Phase 1 Summary Report

On November 16, 2018, 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. They were affixed to the bridge superstructure with magnets and were removed at the conclusion of the survey. 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.

The following document provides a summary of the gathered data and interpretation.

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 1 (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.

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|  | 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 misaligned splices that are located near the midspan of a transit beam. While the gathered data unequivocally shows that poorly aligned splices cause increased dynamic amplification; that amplification cannot be quantified due to the 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).