

Ground-Borne Noise and Vibration Prediction Approaches

Rail Transportation Ground-Borne Noise and Vibration
Prediction Workshop

Transportation Research Board 85th Annual Meeting
Washington, DC – January 22, 2006

DAVID A. TOWERS, P.E.

PRINCIPAL ENGINEER

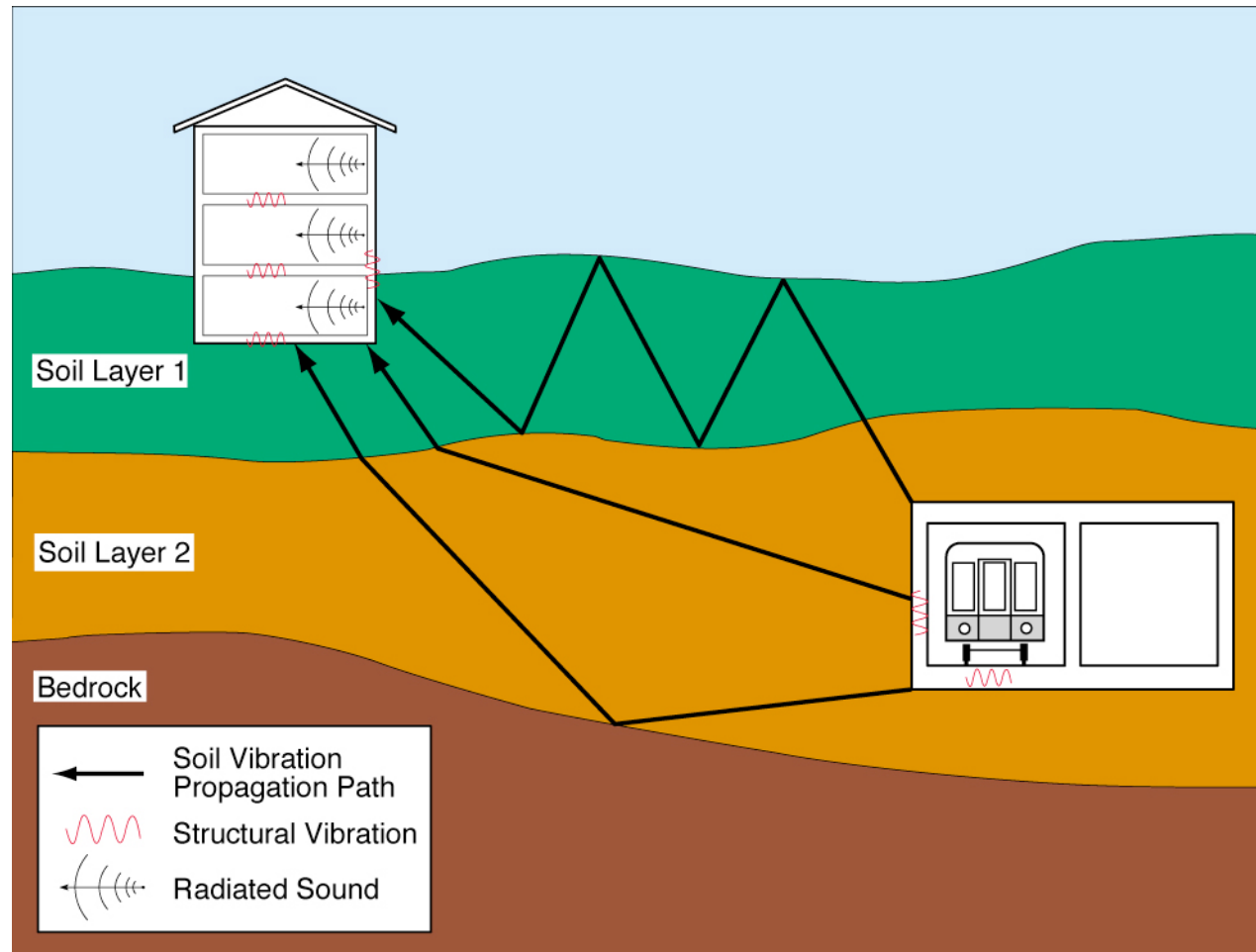
HARRIS MILLER MILLER & HANSON INC.

Burlington, MA USA



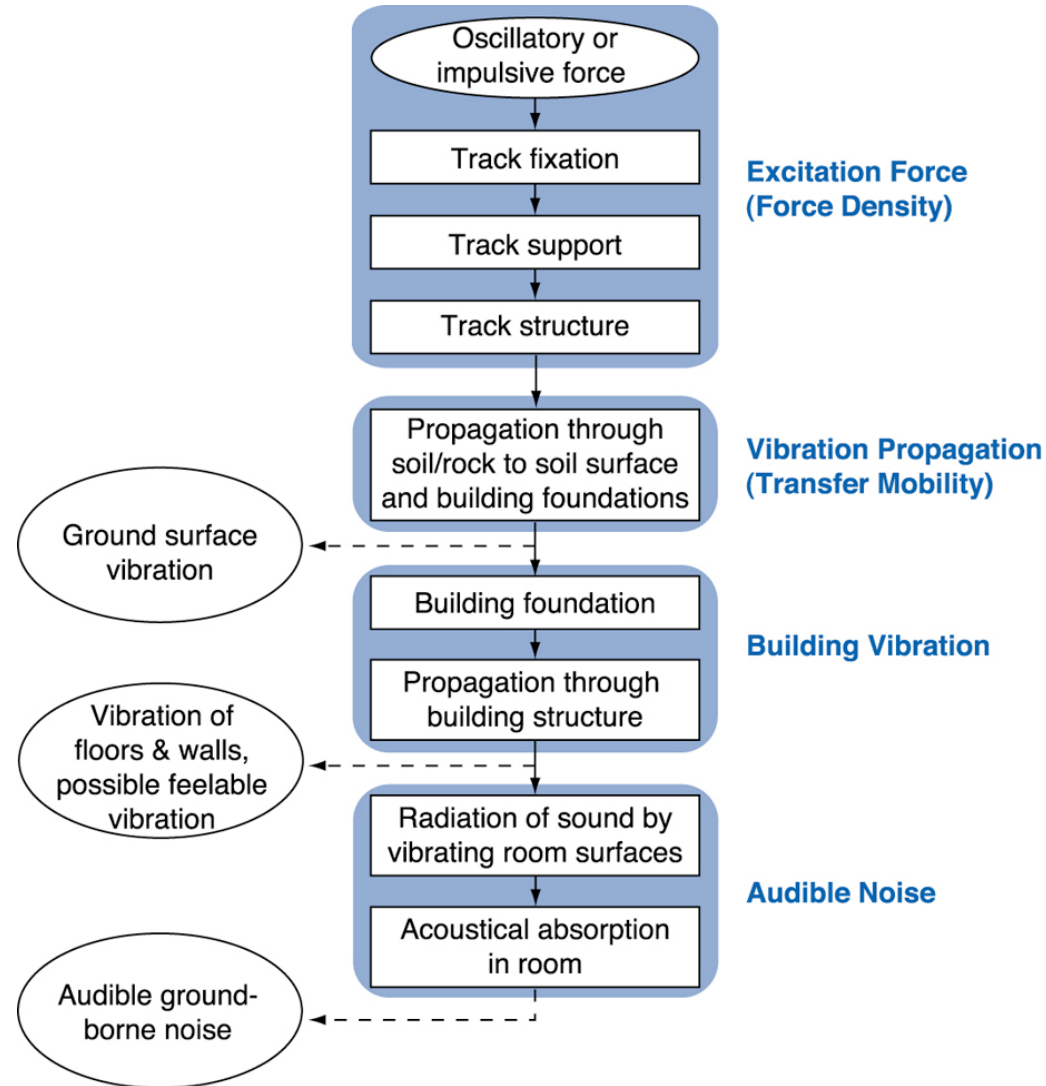
Propagation of Ground-Borne Vibration into Buildings

www.hmmh.com



Block Diagram of Ground-Borne Vibration and Noise Prediction Model

www.hmmh.com



Empirical Prediction Model

www.hmmh.com

For each 1/3 octave band:

$$L_V = L_F + TM_{line} + C_{building} + SF^*$$

$$L_A = L_V + C_{noise}$$

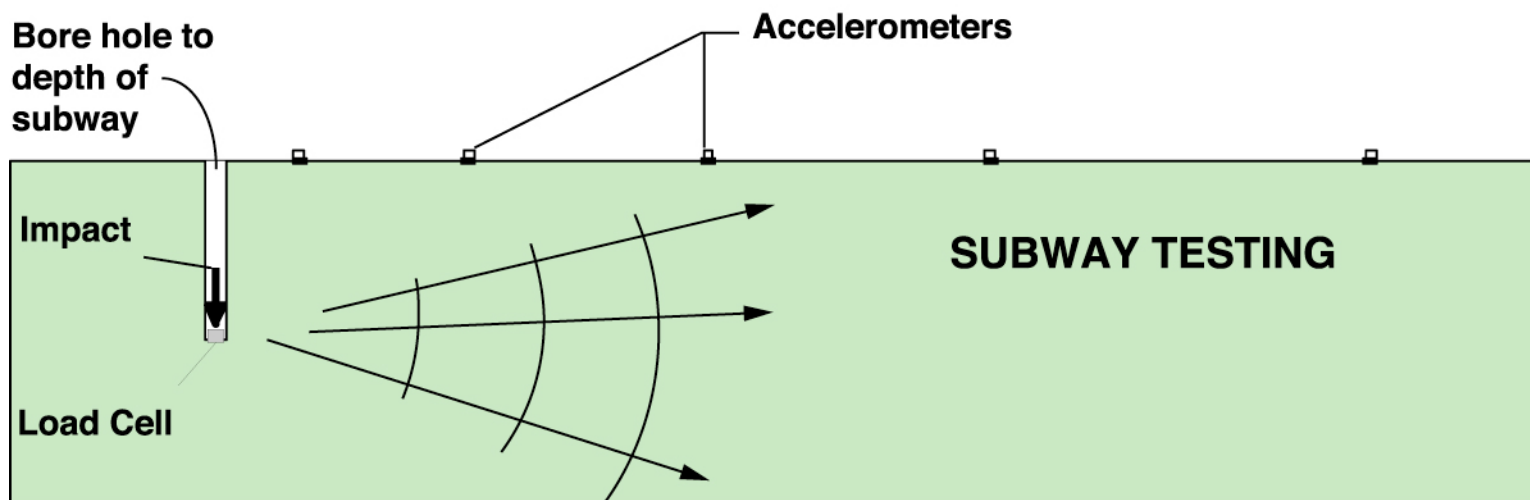
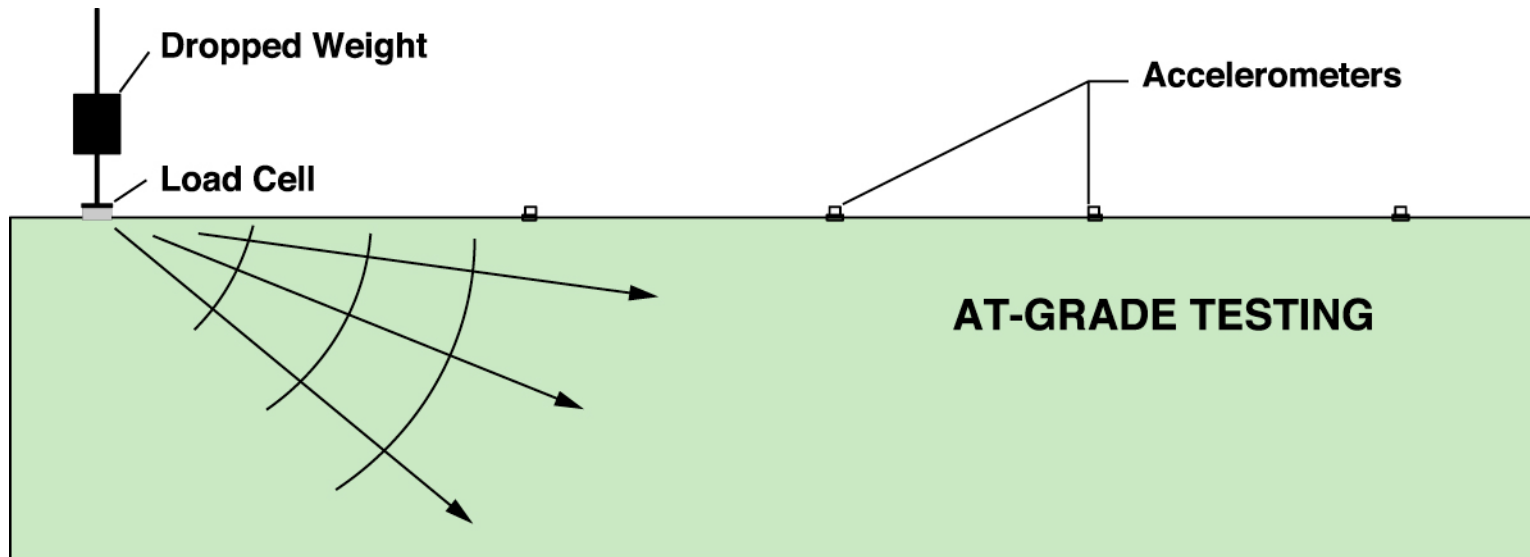
where:	L_V	=	Vibration Velocity Level in Building
	L_A	=	A-Weighted Noise Level in Building
	L_F	=	Vehicle Force Density
	TM_{line}	=	Line Source Transfer Mobility
	$C_{building}$	=	Corrections for building coupling loss and amplification due to resonances
	C_{noise}	=	Correction to noise
	SF	=	Safety Factor

***Safety Factor:** Selected to achieve an appropriate balance between the risk of exceeding the criteria and the cost implications of additional mitigation.



Test Configuration for Measuring Transfer Mobility

www.hmmh.com



Surface Vibration Propagation Test Rig

www.hmmh.com



Vibration Propagation Testing using Tactile Transducer and MLS Signals

www.hmmh.com



Bore-Hole Vibration Propagation Test Method

www.hmmh.com



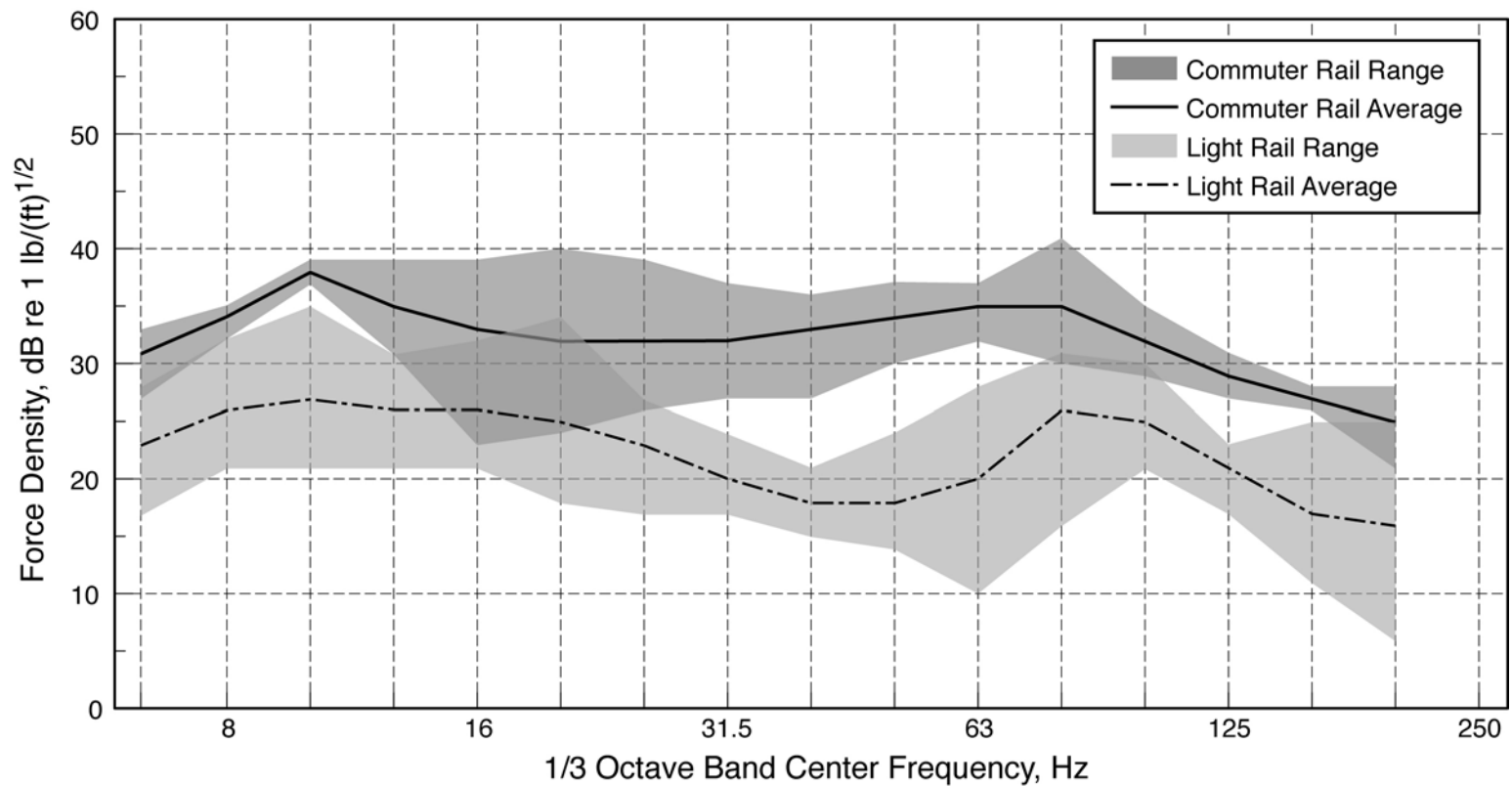
Force Density Testing

www.hmmh.com



Range of Measured Force Densities for U.S. Rail Transit Vehicles (40 mph)

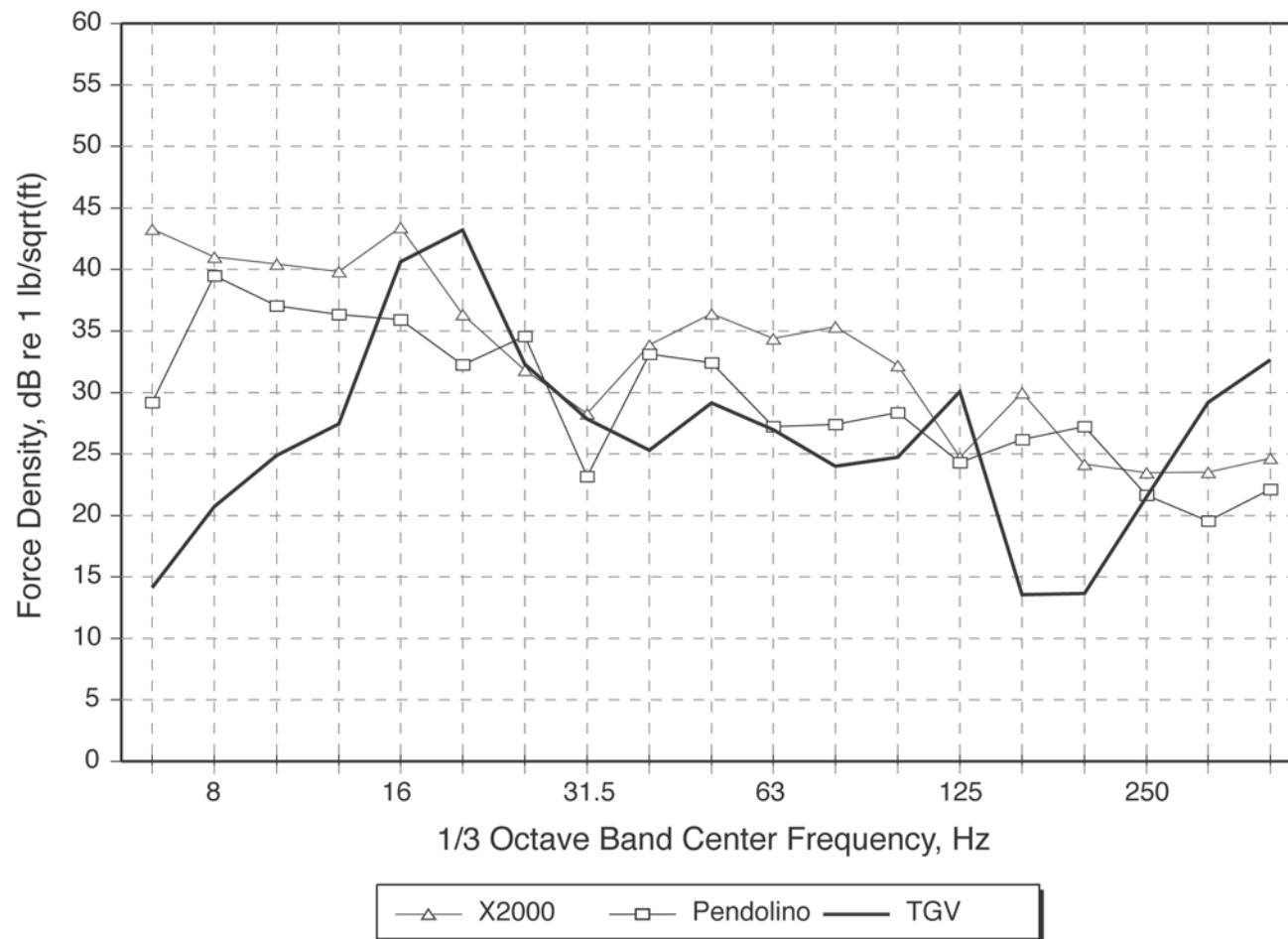
www.hmmh.com



Measured Force Densities for High-Speed Trains in Europe (150 mph)

www.hmmh.com

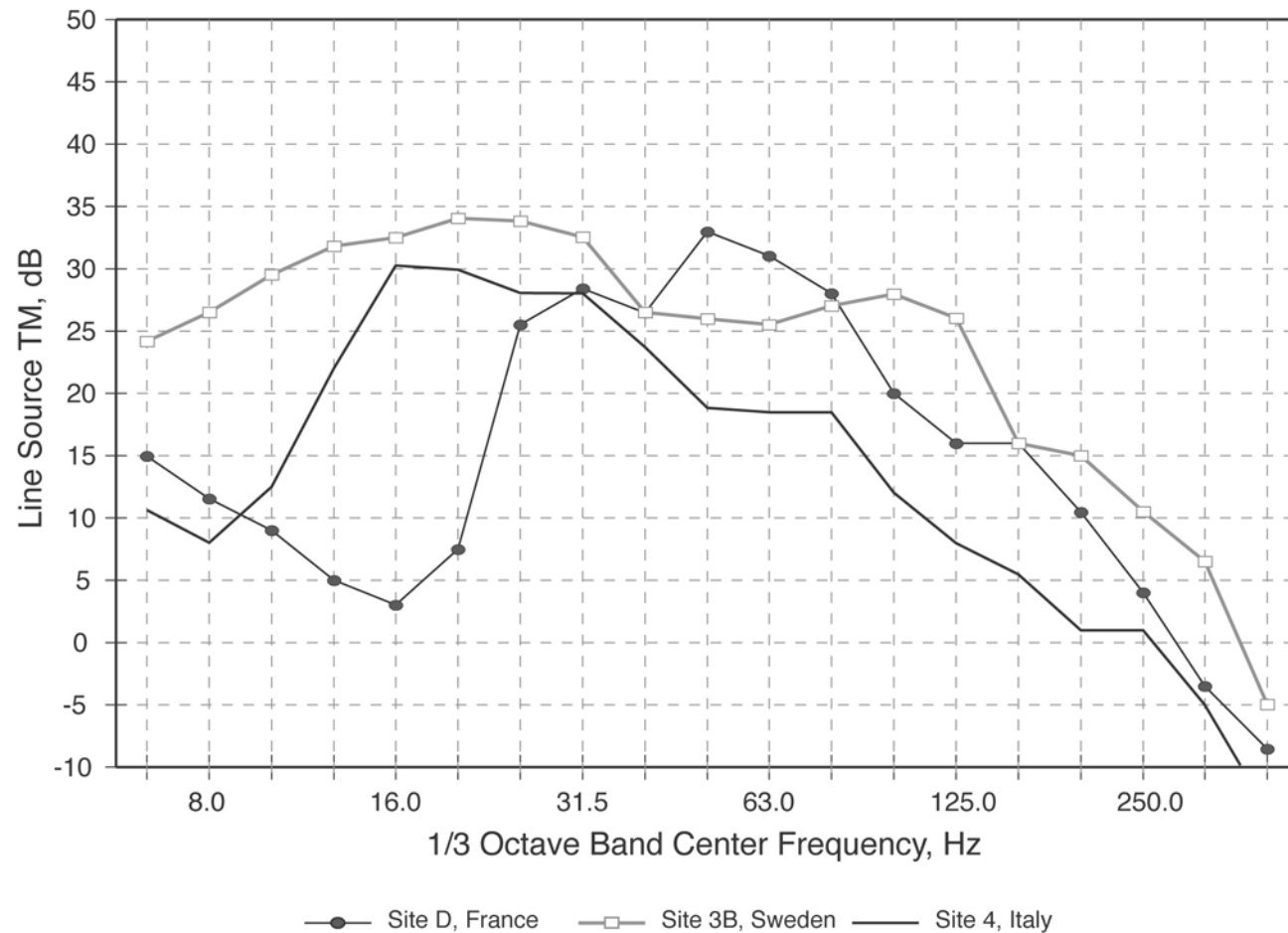
Force Densities, 150 mph
European Measurements, 5/95



Measured Line-source Transfer Mobility at European Test Sites (100 ft from track)

www.hmmh.com

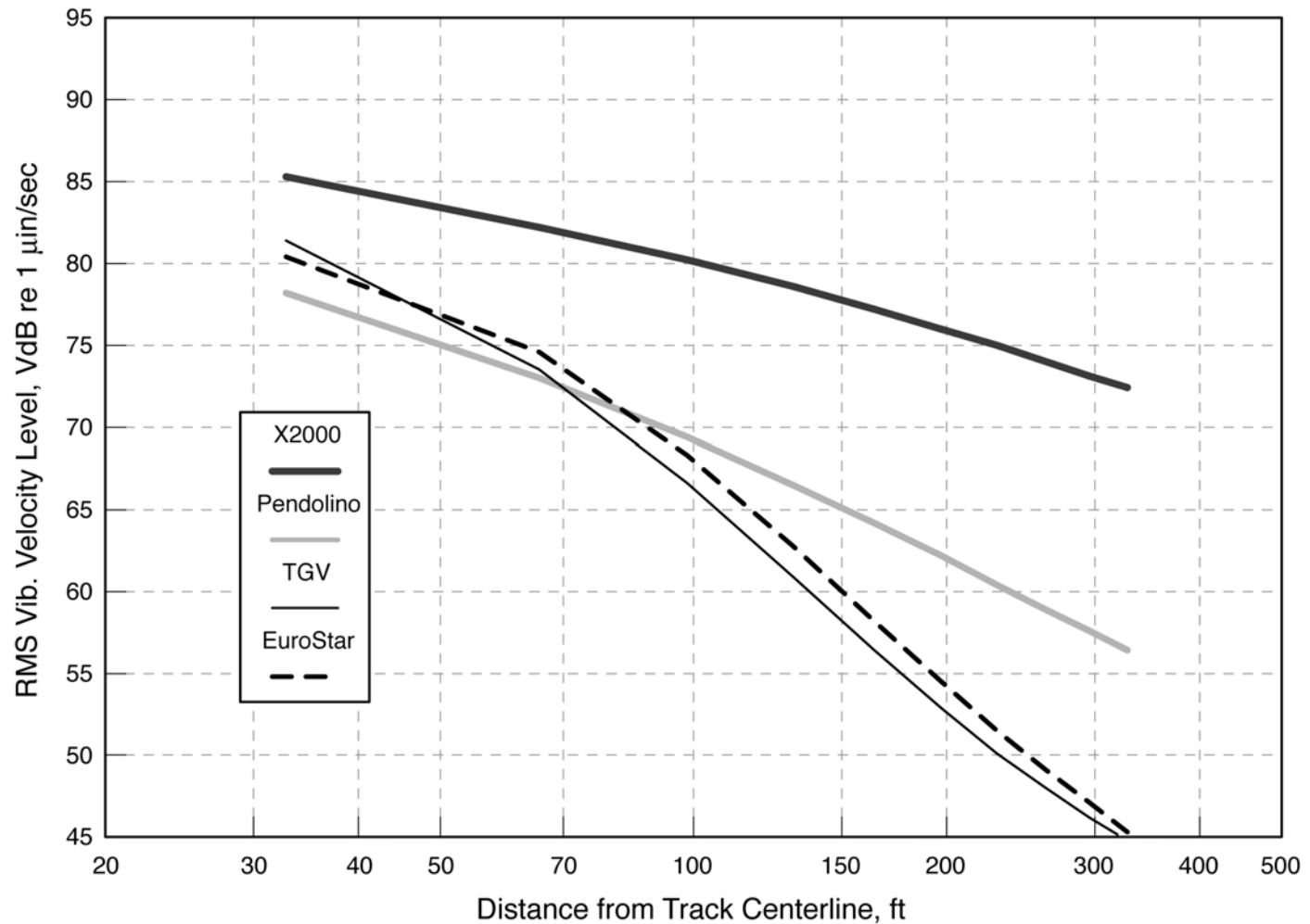
Comparison of Transfer Mobility
100 feet from track centerline



Measured Ground-Borne Vibration Levels vs. Distance at European Test Sites

www.hmmh.com

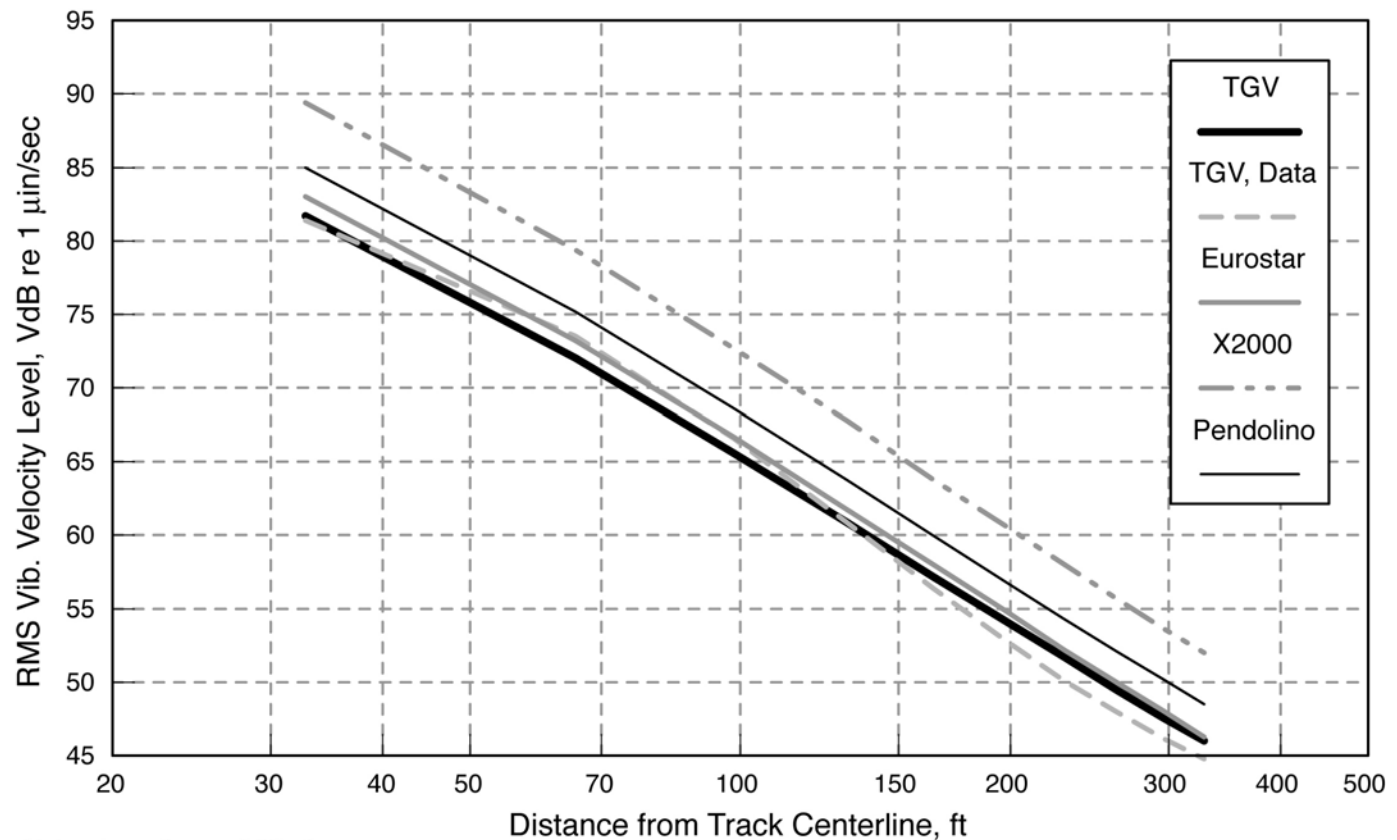
Ground-borne Vibration vs Distance
From 1/3 Octave Band Data



Projected Vibration Levels for European Trains Using Transfer Mobility from Site in France

www.hmmh.com

Ground-borne Vibration vs Distance
Velocity Level Projected using Measured
Force Densities and Transfer Mobility



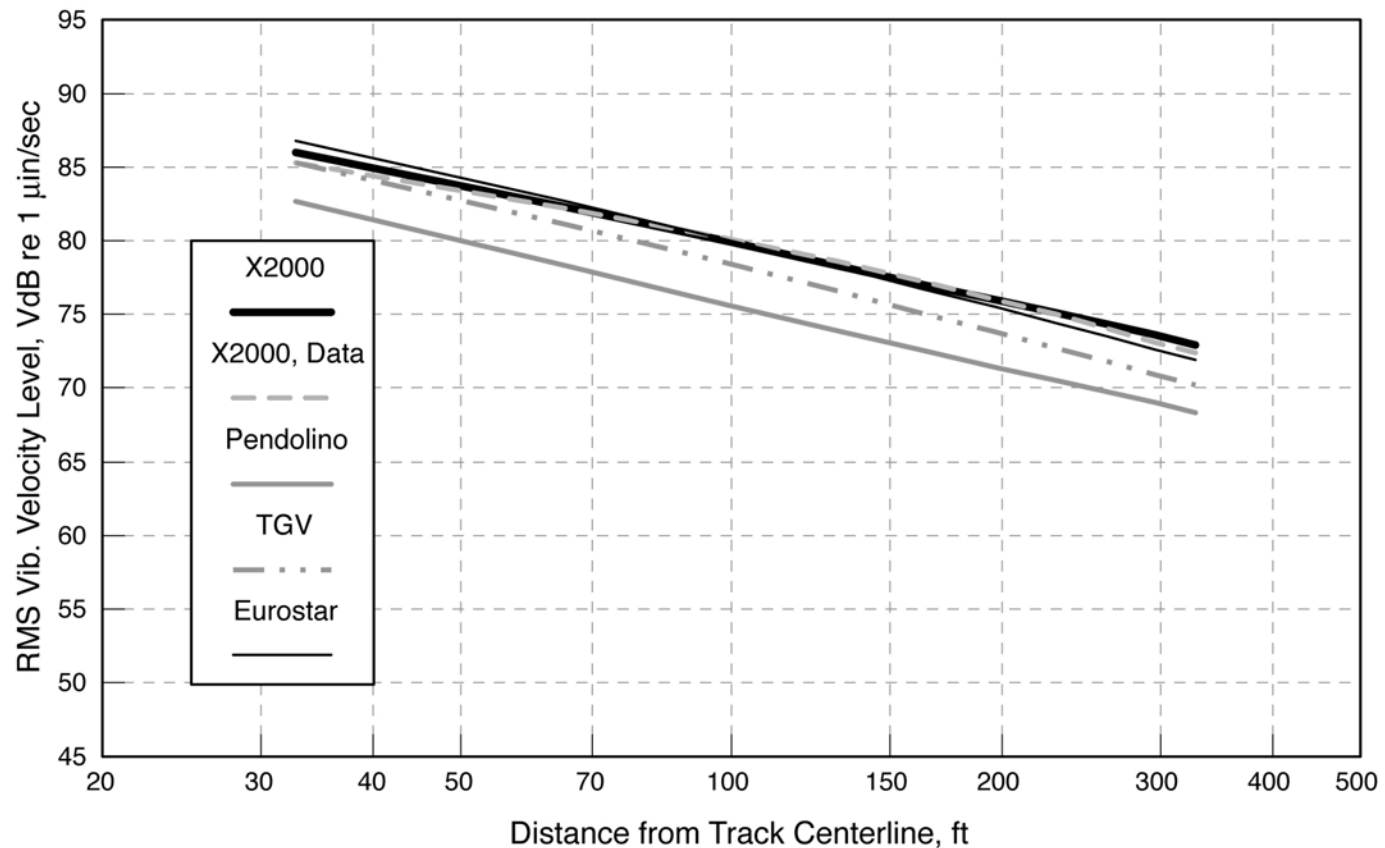
Using transfer mobility from
Site D in France
Train Speed 150 mph



Projected Vibration Levels for European Trains Using Transfer Mobility from Site in Sweden

www.hmmh.com

Ground-borne Vibration vs Distance
Velocity Level Projected using Measured
Force Densities and Transfer Mobility



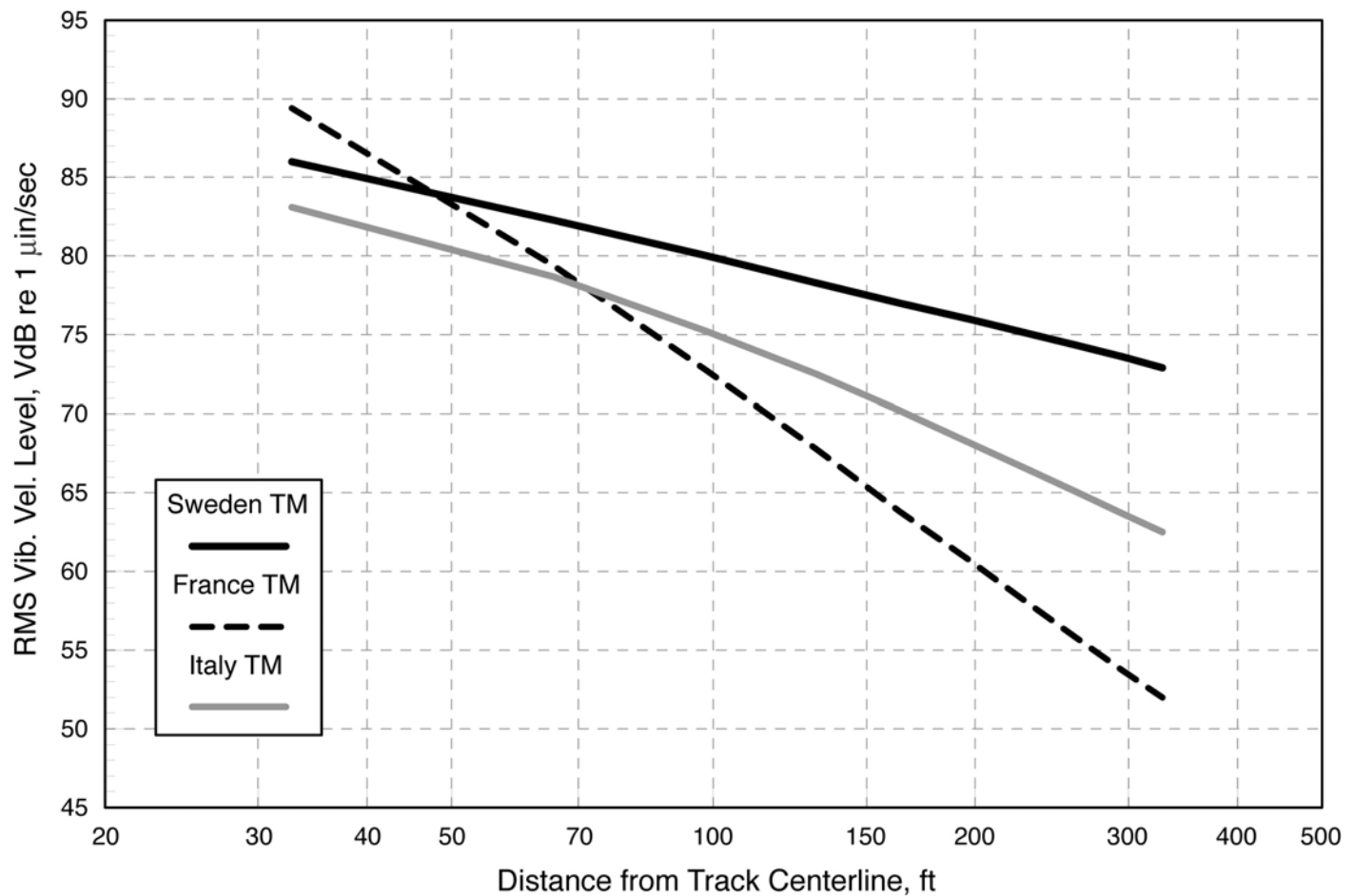
Using transfer mobility from
Site 3B in Sweden
Train Speed 150 mph



Projected Vibration Velocity for X2000 Trainset at Sites in France, Italy and Sweden

www.hmmh.com

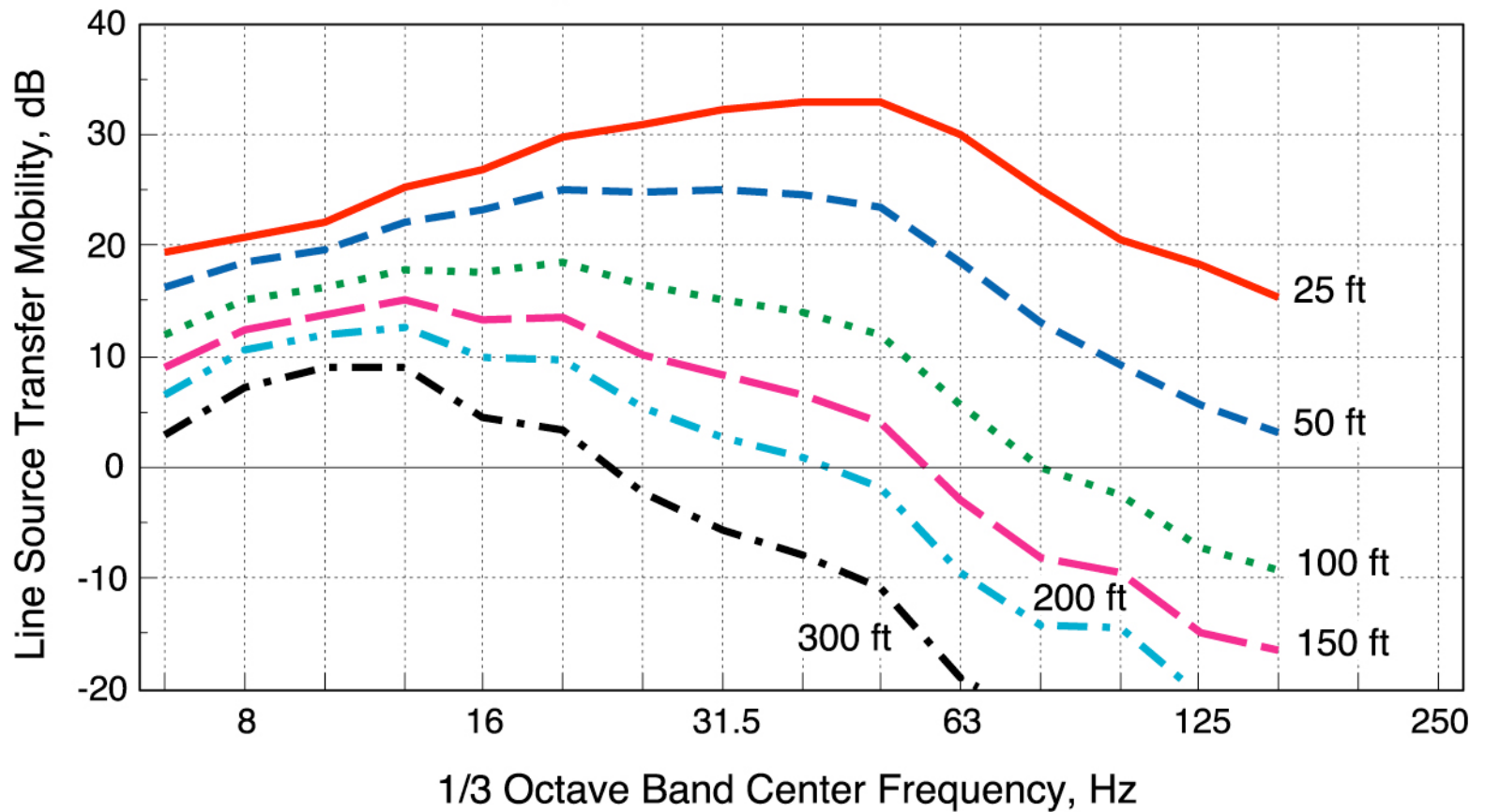
X2000 Ground-borne Vibration
Projected from X2000 Force Density
and Transfer Mobilities at Test Sites



Average Line-Source Transfer Mobility at TTC

www.hmmh.com

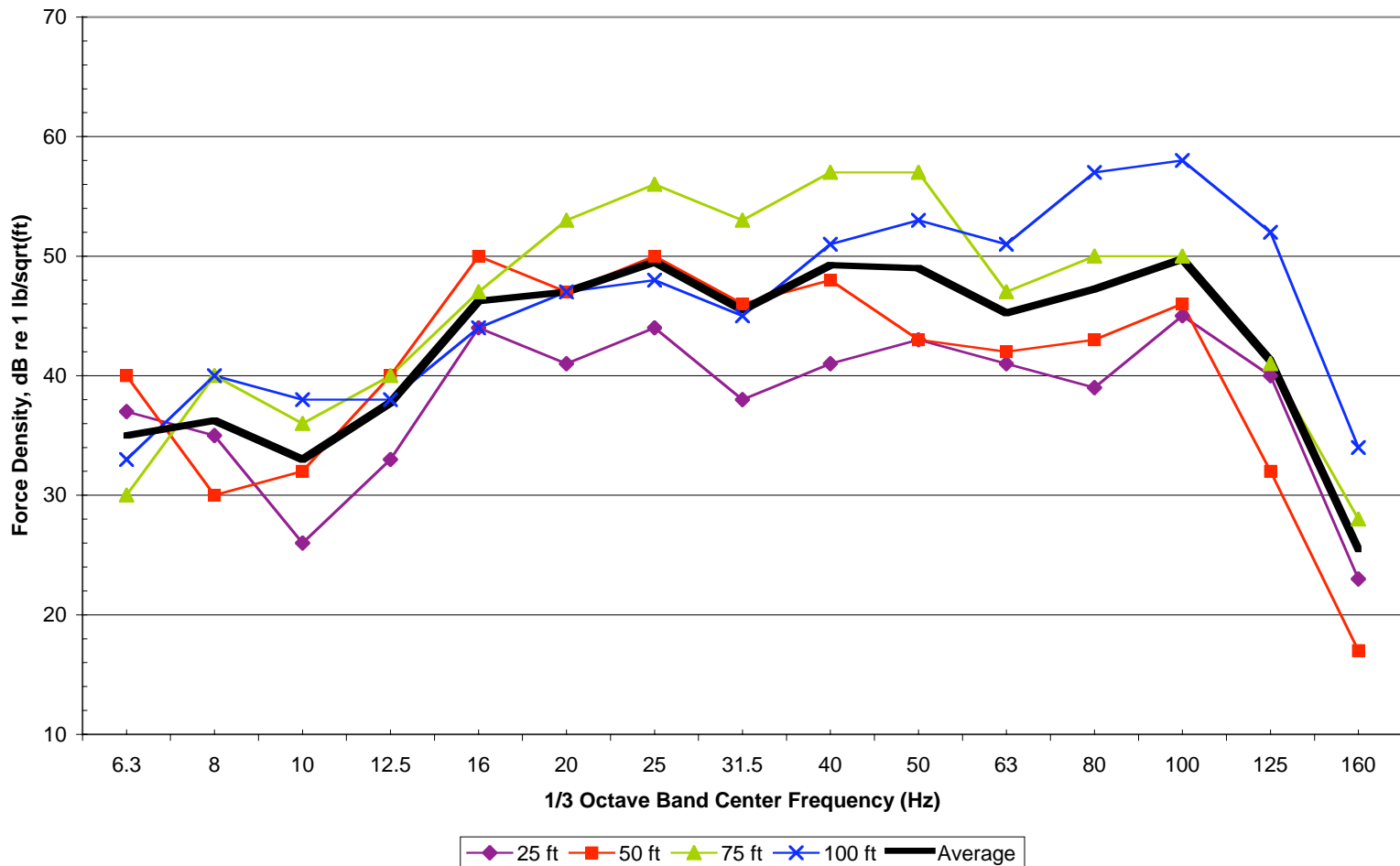
Transportation Test Center: Pueblo, CO



Amtrak Acela Force Density at Various Distances

www.hmmh.com

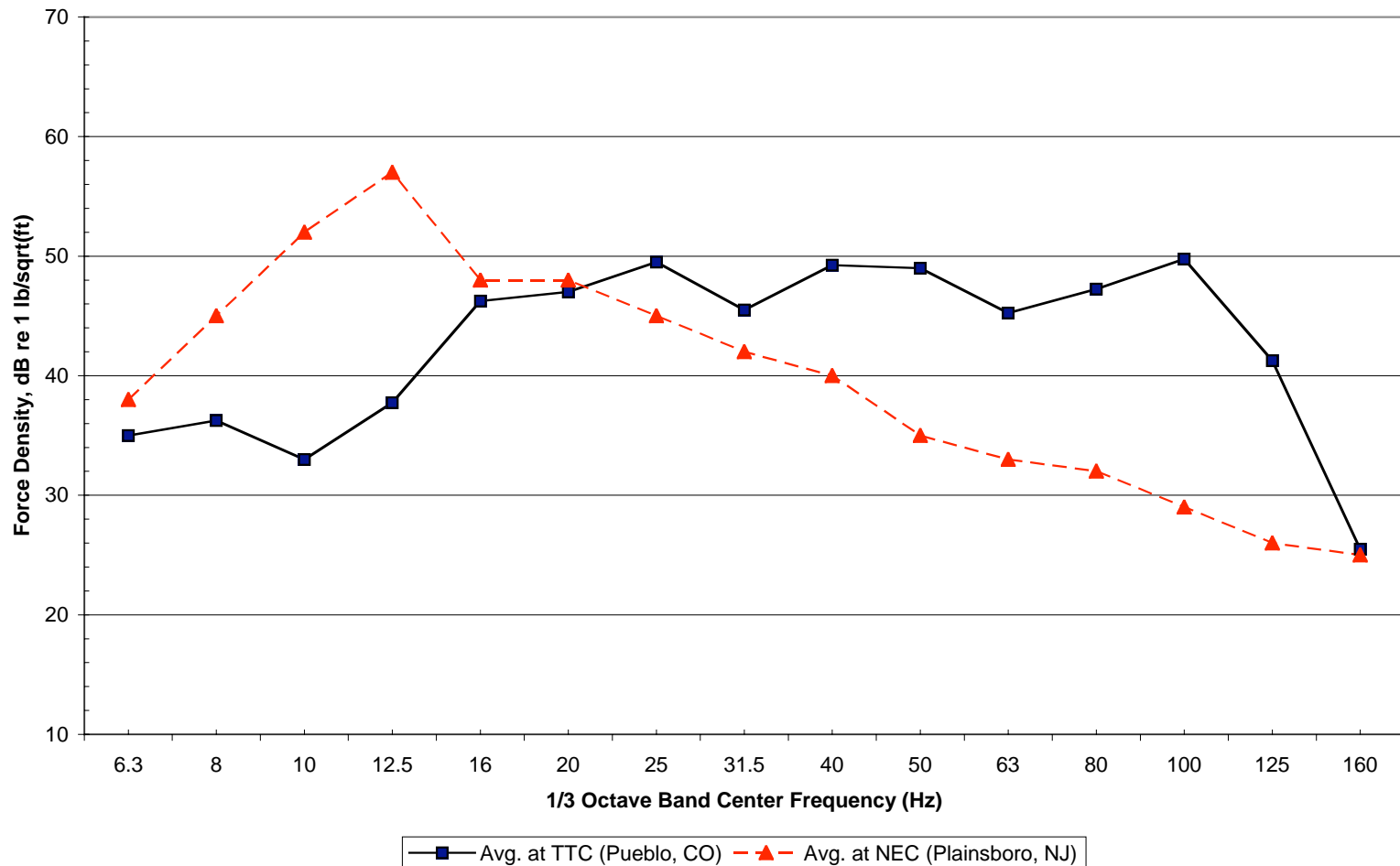
Average Acela Force Densities for Various Distances at TTC in Pueblo, CO (150 mph)



Amtrak Acela Force Density at Different Sites

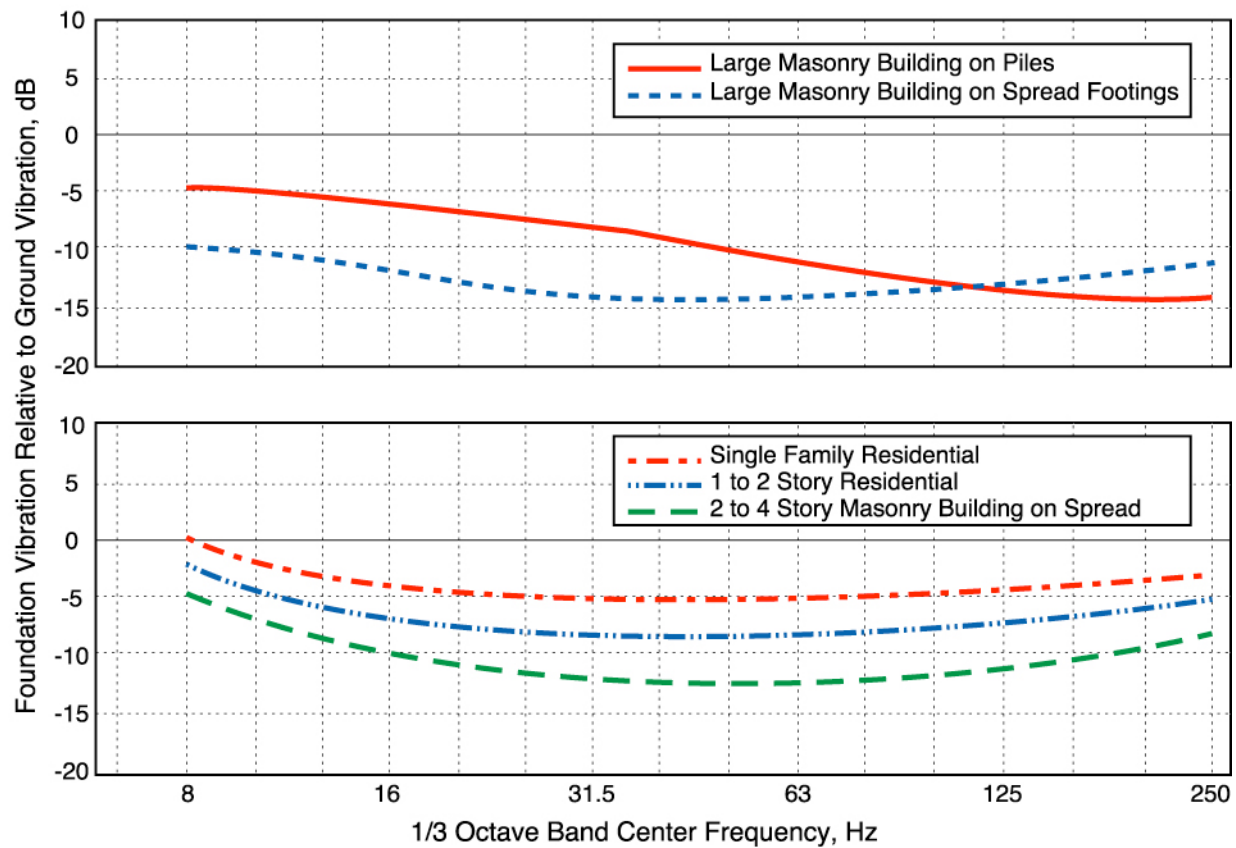
www.hmmh.com

Average Amtrak Acela Force Densities Measured at TTC and at NEC (150 mph)



Foundation Response to Various Types of Buildings

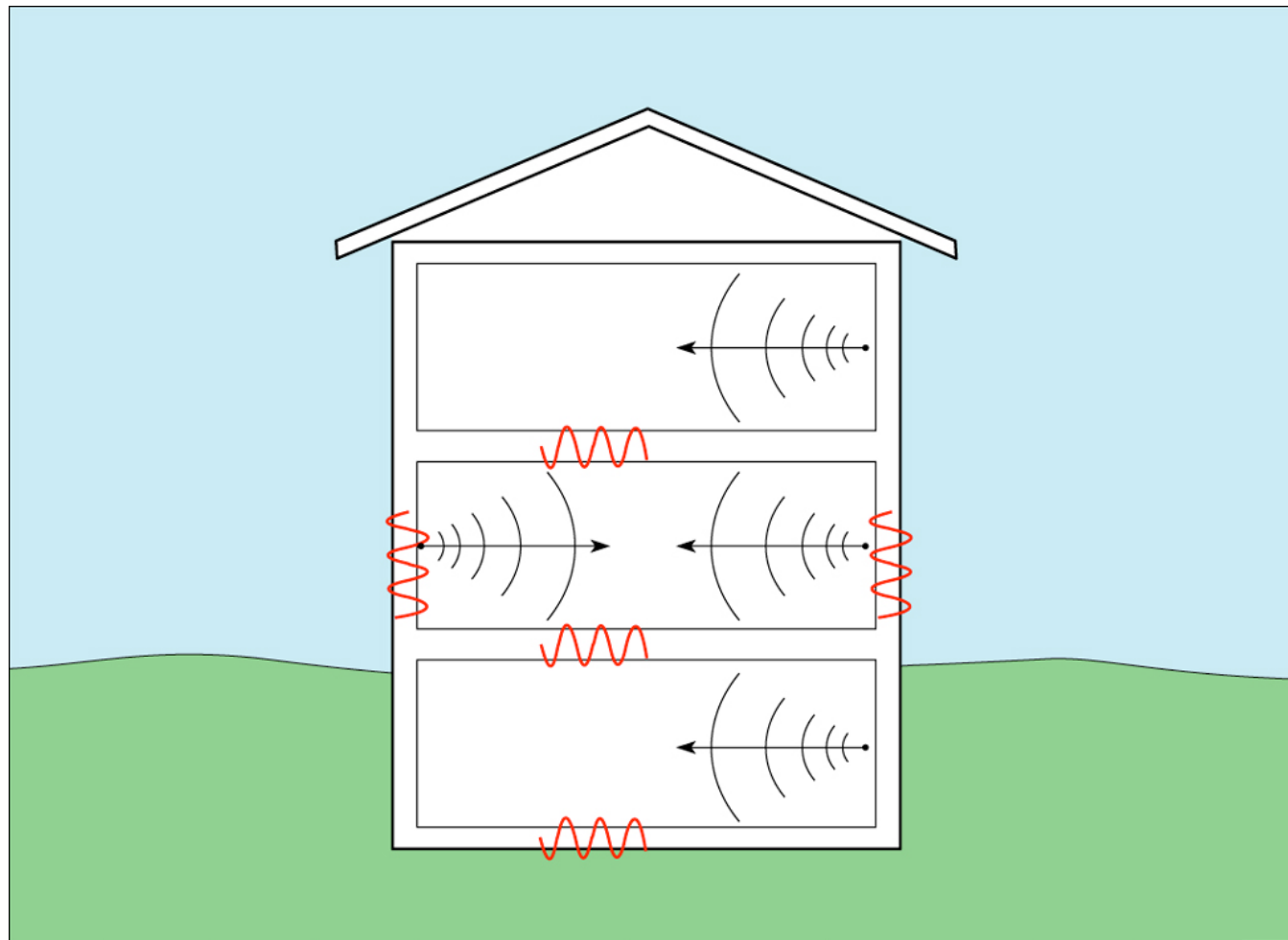
www.hmmh.com



Conversion of Ground-Borne Vibration to Noise

www.hmmh.com

- Conversion of VdB to dB } Same dB value



Ground-Borne Noise/Vibration Prediction Issues

www.hmmh.com

- **Vehicle Force Density (Source Levels)**
 - Can't separate vehicle from track structure.
 - Results are not always consistent.
- **Transfer Mobility (Propagation through Ground)**
 - How representative are results?
 - How many tests are needed?
- **Ground-to-Building Coupling & Conv. to Noise**
 - How accurate are available estimates?
 - Often difficult to measure.
- **Safety Factor**
 - How to select appropriate value?

