Workshop on Vibration

AEP January 2010

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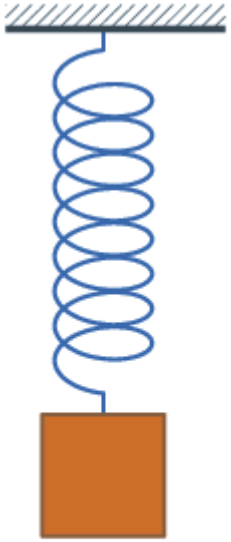
Exercise: Vibration Sources

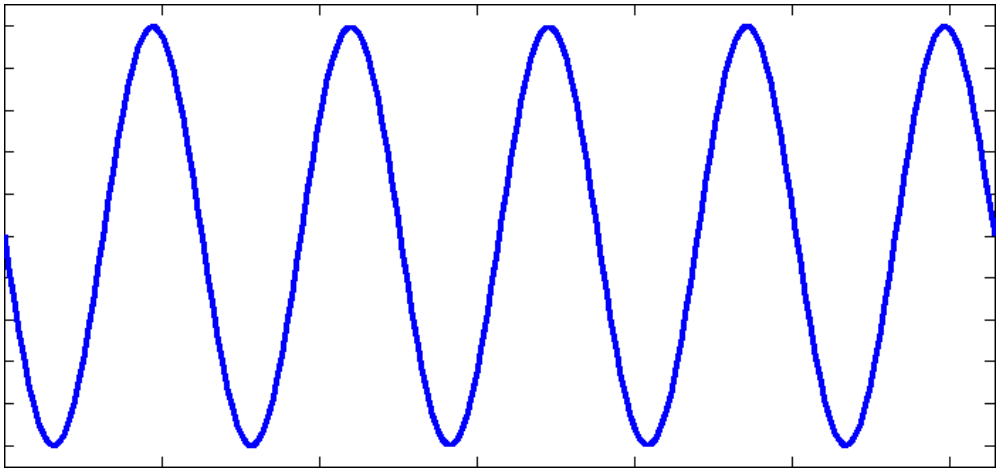
Crack and Seat Pavement Rehab

Vibration Fundamentals

- *Oscillating movement* of an *elastic solid* created by an *un-balanced force*

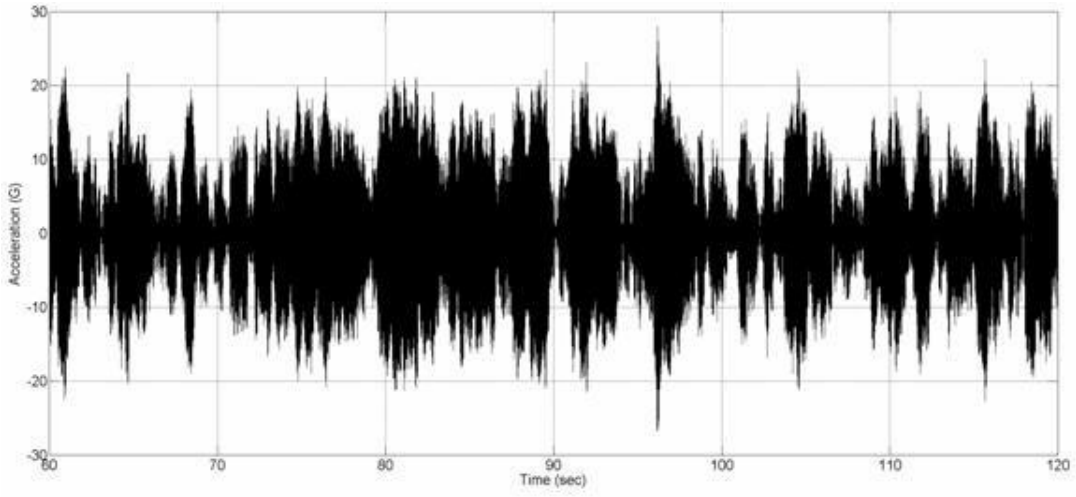
Periodic Vibration



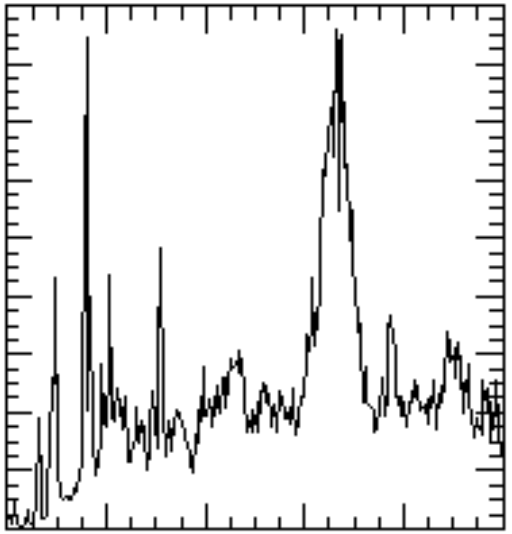


Random Vibration

Time



Frequency



Vibration vs. Groundborne Noise

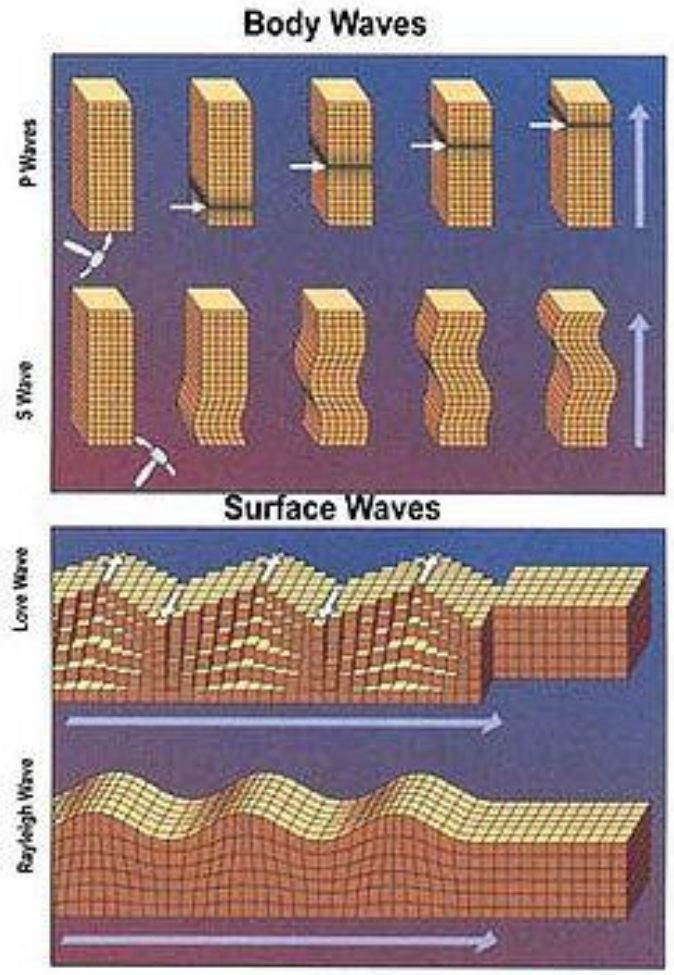
- Both propagate as vibration waves through the ground
- Vibration is detected by touch
- Noise is detected by hearing

Exercise: Rank Source Levels

Source	Rank	PPV at 25ft
Bulldozer	3	0.09
Loaded Dump Truck	4	0.08
Jack Hammer	5	0.04
Impact Pile Driving	2	0.14
Crack and Seat	1	2.4

Propagation – Wave Types

- Compression (P) – like a rope
- Transverse (S) – like a slinky
- Love (SH) – surface shear
- Rayleigh – like a rolling egg

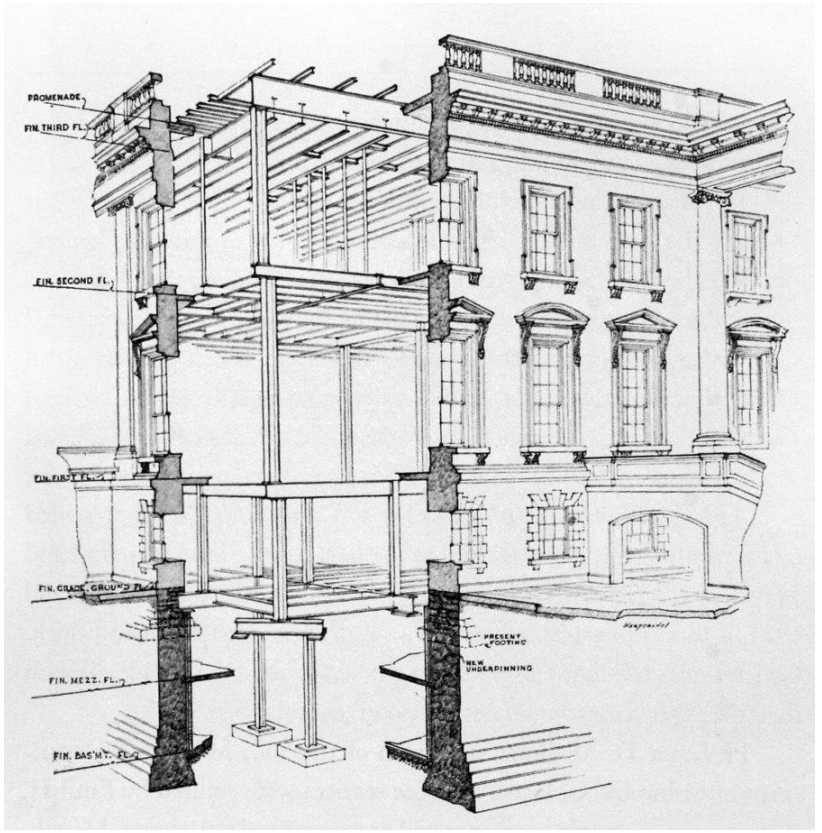


Propagation – Influence of Soil

Soil Type	Propagation Efficiency
Weak or soft soils: shovel penetrates easily *lossy soils, dry or partially saturated peat and muck, mud, loose beach sand, dune sand, recently plowed ground soft spongy forest or jungle floor, organic soils, topsoil*	Lower 
Competent soils: can dig with a shovel *most sands, sandy clays, silty clays, gravel, silts, weathered rock*	
Hard soils: need pick to break up *dense compacted sand, dry consolidated clay, consolidated glacial till, some exposed rock*	
Hard, competent rock (and wet ground): difficult to break with a hammer *bedrock, freshly exposed hard rock*	Higher

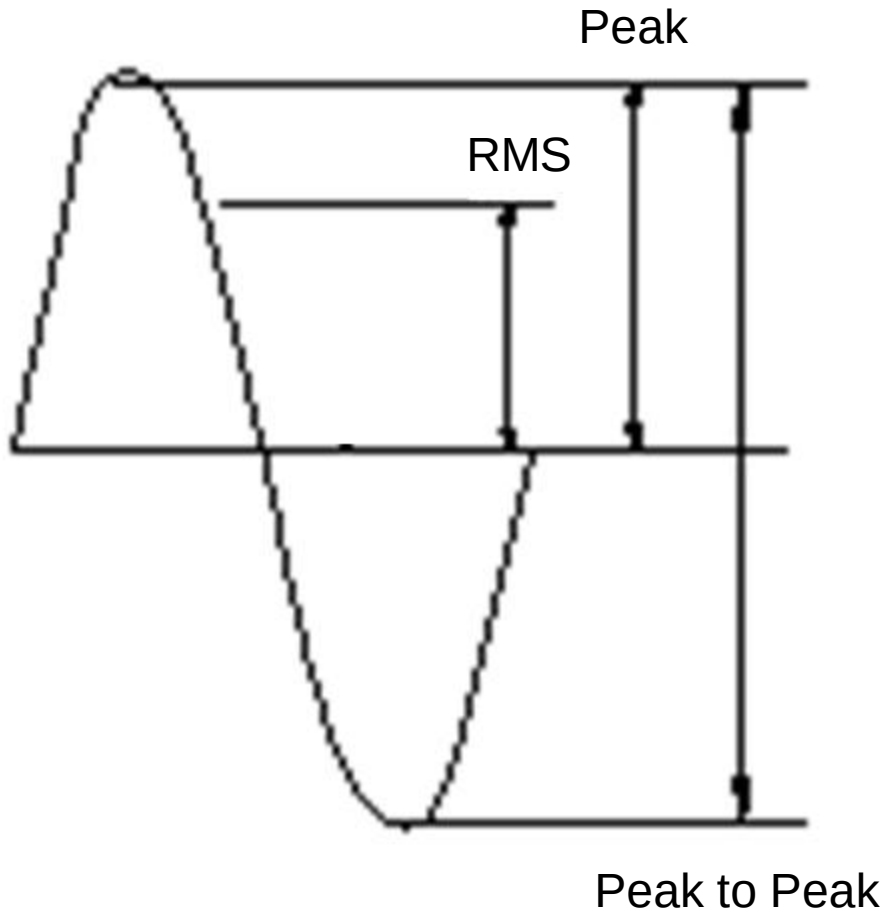
Structure Response

- Attenuation from ground to building
  - Building mass
  - Foundation type
  - 0 to -20 VdB
- Resonance amplification of floors
  - 0 to +5 VdB



Vibration Descriptors

- Displacement (in)
- Velocity (in/sec, VdB)
- Acceleration (in/sec^2)



Vibration Sensitive Uses

XI. NOISE --

Would the project result in:

a) Exposure of persons to or generation of noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?

b) Exposure of persons to or generation of excessive groundborne vibration or groundborne noise levels?

c) A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without

Human Response

FTA: 72 to 80 VdB (0.015 to 0.04 in/sec)

Human Response	Transient PPV (VdB)	Continuous or Frequent PPV (VdB)
Barely Perceptible	0.04 (80)	0.01 (68)
↓		
Severe	2.0 (114)	0.4 (100)

Structure Damage

- CalTrans, FTA and USBM recommend criteria
- In agreement
- 0.12 to 2.0 in/sec PPV

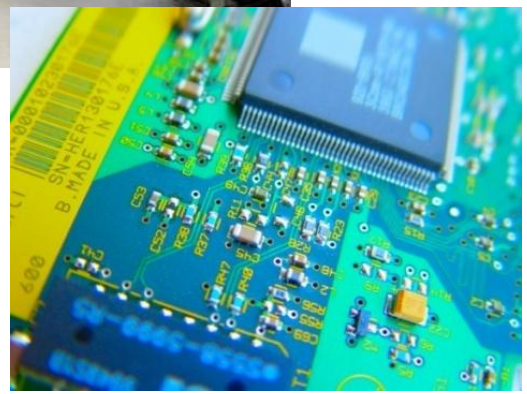
Structure and Condition	Maximum PPV (in/sec)	
	Transient Sources	Continuous/Frequent Intermittent Sources
Extremely fragile historic buildings, ruins, ancient monuments	0.12	0.08
Fragile buildings	0.2	0.1
Historic and some old buildings	0.5	0.25
Older residential structures	0.5	0.3
New residential structures	1.0	0.5
Modern industrial/commercial buildings	2.0	0.5

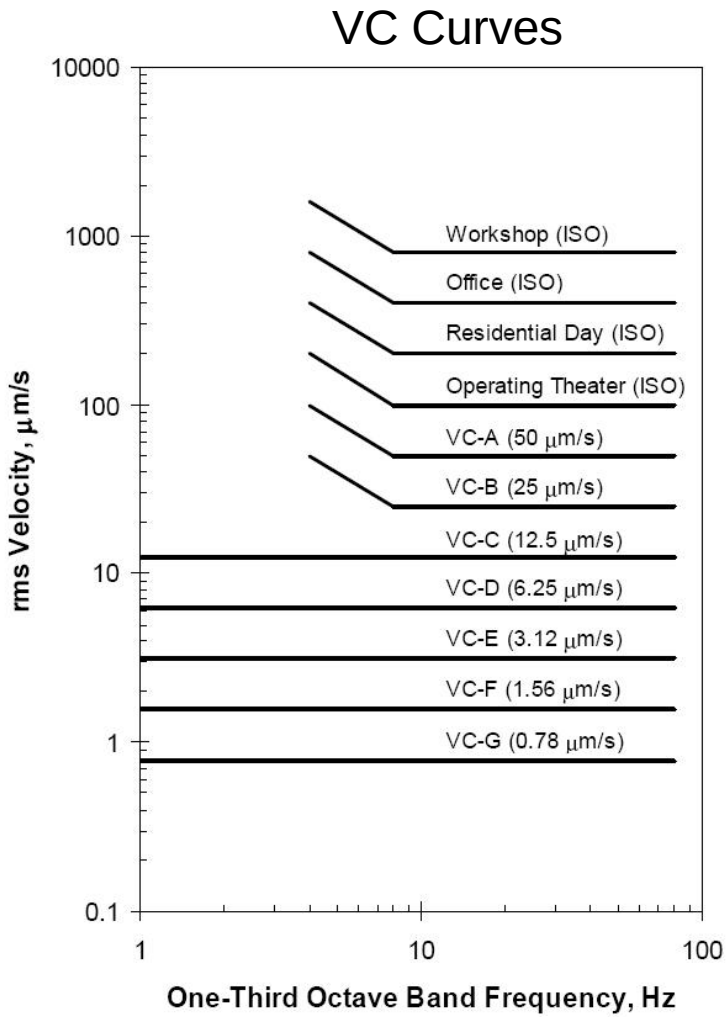
Table 12-3. Construction Vibration Damage Criteria[11]

Building Category	PPV (in/sec)	Approximate L_v[†]
I. Reinforced-concrete, steel or timber (no plaster)	0.5	102
II. Engineered concrete and masonry (no plaster)	0.3	98
III. Non-engineered timber and masonry buildings	0.2	94
IV. Buildings extremely susceptible to vibration damage	0.12	90

[†] RMS velocity in decibels (VdB) re 1 micro-inch/second

Sensitive Facilities





CEQA

- Vibration assessed at high level at program level
- Level of detail required in project EIR depends on project activities
- Assessment at high level of detail more prudent if:
  - Demolition
  - Excavation
  - Blasting
  - Rail transit
  - Vibration sensitive facilities

CEQA/NEPA – Level of Detail

Analysis content	Detail
Qualitative description of sources and receptors	Low
+ Criteria identified	
+ Levels predicted using simple model	
+ Levels predict using site measurements	High

Screening Assessment

Table 9-2. Screening Distances for Vibration Assessment			
Type of Project	**Critical Distance for Land Use Categories* Distance from Right-of-Way or Property Line**		
	Cat. 1	**Cat. 2**	**Cat. 3**
Conventional Commuter Railroad	600	200	120
Rail Rapid Transit	600	200	120
Light Rail Transit	450	150	100
Intermediate Capacity Transit	200	100	50
Bus Projects (if not previously screened out)	100	50	--

* The land-use categories are defined in Chapter 8. Some vibration-sensitive land uses are not included in these categories. Examples are: concert halls and TV studios which, for the screening procedure, should be evaluated as Category 1; and theaters and auditoriums which should be evaluated as Category 2.

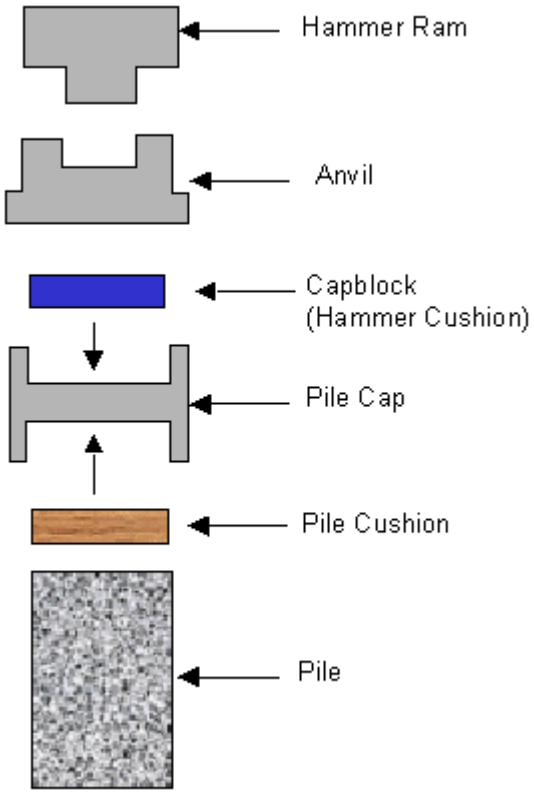
Detailed Assessment

- Compare modeled vibration level to existing vibration level
- Compare modeled vibration level to criteria

Measurement and Monitoring

Mitigation

Pile Installation



Blasting

- Blast design (use smaller charges detonated in sequence)
- Buffer distance

Other Construction Equipment

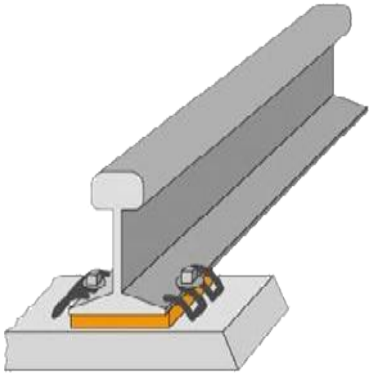
- Use methods that change forces more gradually or at higher frequency, e.g.
  - Concrete saws instead of hydraulic breakers,
  - concrete splitting chemicals instead of concrete saws.

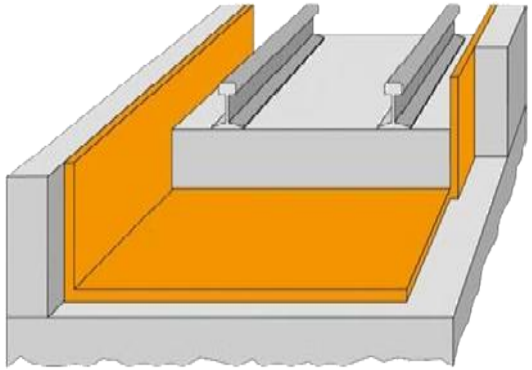
Non-Physical Mitigation

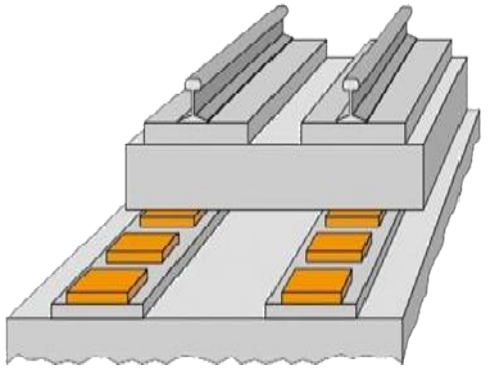
- Identify
- Survey
- Inform
- Schedule
- Design
- Notify
- Monitor
- Respond

Rail Vehicles

- Insert flexible layer between rail and ground







Example Projects

Gallin v. Poulou

- Alleged that hanging plaster was caused to fall on plaintiff by jack hammering by contractors hired by the defendant.
- The plaintiffs case was based on trespass.
- The court held that the vibrations were not an intentional trespass

BART vs. Cypress Lawn Cemetery Association

- alleging violated of CEQA by failing to identify appropriate mitigations for the extension SFO
- Plaintiff concerned by noise, vibration and dust on the sacred, tranquil atmosphere of the cemetery.
- Challenged adequacy of mitigation because mitigation for cemeteries was not specifically mentioned in EIR

Atherton & others vs. California High Speed Rail Authority

- FPEIR stated that the ability of mitigation to reduce vibration to L-T-S was uncertain
- The Authority stated in CEQA findings of fact that mitigation would reduce vibration impacts to L-T-S.
- The Court found that the CEQA finding was not supported by substantial evidence.

University of Washington and SoundTransit

- Light rail tunnel under University of Washington campus
- Potential impact to sensitive research facilities
- Mitigation agreement based on existing ambient levels
- Permanent monitoring system proposed
- Liquidated damages if standards exceeded

University of Minneapolis and MetroTransit

- Light rail line on surface through University of Minneapolis campus
- Potential impact to sensitive research facilities
- Mitigation agreement based on existing ambient levels / VC-F
- Permanent monitoring system proposed

Useful References

- *Transportation- and Construction-Induced Vibration Guidance Manual*, Caltrans, 2004
- *Transit Noise and Vibration Impact Assessment* , 2006, Federal Transit Administration
- ISO 2631:1981 *Guide to the Evaluation of Human Exposure to Vibration and Shock in Buildings (1 Hz to 80 Hz)*, International Standards Organization
- *Structure Response and Damage Produced by Ground Vibrations From Surface Blasting*, 1980, US Bureau of Mines report RI-8507