TEXAS A&M UNIVERSITY
Zachry Department of
Civil & Environmental Engineering

Texas Department of Transportation

Texas A&M Transportation Institute

Develop Performance of Baseplate Connections in COSS and Traffic Signal Structures

0-7192

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August 14, 2025

Outline

- Background
- Fail-Safe System
- Structural Fatigue Improvement
- Experimental Testing
- Database

Background

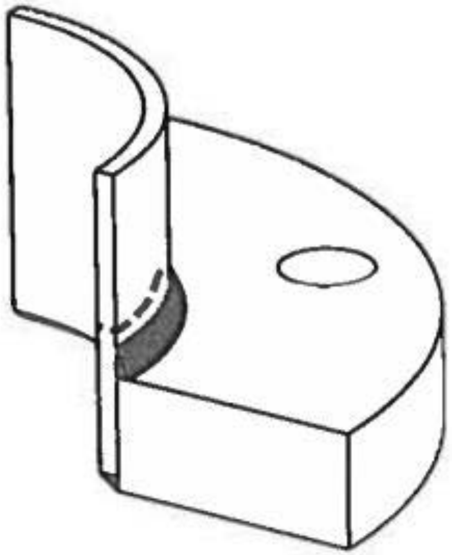
Cantilever Structures Failed in Texas:

- COSS (11 years in service)
- Two TSS (2 years in service)

Potential Reasons:

- Fatigue in pole to baseplate connection

Collapse of Cantilever Structure—Hwy 75, Allen, TX



Collapse of Cantilever Structure—Odessa, TX

Fish, D. (2022) TxDOT BRG: Updates on Ancillary Structures. TASIG Meeting. Austin, TX: Texas Department of Transportation.

Industry Advisor Group Meeting Outcomes—Thursday May 30, 2024

Proposed design Alternates to IAG and TxDOT committee, the following was concluded:

Design Alternates	**IAG**	**Reasons**
Regular Pole without Alternates	✓	Suggested for cost-effectiveness and simplicity
Fail-Safe System	✓	Ensures structural integrity even under failure conditions
Structural Fatigue Improvement	✓	Improves fatigue performance and reduces stress concentrations
Ground Sleeves	✕	Labor-intensive and impractical, increase costs
Welded Stiffeners	✕	Stress range increase due to strong winds at the toe of gusset and fatigue will increase
Improvement of Weld (Grinding & Profiling)	✕	Depends on skill of the operator, required extensive inspections, long process, difficult to implement

Objectives

- Develop a targeted testing program that isolates critical design parameters for the fatigue performance
- Provide recommendations for connection design based on fatigue provisions
- Develop an inventory database of COSS

Fail-Safe System

Stress Diagrams Due to Tightening of Thread Bar to the Pole

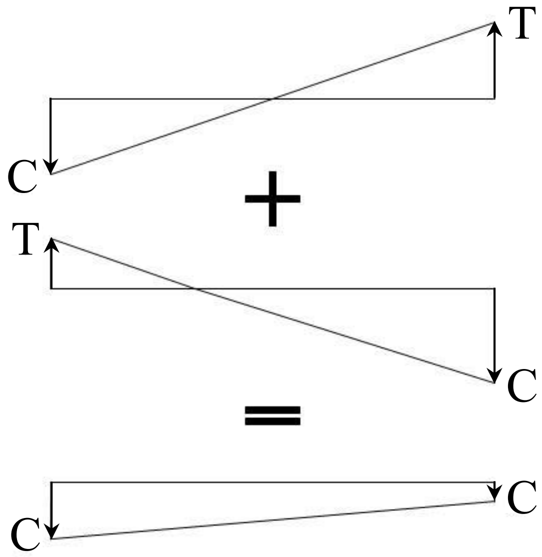
Bending Stress

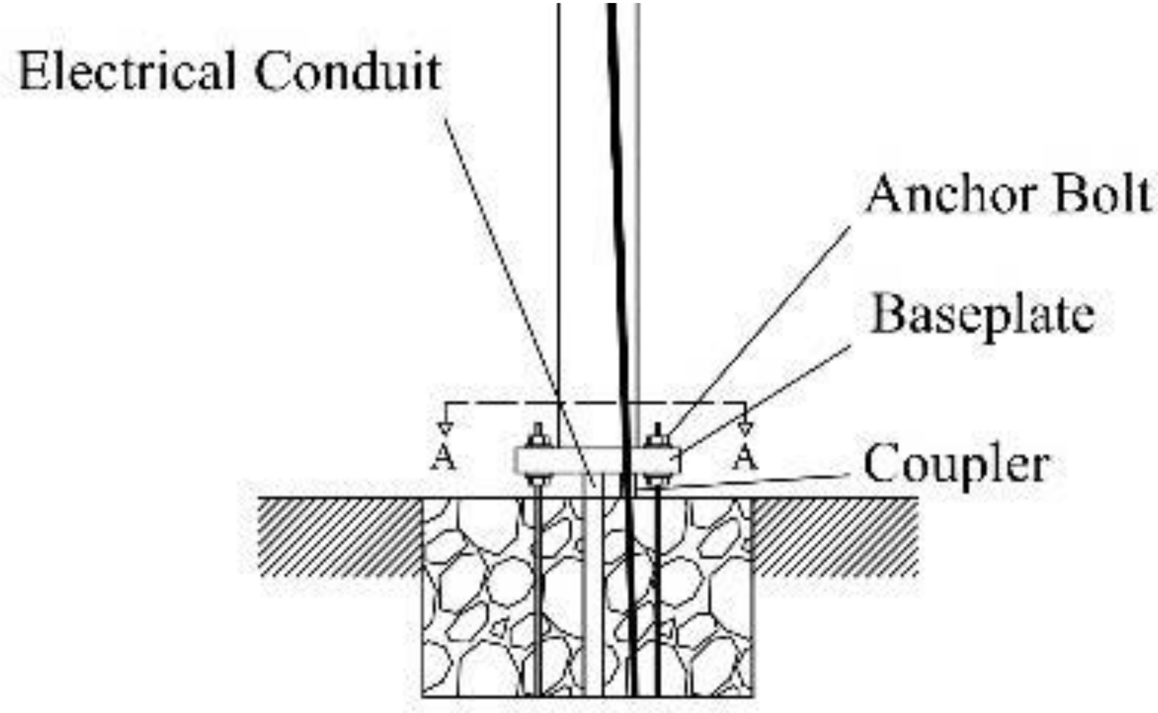
\+

Eccentric Stress Due to Tensioning

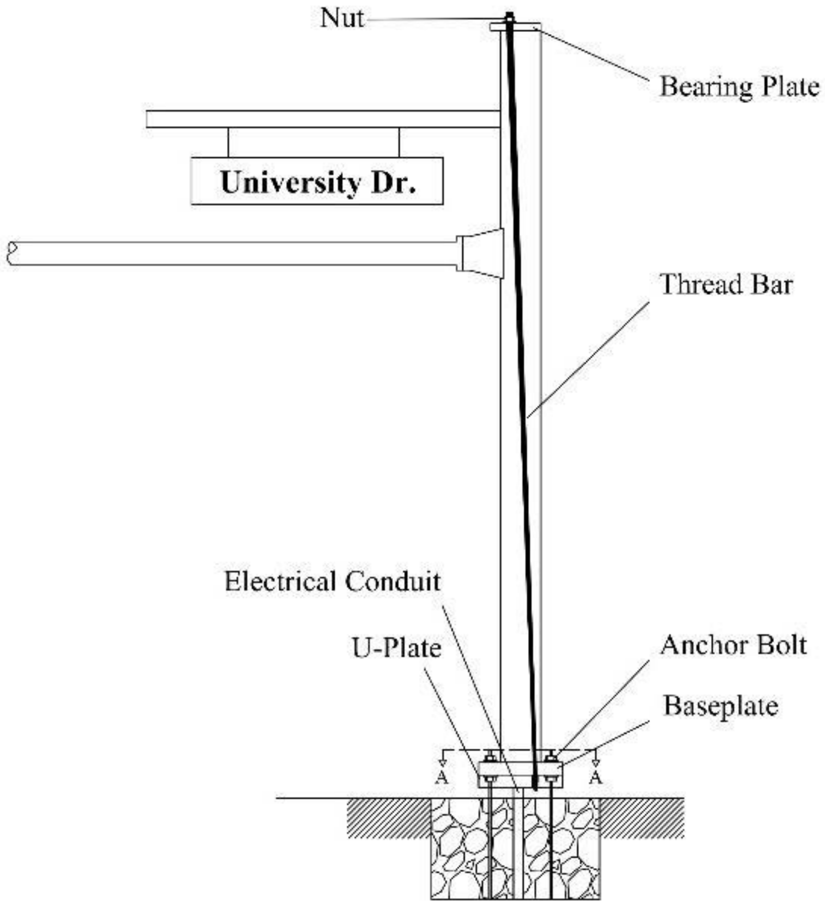
=

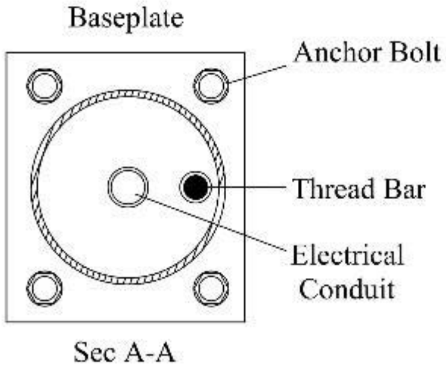
Overall Stress





Fail-Safe System





Structural Fatigue Improvement

Parameters That Affect Fatigue Life

Eight Main Factors:

1. Base Plate Thickness, t_{TP}
2. Pole Thickness, t_T
3. Pole Diameter, D_T
4. Radius of Bends, r_b
5. Number of Sides on the Pole, N_S
6. Number of Bolts, N_B
7. Bolt Circle Ratio, C_{BC}
8. Bolt Location (rotation)

$$K_{F_R} = 2.2 + 4.6(15t_T + 2) \times \left({D_T}^{1.2} - 10\right) \times ({C_{BC}}^{0.03} - 1) \times {t_{TP}}^{-2.5}$$

AASHTO (11.9.3.1-2) for round poles with a socket connection

$$K_{F_{MS}} = K_{F_R}[1 + (D_T - r_b) \times {N_S}^{-2}]$$

AASHTO (11.9.3.1-6) for multi-sided poles with a socket connection

Structural Fatigue Improvement: Case Study

COSS Located at ZONE 4 with Wind Velocity: 70 mph

Pole:

- Pole Height: 29 ft
- Outer Pole Diameter: 30 in.
- Pole Thickness: 0.281 in.
- Baseplate Thickness: 1.75 in.
- Service Life ~ 11 years

Truss:

- Span: 40 ft
- Dead Load on Truss: 56 lbs/ft
- Truss Depth: 4 ft
- Sign: 477 ft^2
- Chord Section: L 3×3×3/8 in.
- Vertical Section: L 2×2×3/16 in.
- Diagonal Section: L 3×3×3/16 in.

Collapse of COSS in Dallas-Collin County on Feb 18, 2022
wfaa.com (2022)

Structural Fatigue Improvement: Case Study

Service life of the modified pole with lower D/t ratio was calculated relative to the failed structure

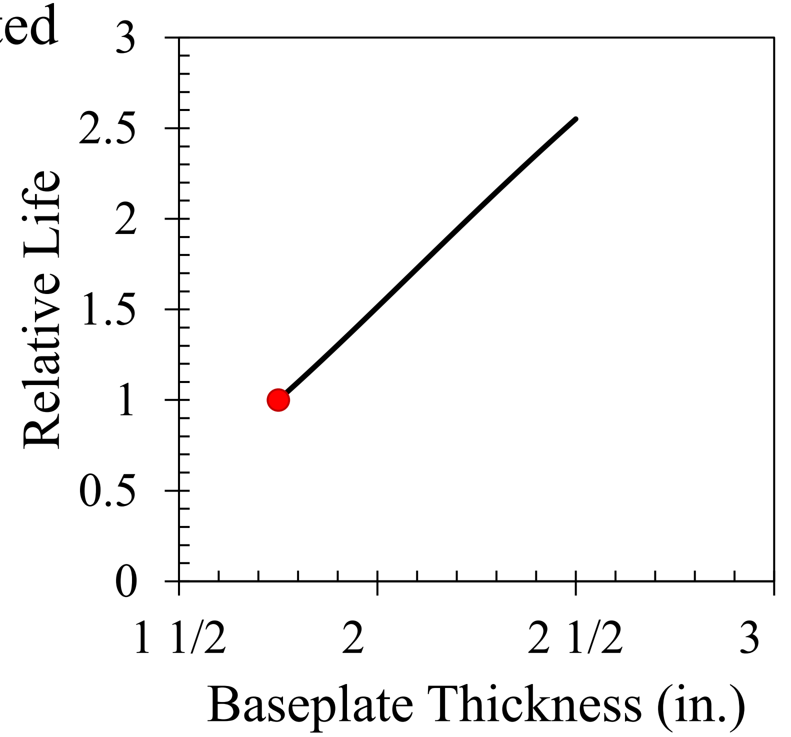
$$\frac{N_m}{N_s} = \left(\frac{S_r^3}{K_f}\right)_s \times \left(\frac{K_f}{S_r^3}\right)_m$$

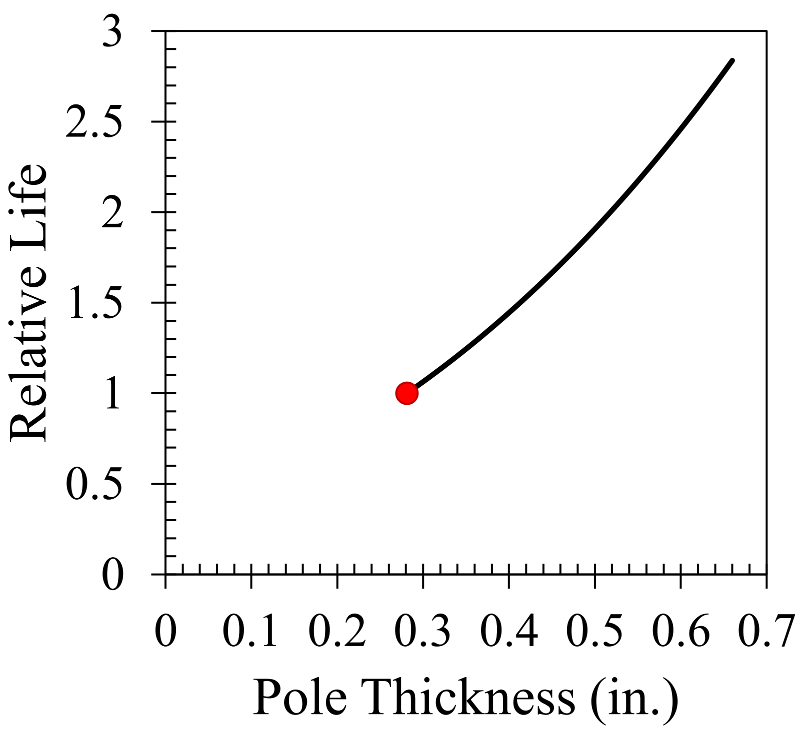
N_s : Service life of standard pole (D/t=106.78)

N_m: Service life of modification

K_f : Finite life constant of modification = 3.9×10^8

S_r: Stress range





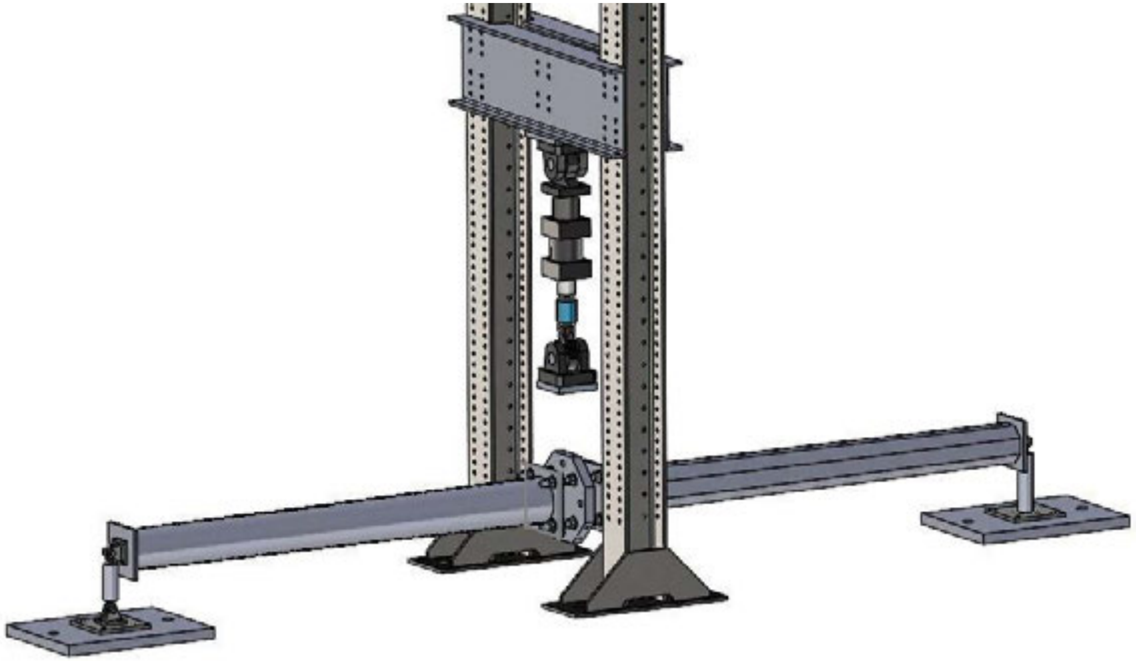
The service life for the collapsed pole was 11 years

- Increasing baseplate thickness to 2 in. and pole thickness to 0.31 in. increases the estimated life to 20 years
- Using fail-safe system increase the fatigue life to an **infinite** lifespan

Testing Program

Acquisition of Poles:

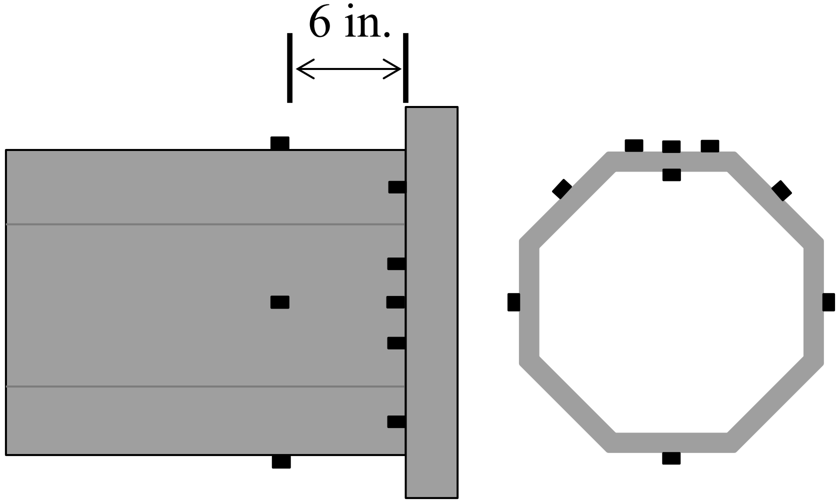
- 5 Poles (TSS) from Austin District
- 6 Poles (TSS) from Paris District
- 1 COSS from Dallas District



Testing Program

Conducting cyclic test of 2 poles simultaneously

- 10 strain gauges on each pole to measure the strain



Location of Strain Gauges

Testing Program of Two Poles

COSS Database

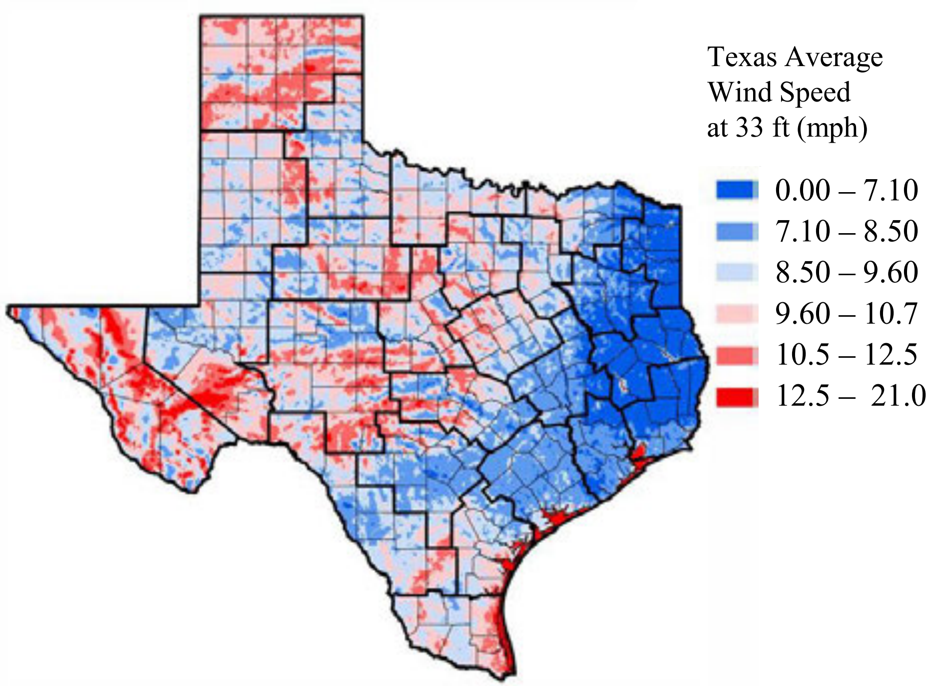
Variables recorded in database:

- Physical Location (Lat/Lon, county, district)
- Structure type and age
- Materials and specifications (Galvanized)
- Connection type and detailing (if data recorded)
- Whether the bottom nuts are in concrete
- Sign Message
- Pole and baseplate geometry
- Truss geometry (span length, attachments area)
- Cantilever Orientation

COSS Database

Variables recorded in database:

- Cantilever Span/Double Cantilever Span
- Wind speed, wind direction and exposure category for wind load
- Damage and/or repair reports
- Modifications or issues during service life (retightening, retrofits)
- Lighting and power requirements



Average wind speed in Texas at a height of 33 ft
Data Collected 2007 – 2013

COSS Database

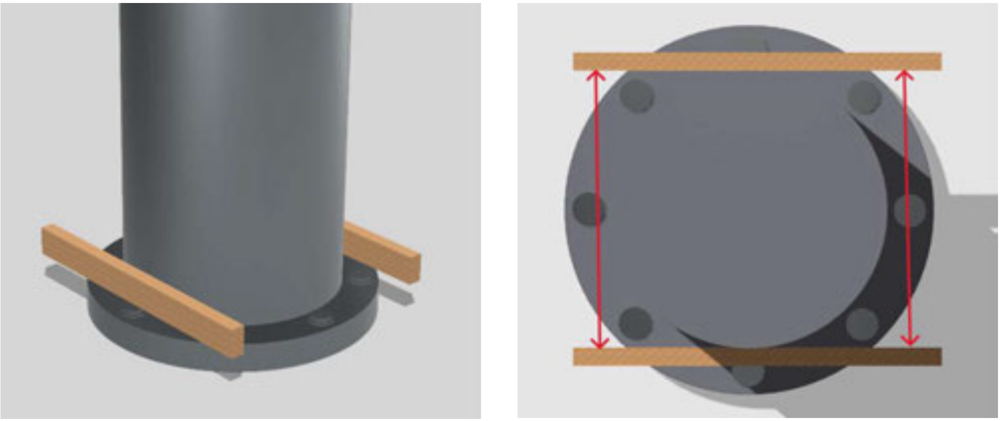
Field Measurements of 32 COSS:

- Outer diameter of the poles was measured using a measuring tape
- Truss Span was measured using Leica DISTO X3 Laser Distance Meter
- Baseplate thickness and wall thickness of the poles was measured using Olympus 27 MG Ultrasonic Thickness Gauge
- Zinc coating thickness was measured using Elcometer 456 Nonferrous Metal Coating Thickness Gauge

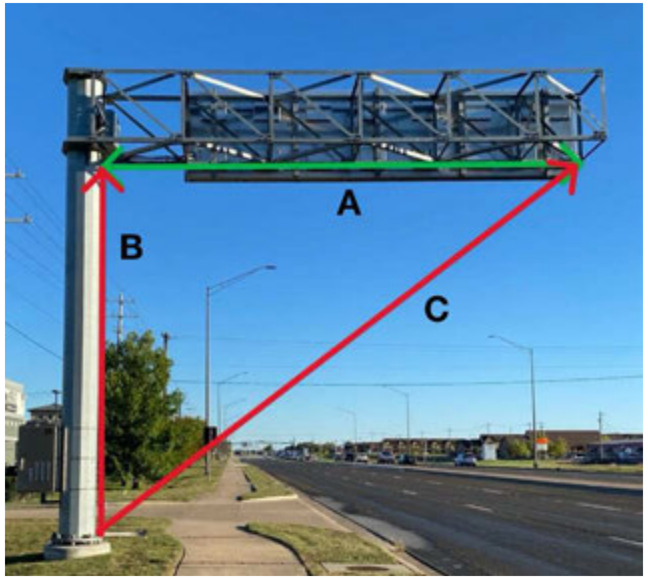
Laser Distance Meter

Ultrasonic Thickness Gauge

Nonferrous Metal Coating Thickness Gauge



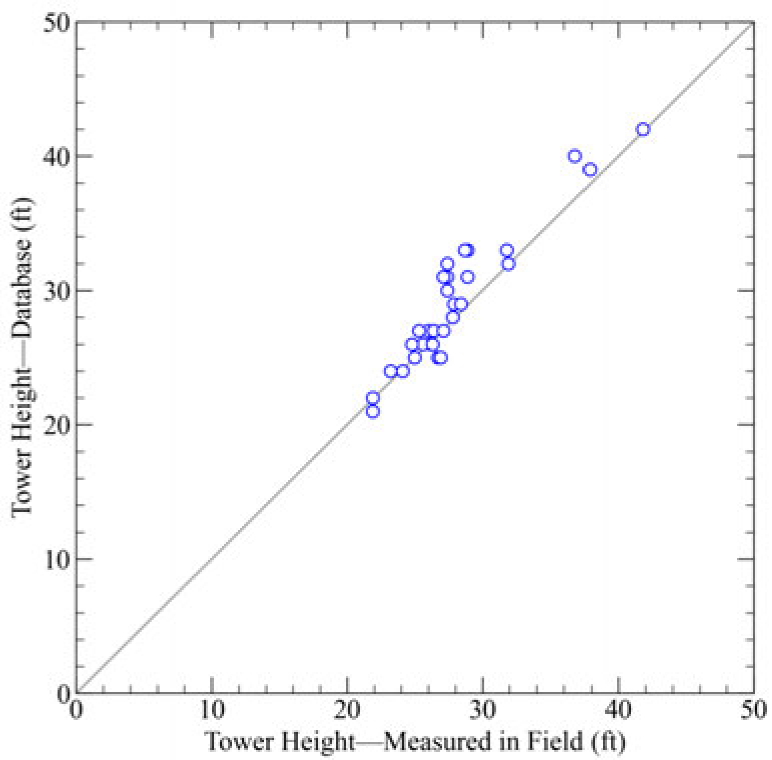
Measurement of the Outer Diameter Pole



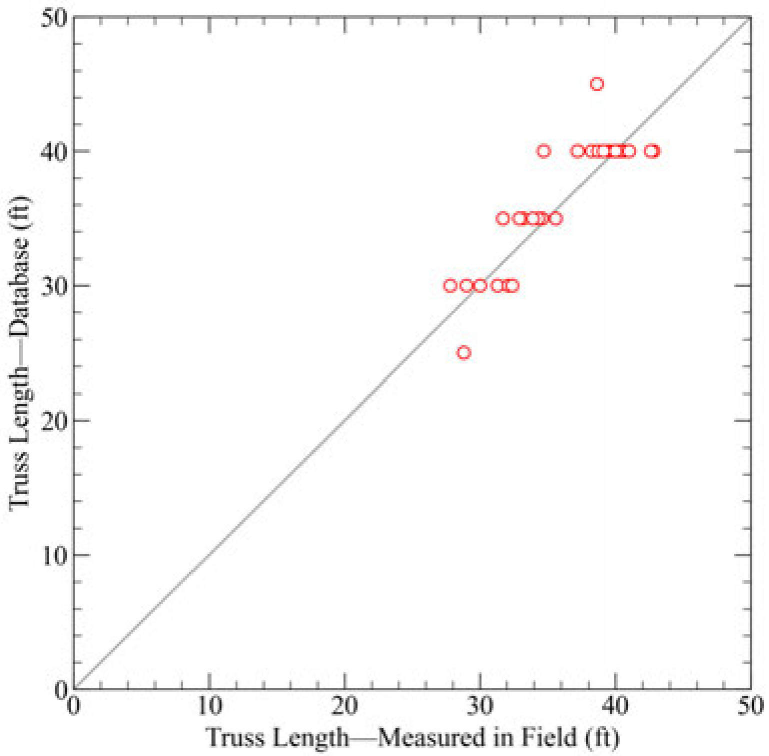
Measurement of the Truss Span

COSS Database

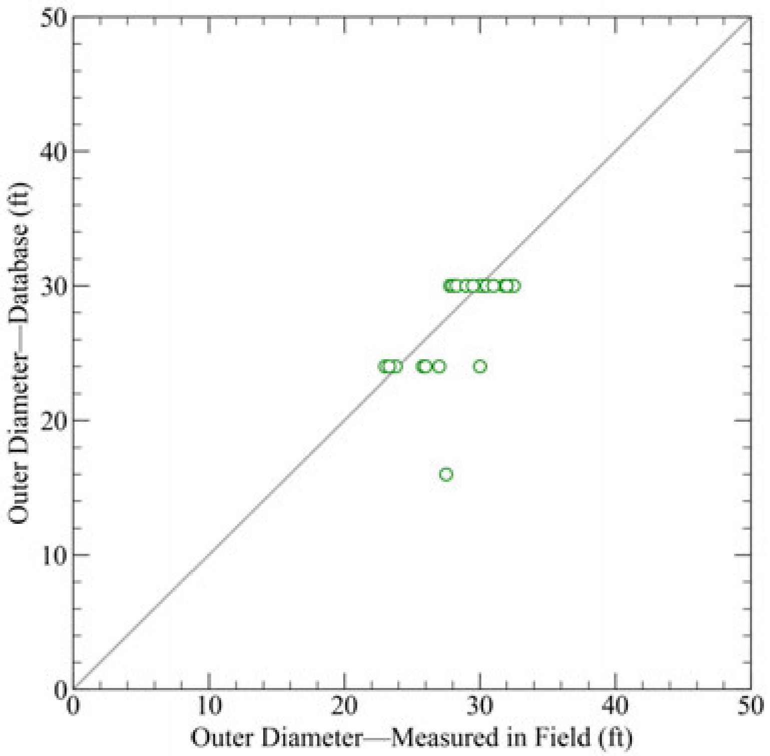
Positive correlation was found between tower height, truss span length, and outer diameter of the poles measured in the field and the ones reported in the database based on TxDOT standards



Field Measurements vs Data Reported in Database (Height)



Field Measurements vs Data Reported in (Truss Span Length)



Field Measurements vs Date Reported in (Outer Diameter)

COSS Database

Pole ID	Physical Location					Structural Properties			Materials and Specifications	Whether the bottom nuts are in concrete	Connections and detailing	Sign Message
	LAT	LON	County	District	More Location Information	Type	First Pole Imagery	Age				
298	32.75410423	-97.47942377	Tarrant	02-Fort Worth	I820 SB	HCOSS	12/27/2009	15	Galvanized	No	No data recorded	Varies - Electronic
299	32.75611994	-97.47845955	Tarrant	02-Fort Worth	I820 NB	COSS	1/31/1995	30	Galvanized	No	No data recorded	EXIT4 WHITE SETTLEMENT RD EXIT ONLY

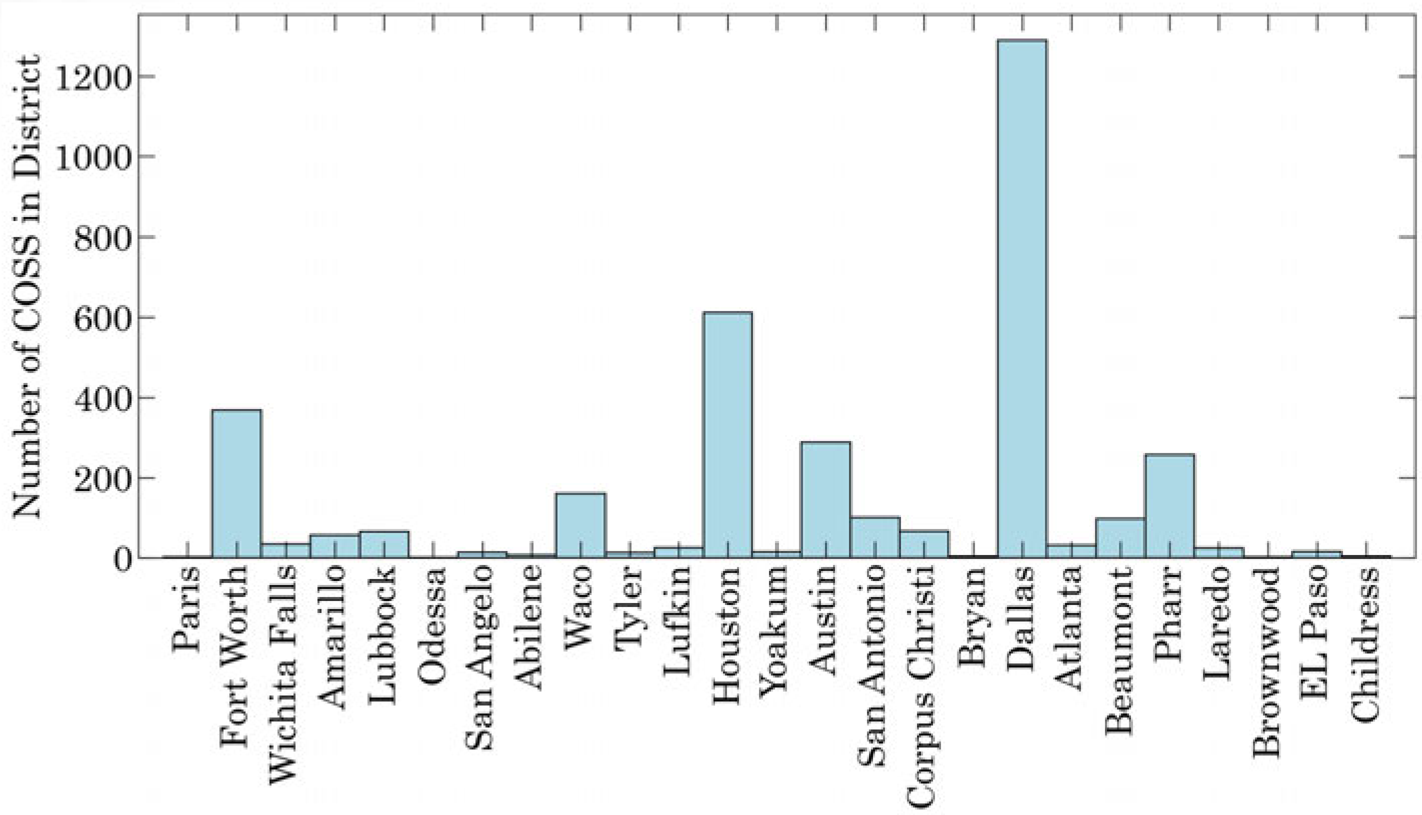
Baseplate Properties			Pole Properties					Pole-base Geometry	Truss									Cantilever Orientation	Span
Geometry (in.)	Thickness (in)	No. of Bolts	Outside Diameter (in)	Wall Thickness	Diameter to Thickness Ratio	Height from Imagery	Height	Multi-sided Round	Length (ft) Main Truss	Secondary Truss	Width	Depth	Attachments (Area of Signs ft^2)						Cantilever Span Double Cantilever Span
35.0	2.375	8	24	0.562	42.7	29.0	27	Multi-sided	15	15	4.5	4.5	283	0.0	0.0	0.0	283	NW-SE	Double Cantilever Span
33.7	1.5	6	24	0.250	96.0	25.2	24	Round	15	15	4.0	4.0	149	0.0	0.0	0.0	149	NW-SE	Double Cantilever Span

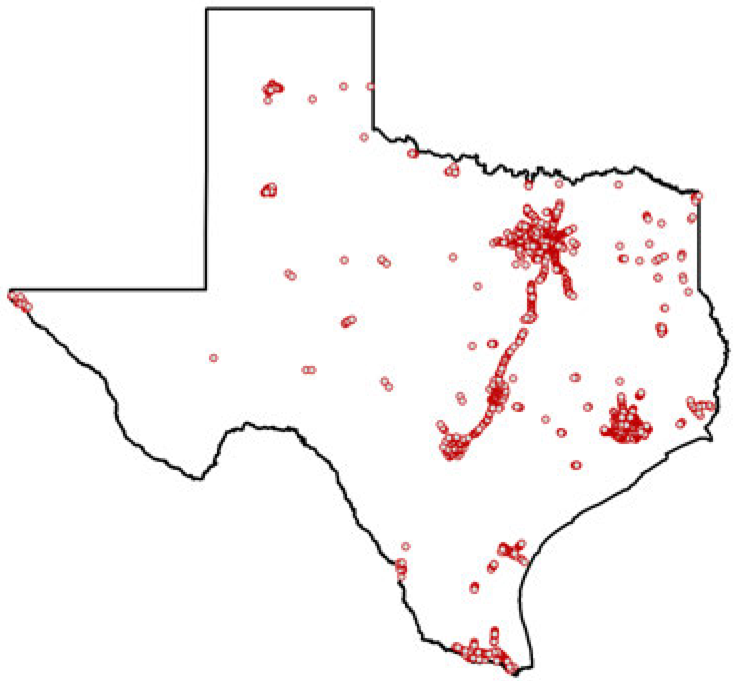
Luminaire	If Source of Power Is Provided?	Wind						Availability	Reports	Modifications or Issues During Service Life	Inspection Records	Current Inspection Frequencies	Lighting and Power Requirements	Fabricator	Note
With Without		Zone 1994	Zone 2013	Average Speed at 33 ft (mph)	Average Speed at 130 ft (mph)	Direction	exposure category	As-built Existing plans	Damage/Repair	Retightening/Retrofits					
Without	Provided	4	4	9.03	20.2	168.4	C		No Inspection Report Available	No Inspection Report Available	Not Available				
Without		4	4	9.17	20.5	168.4	C		No Inspection Report Available	No Inspection Report Available	Not Available				6 Stiffener at Base plate Connection

COSS Database

3561 COSS have been identified across Texas

- Dallas-Fort Worth with a higher percentage of COSS
- Metropolitan areas at the highest risk





Conclusions

- The Fail-Safe system should drastically improve structures' lifespan, giving them an infinite fatigue life.
- The geometry of structures can be slightly altered to significantly improve fatigue life.
- The high concentration of COSS in metropolitan areas makes it crucial to understand and improve the fatigue life of existing structures.