CONSTRUCTION VIBRATIONS IN THE CITY OF EDMONTON

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1. Introduction

The City of Edmonton conducts vibration monitoring in response to vibration complaints or damage claims from the public due to vehicular traffic on uneven road surfaces. Over time, vibration monitoring services have expanded to include construction vibrations during neighborhood renewal projects (residential), streetscape reconstruction in commercial areas, building demolition and pile driving. The following paper presents some of the data collected from traffic vibration monitoring and over 500 construction-related vibration tests which includes a variety of construction equipment collected from demolition, neighborhood reconstruction, and commercial high rise buildings.

2. Method

The City's Roadway Maintenance department has adopted an "annoyance" value of 2.5 mm/s Peak Vector Sum (PVS) to evaluate whether further assessment or action is prudent. The City of Edmonton has adopted the frequency-based US Bureau of Mines USBM RI 8507 criteria to evaluate the potential risk to residential buildings due to vibration (Dowding 1996). For commercial buildings, both USBM-R18507 and the German DIN4150 guidelines are referred to for context.

An Instantel Mini Mate Pro 6 triaxial vibration sensor with dual geophones and datalogger was used to collect data. Vibration monitoring requires measurement of particle velocities and frequencies in 3 directions: vertical, longitudinal and transverse. The vibration source, transmission path and the potential receiver are considered in sensor placement and test duration.

Monitoring equipment is set in histogram combo mode which allows peak values to be displayed throughout the assessment at set intervals. This mode also generates a waveform during histogram recording if the signal exceeds the trigger level.

Vibration test results are presented as Peak Vector Sum (PVS) since this method reflects the effect of all three directional components. Individual waveforms provide the Maximum Peak Particle Velocity (PPV) and frequency level for each axis. The most dominant frequencies for each axis are also reported. The PVS typically occurs concurrently with the PPV of one of the components, but the addition of the two components slightly increases its magnitude.

The USBM-RI8507 guideline is represented graphically, and considers both the PPV and frequencies (Figure 1 and Figure 2). The USBM-RI8507 "simplified approach" provides criteria at two specific frequencies, < 40Hz and > 40 Hz. The guideline levels for modern drywall homes and older plaster homes are most commonly referred to (19.1 mm/s and 12.7 mm/s at <40Hz, respectively). Guideline levels increase to 50.8 mm/s at > 40 Hz (Siskand 1980, Kalinski 2007).

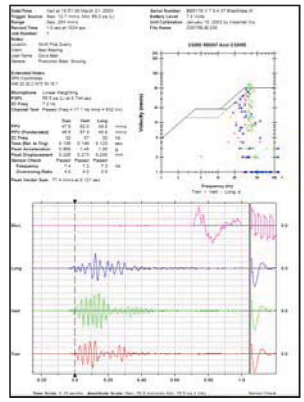

Figure 1

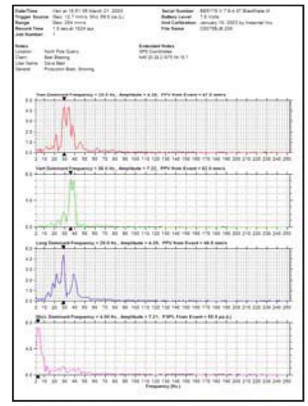

Figure 2

The equipment set-up protocol and sensor coupling method depends on the nature of the assessment. Sensor coupling methods include:

1. 12-inch steel probe with a horizontal sensor-mounting plate, pounded into the ground; or
2. Sand bag placed on top of sensor; or
3. Wall bracket, where the sensor is mounted horizontally.

3. Roadway Maintenance Complaints

Numerous residential vibration complaints come to the city help line each year, usually due to vehicular traffic (primarily large vehicles such as buses). Large cracks, potholes and infrastructure repair are the most common root-cause. Only some of the complaints progress to vibration testing; many of the immediate concerns are corrected by road resurfacing where the problems are obvious. The City conducts approximately twenty vibration tests a year.

Table 1: Roadway maintenance-related vibration assessments on residential properties (Sample of 26 homes tested)

	Maximum Peak Vector Sum (PVS) – mm/s Frequency level at most prominent axis							
	> 10		5 to 10		2.5 to 5		< 2.5	
Frequency	<40Hz	>40Hz	<40Hz	>40Hz	<40Hz	>40Hz	<40Hz	>40Hz
Sensor at property line	-	-	2	3	5	1	12	3
Sensor at foundation	-	-	-	-	5	-	20	1

Typical Distance: Curb to Property Line ~2.0 meters
Curb to Foundation ~10 meters

Note: the simplified USBM RI8507 suggests that a PPV of 12.7 mm/s could result in minor damage to plaster-on-lath interiors of older structures for vibration frequencies of <40Hz

Historically, one sensor was placed at the property line. With the purchase of the Mini Mate Pro 6 Vibration Unit an additional vibration sensor is now placed at the foundation. All triggered events are examined over a 24 hour collection period.

4. Neighborhood Renewal

The City's Neighborhood Renewal Program focuses on upgrade and replacement roads, sidewalks, streetlights and gutters. Reconstruction processes include sidewalk removal and demolition, utility work, street light installation, sidewalk and subgrade reconstruction, pouring of concrete for sidewalks, asphalt pulverization and re-compaction, curb construction, and paving. Numerous construction equipment and different construction processes are monitored for vibration impacts.

Vibration data was collected at selected test houses of typical construction and age for the neighborhood. Baseline vibration levels due to normal traffic were collected prior to construction. The equipment trigger level was set to 1mm/s. The highest vibration events were tabulated for each test site during each major construction process or equipment usage. Using this selection method, all of the events evaluated exceeded the perception threshold of 0.5 – 1 mm/s, meaning that a resident standing near the sensor would notice the vibrations.

Of the 233 peak events selected for evaluation, 8% were above 10 mm/s, which are considered to be "disturbing" and approaches the USBM guideline value of 12.7 mm/s for potential risk of cosmetic damage in older and plaster-and-lath interiors. The data demonstrates that the backhoe with breaker generated the greatest magnitude and greatest percentage of peak vibration events, followed by the vibrating steel roller, and the vibrating padfoot roller (Table 2).

Table 2: Construction equipment vibrations during neighborhood renewal.

Type of equipment	# of times used	Typical Frequency Hz	Maximum Peak Vector Sum (PVS) (mm/s)			
			> 10	5 to 10	2.5 to 5	< 2.5
Backhoe with breaker or bucket	34	<40	6	12	8	8
Vibrating steel roller	53	<40	9	24	16	4
Vibrating pad foot roller	18	<40	2	11	5	0
Hand tamper (1000 lb steel plate)	10	<40	1	3	3	3

Both sensors at foundation: foundation ~10 meters to curb

The removal of sidewalks, catch basins and curb-and-gutter generate significant peak vibration events (Table 3). Most of the concrete removal work was conducted using the backhoe with breaker, identified as one of the three pieces of equipment that generated the highest vibrations during this study. Contact the author for details about the numerous types of equipment used.

Table 3: Vibrations during neighborhood renewal processes.

Type of process	Maximum Peak Vector Sum (PVS)mm/s			
	> 10	5 to 10	2.5 to 5	< 2.5
Asphalt removal	0	0	0	4
Road compaction	1	2	3	4
Sidewalks, catch basins, curb & gutter, demo & reconstruct	7	20	12	13
Pulverization	2	13	7	10
Foaming	3	11	2	12
Paving	4	10	10	32

5. Down Town (Commercial)

Streetscaping activities in the downtown core were monitored, where the construction activities (vibration sources) are typically in close proximity to large commercial properties including high rises and the underground Light Rail Transit system.

Table 4: Construction vibrations during commercial streetscaping

	Maximum Peak Vector Sum (PVS) – mm/s Frequency level at most prominent PPV / Axis									
	>50		10 to 50		5 to 10		2.5 to 5		< 2.5	
Frequency	<40 Hz	>40 Hz	<40 Hz	>40 Hz	<40 Hz	>40 Hz	<40 Hz	>40 Hz	<40 Hz	>40 Hz
Drainage Pipe Replacement	-	2	4	6	-	-	2	-	1	
Road Construction	-	-	2	2	-	1	7	7	10	3

Both sensors at building foundation, 2 to 3 meters from curb

A large-track backhoe with a 4" pin hammer produced the highest vibrations and frequencies. Equipment size and the short distance to the building had a dramatic impact on magnitude.

6. Other Vibration Project

Vibrations were monitored during a major downtown demolition project. The proximity of the neighboring high-rise created space constraints, and particular business concerns necessitated the development of a custom sensor coupling method. A steel wall-mount bracket was fabricated and installed into an interior concrete wall (~ground level) of the adjacent high rise, with the geophones mounted horizontally onto the bracket. Vibration data was collected during demolition which entailed a top-down dismantling of the building, where the debris was dropped down the elevator shaft. Large equipment movements and pile removal also took place.

A large backhoe with a pin-hammer generated the highest PPV measurements: 13.9 mm/s at 3.3 Hz, 69.2 mm/s at >100Hz and 38.2 mm/s at >100 Hz in the transverse, vertical and longitudinal direction respectively. The PVS was 78.9 mm/s. In general the vertical sensor axis was most impacted during this assessment.

7. Conclusions

Equipment selection and distance from source to receiver are major factors influencing the magnitude of measured vibrations. The backhoe with breaker during concrete demolition generated the highest measured vibrations. Historic vibration data combined with real-time data on various equipment and processes provides valuable context and a better understanding of potential risks to buildings, which is invaluable where pre-construction inspections of impacted property were not possible or practical.

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