



## **CONDITION ASSESSMENT OF BRIDGES & RESEARCH NEEDS**



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## Outline

- **Techniques for Strength Evaluation**  
**Inspection & Vulnerability Assessment**  
**Load Rating**  
**Strengthening Measures**
- **System-wide Vulnerabilities**  
**Bearing Failure**  
**Joint Failure**  
**Atmospheric Corrosion**
- **Specific Vulnerabilities:**  
**Degradation of Bridge Cables**  
**Cracking & Deterioration of Orthotropic Deck**
- **Need for Research & Monitoring Techniques**

## Bearing Deterioration





## Bearing Failure



## Joint Failure

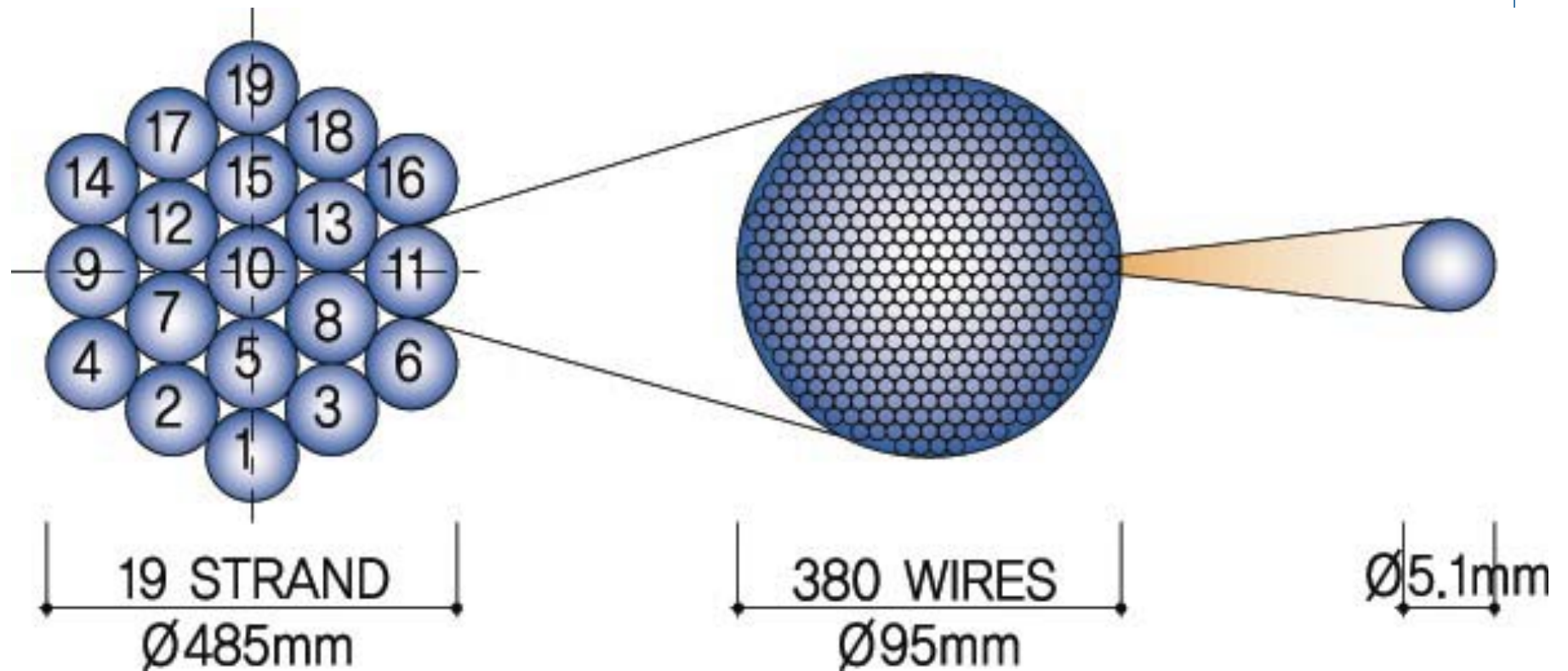




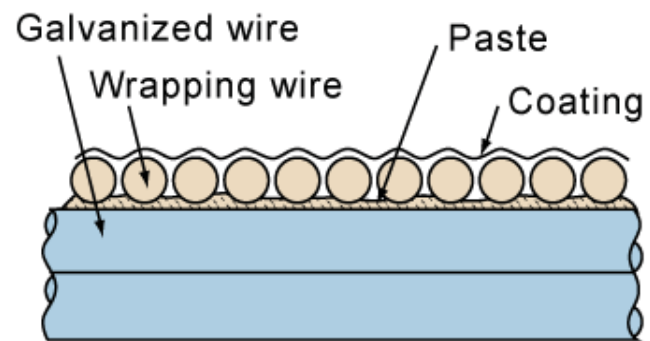
## Atmospheric Corrosion



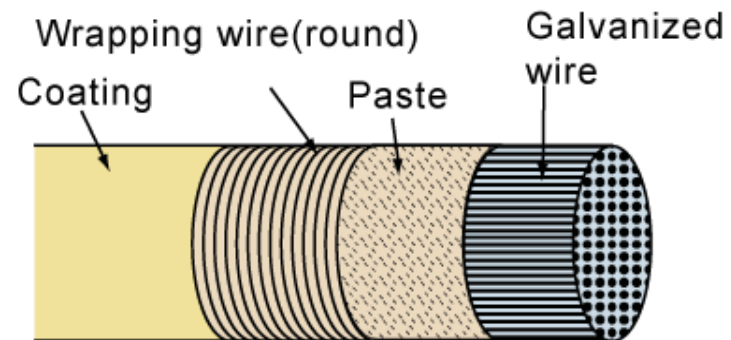
# Suspension Bridge Data



# Corrosion Protection System



Section of wrapping system



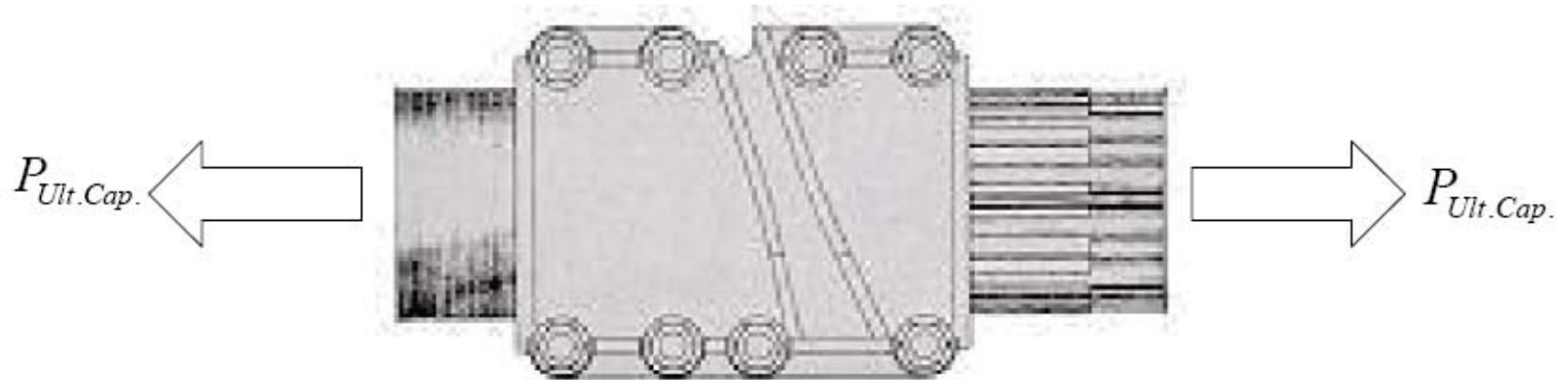


# Cable Unwrapping & Inspection



▲ **Cable Close-Up.** Bridge crews insert wedges to open up a cable in Mid-Hudson River Bridge.

# Cable Force Capacity



$$Factor\ of\ Safety = \frac{P_{Ult.Cap.}}{P_{DL + T + LL}}$$

# **BTC Method for Cable Strength Evaluation**

- **Sample size & Random Sampling**
- **Basic degradation modeling**
  - **Cracked wire proportion**
  - **Broken wire proportion**
  - **Effect of adjacent panels**
- **Wire testing program**
- **Analysis of cracked wires**
- **Forecast of cable strength**
- **Sensitivity Analysis**

# BTC Method for Cable Strength Evaluation

## **BTC Method *for* Evaluation of Remaining Strength and Service Life of Bridge Cables**

### **NYSDOT REPORT C-07-11**

**FINAL REPORT**

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**New York State Department of Transportation**



**New York State Bridge Authority**



In cooperation with the  
**U.S. Department of Transportation**  
**Federal Highway Administration**





## Random Sample Size Determination-BTC Method

- **WHY RANDOM?**

- **Because Damage inside bridge cables is mostly randomly distributed.**
- **Crossing and broken wires were randomly distributed in some bridge cables.**
- **On some other cables, wire tensile strength was also randomly distributed, because of variations in carbon content.**
- **Cracked and broken wires were observed to be randomly distributed.**

- **WHY IDENTIFY SAMPLE SIZE?**

- **To limit invasive wire cutting and splicing.**
- **To obtain a minimum number of samples to achieve high level of confidence in estimated cable strength.**

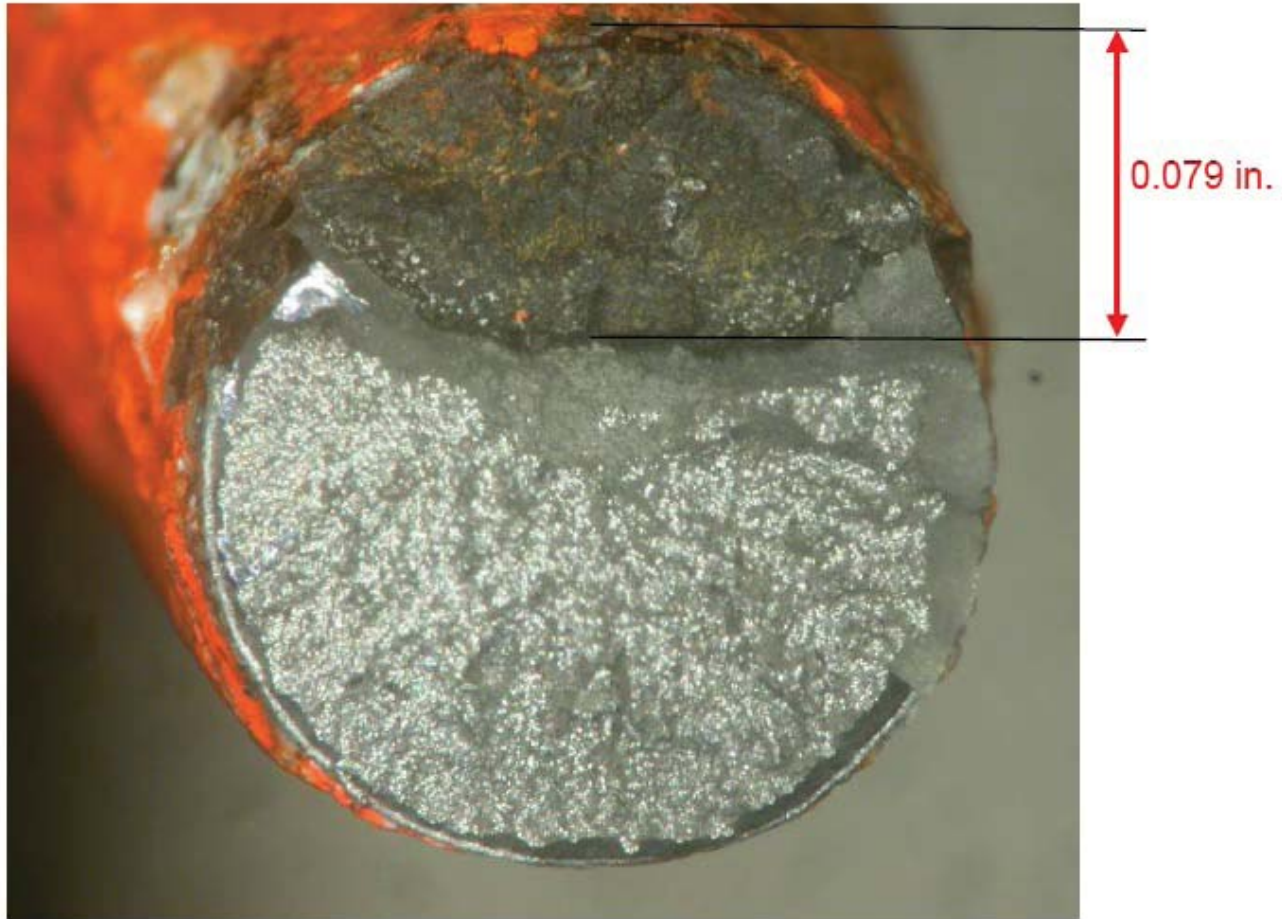
## Random Sample Size Determination-BTC Method



## Random Sampling Plan



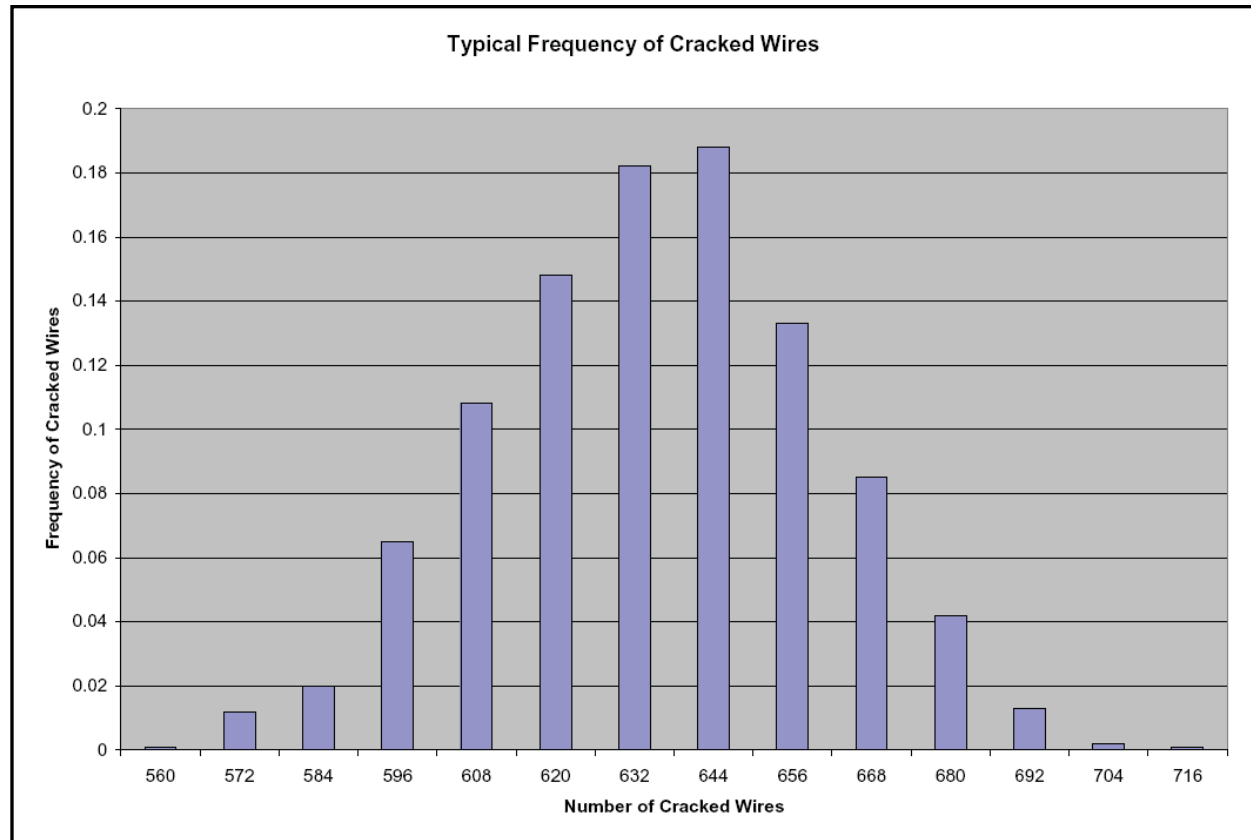
## SEM - Fractographic Identification of Cracks





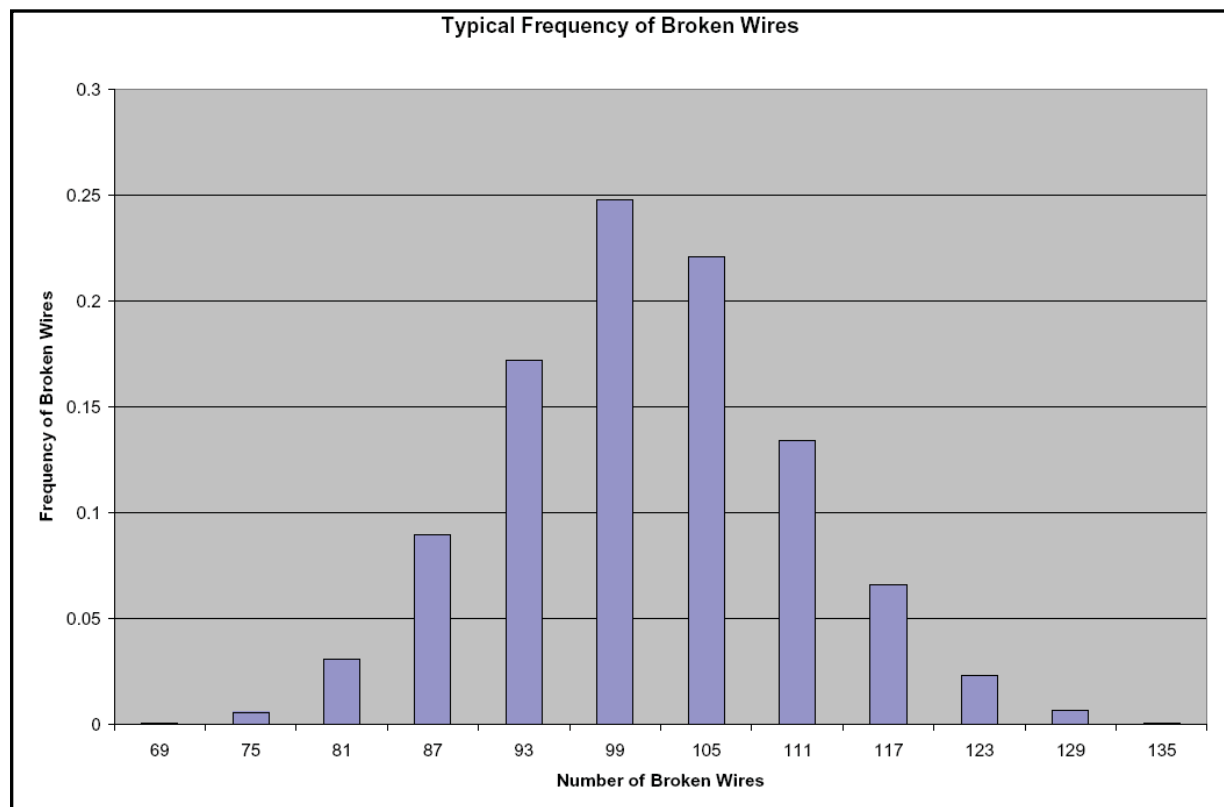
## Cracked Wire Proportion-BTC Method

- Cracked Wires are Identified as Probabilistic Quantity

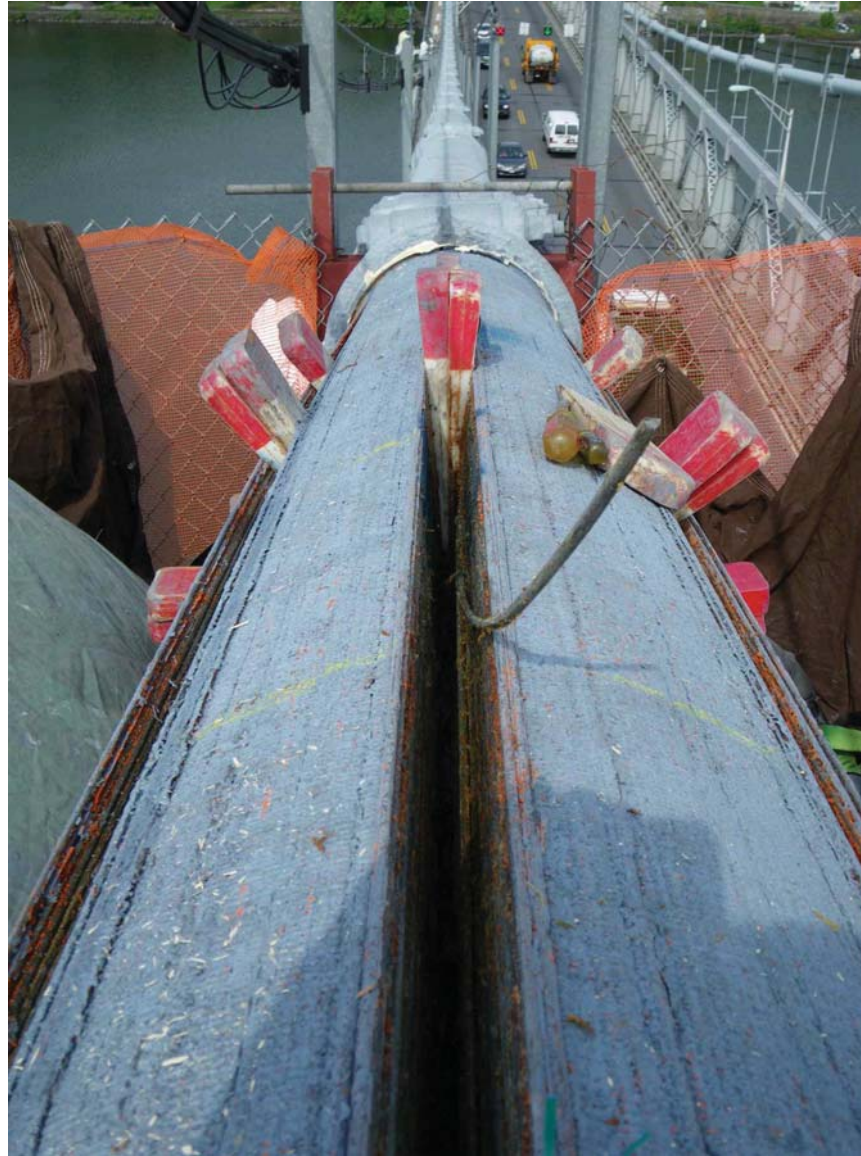


## Broken Wire Proportion-BTC Method

- Broken Wires are Identified as Probabilistic Quantity



## Broken Wire Proportion-BTC Method



## **Wire Test Program-BTC Method**

### **BTC Method Test Program includes:**

- **Enhanced Tension Test for Mechanical Properties**
- **Tensile Test of Long Wires to obtain better assessment of % of Cracked Wires.**
- **Fracture Toughness Test**
- **Fractographic Examination of ALL Fracture Surfaces of Wires tested in tension (both short & long).**



## Analysis of Cracked Wires-BTC Method

**BTC Method uses Principles of Fracture Mechanics to determine Ultimate Strength for Cracked Wires:**

$$(\sigma_{cracked}) = \frac{(K_c)}{Y(\frac{a}{D})\sqrt{\pi \cdot a_c}}$$

$(K_c)$  = **Measured Fracture Toughness.**

$Y(\frac{a}{D})$  = **Crack Shape Factor.**

$a_c$  = **Critical Crack depth obtained from Fractographic Examination.**

## Forecast of Cable Service Life-BTC Method

- **BTC Method uses Data of Wire Strength to forecast service life of cables.**
- **It relies on degradation of Strength for both:**
  - **Intact Wires**
  - **Cracked Wires**
- **It includes effect of adjacent panels; i.e., effect of broken and cracked wires in adjacent panels.**

## **Sensitivity Analysis-BTC Method**

- **Purpose of Sensitivity Analysis:**
  - **Identify the key inputs which influence the estimated cable strength.**
  - **Assess whether the estimated cable strength and the decision making process are likely to be affected by uncertainties.**

## **Sensitivity Analysis-BTC Method**

- **KEY INPUT For Sensitivity Analysis:**
  - **Effect of adjacent panels**
  - **Proportion of cracked wires**
  - **Ultimate strength of cracked wires**
  - **Proportion of broken wires**



# Cable Monitoring



## Cable Monitoring



# Cable Monitoring



## Cable Monitoring



## Conclusions

- **Visual Evaluation of bridge cable wire condition is misleading and provides unreliable results.**
- **Random Sampling Provides good representation of damage in bridge wire.**
- **Fractographic Examination provides the most accurate determination of the proportion of cracked wires.**
- **Fracture-based Analysis of Cracked Wires provides accurate assessment of the ultimate strength of cracked wires.**
- **Evaluation of Time-dependent degradation is an important component necessary in the decision making process and cable strength evaluation.**
- **Monitoring techniques are essential for the condition assessment of bridge cables.**



*Thank you!*



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