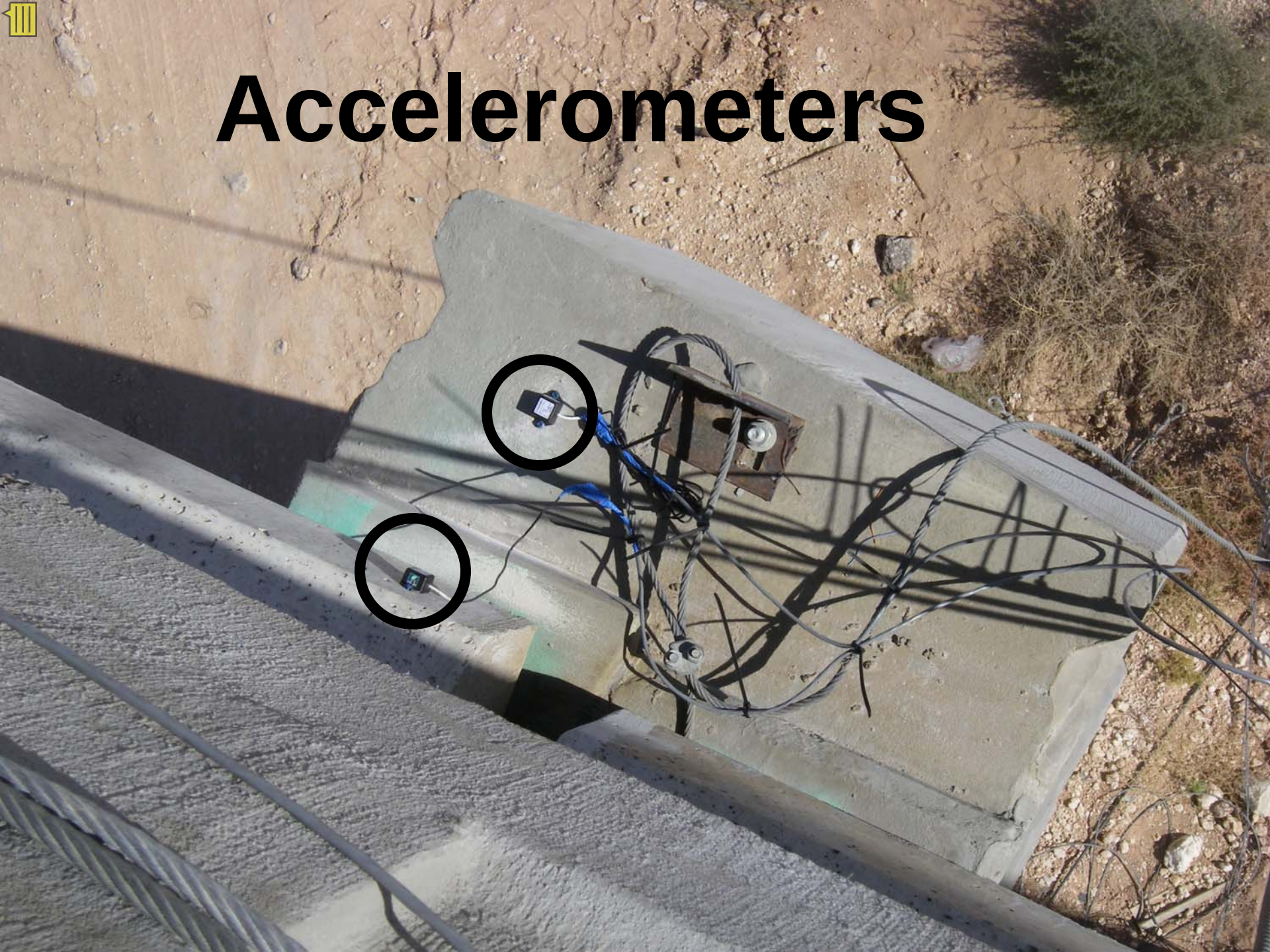
Instrumentation by:

Dr. Delong Zuo, Texas Tech University

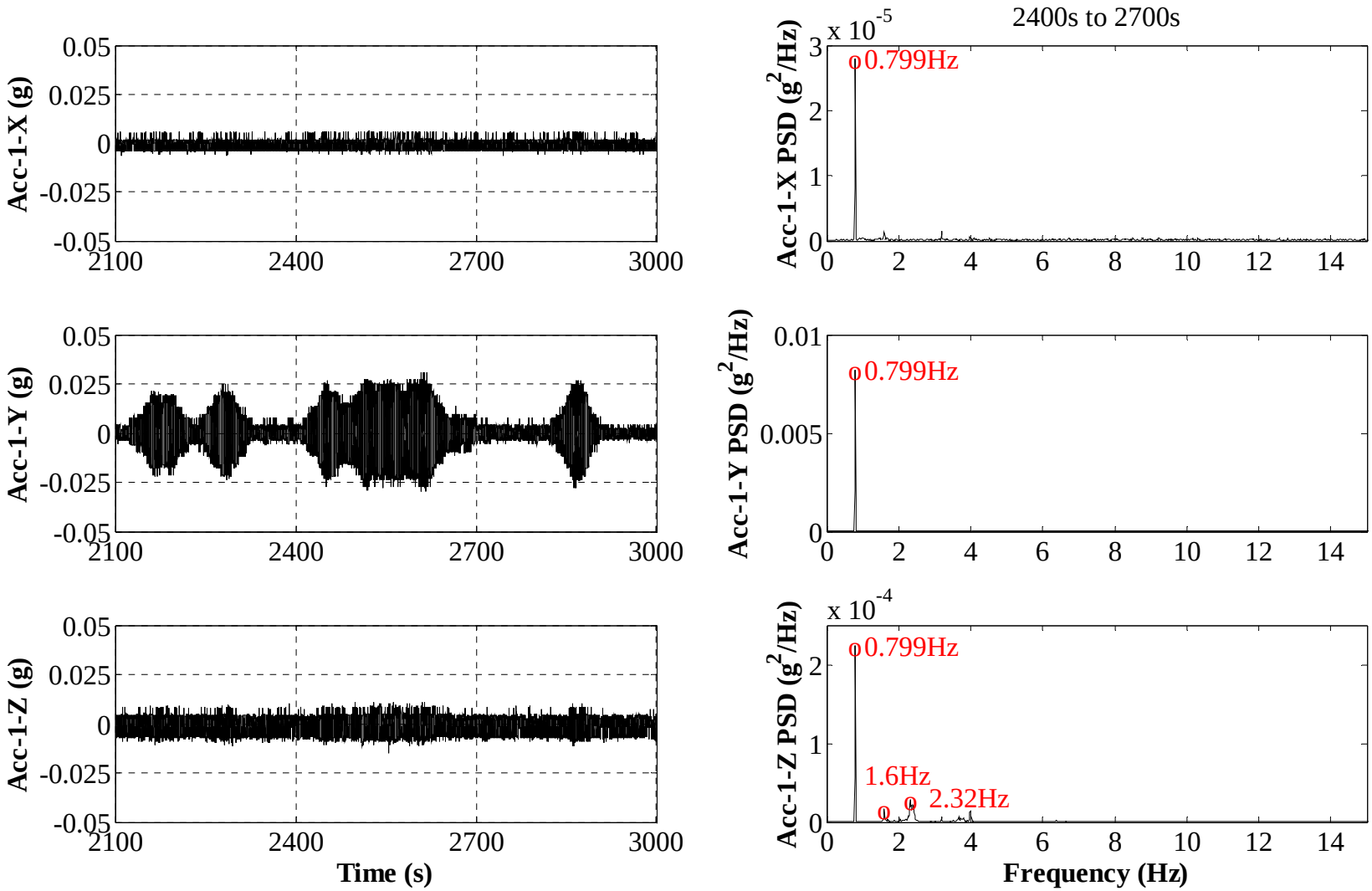

1
2
Span 10 Midspan
3
4
5
6
Span 10 at Bent 11
7
8
Span 11 Midspan
x
y
1
3
5
7
Span 10
Span 11
2
4
6
8
BENT 10
130'
BENT 11
114'
BENT 12

Span 11
Span 10

Accelerometers

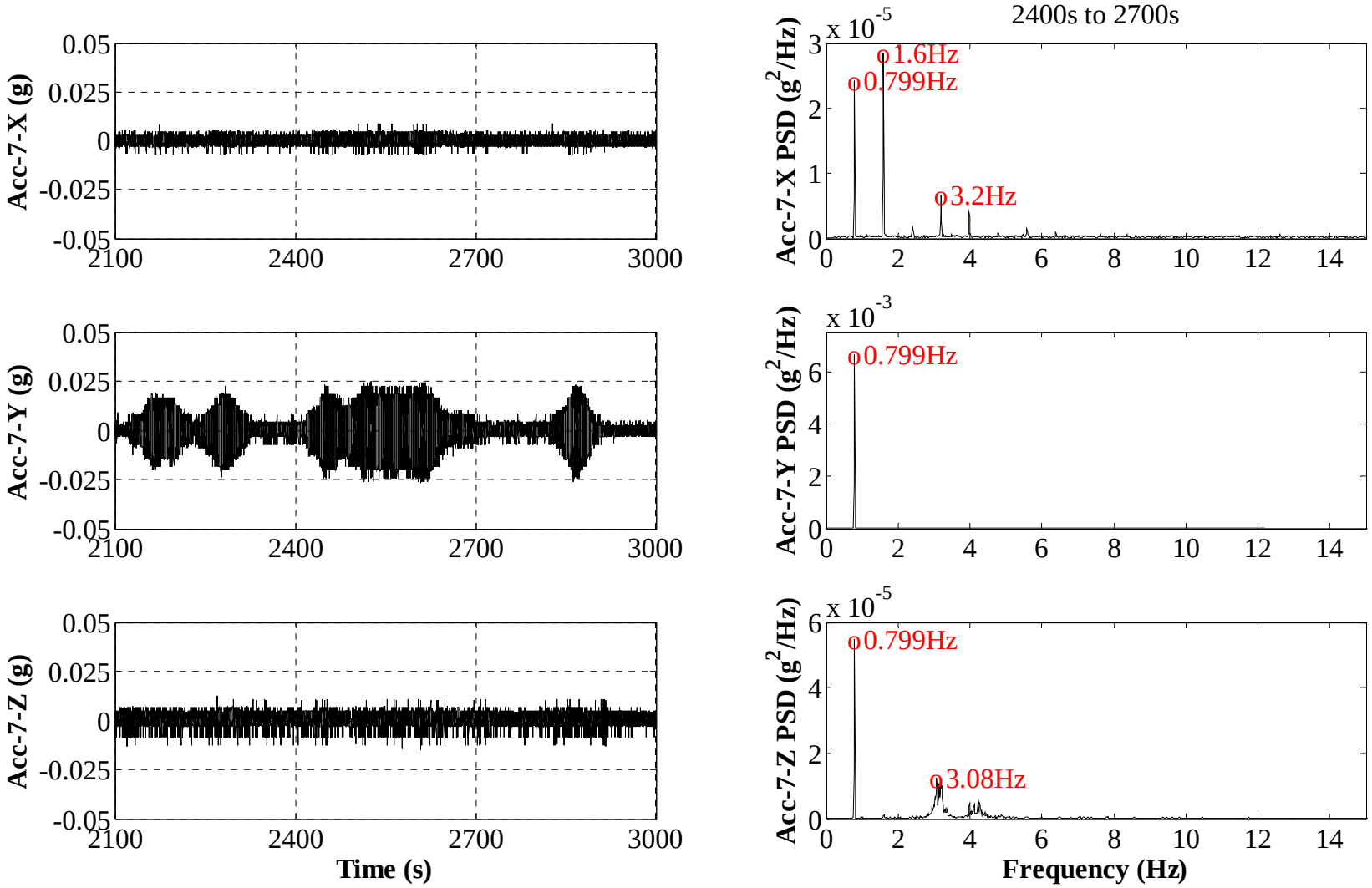


Span 10	Span 11



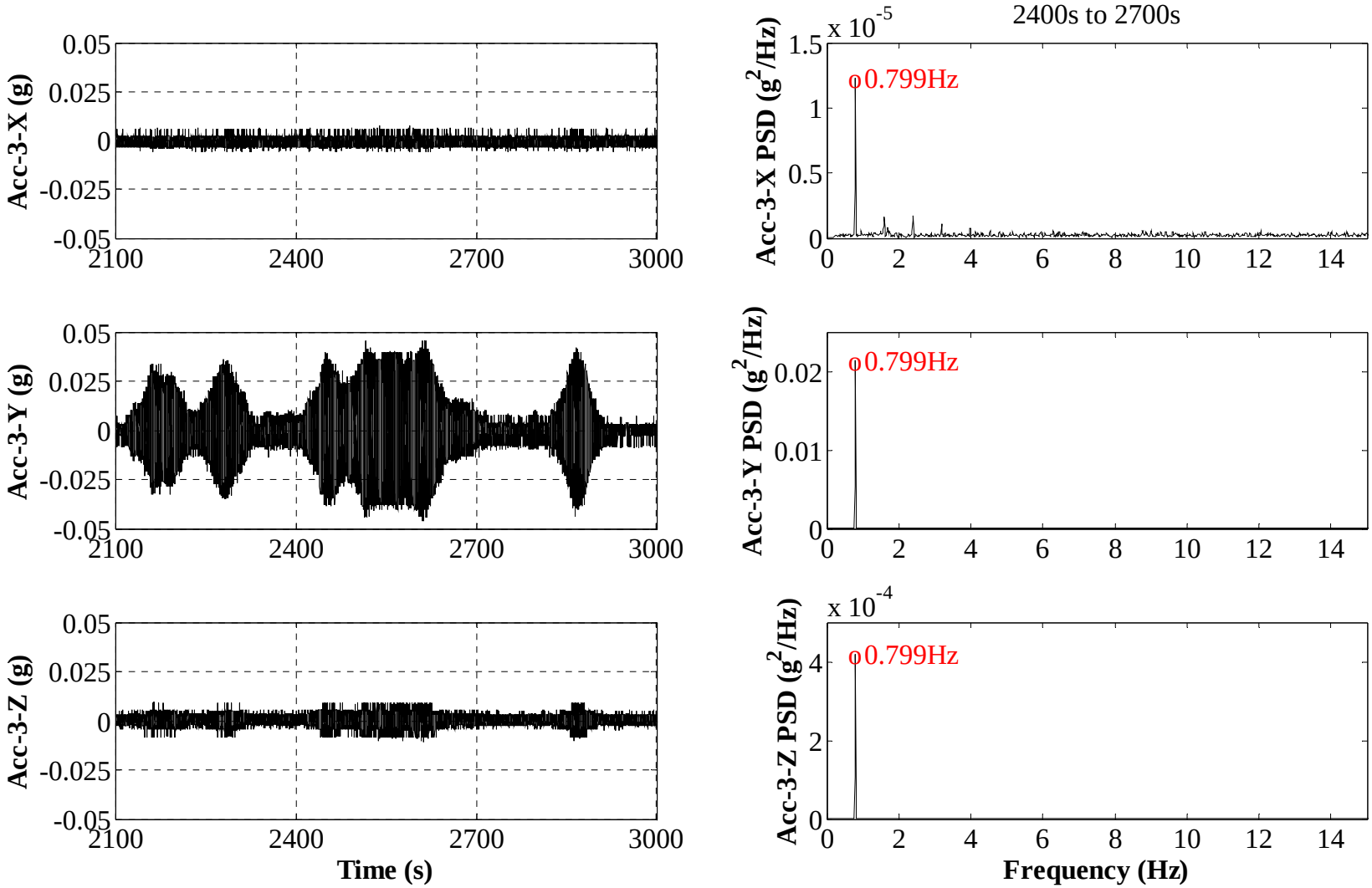
15 min

Span 10	Span 11



15 min

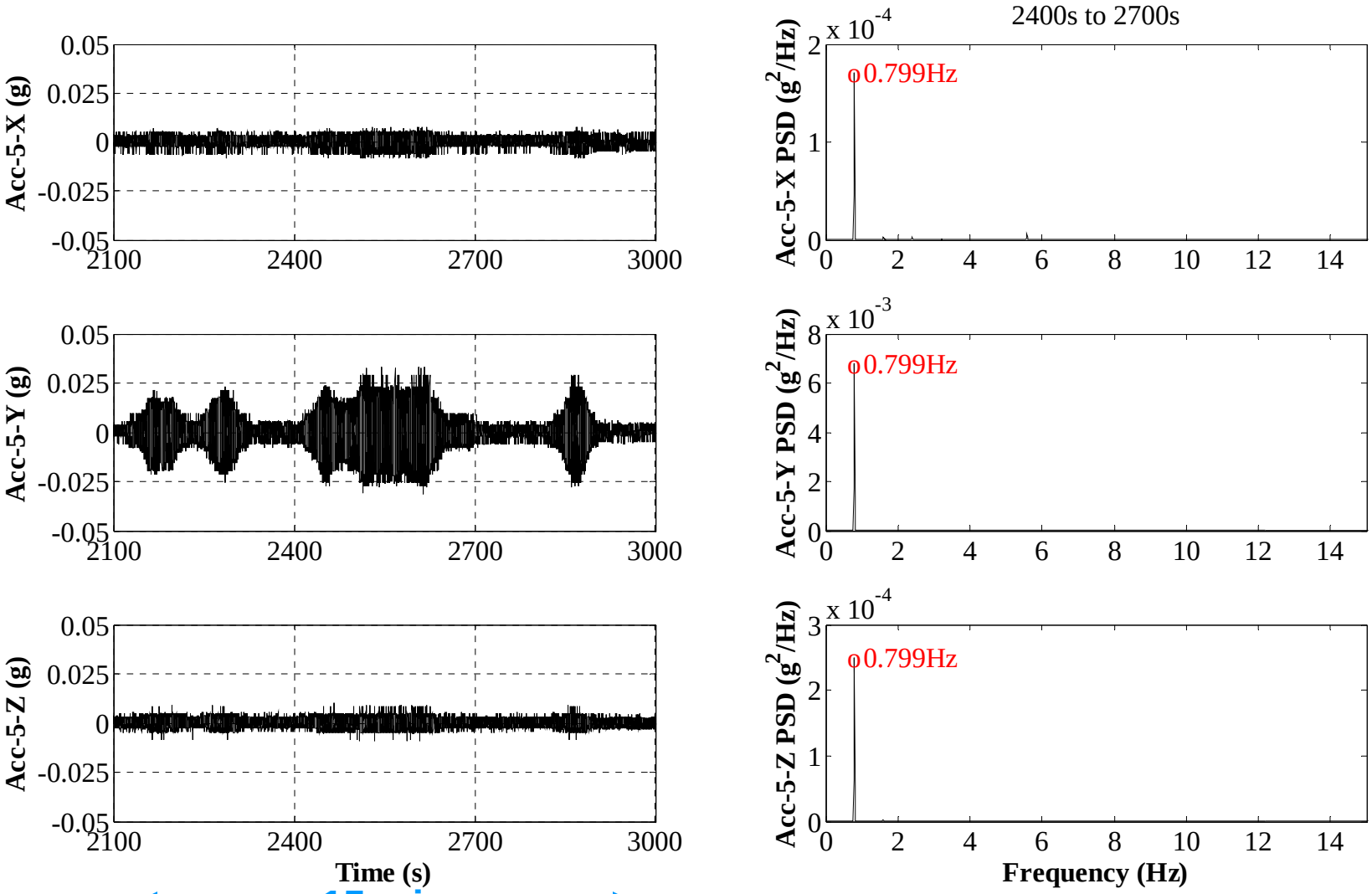
Span 10	Span 11



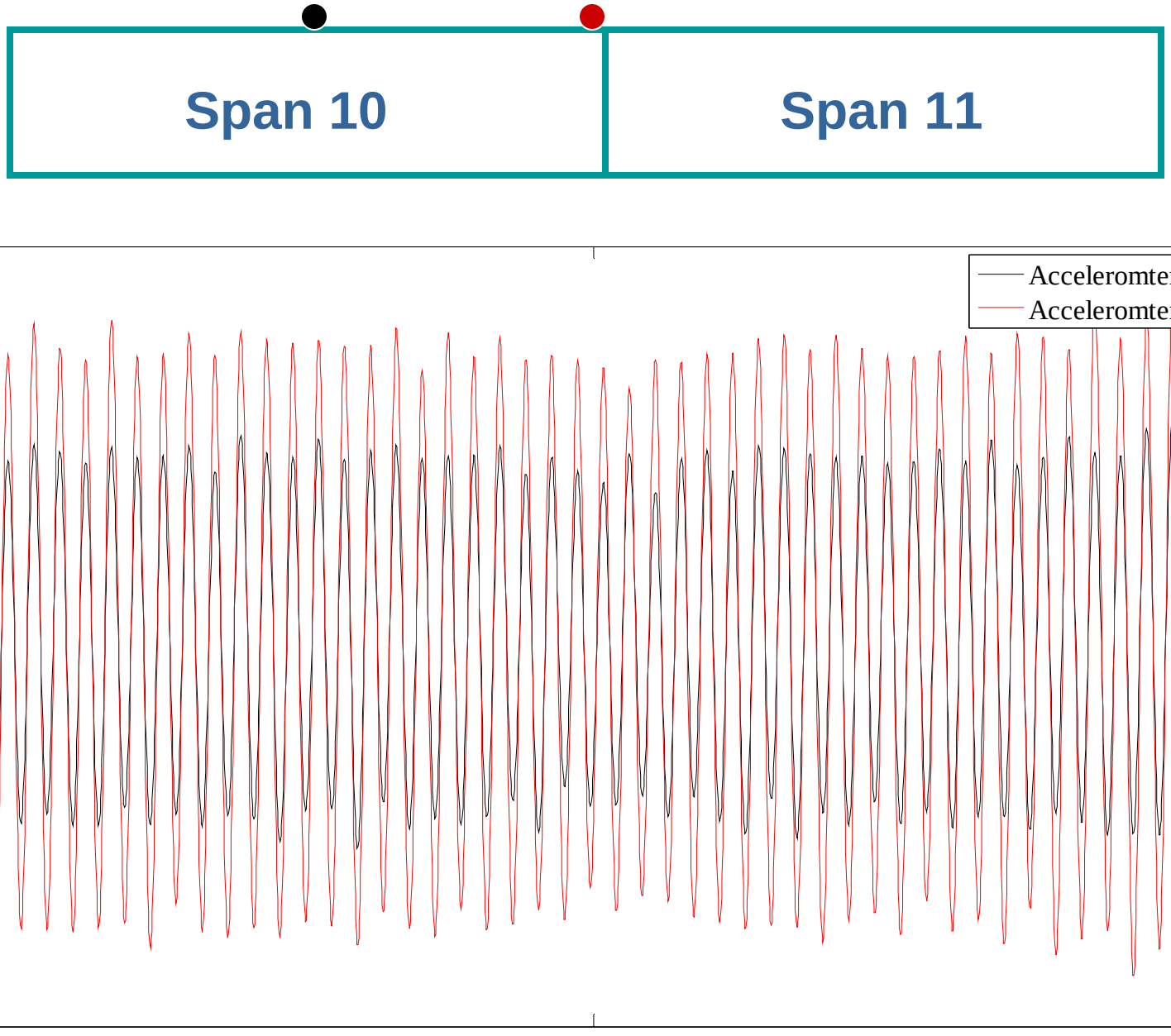
15 min

Span 10

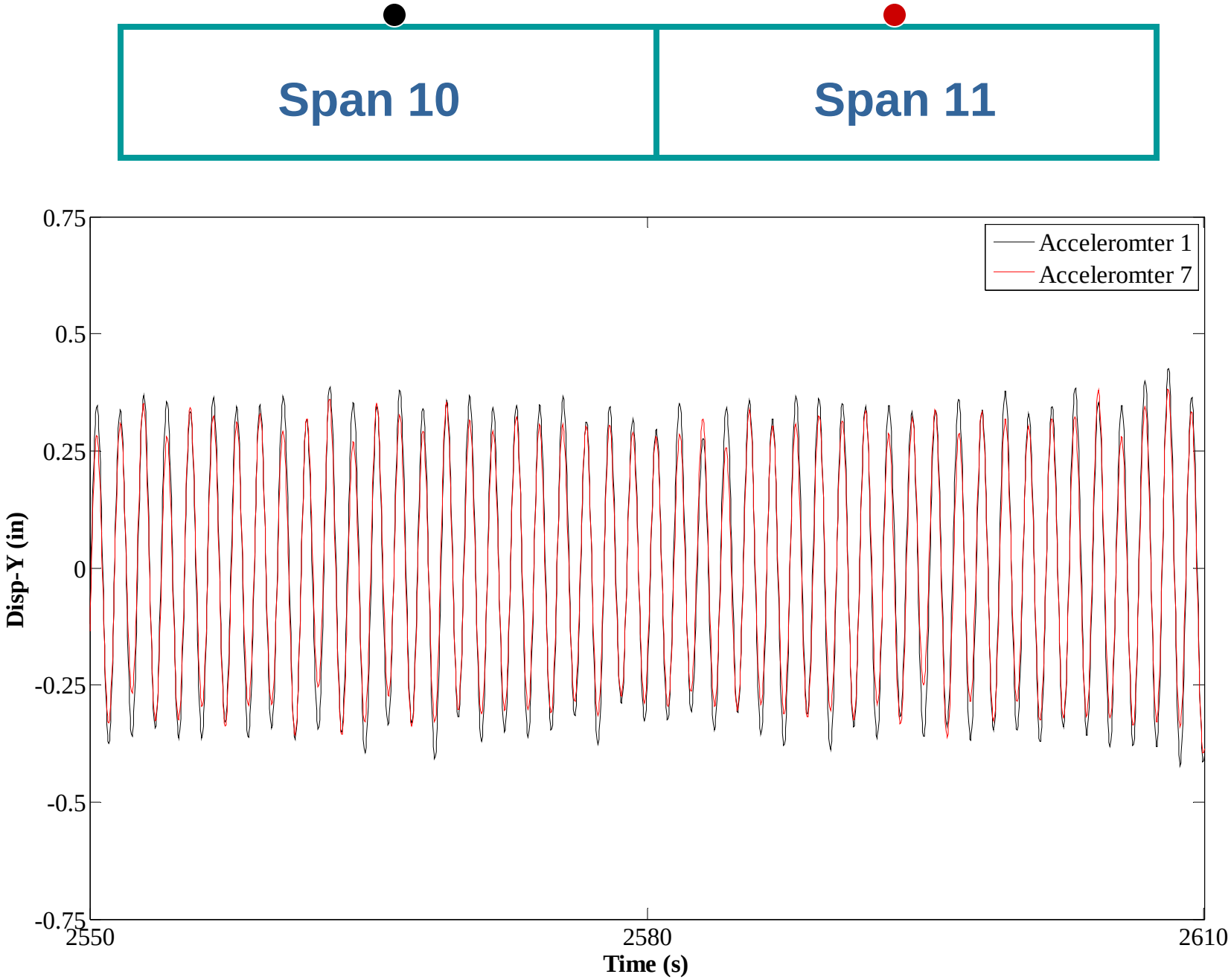
Span 11

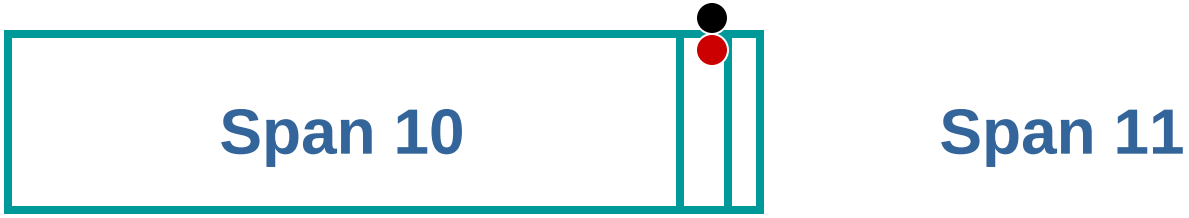


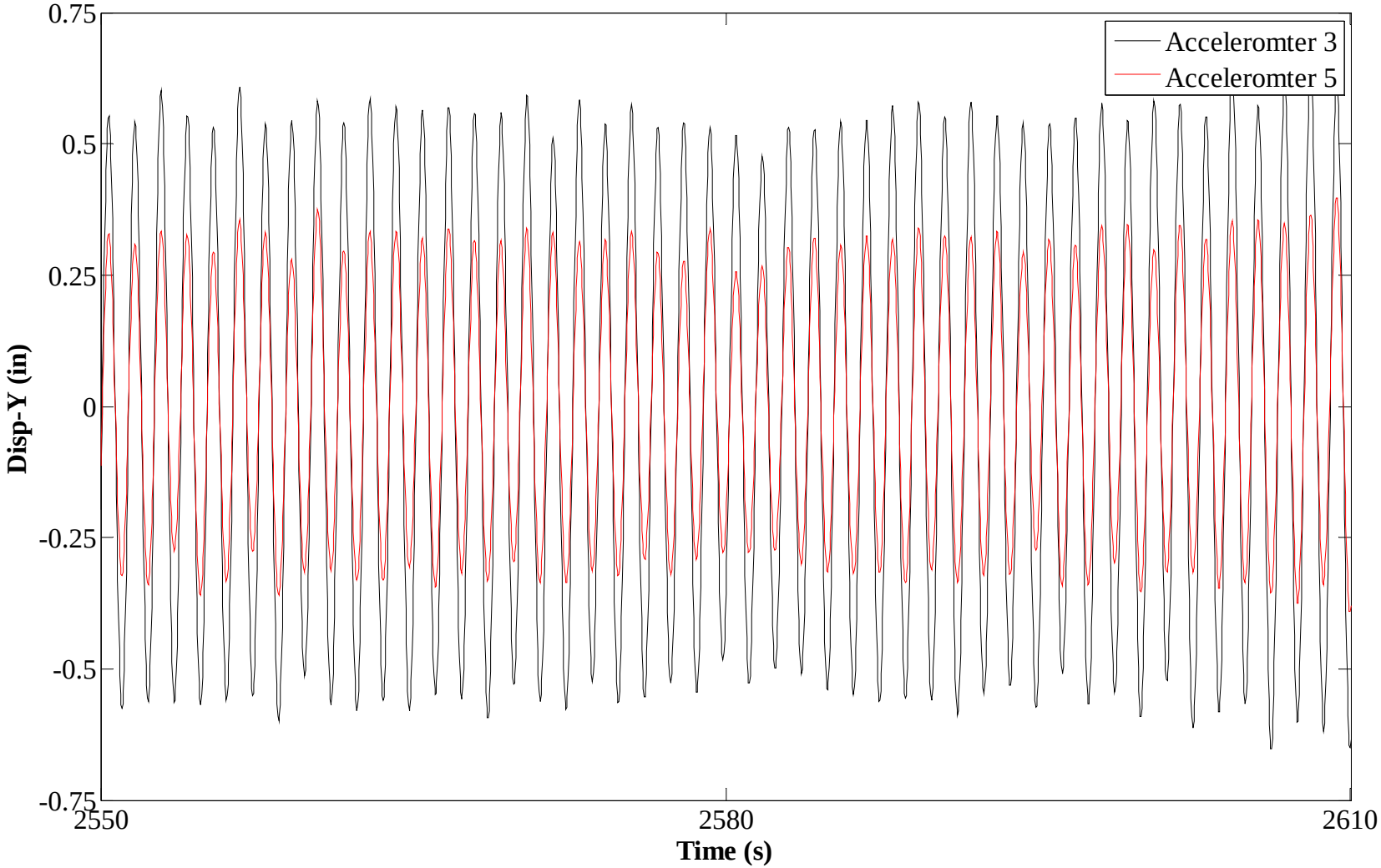
15 min


Span 10
Span 11

Accelerometer 1
Accelerometer 3
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
Disp-Y (in)
2550
2580
2610
Time (s)

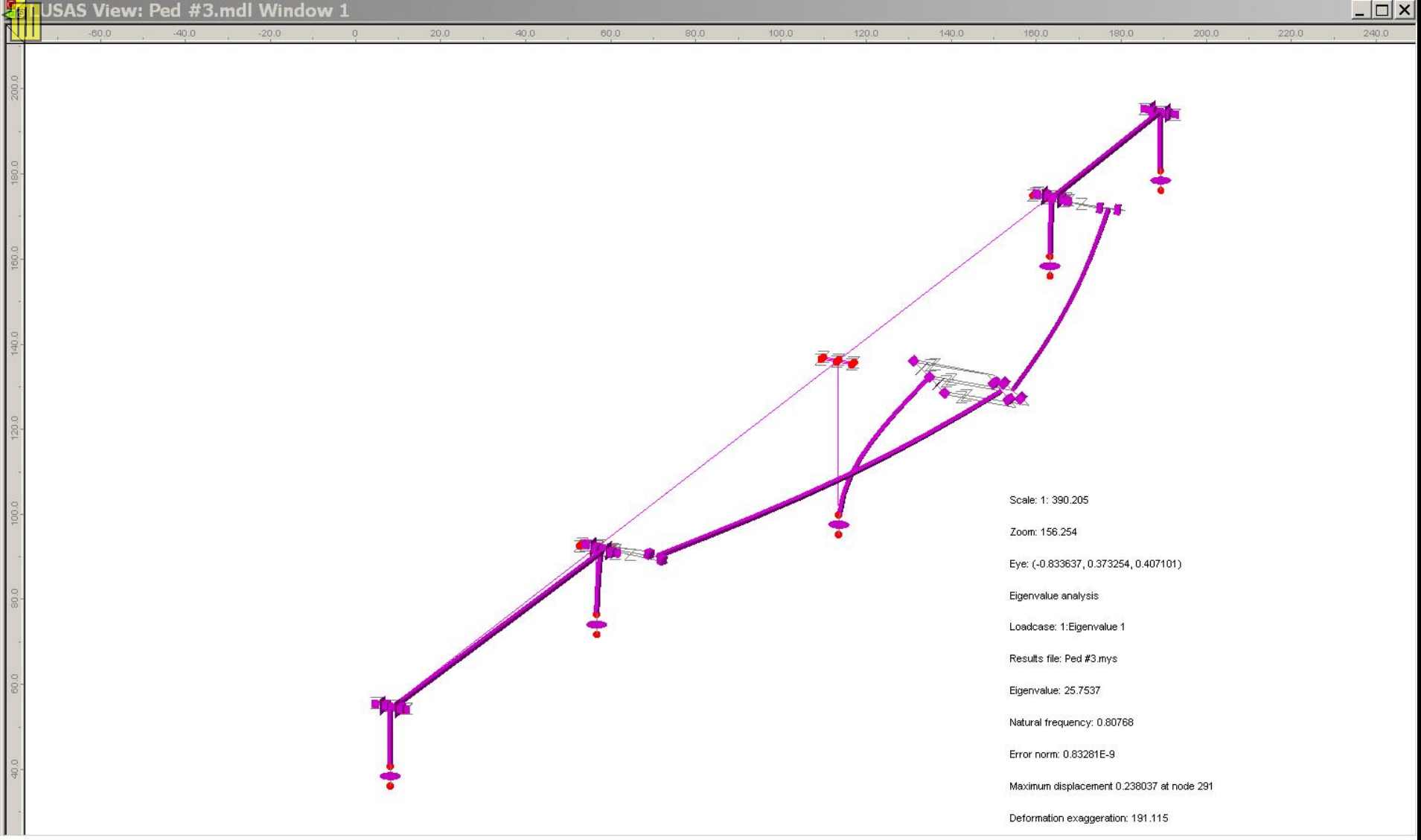

Span 10
Span 11
Acceleromter 1
Acceleromter 7
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
Disp-Y (in)
2550
2580
2610
Time (s)


Span 10
Span 11


Acceleromter 3
Acceleromter 5
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
Disp-Y (in)
2550
2580
2610
Time (s)

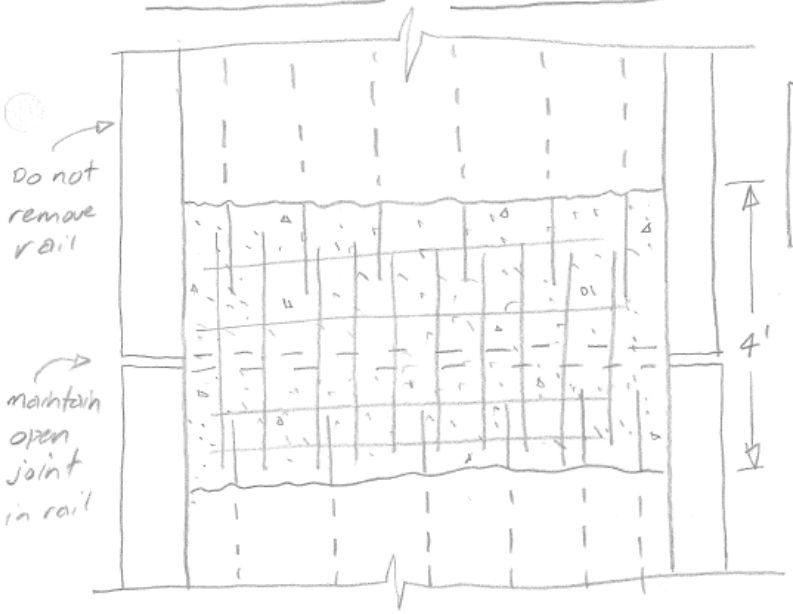
Creating a structural model to recreate TT results

- Swaying Laterally at .80 Hz
- Ends of spans moved more than mid-span of both spans
- Ends of spans moved more than bent
- All elements moving in phase (no snaking)



Existing Bridge N.F. = .80

STIFFENING SUPERSTRUCTURE

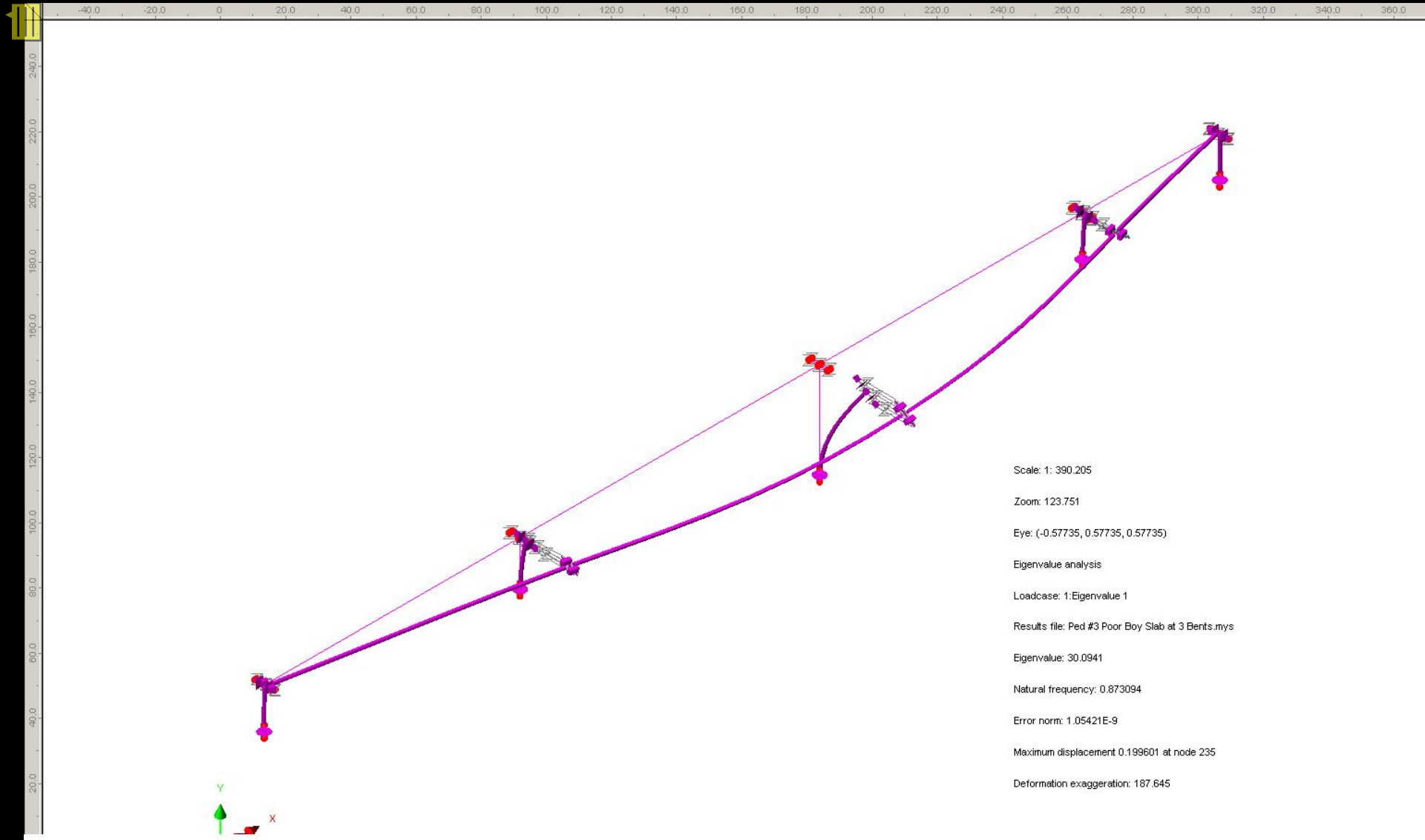


- Remove last few feet of slab ends and re-cast slab without an expansion joint

PLAN VIEW

POOR-BOY CONTINUOUS SLAB

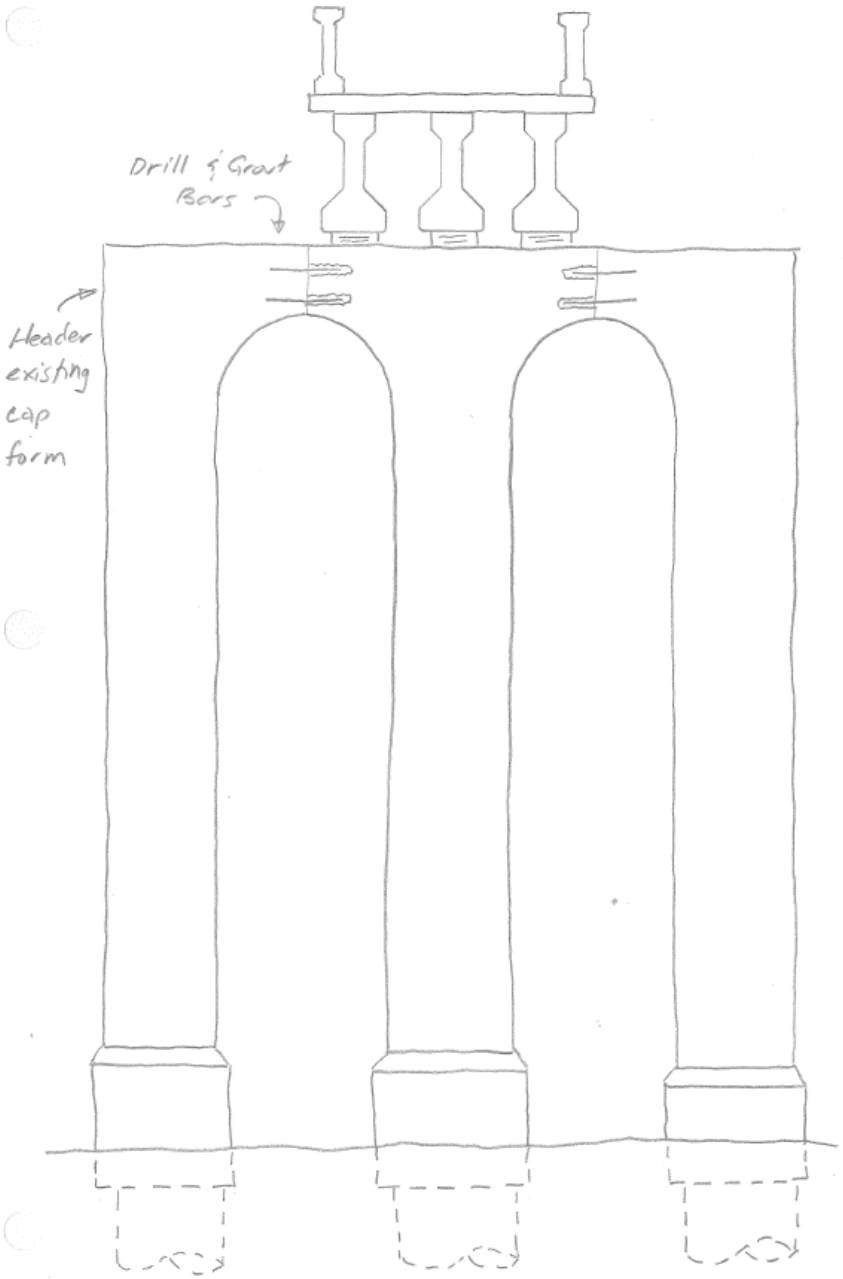
- Stiffens super. by joining spans and eliminating "hinges" at bents
- Locate at least at Bent #11 and probably at Bents 10 & 12
- Not as inexpensive as shear keys
- Disruptive to pedestrians, but could use staged construction w/ longitudinal cold joint to keep bridge open
- Some will see us destroying a portion of a brand new bridge



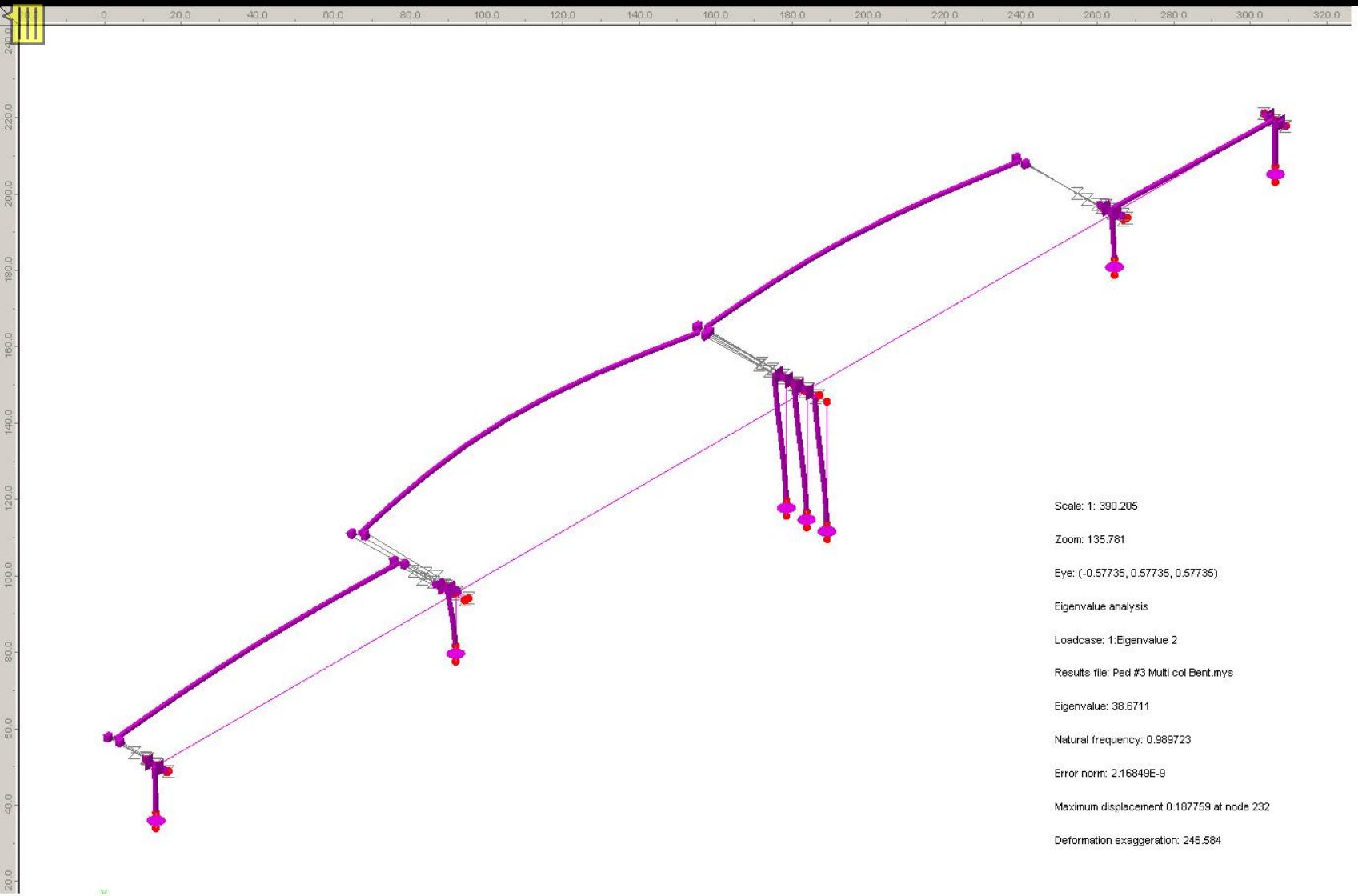
Solution: Poor-Boy Slab at 3 Bents N.F.= .87

STIFFENING SUBSTRUCTURE

WIDENING BENT

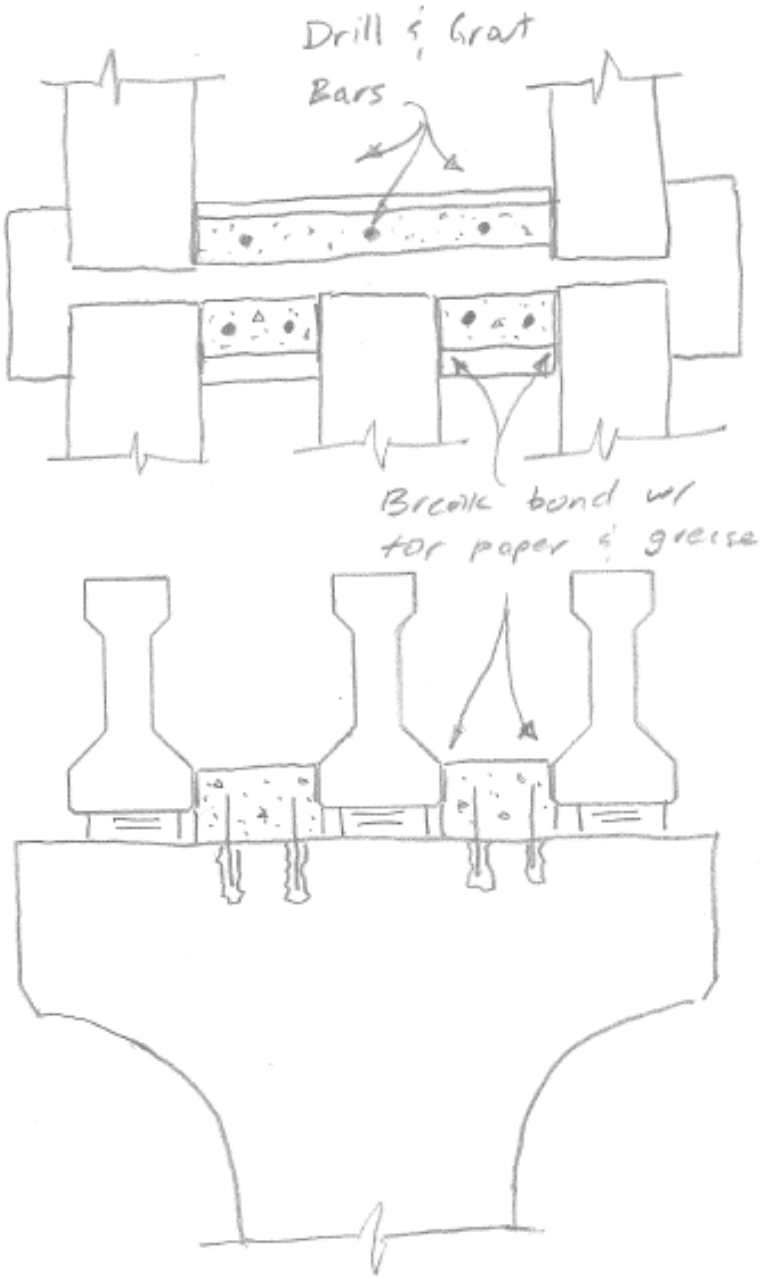


- stiffens bent thru additional columns and frame action
- can utilize existing forms-- need header in cap form -
- most expensive retrofit
- non-disruptive installation



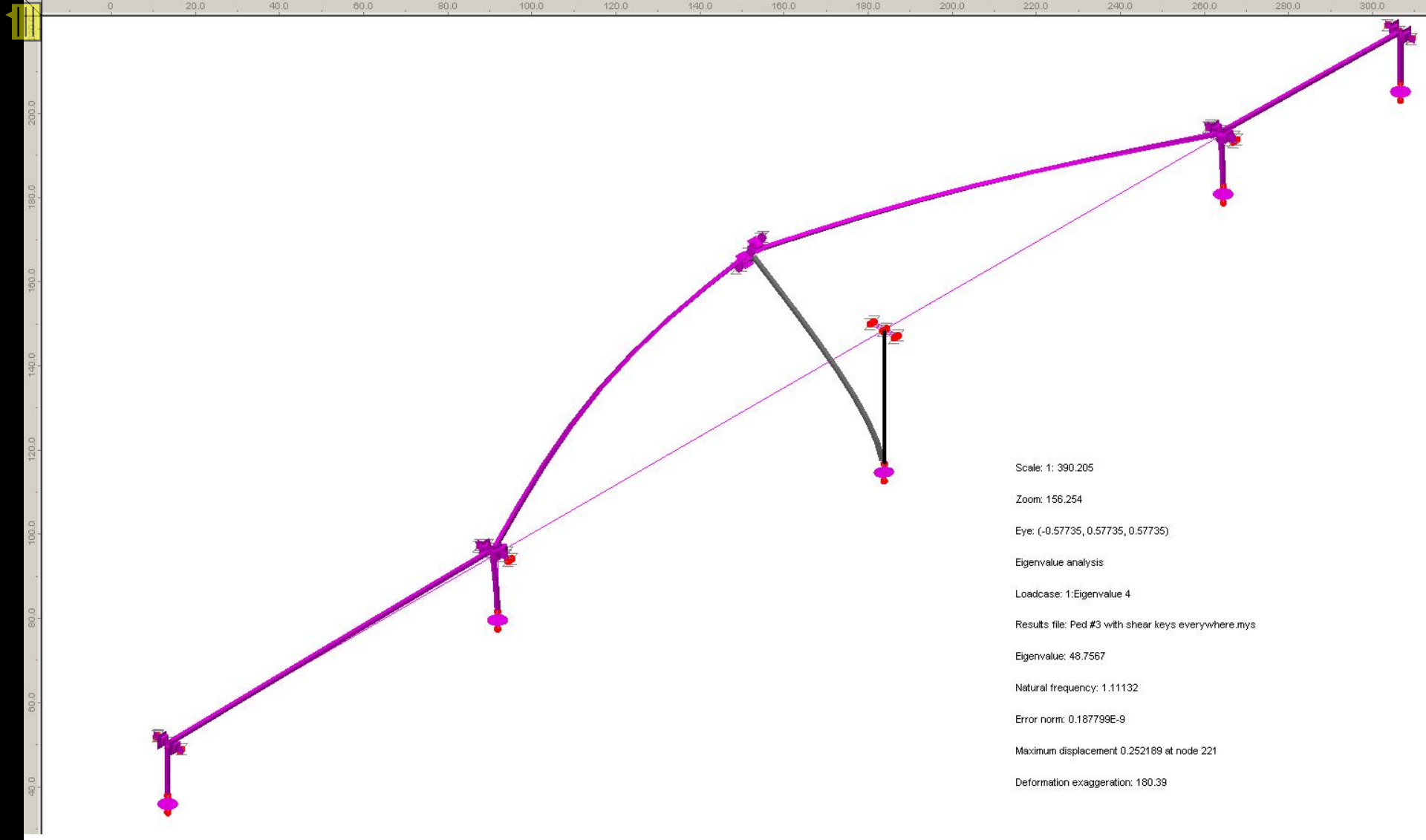
Solution: Multi-Column Bent N.F. = .99

STIFFENING BEARING PADS

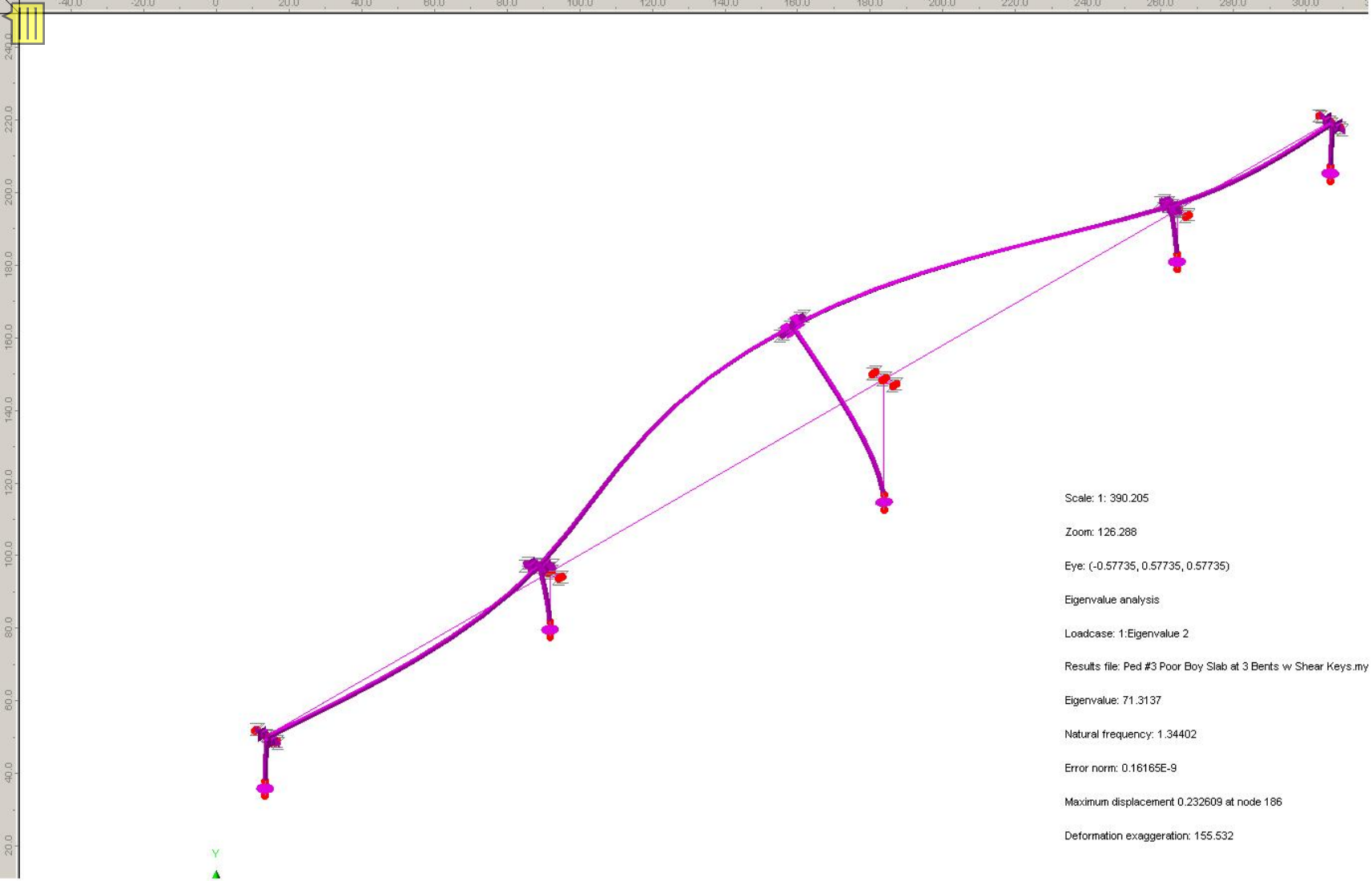


SHEAR KEYS

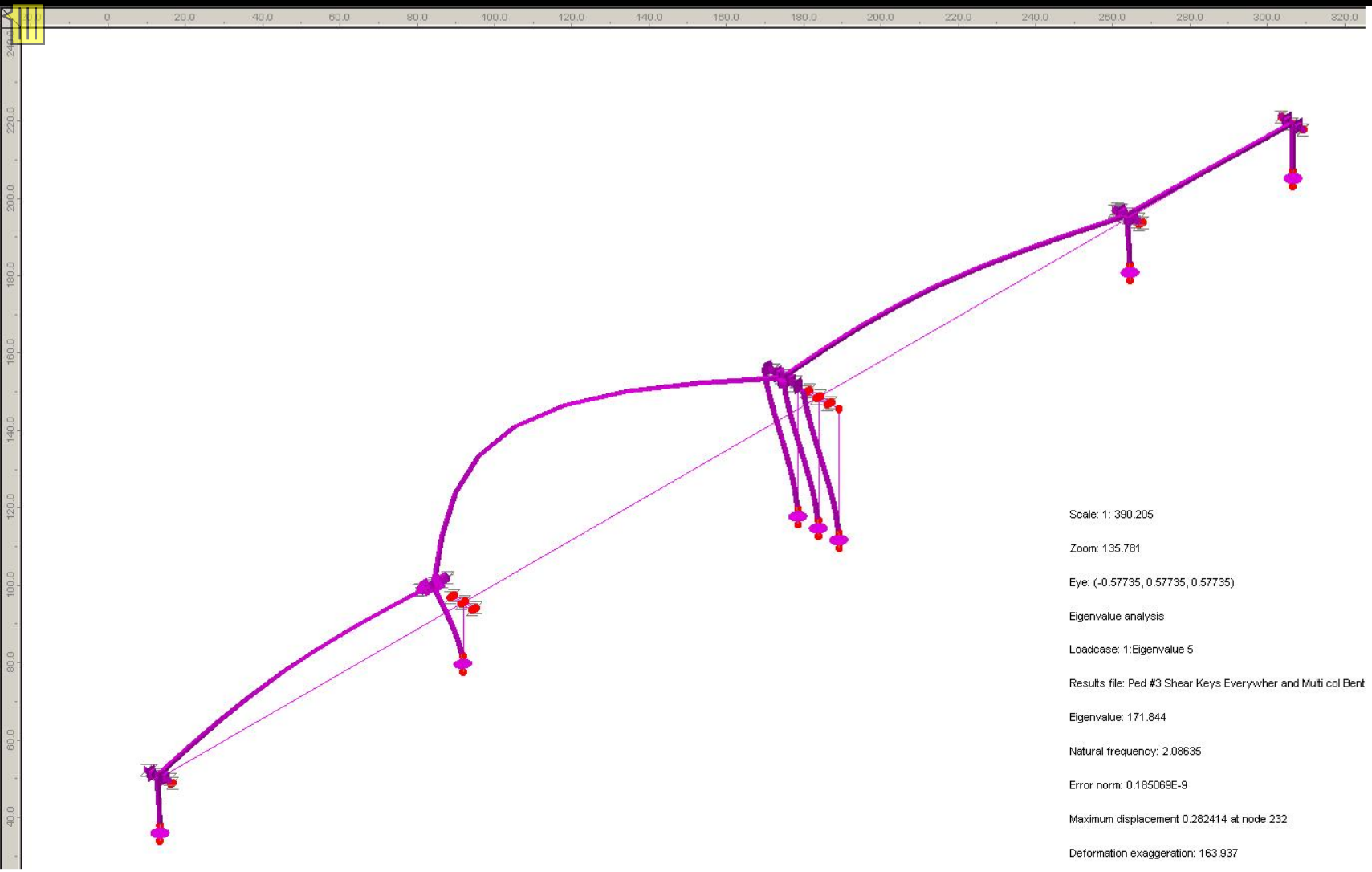
- Shear keys keep pads from translating laterally
- Locate, at a minimum, at Bents 10, 11 & 12
- Least expensive retrofit
- Non-disruptive installation



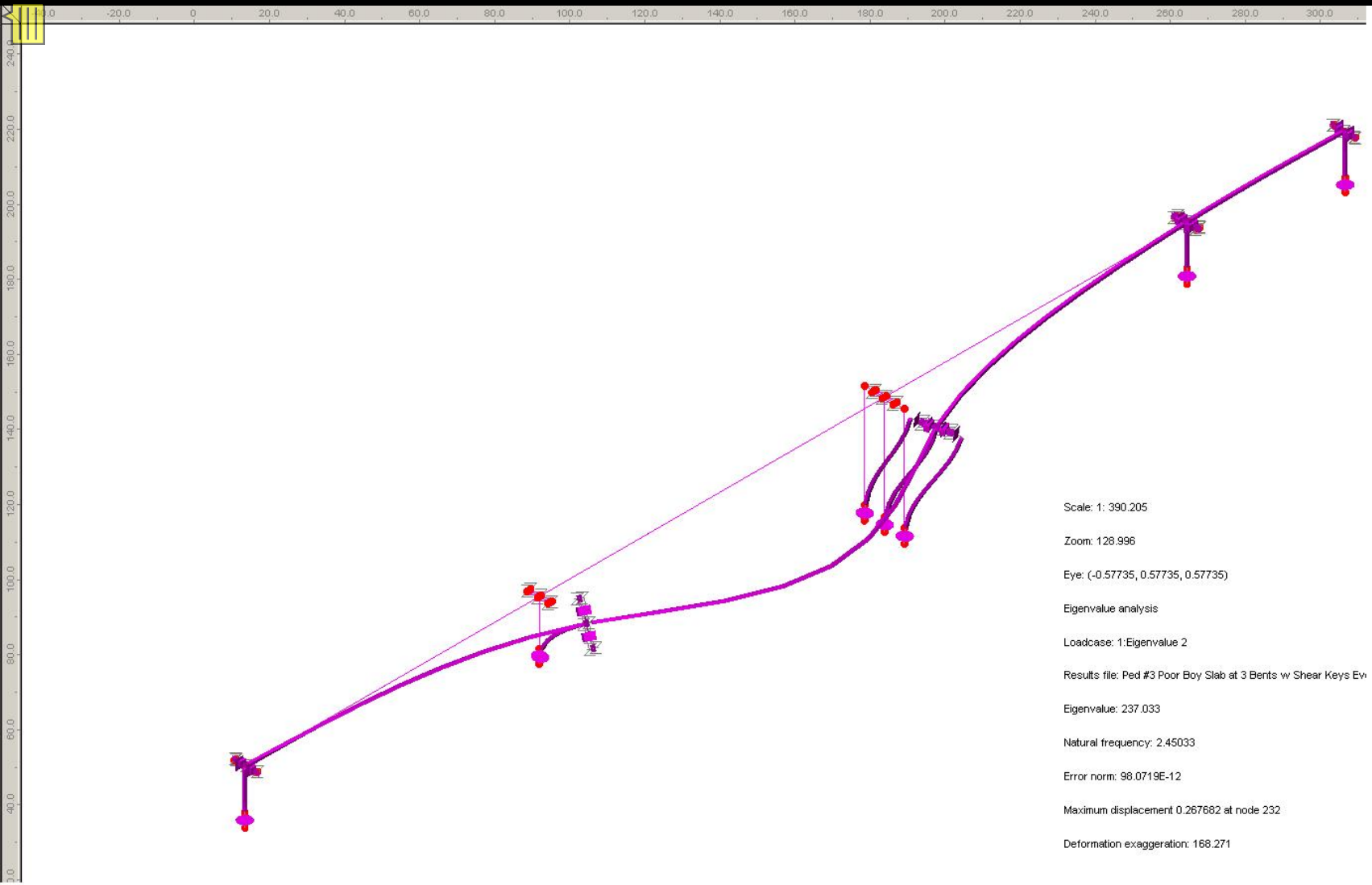
Solution: Shear Keys N.F. = 1.11



Solution: Poor-Boy Slab with Shear Keys N.F.= 1.34



Solution: Multi-Column Bent w/ Shear Keys N.F. = 2.09



Solution: Multi-Column Bent w/ Shear Keys and Poor-Boy Slab N.F.=2.45

Natural Frequencies

Existing	0.80
Poor-Boy Slab	0.87
Multi-Column Bent	0.99
Shear Keys	1.11
Shear Keys + Poor Boy Slab	1.34
Multi-Col Bent + Shear Keys	2.09
Multi-Col Bent + Sh. Keys + Poor Boy	2.45

06/05/2009

06/09/2009

06/17/2009

06/01/2009

Ingredients for the Perfect Storm:

- No AASHTO Bridge Spec provision
- Long Spans
- Tall, narrow column
- Tall, soft, small pads
- ADA requirement—exp. joint at every span
- Aesthetics
- Proximity to large venue

Bridges for only pedestrian and/or bicycle traffic shall be designed for a live load of 0.085 ksf. The frequency of pedestrian footfall loads in either the vertical or transverse lateral direction shall not resonate with the natural frequencies of the structure.

Where pedestrian and/or bicycle bridges can be used by maintenance and/or other incidental vehicles, the following loads shall be considered in the Strength II Load Combination, unless otherwise specified by the Owner:

Clear Bridge Width (w)	Design Load
7 ft. $\leq w <$ 10 ft.	H5
$w \geq$ 10 ft.	H10

The pedestrian load shall not be considered to act concurrently with these vehicles. The dynamic load allowance need not be considered for these vehicles.

The conservatism in this Article reflects the unpredictable nature of pedestrian load, which gains significance where it becomes a primary load. Footfall has been estimated to have a frequency of 2 Hz in the vertical direction, and 0.67 Hz in the transverse lateral direction. Therefore, the fundamental frequency of the structure should be a minimum of 3 Hz and 1.3 Hz in the vertical and lateral directions respectively, unless detailed analysis justifies otherwise. The reduction based on deck influence area from previous specifications has been eliminated due to potential crowding on the structure.

Snow removal and other maintenance vehicles sometimes have access to pedestrian bridges. The slow speed of such vehicles justifies the omission of dynamic effects.

Sidewalks, pedestrian, and/or bicycle bridges less than 7.0 ft. in width need not be designed for a maintenance vehicle. Where vehicles larger than those specified herein could mount a sidewalk, consideration should be given to using the full design truck load. For slab design of beam-slab type bridges, force effects from concentrated wheel live loading may exceed those due to the uniform pedestrian loads. Force effects listed in Table A4-1 may be scaled accordingly.

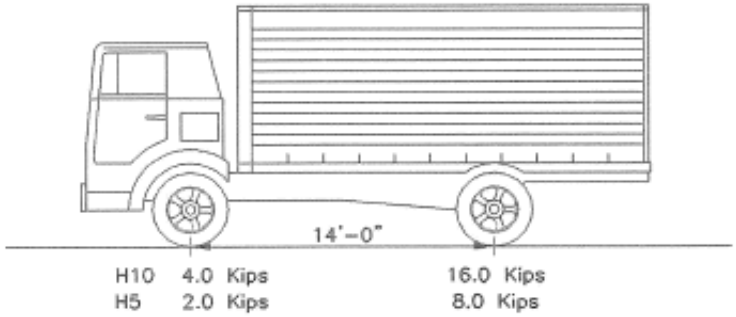


Figure 3.6.1.6-1 H-Vehicle Configurations.

Now they tell us…

AASHTO 2008 Interim Specification

1.3 Hz min. lateral

Success of Retrofit?

POTTS
15

Questions ?