Iowa's High-Mast Lighting Towers: A Proactive Approach to a Problem

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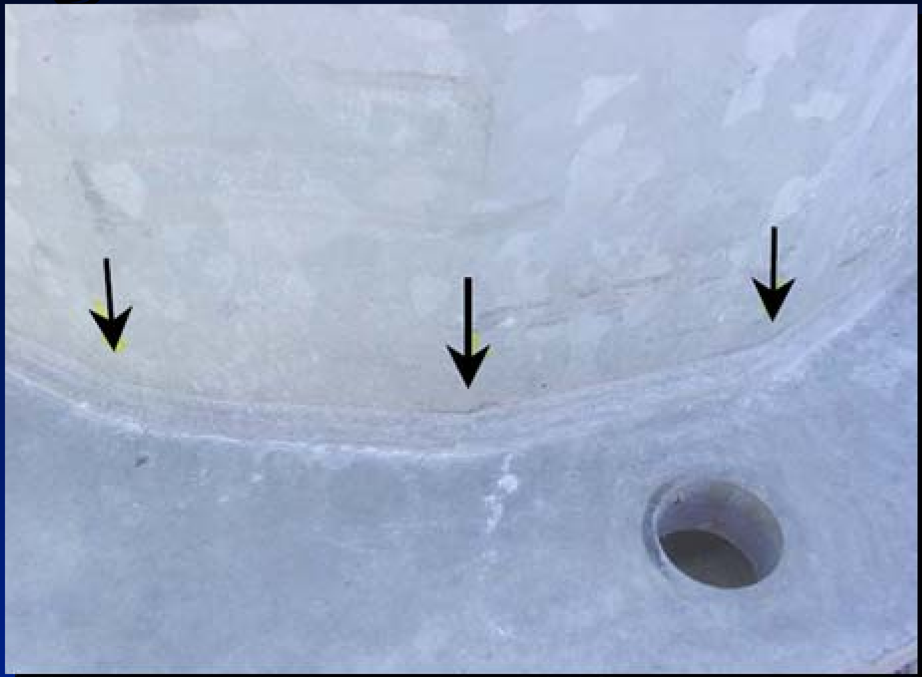
The Problem

- Nationwide failures of HMLT.
- Inadequate design specifications based upon dissimilar structures.

Iowa DOT Background

- 233 High-Mast Towers.
- Statewide inspection in 2000.



- 140 ft tower failed near Sioux City in 2003
  - Fracture in base plate weld (37 mph NW wind).
- Subsequent statewide inspection
  - Other cracks found.

Iowa DOT Background

- Investigation by Dexter and others – speculated wind induced fatigue
- Several different retrofits developed and are currently being implemented
- Determined that further investigation needed to fully understand the problem (e.g., monitoring needed).

Questions to be Answered

- Design for vortex shedding
  - Mode(s) of vibration.
  - Loading profile.
  - Wind/pole interaction characteristics
    - » Roughness length (z).
    - » Lift coefficient (C_L).

Questions to be Answered

- Design for gusting
  - Mode(s) of vibration.
  - Loading profile.
  - Wind/pole interaction characteristics
    - » Roughness length (z).
    - » Coefficient of drag (C_D).

Overall Goal

- Develop a comprehensive long-term inspection and maintenance program.
- Add to the body of knowledge related to the design of slender high-mast structures.

Monitoring System - General

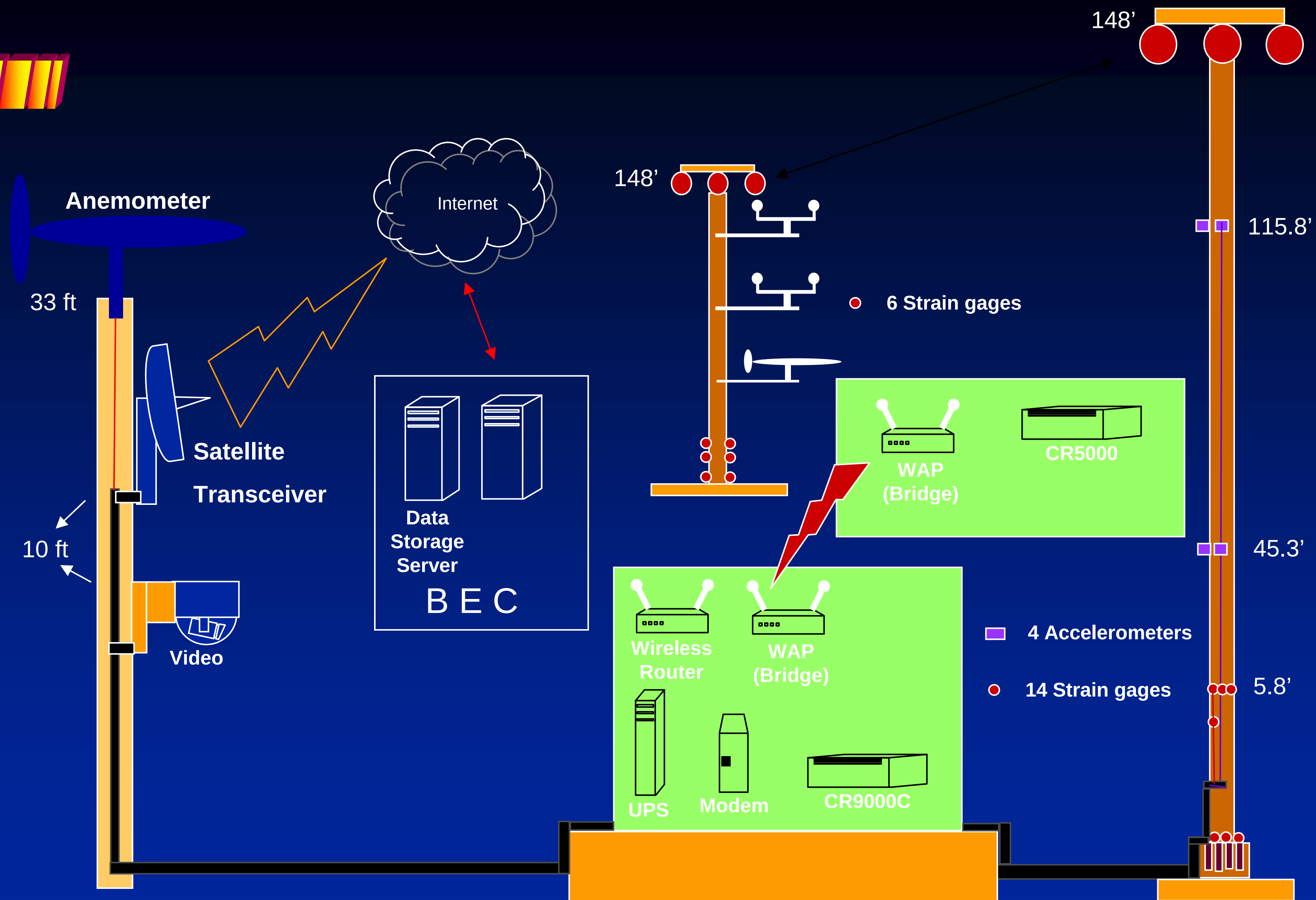
- Two poles being monitored.
- Hardware
  - Two dataloggers.
  - Long-range wireless.
  - Satellite communications.
  - 24x7 data collection
    - » With triggering – specified wind speeds.
    - » Rainflow stress cycle counting.
    - » 1 minute averages calculated on “the fly”.

Monitoring System – Pole 1

- 14 strain gages.
- 4 accelerometers.
- 1 video camera.
- 1 anemometer
  - Wind speed.
  - Wind direction.

Monitoring System – Pole 2

- 6 strain gages.
- 3 anemometers
  - Wind speed.
  - Wind direction.


148’
Anemometer
Internet
148’
115.8’
33 ft
6 Strain gages
Satellite
Transceiver
Data
Storage
Server
B E C
WAP
(Bridge)
CR5000
10 ft
45.3’
Video
Wireless
Router
WAP
(Bridge)
4 Accelerometers
14 Strain gages
5.8’
UPS
Modem
CR9000C

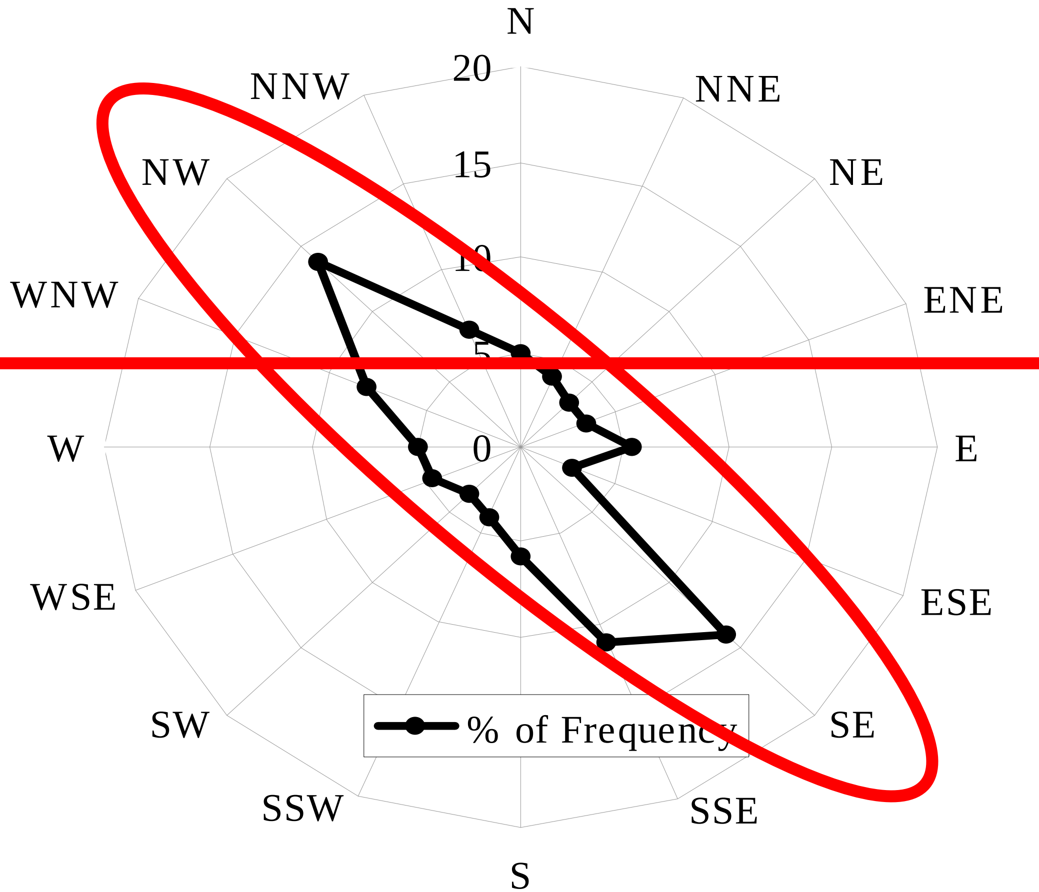
Data Processing

- Extract RMS and average wind speed, stress range, and acceleration (1 minute).
- Vibration information.
- Basic wind rose information (speed/direction)
  - Daily.
  - Monthly.
  - Seasonally.
  - Yearly.

Sample Results

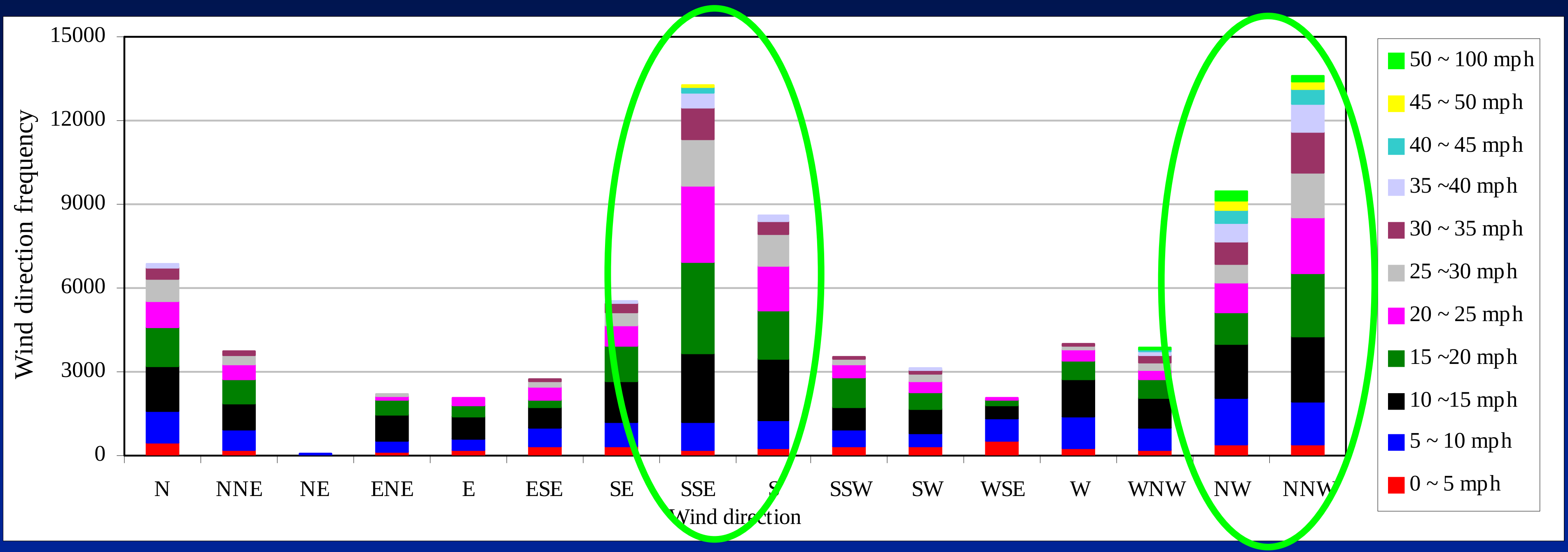
Cumulative Wind Inform

Dir. No.		1
		N
		219.75
Speed		231
Min	Max	242.25
0	5	***625***
5	10	[illegible]
10	15	***1043***
15	20	***737***
20	25	***218***
25	30	***40***
30	35	***1***
35	40	***0***
40	45	***0***
45	50	***0***
50	100	***0***
	Sum	4159
	%	5.0

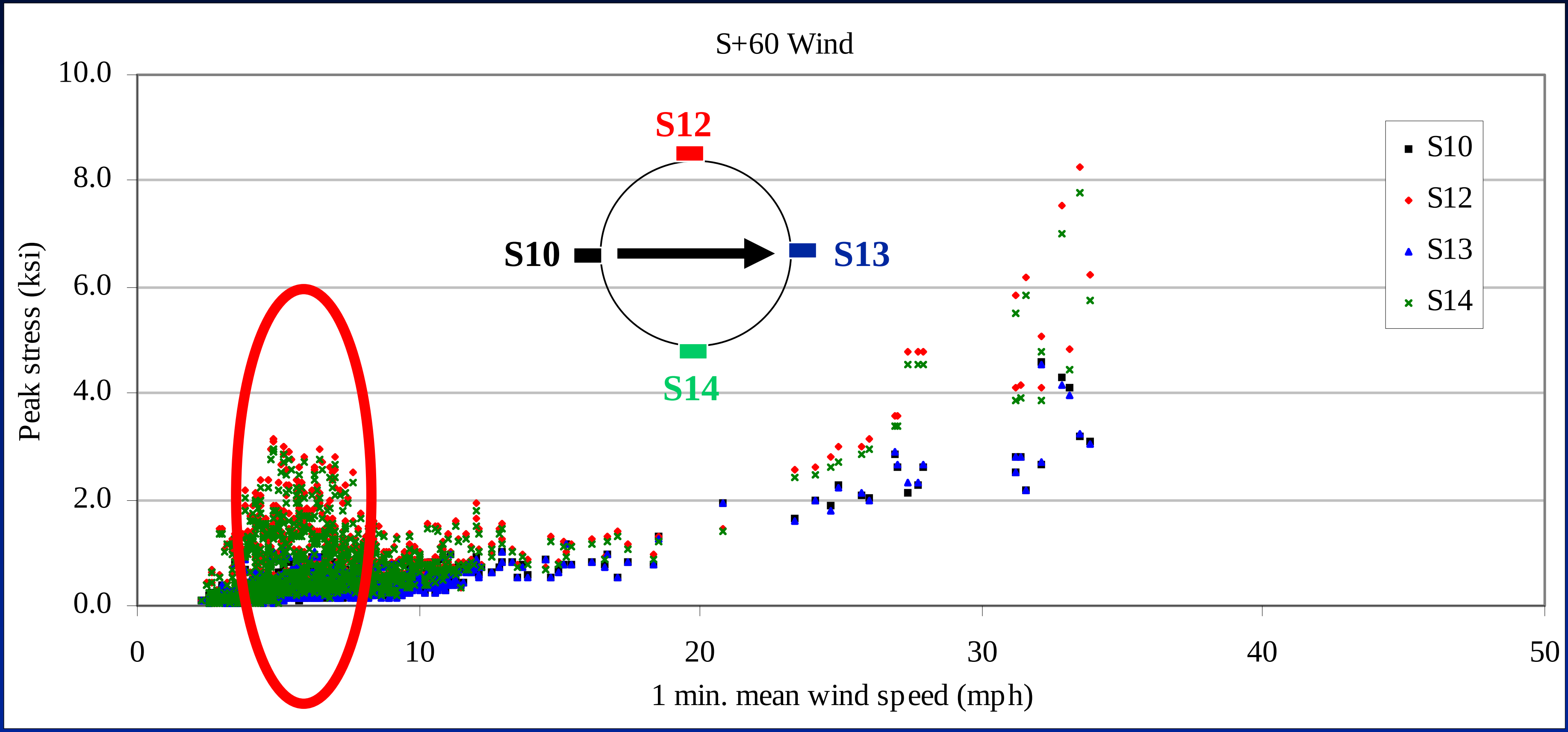


13	14	15	16		
W	WNW	NW	NNW		
.75	152.25	174.75	197.25		
41	163.5	[illegible]	208.5		
.25	174.75	197.25	219.75	Sum	%
741	***927***	[illegible]	***737***	10276	12.3
[illegible]	[illegible]	[illegible]	[illegible]	29774	35.5
890	***1803***	[illegible]	***1615***	24036	28.7
280	***678***	[illegible]	***1176***	13540	16.1
11	***104***	[illegible]	***363***	4778	5.7
2	***25***	[illegible]	***25***	1141	1.4
0	***1***	[illegible]	***1***	273	0.3
0	***0***	[illegible]	***0***	51	0.1
0	***0***	***0***	***0***	9	0.0
0	***0***	***0***	***0***	7	0.0
0	***0***	***0***	***0***	0	0.0
49	6750	11497	5597	***83885***	100
4.9	8.0	13.7	6.7	100	***64%***

Sample Results

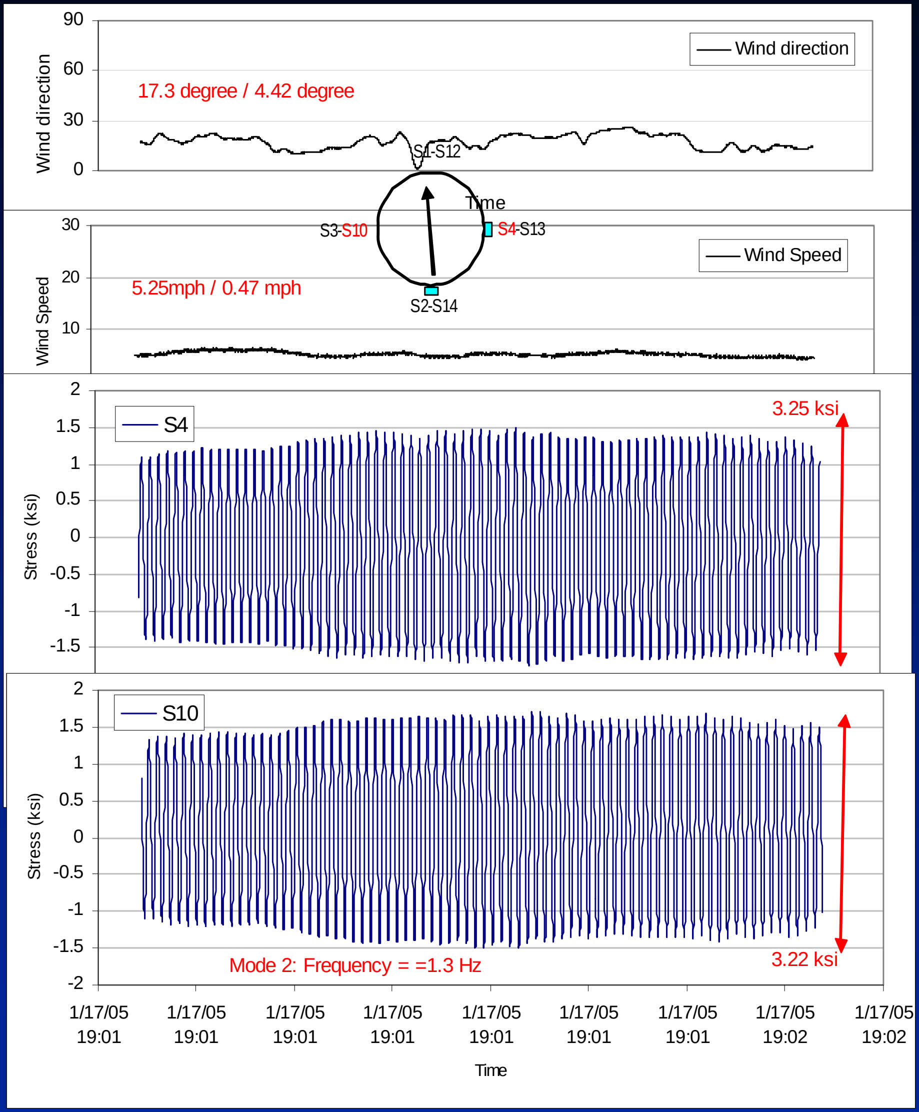


Sample Results



Sample Results

Mode 2:
Frequency = 1.3 Hz
Vortex Shedding



Findings – Gusting

- Response primarily in first mode (f_1= 0.3Hz).
- Overall, largest stress ranges are caused by natural wind gusts.
- Max stress range is approximately 14 ksi.
- Relatively few cycles
  - "Slow" vibration.
  - High wind speeds are not very frequent.

Findings – Vortex Shedding

- Significant vortex shedding observed in the second mode (f_2 = 1.3 Hz)
- Occurs during steady wind speeds of 4 - 11 mph (but, somewhat dependent upon wind direction).
- Stress range = 1.5 ~ 3.3 ksi
- Maximum stress range caused by vortex shedding is approximately 3.3 ksi.
- Relatively high number of cycles
  - "Fast" vibration.
  - Low wind speeds more common.

Future Work

- Wind tunnel testing
  - Scale models to validate field C_D, C_L.
  - Wind profile pressure information.
- Analytical modeling
  - Validated with field/wind tunnel data.
  - Extrapolate to nationwide pole geometries.
- Develop proposed specification modifications.

Acknowledgement

- Iowa Highway Research Board.
- Midwest Transportation Center.

Thank You

Questions?