TRUSS ITN

Reducing Uncertainty in Structural Safety

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TRUSS
Training in Reducing Uncertainty in Structural Safety

Bridge Condition Evaluation using LDVs Installed on a Vehicle

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GREENWOOD ENGINEERING

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Measuring Strategies: Visual Inspection

- Frequently used in bridges
- Worker dependence

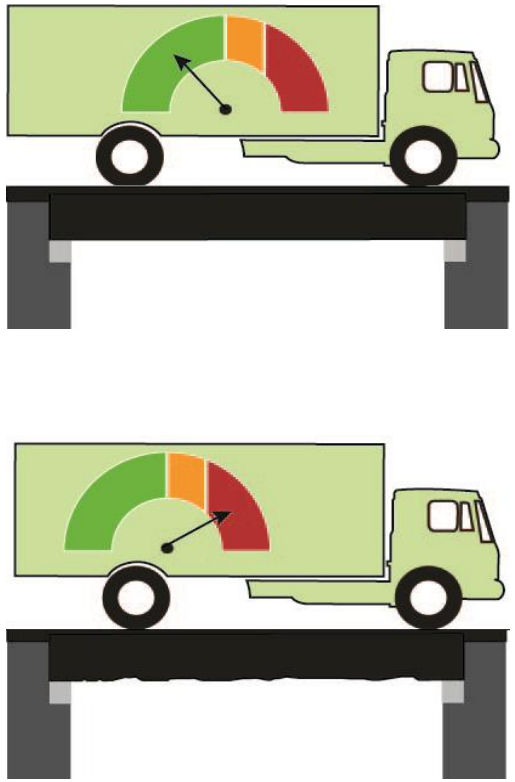
Direct Monitoring

- Sensors installed on the bridge
- Electricity supply needed
- Great number on sensors involved, specially on bridges

Hong Kong Stonecutters bridge, 1.6 km length

Indirect Monitoring (Drive-by)

- Sensors installed in a passing vehicle
- Quick
- Cost affordable
- No risk

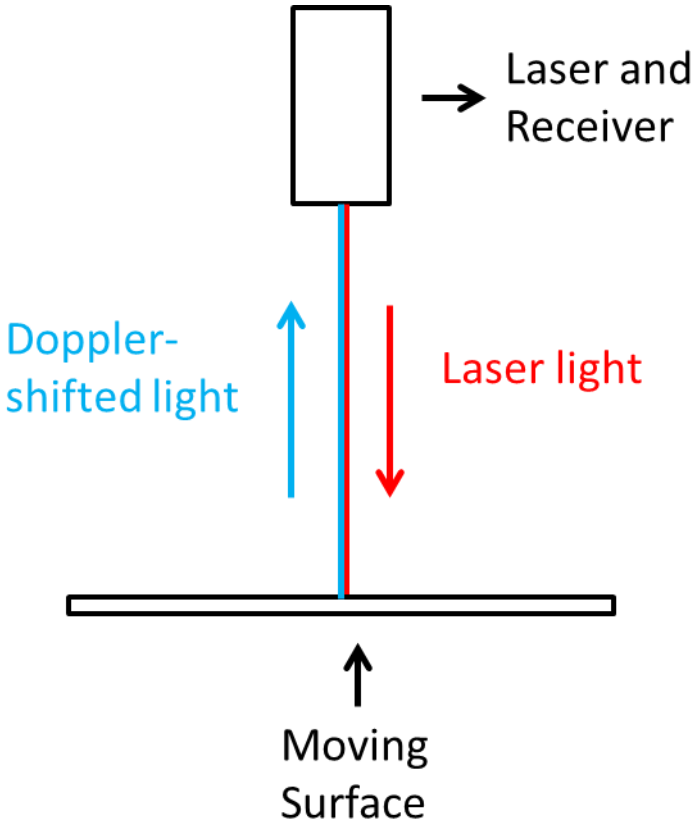


What a TSD is?

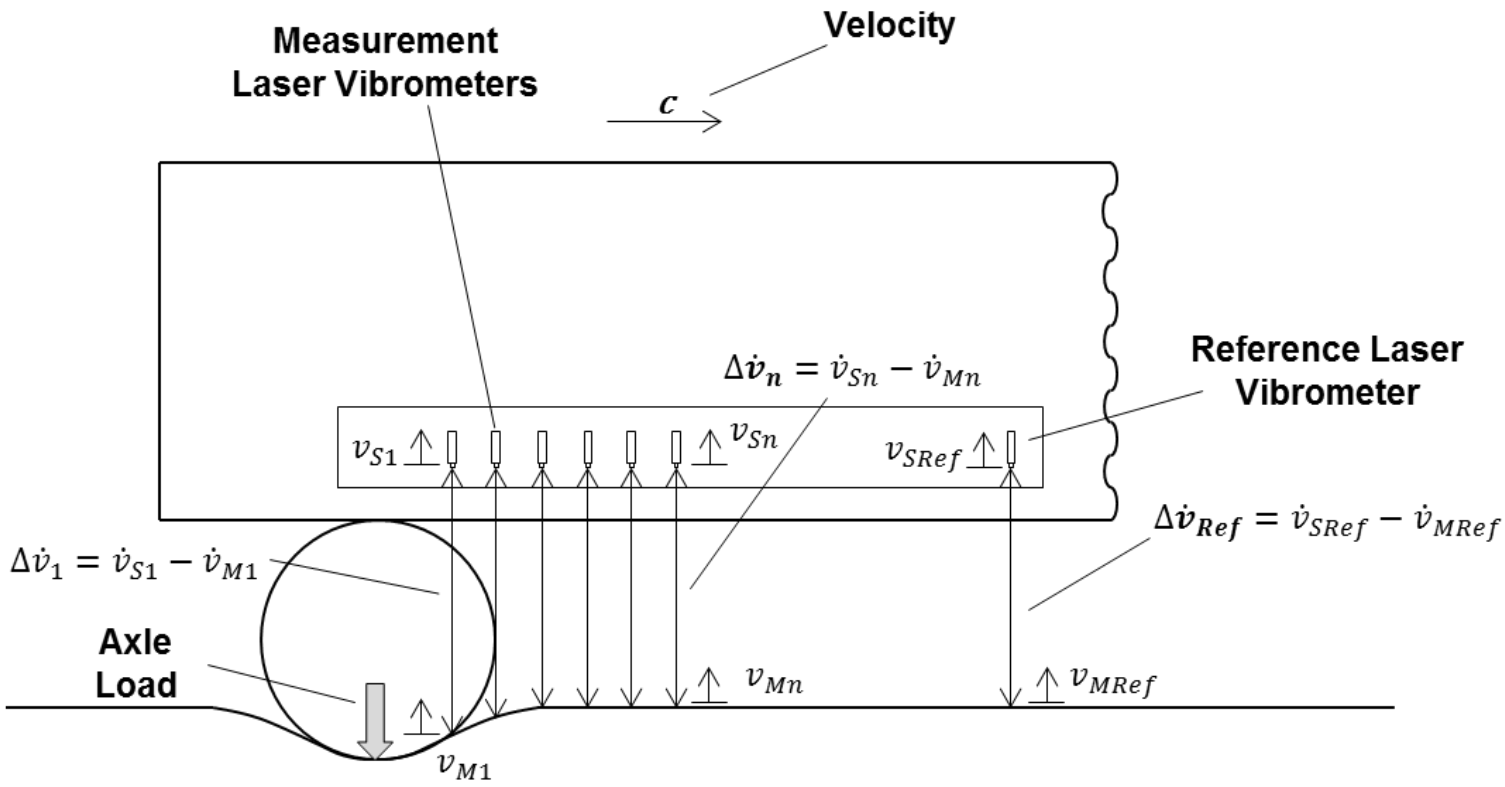
- A Traffic Speed Deflectometer (TSD) is an equipped vehicle that allows us to know the road profile parameters.
- Its characteristics make us to think about the suitability of this kind of vehicle for the bridge measurements.

Main sensors of the TSD

- Doppler Lasers (LDV)
  - Installed on a beam.
  - Reference laser between the two axles.
  - Change in frequency allows to calculate the relative velocity.

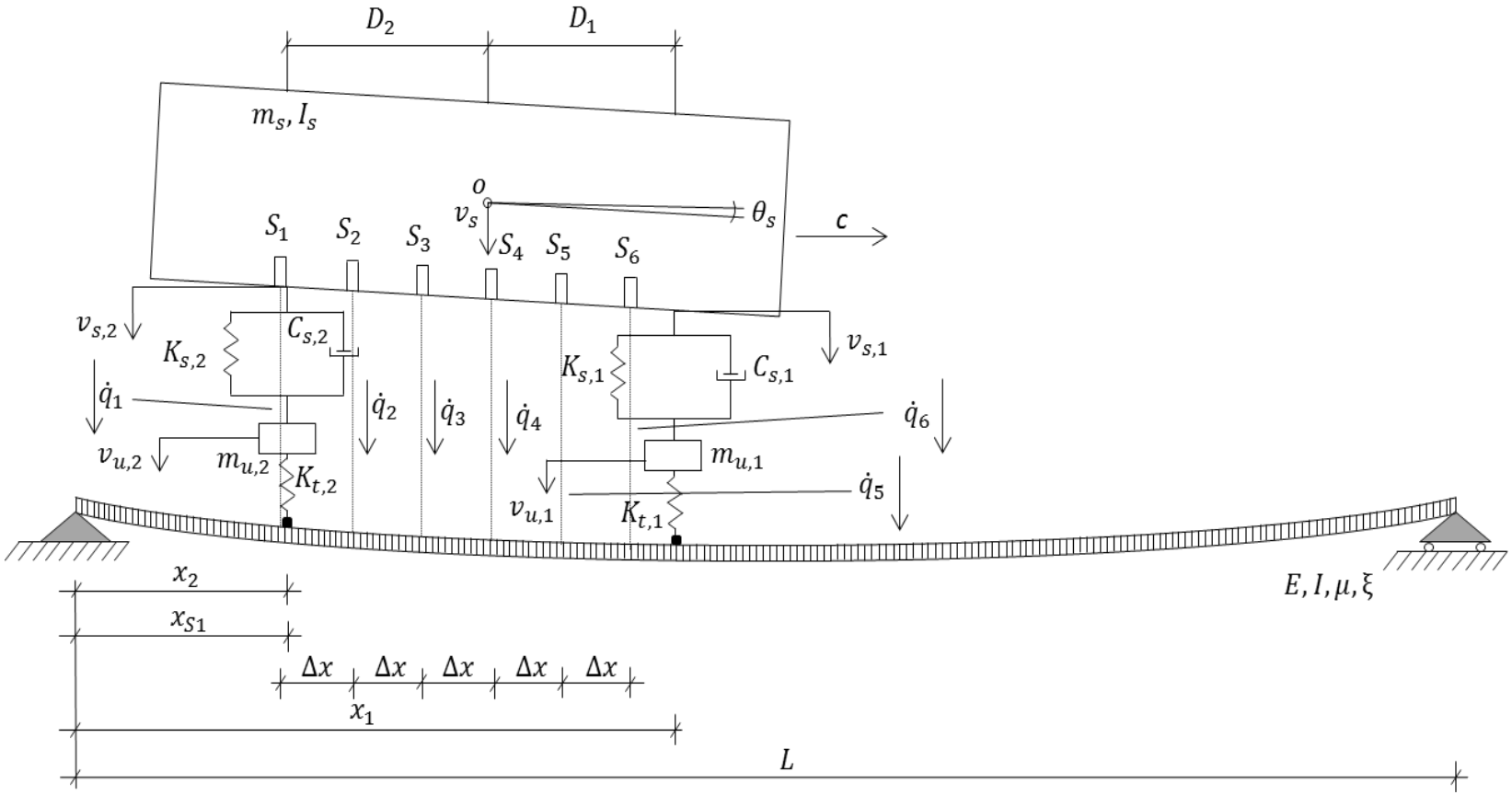


What is the TSD measuring?



What a TSD is?

TSD for Bridge Condition



RIC and MAD for Bridge Damage Location

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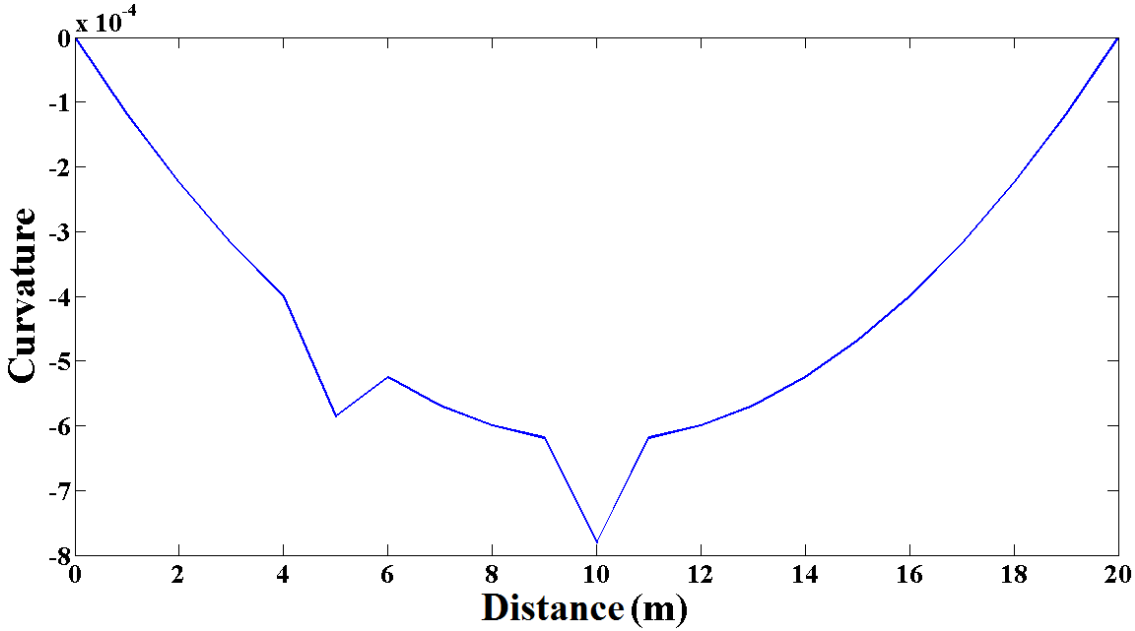
Curvature Methods

$$\kappa_{healthy}(x) = \frac{M(x)}{EI}$$

$$\kappa_{damaged}(x) = \frac{M(x)}{EI_{red}}$$



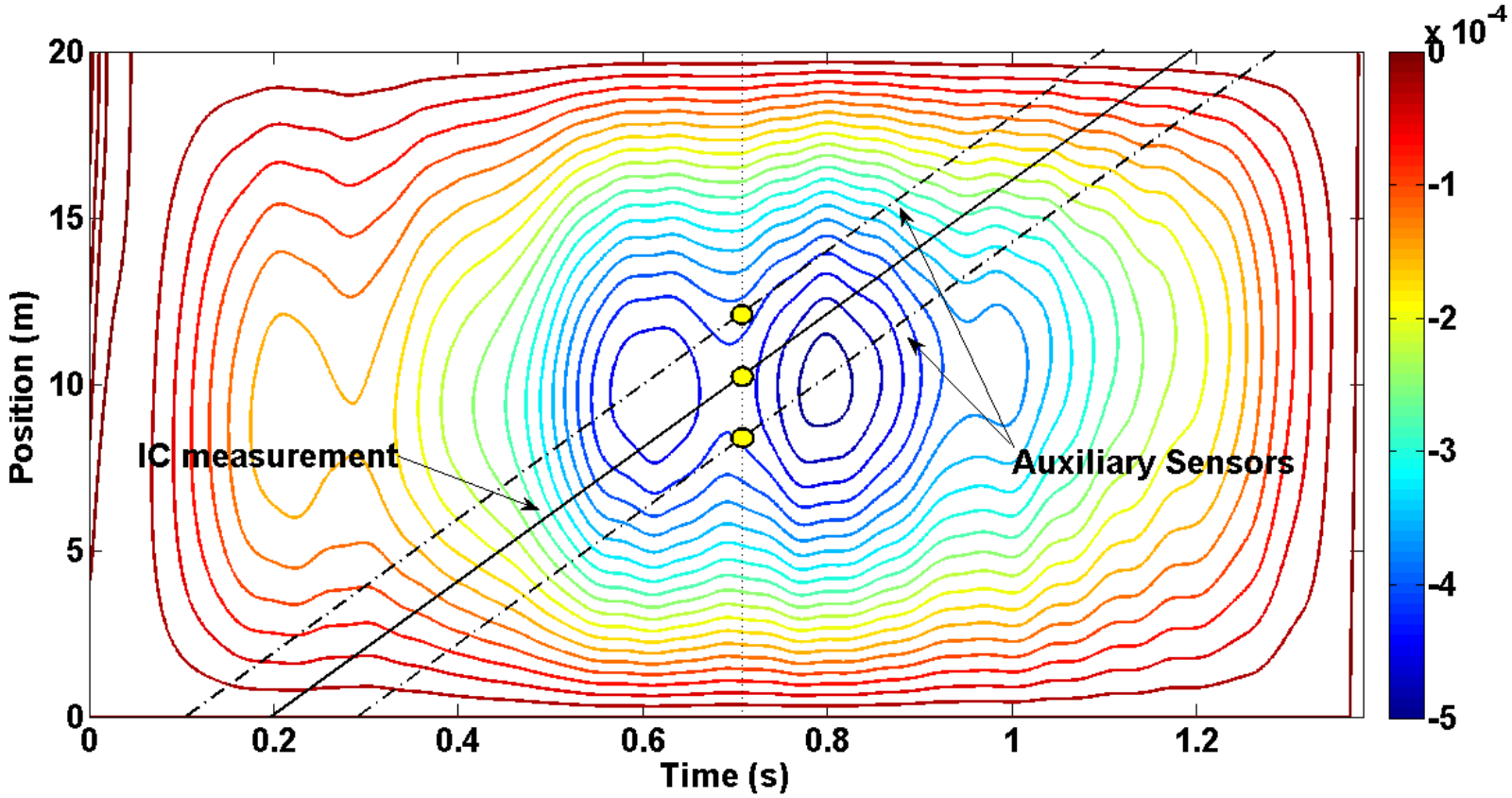
Instantaneous Curvature

- In a moving reference situation this curvature cannot be calculated using only one sensor.
- Instantaneous Curvature (IC) is calculated using three different sensors.

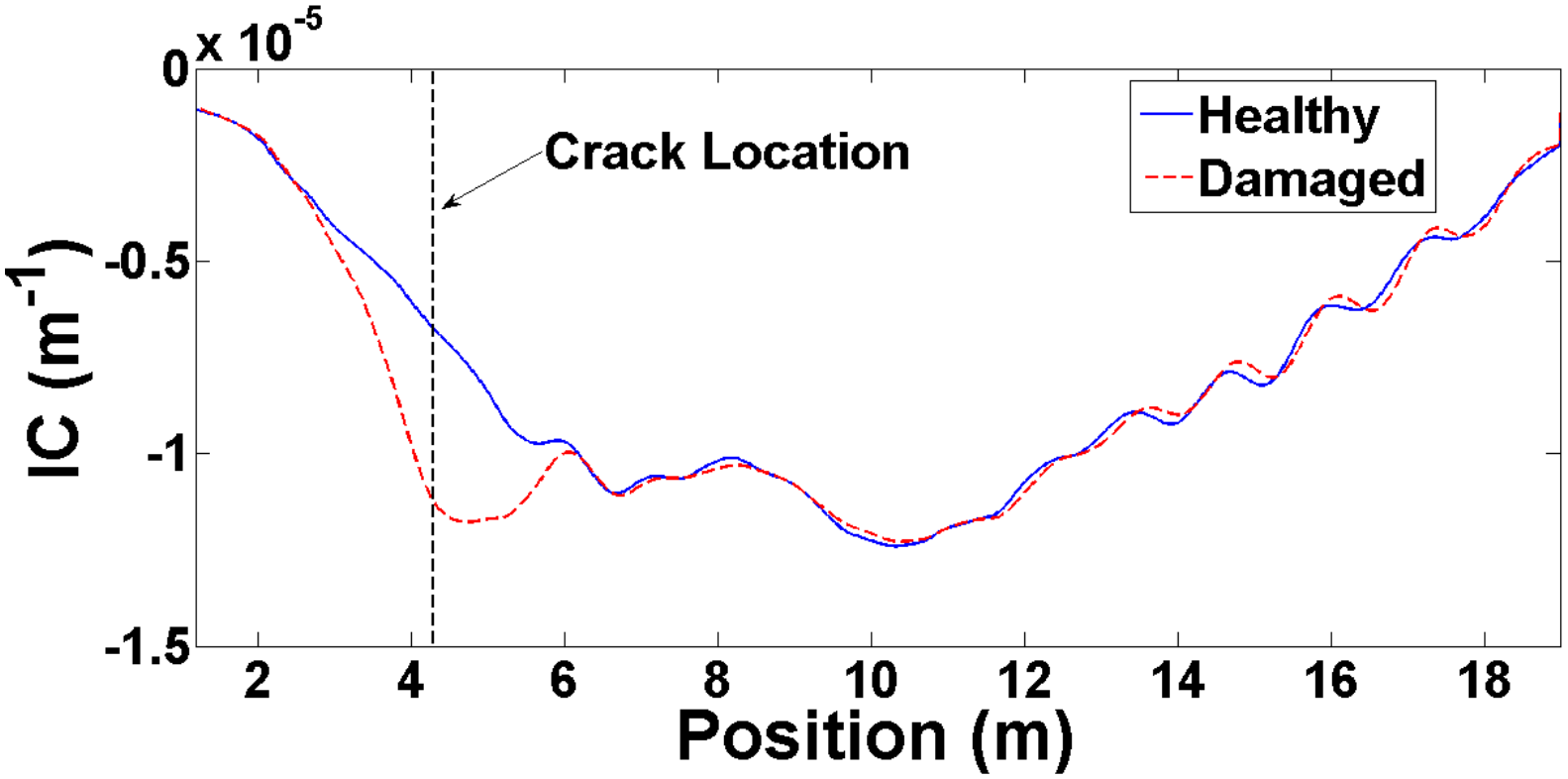
$$IC(x, \mathbf{t}) = \frac{v(x-\Delta x, \mathbf{t}) - 2v(x, \mathbf{t}) + v(x+\Delta x, \mathbf{t})}{\Delta x^2}$$

$v \longrightarrow$ Deflection

Deflection Contour Plot with IC calculation



IC calculation from Contour Plot

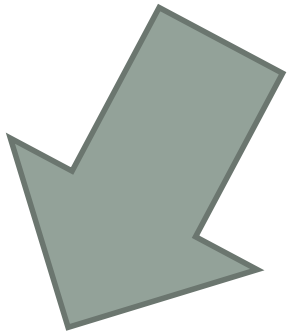


RIC and MAD for Bridge Damage Location

Rate of Instantaneous Curvature

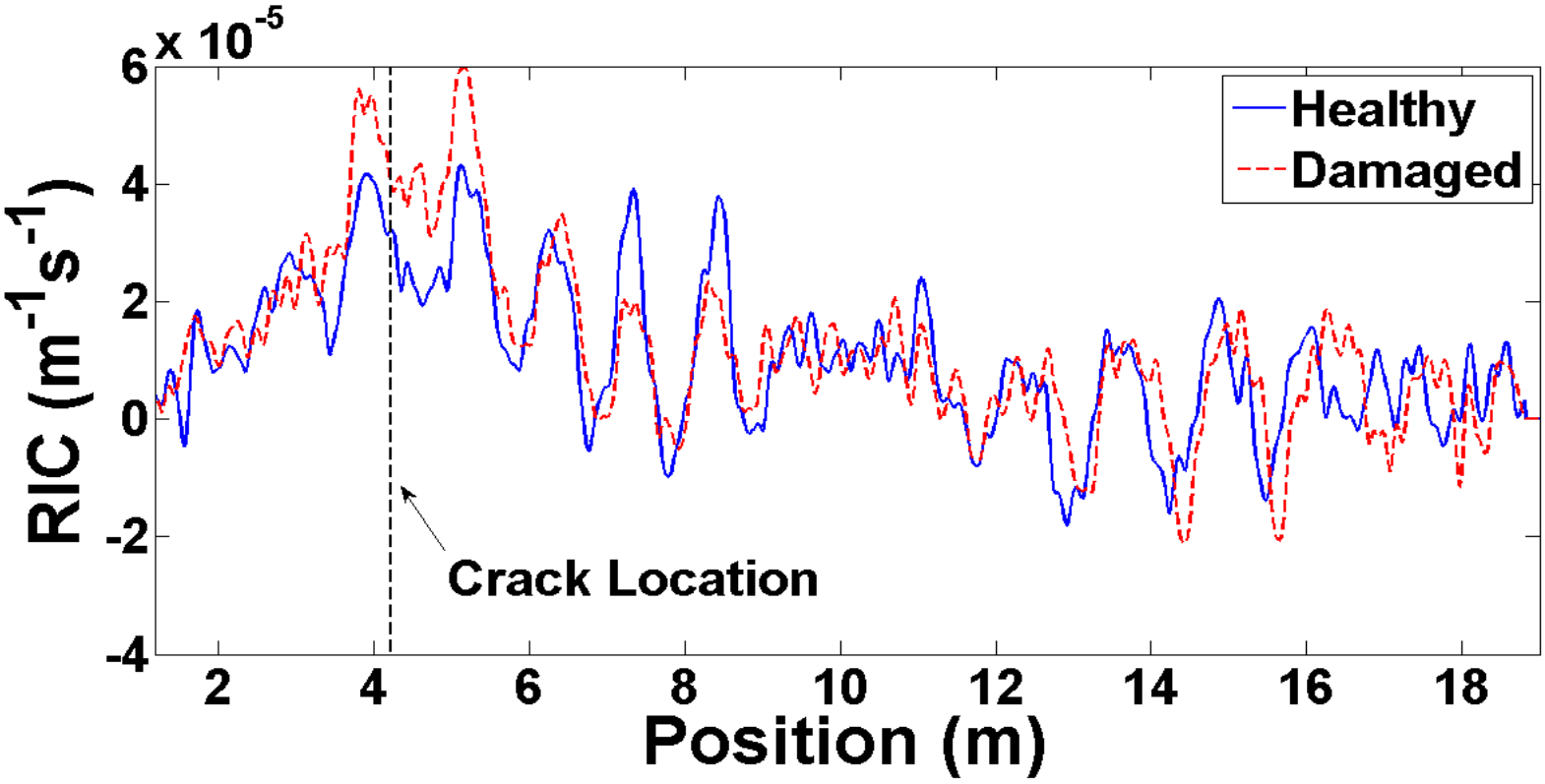
- Same idea is used for relative velocities ($\dot{q}$).
- Rate of Instantaneous Curvature (RIC) is defined similar to IC.

$$\dot{q} = \dot{v}_{bridge} - \dot{v}_{vehicle}$$



$$RIC(x, \mathbf{t}) = \frac{\dot{q}(x-\Delta x,\mathbf{t}) - 2\dot{q}(x,\mathbf{t}) + \dot{q}(x+\Delta x,\mathbf{t})}{\Delta x^2}$$

Rate of Instantaneous Curvature



RIC and MAD for Bridge Damage Location

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Damage Indicator for Bridge Condition

- Moving Average Difference (MAD):

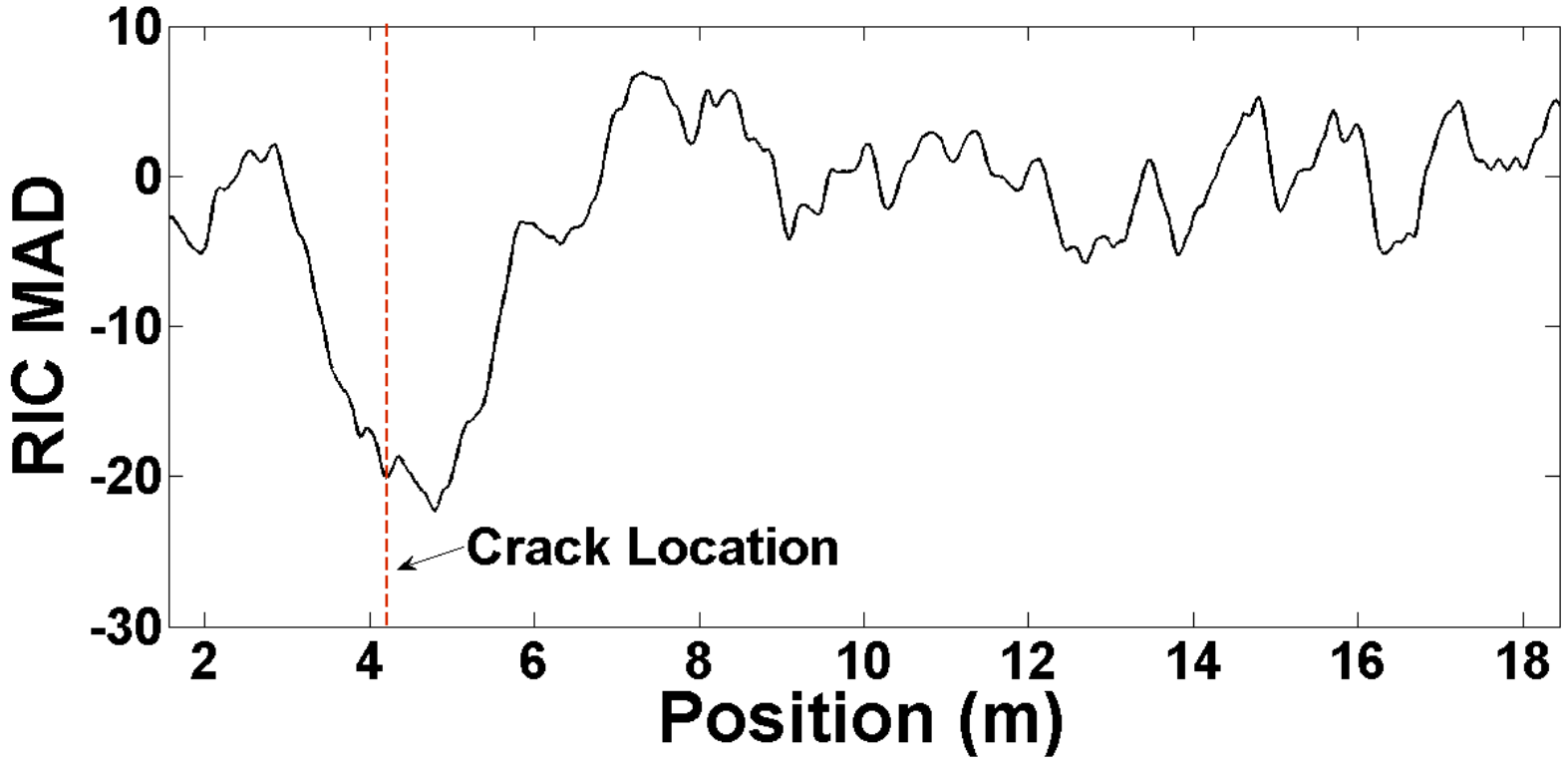
$$\mathrm{MAD}(x) = \frac{\frac{1}{Z}\sum_{n=-\frac{(Z-1)\times L}{2f}}^{\frac{(Z-1)\times L}{2f}} \mathrm{RIC}_{\mathrm{Damaged}}\,(x+n) - \frac{1}{Z}\sum_{n=-\frac{(Z-1)\times L}{2f}}^{\frac{(Z-1)\times L}{2f}} \mathrm{RIC}_{\mathrm{Healthy}}(x+n)}{\min\left(\mathrm{RIC}_{\mathrm{Healthy}}\right)} \times 100\ (\%)$$

Z is the number of points for the moving average.

f is the measuring sampling frequency of the sensors.

L is the length of the bridge.

Moving Average Difference



RIC and MAD for Bridge Damage Location

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Conclusions

- Curvature methods have great potential in drive-by monitoring.
- Relative velocities can be used in bridge damage detection.
- Moving Average Difference (MAD) has the ability of locate damage on bridges.

Thanks for your attention

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