# Response Spectra

Run harmonic profiles through state space models of VBI to develop response spectra for each frequency.

Currently limited to single-span bridge (could write multi-span model)

Where to locate profile (phase)

What is the amplitude of the profile feature

What are the bridge parameters (mass, natural frequency, length)

What are the vehicle parameters (mass, frequency, damping)

How does a profile that consists of many frequencies translate to bridge response?

# Bridge Vulnerability

Develop a handful of problematic profiles (IRI=250, waviness is varied). Look at bridge responses to these profiles. What types of bridge are most vulnerable to “rough” profiles.

# Scope of research

Objectives

What is dynamic amplification?

What are the mechanisms and influential parameters?

What specifications should a bridge owner enforce to ensure minimal dynamic amplification?

Low IRI, 1/8” over 20 ft.

Show how different tools work – which simple models best correlate to dynamic amplification?

Why must an individual profile be analyzed (fft metrics insufficient)

Qcar model, double sprung mass, simply supported bridge (2dof) model

For more complex structures with poor profiles, more advanced simulation may be necessary

Special problems in VBI

Repeated loading

Truck trains and headway specifications Truck

– for a given profile, and a given speed, are there problematic headways, regular vs irregular spacing.

Approach ramps

# Rail Bridge

* Next site visit. manhattan bridge utc,
* Instrumentation plan –

Train amplification,

# Virtual Lab

* Papers, case studies, etc.

# Current Conclusions and future work

The magnitude of the amplification is largely due to the profile of the bridge roadway.

Vehicle contact force, computed without consideration of the bridge, cannot be accurately used to predict bridge response, especially when the bridge is subjected to sequential vehicle crossings.

Bridge response is greatest when the profile has frequency content that produces a forcing frequency just below the bridge’s natural frequency (≈0.9fn), and the vehicle has a natural frequency near and above the bridge’s natural frequency.

While profile frequency content has an effect on bridge response amplification, phase angle distribution contributes large variability. Therefore, the specific profile must be analyzed.

The dynamic amplification (resulting from the profile) can be reduced by enforcing a smooth profile

Straightedge requirements: 1/8” over 20ft keeps amplification under 1.33

Removing frequencies corresponding to the bridge natural frequency.

Profiles with low IRI will have low amplification

Profiles with high IRI may have large amplifications based on frequency content (or waviness)

Moving Forward:

Possible relationships

Experimentally determined DAmp

Measure profile or record vehicle acceleration over bridge

Record operational bridge acceleration

Analyze vehicle over measured profile to obtain vehicle acceleration

DAF\_V = (max vehicle acceleration (filtered)+1)\*vehicle\_weight

Note: if acceleration of vehicle is recorded, the results will only pertain to that vehicle (i.e. one cannot say the resulting determined amplification factor can be used for any other vehicles/traffic)

Total LL Response = (Dead\_load or 1st mode @ 1G)\*max\_bridge\_accel(%g filtered)\*α+Static\_LL\_response\*DAF\_V

Or… the total live load response is a function of a portion of the dead load to account for body forces from vibration plus the response from the vehicle load that is amplified due to its acceleration.

Analytically Determined DAmp

1. Analyze vehicle acceleration due to profile (Future work: develop vehicle acceleration standards based on real profiles)
2. Response from (max vehicle acceleration+1)\*vehicle\_weight/vehicle\_weight = 1 + max\_vehicle\_accel = amplification factor due to vehicle acceleration (DAF\_V)
3. Assuming the structure behaves linearly, we can also say: bridge response from dynamic contact force = bridge response from static vehicle \* (1 + max\_vehicle\_accel)
4. Hypothesis: this portion of amplification is relatively independent of bridge structure (i.e. profile controls)
5. Perform natural frequency analysis and Dead Load Analysis and modal parameter identification of vehicle acceleration
6. Additional component of amplification due to motion of bridge can be calculated by apportioning bridge response from dead-load. That portion would be a function of the level of plausible excitation of the bridge’s first couple modes which is dependent on the structure and the traffic.
7. A possible function for this portion may include the following parameters:
   * Max %g vehicle acceleration (stop filter > X mode) or
   * some parameter related to the PSD (i.e. how much of the traffic excitation is in a specific frequency range)
   * Dead-load deflection (stand-in for stiffness)
   * First natural frequency