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.
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

S+60 Wind

Peak stress (ksi)

1 min. mean wind speed (mph)

Sample Results

S10
S12
S13
S14
Sample Results

Mode 2:
Frequency = 1.3 Hz
Vortex Shedding
Findings – Gusting

- Response primarily in first mode \( (f_1 = 0.3 \text{Hz}) \).
- 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 = $1.5 \sim 3.3$ 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.
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Thank You

Questions?