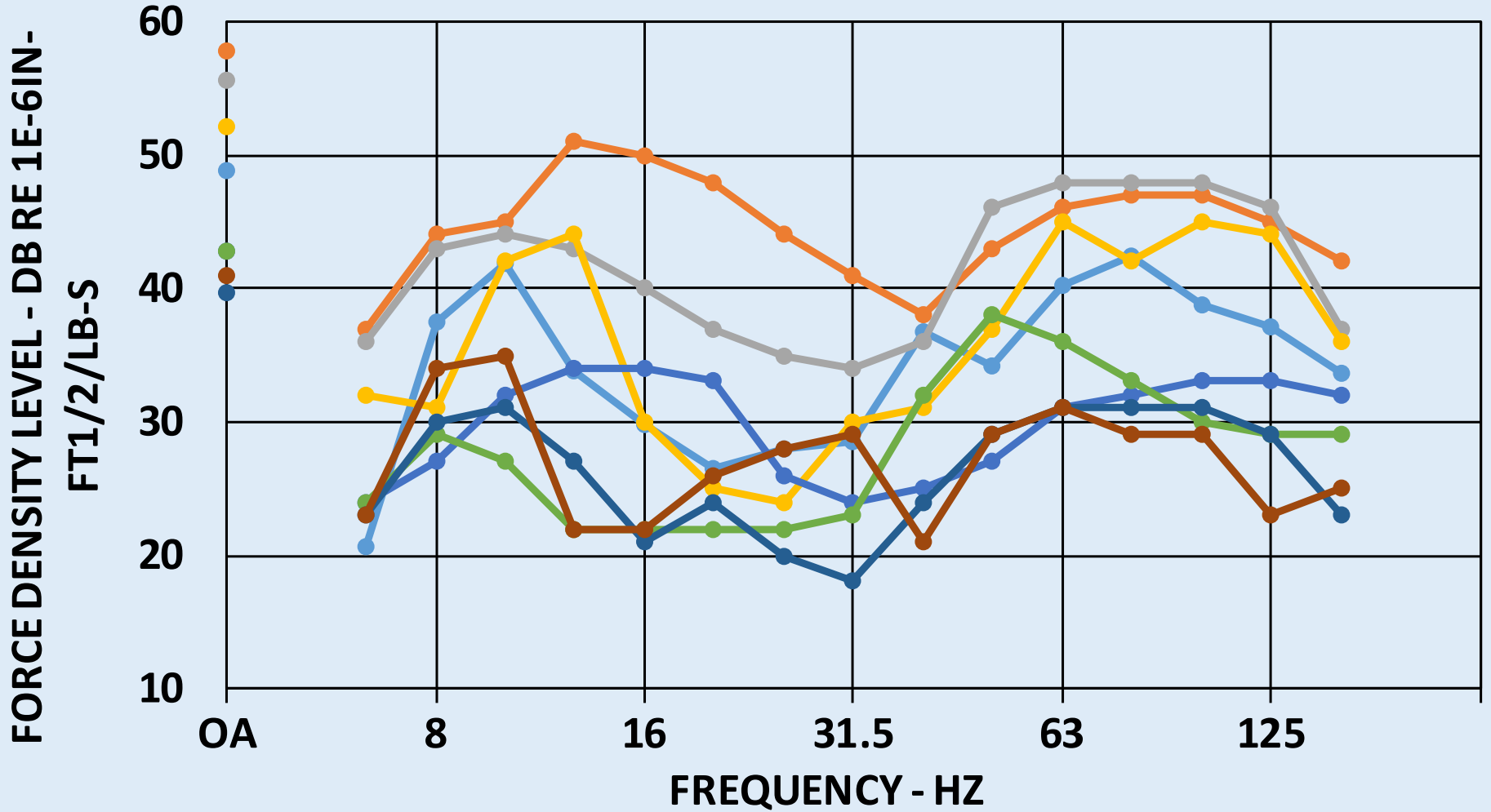


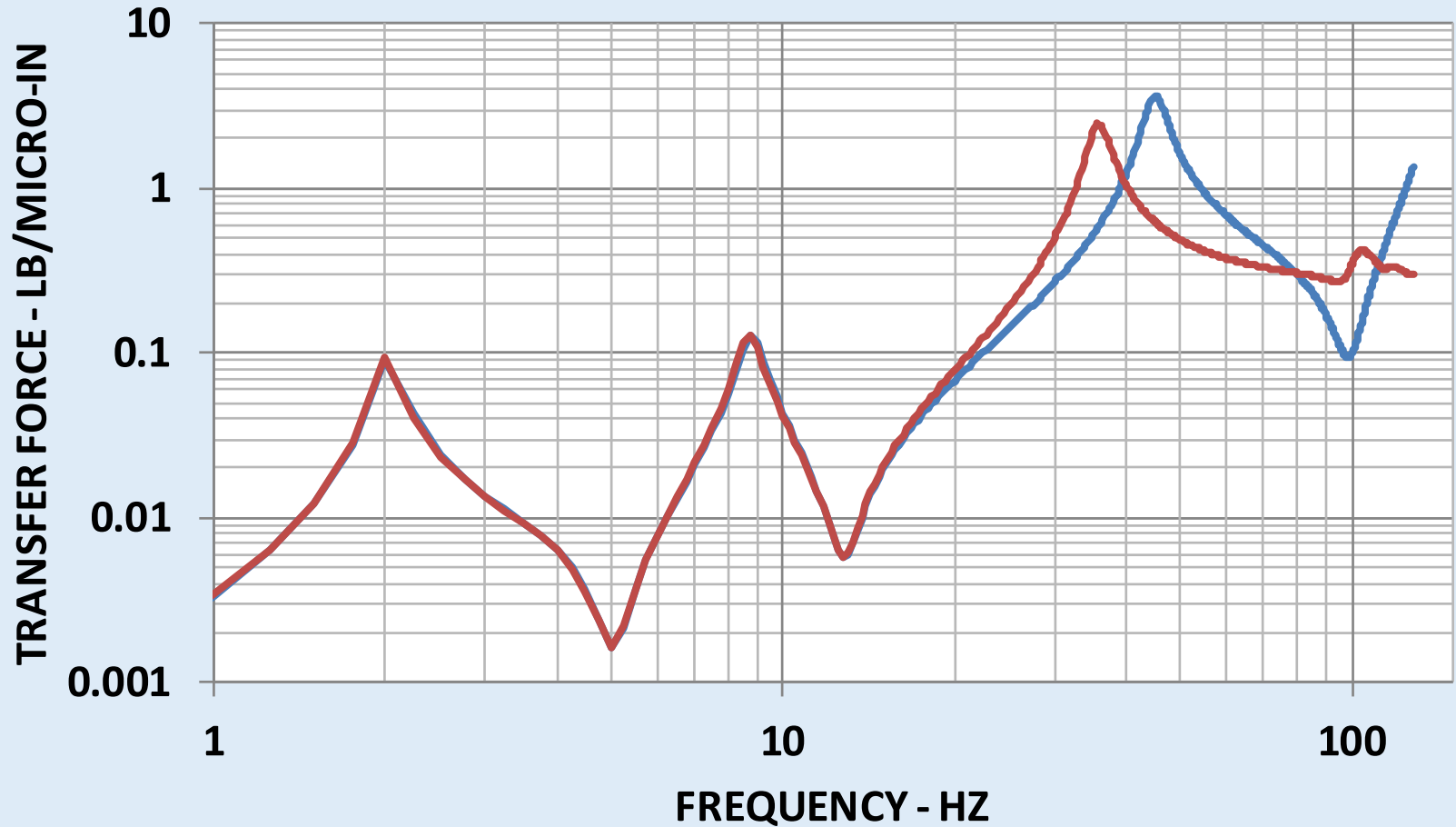
GROUND VIBRATION CHARACTERISTICS OF RAIL TRANSIT SYSTEMS

JAMES TUMAN NELSON
WILSON, IHRIG & ASSOCIATES
TRB ADC40 SUMMER MEETING
MISSOULA, MONTANA
JULY 2016



- SAN JOSE KINKISHARYO
- SF MUNI SLRV
- SAN DIEGO U2
- SAN JOSE UTDC
- SF MUNI LRV2 (JOURNAL BUSH)
- LA BLUE LINE
- PORTLAND TRIMET TYPE 1
- PORTAND TRIMET TYPE 2

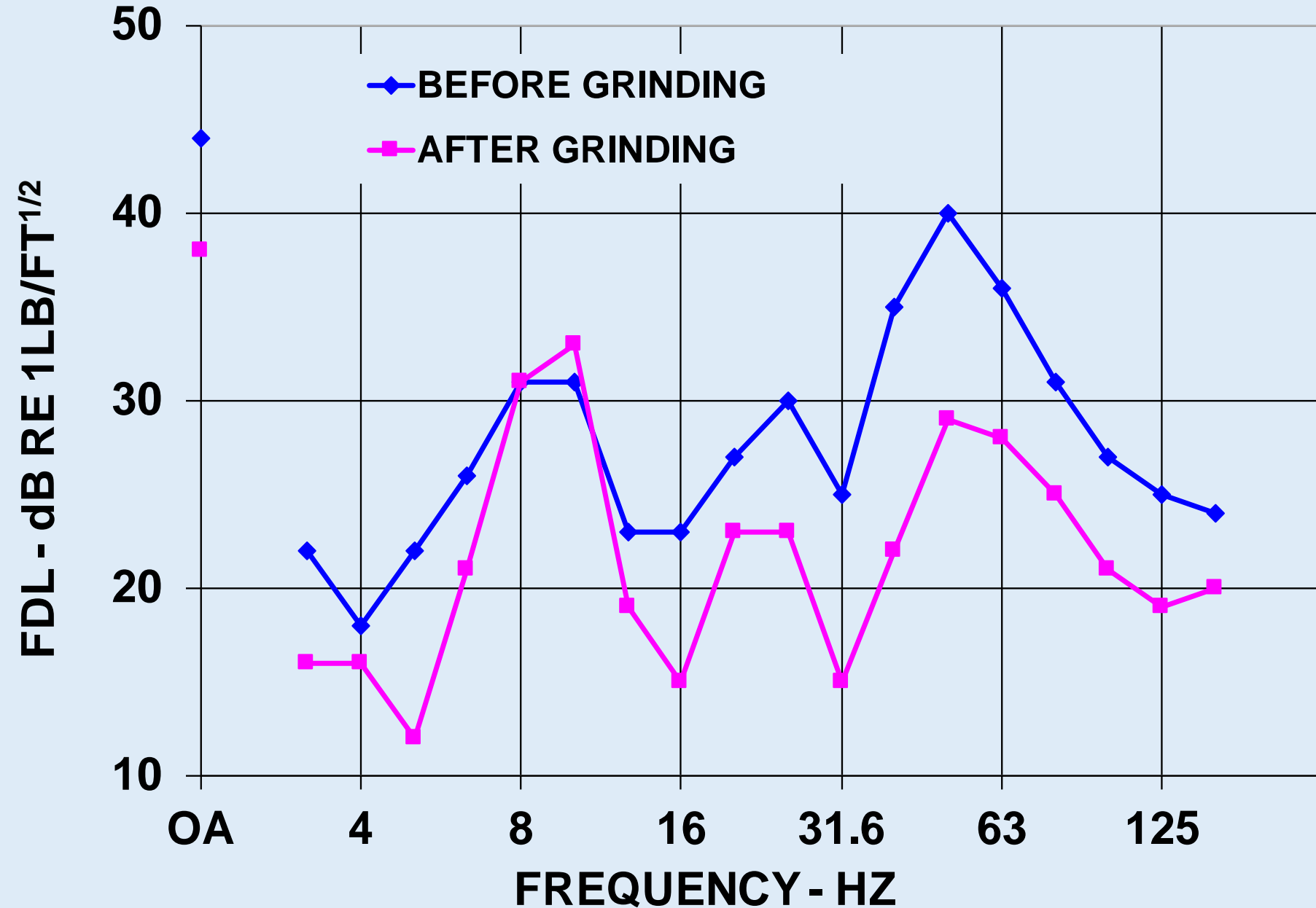
TRANSFER STIFFNESS OF SOUND TRANSIT VEHICLE ON DIRECT FIXATION TRACK



— STANDARD DF - 300,000 LB/IN AT 24 IN OC

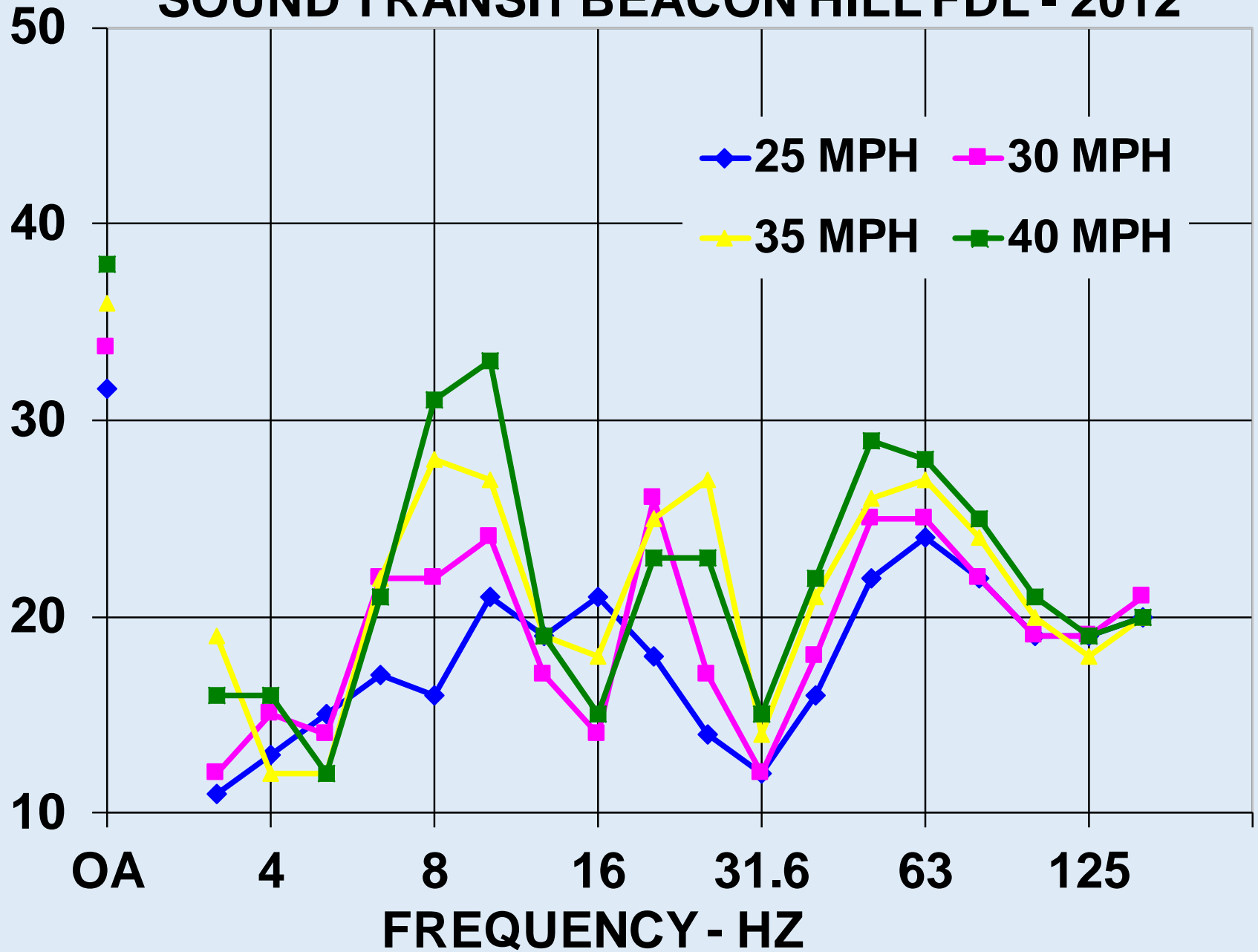
— HIGH COMPLIANCE DF - 77,000 LB/IN AT 24 INCHES OC

SOUND TRANSIT BEACON HILL - DF - 40 MPH

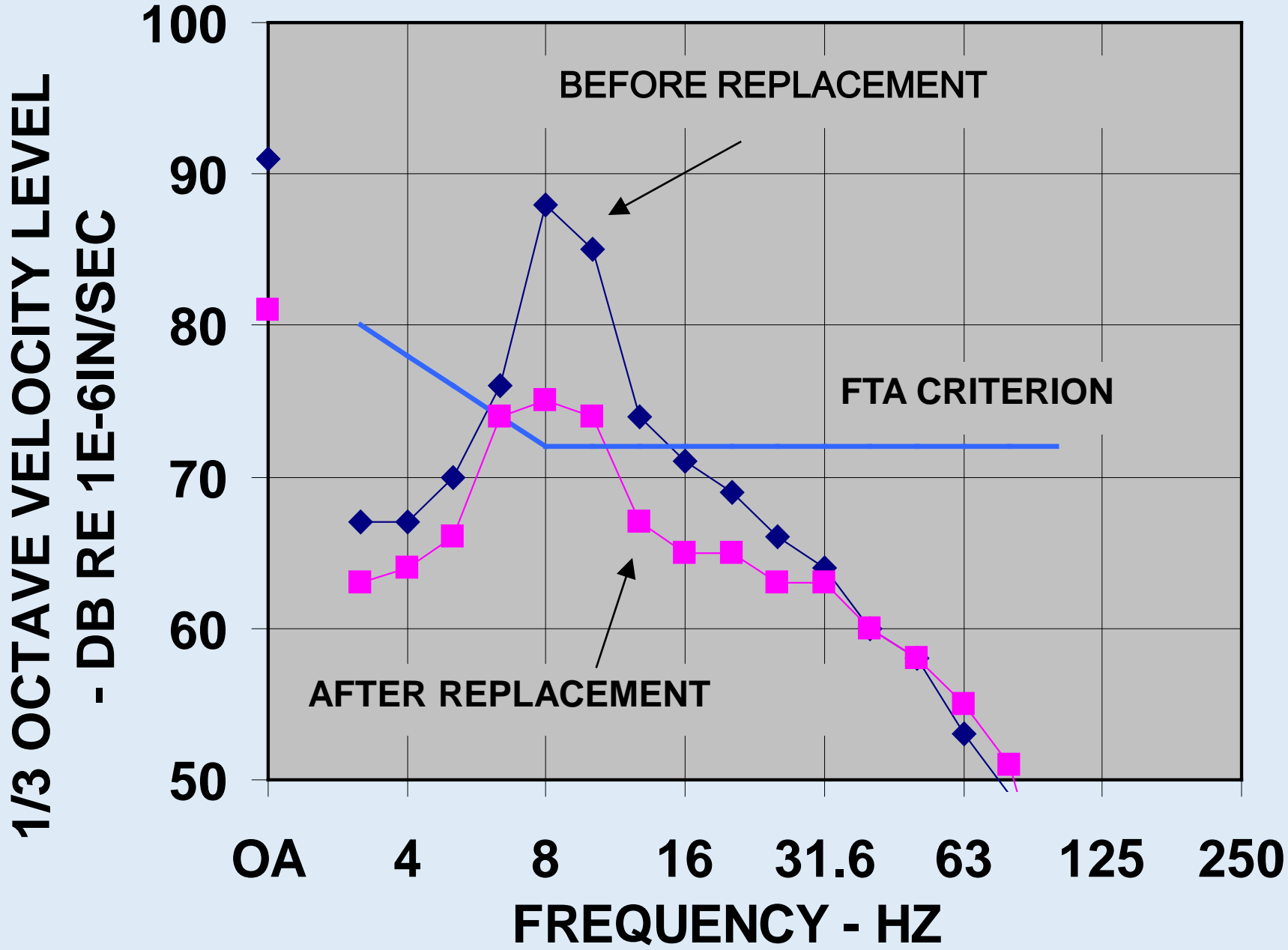


SOUND TRANSIT BEACON HILL FDL - 2012

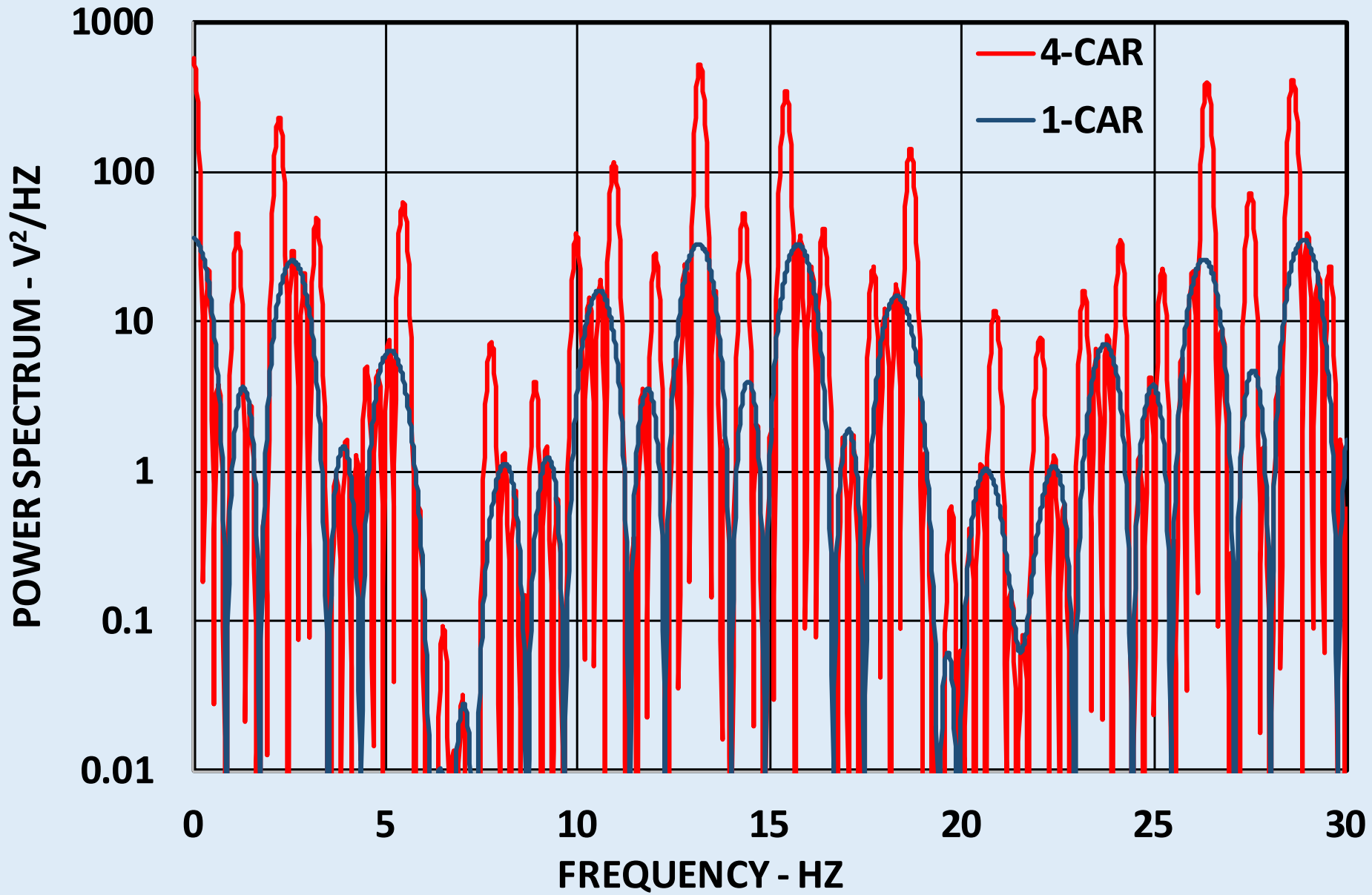
FDL - dB RE 1LB/FT^{1/2}



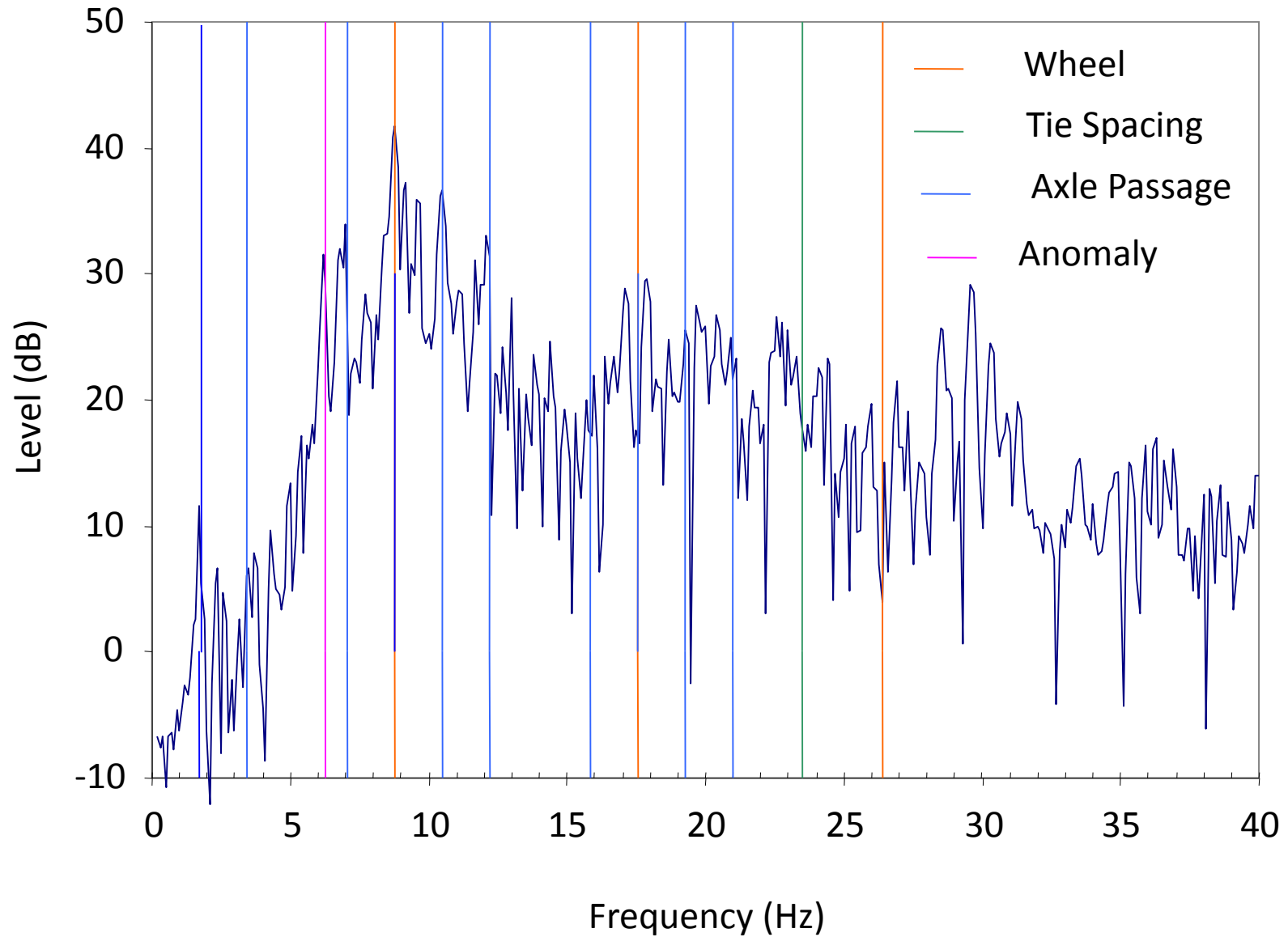
Rail Undulation At CNRail Kamloops



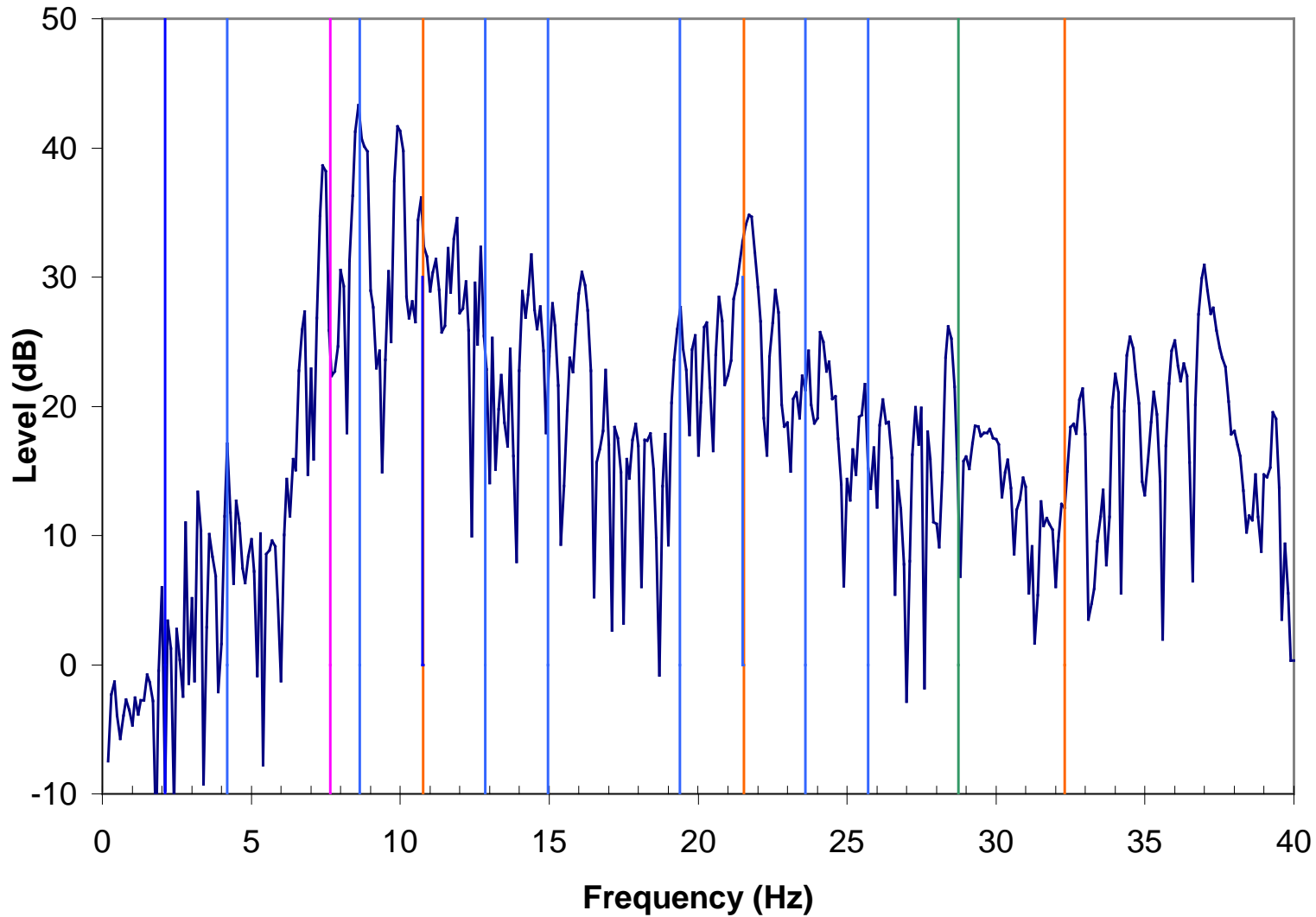
MODULATION SPECTRUM



VIBRATION SPECTRUM – 40MPH



VIBRATION SPECTRUM – 49MPH



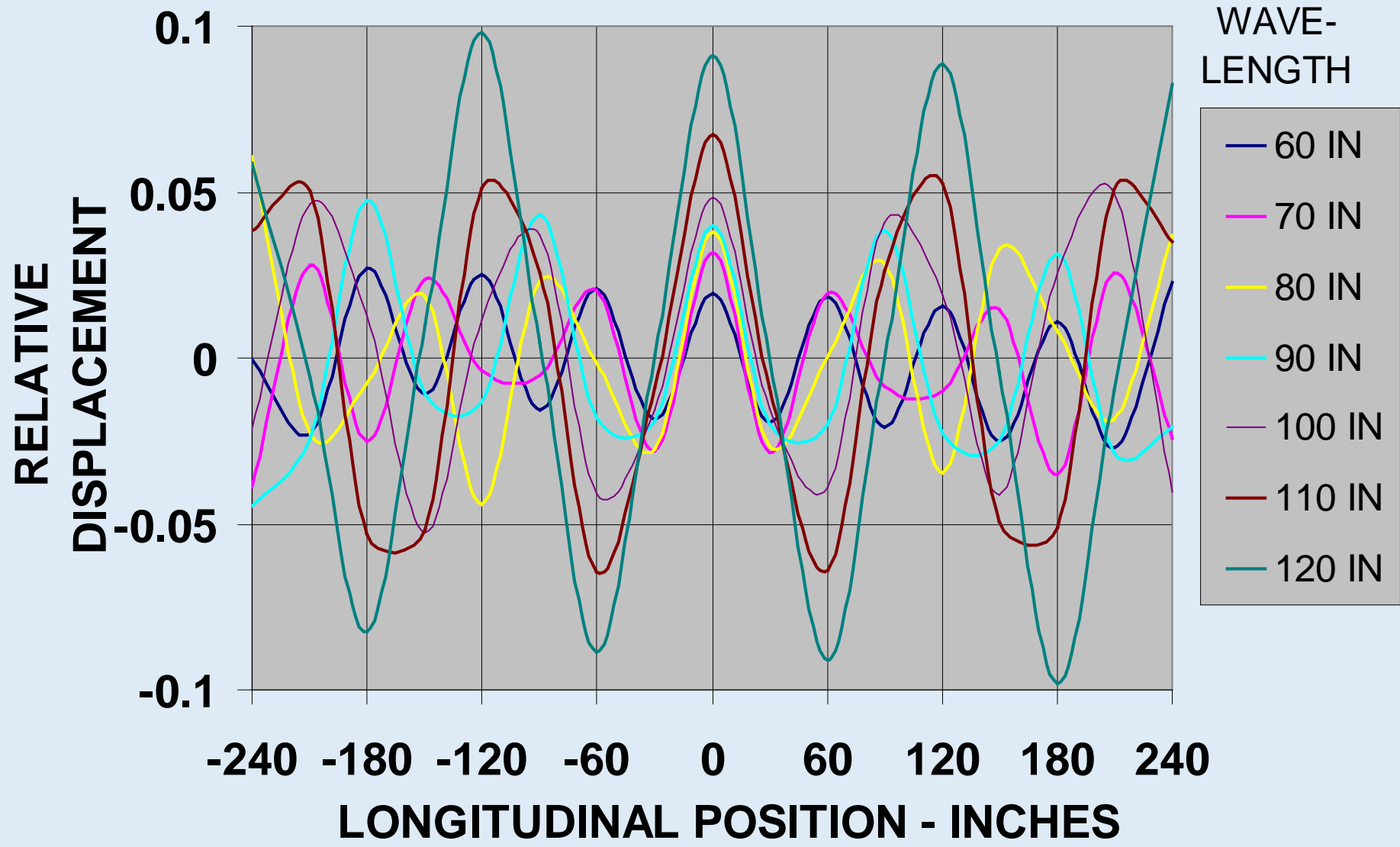
— Wheel Harmonic — Tie Spacing — Axle Passage — Anomaly

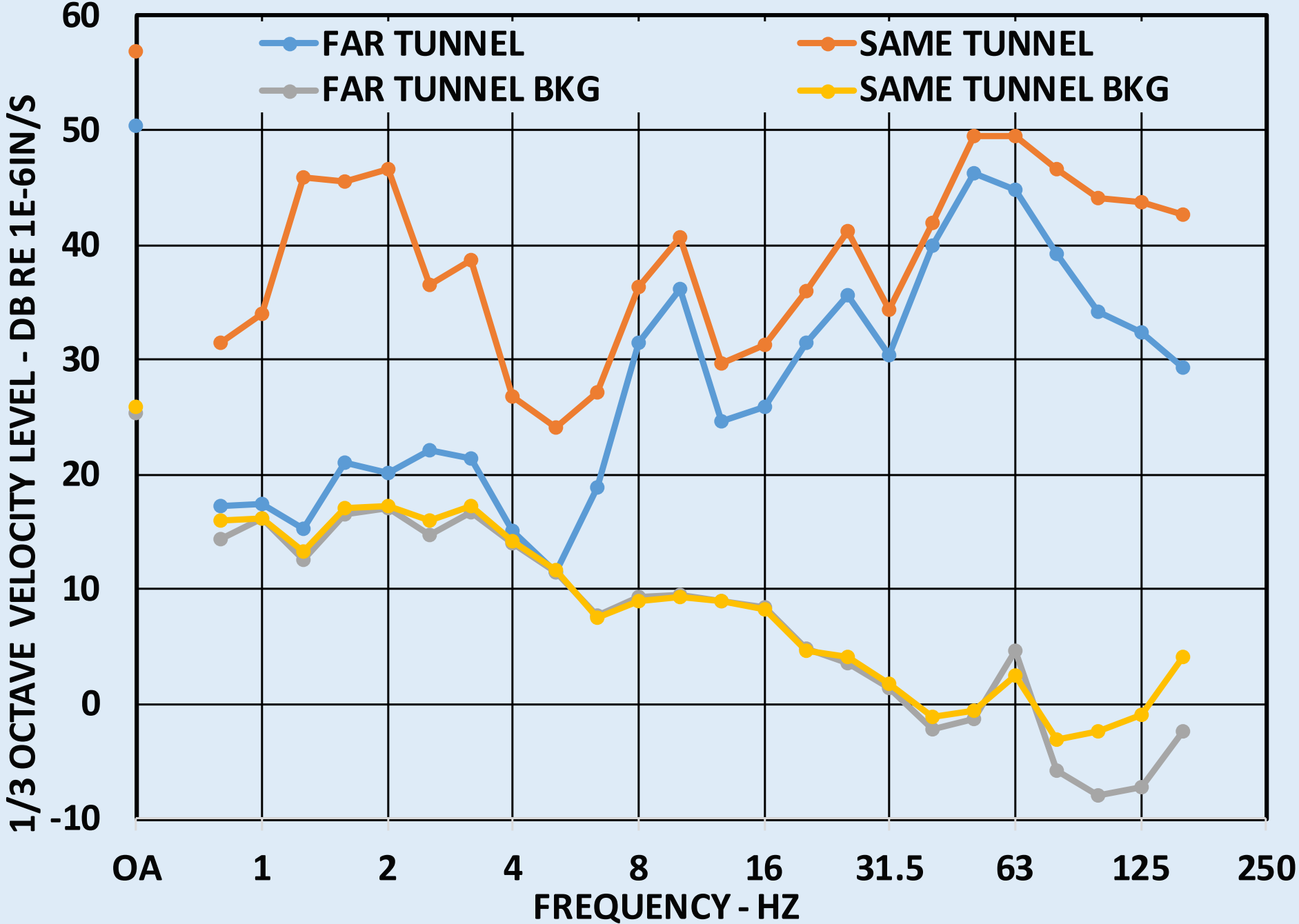
Train Sample: WB50-A

Estimated Train Speed (MPH): **49**

DF Fastener Effect on Invert Roughness

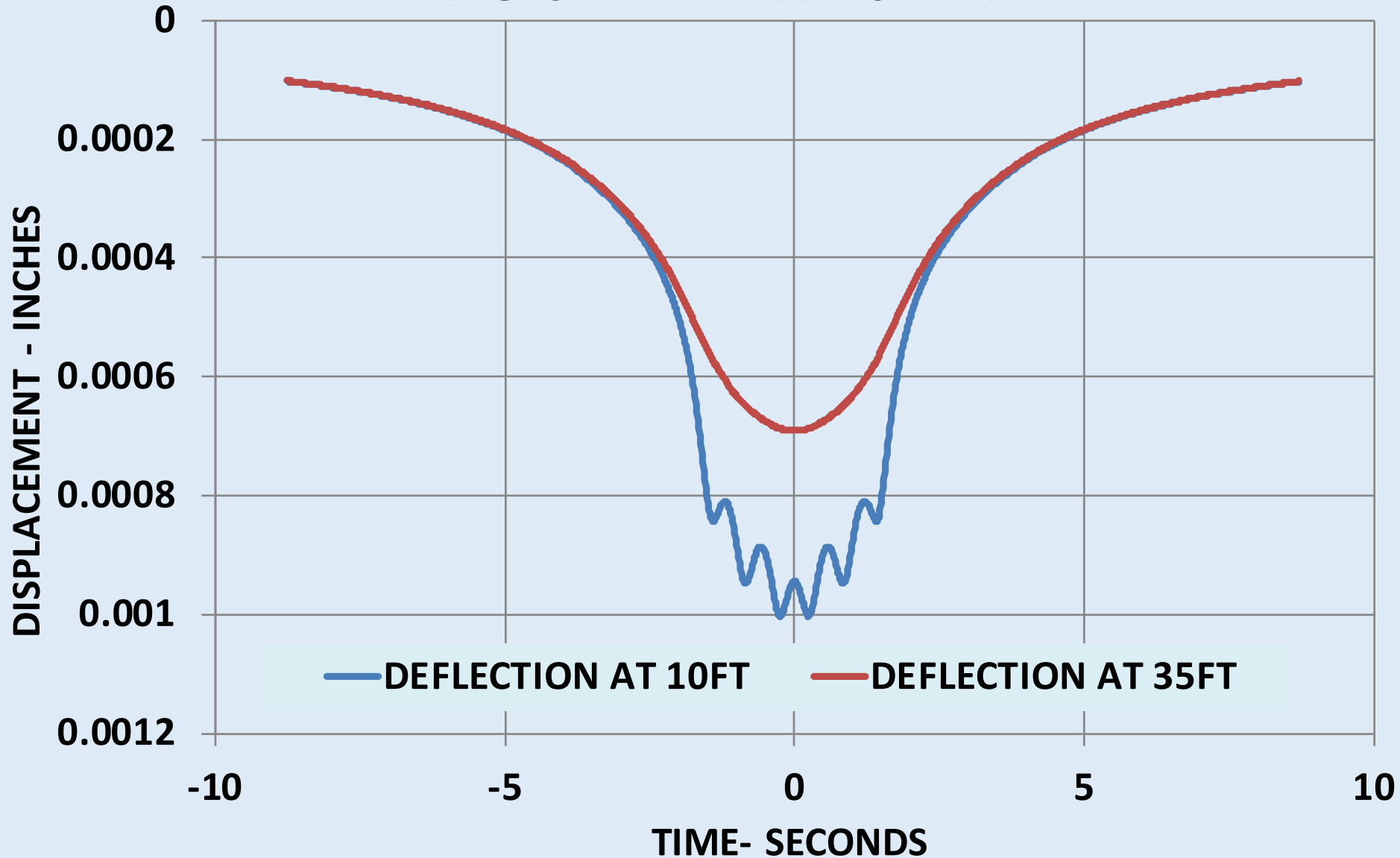
RAIL DEFLECTION VS INVERT ROUGHNESS 50 KIP/IN DF AT 30-INCH PITCH





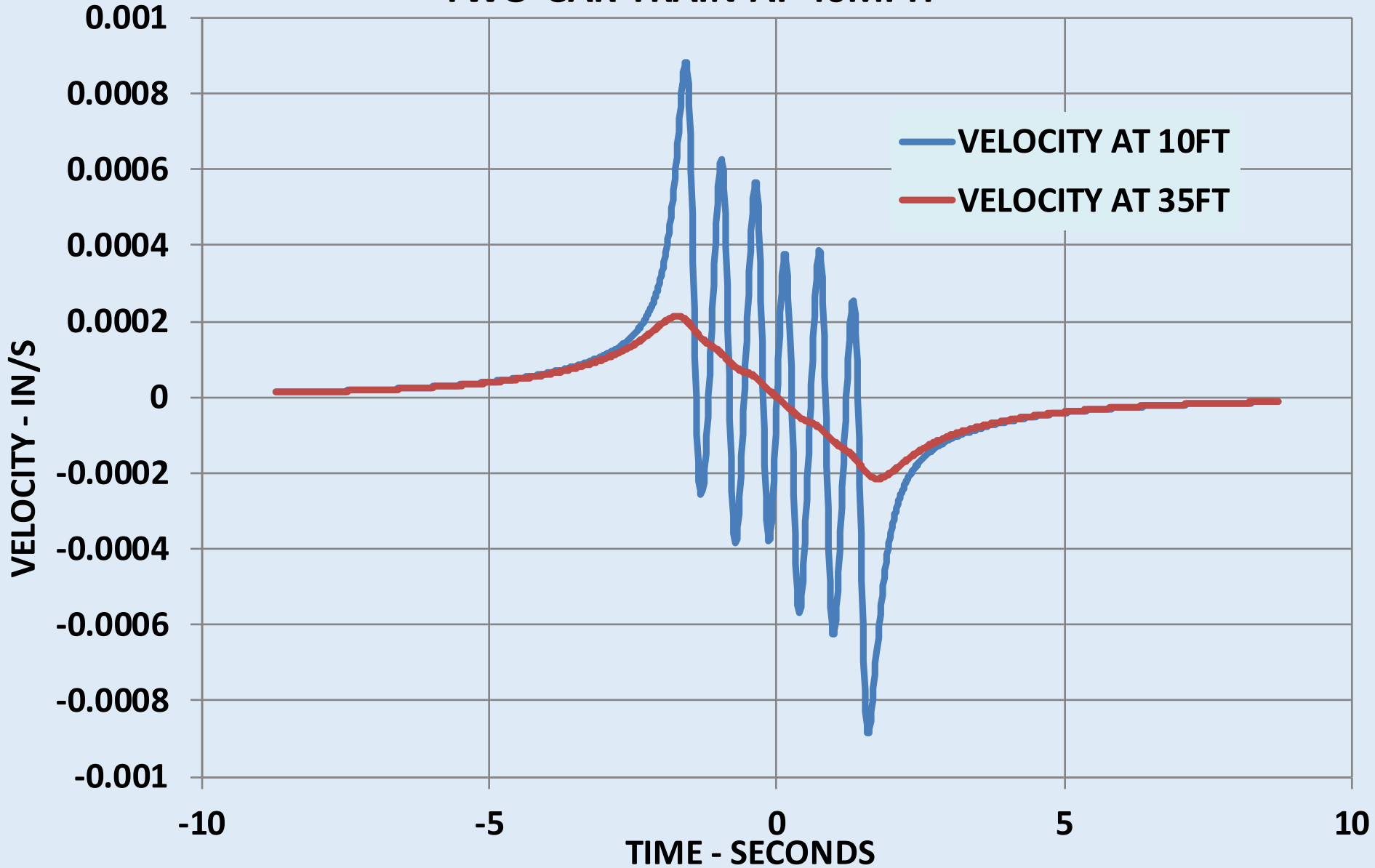
TUNNEL WALL VERTICAL DEFLECTION

TWO-CAR TRAIN AT 40MPH

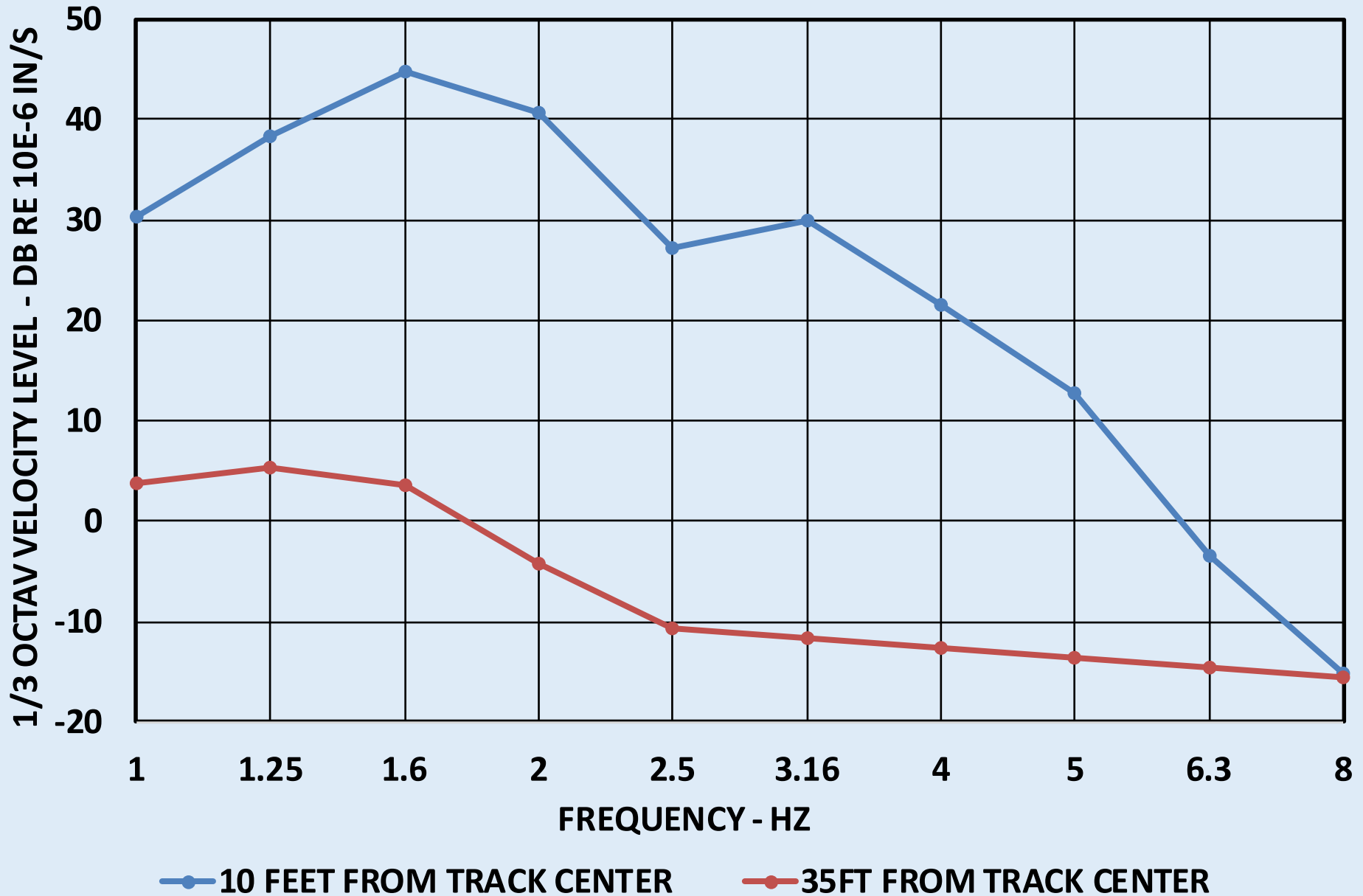


TUNNEL WALL VERTICAL VIBRATION

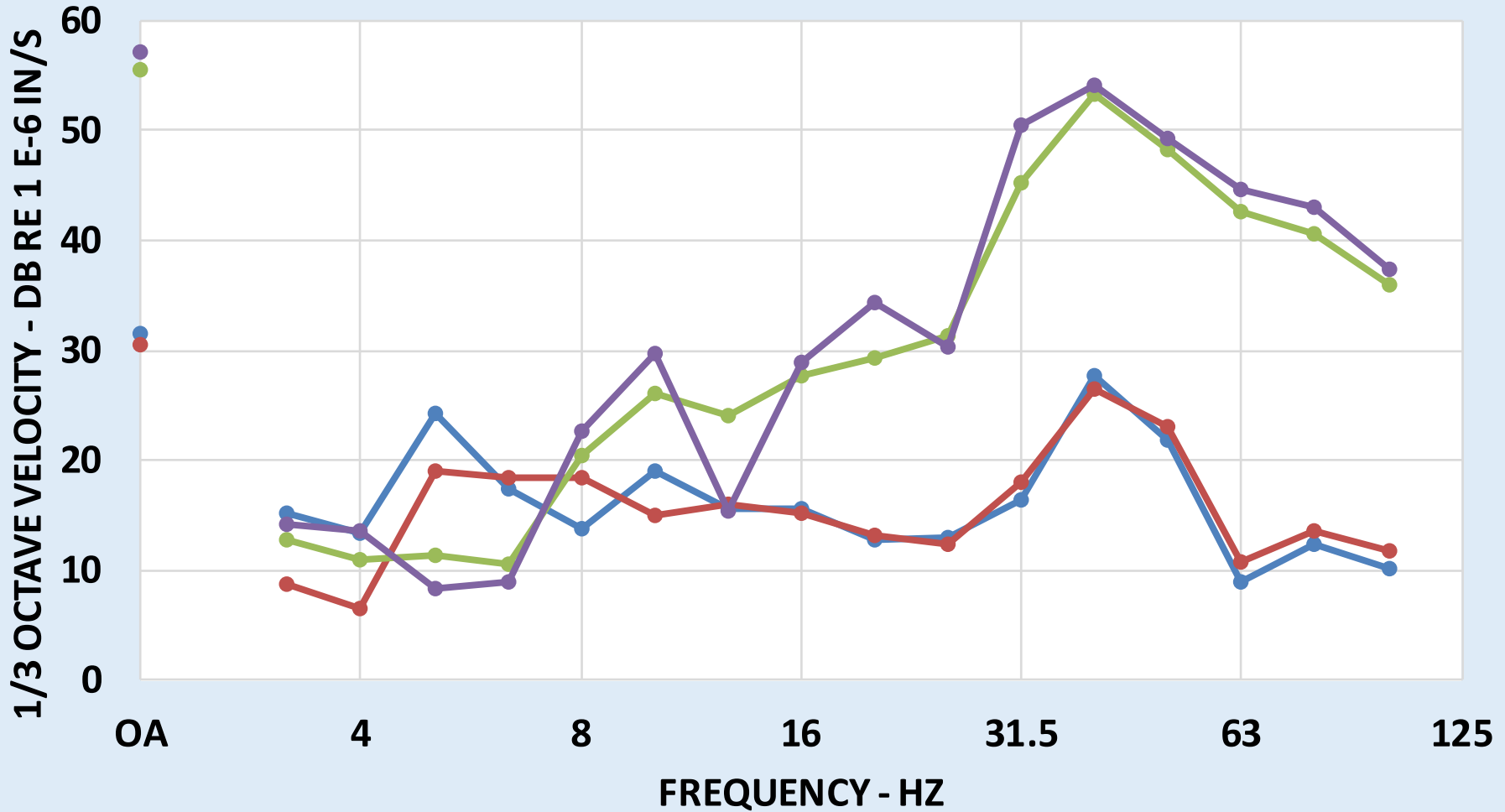
TWO-CAR TRAIN AT 40MPH



MOVING STATIC LOAD - TWO CAR TRAIN AT 40MPH



CROSS-TUNNEL VIBRATION - 2-CAR TRAINS



—●— FLOATING SLAB - 30MPH

—●— FLOATING SLAB - 35MPH

—●— RIGID INVERT - 30MPH

—●— RIGID INVERT - 35MPH

CONCLUSION

- FACTORS THAT AFFECT GROUND VIBRATION
 - RAIL AND WHEEL ROUGHNESS
 - SUSPENSION DESIGN
 - TRAIN SPEED AND AXLE SPACING
 - TRACK COMPLIANCE
 - LATERAL SLIP
 - LOW FREQUENCY STATIC DEFLECTION FIELD
 - VIBRATION ISOLATION

ACKNOWLEDGEMENTS

- SOUND TRANSIT
- VTA
- TRIMET
- PARSONS BRINCKERHOFF
- CN RAIL
- SFMUNI
- SAN DIEGO TROLLEY
- LA BLUE LINE
- PUGET SOUND TRANSIT CONSULTANTS
- PARSONS BRINKERHOFF
- JACOBS ASSOCIATES