I-35W Mississippi River Bridge in Minnesota

NDT on Bridges

MSE 533

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Civil Engineering

- Schmidt Rebound Hammer Test
- Case Study Using Ultrasonic Pulse Velocity Tomography and Impact-Echo Testing
- Case Study on Acoustic Emission
- Bridge Rating with Weigh-In-Motion System

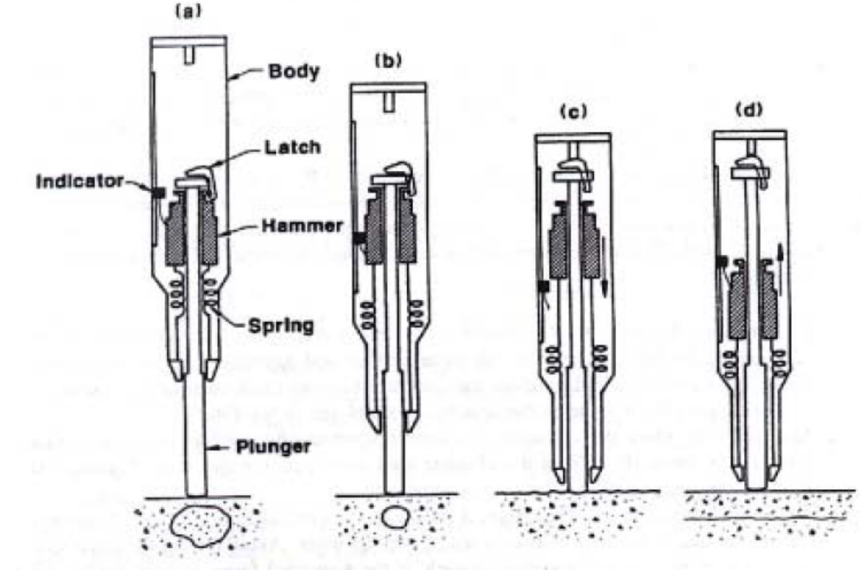
Concrete NDE Technique	State DOT	County DOT	Contractors
Visual Inspection	38	46	6
Mechanical Sounding	32	31	4
Cover Meter	21	0	2
Rebound Hammer	19	9	2
Electrical Potential Measurements	11	0	2
Radar	9	0	1
Ultrasonic (impact-echo)	8	0	1
Thermal Infrared	5	1	1
Acoustic Emission	1	1	0
Vibration Analysis	0	1	0
Radiography	0	0	0
Ultrasonics (pulse velocity)	0	0	0

NDT usage on concrete structures [Rolander, et al, 2001]

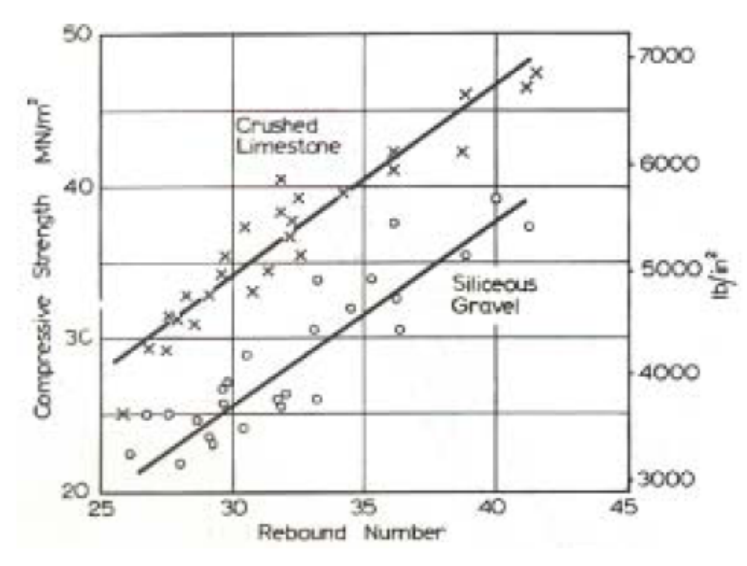
NDE Technique	NDEVC 998	Caltrans 1994	Rens, et al. 1993
Ultrasonic Testing	81%	70%	69%
Liquid Penetrant Testing	81%	68%	25%
Magnetic Particle Testing	64%	46%	40%
Radiographic Testing	17%	14%	12%
Eddy Current Testing	13%	3%	12%

Schmidt Rebound Hammer Test

- Concrete surface hardness
- Empirical correlations have been established between strength properties and the rebound number.



Comparison between correlation curves for crushed limestone and siliceous

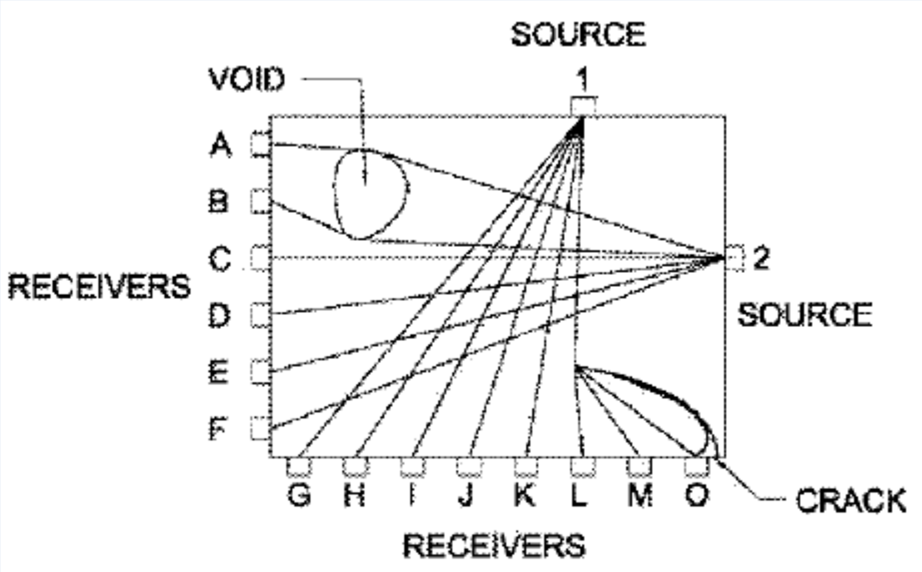


The results are affected by:

1. Smoothness of the test surface
2. Size, shape and rigidity of the specimen
3. Age of the specimen
4. Surface and internal moisture conditions of concrete
5. Type of coarse aggregate
6. Type of cement
7. Carbonation of the concrete surface

Case Study Using Ultrasonic Pulse Velocity Tomography and Impact-Echo Testing

Strengthened with a beam between two columns

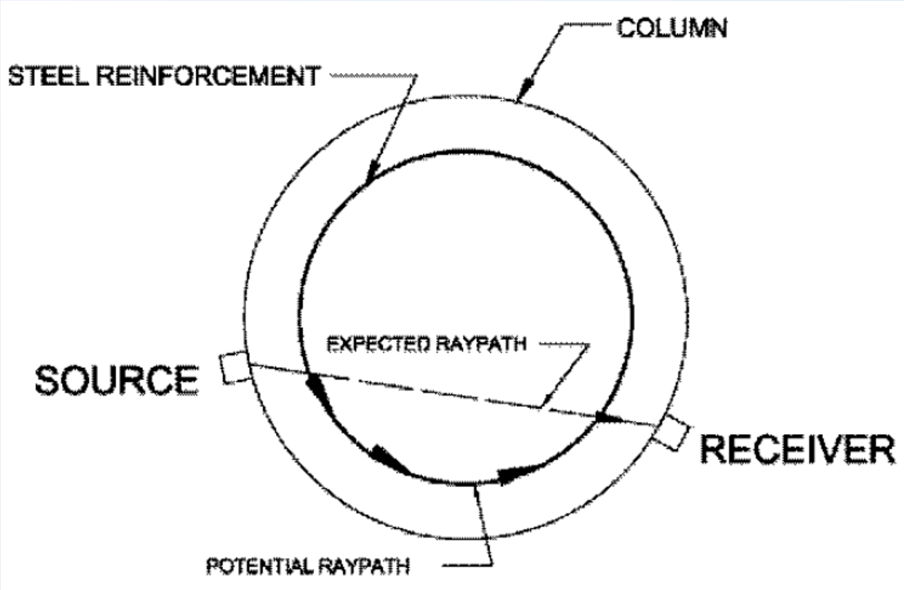


Ray paths and the effects of internal defects in a solid specimen [C. C. Ferraro, et al, 2007]

Ultrasonic Pulse Velocity Tomography

- The tomography theory is applied to concrete specimens by collecting a series of straight-line UPV measurements along a series of ray paths for a given specimen.

Potential ray-path discrepancies in reinforced concrete structures [C. C. Ferraro, et al, 2007]

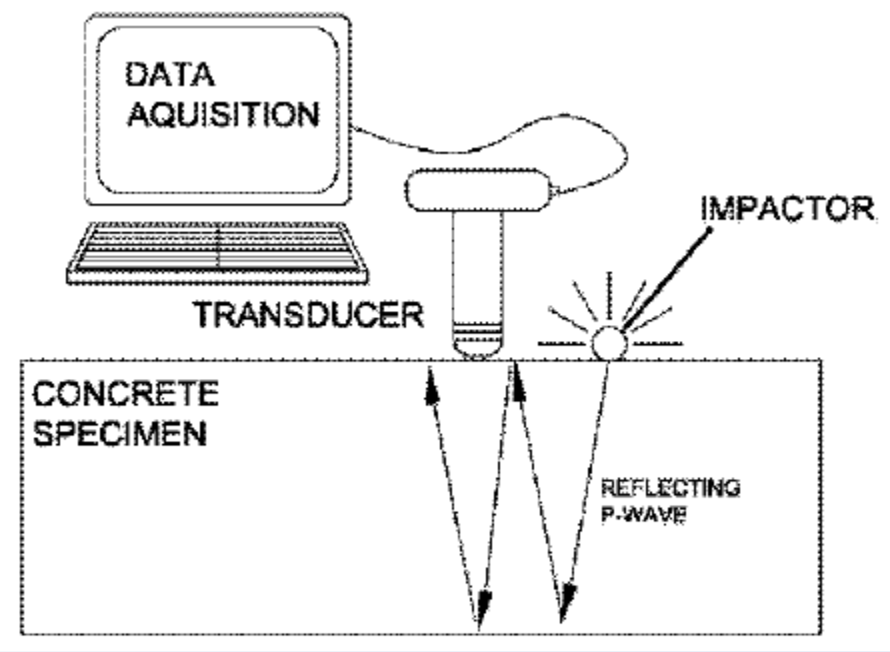


- Stress wave velocity for sound concrete is 3500-4500 m/s, whereas for steel is 5900 m/s.

- Higher wave velocity of steel results in a decrease in travel time for reinforced concrete.

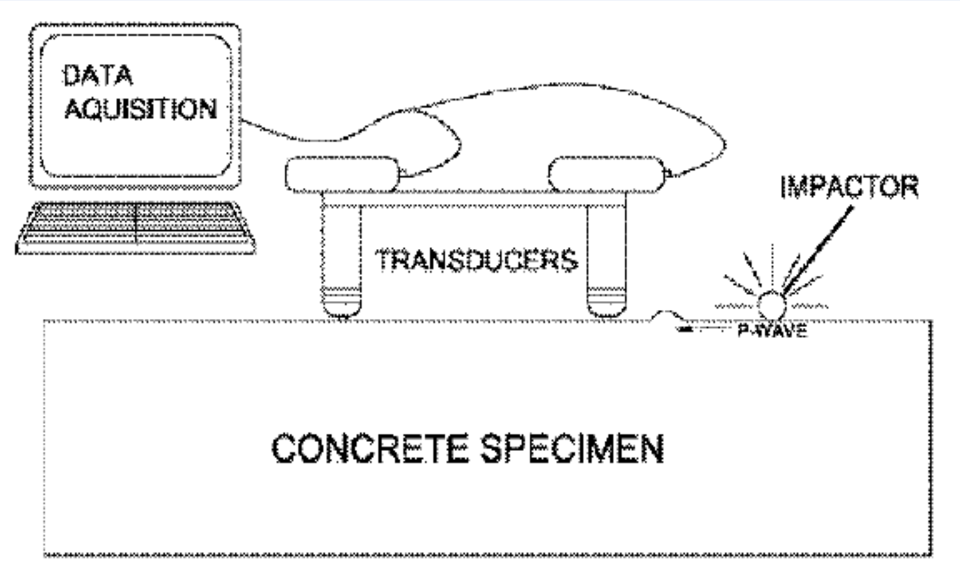
Impact-Echo Testing

- The impact-echo method measures the wave velocity parallel to the surface of a concrete structure and thus the travel path of the stress wave or surface wave is visible.

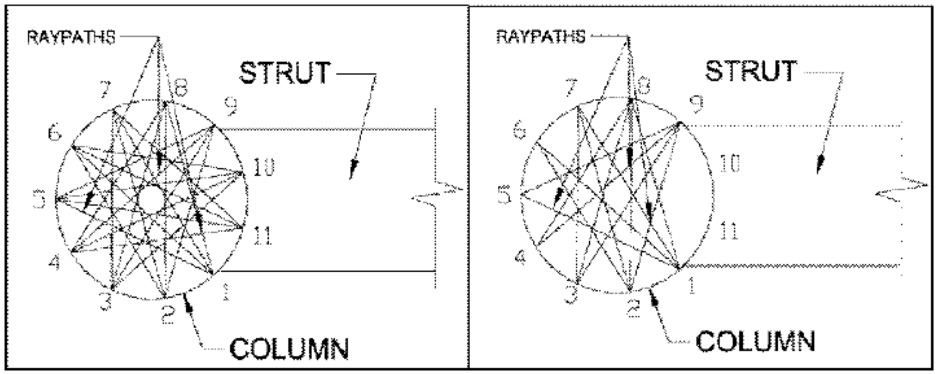


Thickness measurement using impact-echo technique. [C. C. Ferraro, et al, 2007]

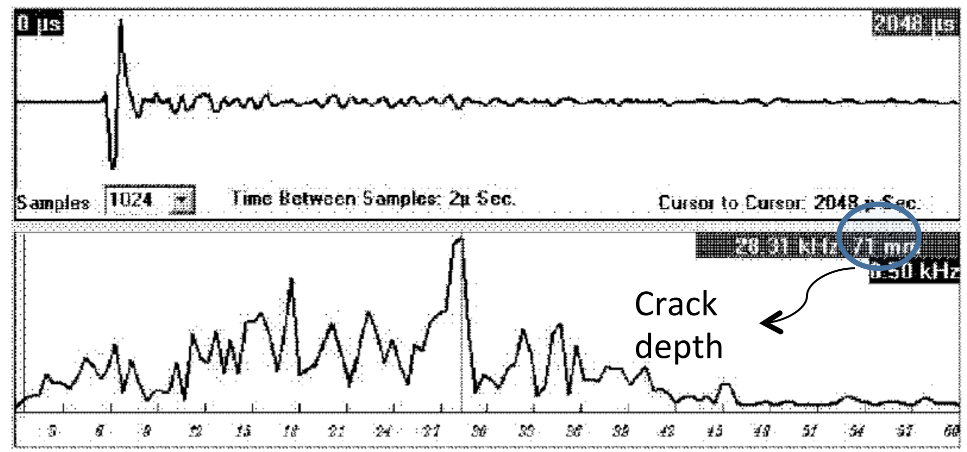
Surface wave velocity measurement using impact-echo technique. [C. C. Ferraro, et al, 2007]

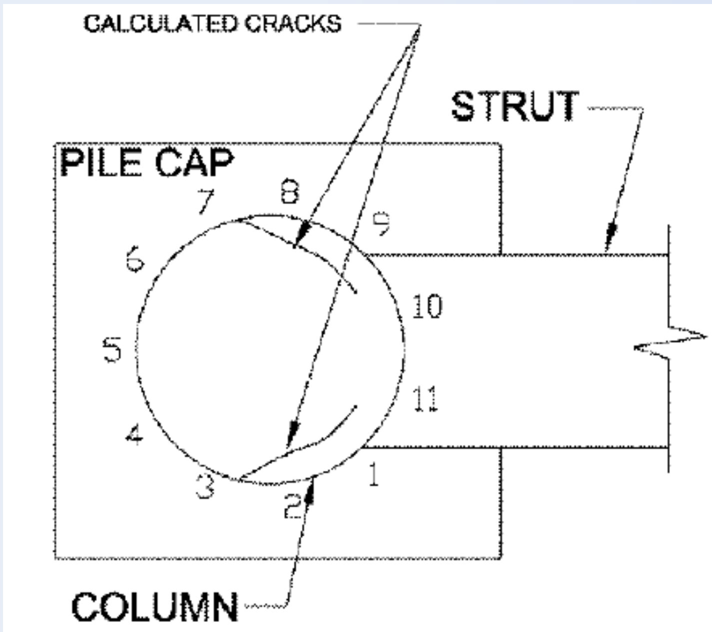


Plan view of full (left) and partial (right) 2D tomography grids.



Impact-echo waveform and resulting frequency spectrum.





Discussion

Column number	Max. impact-echo (m/s)	Max. UPV (m/s)
1	3853	4448
2	4000	4560
3	3789	4481
4	3828	4476
5	4261	4708
6	4001	4604
7	3999	4508
8	3788	4388

- The UPV ray paths were all through-column, the effect of the reinforcing steel resulted in wave velocities approximately 1.15 times larger than those obtained with the impact-echo method.

- This result is to be expected because the wave velocity of steel is 1.4-1.7 times that of plain concrete.

- The UPV method was used to provide researchers with defect location on a global scale, following which the impact echo was employed to verify defect location and size with more precision and accuracy.

- However, these systems require a HIGH DEGREE of EXPERIENCE and specialization and EXPENSIVE equipment.

Case Study on Acoustic Emission

Varina-Enon Bridge on I-295 near Richmond, VA (Courtesy VDOT/VTRC)

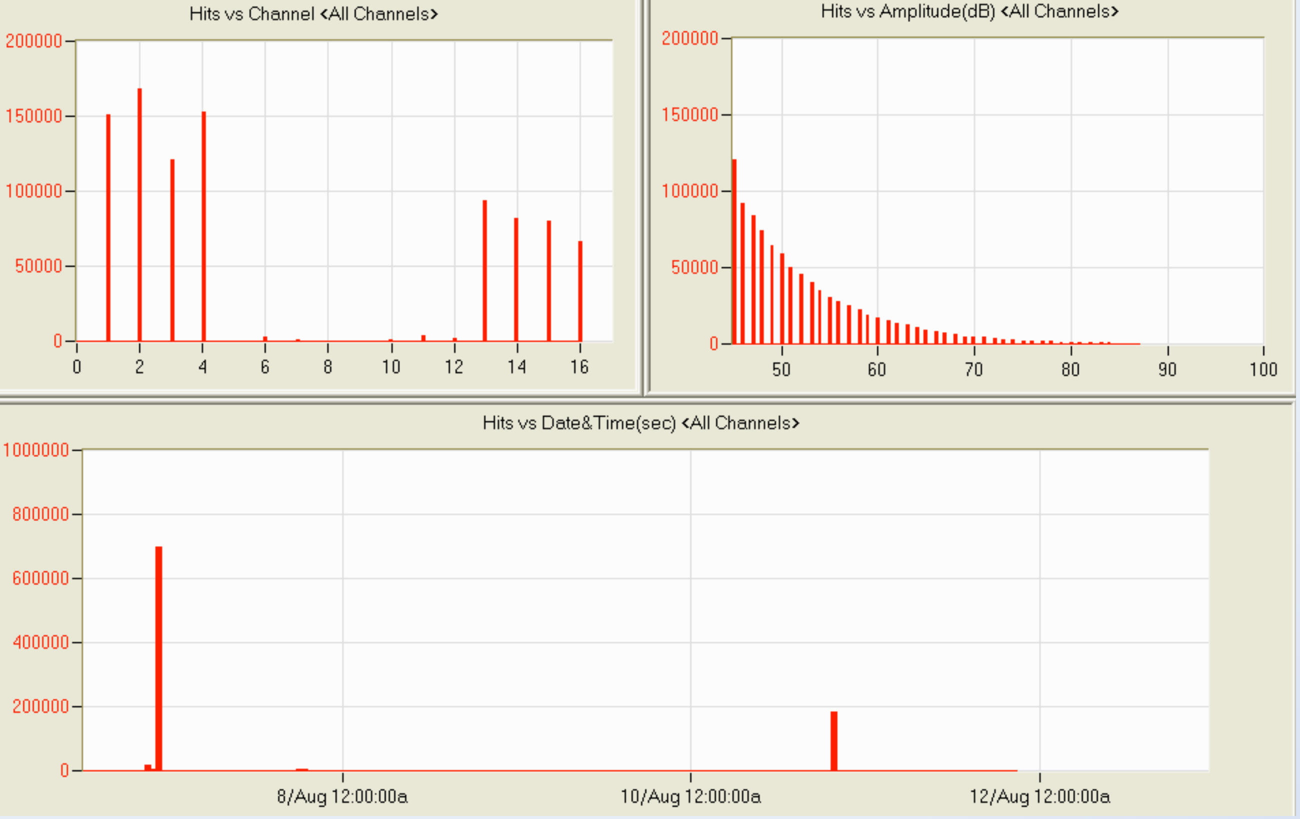
This study is on the short-term evaluation of VDOT owned Varina-Enon bridge cables using AE sensors to determine:

-if a bridge cable wire broke, (friction) will cause AE to be generated when broke.
-if corrosion is taking place in the area close to sensor, AE sensors will hear it.
-if micro cracking is taking place in the test element, AE will sense it.
-if the AE could be used as inspection tool for VDOT

Sensor installation

Acoustic emission sensors have been strategically affixed to a single cable and monitored for two and a half months each during the winter and the summer months of 2008 and 2009.

Sensor highway II DAQ system installed near the north pylon.



Plot of the acquired data during August 6 – 12, 2008.

- It is remarkable to note absence of any AE activity between the two rainy days of August 6 and August 11, the rain fall being higher on August 6-7 than on August 11-12.

- The directional effects of rain fall on the cable, being more intense from south are also clear.

- Absence of AE activity during these two events is an indication of sound health of the test cable.

- The plot of the data recorded between August 6 -12, 2008, indicates the bridge being hit by heavy rain and perhaps also a storm on August 7 – 9, 2008.

Conclusion

1. AE technique is capable of hearing even feeble sounds originating from impacts on the bridge cable.

2. The preliminary AE recordings thus far indicate that the cable #10 under investigation is in sound health.

3. The AE data can be monitored, recorded and analyzed on a real time basis from a remote location such as from the office of the bridge engineer/inspector.

4. AE is capable of identifying factors related to the health of the bridge cable and factors such as weather unrelated to the health of the bridge cable.

Bridge Rating with Weigh-In-Motion System

Rating Factor

$$\Phi R_n > \gamma_D D + \gamma_L L(RF)(1+I)$$

$$RF = \frac{\Phi R_n - \gamma_D D}{\gamma_L L(1+I)}$$

R_n = the bearing capacity of cross section;

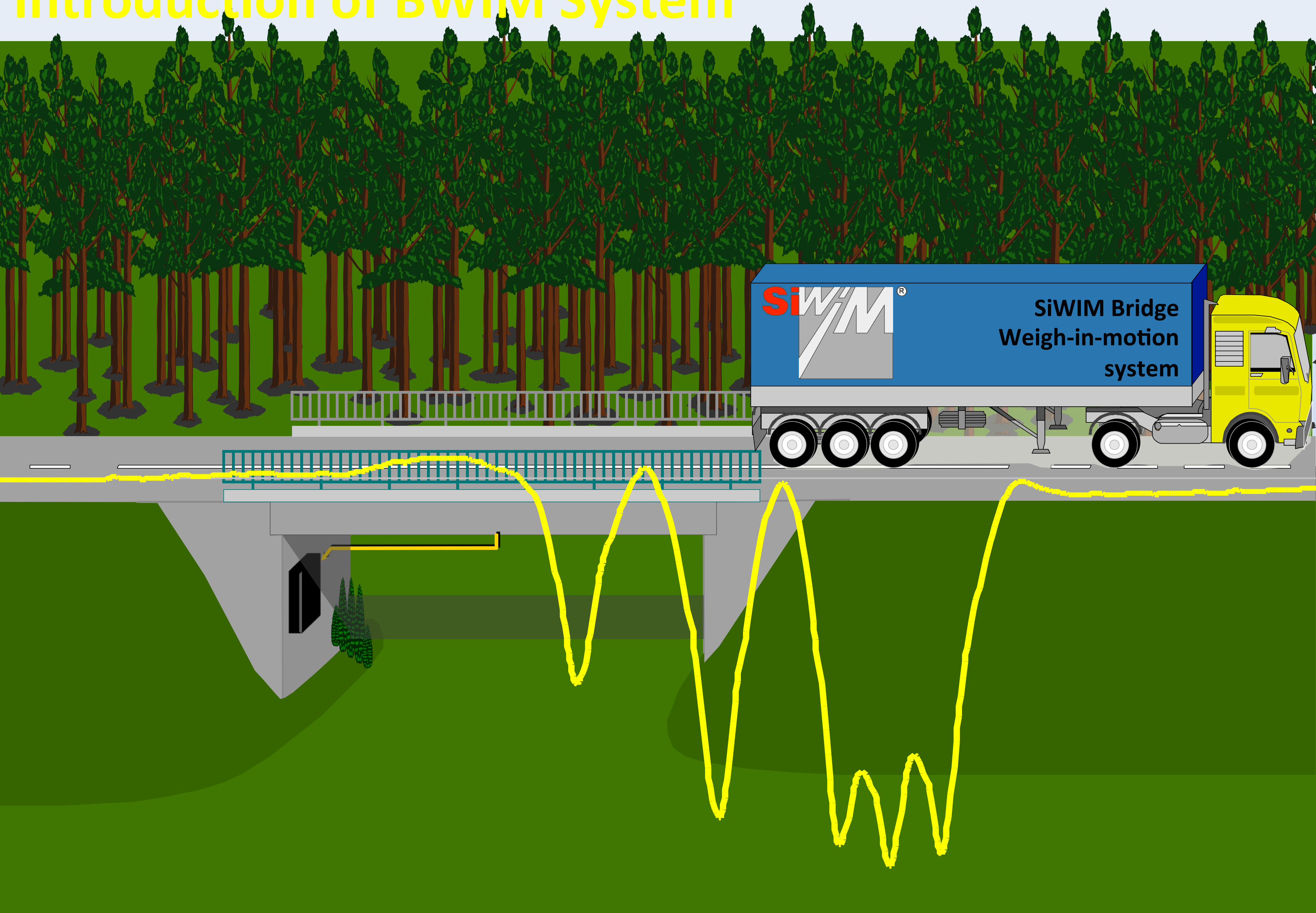
Φ = the capacity reduction factor or resistance factor;

$D \quad L$ = the dead load effects

$\gamma_D \quad \gamma_L$ = partial safety factors of dead and traffic load effects.

(Only R_n and γ_L will change)

Introduction of BWIM System



Introduction of BWIM System (cont.)

Advantage of BWIM system

- Portability
- Invisibility
- Reusability
- Cost effective
- No damage to pavement
- Providing pictures to enforcement crews
- Without interrupting traffic during installation and test
- Providing structural parameters for bridge safety assessment

Field test of bridge on I-78

Overview of bridge

Overview of bridge

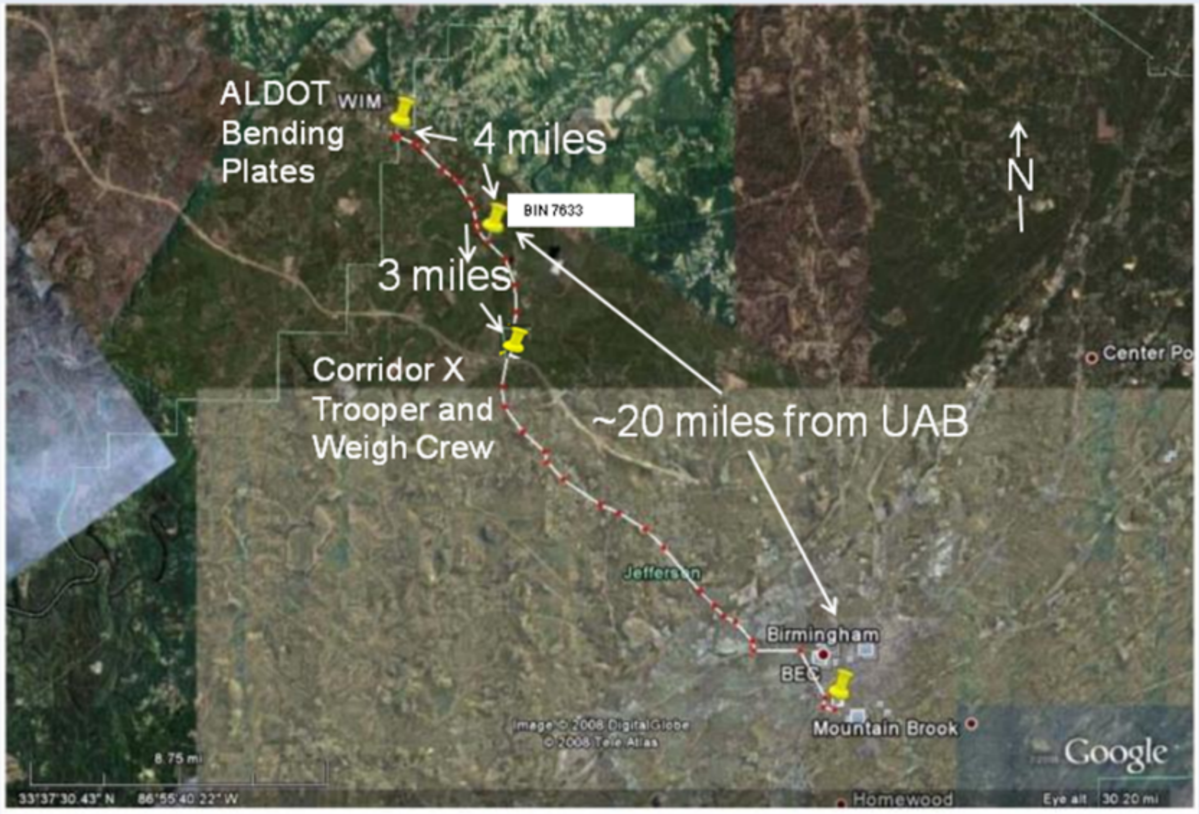
Calibration vehicles

System cabinet

Sensors

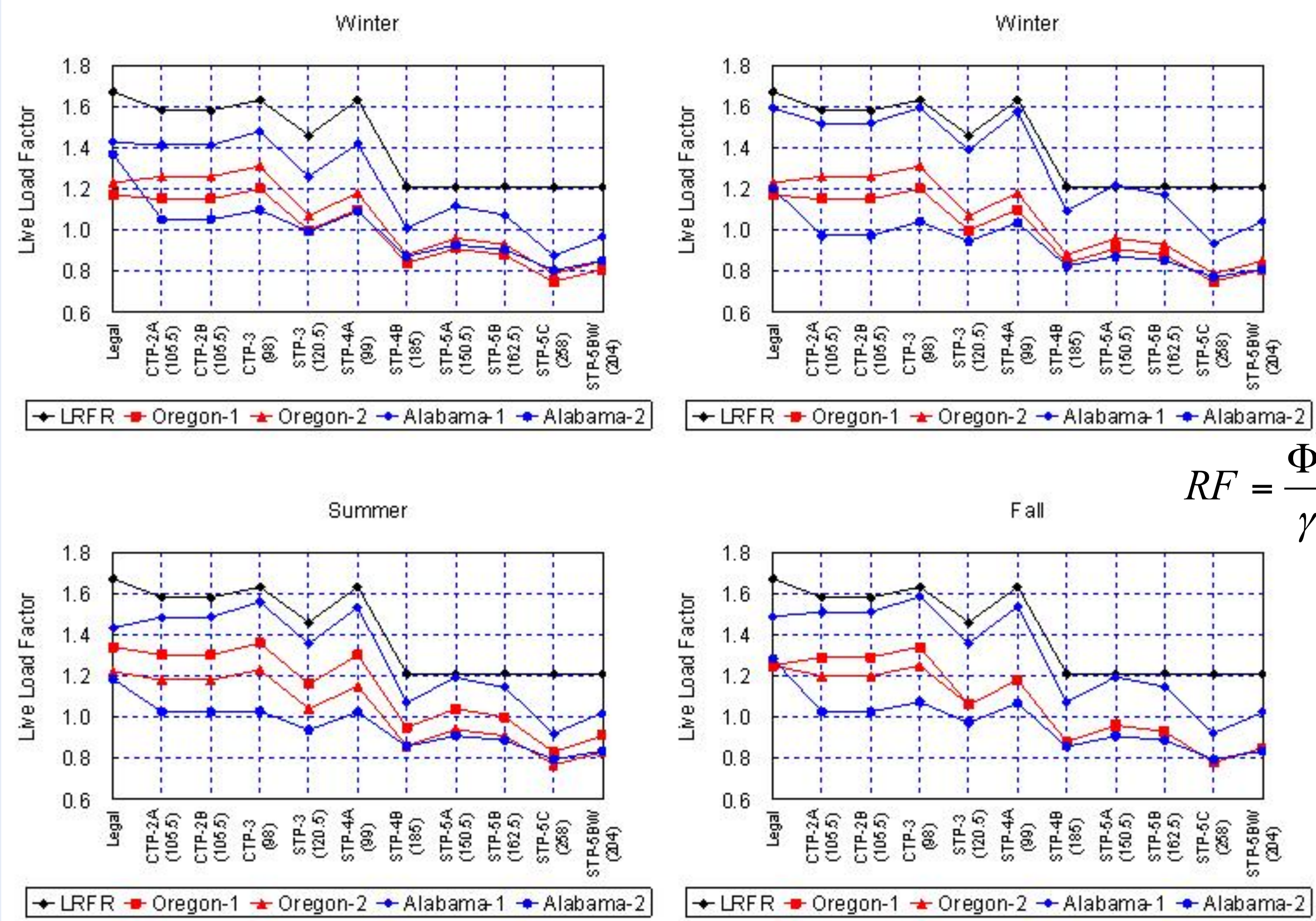
Sensor installation

WIM on Road



Bending Plate WIM (BP-WIM) system is 4 miles to the west of the bridge

Results



$$RF = \frac{\Phi R_n - \gamma_D D}{\gamma_L L(1+I)}$$

- The Alabama 1 curve, which is based on the ODOT classification and data from WIM sites in Alabama
- The Alabama 2 curve, which is based on the ALDOT classification and data from WIM sites in Alabama, ranks the lowest in most figures
- Oregon 1 and Oregon 2 curves are obtained from the two WIM sites OR58 and I-84 respectively.

Questions?