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FIELD MONITORING OF REBAR VIBRATIONS IN CONCRETE BRIDGE DECKS UNDER TRAFFIC LOADS

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Outline

- Introduction
    - Cracking Evaluation of the Delware River Bridge
- Field Monitoring of the Hackensack River Bridge
- Signal Processing and Analysis
- Conclusions
- Future Research

Problem Statement

- Bridge deck concrete at early age may be subjected to vibrations due to adjacent lane traffic
- High rebar velocities relative to adjacent concrete can weaken rebar bond
- Direct measurement of displacements and velocities of bridge components can be difficult and impractical

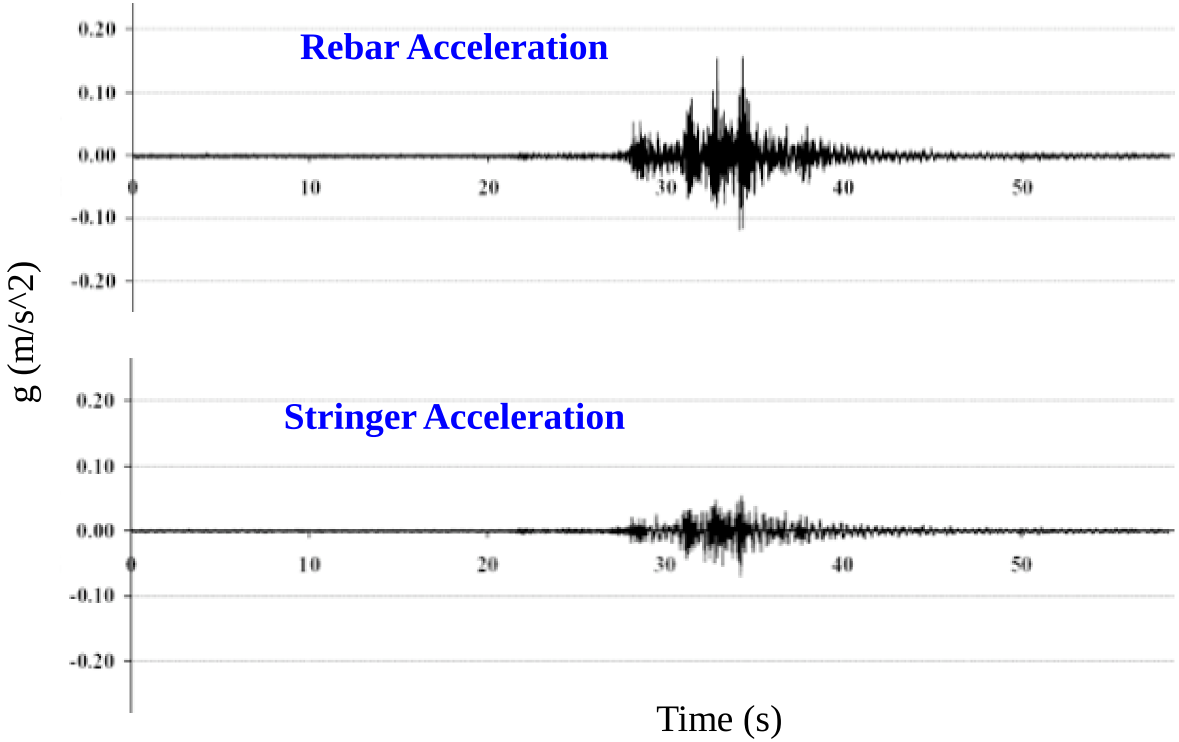
Objectives

- Obtain field measurements of accelerations, velocities and displacements of bridge components
- Estimate bridge velocities and displacements from accelerometer data
- Investigate deck rebar debonding due to adjacent traffic vibrations

Rebar Debonding on the Delaware River Turnpike Bridge (Structure No. P0.00)

- **Adjacent lane vibrations can damage paste-aggregate bond and paste-rebar bonds**
  - **Cracks circumnavigate aggregate when the binding paste is still weak (early age)**
  - **Coring samples showed smooth rebar imprints with shallow rib depth, signifying poor epoxy-coated rebar bond**

Rebar Debonding on the Delaware River Turnpike Bridge (Structure No. P0.00)



- **Results showed that the rebar vibration relative to the deck was significant, prompting additional investigation on other bridges**

Summary of Field Testing Program: Hackensack River Bridge

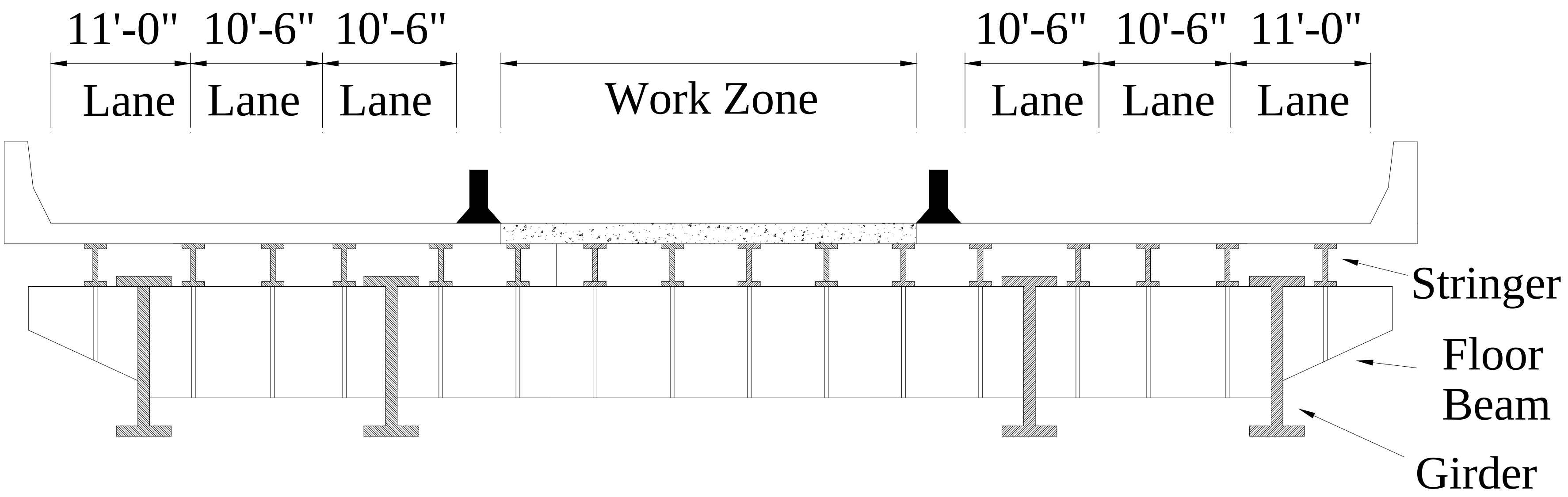
- Directly measure girder accelerations, velocities, displacements, and strains

- Monitor bridge dynamic response during the deck pour at 5 different phases:

  1. At 50% tiedown of rebar intersections
  2. At 100% tiedown of rebar intersections
  3. During concrete placement on span
  4. During the first 4 hours of concrete age
  5. At 3 days concrete age

Bridge Details and Instrumentation

- Stringer and floor beam systems in the approach span
- Center portion of the roadway was poured for two simple spans



Bridge cross section

Testing Equipment

Structural Testing System (STS) by Bridge Diagnostics, Inc. (BDI)

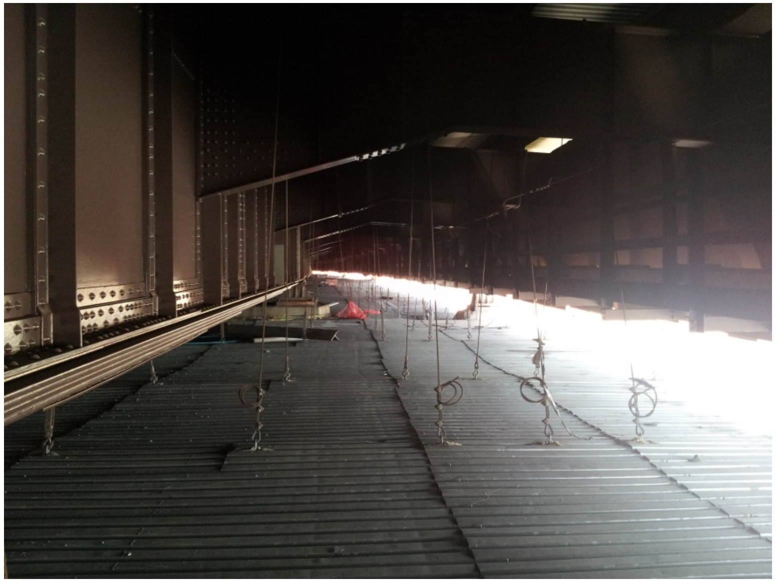
- **Modular data acquisition system**
- **Rugged and allows for arbitrary wiring**

Transducer **Junction box** **Base station** **Computer**

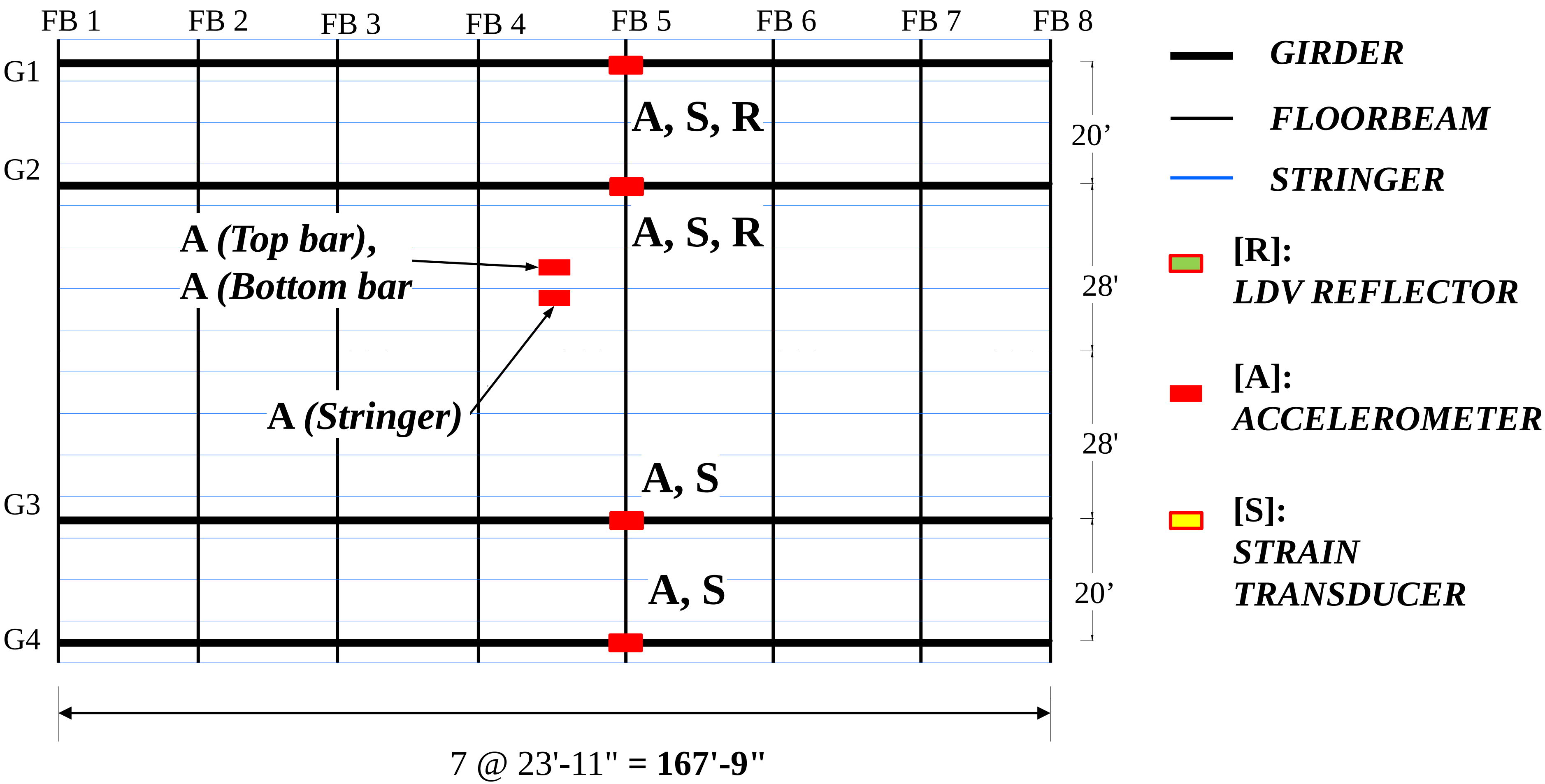
Wired (50 ft) ***Wi-Fi (300 ft)*** ***Wi-Fi (~50 ft)***

Accessibility

- Ease of access via scaffolding
- LDV access to only 2 girders out of 4



Instrumentation



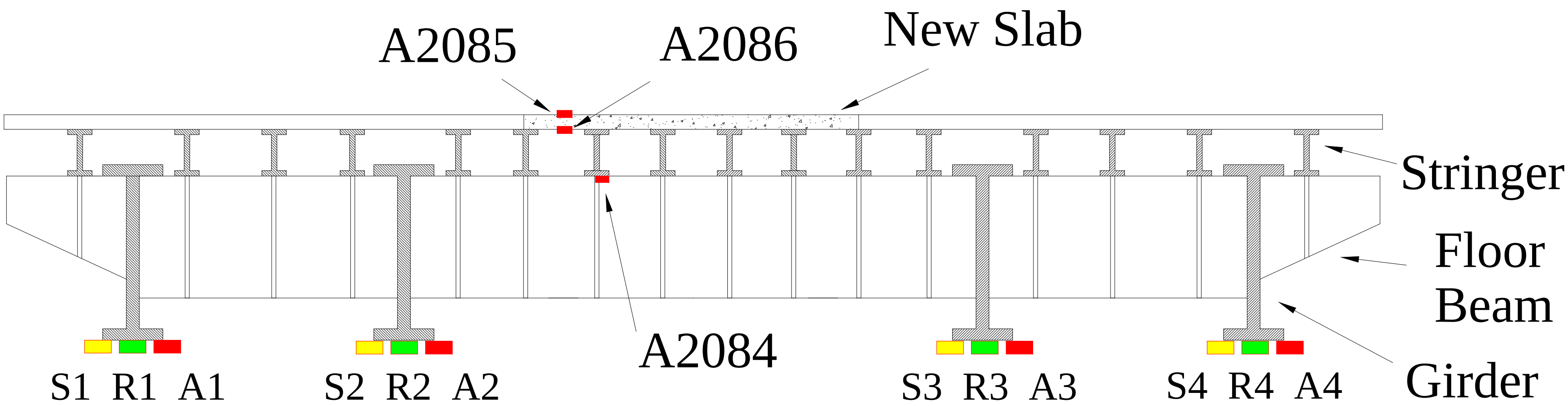
Plan view

Instrumentation

[R]: ***LDV REFLECTOR***

[A]: ***ACCELEROMETER***

[S]: ***STRAIN TRANSDUCER***

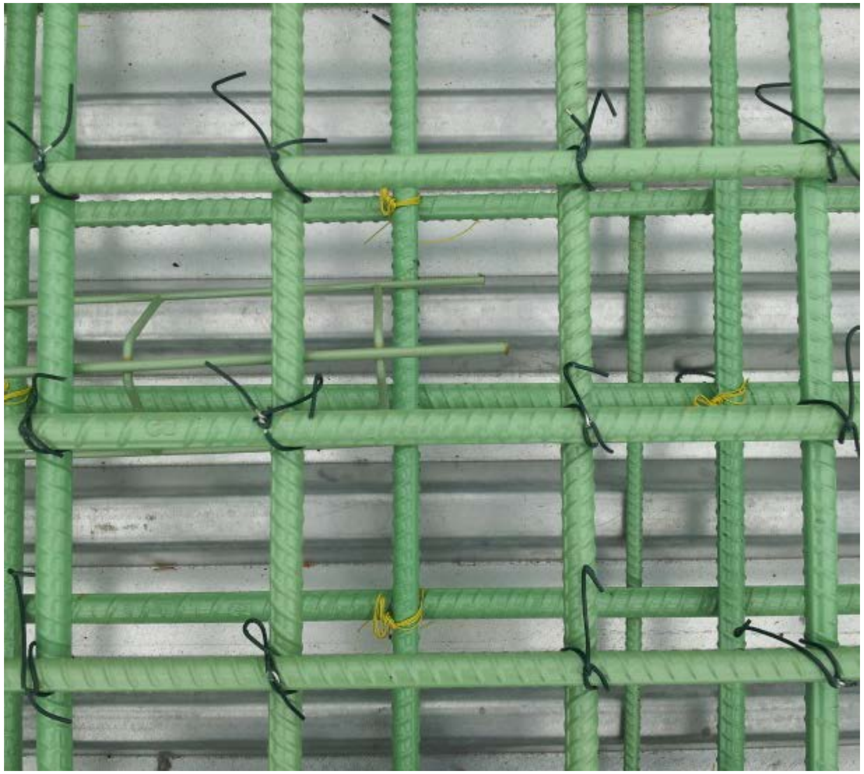


Section view

Rebar Tiedown Conditions

- Vibration comparison of 50% vs 100% tiedowns of rebar intersections

50% tiedowns



100% tiedowns

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Analysis and Results

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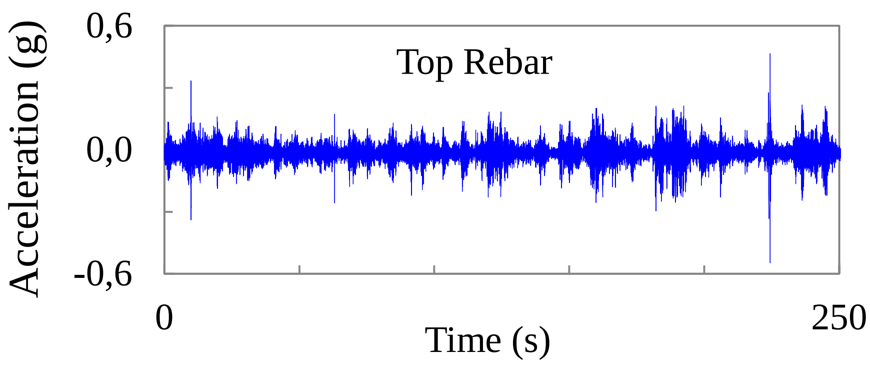
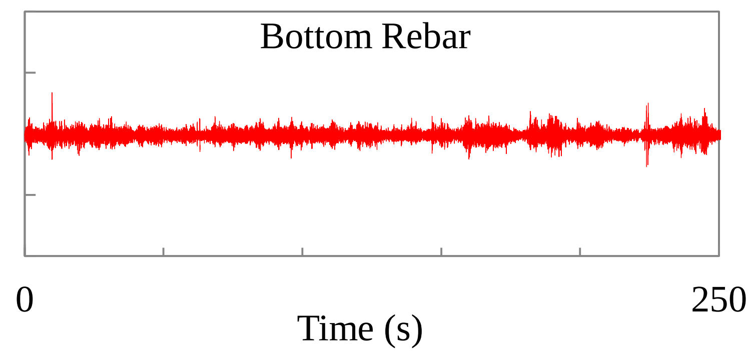
50% Tiedowns of Rebar Intersections

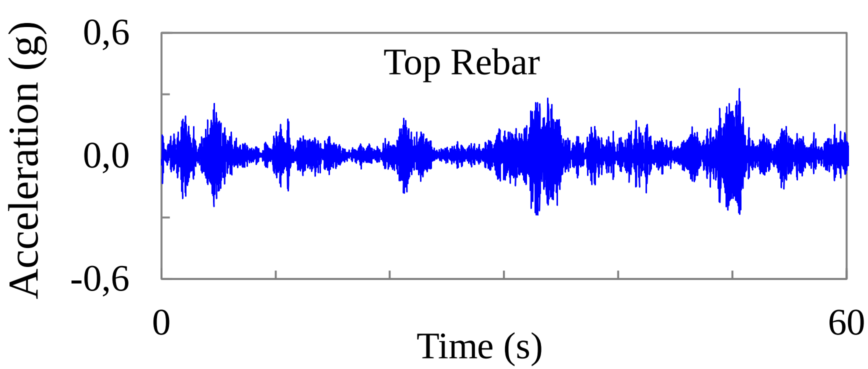
Top rebar acc. = 273% Bottom rebar acc.

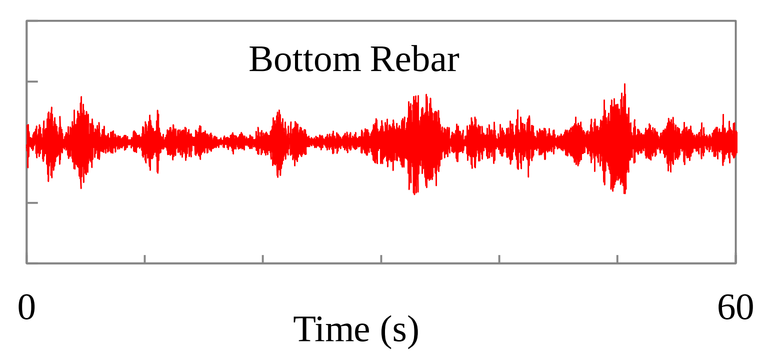




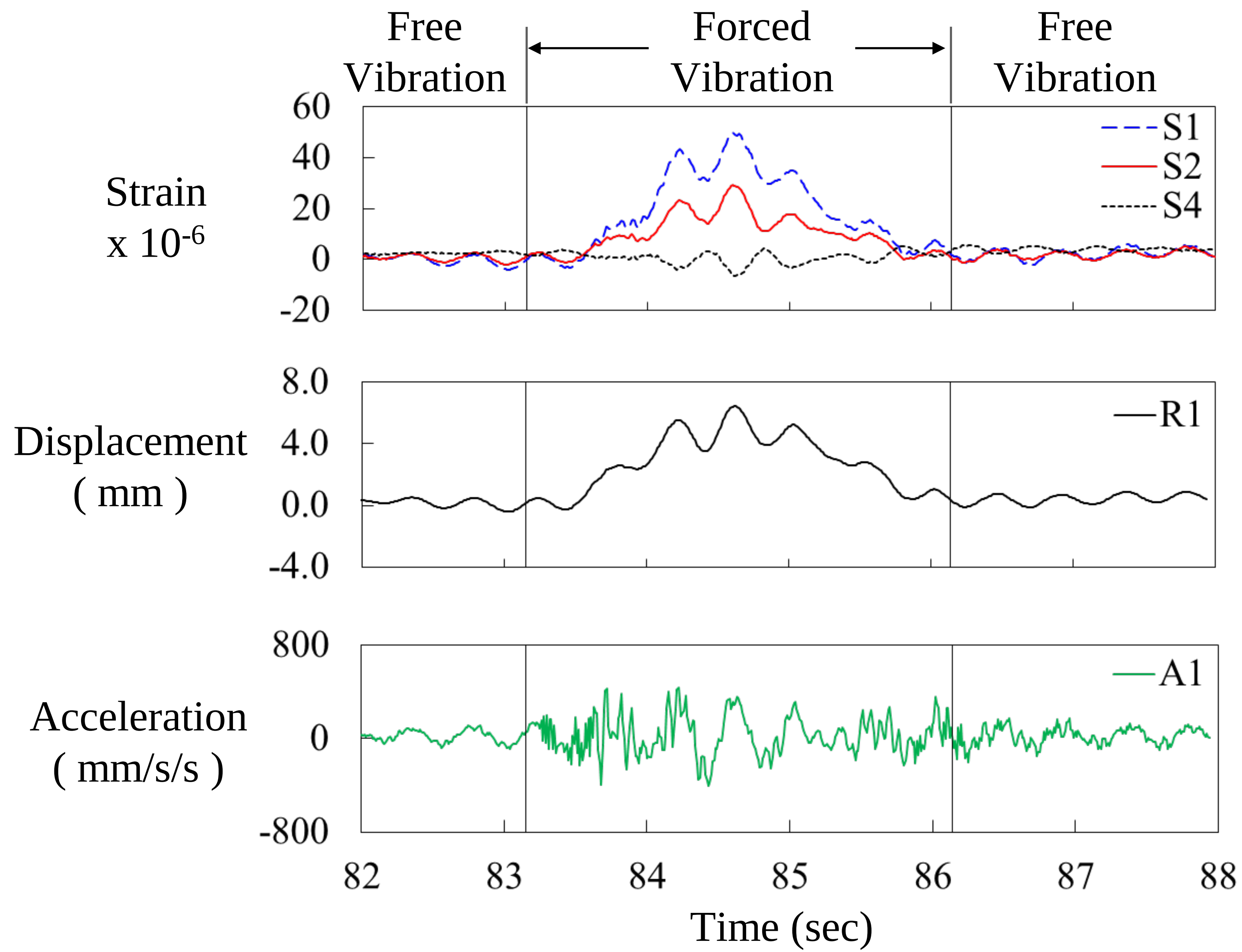
100% Tiedowns of Rebar Intersections

Top rebar acc. = 115% Bottom rebar acc.



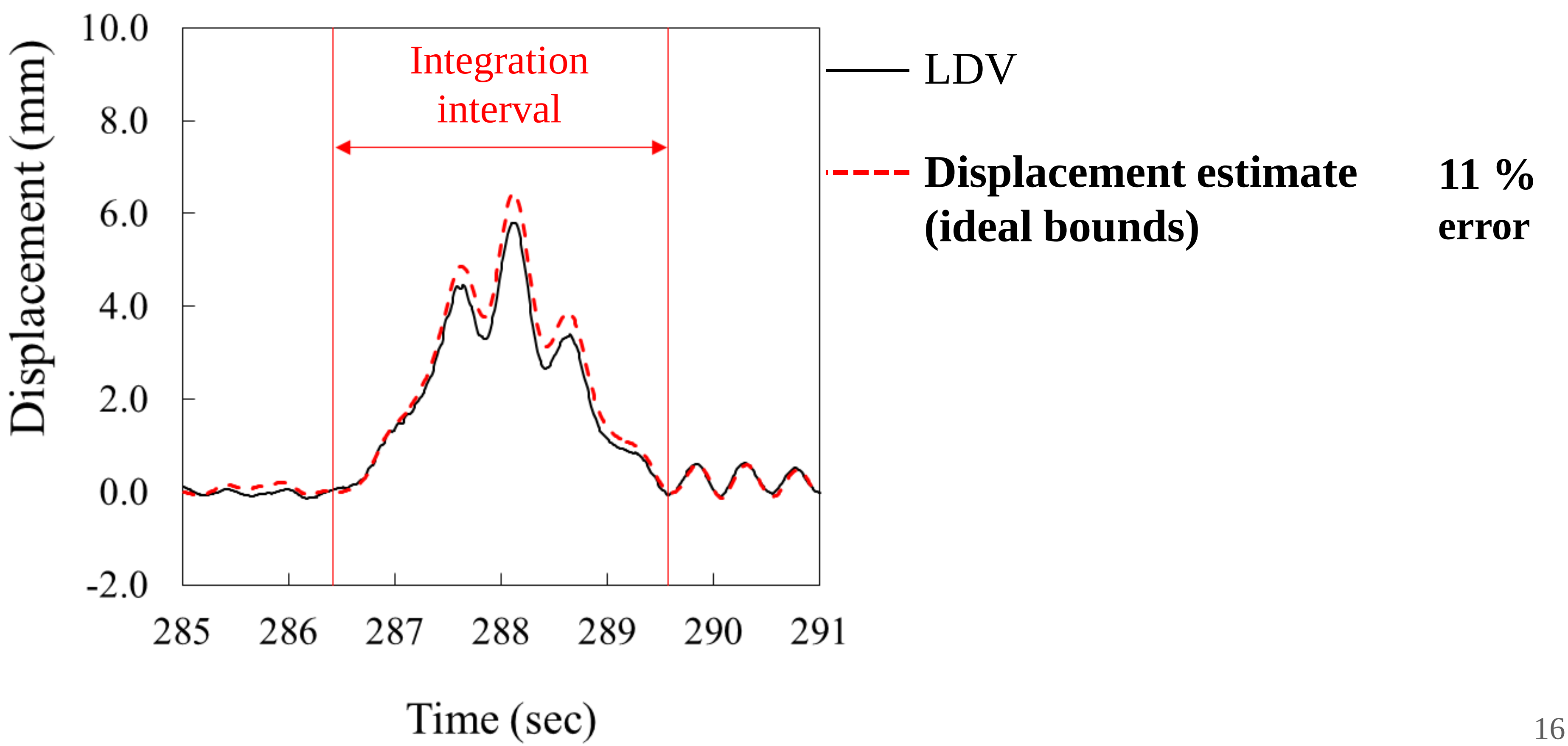


Isolated Forced Vibration Response



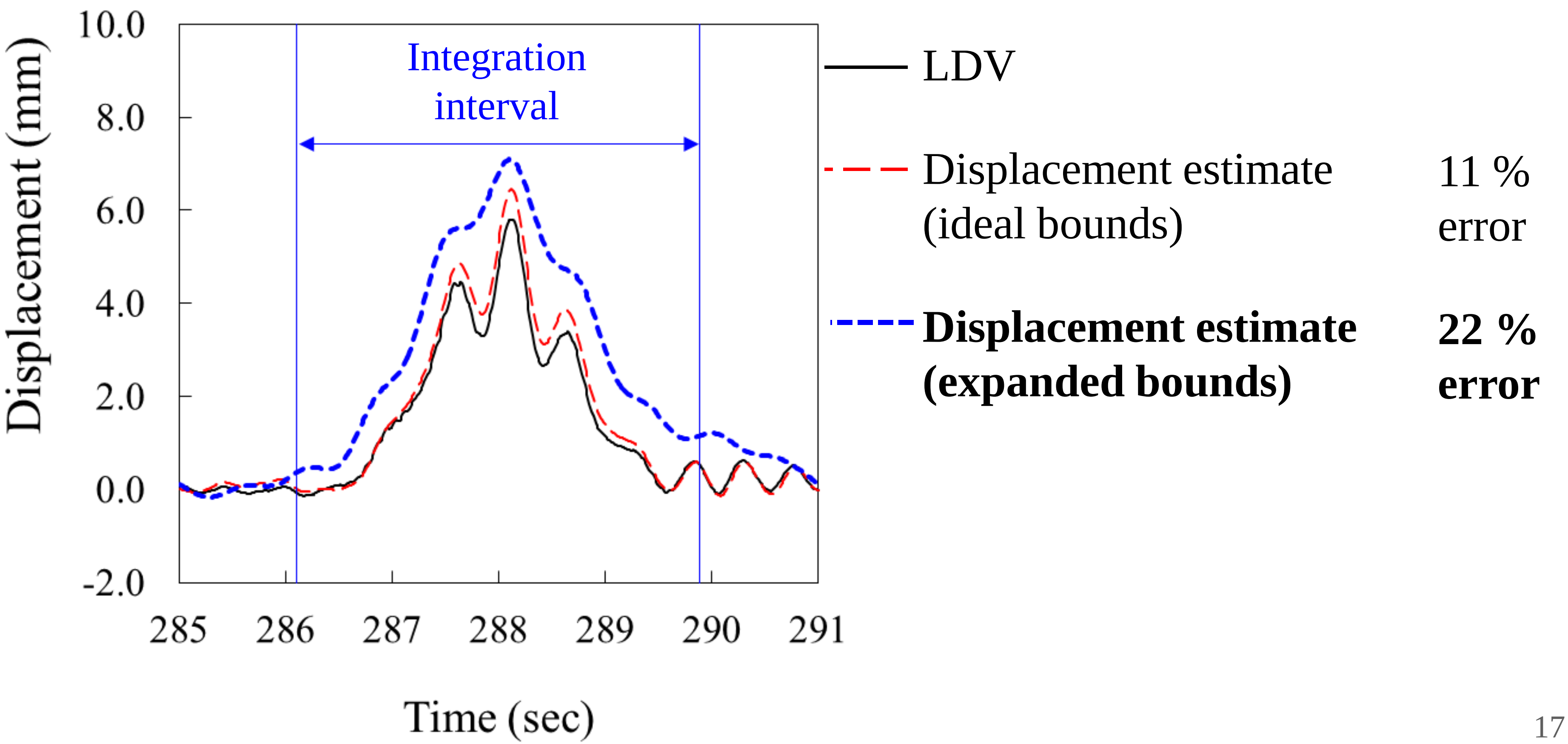
Typical Girder Displacement Estimates

The user can approximate the bounds of integration graphically for isolated forced response segments



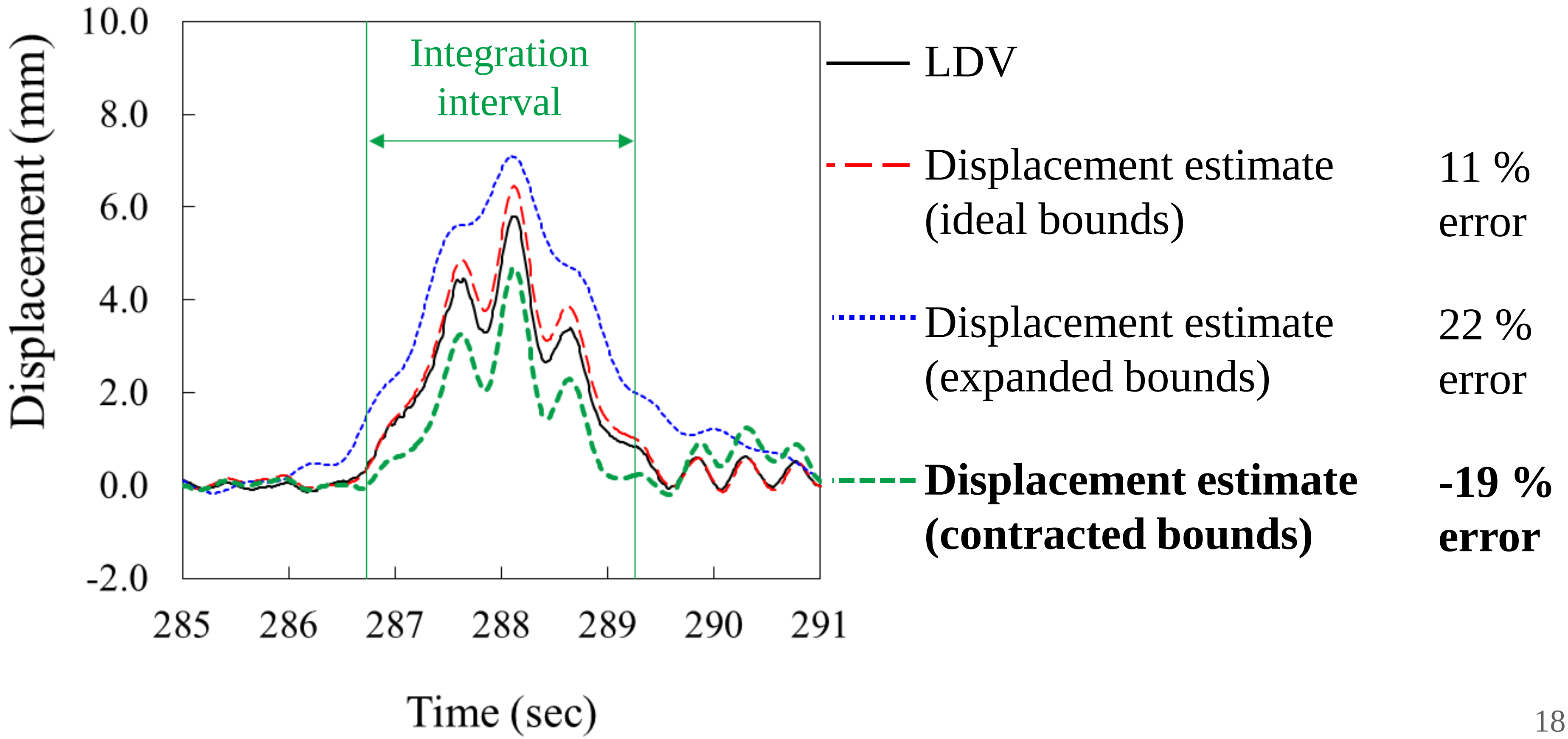
Typical Girder Displacement Estimates

A 10% expansion of the integration interval typically results in an overestimate of displacement

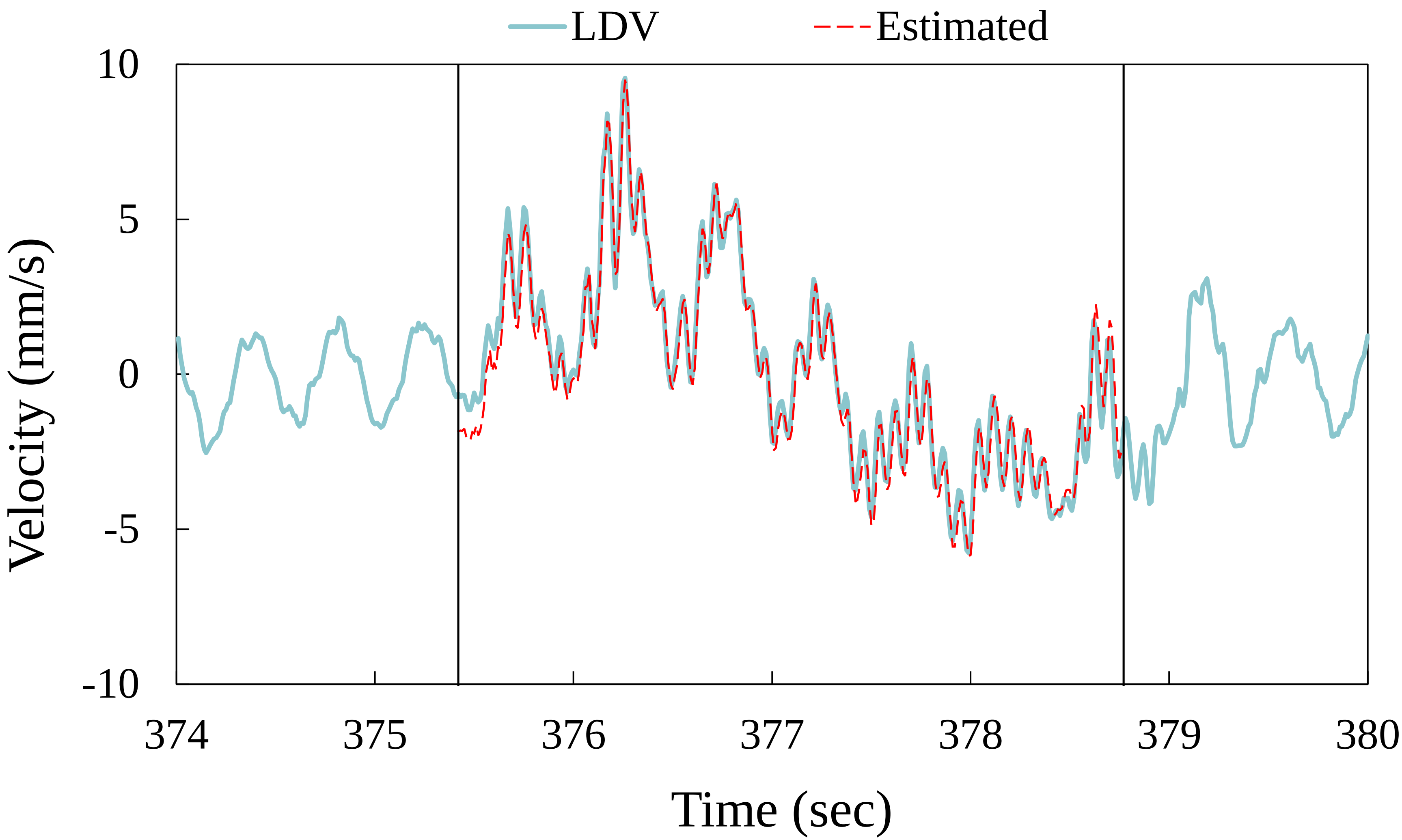


Typical Girder Displacement Estimates

A 10% contraction of the integration interval typically results in an underestimate of displacement

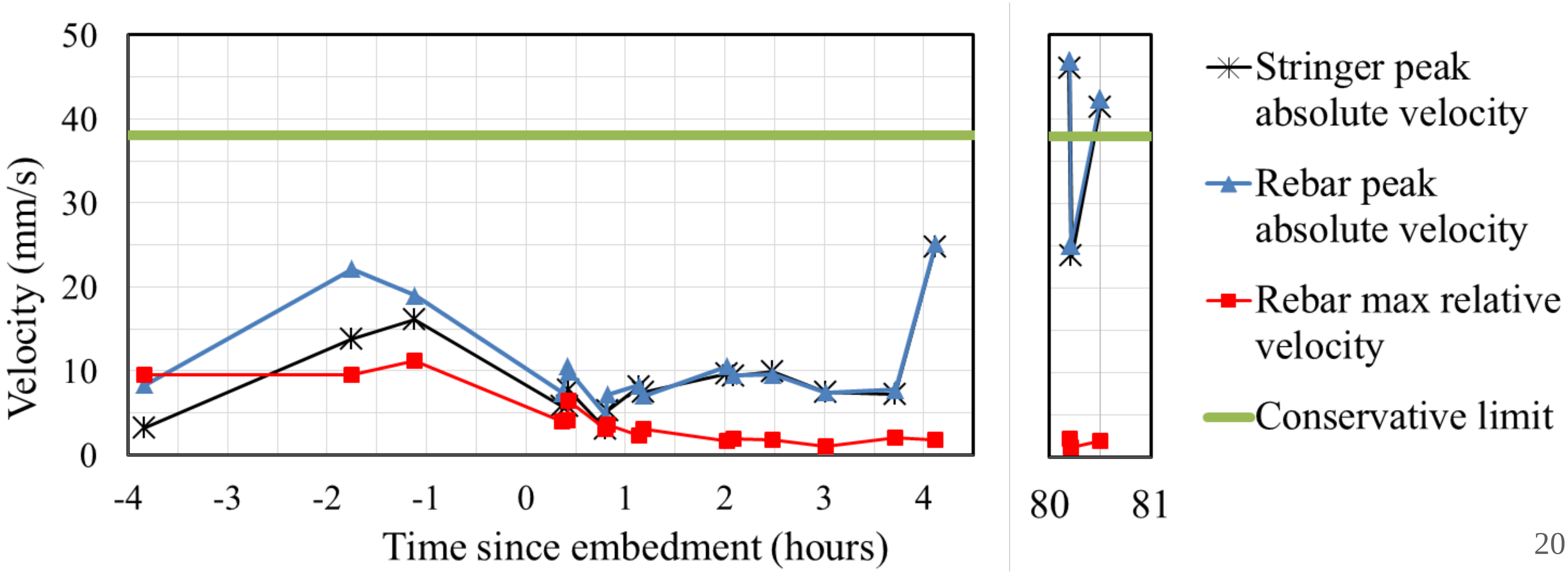


Typical Girder Velocity Estimate

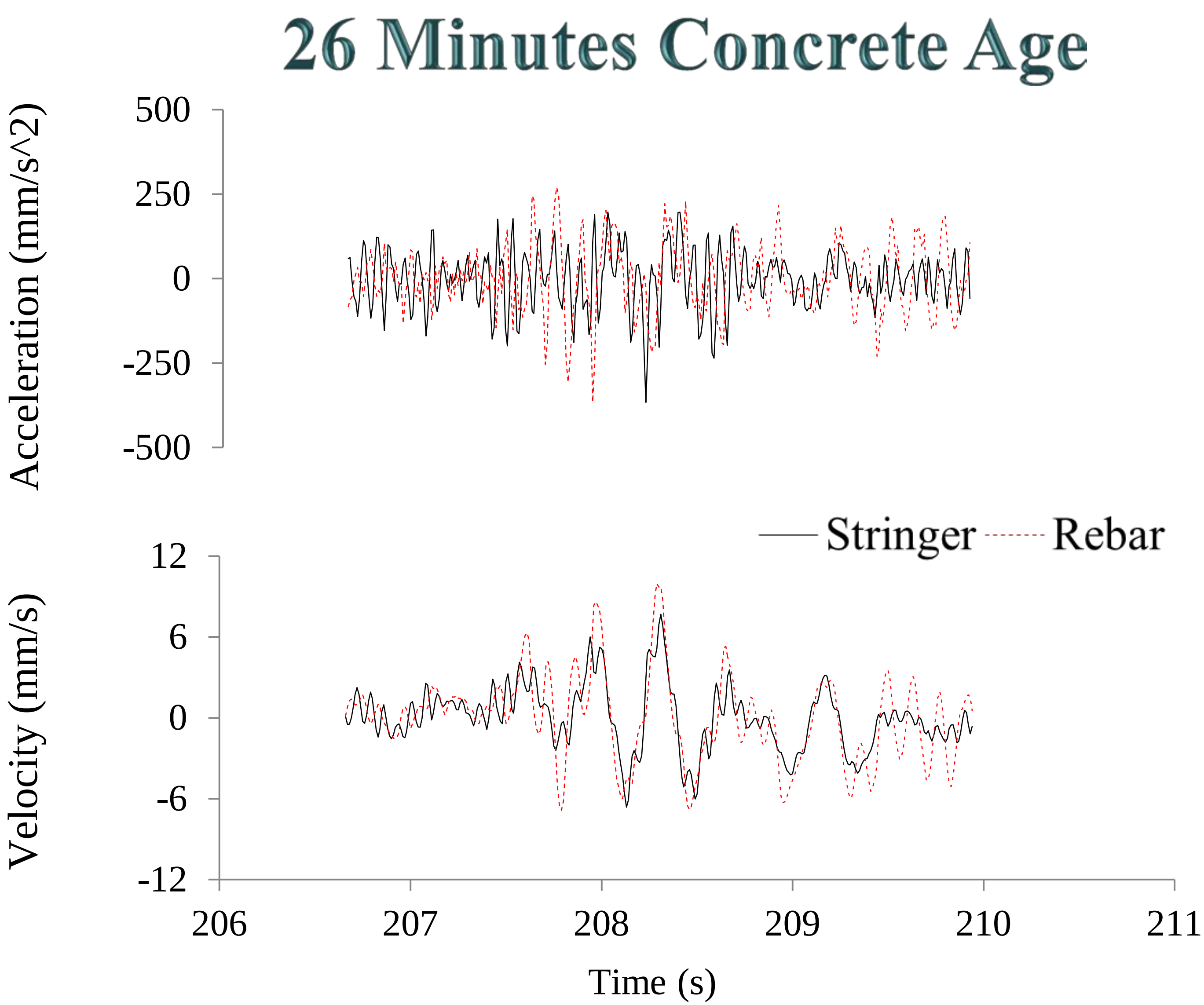


Rebar and Stringer Velocity Estimates

- The same bounds of integration used to estimate the girder response are applied to the rebar and stringer acceleration data
- The **rebar global response** and **stringer global response** fluctuate due to different live loads
- Meanwhile, **rebar relative velocities** steadily diminish



Rebar and Stringer Velocities over Time



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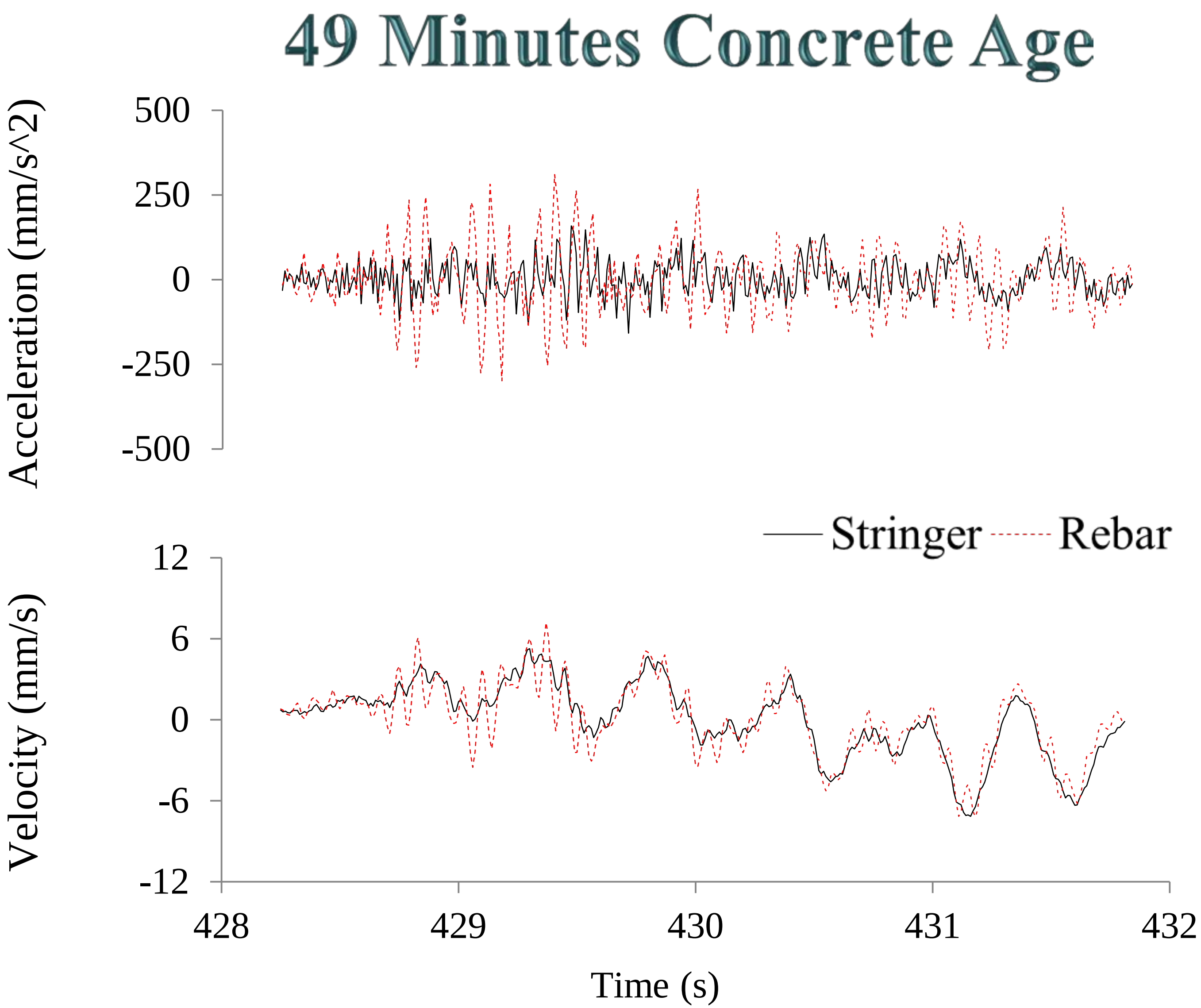

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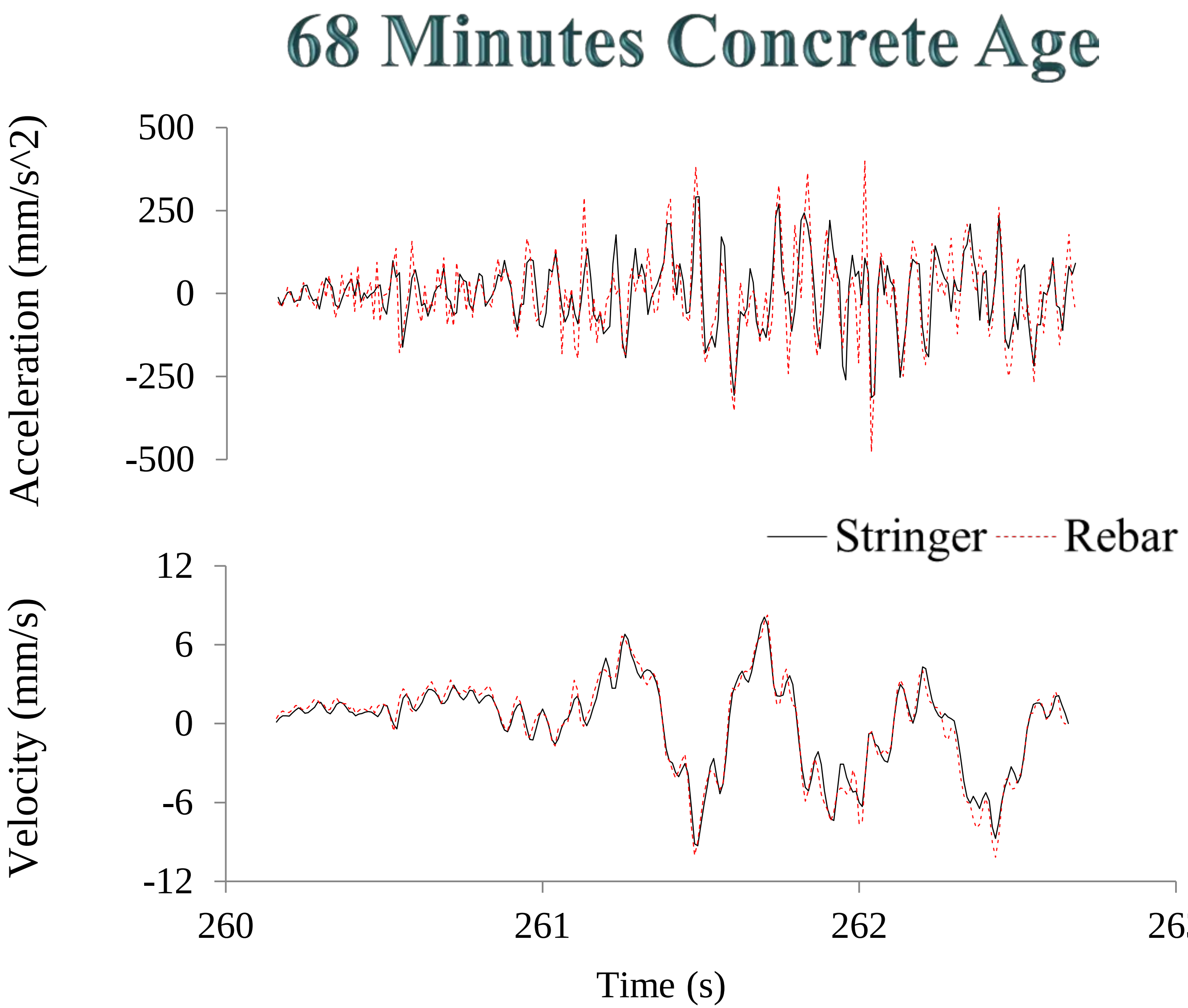
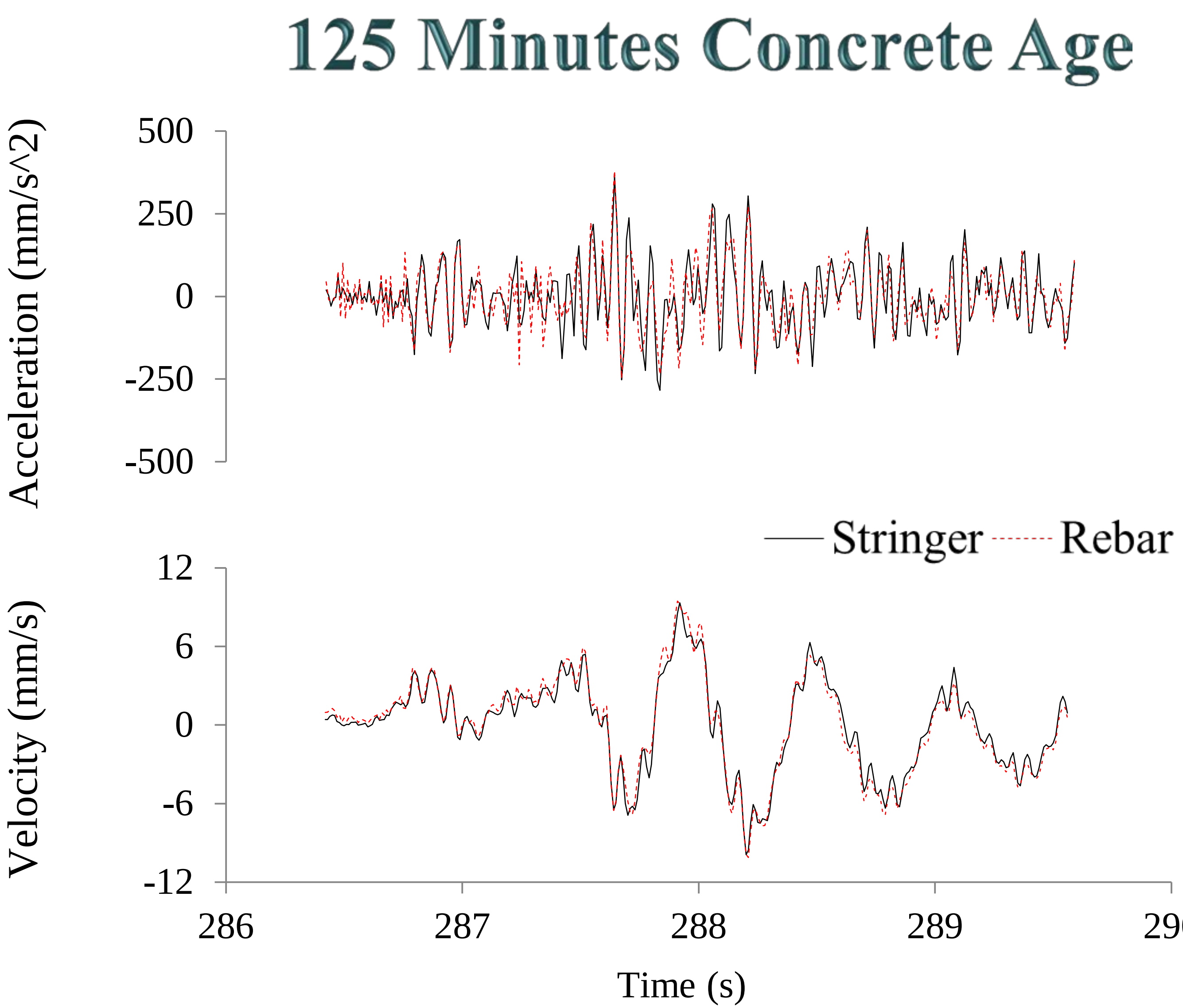
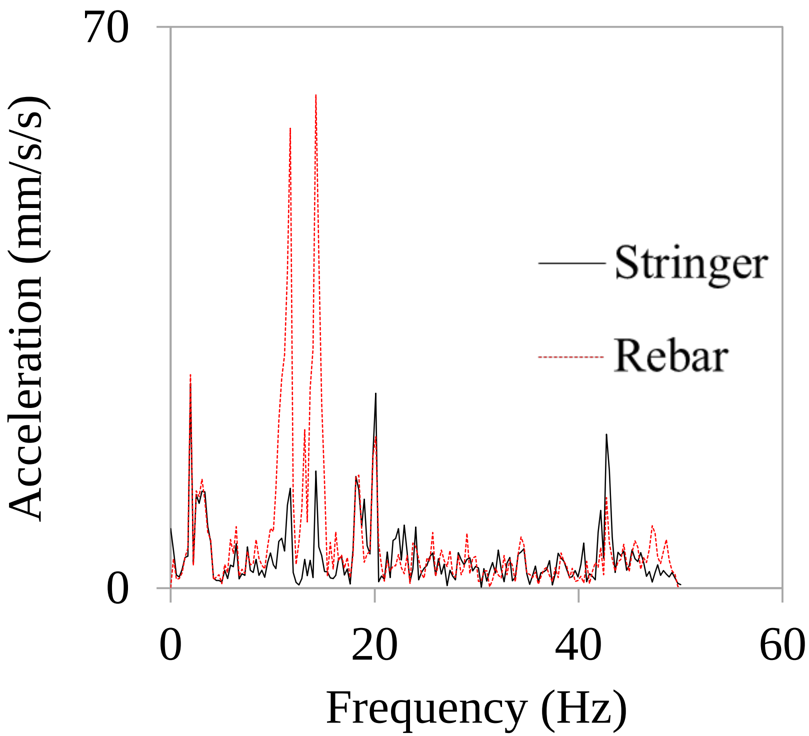


Rebar and Stringer Velocities over Time

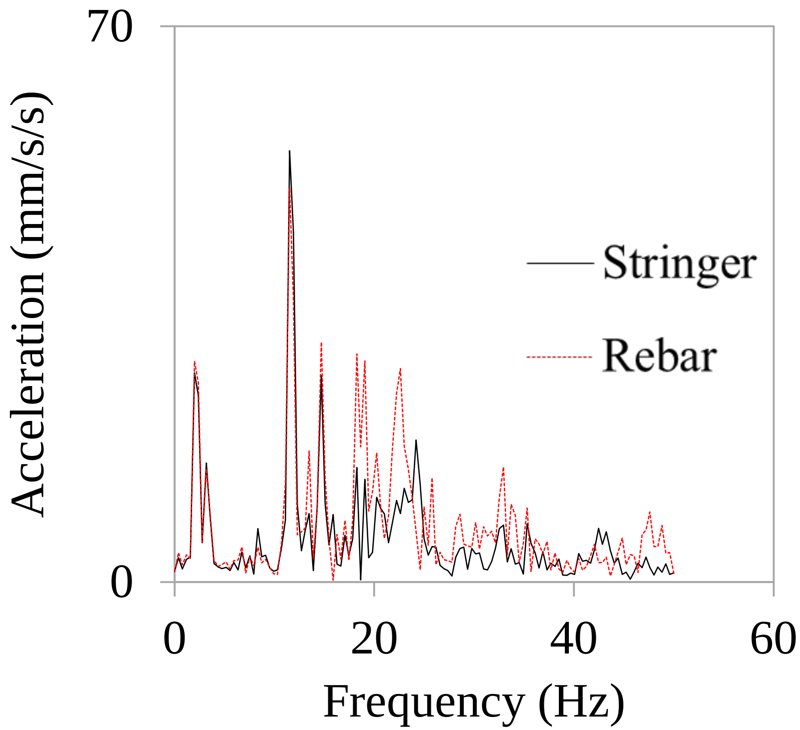


Rebar and Stringer Frequency Spectra

49 Minutes Concrete Age

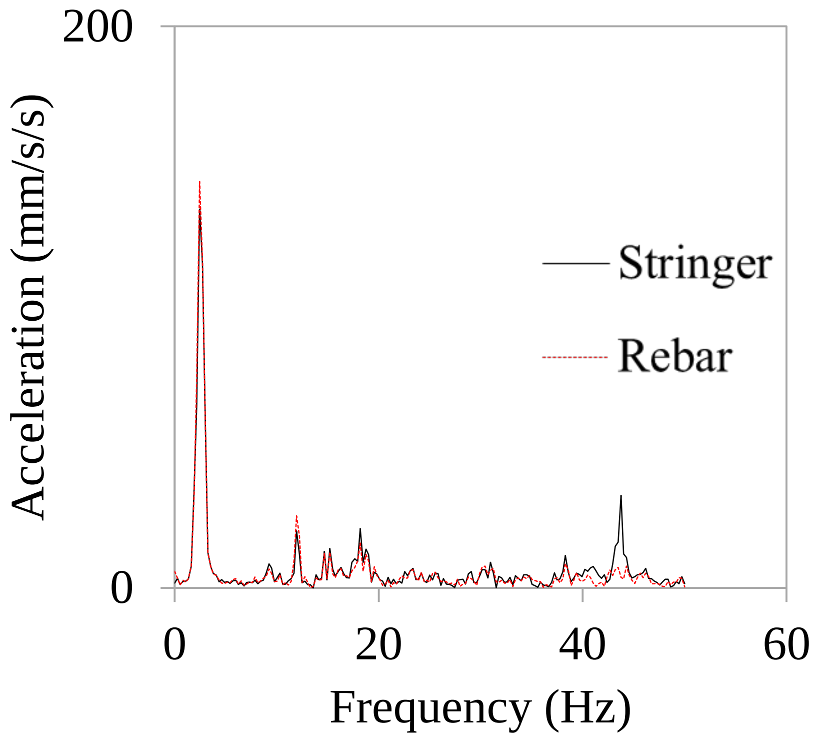


68 Minutes Concrete Age

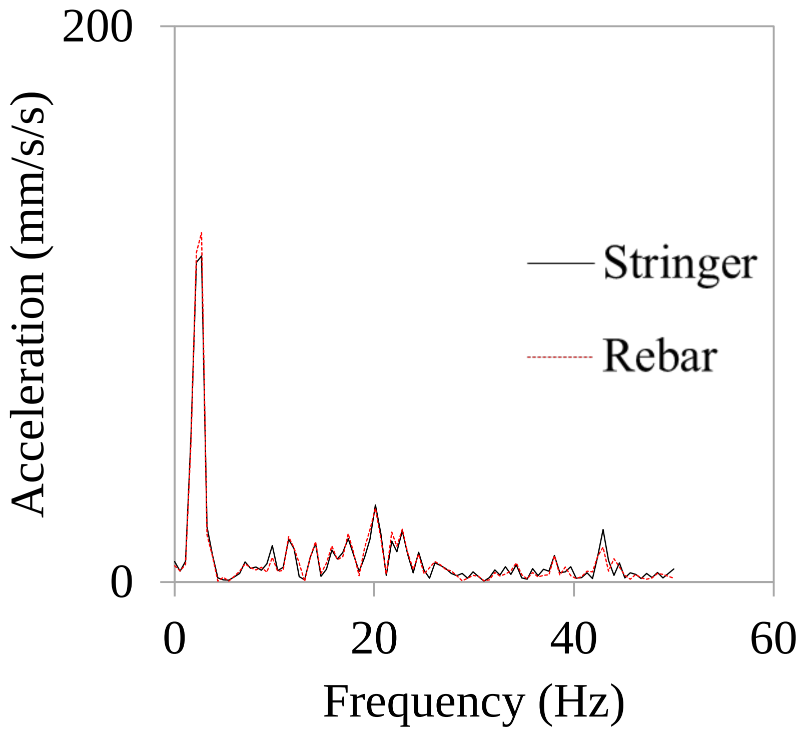


Rebar and Stringer Frequency Spectra

4 Hours Concrete Age



3 Days Concrete Age



Conclusions

1. The estimation procedure can be applied to highway traffic when heavy vehicles are sufficiently isolated

2. A specific set of integration bounds that yields accurate estimates for one bridge component can be used to evaluate the responses of other loaded components in the same span

3. Given the accuracy of the bridge response estimates and the margin of safety provided by the conservative vibration limits, there was no evidence to suggest threat of debonding of reinforcement

Future Research

- A more rational method is needed to determine the bounds of forced vibration. Weigh-in-Motion (WIM) sensors at the bridge supports may be used to signal the start and end times of the span loading.

- Adequate development of rebar bond can be verified experimentally by obtaining coring samples above the top layer rebar. Alternatively, nondestructive ultrasound testing may be performed

- Laboratory work can done to model the extreme cases of vibration that can occur in the field. Upper limits on vibration may be more accurately defined.

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