Acentech Incorporated
33 Moulton Street
Cambridge, MA 02138

Telephone: 617-499-8000
Facsimile: 617-499-8074
E-mail: postbox@acentech.com

Acentech

22 August 2014

Jeffrey M. Puleo, AIA
Wilson Architects Inc.
374 Congress Street, Suite 400
Boston, MA 02210

Subject: FSU Interdisciplinary Research Building – Vibration and Acoustics
Acentech Project No. 624854

Dear Mr. Puleo:

On August 12th I measured the sound and vibration environments in a number of lab spaces at Florida State University in Tallahassee, FL. The purpose of these measurements was to provide information to support your programming study for the new Interdisciplinary Research Building. This letter details the results of my measurements.

Overview

My measurements at FSU are summarized in Table 1. The in-building measurements were intended to document existing conditions. The two sites being considered for the new building are shown in Figure 1, along with my measurement locations.

Table 1: Measurement Summary

Location	Room Number	Measured Data	Notes	NC Level	Ambient Vibration Level
Outdoor location 1	-	Sound & Vibration	Near the wind tunnel experiment	No ambient without wind tunnel 81 dBA (with wind tunnel)	VC-E (with no wind tunnel) VC-C (with wind tunnel)
Outdoor location 2	-	Vibration	Closest location to train tracks	No ambient sound data	VC-G (with no trains) VC-B (with trains)
AME Building	Room 154	Vibration	Wind tunnel experiment in this building	No ambient sound data	VC-D
Materials Research Building	Room 126	Sound & Vibration	Atomic Force Microscope	NC 47	VC-D
Magnet Lab Building	Room C123D	Sound & Vibration	Transmission Electron Microscope	NC 41	VC-F / VC-E
Shaw Building	Room 147	Sound & Vibration	Scanning Electron Microscope	NC 38	VC-E
Keen Building	Room 421	Sound & Vibration	Scanning Electron Microscope	NC 48	VC-B
Keen Building	Room 106	Sound & Vibration	Atomic Force Microscope Scanning Tunneling Microscope	NC 57	VC-C
Keen Building	Room 12	Sound & Vibration	Scanning Tunneling Microscope Optical Microscope	NC 60	VC-B

The first outdoor measurement location was adjacent to the AME building which houses a large wind tunnel that has been identified as a potentially large source of vibration in this area of campus. I first measured the sound and vibration when the wind tunnel was operating. Afterwards I measured the ambient vibrations[1] in the same location for approximately 5 hours. In the late afternoon I moved the vibration measurement system to site #2 which is closer to rail tracks to the north. The vertical ground vibrations were recorded here from about 5:00 pm on August 12th to 11:00 am the next day.

[1] All vibration measurements were made in the vertical direction only.

Vibration Measurements

Outdoor Location 1

The vertical ground vibration spectra (frequency distributions) at outdoor location 1 during operation of the AME building wind tunnel are shown in Figure 2. The measured spectra are also plotted alongside the familiar vibration criterion (VC) curves that are used to characterize vibration sensitive spaces. The maximum, average, and minimum vibration spectra are presented. During operation of the wind tunnel a large volume of high pressure air is vented through the test section to atmosphere. A typical run is about 10 seconds long. The maximum vibration curve corresponds to the short period of time when the wind tunnel was in use. As the figure shows, the operation of the tunnel produced a short duration spike (VC-C) in the 8 Hz 1/3 octave band.

Following the wind tunnel, I left the equipment to record the ambient ground vibrations for a period of approximately 5 hours. I processed the data in 10-second intervals (there were 1,800 intervals in the 5-hour sample). The statistical summary of the interval data is presented in Figure 3. The upper and lower bounds are simply the largest and smallest vibrations at each frequency throughout the measurement period. The quantity L1 refers to the vibrations that were exceeded 1 percent of the time (i.e. the vibrations exceeded the L1 level in 18 of the 1,800 interval samples). The L10, L50, L90, and L99 are defined similarly.

Overall, the vibration levels at outdoor location 1 were below VC-E the vast majority of the time. The upper bound vibrations may have been caused by other wind tunnel events or vehicle traffic on the nearby road.

We would not expect the vibrations to be dramatically different in a building at this location on a ground level, grade-supported slab. Our experience is that the vibrations inside a building are on the order of ½ to ¼ the levels on the ground before the building is built.

Outdoor Location 2

The vertical ground vibrations were measured at outdoor location 2, as shown in Figure 1, for approximately 18 hours. The statistical spectra from this time period are presented in Figure 4. Because of the trains the L1 and upper bound levels were much higher here. I was able to identify at least two train events that produced the levels between L1 and the upper bound.

The vibrations when trains are not present are quite low, below VC-G. A building at this site would be expected to have a very low vibration environment when no trains are present. The greatest vibrations occurred between 5 Hz and 12.5 Hz which is not uncommon for freight trains with diesel locomotives. The train-related vibrations were about 1,000 micro-in/sec and because they occur at such low frequencies we would not expect the vibrations inside a building to be much lower (perhaps a factor of two lower).

Obviously, when considering this site it will be important to understand not only the vibration criteria, but also whether or not an occasional disturbance due to a train passage can be tolerated.

AME Building

The vertical floor vibrations measured inside the AME building during the wind tunnel test are shown in Figure 5. Data was recorded for approximately 30 minutes and the resulting spectra were combined into maximum, average, and minimum levels. The maximum spectrum is indicative of when the tunnel was operated. The peak at 12.5 Hz is likely due to a piece of mechanical equipment inside the building.

Materials Research Building

The vertical floor vibrations inside the Materials Research Building (MRB) Room 126 are shown in Figure 6. Data was recorded for approximately 30 minutes. The greatest vibrations in this room, which houses an atomic force microscope, were approximately 200 micro-in/sec, although this was probably due to a piece of mechanical equipment. Otherwise the vibrations were less than VC-E.

Magnet Lab Building

The vertical floor vibrations in the Magnet Lab Building room C123D are shown in Figure 7. This room houses a transmission electron microscope. This is a fairly quiet lab space – the vibrations were generally less than VC-F.

Shaw Building

The vertical floor measurements in room 147 of the Shaw building are shown in Figure 8a. This room houses a scanning electron microscope. The maximum vibrations were likely produced by rolling desk chairs around the room while the researchers worked. The researchers in this space explained that the floors of the scanning electron microscope rooms were isolated from the rest of the building, meaning that there is a physical gap in the foundation surrounding the room. To understand the difference between these "isolated" rooms and the rest of the building I then measured in the hallway outside of room 147 for about 10 minutes. This data is presented in Figure 8b. As you can see, there is little difference between the main foundation and the isolated slabs in the SEM rooms. This is consistent with observations we have made in many other lab spaces with this type of isolation gap construction. In general we have found that with grade-supported slabs, physically separating the slab from the rest of the building has some reduction effect at frequencies greater than 30 Hz, but has little benefit below that.

Keen Building

I measured in three spaces within the Keen building. The first space was in a scanning electron microscope area in room 421. The vibration data from this room is presented in Figure 9. This above grade floor performs to VC-B at the microscope location, even when walking around the room and external hallways.

Vibrations measured in room 106 on the first floor of the Keen building are shown in Figure 10. This room houses an atomic force microscope and a scanning tunneling microscope. There was a local air conditioning unit in this room, which may explain the higher vibrations in the 63 Hz 1/3 octave band.

Vibrations measured in room 12 in the basement of the Keen building are shown in Figure 11. A scanning tunneling microscope and an optical microscope are in this room. There were also fume hoods and HVAC ductwork in this room that produced a noticeable amount of audible sound. This may explain the higher vibrations seen in the 31.5 Hz and 63 Hz 1/3 octave bands.

Sound Measurements

The sound measurements at outdoor location 1 during the wind tunnel test are shown in Figure 12. The Lmax and L1 curves characterize the 10 second period when the test occurred. The statistical spectra are plotted as un-weighted sound pressure levels in 1/3 octave bands. This information can be used to estimate the amount of sound that may enter a building at outdoor location 1. The equivalent A-weighted sound levels for each spectrum are included in the plot legend.

The average sound measurement in each of the lab spaces is presented in Figure 13. These spectra are presented in octave band frequencies along with noise criterion (NC) curves. NC levels are used to characterize indoor noise from HVAC and other steady sound sources. The NC level for each space is included in the plot legend. These levels are representative of the environments in which the equipment is being used. In the magnet lab room C123D there was computer equipment with cooling fans responsible for the sound in the room (not HVAC equipment). In Shaw room 147 there were researchers working in the space, which may account for an NC level that is higher than if it were unoccupied. In all of the other labs, the HVAC equipment was the main source of sound in the room.

Discussion

Overall the vibration levels at the two outdoor locations were less than VC-E a large majority (99%) of the time. At location 1, the wind tunnel and transient events (presumably street traffic) produced levels as high as VC-C. At location 2, transient levels up to VC-B were due to rail traffic.

We would expect the vibrations on a ground level grade-supported slab in the new building to be on the order of ½ to ¼ as large as our outdoor measurements. This would mean the ambient vibrations in both buildings would be in the VC-F to VC-G range which is consistent with existing buildings on campus. The expected transient vibrations would be in the range of VC-D to VC-E at location 1 (due to the wind tunnel and street traffic) and VC-C to VC-D at location 2 (due to trains).

The outdoor sound measurements near the wind tunnel are not overly loud. At 81 dBA for only a few seconds they are comparable to the sound of a large truck passing by. However, they should be considered when designing the exterior facade of the building.

The current interior noise levels in existing rooms range from NC-38 to NC-60. Labs that are sensitive to acoustical noise, commonly electron microscope areas, typically have a design goal of NC-25 to NC-30. Laboratory spaces without the need for special acoustical design goals may range from NC-40 to NC-50. For your programming study, it will be important to understand the acoustical goals for each of the potential lab spaces. Even though my measurements in each lab space were acquired during typical operating conditions, the sensitive equipment manufacturers may require better acoustical environments in the new building rooms.

I hope that this letter provides the information you need at this time.

Please contact me at 617-499-8012 or at ebrush@acentech.com with any questions or if there is anything else we can do to be of service.

Sincerely,

ACENTECH INCORPORATED

Ethan R. Brush

Ethan R. Brush
Senior Consultant

J:\624xxx\6248xx\624854 - Wilson Arch - FSU Interdisciplinary Research Bldg - Programming\Site Measurements\Report

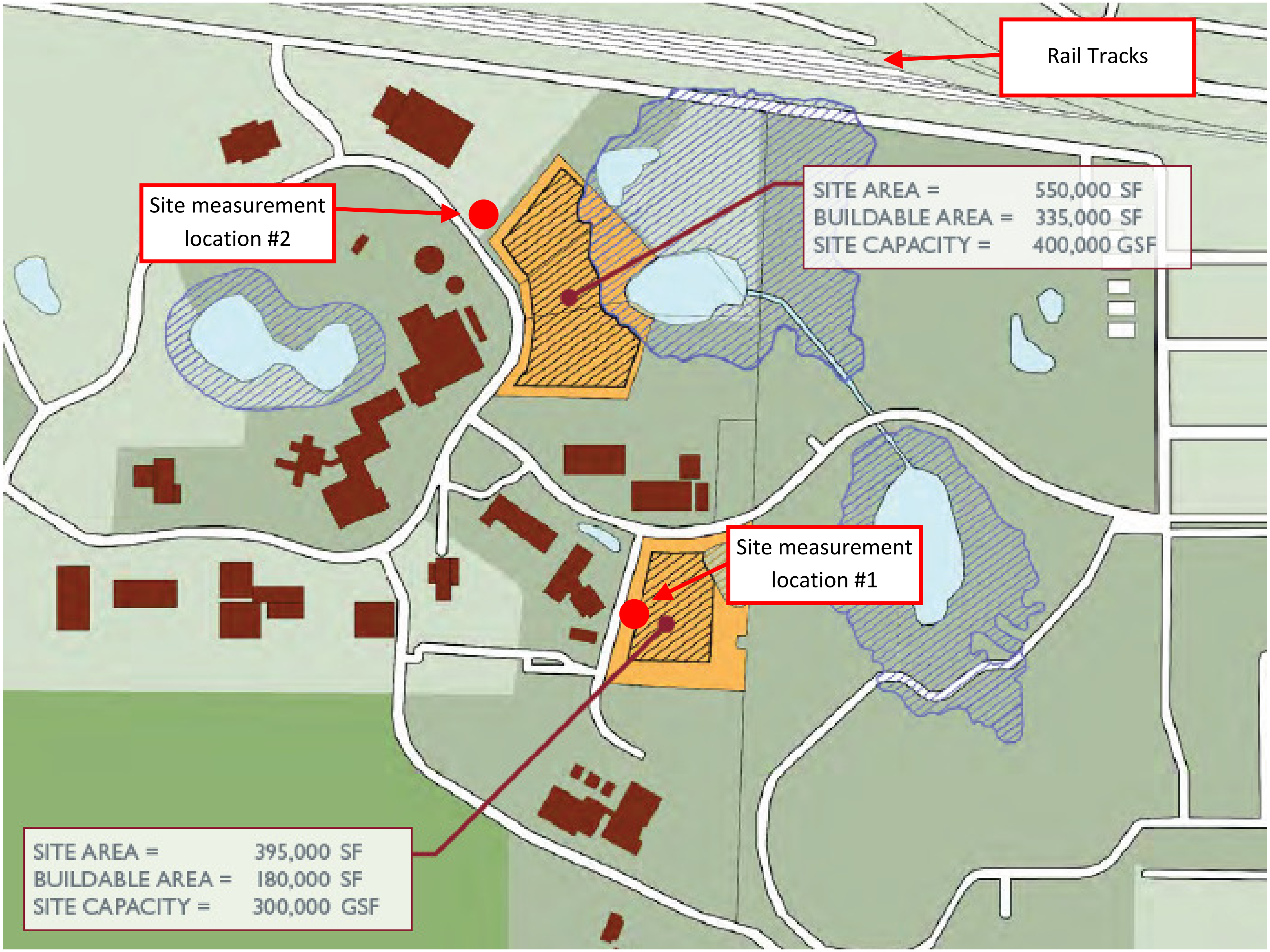

Figure 1: Outdoor vibration measurement locations

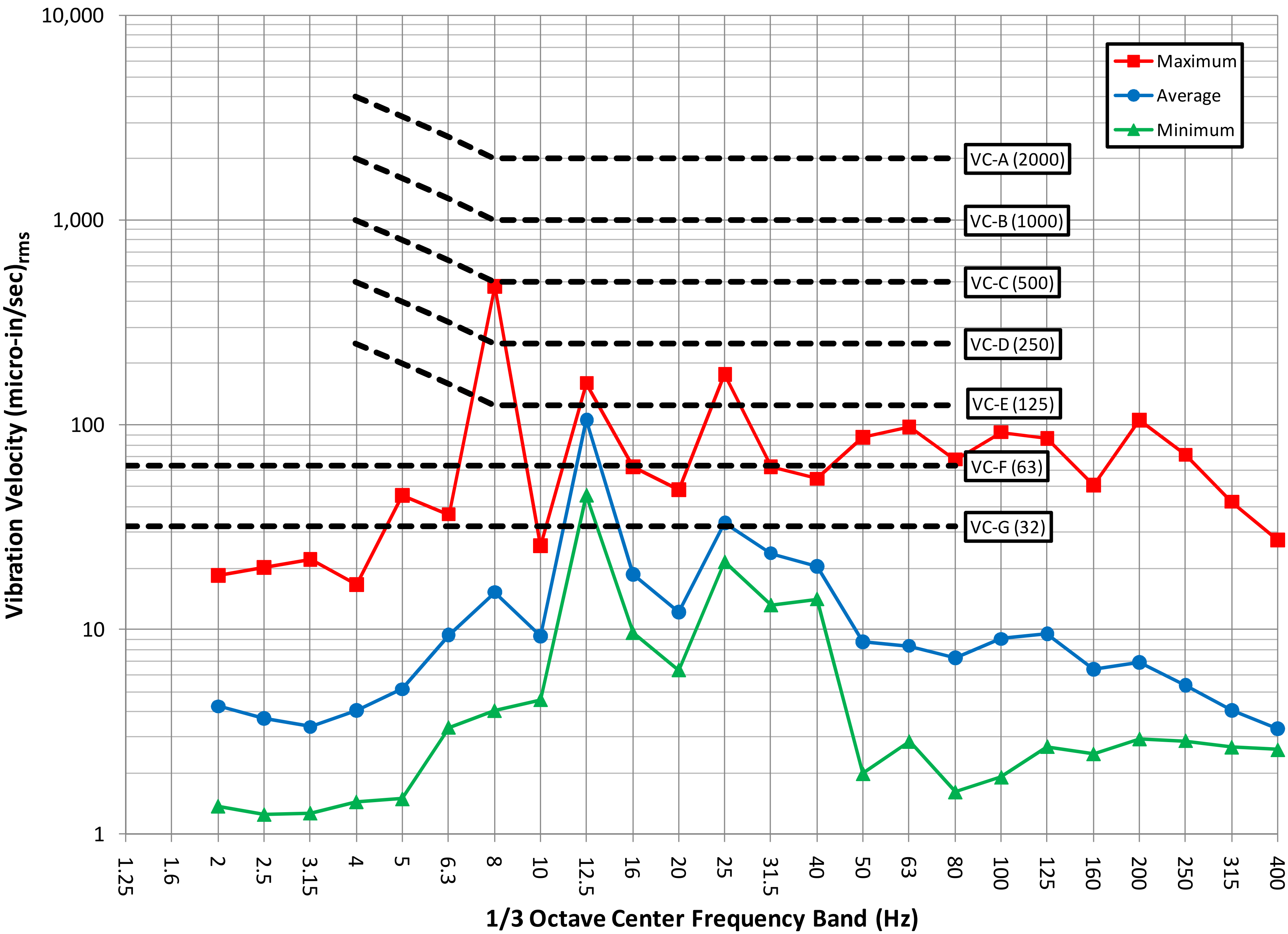

Figure 2: Outdoor Vibration Measurement Location #1 – AME Building Wind Tunnel Event

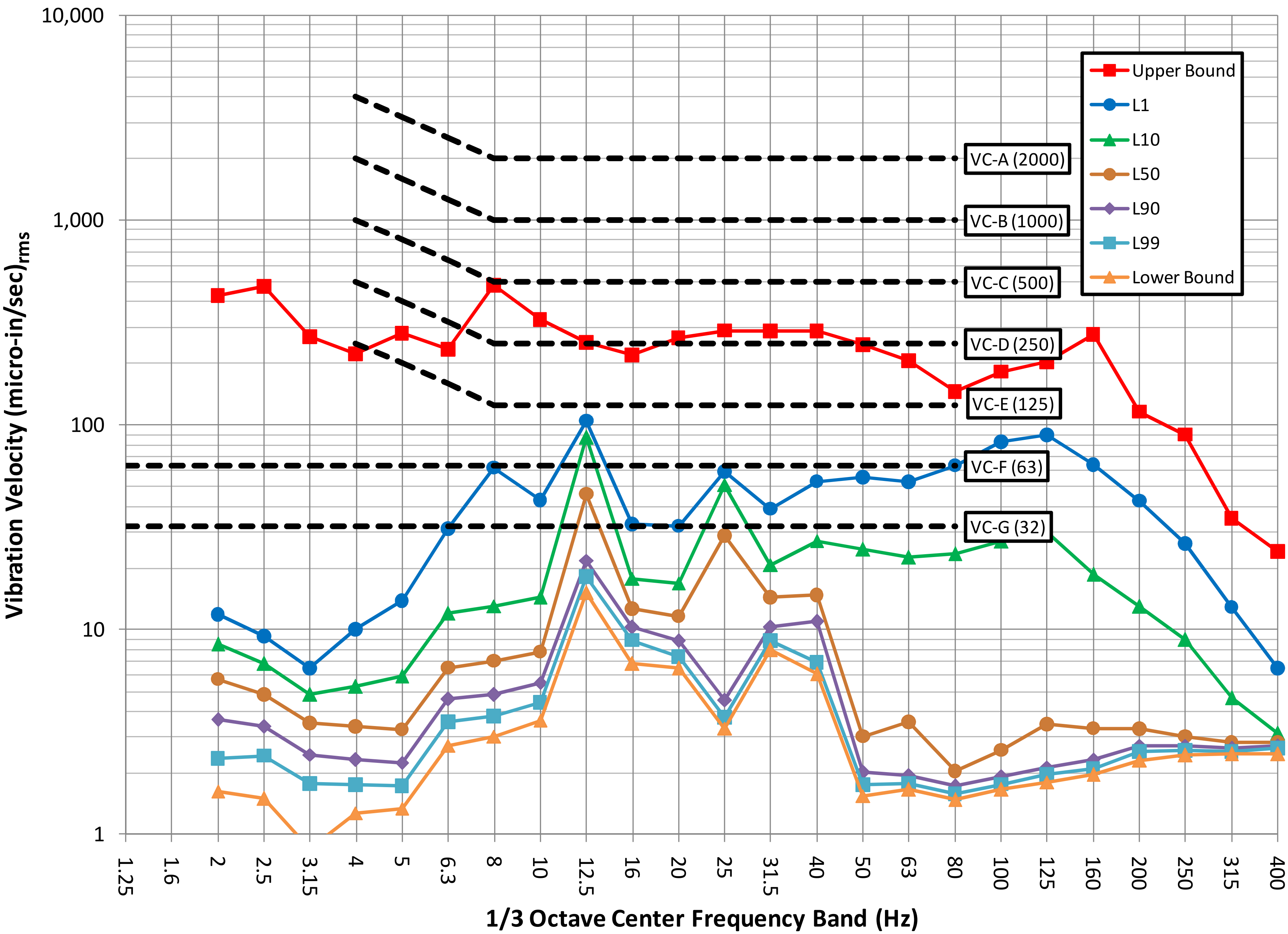

Figure 3: Outdoor Vibration Measurement Location #1 – Ambient Environment

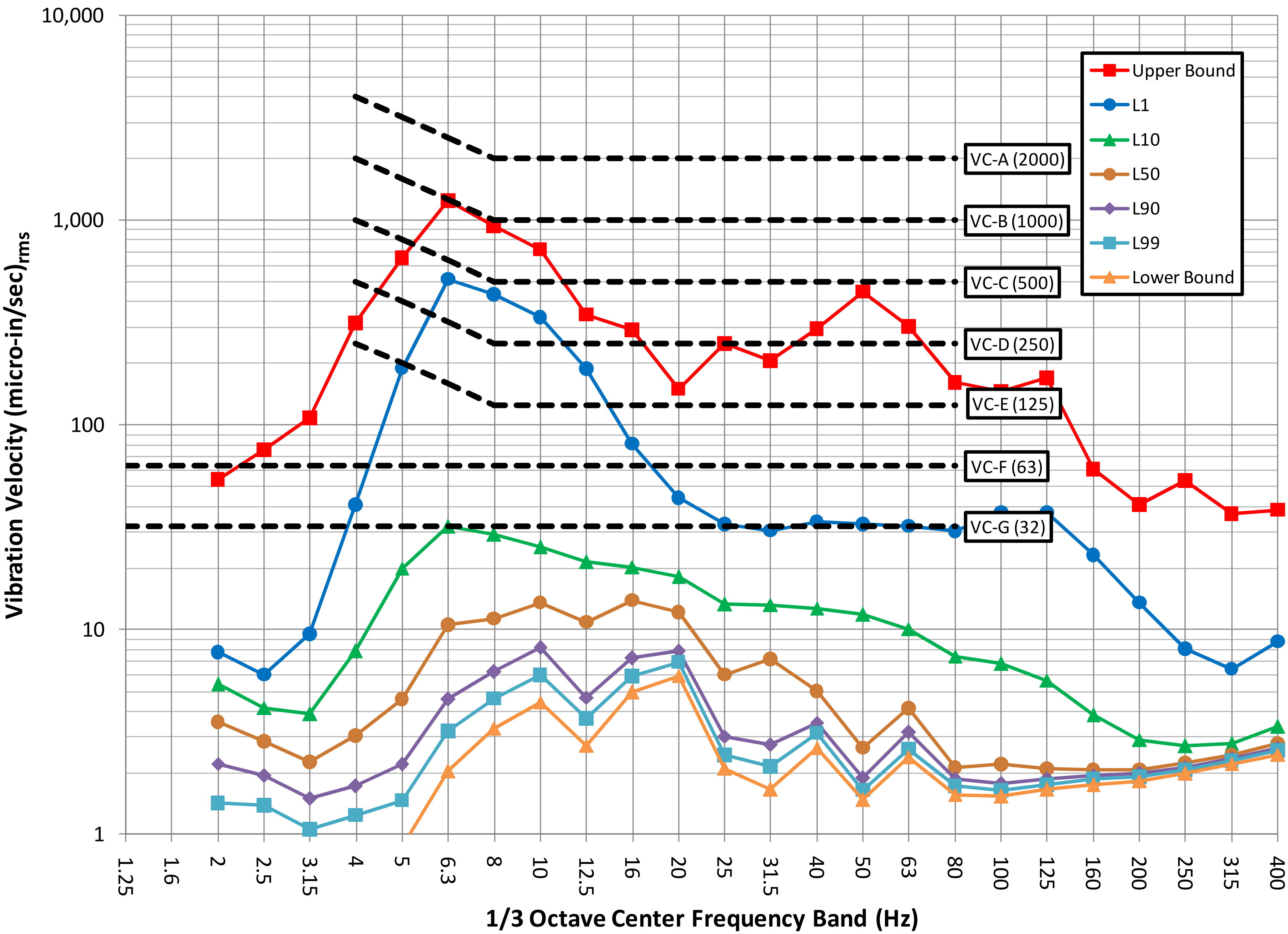

Figure 4: Vibration Measurement Location #2 – Ambient Environment

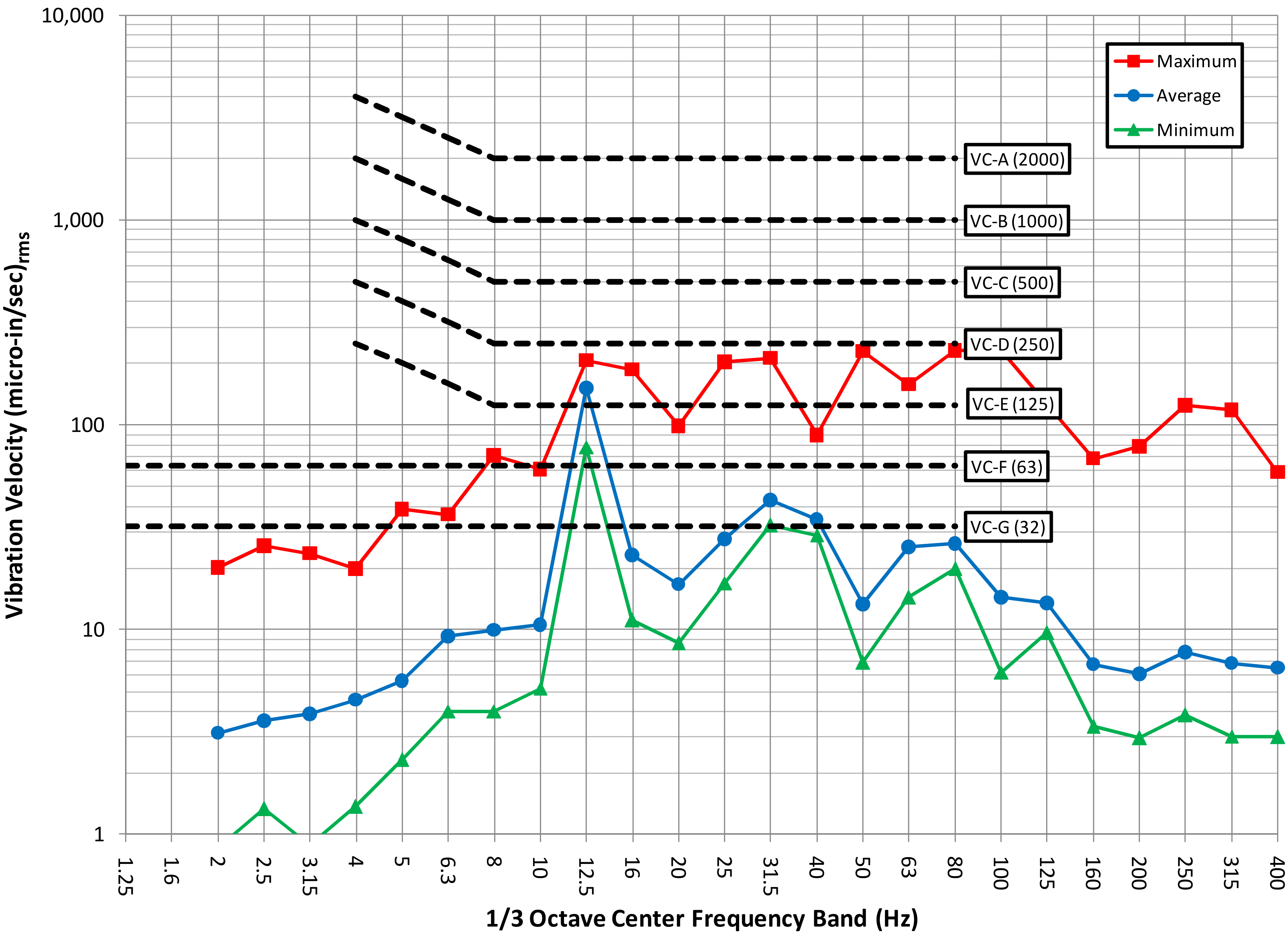

Figure 5: Vertical Floor Vibration Measurements in the AME Building – Hallway Near Room 154

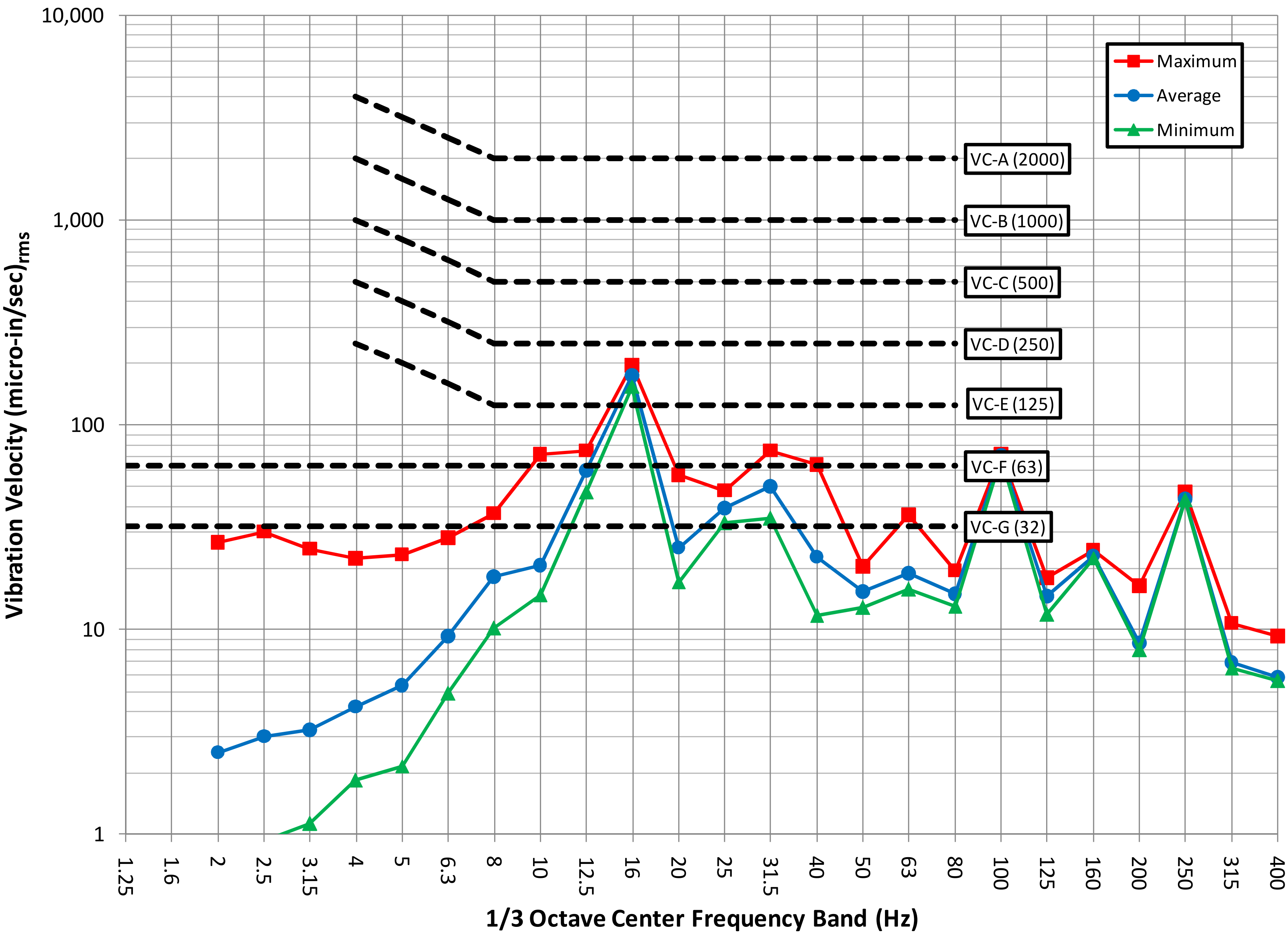

Figure 6: Vertical Vibrations in the Materials Research Building – Room 126 (Atomic Force Microscope)

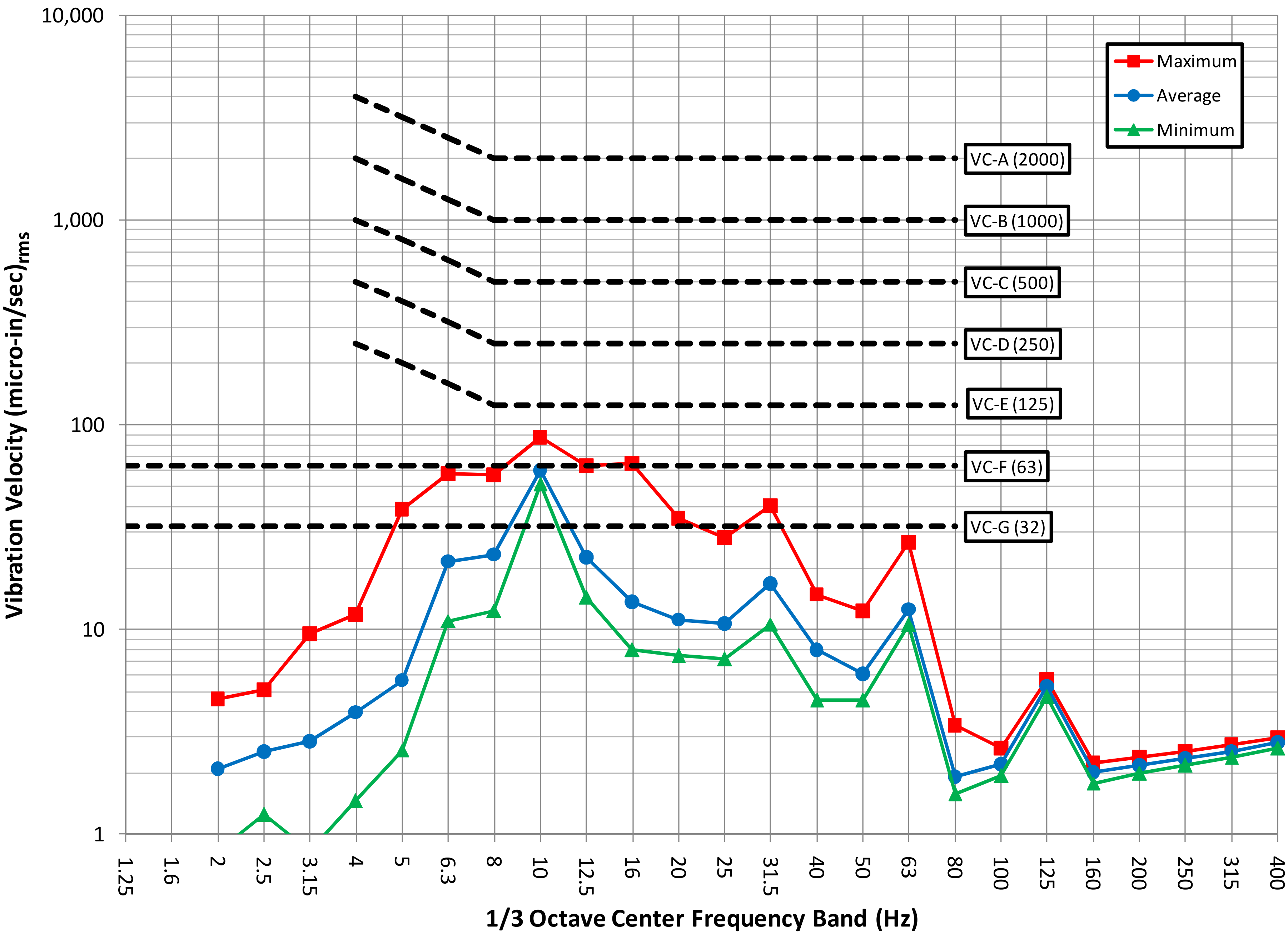

Figure 7: Vertical Vibrations in the Magnet Lab Building – Room C123D (Transmission Electron Microscope)

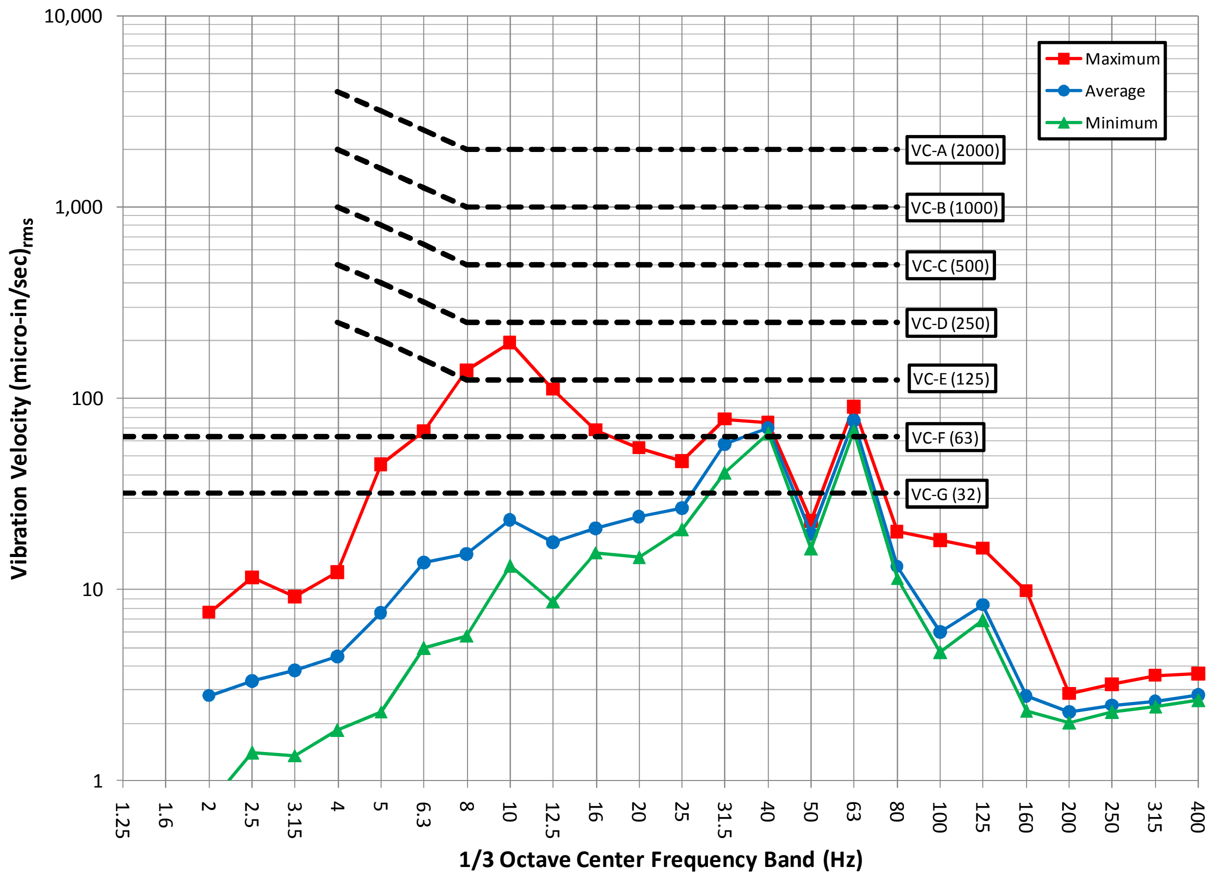

Figure 8a: Vertical Vibrations in the Shaw Building – Room 147 (SEM: On “Isolated” slab floor)

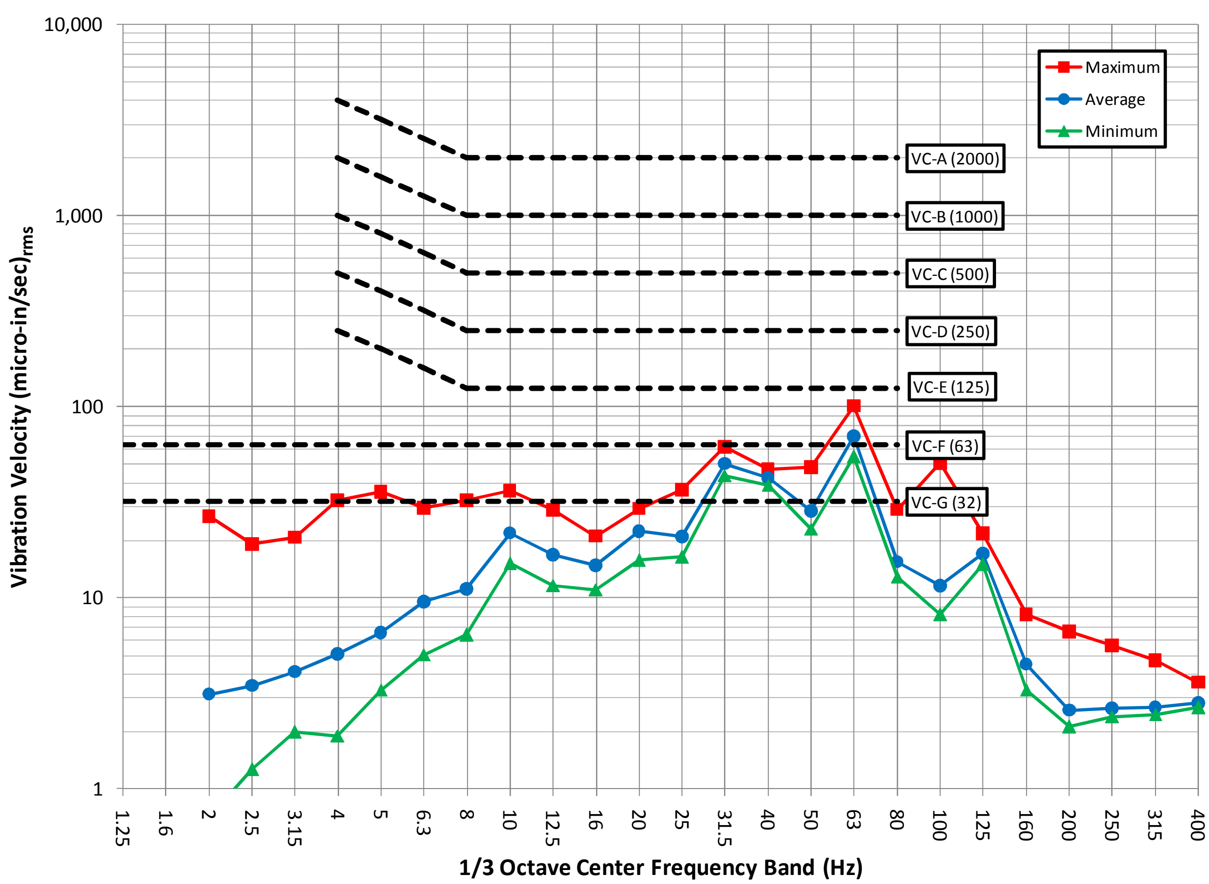

Figure 8b: Vertical Vibrations in the Shaw Building – Outside of Room 147 (Off “Isolated” Slab)

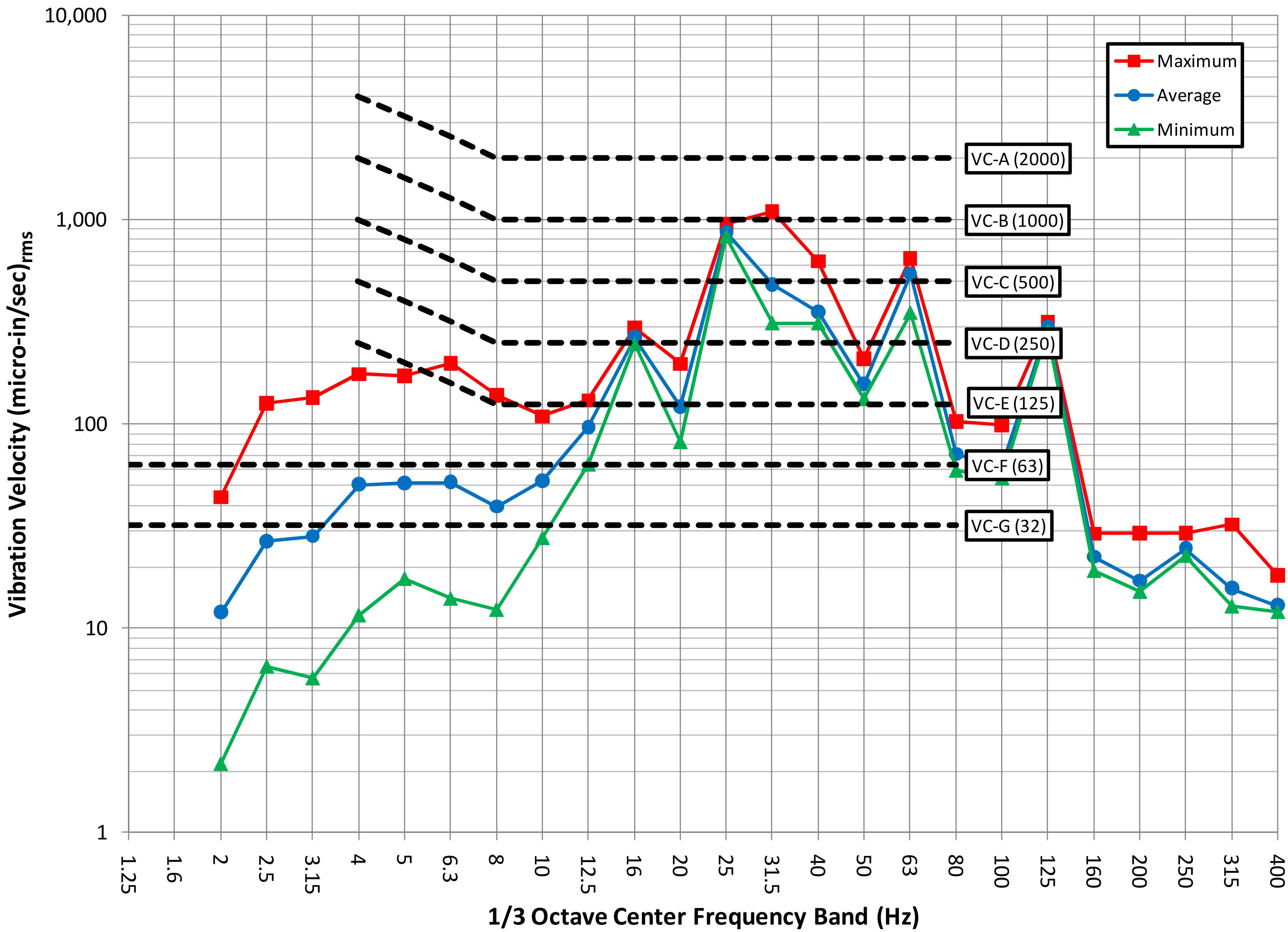

Figure 9: Vertical Vibrations in the Keen Building – Room 421 (Scanning Electron Microscope)

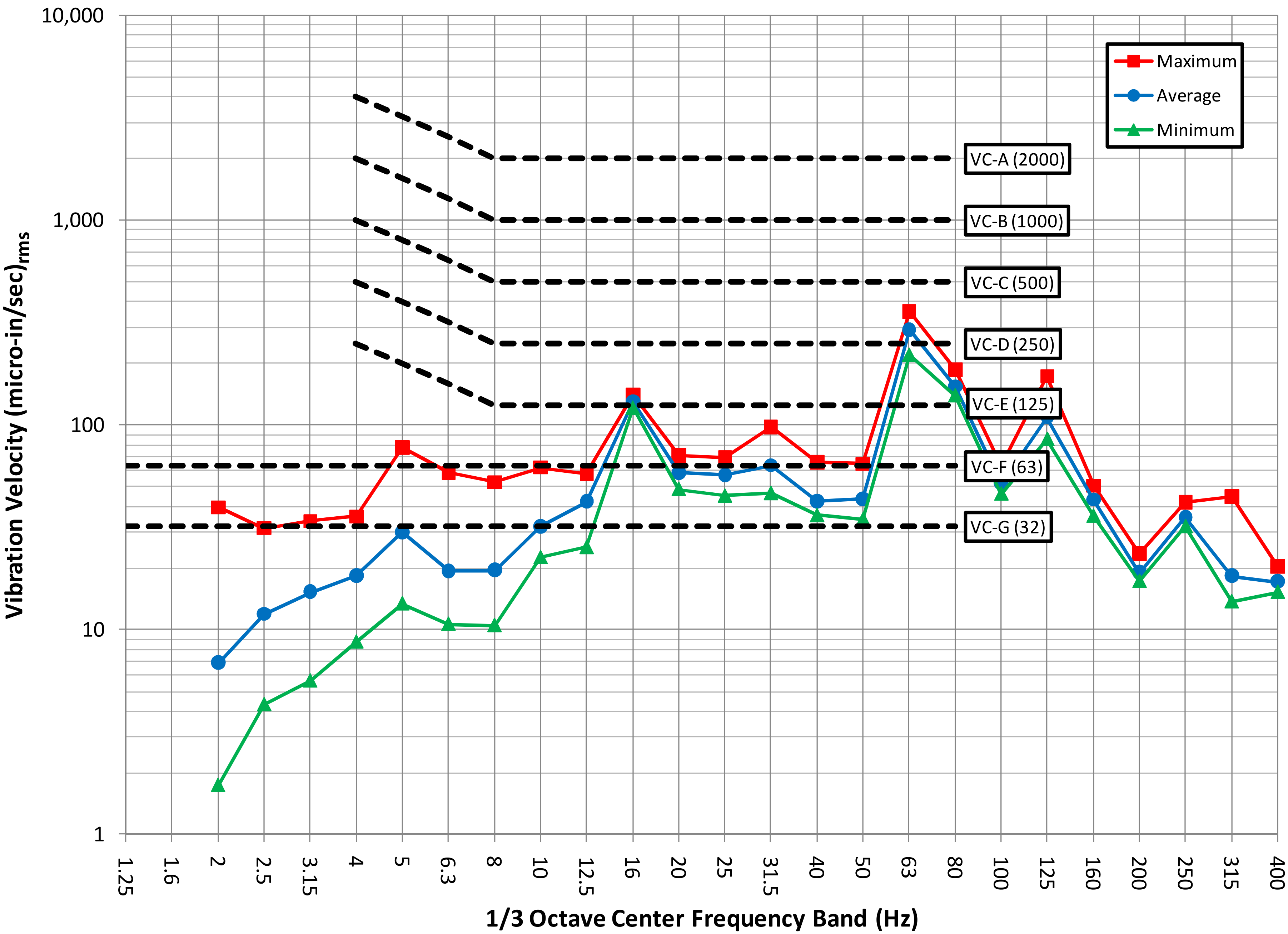

Figure 10: Vertical Vibrations in the Keen Building – Room 106 (Atomic Force and Scanning Tunneling Microscopes)

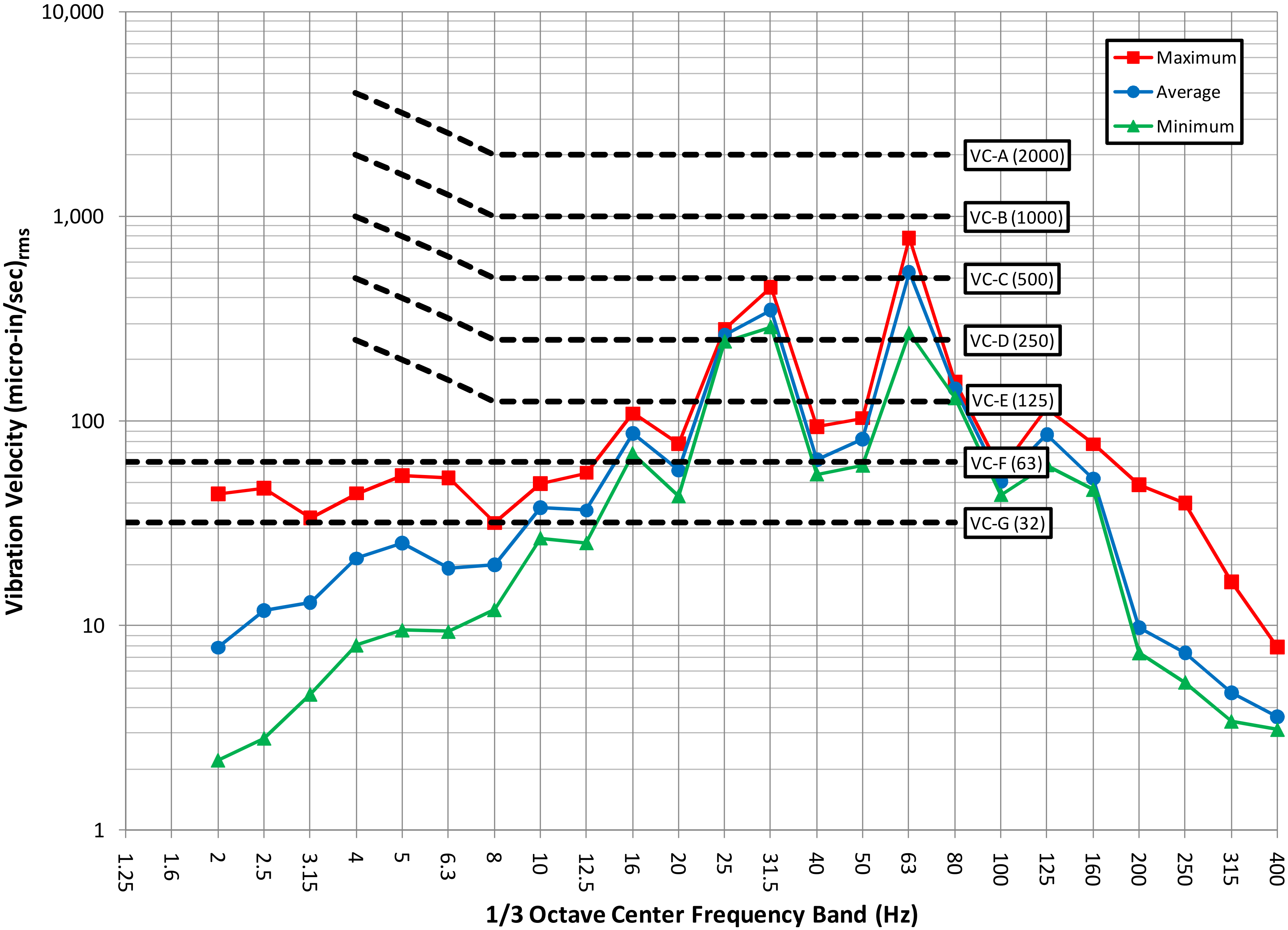

Figure 11: Vertical Vibrations in the Keen Building – Room 12 (Basement: Scanning Tunneling and Optical Microscopes)

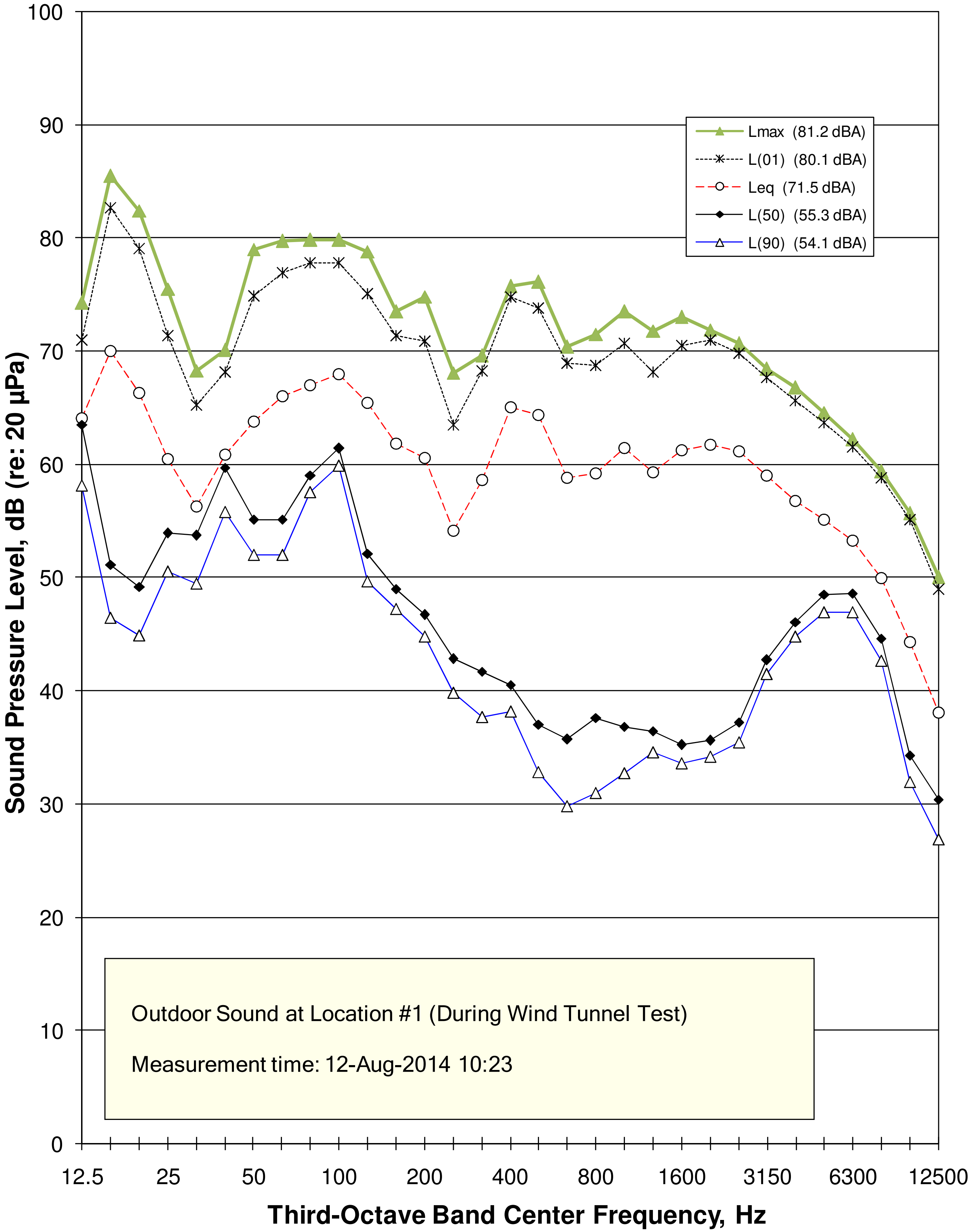

Figure 12: Sound Measurements at Outdoor Location #1 During Wind Tunnel Test

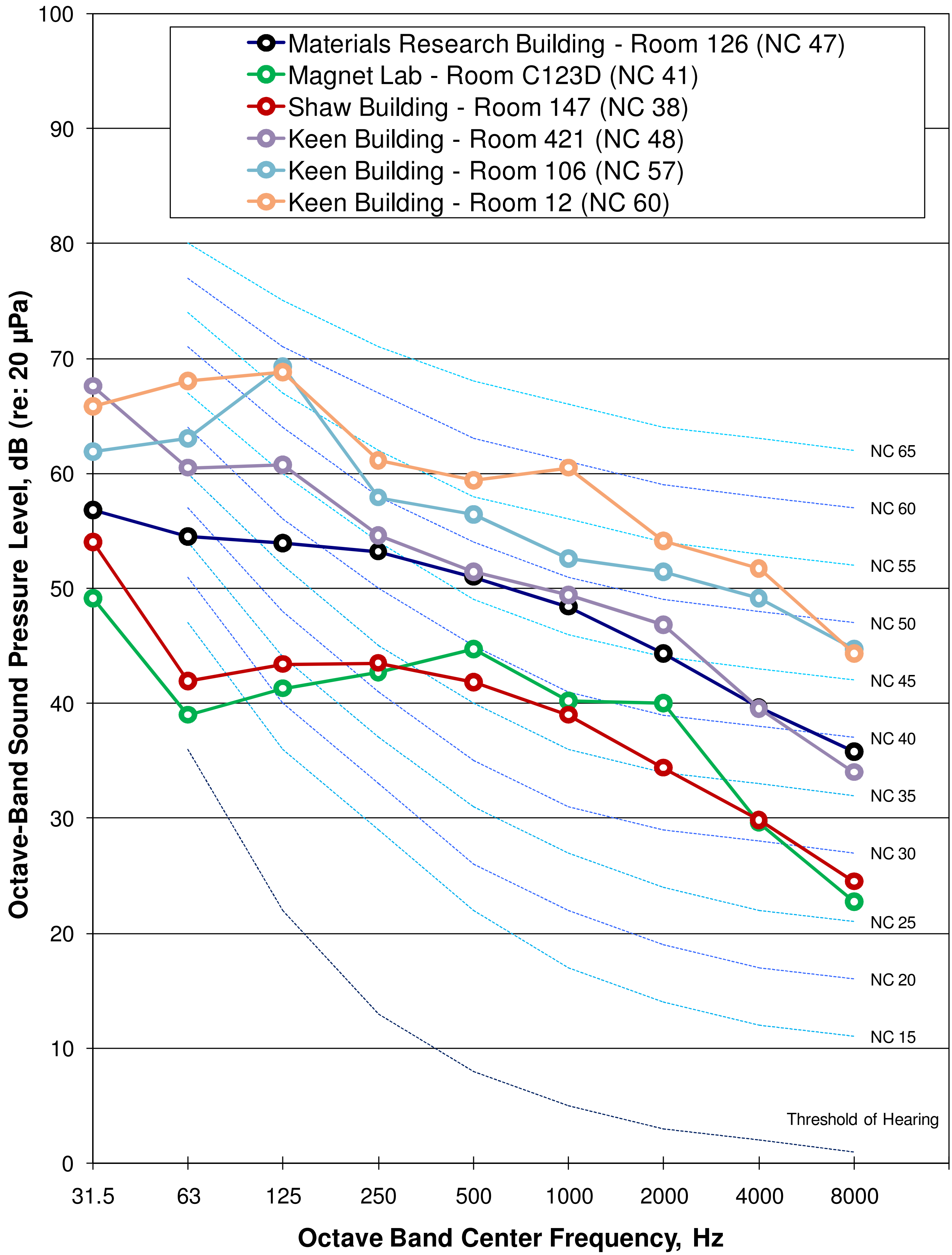

Figure 13: Sound Measurements in the Lab Spaces