12th National LRT Rail Conference

Noise and Vibration Issues of Modern Streetcars

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Some Streetcar Projects

Vancouver
Seattle
Portland
Tucson
Tempe
New Orleans
Washington
DC
Los Angeles
Sacramento
Reno
Kansas City
Milwaukee
Ft Lauderdale
Austin
Dallas
Cincinnati
Atlanta
Oklahoma City
New Haven
Stamford
DC
Hampton Roads
Montreal
Vancouver
Montreal
New Haven
Stamford
DC
Hampton Roads
Issues in Recent Projects

• Limited information available on noise and vibration characteristics
• Relatively high speeds in some area
• Route passing through university research area
• Special trackwork that will be located near residences
• Wheel squeal
Portland Streetcar Noise Spectrum

Measured Streetcar Noise Level, Lmax

A-Weighted Sound Level, dB re 20 μPa

1/3 Octave Band Center Frequency, Hz

Corrugation
Building Reflections
Relatively New Track
S squeal

Site 1 (20 mph)
Site 2 (20 mph Near Track)
Site 2 (16 mph Far Track)
Site 3 (15 mph)
Streetcar Noise versus Speed

Streetcar Measurements:
- $L_{\text{max}} = 72$ dBA @ 15 mph
- $L_{\text{max}} = 73$ dBA @ 20 mph
- $L_{\text{max}} = 75$ dBA @ 25 mph

LRT Embedded Track:
- $L_{\text{max}} = 81$ dBA @ 40 mph

Wheel Equipment Noise Regime

Transition Regime

Wheel/Rail Noise Regime

FTA Speed Adjustment

12*log(Speed)

30*log(Speed)
Streetcar Vibration Force Density

Streetcar FDL

Force Density Level, dB re 1 lb/ft$^2$

1/3 Octave Band Center Frequency, Hz

- SLU Purple, 25 mph
- SLU Blue, 25 mph
- Portland Site A 2007, 25 mph
- Portland Site B 2007, 25 mph
- Portland Site C 2011, 25 mph
Streetcar Vibration Force Density

Streetcar FDL (Composite)

- SLU Purple, 25 mph
- SLU Blue, 25 mph
- Portland Site A 2007, 25 mph
- Portland Site B 2007, 25 mph
- Portland Site C 2011, 25 mph
- Composite FDL, 25 mph

Force Density Level, dB re 1 lb/ft^{1/2}

1/3 Octave Band Center Frequency, Hz

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acoustics, transportation + strategy
Streetcar versus LRT Force Density

Streetcar & LRT Force Density

- Hiawatha Emb, 25 mph
- TriMet Emb, 25 mph
- Portland Streetcar, 25 mph

Force Density Level, dB re 1 lb/ft²

1/3 Octave Band Center Frequency, Hz

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Case Study 1: Tucson Streetcar

National Optical Astronomy Observatory (NOAO)
Case Study 1: NOAO Measurements

Revised Alignment

Impact Line

North Cherry Avenue

North Warren Avenue

East 2nd Street

300 Feet
Case Study 1: NOAO Vibration

Predicted Vibration: Optics Lab

RMS Velocity Level, Y dB re 1 μm/sec

1/3 Octave Band Center Frequency, Hz

- Ambient (air handlers off)
- Ambient (air handlers on)
- Predicted Vibration: Optics Table Floor
- VCE
Case Study 1: Tucson Streetcar

Conclusion for NOAO, Mitigation required

Options:
1. Track treatment to reduce vibration levels in 16 to 30 Hz range (approximately $0.5M to $1M)
2. Purchase new equipment interferometer equipment that is not vibration sensitive (~$150k)
Case Study 2: New Orleans Streetcar

New Orleans Union Pacific Terminal (NOUPT)

French Quarter
Case Study 2: NOUPT Streetcar
Case Study 2: N&V Impacts from Frogs
Case Study 2: NOUPT Streetcar

Conclusion: Potential Vibration Impacts from Wheel Impacts at Special Trackwork Frogs
- Mitigation: “Low Impact” frogs
Case Study 3: Tempe Streetcar
Case Study 3: Tempe Streetcar

• Conclusion: Potential for vibration impact (20 residences) because of 40 mph speed and proximity to residences

• Mitigation options:
  1. Low vibration trackforms
  2. Maintenance to minimize vibration
Rail Roughness Measurements
Results of Rail Roughness Measurements
Conclusions

- Streetcars do not have noise and vibration issues under normal conditions (low speed, busy urban areas).
- Potential for noise and vibration issues when:
  - Speeds will exceed 25 mph
  - Streetcar route is close to buildings housing sensitive equipment
  - Special trackwork will be located near sensitive receptors
- Several track-based mitigation options are available to reduce vibration
- Maintenance of optimal wheel profile and smooth rails could reduce N&V levels