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NCTSPM

NATIONAL CENTER FOR TRANSPORTATION SYSTEMS PRODUCTIVITY AND MANAGEMENT

Mitigating Fatigue of Cantilevered Overhead Sign Structures Due to Natural Wind and Truck-Induced Gusts

Presented at the University Transportation Center
Conference for the Southeastern Region

Georgia Tech Global Learning Center

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Problem Statement

- Failure of overhead sign structures due to **wind induced fatigue vibrations** have been reported, with an estimate of about 20 cantilever support structures fail every year in the U.S.
- Wind induced fatigue vibrations are primarily caused by:
  - Natural Wind gusts
  - Truck induced gusts

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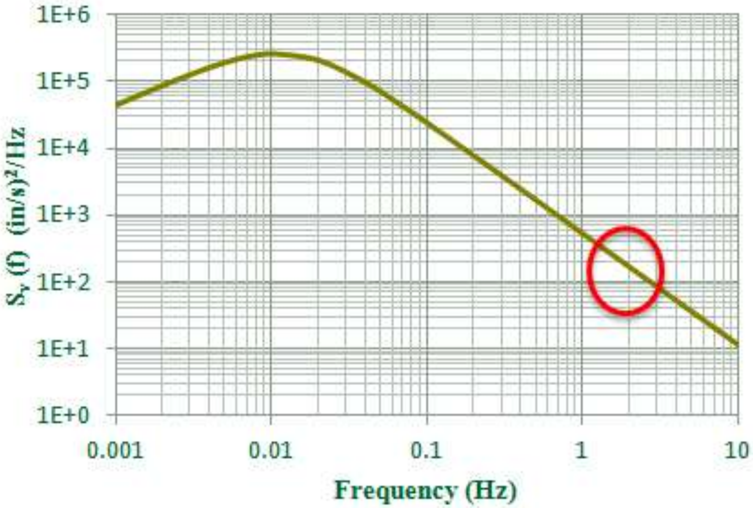
Background

- Fatigue
- Susceptibility of overhead sign structures to fatigue vibrations
- Nature of wind loads
- Frequencies of sign structures vs. wind frequencies



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Objective

- Mitigate fatigue stresses of cantilevered overhead sign structures due to natural wind and truck-induced gusts

Approach

- Modify structural fundamental frequency
  - Stiffness and mass distributions $f_o = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

Considerations

- AASHTO Supports Specifications
- Practical member shapes
- Design economy

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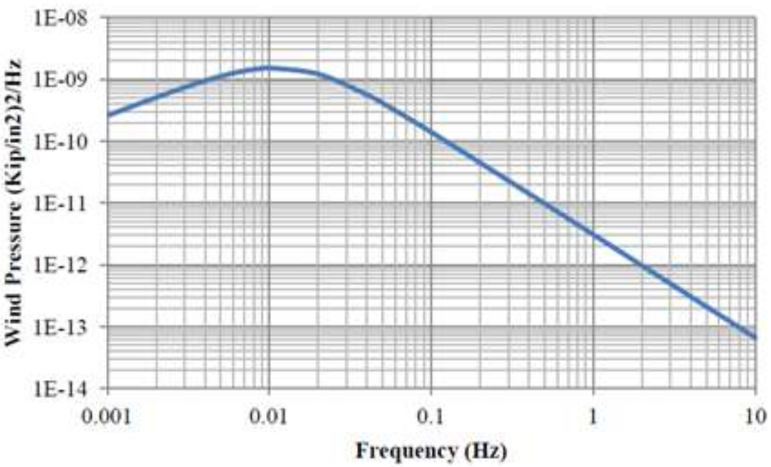
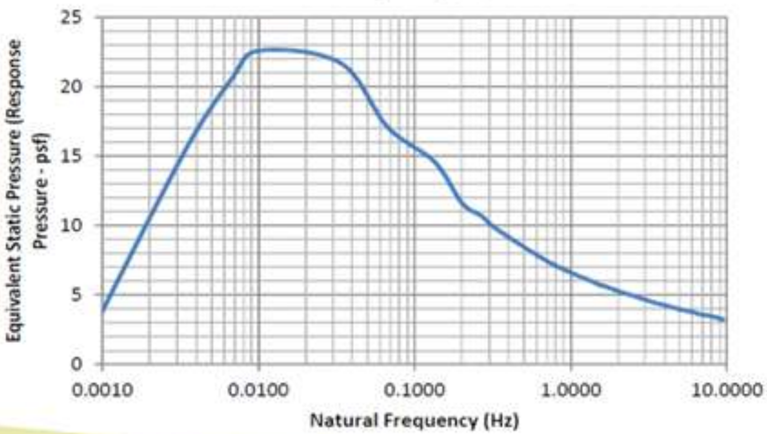
Work Plan

- Assemble shop drawings
- Define fatigue loading functions, EXCITATION
- Full scale 3D FEA modeling
- Calculate frequencies and fatigue stresses, RESPONSE
- Check Model Accuracy
- Investigate factors affecting structure's dynamic performance and induced fatigue stresses:
  - Member Size
  - Member shape
  - Truss member arrangement
  - Structure Type
- Conclusions
- Final Report

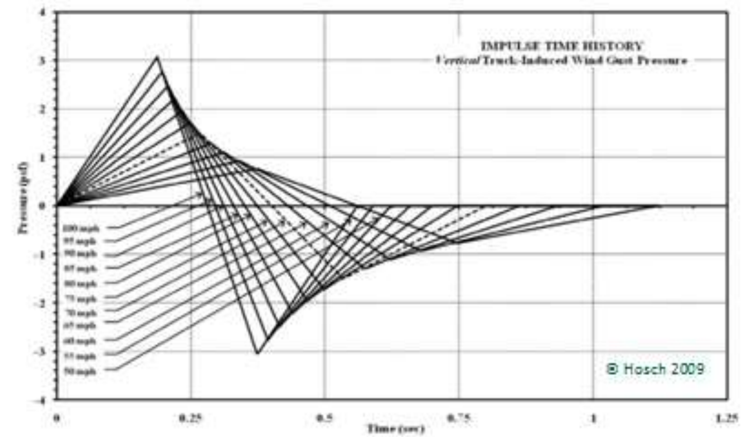
Structure Excitation

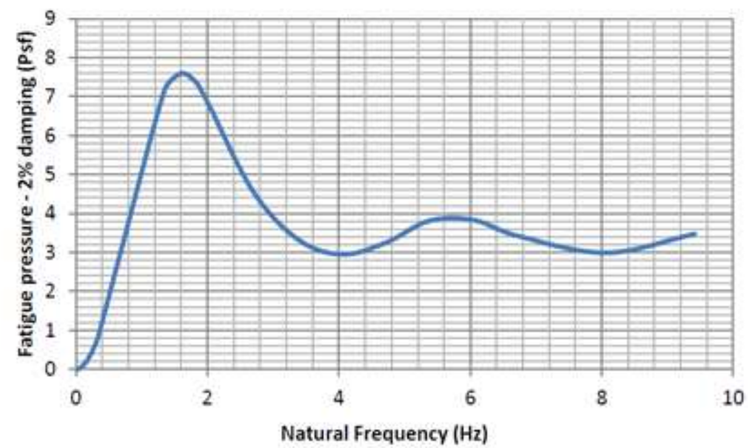
- Natural Wind Gusts (PSD)



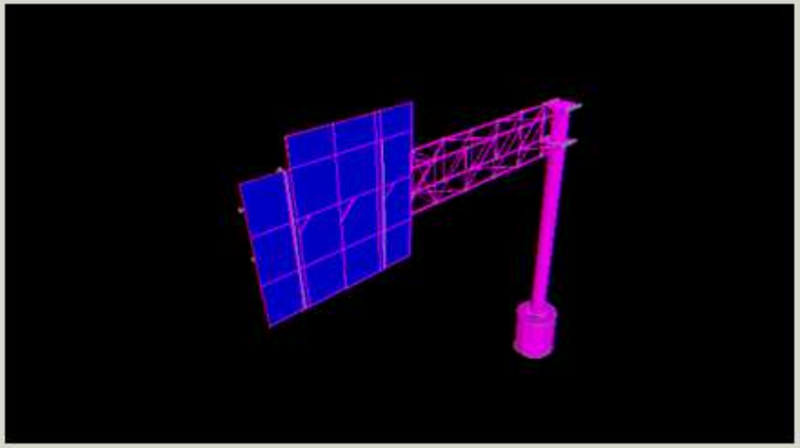
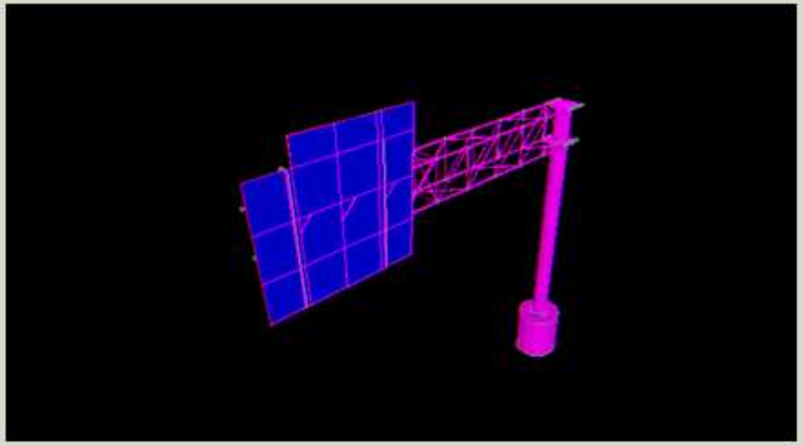


- Truck-induced Wind Gusts (TH)



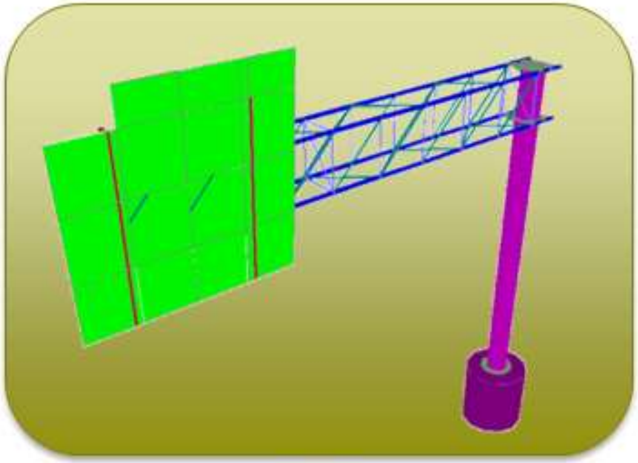


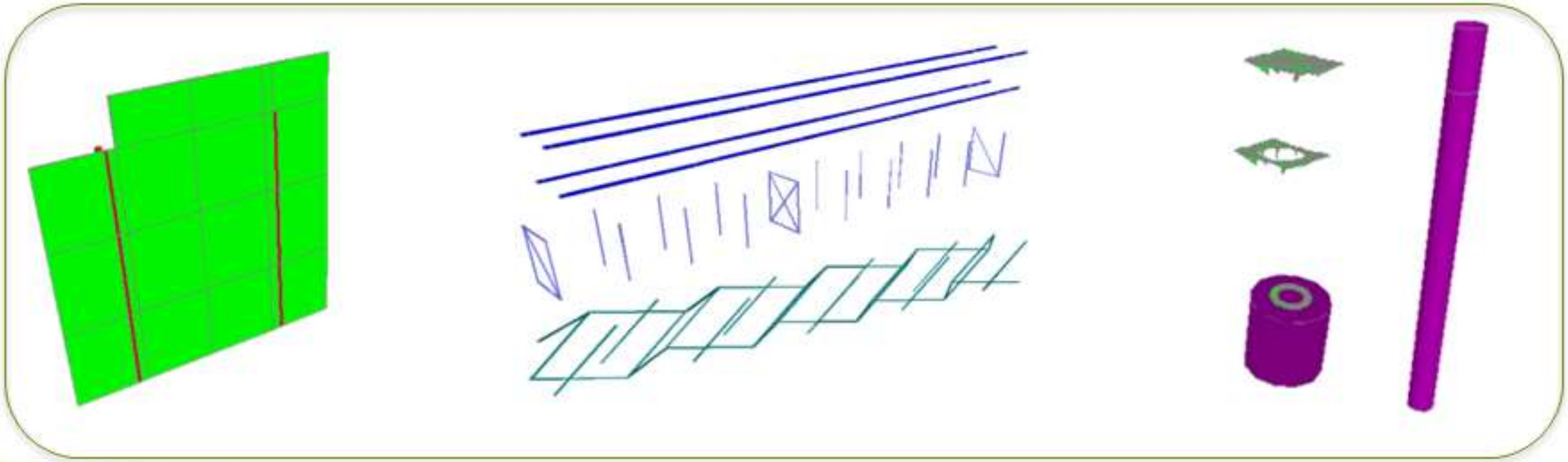
Structure Response

First mode of vibration (Natural wind)	Second mode of vibration (Truck wind)
	
Experimental frequency = 1.61 Hz	Experimental frequency = 1.64 Hz
FEA frequency = 1.53 Hz	FEA frequency = 1.64 Hz
Difference = 4.97 %	Difference = 0.0 %
Max. Fatigue Stress at Post Base = 5.28 ksi	Max. Fatigue Stress at Post Base = 0.306 ksi

Structure Types

1) **4-chord Cantilevered Sign Structure**





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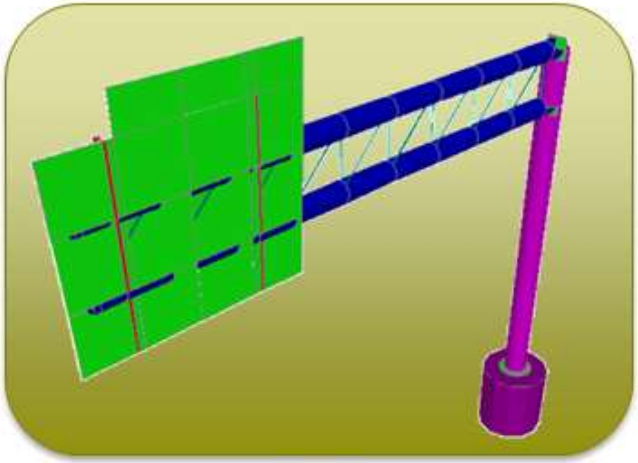
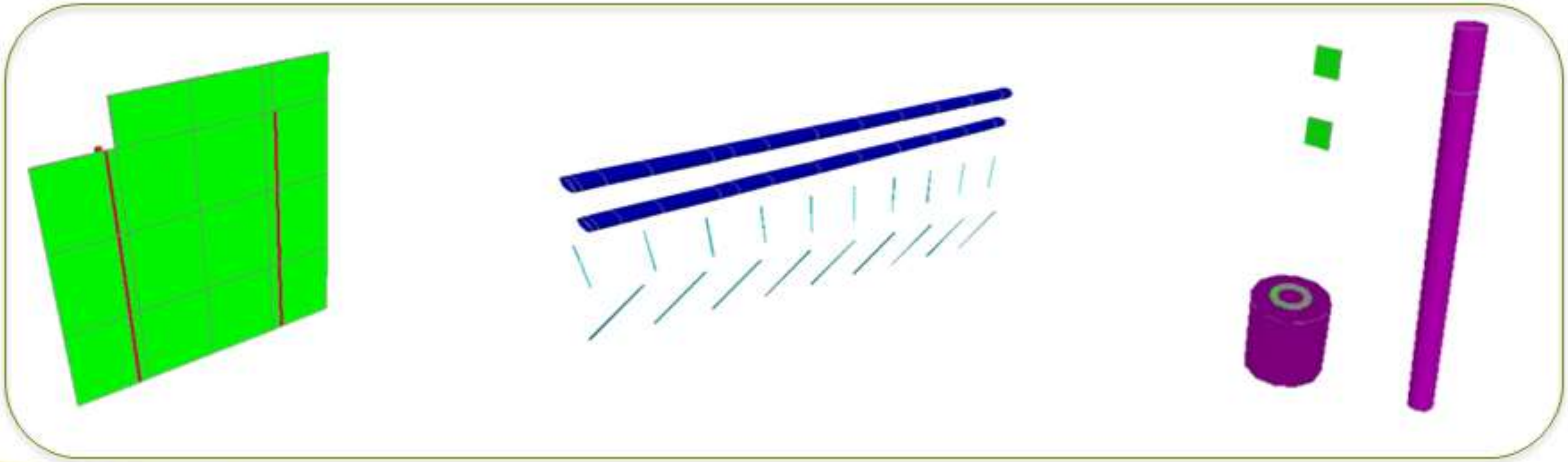
Structure Types… *(Cont'd.)*

2) **2-chord Cantilevered Sign Structure**

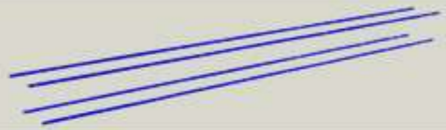
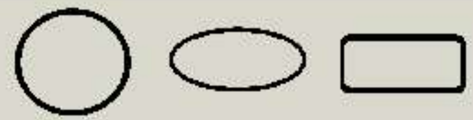
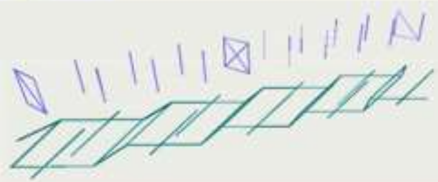
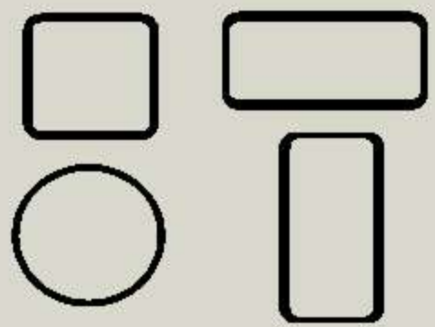




Structure Types… *(Cont'd.):*

Factors Affecting Dynamic Response of 4&2-chord Cantilevered Sign Structures:

1. Member shape: Lowest fatigue forces from dynamic response resulted from using round tubes for mast-arm members and post

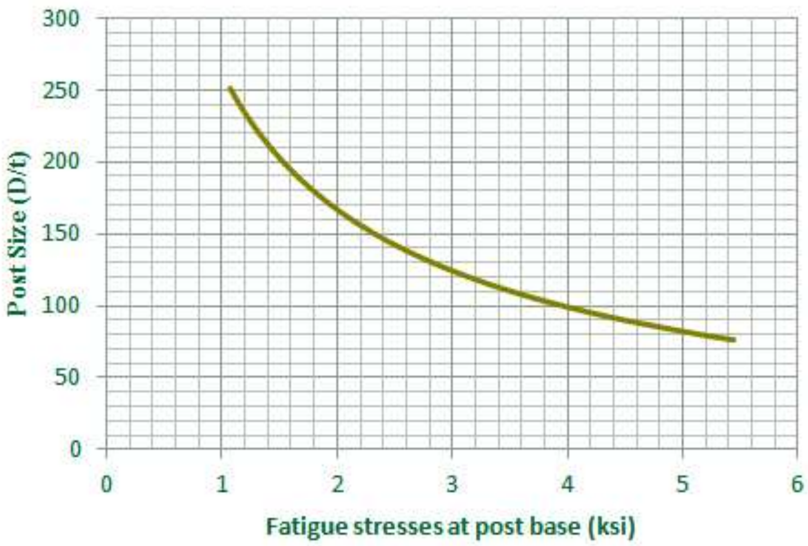
Members	Section Shape
	
	
	

Structure Types... *(Cont'd.):*

Factors Affecting Dynamic Response of 4 & 2-chord Cantilevered Sign Structures:

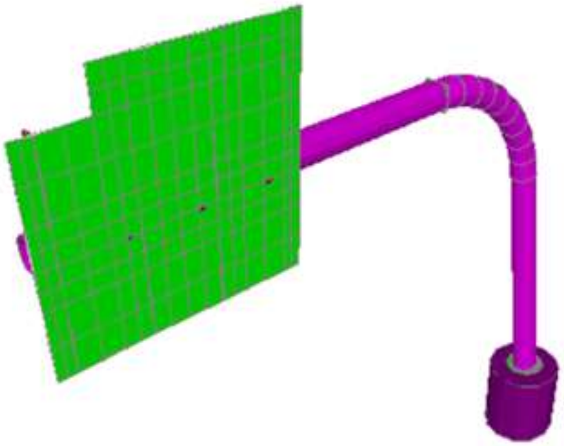
2. Member size: Post size has the greatest effect in controlling dynamic response and fatigue stresses

3. Members arrangement: different truss configurations for the same layout doesn't have significant effect on dynamic response

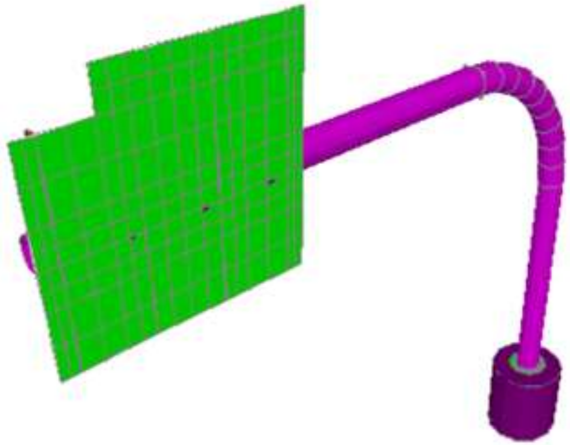


Structure Types… *(Cont'd.):*

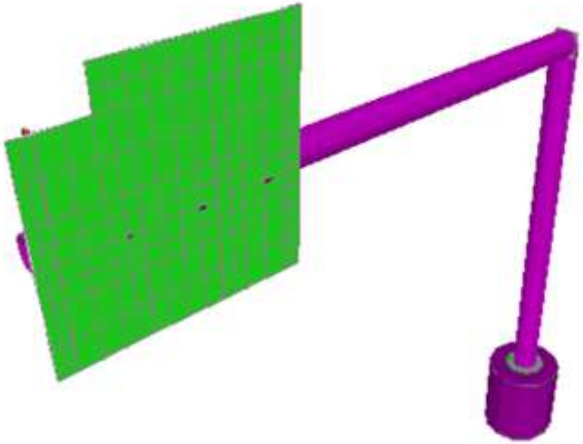
3) Monotube Cantilevered Sign Structure



a) Slanted Post (Curved End)



b) Vertical Post (Curved End)



c) Vertical Post (Straight End)

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Structure Types... *(Cont'd.):*

Factors Affecting Dynamic Response of Monotube Cantilevered Sign Structures:

1. Layout

a) Slanted Post (Curved End)	b) Vertical Post (Curved End)	c) Vertical Post (Straight End)
Freq. = 1.344 Hz	Freq. = 1.239 Hz	Freq. = 1.160 Hz
- Fatigue@post base = 6.00ksi - At field Splice = 2.40 ksi	- Fatigue@post base = 6.03ksi - At field Splice = 2.92 ksi	- Fatigue@post base = 6.16ksi - At field Splice = 4.60 ksi

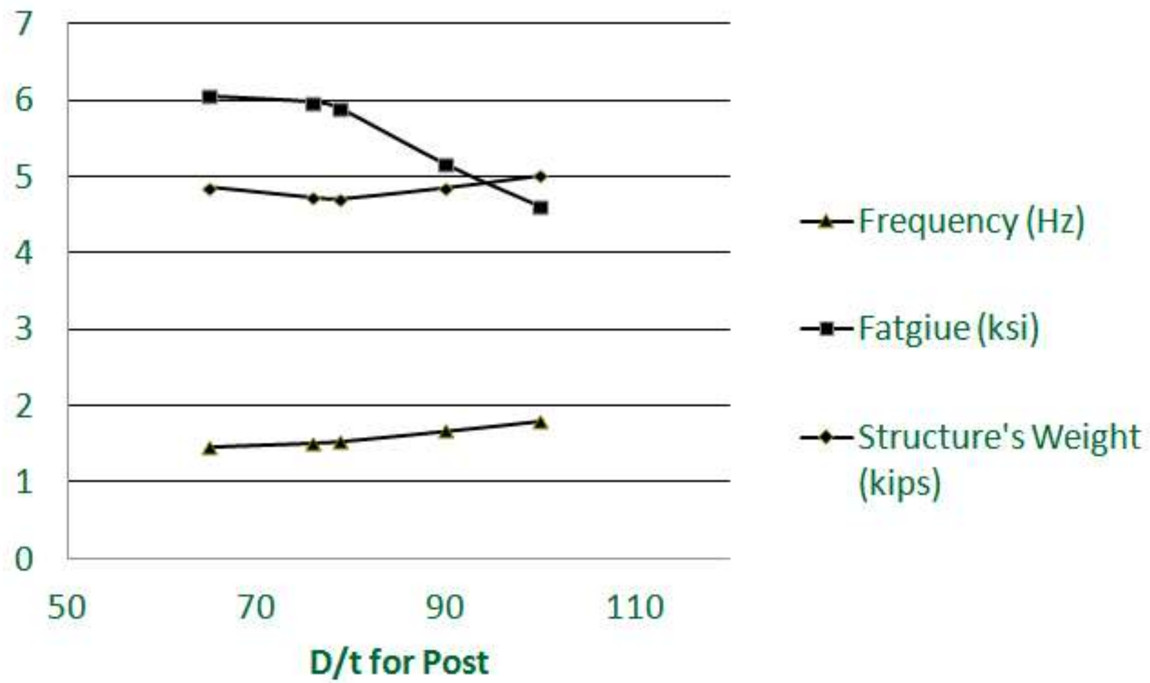
2. Radius of post curve (Structure Redesign)

R = 8 ft	R = 10 ft	R = 12 ft
Freq. = 1.452 Hz	Freq. = 1.480 Hz	Freq. = 1.507 Hz
- Fatigue@post base = 6.01ksi - At field Splice = 5.14 ksi	- Fatigue@post base = 5.98ksi - At field Splice = 5.00 ksi	- Fatigue@post base = 5.97ksi - At field Splice = 4.87 ksi

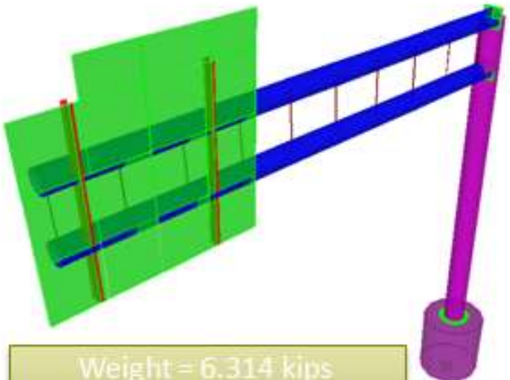
Structure Types…*(Cont'd.)*

Factors Affecting Dynamic Response of Monotube Cantilevered Sign Structures:

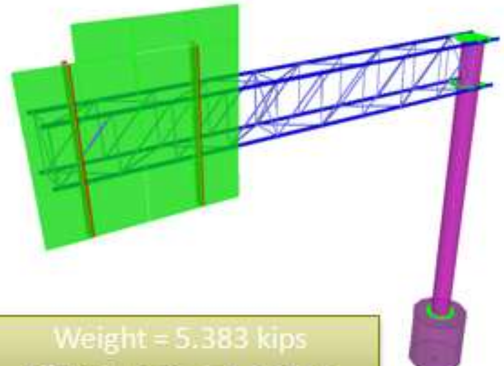
3. Members' Size: As D/t for the post increases, fatigue stresses decrease



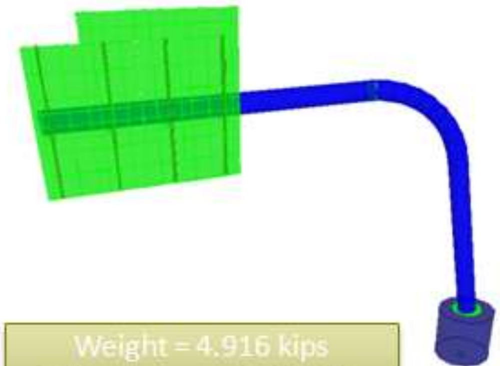
Comparing Structure Types



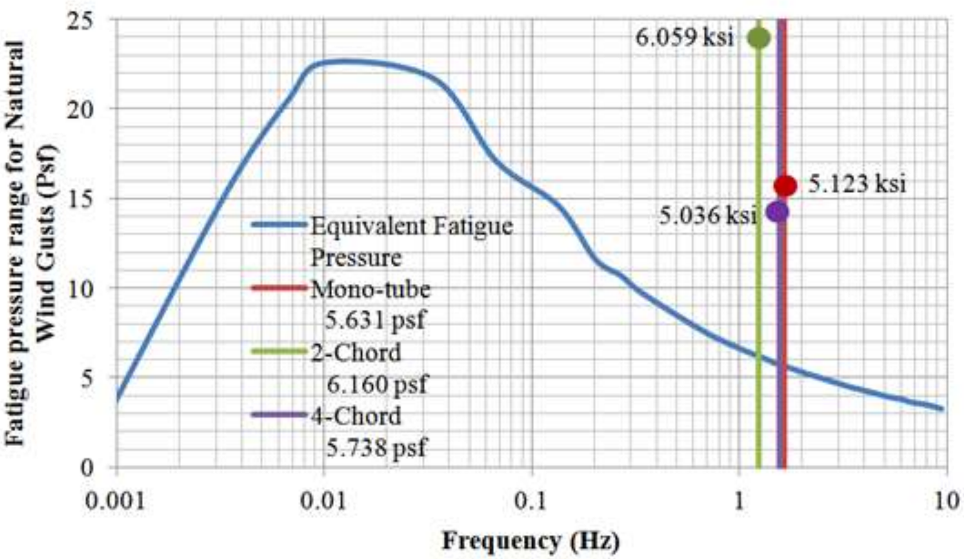
Weight = 6.314 kips
1st Frequency = 1.247 Hz
2nd Frequency = 1.367 Hz

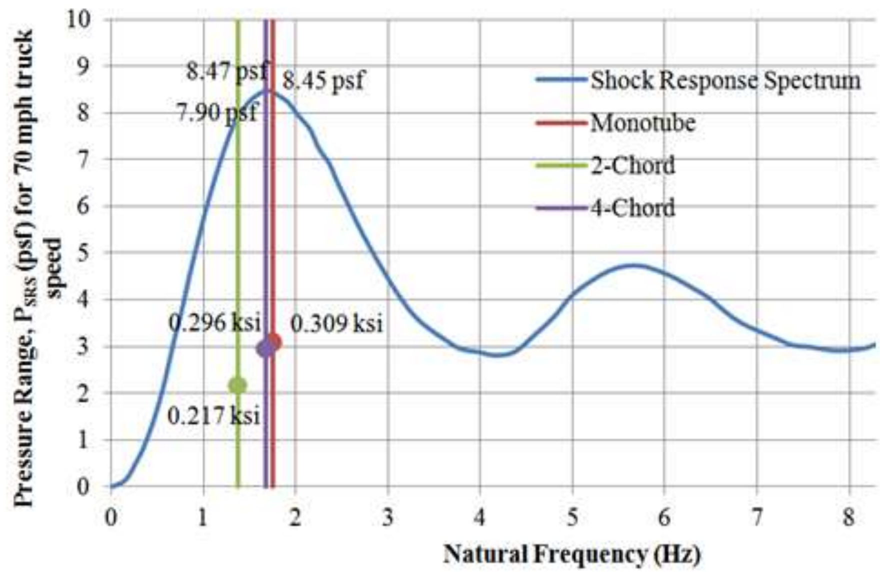


Weight = 5.383 kips
1st Frequency = 1.557 Hz
2nd Frequency = 1.669 Hz



Weight = 4.916 kips
1st Frequency = 1.652 Hz
2nd Frequency = 1.745 Hz





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Fatigue Mitigation in Cantilevered Overhead Structures

Conclusions:

- Fatigue critical sections are located at main connections (mast-arm/post connection and base connection)
- Fatigue stresses due to truck-induced wind gusts are insignificant in comparison with natural wind gusts (≈1:20)
- Increasing structure's frequency reduces fatigue stresses
- Increasing stiffness of mast-arm is not as effective as increasing post stiffness in controlling fatigue stresses
- Lowest fatigue forces from dynamic response resulted from using round tubes for mast-arm members and post
- Increasing D/t of the post reduces fatigue forces and stresses

Fatigue Mitigation in Cantilevered Overhead Structures

Conclusions…*(Cont'd.)*:

- Different truss configurations for the arm layout didn't have significant effect on fatigue stresses
- Slanted mono-tube sign structure is preferred because of its high frequency, small fatigue stresses, and light weight in comparison with other layouts

THANK YOU
ANY QUESTION!