GRAND AVENUE BRIDGE
Vibration Investigation at the River Bank Lofts
550 North Kingsbury Street, Chicago, Illinois

Final Report
September 18, 2009
WJE No. 2009.0820

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Figure 36. Drawing of the grand Avenue Bridge structure, circa 1910, provided by DCOT.

Figure 37. Drawing of the grand Avenue Bridge structure, circa 1910, provided by DCOT.

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INTRODUCTION

Wiss, Janney, Elstner Associates, Inc. (WJE) performed a vibration investigation at the request of the Chicago Department of Transportation, Division of Engineering (CDOT), at the River Bank Lofts condominium building at 550 North Kingsbury Street, adjacent to the Grand Avenue Bridge. The investigation was prompted by complaints by several condominium owners who claimed that certain traffic on the bridge produced vibrations that were disturbing in their units. This investigation was performed under Contract Number 12140 and Specification Number C968990037.

BACKGROUND

The River Bank Lofts condominium building is located on the east bank of the North Branch of the Chicago River and on the north side of West Grand Avenue. An overall view, looking east across the bridge toward the building is shown in Figure 1. The building, adjacent to the northeast corner of the Grand Avenue Bridge, was reportedly constructed as a cold storage facility with wood timber framing and brick masonry walls. It is six stories tall with an occupied basement level that opens to patios along the east bank of the Chicago River. The 6th floor condominium units each have a spiral stairway that leads to roof-level rooms. Portions of the architectural drawings that show floor plan views of the basement and 6th floors are shown in Figures 2 and 3. A thick masonry firewall extends east-west across the building approximately 55 ft from the southeast corner of the building and 133 ft from the southwest corner. In drawings for the Grand Avenue Bridge, provide by CDOT, the River Bank Lofts building is referred to as the “Railways Terminal & Ware House Cos Bldg.”

The Grand Avenue Bridge is a bascule bridge that was built circa 1913, sometime after the River Bank Lofts. Copies of selected original drawings of the bridge are shown in Figures 34 through 37. At the time that the design drawings were made, the street was referred to as Indiana Street. The bridge is comprised of two tilt-up leaves that meet at the center of the river. A below-grade vault area at each bank houses the counterweights that balance the rotating bridge deck. When the bridge is in the “down” position, the two leaves meet at the center of the river and align vertically and horizontally. They are held in this alignment position with a locking mechanism that is intended to release when the bridge is to be raised.

The bridge was originally constructed with a locking mechanism located below the pavement deck. It was designed so that it could be operated from the bridge house that is located at the river edge. The original mechanism failed and it was eventually replaced by mechanisms that were mounted on the steel support framing above the deck on the north and south sides of the bridge. The current locking mechanism is shown in Figure 4. It consists of 2 steel frames bolted to the vertical bridge frame element on either side of the mid-bridge joint. Each frame has a rectangular opening that allows passage of a steel beam that slides across the gap between the frames. It is intended to limit the relative vertical movement between the ends of the two bridge leaves.

The building was converted to apartments in 1995. The occupants of the building noted the occurrence of impulsive vibrations from the time that they moved into the building. The vibrations are reportedly experienced by occupants on all seven floors in all of the units south of the firewall. Occupants of
Unit 602 and 002, who face the Chicago River, met with representatives of WJE, CDOT, and the building management company on January 15, 2009 to discuss the vibration issues. They described the history of the problem and characteristics of the events while the visitors observed the vibration occurrences, first-hand. The worst events are reportedly caused by eastbound city busses as they pass the middle of the bridge. The unit owners have noted that an earlier modification to the center locking mechanism alleviated the problem for a short time, until a series of heavily laden construction vehicles passed over the bridge and, apparently broke the locking devices. While on-site on the 6th floor, the visitors noted that perceptible vibration occurrences appeared to coincide with busses travelling east over the joint at the middle of the bridge.

SCOPE OF WORK

WJE was directed to develop a scope of work that would document the vibrations that the unit owners were experiencing and identify their source. WJE proposed to monitor vibrations on the ground floor and the top floor with vibration sensors and a webcam directed at the bridge for a sufficient period to capture a representative sampling of traffic. While the monitoring equipment was installed at the site, a construction vehicle of known weight was to drive over the bridge in a controlled test. In addition to the monitoring effort, WJE proposed to review any available drawings of the building and bridge in order to identify possible connectivity between the building and the bridge structure.

MEASUREMENT EQUIPMENT

Vibrations were measured with 2 PCB Model 356A17 tri-axial accelerometers and 2 PCB Model 353B33 single-axis accelerometers connected to a National Instruments (NI) cDAQ 9172 chassis with 2 NI 9233 4-channel data acquisition modules. This constituted eight channels of vibration data. The cDAQ system was connected to a laptop PC running a dynamic data acquisition program developed by WJE in the NI LabVIEW programming language. The laptop PC was also connected to a Logitech Quickcam Pro 4000. The system continually scanned the output of the 8 accelerometers at a rate of 2000 scans/second and evaluated incoming data every second. It also captured images from the webcam at a rate of two pictures per second.

The system stored the peak acceleration from each of the eight channels and their associated frequencies every 20 seconds. If a preset trigger level was exceeded by any channel the system stored a 10-second waveform file of the vibration data and the 20 photos that were being collected from the webcam at the time of the event. This allowed for subsequent review and classification of captured events with coinciding photographs of activity on the bridge.

Measurements in the River Bank Lofts

The accelerometers were located in the basement and 6th floor units identified in the drawings as Units 002. The exterior walls of both of these units are on the west side of the building and face the river. In the basement unit, a tri-axial accelerometer was placed on the hardwood floor adjacent to the northwest corner of column 7L, as identified on the drawing in Figure 2. A second, single-axis, accelerometer was mounted on the floor at the base of a bar near the south end of the unit, as shown in Figure 2. Photographs of the interior surfaces in Unit 002 are shown in Figures 5 through 8.

In Unit 602, the tri-axial accelerometer was placed on the hardwood floor approximately 10 ft north of Column 7L, as shown in Figure 3. The single-axis accelerometer was placed at the roof level above the 6th floor measurement location on the sill of the window in the wall facing the river. The sensors were attached to the floors with petrol wax and secured in position, in some cases, with duct tape. The single-
axis sensors were oriented to measure vertical vibrations. Photographs of the interior surfaces in Unit 602 are shown in Figures 9 through 15.

The webcam was mounted on the handrail of the Unit 602 balcony. It was oriented to provide a view of the east 2/3 of the bridge, including the joint at the middle. Figure 16 shows the field of view provided by the webcam. Cables from all of the sensors were routed to the data acquisition system, which was located in the southwest corner of Unit 602. The laptop PC controller of the monitoring system was connected to a cellular modem, which provided an internet-based communication link to the system. This allowed WJE to observe the status of the monitor and control the operation of the program.

**Measurements at Street Level**

After monitoring in the building for two days, the system was relocated to street level to measure vibrations at four locations along the north curb of Grand Avenue. The measurement locations are shown in Figure 17. Location A was on the east end of the raised concrete curb. Locations B, C, and D were on the concrete sidewalk just north of and built integrally with the fixed framing that supports the east approach roadway. The numbers in parentheses after the location designations indicate the channel numbers (0 through 7) in the data acquisition system. Near the end of the test period a material hauling truck, identified as the test truck, was directed to pass over the bridge in a controlled manner. It made four passes in each direction, driving over observed discontinuities in the pavement surface. This included the joints in the roadway, a manhole cover in the westbound lane east of the east abutment, and a steel plate along the south edge of the eastbound lanes.

Also, during this test period WJE and CDOT personnel examined the above-deck locking mechanisms on the north and south sides of the bridge, the steel gratings at several areas of the bridge deck, and the structural framing of the bridge deck and sidewalks exposed in the counterweight and machinery vault at the east end of the bridge.

**VIBRATION MEASUREMENT RESULTS**

**Measurements in the Riverbank Loft Units**

The monitoring system was installed on May 27, 2009, and began monitoring at 9:47 a.m. The program stopped operating at 10:58 p.m. that evening after 13 hours, due to a memory issue on the controlling PC. It was restarted on May 28, 2009 at 8:17 a.m., and after 15.5 hours, stopped again at 11:40 p.m. It was restarted at 6:06 a.m. on May 29, 2009, and was stopped 2.5 hours later for relocation to street level at 8:44 a.m. The system monitored at street level from 9:39 a.m. until 10:56 a.m. on May 9, 2009.

During the first hour of monitoring, the tri-axial accelerometer on the floor of Unit 602 became disengaged from the floor and rotated such that the east-west sensor was measuring vertical vibrations and the vertical sensor was measuring the east-west vibrations. It was held in that position, suspended approximately 1/2 in. above the floor, by the duct tape that had been used to secure it. The result was that the vibration amplitudes measured for that sensor were not considered valid after 10:33 a.m. on May 27. Prior to 10:33 a.m., the system captured several vehicle passages, including eastbound and westbound city busses. Review of those events verified that the magnitude and frequency characteristics of the top floor accelerometer closely matched the response of the 6th floor location.

In 31 hours of monitoring within the building, the system captured a total of 1,902 waveform events. Each of the captured events was reviewed and categorized as to what type of vehicle triggered it. The events were categorized as eastbound (EB) or westbound (WB), and further categorized in three different
vehicle groups. Of 1,902 captured events, 930 events were clearly identified as being caused by one of the six vehicle categories listed below. Another 217 events were clearly produced by activity within the building units and 677 events were produced by unidentified activity. Many of the unidentified events were just continuations of events that were categorized as particular vehicles. There were 78 events triggered by intermittent cable connections or other electrical sources.

The distribution of events by vehicle category is shown in the following table. The summary table also lists the maximum and average vertical acceleration amplitudes and associated frequencies at the two basement locations and the top floor location. The data presented in this table demonstrates that the magnitude of vibrations measured on the top floor is at least three times larger than the basement level. The table also demonstrates that the eastbound city bus produces the largest vibration, though significant vibrations are also produced by other vehicle and directional categories.

The images captured with the waveform files helped to verify that the largest externally produced vibrations originated from eastbound busses or heavy trucks travelling in the right, or south, lane when they pass over the joint at the middle of the bridge. The heavy eastbound vehicles produce a large vibration event, lasting approximately 2 seconds, when they travel in the furthest south eastbound lane. Otherwise the heavy vehicles produce lower-amplitude, but longer duration events. Heavy vehicles travelling in the westbound direction produce lower-amplitude but still perceptible levels of vibration lasting up to 10 seconds and beginning as the vehicles are adjacent to the River Bank Lofts building.

The vibration amplitudes from the triggered vehicle-related events are graphically presented in Figures 17, 18, and 19, as plots of peak vertical acceleration versus time for the nominal 2.5-day monitoring period. These plots demonstrate the relative distribution of vehicle-related vibration events over time. The data points are grouped by vehicle type in order to show the relative magnitude of vibrations produced by the various categories of vehicles.

### Summary of Vibrations Measured in the River Bank Lofts Building (g’s)

<table>
<thead>
<tr>
<th>Category</th>
<th>No. of Events</th>
<th>Basement South</th>
<th>Basement Middle</th>
<th>Top Floor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>g, max</td>
<td>g, avg</td>
<td>Hz</td>
</tr>
<tr>
<td>EB City Bus</td>
<td>163</td>
<td>0.0067</td>
<td>9.5</td>
<td>0.0048</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0041</td>
<td></td>
<td>0.0033</td>
</tr>
<tr>
<td>EB Semi-Truck</td>
<td>49</td>
<td>0.0050</td>
<td>9.6</td>
<td>0.0036</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0021</td>
<td></td>
<td>0.0017</td>
</tr>
<tr>
<td>EB Truck</td>
<td>228</td>
<td>0.0051</td>
<td>9.5</td>
<td>0.0033</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0019</td>
<td></td>
<td>0.0014</td>
</tr>
<tr>
<td>WB City Bus</td>
<td>204</td>
<td>0.0046</td>
<td>9.5</td>
<td>0.0042</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0019</td>
<td></td>
<td>0.0015</td>
</tr>
<tr>
<td>WB Semi-Truck</td>
<td>68</td>
<td>0.0059</td>
<td>9.3</td>
<td>0.0048</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0019</td>
<td></td>
<td>0.0016</td>
</tr>
<tr>
<td>WB Truck</td>
<td>216</td>
<td>0.0035</td>
<td>6.8</td>
<td>0.0037</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0016</td>
<td></td>
<td>0.0012</td>
</tr>
</tbody>
</table>

A typical waveform event produced by an eastbound bus impacting the mid-bridge joint is shown in Figure 20. A typical waveform event produced by a westbound bus passing by the River Bank Lofts building and onto the bridge is shown in Figure 21. These two plots demonstrate the difference in the vibration responses produced by the same vehicle travelling in different directions on the bridge.
In the waveform display in these figures, the 10-second acceleration waveforms of all eight sensors are displayed in a single plot window with a vertical spacing of 0.2 g between traces, where 1g is acceleration due to gravity (9.8 m/s² or 386.04 in/sec²). The individual sensor designations are listed below, from top to bottom:

1. Basement Unit 002, near Column 8L, horizontal, north-south
2. Basement Unit 002, near Column 8L, horizontal, east-west
3. Basement Unit 002, near Column 8L, vertical
4. Basement near south end of Unit 002, vertical
5. Unit 602, 10 ft north of Column 8L, horizontal, north-south
6. Unit 602, 10 ft north of Column 8L, horizontal, east-west
7. Unit 602, 10 ft north of Column 8L, vertical
8. Top floor, 10 ft north of Column 8L, vertical

**Measurements at Street Level**

The vibrations measured at street level were obtained in order to help evaluate the vibrations entering the building and the source of the predominant vibrations. Pictures captured with the webcam were used to assist with the subsequent categorization of the events. The events captured by the system were sorted into the same categories of eastbound and westbound trucks and busses, as well as cars and the test truck. A summary of the vibrations captured by the system during this test period is provided graphically in the amplitude-versus-time and amplitude-versus-frequency plots for each of the four monitored locations. The vibration levels that were measured in the captured events are summarized in the following table.

<table>
<thead>
<tr>
<th>Category</th>
<th>Location A</th>
<th>Location B</th>
<th>Location C</th>
<th>Location D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g, max</td>
<td>Hz</td>
<td>g, max</td>
<td>Hz</td>
</tr>
<tr>
<td>EB Bus, Truck or Semi</td>
<td>0.0069</td>
<td>9.8</td>
<td>0.0116</td>
<td>5.8</td>
</tr>
<tr>
<td>WB Bus, Truck or Semi</td>
<td>0.0109</td>
<td>7.6</td>
<td>0.0122</td>
<td>7.7</td>
</tr>
<tr>
<td>EB Test Truck, Between Lanes</td>
<td>0.0020</td>
<td>5.8</td>
<td>0.0034</td>
<td>5.8</td>
</tr>
<tr>
<td>EB Test Truck, Right Lane Over Steel Plate</td>
<td>0.0013</td>
<td>5.7</td>
<td>0.0061</td>
<td>7.0</td>
</tr>
<tr>
<td>WB Test Truck, Right Lane, Left Wheel on Manhole Cover</td>
<td>0.0024</td>
<td>6.1</td>
<td>0.0060</td>
<td>6.9</td>
</tr>
<tr>
<td>WB Test Truck, Left Lane, Right Wheel on Manhole Cover</td>
<td>0.0022</td>
<td>7.0</td>
<td>0.0035</td>
<td>6.8</td>
</tr>
<tr>
<td>WB Test Truck, Abutment &amp; Transition to Bridge Deck</td>
<td>0.0017</td>
<td>6.4</td>
<td>0.0040</td>
<td>6.6</td>
</tr>
<tr>
<td>WB Test Truck, Left Lane, Right Wheel on Manhole Cover</td>
<td>0.0026</td>
<td>6.4</td>
<td>0.0092</td>
<td>6.4</td>
</tr>
<tr>
<td>WB Test Truck, Left Lane, Right Wheel on Manhole Cover</td>
<td>0.0037</td>
<td>6.5</td>
<td>0.0020</td>
<td>5.0</td>
</tr>
</tbody>
</table>

The vibration levels that were measured in the captured events are summarized in the following table.
The frequencies listed in this table for the normal traffic were taken as the average frequency of all the events in the respective category. Locations A through D responded at frequencies from approximately 6 to 9.5 Hz, likely the natural frequencies of the different locations of the sidewalk framing. Location C responded most often at about 9 Hz and had the largest magnitudes of vibration, likely because this location is next to the bridge pinion; vibrations from the bridge roadway apparently transmit most readily through the pinion and into the adjacent fixed framing and sidewalk framing.

**Comparison to Perception Thresholds**

The International Standards Organization (ISO) International Standard 2631-1 “Mechanical Vibration and Shock - Evaluation of Human Exposure to Whole-Body Vibration - Part 1: General Requirements” provides a means of evaluating transient (short duration) vibrations with regard to human perception. This standard defines the mean threshold of perception as a frequency-weighted peak acceleration of 0.015 m/s² (0.0015 g, peak). The frequency weighting functions are defined in the ISO standard, which includes a statement that “occupants of residential buildings are likely to complain if vibration magnitudes are only slightly above the perception threshold.” At 9.1 Hz, the threshold of perception is 0.0015 g, which corresponds to a peak particle velocity of 0.010 in/s. Previous experience that we have with vibration-related complaints from occupants in buildings suggests that a threshold of 0.011 in/s is applicable to rumbling, or pseudo-transient, vibrations. This experience supports the use of the 0.0015 g frequency-weighted threshold for incidence of complaints from randomly-occurring transient vibrations.

The vibration amplitudes from vehicle-related events are plotted in Figures 23, 24, and 25 as peak vertical acceleration versus frequency for each of the 3 monitoring locations. These plots show that the basement-level locations were excited at frequencies from approximately 5.5 to 9.5 Hz. The top floor location responded almost exclusively at approximately 9 Hz. The plots also demonstrate that most of the vehicle-related vibration events exceeded the ISO threshold of perception for transient vibrations by a significant margin, and as such are expected to be disturbing to building occupants.

Vibrations produced by activity within the condominium units typically occurred at higher frequencies and did not typically excite significant amplitude response in the range of 5.5 to 9.5 Hz. Because they occurred at higher frequencies they did not have as much potential for exceeding the perception threshold. They were likely the result of localized impacts near the sensor or activities such as vacuuming or possibly household pets disturbing the sensor.

**Results from Street Level Tests**

The accelerations measured along the north side of Grand Avenue are presented graphically in the amplitude-versus-time plots of Figures 26 through 29 and the amplitude-versus-frequency plots of Figures 30 through 33. The comparison of the frequency plots for the street level measurements indicates that the ground vibrations measured at Locations A through D occur in the frequency range of 5.5 Hz to 9.5 Hz. This is essentially the same range of frequencies as those measured in the basement locations of Unit 002. However, the magnitude of vibration in the basement location was generally smaller than the magnitude measured at street level since it is farther from the vibration source. Location C responded most often at 9.5 Hz, which closely corresponds with the frequency measured at the top floor location above Unit 602. The magnitude of vibration measured at Location C was very similar to the magnitudes measured at the top floor.
EXAMINATION OF THE BRIDGE STRUCTURE

Three possibly relevant observations were made about the bridge structure during the street level monitoring period.

1) The first observation was the comparison of the slide-bolt locking mechanisms on the north and south sides of the bridge. The mechanism on the north side of the bridge has a much tighter fit between the beam and the rectangular frame that it slides through than the mechanism on the south side. On the north side mechanism, the gap between the top of the sliding beam and the frame is filled with steel shim plates that are welded in place. On the south locking mechanism, there is a clear gap of at least 1/8 in. in the frame on the west side of the joint.

The mechanisms were closely observed while several large vehicles passed over the bridge. When a heavy eastbound vehicle passes over the bridge in the furthest south lane (closest to the south edge), the east end of the west leaf drops with respect to the west end of the east leaf just as the heavy wheel of the truck or bus reaches the end of the west leaf. This was visibly evident when watching the gap between the frame on the west side of the joint and the beam that slides through it. This produces a “step” as the wheel travels toward the east leaf. It causes the wheel to impact the edge of the east leaf. On the north side of the bridge, the same phenomenon did not appear to occur.

2) There are two areas in the east leaf where the driving surface consists of steel grating. The grating is welded to the structural steel framing below it. The CDOT engineer observed that the welds between the one of the grating sections and the transverse beam below it were broken. This caused the vehicles to produce an impacting noise as they passed over the grating.

3) We examined the area below street level, in the chamber surrounding the bridge counterweight and pinion gear. The examination revealed that the vault area below the bridge and the River Bank Lofts building share a common wall. The sidewalk along the north edge of Grand Avenue is in direct contact with the south wall of the building. The fixed framing and sidewalk framing west of the abutment, shown in Figure 17, comprise the roof of the vault, and the sidewalk framing is in direct contact with and may gain secondary support from the south wall of the building. It was apparent that any vibrations occurring on the bridge or in the pavement of the approach slab would readily transmit into the building through this contact.

CDOT provided WJE with a compact Disc containing all of their available drawings of the Grand Avenue Bridge. Selected original drawings dated 1910-1913 are shown in Figures 34 through 37. These drawings show the proximity between the River Bank Lofts building and the sidewalk framing. The plan drawings appear to show that the primary structural framing of the bridge is independent from (i.e., not structurally connected to) the building wall. However, there are no sections indicating the nature of the separation. Observations made during the visual examination indicate that the sidewalk structure is in direct contact with and may gain secondary structural support from the south wall of the building, as shown in the photograph in Figure 38.

All three of these items were examined by the CDOT Engineer and remedial actions were determined at the time of the examination. At the locking mechanism on the south end of the joint, the gap between the frame on the west side of the joint and the sliding beam will be closed by inserting an appropriately sized steel shim plate and welding it into position. The broken welds between the grating and the framing were to be repaired soon after the testing was completed. The north edge of the sidewalk is intended to be separated from the south wall of the River Bank Lofts building and, if necessary, supported by columns.
bearing on the floor slab below. Details of the sidewalk separation/modification warrant further study by CDOT.

**DISCUSSION**

Vehicles travelling on Grand Avenue and on the Grand Avenue Bridge produce vibrations that transmit into the River Bank Loft building. At both the basement and top floor levels of the building, vibration amplitudes are large enough to be considered perceptible and likely disturbing to occupants. However, the magnitude of vibrations on the top floor of the building is significantly larger than at the basement level. The traffic-induced vibrations on the top floor occur primarily at approximately 9 Hz, while the vibrations at the basement level occur at frequencies in the range of 5.5 to 9.5 Hz. The review of the captured vibration events indicate that the largest vibrations occur when eastbound busses or heavily-loaded trucks, travelling in the right lane, cross the joint at the middle of the bridge where the east and west leaves of the bridge meet. Lesser, though still above-threshold vibrations are caused by other heavy vehicles travelling in both the eastbound and westbound directions over the bridge.

The fact that the top floor responds to the traffic-induced vibrations almost exclusively at 9 Hz indicates that it is, or at least is very close to, the fundamental frequency of the building framing system at the location of the sensor. It could be described as the frequency at which the framing responds with the least amount of resistance. External dynamic forces from impacts or other transient sources may occur at a variety of frequencies, but the response of a structure to these forces tends to occur at the fundamental frequency of the structure, or sometimes a multiple thereof. At the basement level, the frequency of the response occurs in a range from approximately 5.5 to 9.5 Hz, likely due to the more complicated vibration attenuation characteristics of the supporting soil and grade-level structure at the basement.

The magnitude of the response at the top floor is notably larger than the response at the basement level. Vibrations from sources external to the building apparently transmit quite readily up through the vertical masonry walls and then affect the upper level floors that are supported by the walls. On the other hand, to reach the basement level floors, the vibrations likely transmit primarily through the soil and grade-supported elements, which tend to dampen the vibrations somewhat.

**CONCLUSIONS AND RECOMMENDATIONS**

The investigation of vibrations in the River Bank Lofts building, north of the Grand Avenue Bridge, demonstrated that heavy vehicles travelling on the bridge produce perceptible and likely disturbing levels of vibration within the building. The largest magnitudes of vibration occur when eastbound busses or heavy trucks drive over the south end of the mid-bridge joint. The cause of these large vibration events was identified as a loose fit in the remedial locking mechanism on the south end of the joint between the east and west leaves of the bascule bridge. The loose fit allows differential vertical movement between the east and west leaves of the bridge as the wheels of the heavy vehicles pass from the west leaf to the east leaf. When the wheels hit the west edge of the east leaf, the impact produces a dynamic response in the west leaf of bridge structure, which is transmitted into the building due to the continuity of the sidewalk framing and building wall. Other heavy vehicles travelling in both directions on the bridge cause lesser, though still above-threshold vibrations within the building.

The largest magnitudes of vibration occur on the upper floors of the building. The fundamental frequency of the floor structure appears to be very close to the frequency of the vibrations produced on the bridge by impacts on the roadway and at the mid-bridge joint. The basement level condominium unit responds to the same range of frequencies that are produced in the bridge structure, but at reduced levels.
Although westbound and eastbound trucks and busses all produce vibrations with magnitudes that could be considered perceptible, it is our understanding that the complaints from building occupants are attributed only to the vibrations typically produced by impacts from heavy vehicles at the south end of the mid-bridge joint. This suggests that the actual disturbance threshold is higher than what we have used in this evaluation. The incidence of complaints could be significantly reduced, or eliminated, by tightening the gap in the locking mechanism on the south side of the bridge. This would significantly reduce the occurrences of dynamic energy entering the building.

Given the results of this study, it would also be prudent to keep the adjacent roadway surfaces in good condition in order to limit rumbling and localized impacts on the roadway from heavy vehicles, which could also produce perceptible levels of vibrations within the building.

Separation of the sidewalk structure from the south wall of the building would further reduce the magnitude of dynamic energy entering the building from the bridge structure. Because the sidewalks are primarily supported by framing that does not appear to be bearing on the building wall, it would likely not be necessary to provide any additional vertical support for the short span of sidewalk slab that extends north of the last east-west girder. Whatever gap is produced between the structures should be filled with a soft elastomeric expansion joint material to prevent water ingress and limit vibration transmission.
Figure 1. View toward the East, across the Grand Avenue Bridge, toward the River Bank Lofts building.
Figure 2. River Bank Lofts building, partial basement floor plan showing vibration sensor locations (blue dots) and proximity to Grand Avenue and the bridge.
Figure 3. River Bank Lofts building, partial 6th floor plan showing vibration sensor location (blue dot). Top floor location is directly above this location.
Figure 4. Locking mechanism at the center joint on the south side of the Grand Avenue Bridge.
Figure 5. View of interior in Unit 002 (Photo taken on January 15, 2009).
Figure 6. View of interior in Unit 002 (Photo taken on January 15, 2009).
Figure 7. View of the interior in Unit 002 (Photo taken on January 15, 2009).
Figure 8. View of the interior in Unit 002 - close-up of corner shown in Figure 7 (Photo taken on January 15, 2009).
Figure 9 View of the interior in Unit 602 (Photo taken on January 15, 2009).
Figure 10. View of the interior in Unit 602 (Photo taken on January 15, 2009).
Figure 11. View of the interior in Unit 602 (Photo taken on January 15, 2009).
Figure 12. View of the interior of Unit 602 (Photo taken on January 15, 2009).
Figure 13. View of the interior of Unit 602 (Photo taken on January 15, 2009).
Figure 14. View of the interior of Unit 602 (Photo taken on January 15, 2009).
Figure 15. View of the interior of Unit 602 (Photo taken on January 15, 2009).
Figure 16. Typical view of east-bound truck crossing the mid-bridge joint.
Figure 17. Schematic plan view at the east end of the Grand Avenue Bridge showing vibration measurement locations.
Figure 18. Event triggered by eastbound city bus. Top 4 traces located at the basement level. Bottom 4 traces at the top floors.
Figure 19 Event triggered by westbound city bus. Top 4 traces located at the basement level. Bottom 4 traces at the top floors.
Figure 20. Vertical Accelerations Measured on the Ground Floor near Column 8L at the River Bank Lofts
Figure 21. Vertical Accelerations Measured in the Basement, South End of Unit 002, at the River Bank Lofts
Figure 22. Vertical Accelerations Measured on the Top Floor above Unit 602 at the River Bank Lofts
Figure 23. Vertical Acceleration Amplitude versus Frequency Measured in the Basement Near Column 8L at the River Bank Lofts.
Figure 24. Vertical Acceleration Amplitude versus Frequency Measured near the South End of Unit 002 at the River Bank Lofts.
Figure 25. Vertical Acceleration Amplitude versus Frequency Measured on the Top Floor above Unit 602 at the River Bank Lofts.
Figure 26. Vertical Accelerations Measured Along North Side of Grand Avenue at Location A.
Figure 27. Vertical Accelerations Measured Along North Side of Grand Avenue at Location B.
Figure 28. Vertical Accelerations Measured Along North Side of Grand Avenue at Location C.
Figure 29. Vertical Accelerations Measured Along North Side of Grand Avenue at Location D.
Figure 30. Amplitude versus Frequency Plot of Vertical Accelerations Measured Along North Side of Grand Avenue at Location A.
Figure 31. Amplitude versus Frequency Plot of Vertical Accelerations Measured Along North Side of Grand Avenue at Location B.
Figure 32. Amplitude versus Frequency Plot of Vertical Accelerations Measured Along North Side of Grand Avenue at Location C.
Figure 33. Amplitude versus Frequency Plot of Vertical Accelerations Measured Along North Side of Grand Avenue at Location D.
Figure 34. Drawing of the grand Avenue Bridge structure, circa 1910, provided by DCOT.
Figure 35. Drawing of the grand Avenue Bridge structure, circa 1910, provided by DCOT.
Figure 36. Drawing of the grand Avenue Bridge structure, circa 1910, provided by DCOT.
Figure 37. Drawing of the Grand Avenue Bridge structure, circa 1910, provided by DCOT.
Figure 38. Looking at the underside of the sidewalk, at the northeast corner of the vault beneath the Grand Avenue Bridge east approach.