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Reverberation Room Simulation

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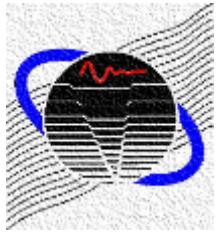
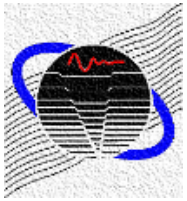


Project Definition

- Blachford Acoustics Laboratory
  - Located in West Chicago, IL

Project Definition

- Simulation of reverberation room
  - Goals
    - Predict room behavior in the low frequency field
      - Material dependent surface absorption
    - Simulate room modifications
  - Model Validation
    - Standard deviation
      - Spatially averaged SPL on two planes
    - Reverberation time



Room Layout

- Solid concrete floor, walls, and ceiling
- Five stationary diffusers
- One rotating diffuser
- Vertical & horizontal transmission loss panels
- Buck chamber
- Loudspeaker broadband source

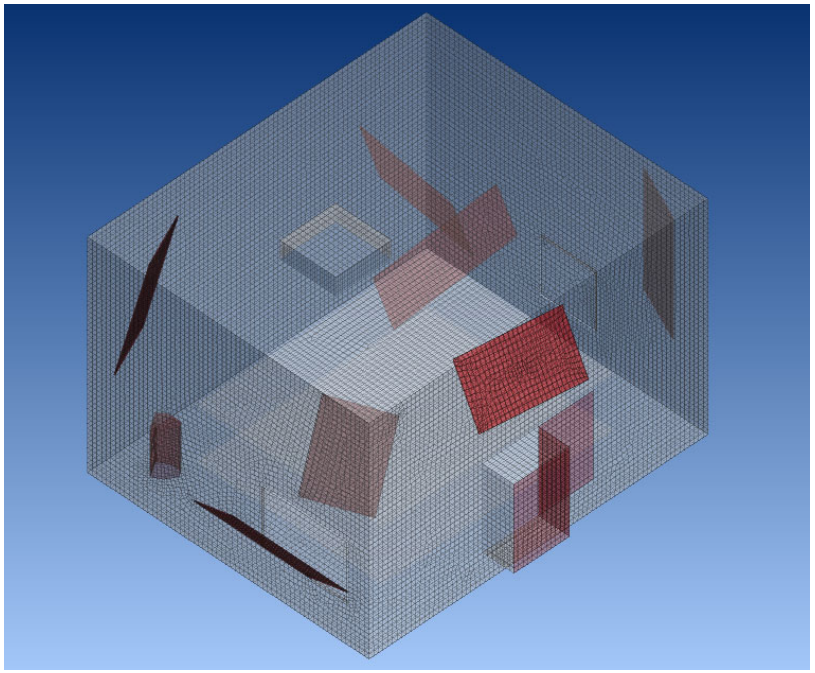
Process and Setup

- Actran VI – FEM Software
  - Creo Parametric
  - Hypermesh

- Mesh Convergence Study
  - Quadratic elements
    - 5 elements per wavelength
  - Mesh adaptivity enabled

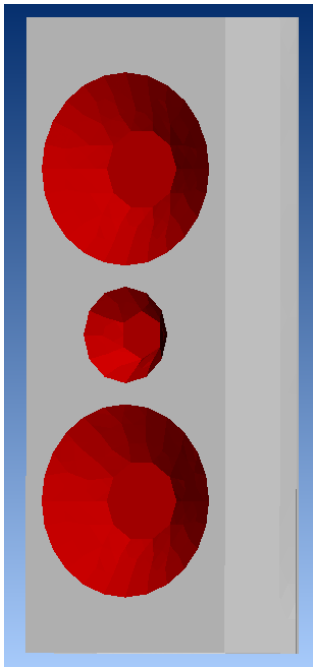
Model Setup

- Frequency Range and Resolution
  - One third octave bands from 100 Hz to 400 Hz
  - 1 Hz Resolution



Boundary Conditions

Source



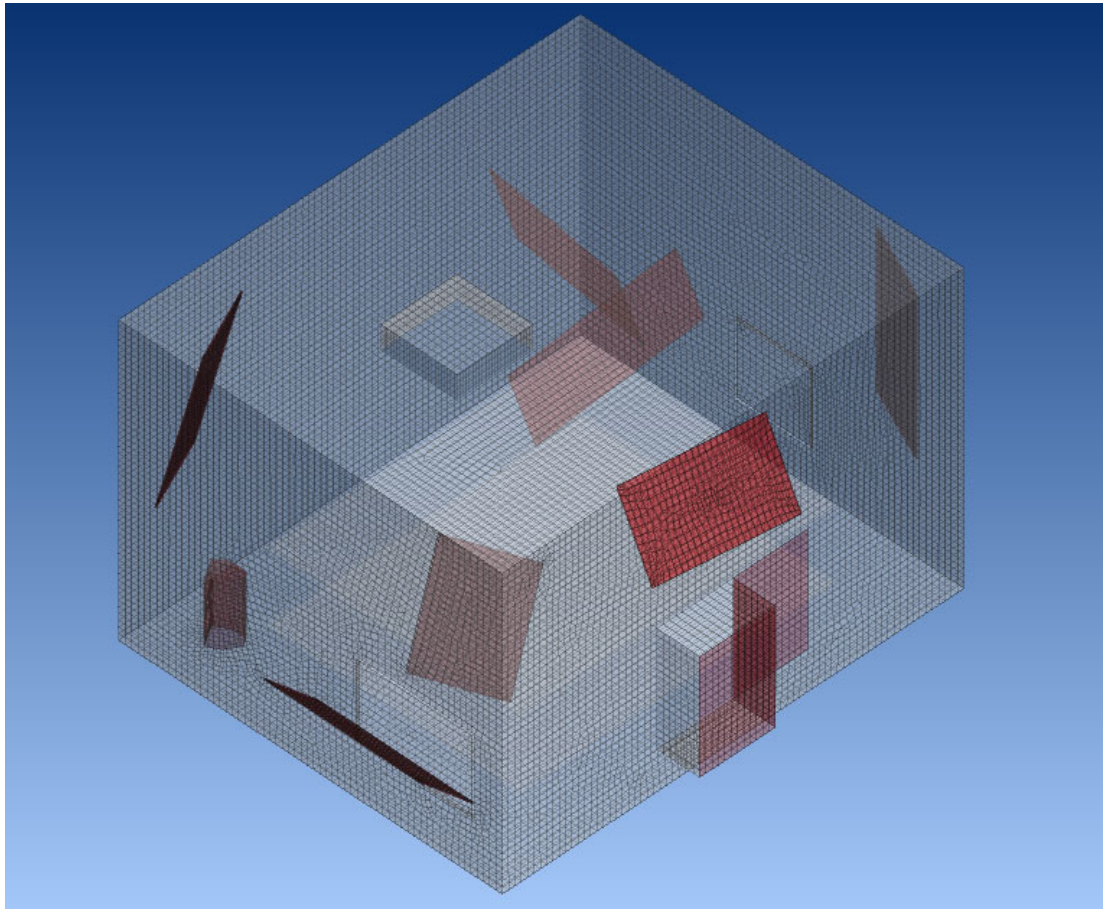
Unit Velocity (1 m/s)

Absorption Coefficients

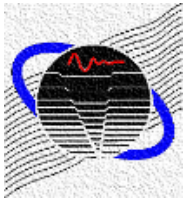
Material	Frequency		
	125	250	500
Double Drywall	0.29	0.10	0.05
Thin Metal Panel	0.13	0.09	0.08
Glass	0.10	0.06	0.04
Plywood Diffusers	0.05		
Metal Diffusers	0.01		
Concrete Surfaces	0.003		

$$\alpha = \frac{4r_n}{(1+r_n)^2 + x_n^2} \quad \text{where,} \quad \frac{z}{\rho_0 c} = r_n + jx_n$$

Boundary Conditions



Reverberation Time Determination



ASTM Standard Test Method: C423-17

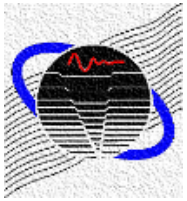
The measured bare room absorption (2-year average) was used to determine the reverberation time

Equation 1:

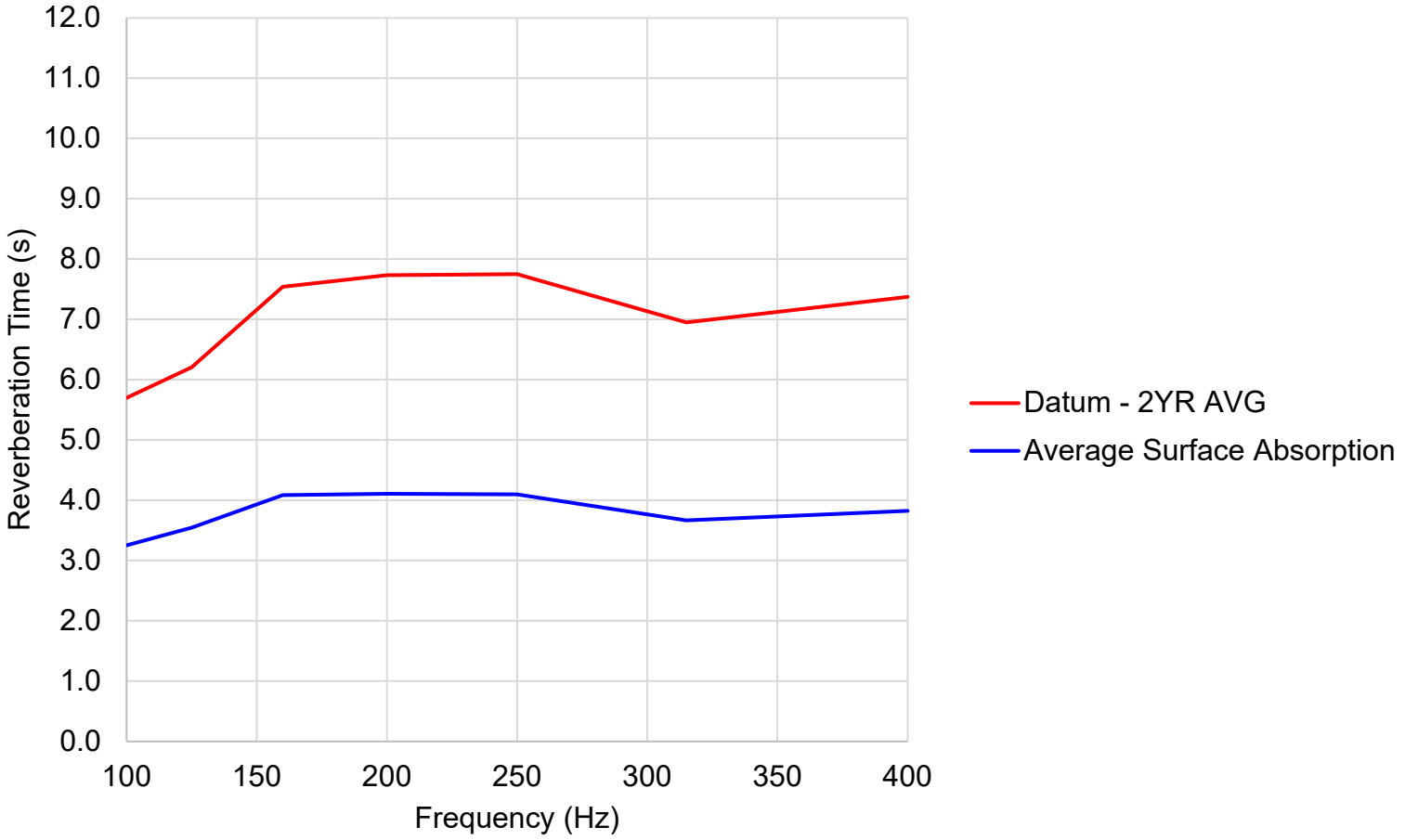
$$A = 0.9210\frac{Vd}{c} \longrightarrow d = \frac{Ac}{0.9210V} \longrightarrow T_{60} = \frac{60}{d}$$

where,

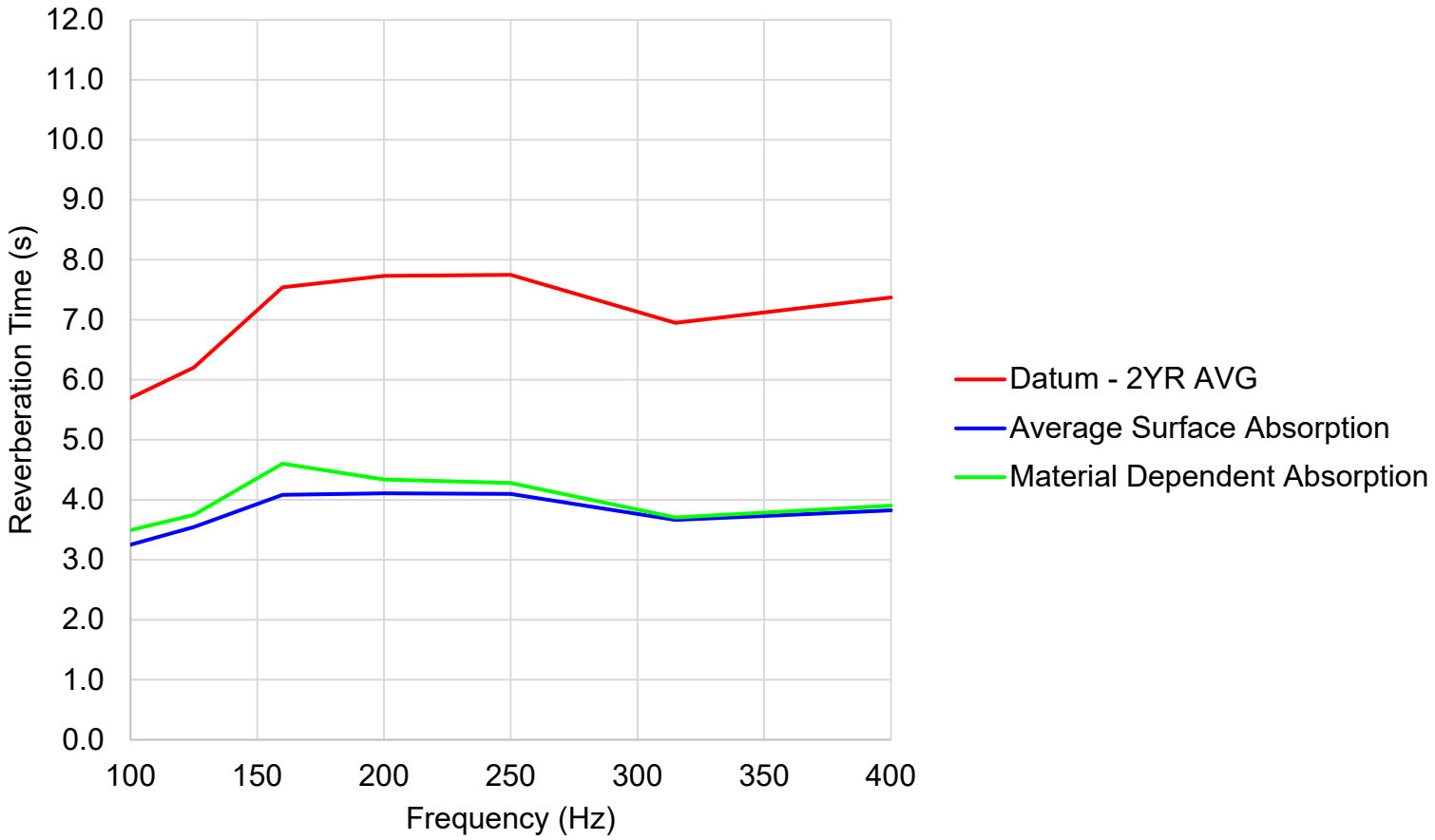
$A = \alpha_{diff}S$ = Room Absorption [m^2]
V = Room Volume [m^3]
d = Decay Rate [dB/s]
c = Speed of Sound [m/s]



Reverberation Time Validation



Reverberation Time Validation



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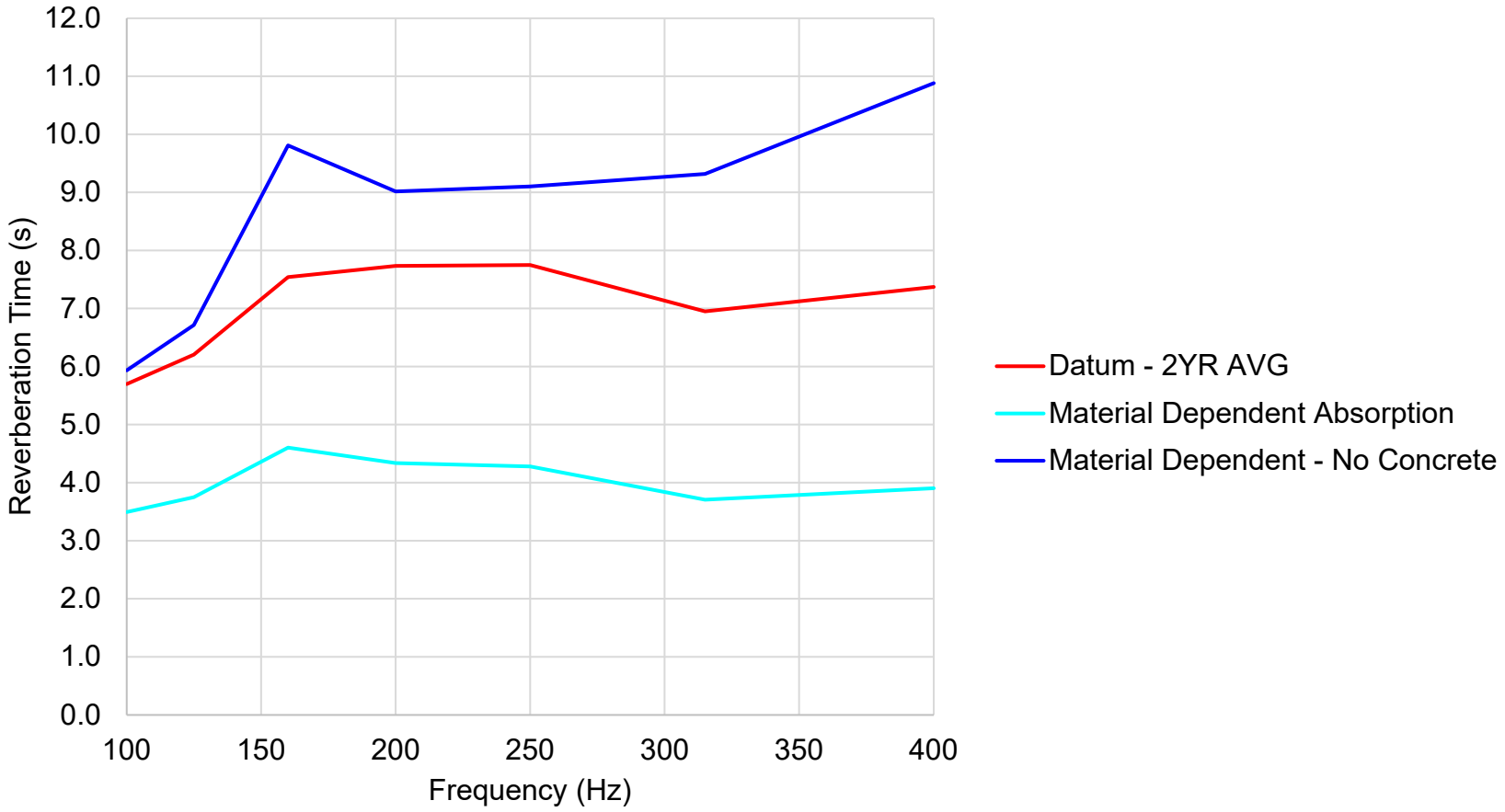

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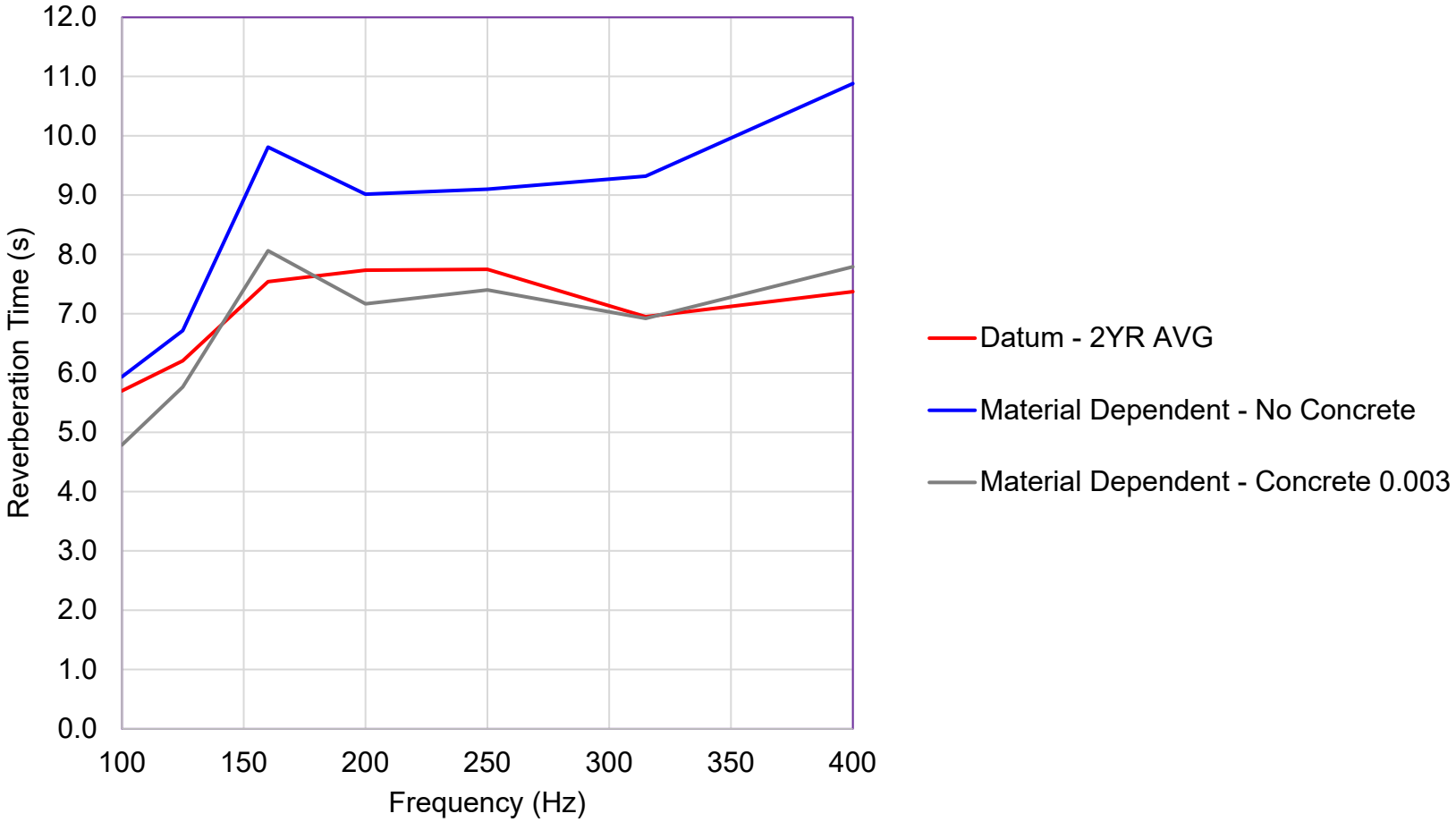
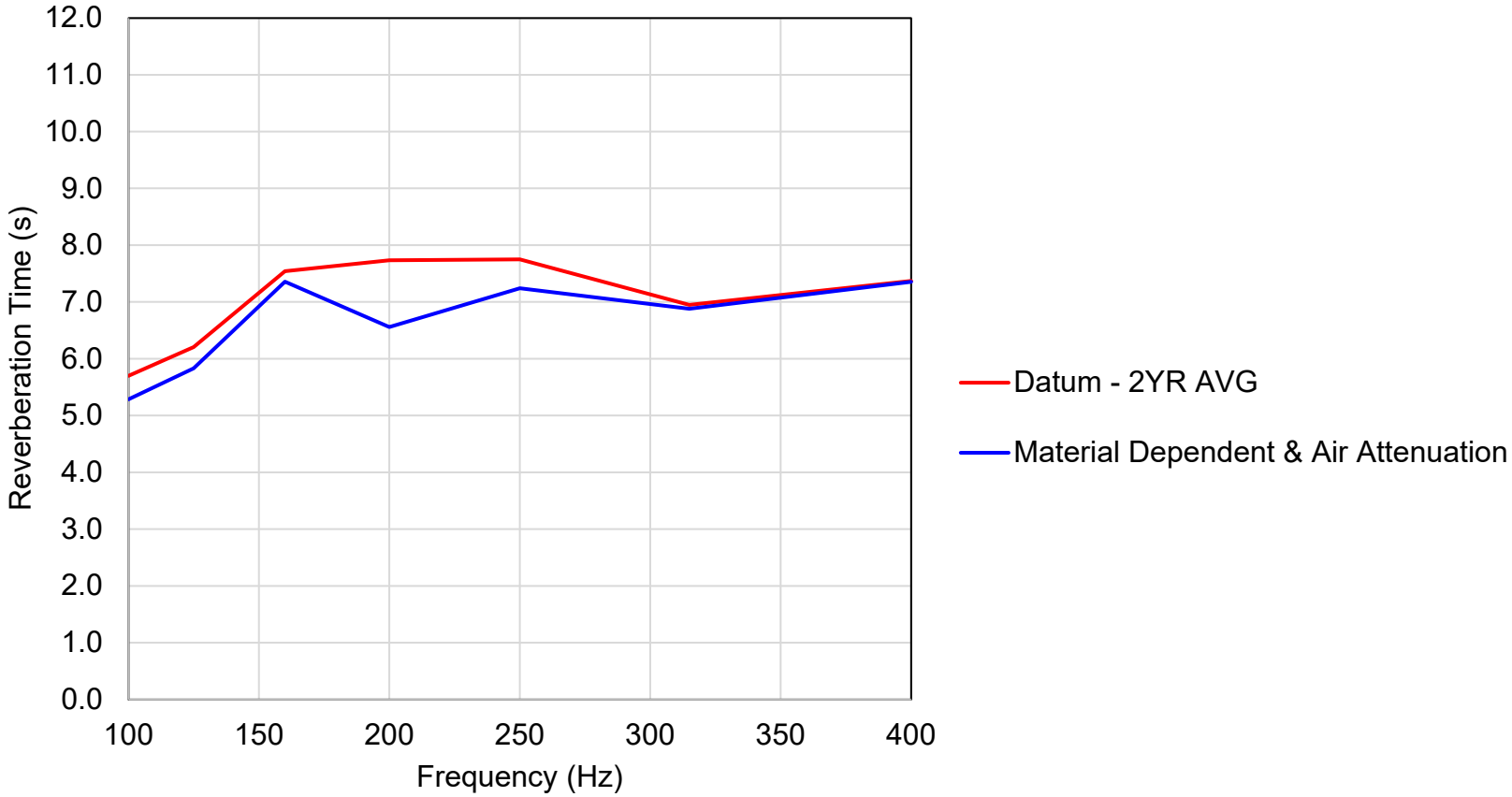
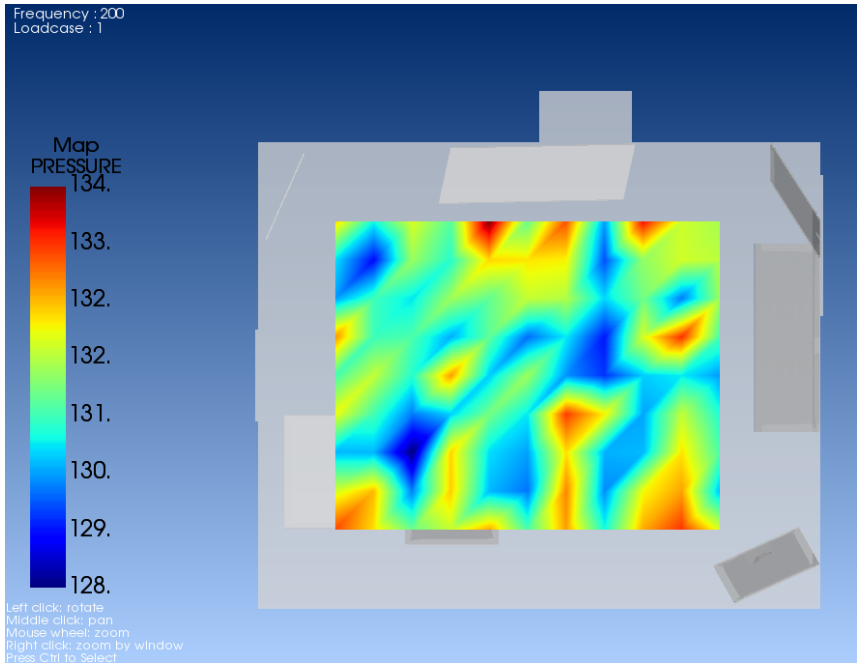


Reverberation Time Validation

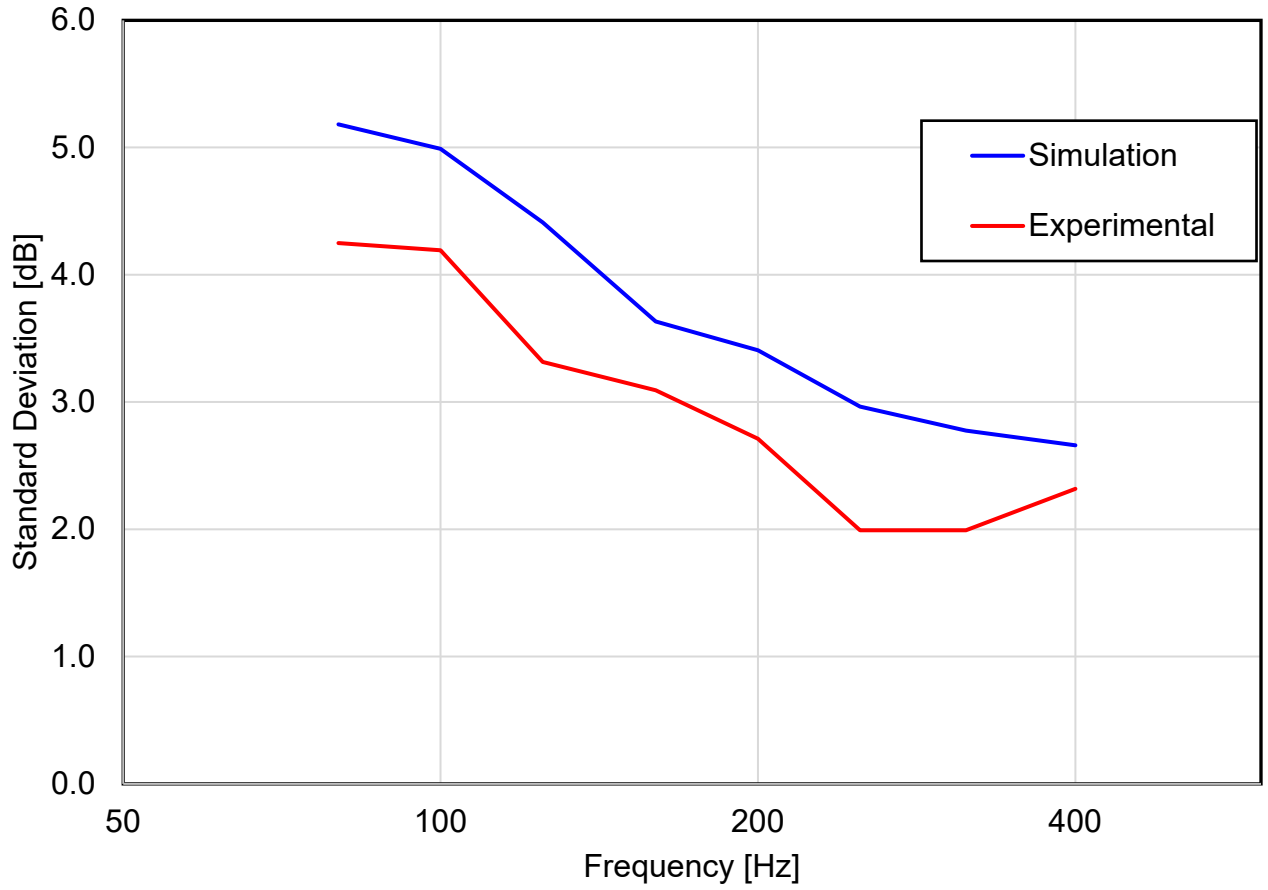


Diffuse Field Validation

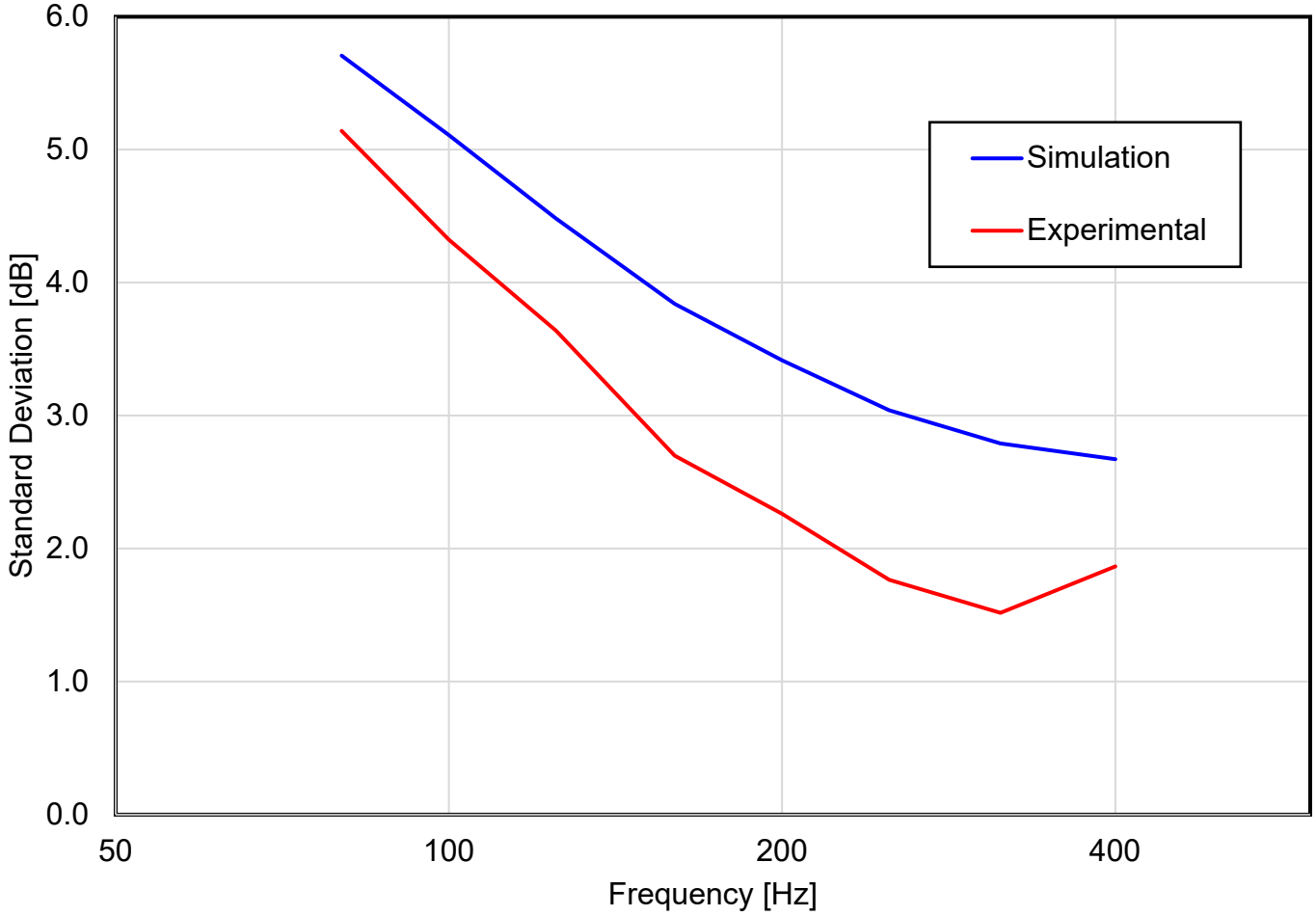
- Standard deviation of spatially averaged sound pressure levels
  - Rotating diffuser was rotated at 60-degree increments
  - Diffuseness is considered acceptable if ± 3 dB



Results 6 cm Plane



Results 1.2 m Plane



Future Directions

- Continue to refine surface boundary conditions
  - Compare actual measurements to simulation
    - Remove and/or change location of diffusers
    - Apply absorption to surface
- Simulate room modifications to improve diffuse field.