All crossing events (train over instrumented beams) caused acceleration that exceeded the accelerometer range of 5Hz on at least 1 channel. Usually all those channels near problematic splices.

The plot below shows the fft performed on acceleration data for two different train events: one in which a train passed directly over the instrumented girder, and one in which a train passed on an adjacent rail (B). The plotted response is for a location that was midspan of a transit beam and under a problematic splice (location 9).



We can also compare locations 5 and 15. 5 is in an area without problematic splices, while 15 is almost directly under a problematic splice.



To approximate the effect this acceleration is having on the structure, we may convert the acceleration to displacement by computing the fft of an event, multiplying the transformed data by the corresponding radial frequency squared, and then computing the inverse fft on the resulting product.

Because the accelerometers are not capable of measuring vibrations less than 0.5 Hz, these components were zeroed out before the inverse fft was performed.



We can compare the computed displacement using the above method. This displacement is only the amplification portion since we cannot capture the near 0 Hz motion associated with static deformation of the structure. We may compare areas with good splices or no splices with the problematic areas, however, responses even in the “good” regions will be affected by poor profile at other regions. I expect the responses in the good regions would still benefit from repairs made on problematic sections.

Plotted again with frequency range of 0.5 to 100 Hz.



Clearly the joints are causing significantly more deflection than areas with a smooth profile. Although the exact amount cannot be known with just the data that has been collected. We can definitively say that this rail profile is causing significant stress to the load carrying mechanisms of the bridge. The train over the rail profile is causing a broad-band input much like an impact, thereby exciting the natural frequencies of the both the bridge and train. Both serve to amplify the force effect of the train.

Story

Summary

A preliminary data survey was conducted on the Manhattan Bridge as part of a larger effort to better understand the effect of rail splice misalignment on bridge performance. The survey was performed to assess the suitability of locations for more in depth instrumentation, and to gain further understanding of the nature of the coupled dynamic system (train-bridge interaction).

Over twenty sensors were deployed on the underside of the Manhattan bridge, and operational acceleration was recorded for over 30 train crossings (A and B rails). The resulting data confirms that misaligned splices are consistently causing an increase in structural acceleration and this acceleration is undoubtedly resulting in a significant increase in member stress levels. The next phases of monitoring will serve to quantify this amplification.

Body

Acceleration was recorded at 20 locations with piezoelectric accelerometers. A sample time history of acceleration during a train crossing is provided below.



It is immediately obvious from the above plot that the location with poor rail alignment is experiencing greater acceleration and in excess of 5g resulting in “clipping” of the data. This is due to the limitations of the sensor (±5g range). While the clipping reduces the accuracy of the data, it remains useful for our purposes of comparison. The following exercise demonstrates the effect this clipping has in the frequency domain.

A data sample was selected which exhibited no over-ranged samples. This data set was subsequently clipped for any value exceeding 2g. An FFT was performed on the clipped and original signals. The resulting frequency content, compared below, shows that clipping the signal serves to increase the contribution of high frequency content (165 Hz) but does not appreciably increase the lower frequency.



Figure (Left): Percent change in FFT values due to clipping; Figure 2 (Right): FFT of original signal compared to difference in FFT values

Given the assumption of harmonic, steady-state motion, the displacement is related to acceleration by the equation: , where ω is the radial frequency of the acceleration. Therefore the displacement due to a given frequency component is the amplitude at that frequency line divided by the square of the radial frequency. Since we are interested in motion that results in deformation of the structure, it follows that we should be most interested in low frequency content that contributes most to the cumulative displacement of the structure.

The sensors employed for this preliminary survey are not able to accurately capture motion below 0.5Hz and thus the resulting data is incapable of accurately predicting displacement. However, it can be seen from just comparing frequency content for different locations that the poorly aligned splice is resulting in greater acceleration amplitudes across all frequency bands, including content below 10Hz. The increase in low frequency content must therefore result in increased displacement and increased stress levels.

|  |  |
| --- | --- |
|  | Location Key |
| Location Key |

Figure 3: Frequency content (FFT) of acceleration

The event characterized with the above plots is not dissimilar to the many other events recorded. The increase in broad-band structural acceleration was observed at locations with misaligned splices for nearly every train crossing event. The amplification appears to be more severe for locations with splice misalignment near midspan of a transit beams. While the gathered data unequivocally shows that poorly aligned splices cause increased dynamic amplification; that amplification cannot be quantified due to the discussed limitations inherent to the acceleration data. The next stage of monitoring will seek to capture strain and/or displacement data which can be more directly related to structural performance metrics (e.g. stress).

that had no clipping was selected to quantify the effect that c To examine the effect of this clipping on the data,

They cannot exceed 5G of excelleration.

Overranging

How does clipping impact frequency content

Compare time histories – just because higher – not damaging (never a good thing)

Compare frequency content

Adriana’s LIDAR results.