SOUND TRANSIT LIGHT RAIL VIBRATION ISSUES AT THE UNIVERSITY OF WASHINGTON

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MODERN RESEARCH ENVIRONMENTS

Highly Competitive
Attractiveness of Site
State-of-the-Art Research:
  Gravitation
  Semiconductor Research
  Nanotechnology
PRELIMINARY ENGINEERING

Discussion with UW
Vibration Design Criteria
Vibration Impact Evaluation
LSR Testing at UW
FDL Testing at San Jose
Mitigation
Criteria For Vibration Sensitive Activities

- FTA criterion is based on levels acceptable for most moderately sensitive equipment such as optical microscopes - 65 VdB.
- APTA Criteria for Vibration Sensitive Industrial or Research Laboratory – 70 to 60 dB
- ISO Criteria for Operating Theaters – 72 dB.
- Institute of Environmental Sciences (IES) – 66 to 42 dB.

NEW IES CRITERIA

1/3 Octave rms Velocity – µm/s

<table>
<thead>
<tr>
<th>Frequency, Hz</th>
<th>Workshop (ISO)</th>
<th>Office (ISO)</th>
<th>Residential Day (ISO)</th>
<th>Operating Theater (ISO)</th>
<th>VC-A (50 µm/s)</th>
<th>VC-B (25 µm/s)</th>
<th>VC-C (12.5 µm/s)</th>
<th>VC-D (6.25 µm/s)</th>
<th>VC-E (3.12 µm/s)</th>
<th>VC-F (1.56 µm/s)</th>
<th>VC-G (0.781 µm/s)</th>
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1/3 Octave Velocity Level – dB re 1min/s

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</table>
“In order to preserve the ambient condition for current and future research activities on the UW campus, the UW wishes Sound Transit to design a train that limits the ST Vibration to be equal to or less than the measured ambient vibration spectra at each building foundation. The train generated vibration levels should be expressed in terms of maximum amplitude per each 1/3 octave band frequency determined at the distance of closest approach for each building under consideration. Using these definitions, the UW requests that the train vibration levels be less than or equal to the current ambient vibration levels. This criteria needs to be met using source mitigation only.”
PREDICTION APPROACH

FTA Methodology – FDL, LSR

\[ \text{Lv} = \text{FDL} + \text{LSR} \]

FDL = Force Density Level
LSR = Line Source Response

KINKI SHARYO FDL

![Graph showing FDL values for different speeds and frequencies.](image-url)
COMPARISON OF LIGHT RAIL FDL'S

FREQUENCY - Hz

MODULATION ENVELOPE

Frequency - Hz

Power Spectrum

55 MPH
LSR ESTIMATION

Borehole Impact Tests
Vertical Seismic Velocity Surveys
Numerical Modeling of Layered Soil
Extrapolation to Large Offset
BORE HOLE TEST

PSR CURVE FIT

Distance - Feet

Point Source Response - dB re 1 micro-in/sec/lb

16 Hz
- 253 120 ft 140 lb
- 254 110 ft 140 lb
- 255 115 ft 140 lb
- 256 110 ft 140 lb
- 253 120 ft 300 lb
- 254 110 ft 300 lb
- 255 115 ft 300 lb
- 256 110 ft 300 lb

+1 STDEV
Best Fit

SOUND TRANSIT  PSTC / PARSONS BRINCKERHOFF  WILSON IHRIG & ASSOCIATES
Vibration Velocity at 100 Feet from Track Center Line
Train Length=380 ft Source Depth=110-120 ft

SEISMIC WAVE VELOCITIES

- NB-123-P
- NB-255-P
- NB-253-P
- NB-354-P

- NB-123-S
- NB-255-S
- NB-253-S
- NB-354-S

- NB-259-P
- NB-256-P
- NB-259-S
- NB-356-P
- NB-356-S

SOUND TRANSIT  PSTC / PARSONS BRINCKERHOFF  WILSON IHRIG & ASSOCIATES
LONG RANGE NUMERICAL MODEL PREDICTIONS

IMPOSE RESPONSE - dB RE 1E-6 M/SLB

FREQUENCY - HZ

MODELED VS MEASURED LSR

1/3 Octave LSR

dB re 1 (micro-in/sec/ft)\textsuperscript{1/2}

Frequency - Hz

Mean Theoretical Values

Mean Measured LSR

100 ft Offset

SOUND TRANSIT PSC / PARSONS BRINCKERHOFF WILSON IHRIG & ASSOCIATES
WILCOX HALL 30-40 MPH

GROUND SURFACE
110 FT OFFSET, 100 FT DEPTH

BAGLEY HALL 45-55 MPH

Ground Surface Vibration Velocity
VIBRATION CONTROL PROVISIONS

Avoidance of Core Buildings
16Hz Floating Slab
Resilient Direct Fixation Fasteners
Moveable Point Frog
Speed Reduction
Single Train Operation
Wheel&Rail Maintenance
Monitoring
FINAL ENGINEERING

FDL Test of Sound Transit Vehicle
4Hz Floating Slab – GERB Spring
Rail Straightness
Long wave rail grinding
Wheel Runout
Wheel/Rail Profiles

CONCLUSION

Future
   Technological Research
   Increasing demand for transit
Prediction Methods
   Geophysical testing
   Modeling
Control
   Low Frequency Floating Slabs
   Rail Straightness
   Wheel Runout