A new methodology for condition assessment of utility wood poles based on ultrasonic waves

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Background

- Utility wood poles are categorized as Priority 1 (high value, high risk).
- 5% of the wood pole infrastructure requires replacement within the next f ve years (in 2011, 9,500 poles with an asset replacement of $59 million).
- 50% of the Hydro-One transmission's system is more than 35-year old.
- A subset of 55,000 new poles (red pine, age: 7 to 14 years) has shown early decay (replacement cost $165 million).
- There are 100,000 transmission poles with a historic replacement of 1,800 poles per year (average replacement cost per year $11 million).

Current inspection methods

- Visual assessment (sounding and visual inspections)
- Resistographs and core sample inspection for poles identif ed as suspected

NESC, Section 26, Rule 261

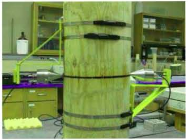
”...a wood pole must be replaced or rehabilitated when deterioration reduces the pole strength to 2/3 of the required value when it is installed.”

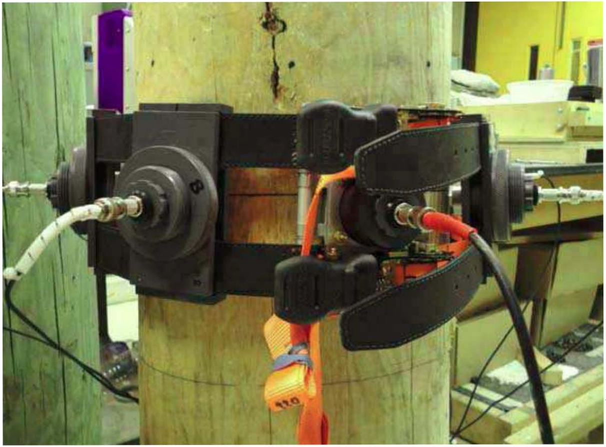
Therefore...

- Hydro-One needs a reliable non-destructive evaluation of its wood-pole infrastructure for
  - ✓ planning maintenance programs by creating a data base to pinpoint problems before they occur,
  - ✓ maintaining staff and public safety by addressing unexpected pole failures,
  - ✓ improving the reliability of the electric system network by detecting early deterioration on new poles, and
  - ✓ reducing the cost of replacing utility poles too early or too late.

Prototype

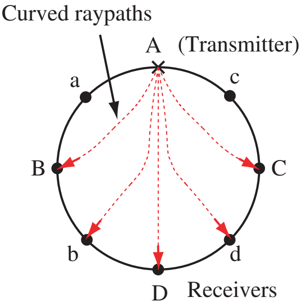
From the Lab





to the field

Methodology



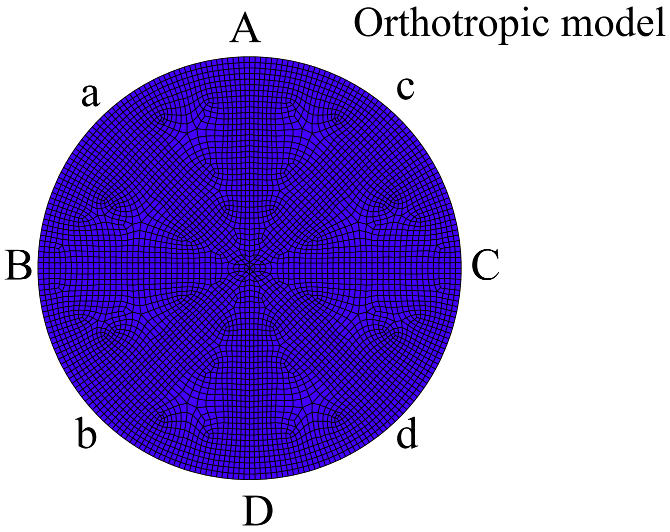
- Numerical analysis (orthotropic model)
- Experimental results
- Statistical analysis

$$\mathrm{DI} = \frac{\text{(measured parameter)-(expected value)}}{\text{(standard deviation)}}$$

- Travel time
  - Wave velocity — DI — Tomographic imaging (decay location) ①
  - Modulus of elasticity — DI — Condition rating (remaining strength) ②
- Full waveform analysis
  - Wave attenuation — DI — Confirmatory assessment ③

Overall dissimilarity index

Numerical simulations



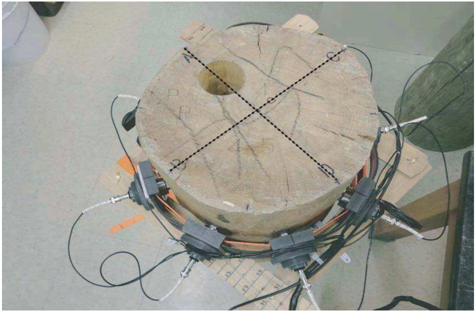
Initial results

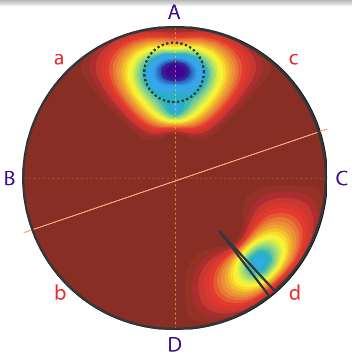
- New red pine with an eccentric hole

✓ $\phi_{pole} = 32$ cm

✓ $\phi_{hole} = 6$ cm

✓ $\frac{S_0}{S_1} = 0.94$





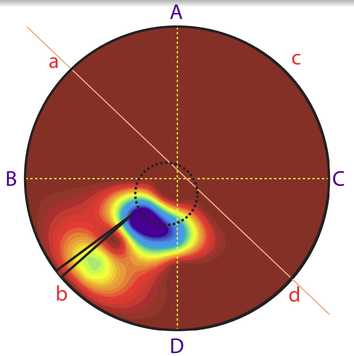
- Non-destructive evaluation

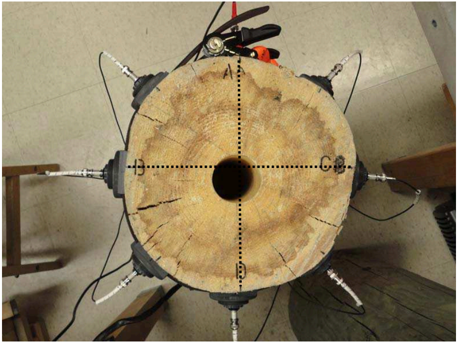
✓ $E[CR] = 0.92$

✓ $E[E_l] = 12.9$ GPa, $COV = 0.13$

Initial results

- New red pine with a centric hole
  - ✓ $\phi_{pole} = 30$ cm
  - ✓ $\phi_{hole} = 6$ cm
  - ✓ $\frac{S_0}{S_1} = 0.98$

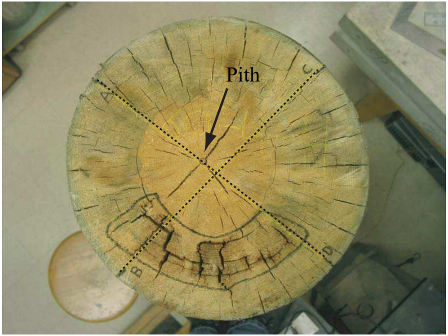


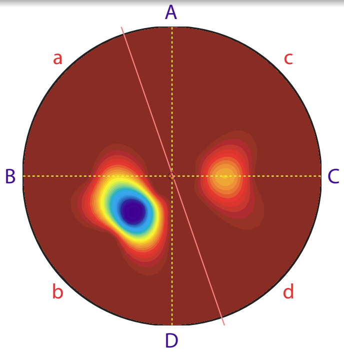


- Non-destructive evaluation
  - ✓ $E[CR] = 0.90$
  - ✓ $E[E_l] = 9.6$ GPa, $COV = 0.17$

Initial results

- Destructive evaluation
- ✓ New red pine pole
- ✓ $\phi_{pole} = 33$ cm
- ✓ $MOR = 31.7$ MPa
- ✓ $I_r = \frac{MOR}{45.5} = 0.70$

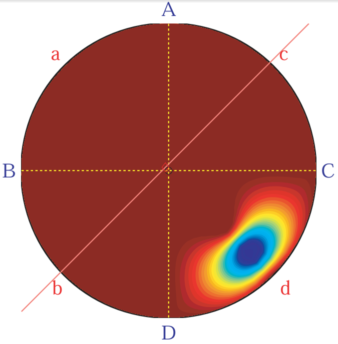




- Non-destructive evaluation
- ✓ $E[CR] = 0.69$
- ✓ $E[E_l] = 6.8$ GPa, $COV = 0.24$

Initial results

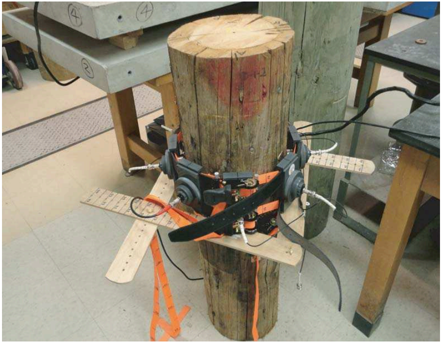
- Destructive evaluation
- ✓ New red pine pole
- ✓ $\phi_{pole} = 33$ cm
- ✓ $MOR = 35.02$ MPa
- ✓ $I_r = \frac{MOR}{45.5} = 0.77$

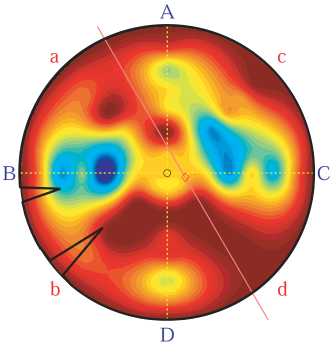


- Non-destructive evaluation
- ✓ $E[CR] = 0.92$
- ✓ $E[E_l] = 10.5$ GPa, $COV = 0.12$

Initial results

- Destructive evaluation
  - ✓ 32 years in-service, $\phi_{pole} = 27$ cm
  - ✓ Internal decay level = 3
  - ✓ $MOR = 7.53$ MPa
  - ✓ $MOE = 5$ GPa
  - ✓ $I_r = \frac{MOR}{45.5} = 0.2$





- Non-destructive evaluation
  - ✓ $E[CR] = 0.22$
  - ✓ $E[E_l] = 5.8$ GPa, $COV = 0.28$

Initial results

- Destructive evaluation

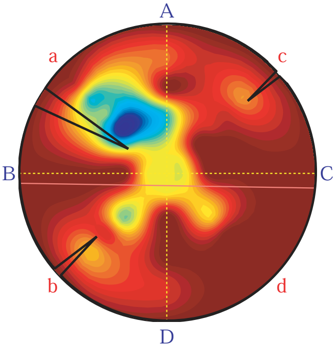
✓ 26 years in-service, $\phi_{pole} = 26$ cm

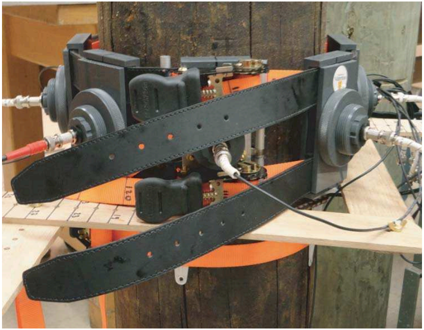
✓ Internal decay level = 2

✓ $MOR = 26.89$ MPa

✓ $MOE = 9$ GPa

✓ $I_r = \frac{MOR}{45.5} = 0.59$





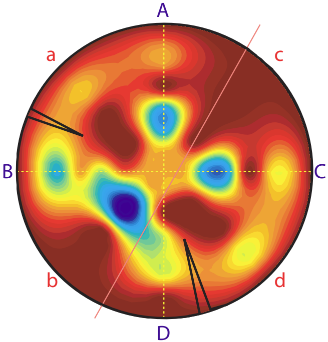
- Non-destructive evaluation

✓ $E[CR] = 0.63$

✓ $E[E_l] = 7.8$ GPa, $COV = 0.37$

Initial results

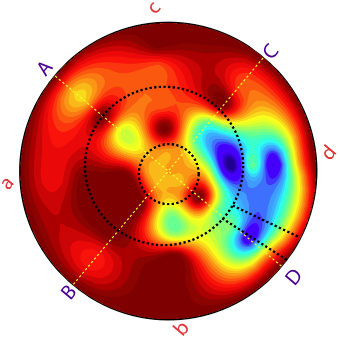
- Destructive evaluation
  - ✓ 22 years in-service
  - ✓ $\phi_{pole} = 30$ cm
  - ✓ Internal decay level = 2
  - ✓ $MOR = 30.10$ MPa
  - ✓ $I_r = \frac{MOR}{45.5} = 0.66$

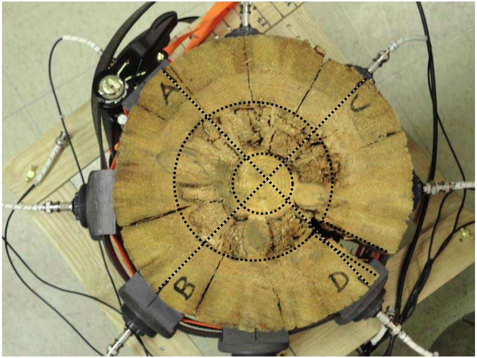


- Non-destructive evaluation
  - ✓ $E[CR] = 0.72$
  - ✓ $E[E_l] = 8.4$ GPa, $COV = 0.14$

Initial results

- In-service pole
- ✓ $\phi_{pole} = 25$ cm





- Non-destructive evaluation
- ✓ $E[CR] = 0.40$
- ✓ $E[E_l] = 6.6$ GPa, $COV = 0.46$

Next steps

- Complete the calibration of the system with 80 wood pole specimens available in the NDT Lab.
- Test the system on a sample of 30 poles or more at the Kleinburg Training Facility from Hydro-One.
- Evaluate a sample of 100 poles in the f eld, selected by Hydro-One.
- Perform a risk-based asset management of the wood pole network based on NDT measurements

Acknowledgements

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