David K. Davies
Director of Engineering
ddavies@hodgestructural.com
812.459.1341

October 16, 2018

Comprehensive Tower Engineering Services

HODGE
TOWER DIVISION
STRUCTURAL ENGINEERS

- **Structural Analysis**
- **Rigging Plans**
- **Project Management**
- **Reinforcing Design & Materials**
- **Corrosion Analysis**
- **Construction Services**

PREVENTING THE NEXT TOWER DISASTER THROUGH ANCHOR INSPECTION

A Pro-Active Guide

PRESENTED BY

David Davies

Director of Engineering

Hodge Structural Engineers

IMPLICATIONS OF ANCHOR FAILURE

- POTENTIAL LOSS OF LIFE
- PROGRAM/BROADCAST DISRUPTION
- LOSS OF RENTAL INCOME
- DENIAL OF INSURANCE CLAIM

KFXL-TV (Sinclair) and KHGI-TV (Gray)

MATT OLBERDING Lincoln Journal Star – October 20, 2017

A TV tower in north Lincoln collapsed Friday morning, **knocking out two television stations, phone, internet and other service**.

"It's just chaos," said a woman who works at the tower site who declined to give her name. "I've got customers coming out of my ears." "**Several businesses that lease space had already been to the site to inspect the damage and look for alternatives locations**."

Sinclair Broadcasting-owned station KFXL, said its over-the-air signal would be "**off the air for an undetermined amount of time**."

KFXL – KHGI FORCED TO RELOCATE

LOSS OF LIFE?

- *Tower failed at 7:55 a.m.*
- *Climbing crew scheduled to arrive at 8:30 a.m.*

Had the anchor shaft held another couple of hours . . .

WHAT ABOUT THIS "NO INSURANCE"?

Following the anchor failure and subsequent tower collapse of the KSMQ-TV tower in Austin, Minnesota, the station turned to their insurance carrier when it came time to rebuild their tower.

The Hanover Insurance Group denied the claim, stating a lack of due diligence by the station, to inspect for, and correct damage caused by anchor shaft corrosion.

THE CAUSE OF THESE FAILURES?

ANCHOR SHAFT CORROSION

ANCHOR SHAFT CORROSION IS THE 5th LEADING CAUSE OF BROADCAST TOWER FAILURE

Telecommunications towers have an even higher risk

INSPECTING 10-FEET BELOW GRADE?

Tulsa, Oklahoma

Chief Engineer Ed Bettinger was shocked…

"The tower had just been inspected. Guy wires were tensioned and everything appeared fine."

Bettinger stated, "Corrosion was present on the anchor shafts – *several feet below grade*."

A DIG-TO-BLOCK PROCEDURE, OR DTB, IS THE *MOST-CONCLUSIVE METHOD* OF INSPECTING ANCHOR SHAFTS

DTB IS AN EXPENSIVE PROCEDURE

ESTIMATED COST IS BETWEEN $17,000 and $22,000

(6) ANCHORS • (3) MEN • (2) DAYS

DIG-TO-BLOCK IS UNNECESSARY

FOR 80% OF ALL SITES (1:5 Ratio)

CHALLENGE: Determining the 20% in need of DTB

SHORT STORY ANOLOGY

Not unlike structures and machinery, the effects of poor/inadequate maintenance will become evident.

Hoping to counteract some of the neglect, while improving my overall physical condition, I decide to begin a workout regiment.

To err on the side of caution, I'll consult with my physician, first!

PHYSICIAN VISIT IS NON-INVASIVE

TEMPERATURE ✓

WEIGHT ✓

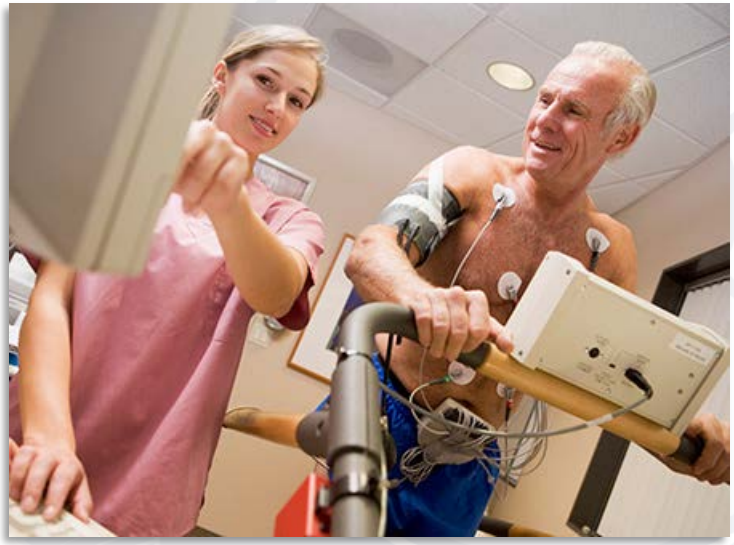
HEART RATE / PULSE ✓

BLOOD PRESSURE ✓

DISCUSSION OF ✓
LIFESTYLE, SYMPTOMS & ISSUES

REVIEW OF R_X & SUPPLEMENTS ✓

ADDITIONAL TESTING MAY BE IN ORDER



Blood Work • Stress Test • MRI

INTERESTLY, THESE INITIAL TESTS DO NOT INCLUDE OPEN HEART SURGURY, THE MOST-INVASIVE PROCEDURE OF ALL

Helluva way to get a clean bill of health before starting exercising.

Unfortunately, the cost is out-of-pocket!

DIG-TO-BLOCK IS THE OPEN HEART SURGERY OF ANCHOR SHAFT INSPECTION

- *Extremely invasive*
- *Risk to workers and tower/anchors*
- *Requires Class IV Rigging Plan*
- *Corrosion may*
- *Costly*

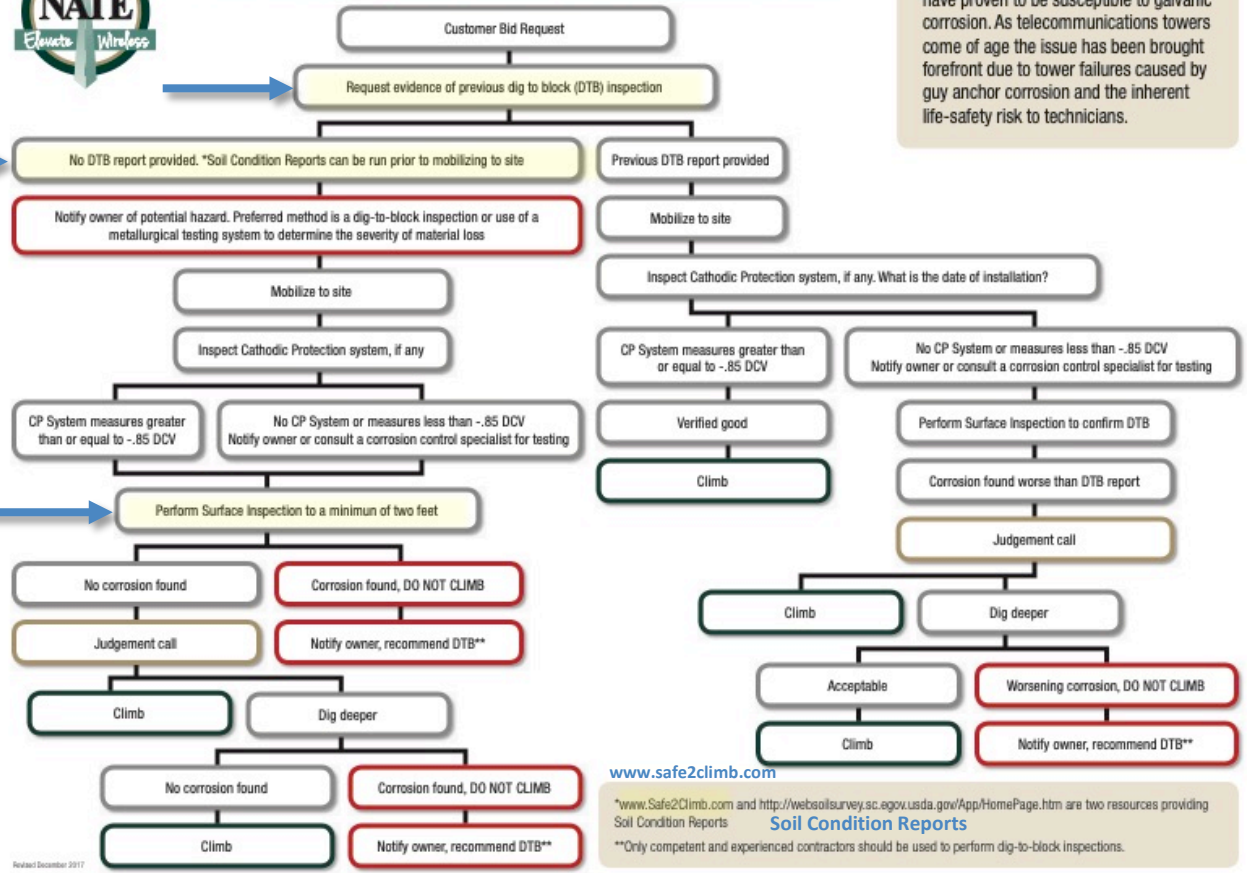
DIG-TO-BLOCK ALTERNATIVES

- **SOIL AND ENVIRONMENTAL REPORT**
  Known as a CRA or Corrosion Risk Analysis
- **ON-SITE EVALUATION**
- **ULTRA SOUND TESTING**

Let's look at the NATE® Protocol

Anchor Inspection/Safe to Climb Guide

Guy anchors in direct contact with soil have proven to be susceptible to galvanic corrosion. As telecommunications towers come of age the issue has been brought forefront due to tower failures caused by guy anchor corrosion and the inherent life-safety risk to technicians.



www.safe2climb.com

*www.Safe2Climb.com and http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm are two resources providing Soil Condition Reports

Soil Condition Reports

**Only competent and experienced contractors should be used to perform dig-to-block inspections.

DIG-TO-BLOCK ALTERNATIVES

SOIL CONDITION REPORT

Anchor Inspection/Safe to Climb Guide

CORROSION RISK ANALYSIS – CRA

CRA QUANTIFIES BOTH SOIL AND SITE PROPERTIES IMPACTING THE RATE OF CORROSION

- **MOISTURE CONTENT**
- **HYDROLOGY**
- **CHEMICAL COMPOSITION *(including pH and salinity)***
- **ELECTRICAL CONDUCTIVITY/RESISTIVITY**
- **STRAY & TRANSIENT CURRENT *(i.e., pipelines)***
- **OTHER INFLUENCES *(Agriculture/farming and mining spoils)***

CORROSION RISK ANALYSIS*

MILFORD MET #2

SITE NAME: MIL MET #2
SITE ADDRESS: Milford, UT
COMPANY: firstwind™
1200 Folsom St. Suite 100
San Francisco, CA 94103

LATITUDE: 38.5368
LONGITUDE: -112.9437
COUNTY: Beaver
COMM. DATE: 11/3/09

*Actual Client Report

Note: *The following data was taken from the Milford Met #2 report and has not been altered/modified for the purposes of this presentation*

ANCHORS

MET #2 has ONE (1) ring of three (3) SOLID ROUND anchors

MILFORD MET #2 – TYPICAL ANCHOR – **Each of these anchors is in direct contact with soil and has not been equipped with any type of corrosion protection.**

SOIL *The primary types of soil are listed below. All soils fall into one of these categories, or is a combination of one or more.*

- SAND: *Sand possesses the largest particles and consists primarily of quartz. The fragments range between 0.05 mm to 2.0 mm, the largest of all the soils. As a soil class, 85% must be sand and < 10% is clay. Sand is the least conductive of all the soils.*
- SILT: *Silt has individual mineral particles ranging between 0.002 mm to 0.05 mm. As a soil class, 80% or more is silt. Less than 12% is clay.*
- LOAM: *Loam is soil material that is a combination of Sand, Silt and Clay.*
- CLAY: *The mineral soil particles are < 0.002 mm in diameter, the smallest particles of all the soil types and the most conductive of all the soils.*
- COMPLEX: *A Complex is two or more soils.*

SOIL #1 Drum Taylorsflat

- Depth to Water Table > 80 inches
- Available Water Capacity < 5 inches
- Depth to Restrictive Feature > 80 inches
- Well-Drained

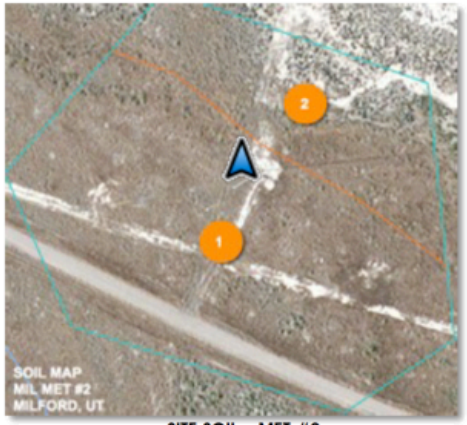
PROFILE
0 to 6 inches: Loam
6 to 11 inches: Loam
11 to 20 inches: Silty clay loam*
20 to 60 inches: Silty clay loam*

SOIL #2 Robozo silt loam

- Depth to Water Table > 80 inches
- Available Water Capacity is Moderate at 6.5 inches
- Depth to Restrictive Feature > 20 inches to petrocalcic
- Well-Drained

PROFILE
0 to 2 inches: Silt loam
2 to 5 inches: Silty clay loam*
5 to 38 inches: Silt loam
38 to 39 inches: Indurated

**The "clay" components of these soils make them more conductive and corrosive.



SITE SOIL – MET #2
MILFORD, BEAVER COUNTY, UT

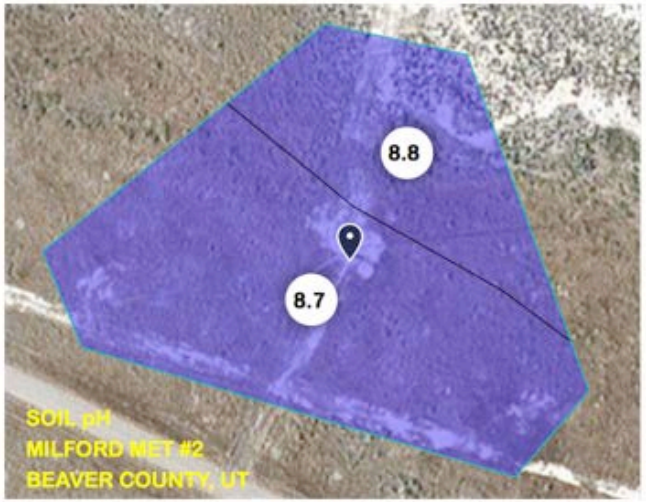
SOIL NUMBER	SOIL NAME	% OF SITE
1	Drum-Taylorsflat	72%
2	Robozo silt loam	28%

pH: *Soil reaction is a measure of acidity or alkalinity. In general, highly alkaline and highly acid soils create the most corrosive environment for steel. The integrity of concrete is most compromised in soils with the lowest pH, or extremely acidic soil.*

A range of 5 to 8 is typical for most soil types.

pH LEGEND

- Ultra Acid (pH < 3.5)
- Extremely Acid (pH 3.5-4.4)
- Very Strongly Acid (pH 4.5-5.0)
- Strongly Acid (pH 5.1-5.5)
- Moderately Acid (pH 5.6-6.0)
- Slightly Acid (pH 6.1-6.5)
- Neautral (pH 6.6-7.3)
- Slightly Alkaline (pH 7.4-7.8)
- Moderately Alkaline (pH 7.9-8.4)
- Strongly Alkaline (pH 8.5-9.0)
- Very Strongly Alkaline (pH > 9.0)
- Not Rated or N/A

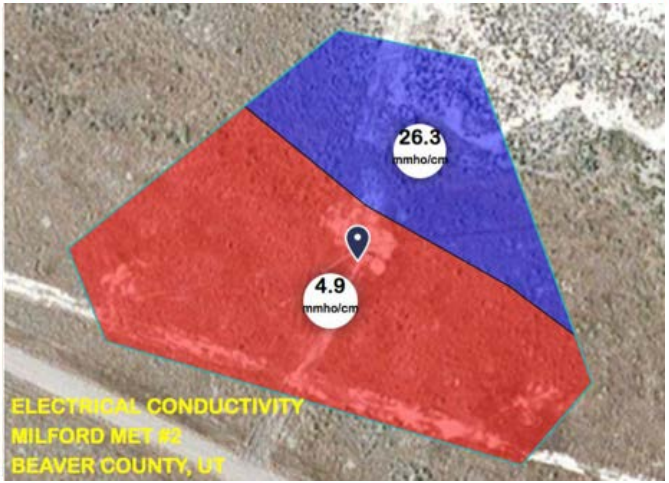


Strongly alkaline soil is prevalent at Met #2. Highly alkaline soils can be as corrosive as those with very low, or acid, pH.

SOIL pH – MET #2
MILFORD, BEAVER COUNTY, UT

SOIL NUMBER	RATING	% OF SITE
1	8.7	72%
2	8.8	28%

ELECTRICAL CONDUCTIVITY *(EC) is the electrolytic conductivity of an extract from saturated soil paste, expressed in milliMhos per centimeter at 25° C. The electrical conductivity of soils varies depending on the amount of moisture held by soil particles. Sandy soils are the least conductive. Silt soils are considered moderately conductive, with clay soils exhibiting the highest conductivity. Areas with multiple soils are generally more conductive than sites with a single soil. The boundary lines dividing soil types are often the most conductive areas of a site.*



ELECTRICAL CONDUCTIVITY LEGEND
WITH EFFECT ON STEEL
(Displayed in deciSiemens/meter)

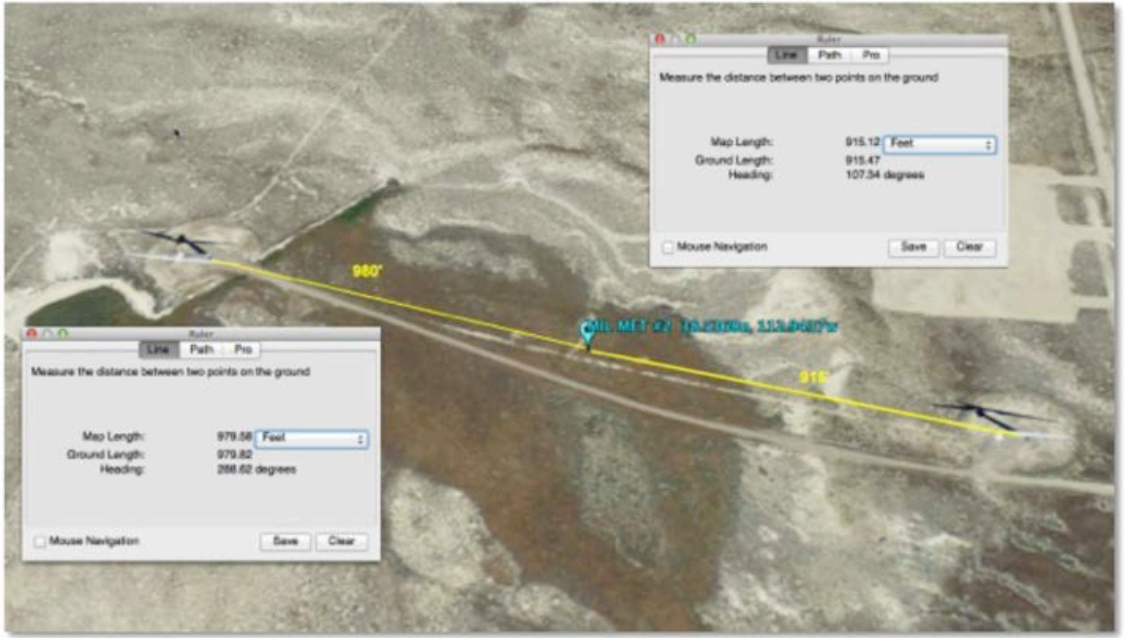
< .05	***Essentially Non-Corrosive***
.05 - .10	***Mildly Corrosive***
.10 - .20	***Moderately Corrosive***
.20 - .33	***Corrosive***
.33 - 1.0	***Highly Corrosive***
> 1.0	***Extremely Corrosive***

ELECTRICAL CONDUCTIVITY – MET #2
MILFORD, BEAVER COUNTY, UT

SOIL NUMBER	RATING	% OF SITE
1	4.9 dS/m	72%
2	26.3 dS/m	18%

Electrical Conductivity at the Milford Met #2 site is "off the chart", with an *extremely high risk for corrosion of steel.*

OTHER INFLUENCES – STRAY CURRENT

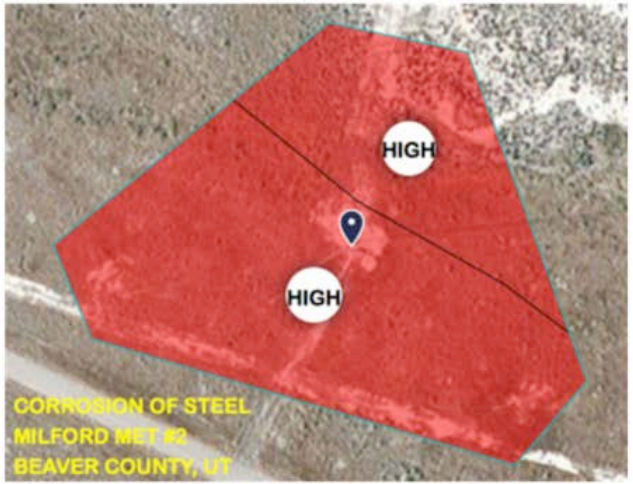


MIL MET #2 is surrounded by wind turbines, known producers of transient, or stray current, injected into the soil. This current can be picked up by nearby anchors, travel through the structure and cause damage as the current exits the tower through another anchor.

This site is situated between two (2) wind turbines, 980' *(west of tower)* and 915' *(east of tower)*, respectively.

CORROSION OF STEEL

Potential soil-induced electrochemical or chemical actions that corrode and weaken anchor steel, increasing the risk for structure failure. The rate of corrosion is dependent upon factors such as the type and characteristics of soil, moisture content, acidity and alkalinity, and electrical conductivity. The shape of individual anchors may also hasten the corrosion process. The steel in installations that in intersect soil boundaries or soil layers is more susceptible to corrosion than the steel of installations that are entirely within one type or one layer of soil.



LEGEND: RISK FOR CORROSION OF STEEL

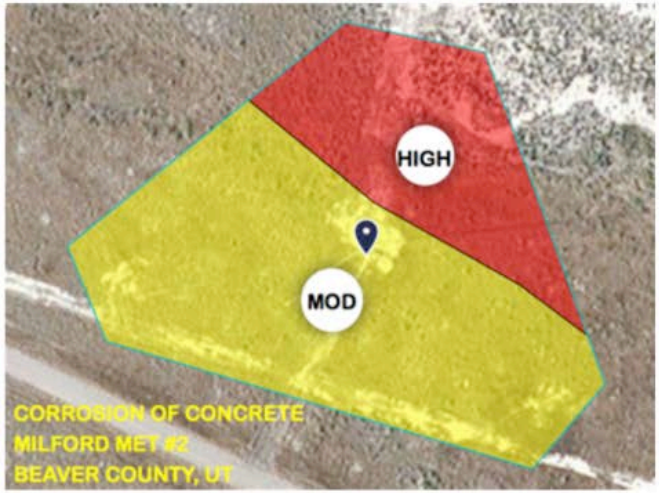
- HIGH
- MODERATE
- LOW

100% of the soil is rated HIGH for Corrosion of Steel.

CORROSION OF STEEL – MET #2
MILFORD, BEAVER COUNTY, UT

SOIL NUMBER	RATING	% OF SITE
1	HIGH	72%
2	HIGH	28%

CORROSION of CONCRETE *pertains to potential soil-induced electrochemical or chemical action that corrodes or weakens concrete and steel within the concrete. Corrosion of reinforcing steel and other embedded metals is one of the leading causes of deterioration of concrete. When steel corrodes, the resulting rust occupies a greater volume than steel. The expansion creates tensile stresses in the concrete, which can eventually cause cracking and spalling.*



LEGEND: RISK FOR CORROSION OF CONCRETE

- HIGH
- MODERATE
- LOW

Close to 30% of this site is rated HIGH for Corrosion of Concrete, while 72% of MET #2 carries a MODERATE risk.

CORROSION OF CONCRETE – MET #2
MILFORD, BEAVER COUNTY, UT

SOIL NUMBER	RATING	% OF SITE
1	MOD	72%
2	HIGH	28%

PROS OF THE CRA SOIL ANALYSIS

- ✓ Investigates soil chemistry & characteristics entire depth of anchor
- ✓ Includes sources of stray/transient electrical current
- ✓ Investigation of entire site, including environmental factors
- ✓ Analytical study with short lead time
- ✓ Meets requirements of Insurance carriers *(Due Diligence)*
- ✓ Capable of identifying 80% of sites requiring *no further investigation*, while determining those 20% in need of further action, a 1:5 ratio
- ✓ Cost-effective - $1500, per site. CAPEX (100% tax-deductible expense)

LIMITATIONS OF THE CRA / SOIL ANALYSIS

- **Analytical Study based on research and reporting –** ***Site visit not included.***
- **Provides a *prediction* of material loss, based on site-specific conditions.**
- **Technical knowledge and understanding of corrosion and related precursors is the key to accuracy.**

WHEN THE CRA INDICATES FURTHER ACTION IS NEEDED

What's next for the 1:5?

The 20% of sites, previously discussed

- **SURFACE INVESTIGATION/PARTIAL EXCAVATION**
- **ON-SITE MEASUREMENTS AND OBSERVATIONS**
- **ULTRASOUND TEST**
- **DIG-TO-BLOCK**

SURFACE INVESTIGATION/PARTIAL EXCAVATION

1. Hand tools
2. Excavate 24-36-inches, below grade
3. Caliper measurements and photographs
4. Determine extent of corrosion affecting visible portion of shaft.

SURFACE INVESTIGATION/PARTIAL EXCAVATION

WHAT ARE WE LOOKING FOR?

1. Steel discoloration
2. Loss of galvanizing
3. Scaling or rust
4. Pitting
5. Measured steel loss

SOMETIMES, FINDINGS ARE OBVIOUS

SOMETIMES, NOT!

RESULTS OF SURFACE INVESTIGATION/ SHALLOW EXCAVATION CAN BE DECEIVING

The upper 24-inches are <u>not</u> always indicative of rod condition

PROS OF SURFACE INVESTIGATION/ SHALLOW EXCAVATION

- ✓ ALLOWS CONTACT WITH, AND DIRECT MEASUREMENT OF SHAFT
- ✓ EXTENSIVE PERSONNEL TRAINING IS NOT REQUIRED
- ✓ MODERATE COST: $3,000 to $6,000, PER SITE

CONS OF SURFACE INVESTIGATION/ SHALLOW EXCAVATION

- DETERMINATION OF CORROSION IS LIMITED TO DEPTH OF EXCAVATION
- SUBJECTIVE – NO STANDARD
- DESTRUCTIVE – SOIL COMPACTION AND AERIATION ALTERED, INCREASING CORROSION POTENTIAL
- NOT APPLICABLE FOR EVERY SITE

ON-SITE TESTING & VISUAL INSPECTION

- CONDUCTIVITY/RESISTIVITY MEASUREMENT
- SOIL pH TEST
- MEASUREMENT OF POTENTIALLY CORROSIVE ELECTRICAL CURRENT TRAVELING ALONG EACH ANCHOR SHAFT
- SAMPLES OF RUST/CORROSION FOR LAB ANALYSIS
- SOURCES OF STRAY/TRANSIENT CURRENT MAY BE IDENTIFIED

ON-SITE TESTING & VISUAL INSPECTION

MEASURING RESISTANCE AND CURRENT FLOW

A SINGLE AMPERE OF DISCHARGED CURRENT IS CAPABLE OF CORRODING 20-POUNDS OF STEEL, EACH YEAR

1 AMP, PER YEAR = 20 lbs. STEEL

43 mA = 0.043 Amps

0.043 Amps x 20 lbs.

EQUALS

0.9 lbs. OF STEEL LOSS,

OVER THE COURSE

OF ONE YEAR

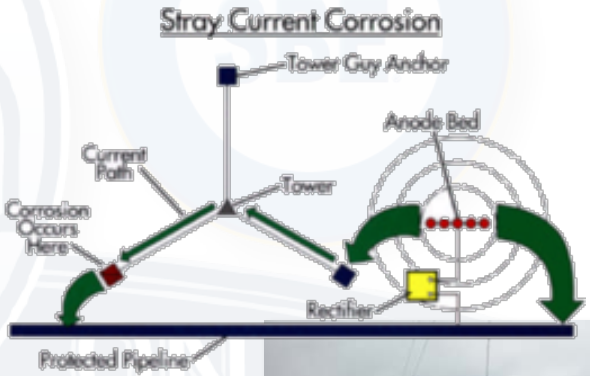
EVER WONDER WHAT 0.9 POUNDS OF STEEL LOSS LOOKS LIKE, COMPARED WITH A 2-INCH DIAMETER ANCHOR SHAFT?

ON-SITE TESTING & VISUAL INSPECTION

SAMPLE COLLECTION FOR ANALYSIS

ON-SITE TESTS & VISUAL INSPECTION

IDENTIFYING SOURCES OF STRAY/TRANSIENT ELECTRICAL CURRENT



PROS OF ON-SITE TESTING & VISUAL INSPECTION

- ✓ Provides site-specific data not available with a Surface Investigation/ Shallow Excavation
- ✓ May be included with a P.E./S.I. site visit
- ✓ Cost is ~$2,000 when included with an existing Partial Excavation/Surface Investigation project

CONS OF ON-SITE TESTING & VISUAL INSPECTION

- SPECIALIZED EQUIPMENT AND TRAINING REQUIRED
- RAW DATA INTERPRETATION BY SPECIALISTS
- CORROSION SAMPLES REQUIRE LAB ANALYSIS
- MAY DUPLICATE DATA INCLUDED IN THE CRA

ULTRASOUND TESTING

TWO METHODS

1) LONGITUDINAL WAVE ULTRA SOUND

2) GUIDED WAVE ULTRA SOUND

LONGITUDINAL WAVE ULTRASOUND

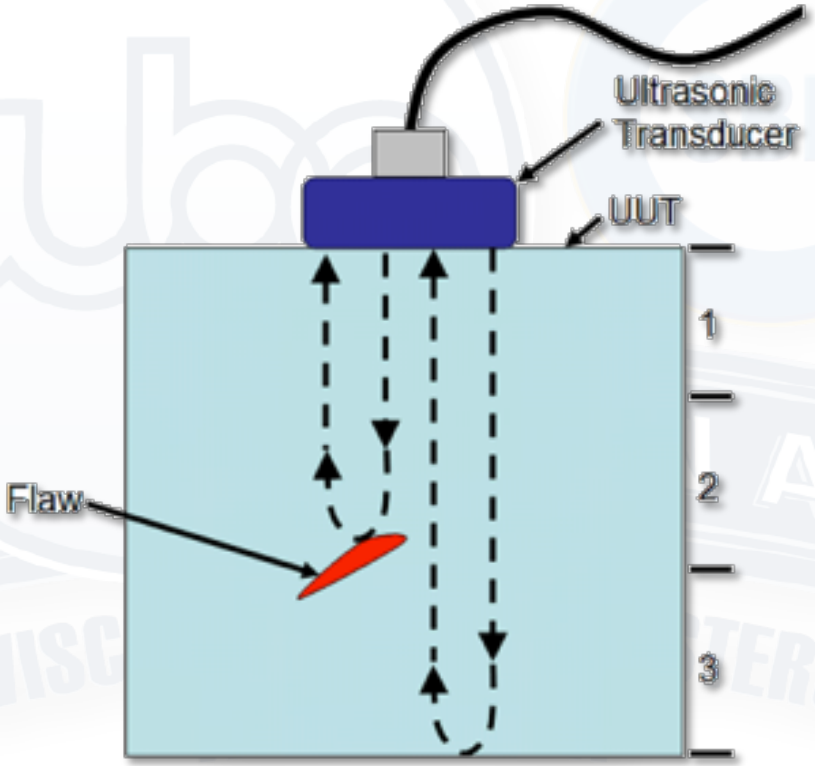
- **LONGITUDINAL WAVE ULTRASOUND INSPECTION is a non-destructive method accomplished by projecting a sound beam into the end of a rod to obtain pulse echo reflections.**

- **Sound waves travel through the material and are reflected by large discontinuities.**

- **Reflected waves are analyzed to determine the presence and location of flaws.**

LONGITUDINAL WAVE ULTRASOUND

LONGITUDINAL WAVE ULTRASOUND

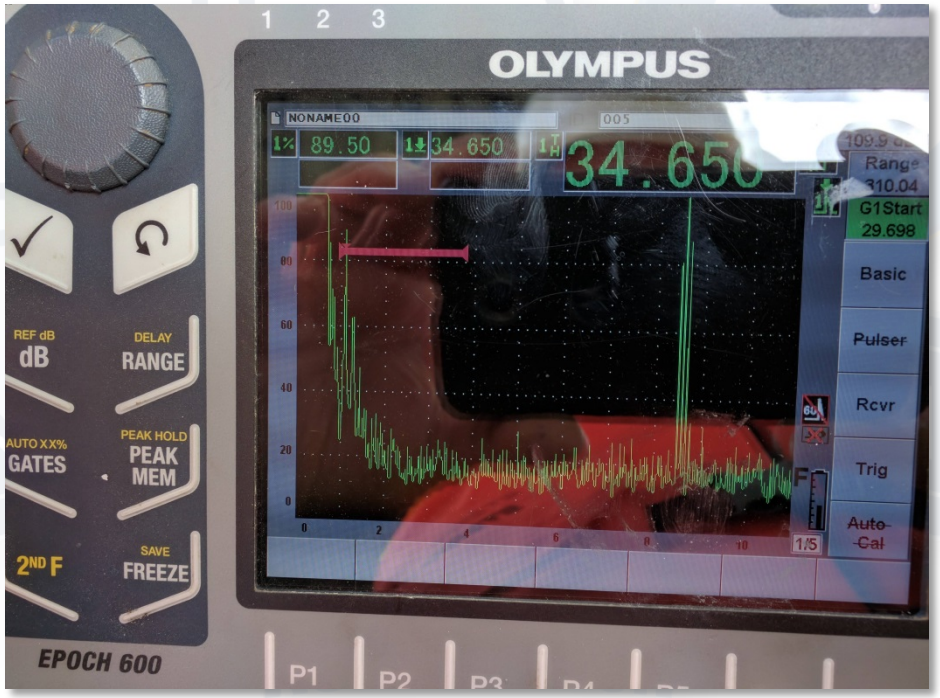


TESTING ANCHOR SHAFTS

LONGITUDINAL WAVE

LONGITUDINAL WAVE ULTRASOUND

SCREEN SHOT OF RESULTS



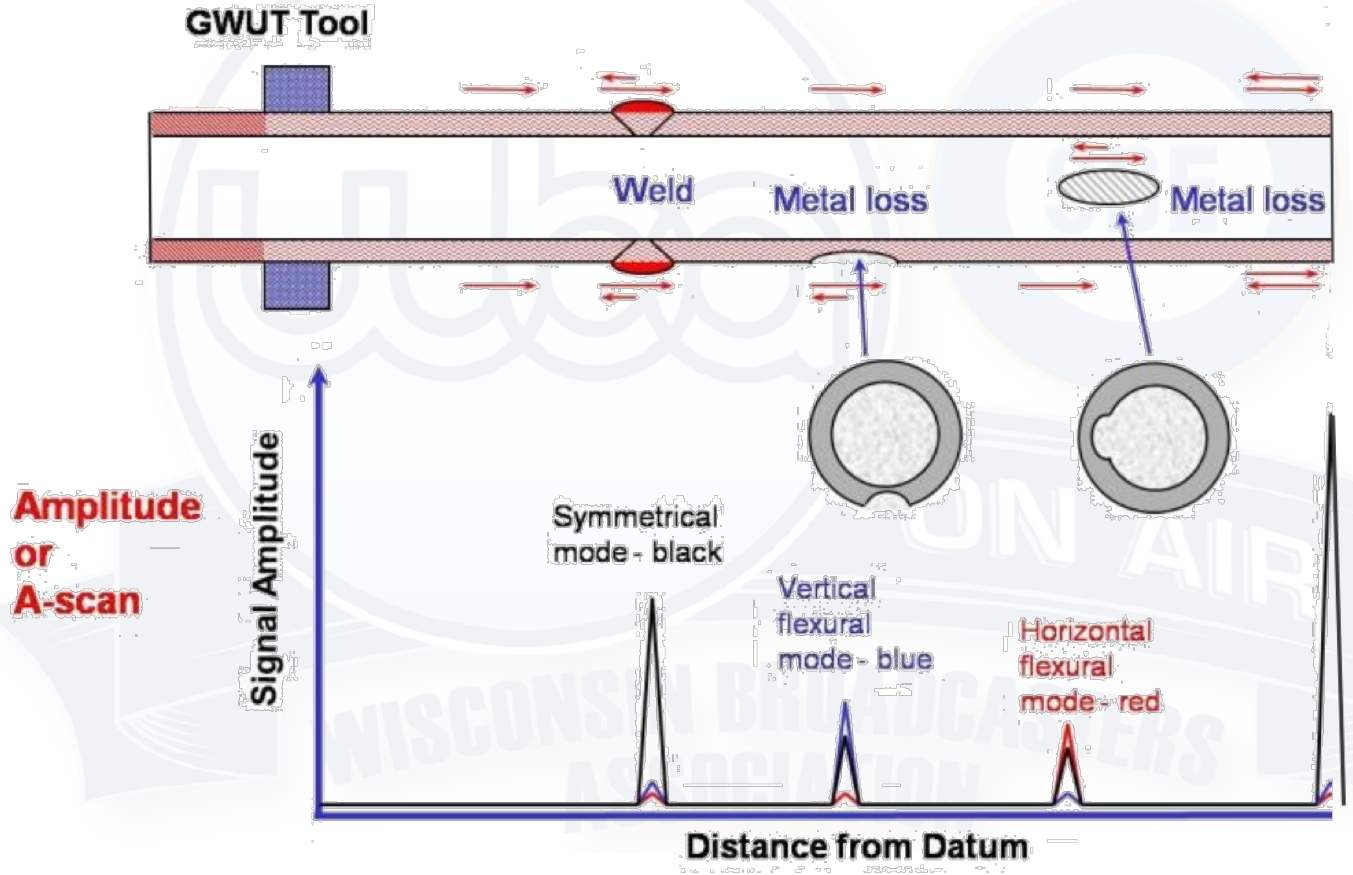
GUIDED WAVE OR SURFACE WAVE ULTRASOUND

- GUIDED WAVE TESTING (GWT) employs mechanical stress waves propagating along the surface of an elongated structure and guided by its boundaries, allowing waves to travel longer distances, with negligible loss of energy.

- Relatively new to inspection of tower anchors, the pipeline industry has utilized GUIDED WAVE ULTRASOUND for 20+ years.

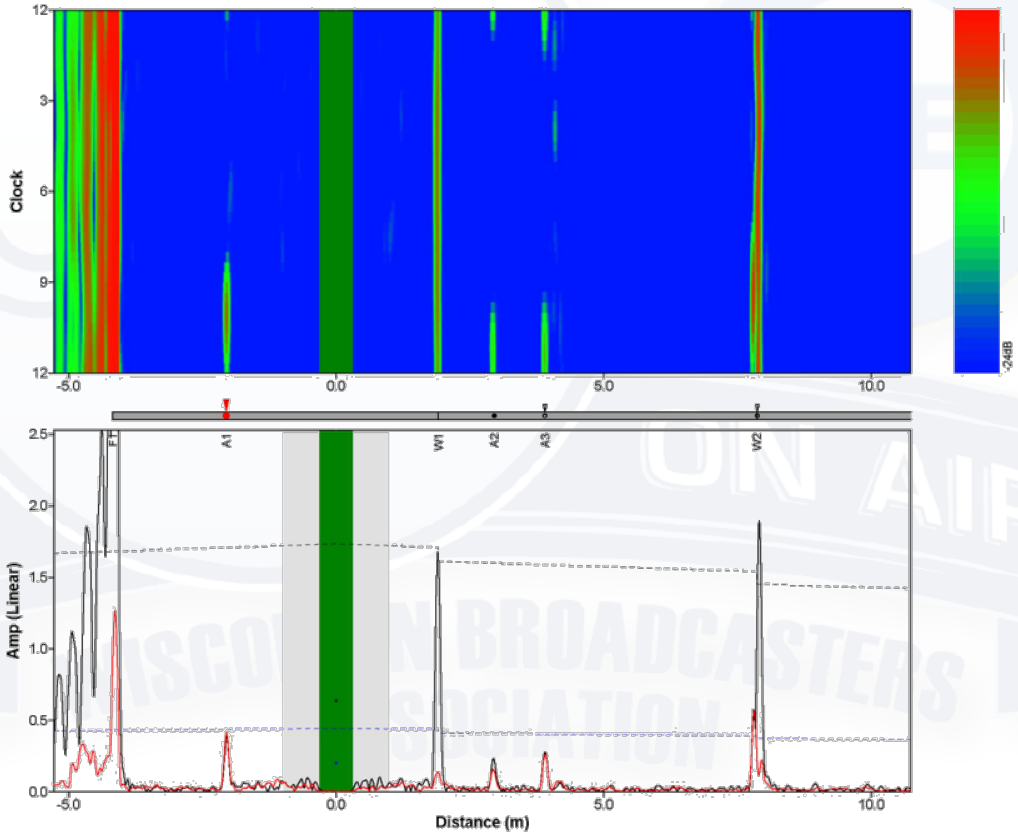
GUIDED WAVE ULTRASOUND ATTACHMENT

GUIDED WAVE TECHNOLOGY



GUIDED WAVE TECHNOLOGY

DATA EXAMPLE



PROS OF ULTRASOUND INVESTIGATION

- ✓ **Non-destructive - *no digging or soil alteration***
- ✓ **ASNT/ASTM-APPROVED**
- ✓ **Minimal preparation**
- ✓ **Entire anchor shaft may be inspected**
- ✓ **Testing equipment is portable**
- ✓ **Fairly inexpensive - $3,000 to $5,000, *per site***

CONS OF ULTRASOUND INVESTIGATION

- **LIMITED TO INSPECTION OF SOLID ROUND SHAFTS**
- **ACCURACY REQUIRES SIGNIFICANT TRAINING AND EXPERIENCE**

LONGITUDINAL WAVE

- *Detects anomaly - Unable to determine size*
- *End of anchor shaft must be accessible*

GUIDED WAVE

- *Unsuitable for concrete-encases or coated anchor shafts*
- *Transducer size limitations*

WHEN DIG-TO-BLOCK IS THE BEST RECOURSE

POINTS TO CONSIDER

1) ADVANTAGES
2) DISADVANTAGES
3) ESTIMATED COST

ADVANTAGES OF DIG-TO-BLOCK

- ✓ SHAFT IS COMPLETELY EXPOSED
- ✓ INFORMED DISCUSSION TO REPAIR OR REPLACE
- ✓ IDEAL TIME TO EMPLOY ADDITIONAL CORROSION MEASURES/PROTECTION

ADVANTAGES OF DIG-TO-BLOCK

CORROSION PROTECTION OPTIONS, WHILE SHAFTS ARE COMPLETELY EXPOSED:

1) **SHAFT COATING**
2) **ANODES**

DISADVANTAGES OF DIG-TO-BLOCK

#1 - NOT ALWAYS POSSIBLE

DISADVANTAGES OF DIG-TO-BLOCK

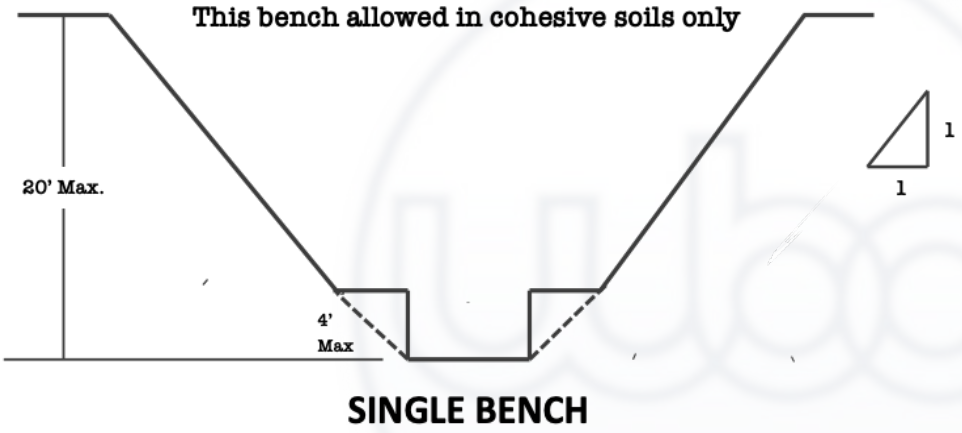
#2 – TOWER INTEGRITY IS COMPROMISED

ADDITIONAL STRESS ON ANCHOR SHAFT COULD LEAD TO FAILURE

DISADVANTAGES OF DIG-TO-BLOCK

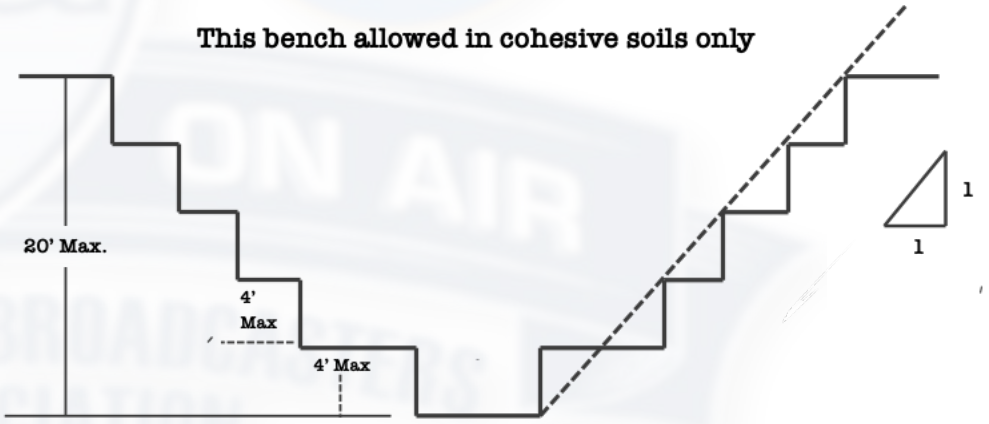
#3 - CONFINED SPACE CREATES ADDITIONAL RISK FOR PERSONNEL

OHSA
SLOPING AND BENCHING REQUIREMENTS
STANDARD 29-CFR



SINGLE BENCH

#4 - Essentially, all anchor resistance is removed, requiring design of temporary anchorage, *including* a Class IV Rigging Plan



MULTIPLE BENCH

DISADVANTAGES OF DIG-TO-BLOCK

#5 - EXPENSIVE

Cost is approximately $20,000

Often, not justified

for 80% of tower sites

HOW EXPENSIVE, YOU ASK?

ESTIMATED COST BURDEN

SIX (6) ANCHORS THREE (3) MEN TWO (2) DAYS

$ 7,200.00 → LABOR & BURDEN OF $150/MAN

\+ $ 2,750.00 → PER DIEM OF $250/MAN & MILEAGE (500 MI)

\+ $10,000.00 → EQUIPMENT RENTAL & CLASS IV RIGGING PLAN

$17,000.00 TO $22,000.00 TOTAL

TIME TO SUMMARIZE

We're in the home-stretch!

PROS AND CONS
CORROSION RISK ANALYSIS (CRA)

- Cost-effective - $1,500
- Research of soil chemistry and features, to depth of anchor.
- Site-specific investigation, including surrounding property, sources of stray/transient current and other potential corrosion-related hazards.
- Easy to order – short lead time.
- Meets insurance inspection requirements.
- Identifies those 80% of sites not requiring additional investigation.

- Analytical research and reporting. Site visit not included.
- Provides a prediction of material loss.
- Technical knowledge with understanding of corrosion and related precursors required.

PROS AND CONS
SURFACE INVESTIGATION/PARTIAL EXCAVATION

- Allows direct measurement of rod.
- Extensive training not required.
- Moderately expensive - $3,000 to $6,000, per site.

- Corrosion evaluation is limited to depth of excavation.
- Subjective means of testing - no applicable Standard
- Destructive – alters soil compaction and aeriation, increasing corrosion potential.
- Not all sites qualify.

PROS AND CONS

ON-SITE TESTING & VISUAL OBSERVATION

- Provides site-specific data not obtained during Surface Investigation/Partial Excavation.
- May be included with Surface Investigation.
- Relatively Inexpensive – adds approximately $2,000 to the cost of a Surface Excavation

- Requires specialized equipment and training.
- Raw data requires interpretation by specialist.
- Corrosion samples require lab analysis.
- Oftentimes, duplicates data reported in a CRA.

PROS AND CONS
ULTRASOUND TESTING

- Non-destructive, as no digging is required, allowing soil to remain intact and undisturbed.
- ASNT/ASTM-approved method.
- Little or no preparation required.
- Entire shaft is inspected.
- Equipment is highly portable.
- Moderately expensive, at $3,000 to $5,000, per site.

- Only effective to solid round shafts.
- Requires high degree of operator training.

LONGITUDINAL WAVE

- Presence of anomaly is detected, though size is not.
- End of shaft must be accessible.

GUIDED WAVE

- Cannot be used with concrete encased or coated anchor shafts.
- Transducer size limitations.

PROS AND CONS
DIG-TO-BLOCK

- Best evidence of entire shaft condition.
- Owner can see shaft and potential safety hazard.
- Good evidence for the *'repair or replace'* discussion
- Additional corrosion prevention can be employed while shaft is exposed.

- DTB is not always possible.
- Soil compaction and aeriation is altered, potentially increasing risk for corrosion.
- Intrusive and hazardous to personnel and tower stability.
- Benching is required, per OSHA.
- Requires a Class IV Rigging Plan and temporary anchorage.
- Costly and labor intensive.

PRICE COMPARISON

ANCHOR INSPECTION METHODS

CORROSION RISK ANALYSIS	$1,500
SURFACE INVESTIGATION / SHALLOW EXCAVATION	$3,000 to $6,000
ON-SITE INSPECTION / VISUAL OBSERVATION	$2,000 + SURFACE INSPECTION
ULTRASOUND TESTING	$3,000 to $5,000
DIG-TO-BLOCK PROCEDURE	$17,000 to $22,00

If you have questions or wish to discuss a project or Engineering needs, please contact Mr. Davies at your convenience.

David K. Davies
Director of Engineering
ddavies@hodgestructural.com
812.459.1341

Comprehensive Tower Engineering Services

HODGE
TOWER DIVISION
STRUCTURAL ENGINEERS

- **Structural Analysis**
- **Rigging Plans**
- **Project Management**
- **Reinforcing Design & Materials**
- **Corrosion Analysis**
- **Construction Services**