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The Use of Internal Constraints to Enhance the Sound Transmission Loss of Poroelastic Linings

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THE USE OF INTERNAL CONSTRAINTS TO ENHANCE THE SOUND TRANSMISSION LOSS OF POROELASTIC LININGS

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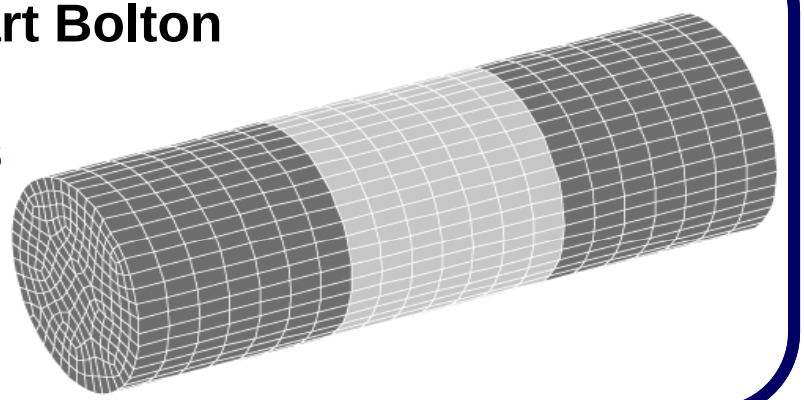
Purdue University



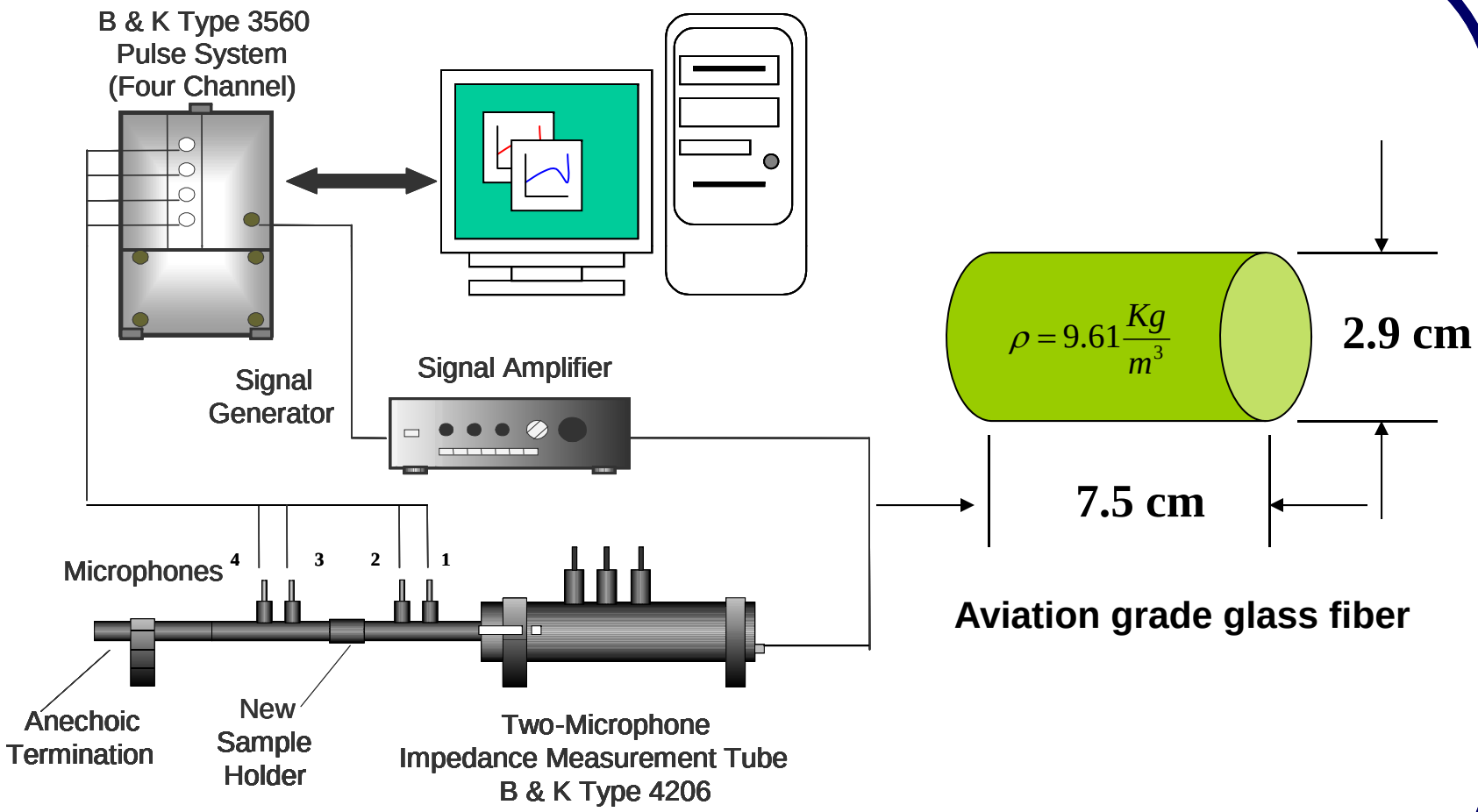
Introduction

- **Investigation of edge constraint effect on samples placed in a modified standing wave tube (B. H. Song et al., *JASA* 1999; J. S. Bolton et al., *SAE* 1997).**

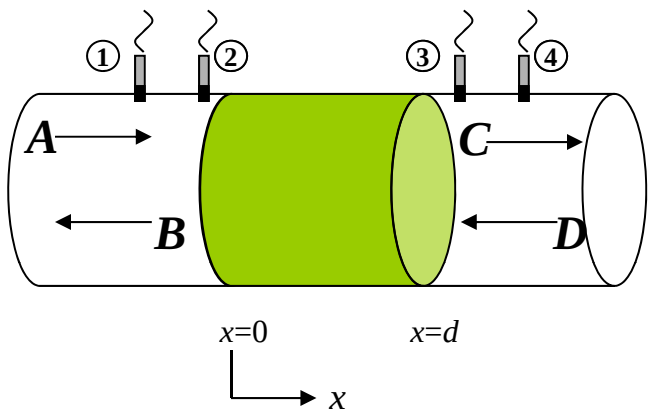
- **Internal constraints may be used to selectively enhance the transmission loss of lining materials at low frequencies**

- **Implications for design of low frequency noise control barriers following from constraint of porous lining materials around their edges.**

Experimental Setup High Frequency Tube



Transfer Matrix Approach I



$$\begin{bmatrix} P \\ V \end{bmatrix}_{x=0} = \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} \begin{bmatrix} P \\ V \end{bmatrix}_{x=d}$$

$T_{11} = T_{22}$ → **symmetry**

$T_{11}T_{22} - T_{12}T_{21} = 1$ → **reciprocity**

4 Equations

- **Solve for transfer matrix elements**

Transfer Matrix Approach II

$$\begin{bmatrix} 1 + R_a \\ \dfrac{1 - R_a}{\rho_0 c_0} \end{bmatrix} = \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} \begin{bmatrix} T_a e^{-jkd} \\ \dfrac{T_a e^{-jkd}}{\rho_0 c_0} \end{bmatrix}$$

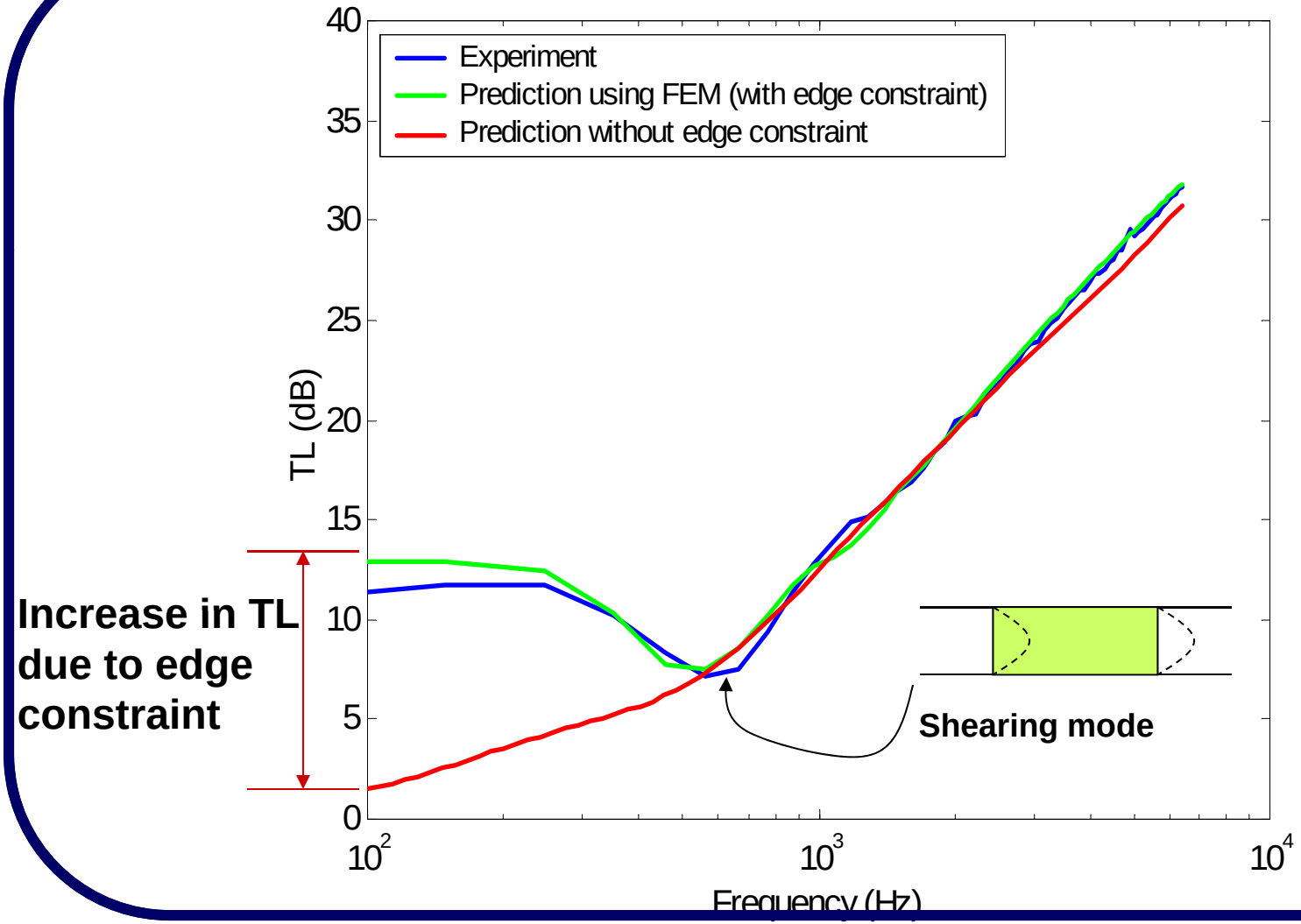
- **Anechoic Reflection Coefficient**

$$R_a = \frac{T_{11} + \dfrac{T_{12}}{\rho_0 c} - \rho_0 c T_{21} - T_{22}}{T_{11} + \dfrac{T_{12}}{\rho_0 c} + \rho_0 c T_{21} + T_{22}} \quad \Rightarrow \quad \alpha = 1 - |R_a|^2 \qquad Z_n = \frac{1 + R_a}{1 - R_a}$$

- **Anechoic Transmission Coefficient**

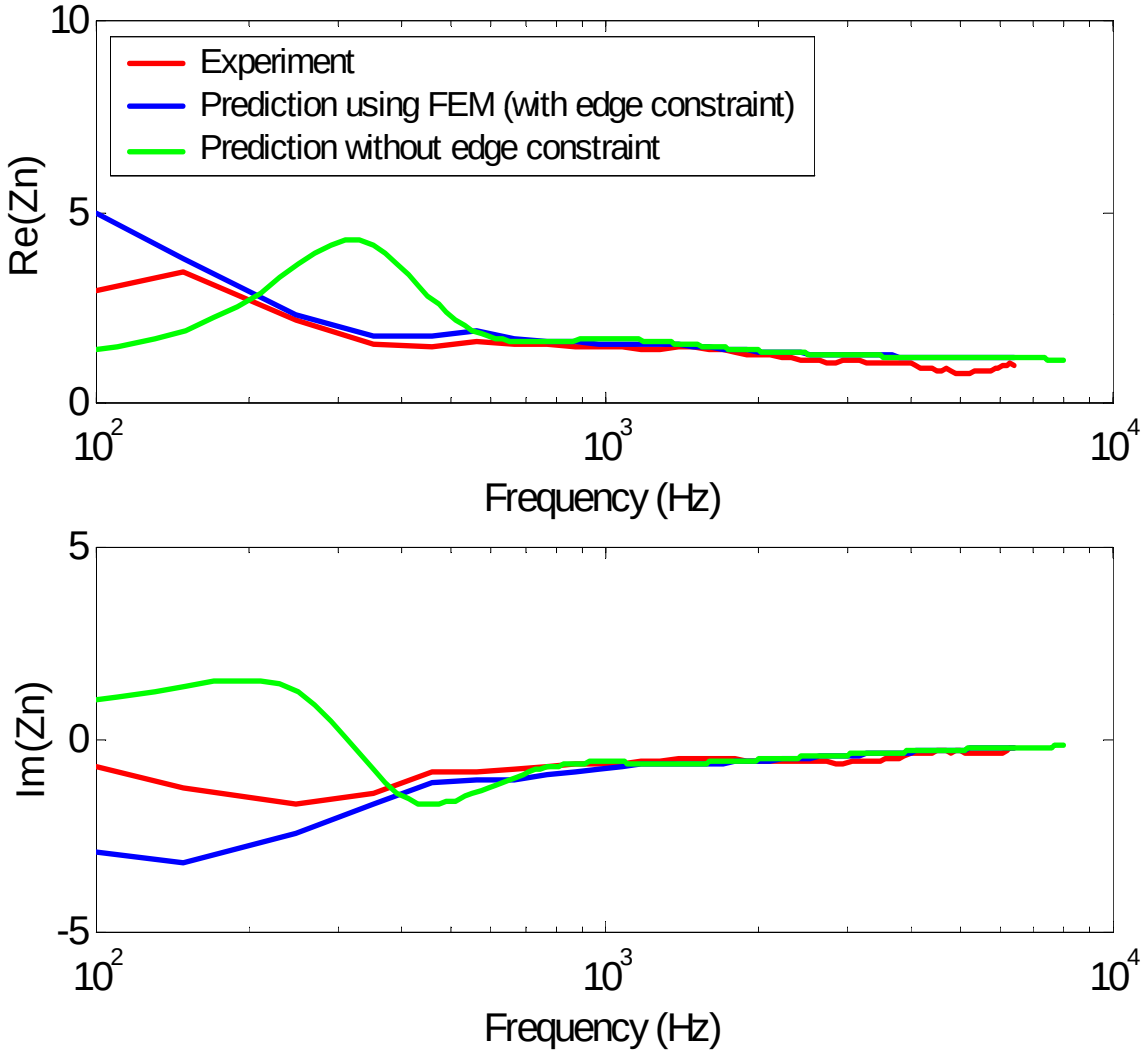
$$T_a = \frac{2 e^{jkd}}{T_{11} + \dfrac{T_{12}}{\rho_0 c} + \rho_0 c T_{21} + T_{22}} \quad \Rightarrow \quad TL = 10 \log(1/|T_a|^2)$$

Anechoic Transmission Loss



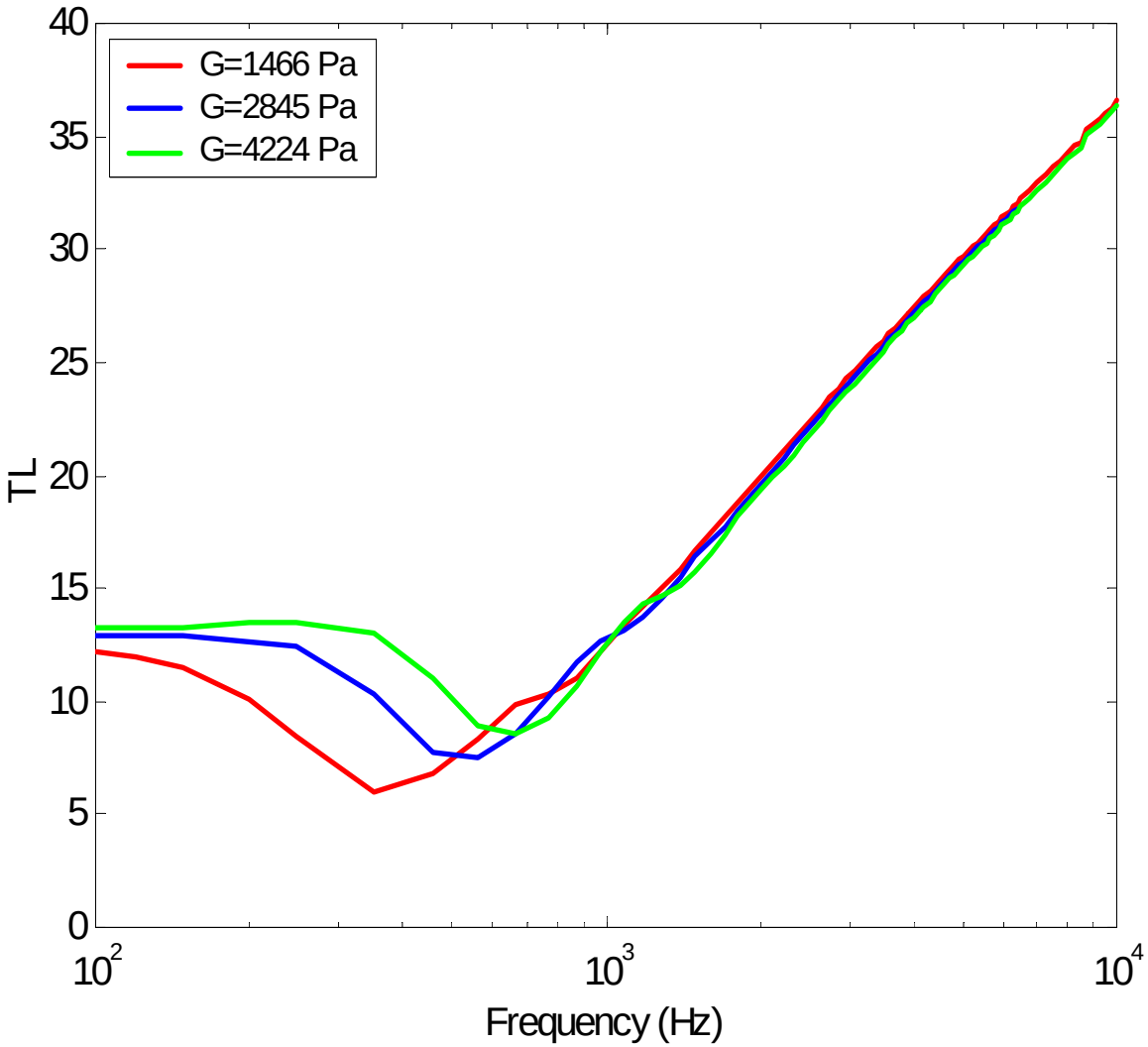
Surface Normal Impedance

(Change from mass-like reactance to stiffness reactance)



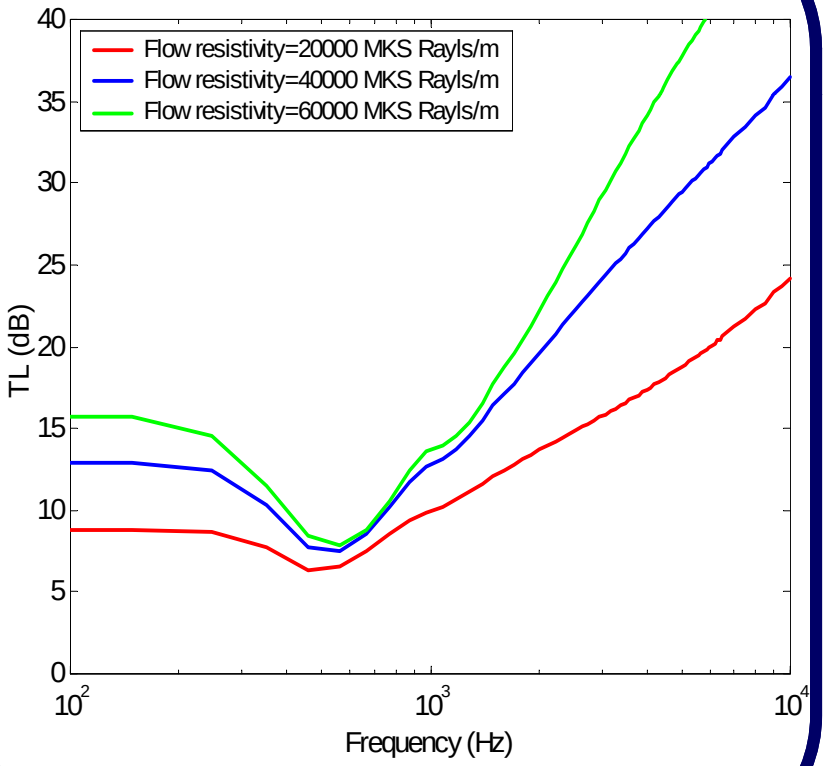
Variation of Shear Modulus

(As G increases, the shearing resonance moves to higher frequency)



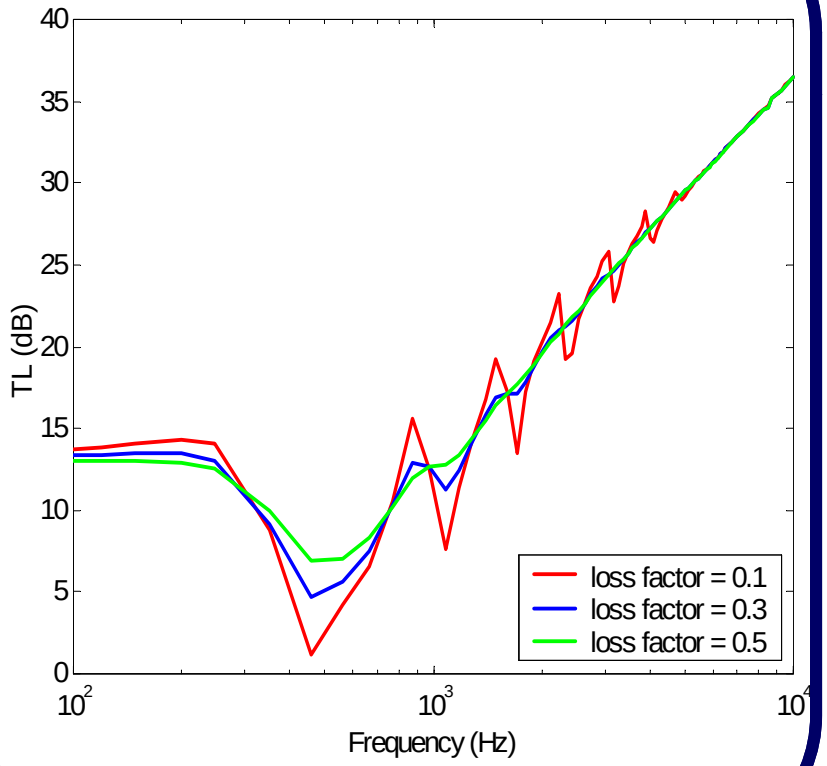
Flow Resistivity

(Controls TL in <u>low and high frequency limits</u>)

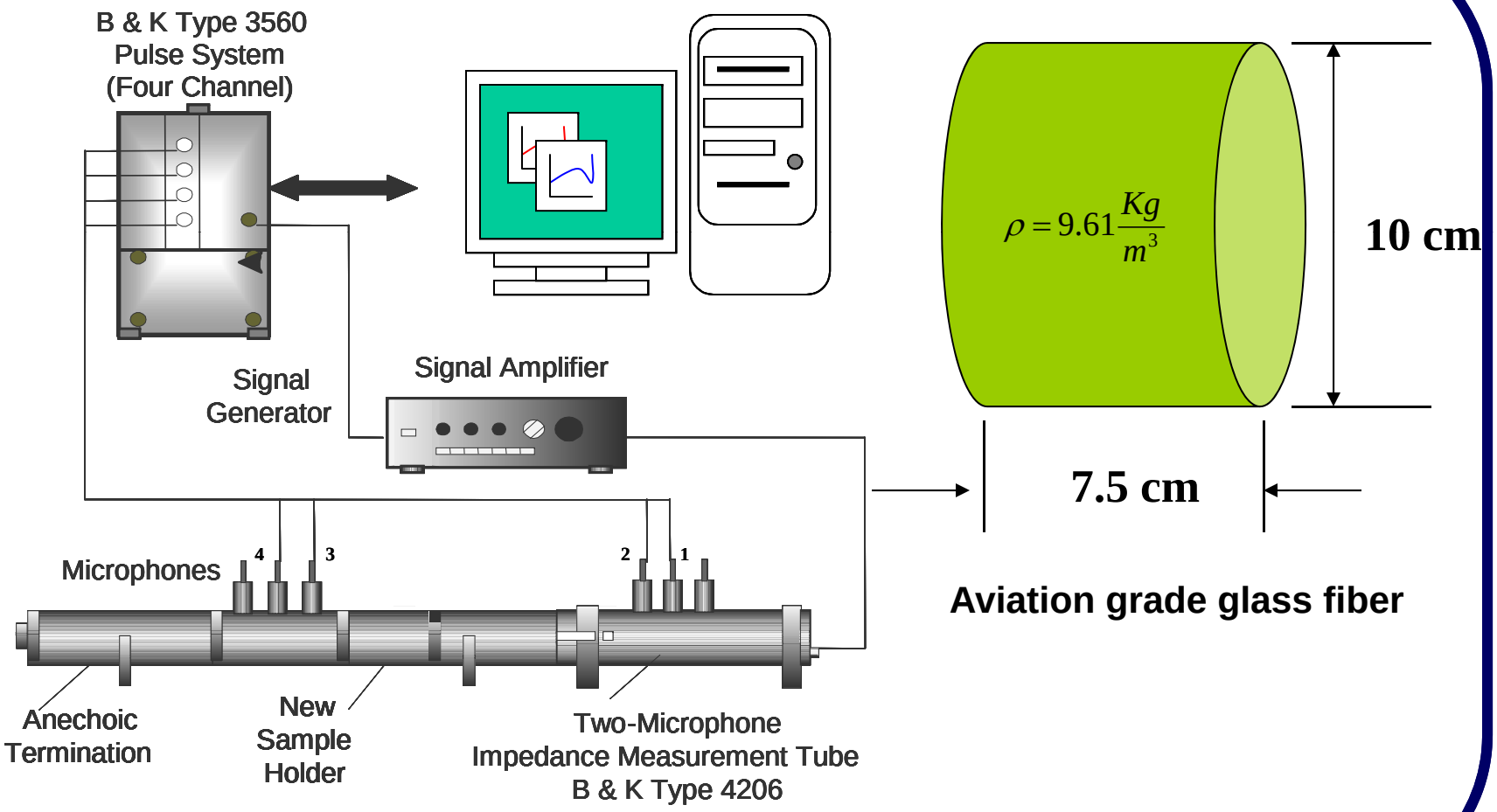


Loss Factor

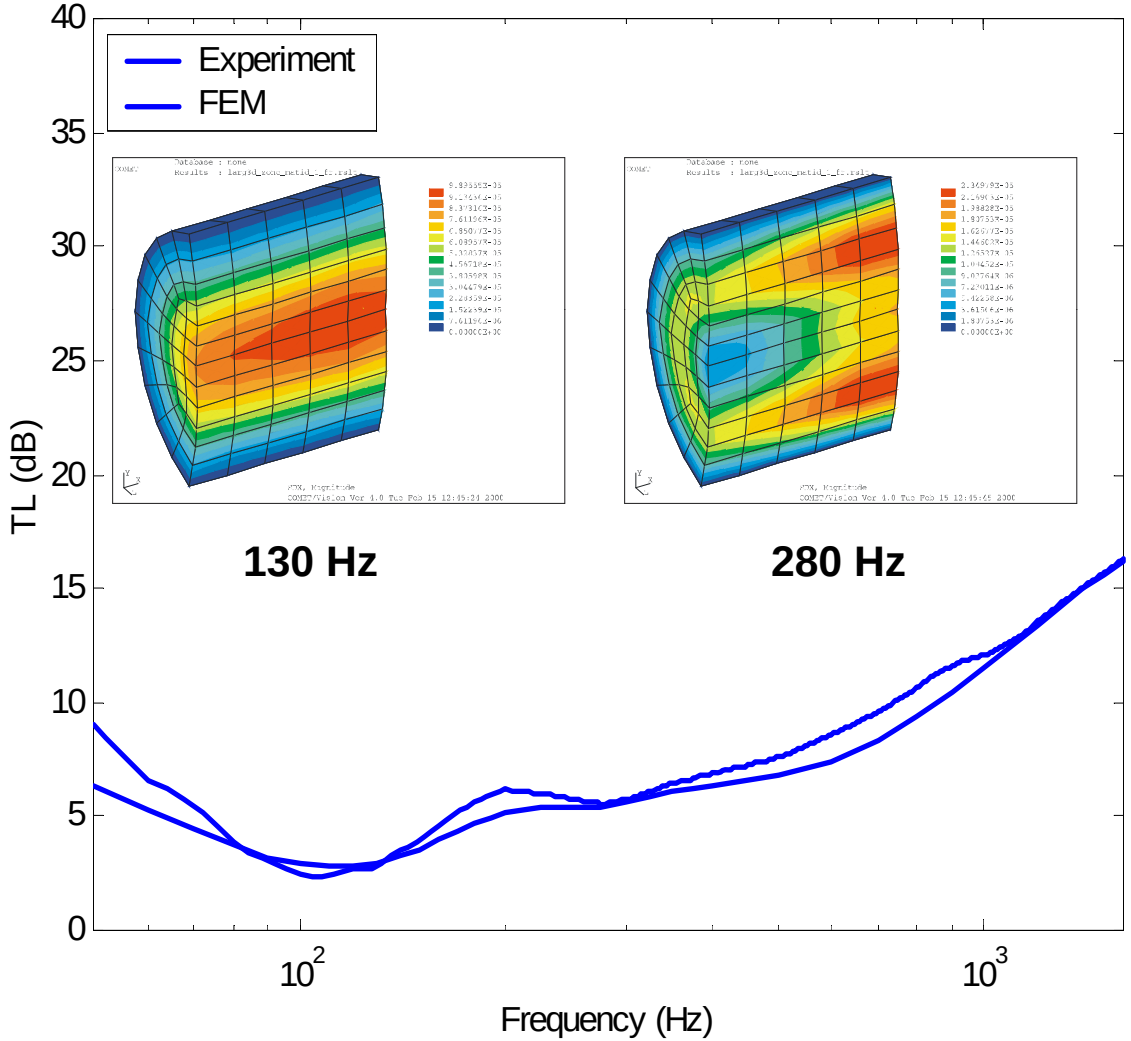
(Loss factor controls depth of TL minimum)



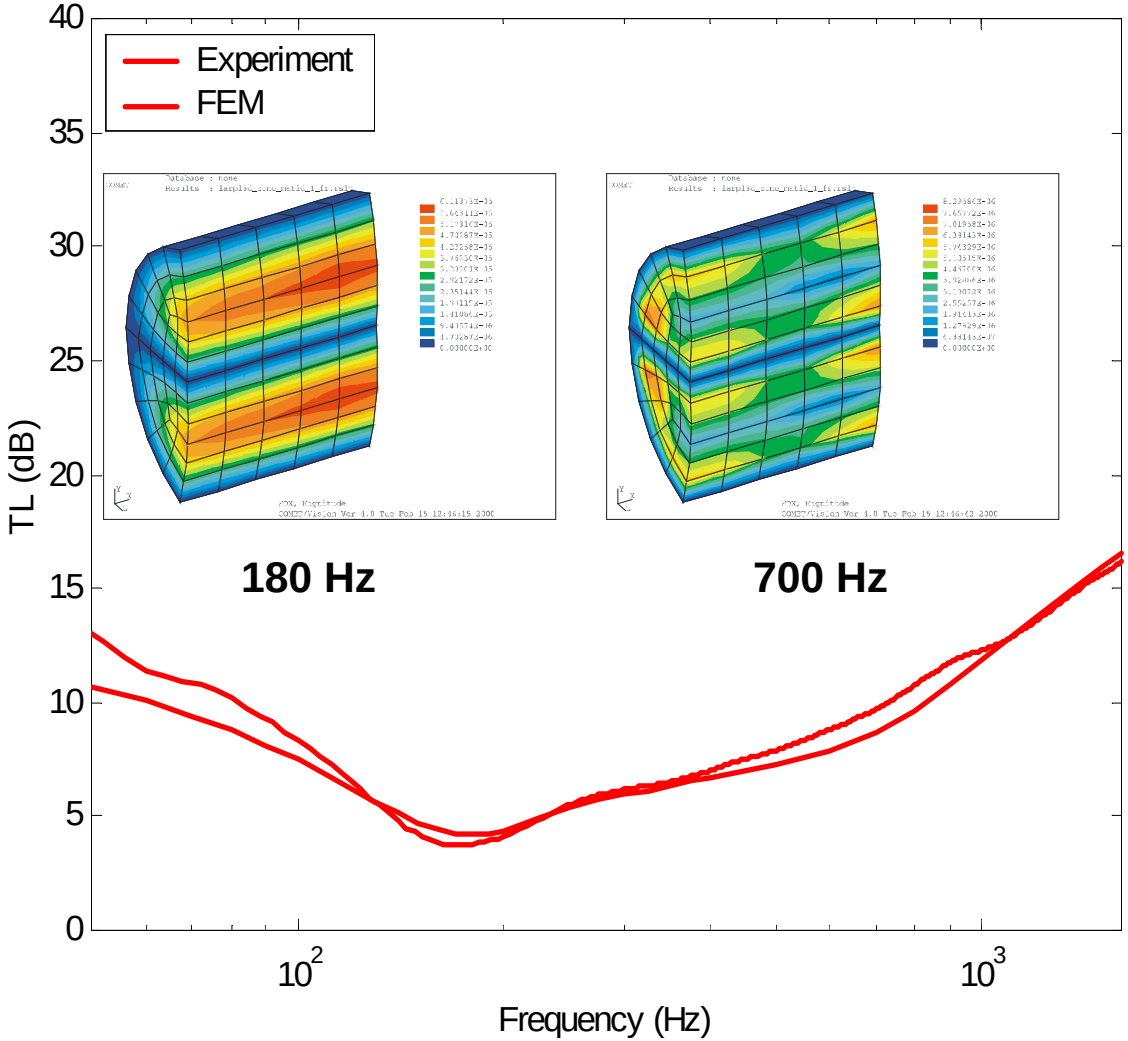
Effect of Sample Size
Experimental Setup for Low Frequency Tube



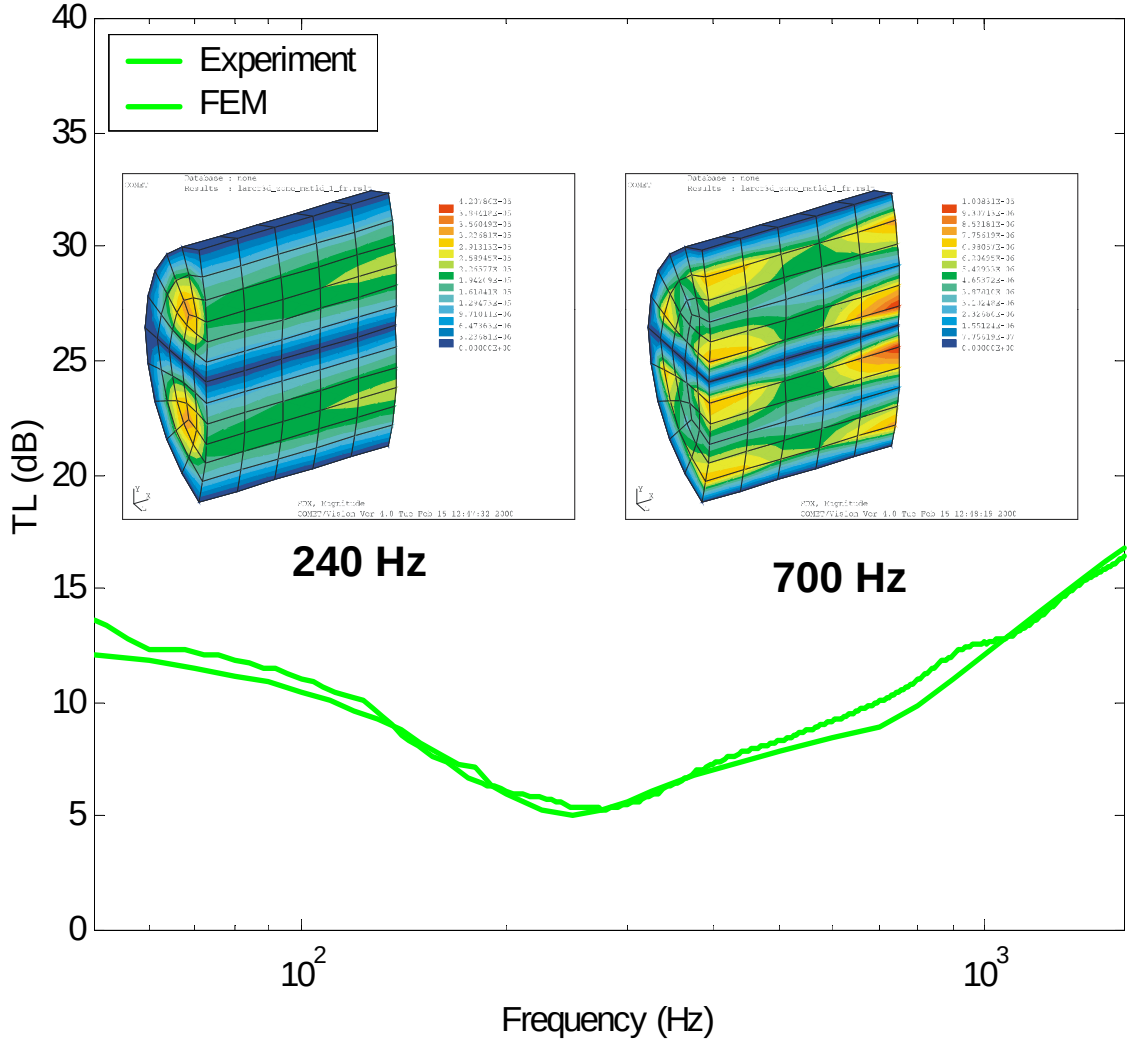
Constrained around Edge (50 Hz - 1600 Hz)



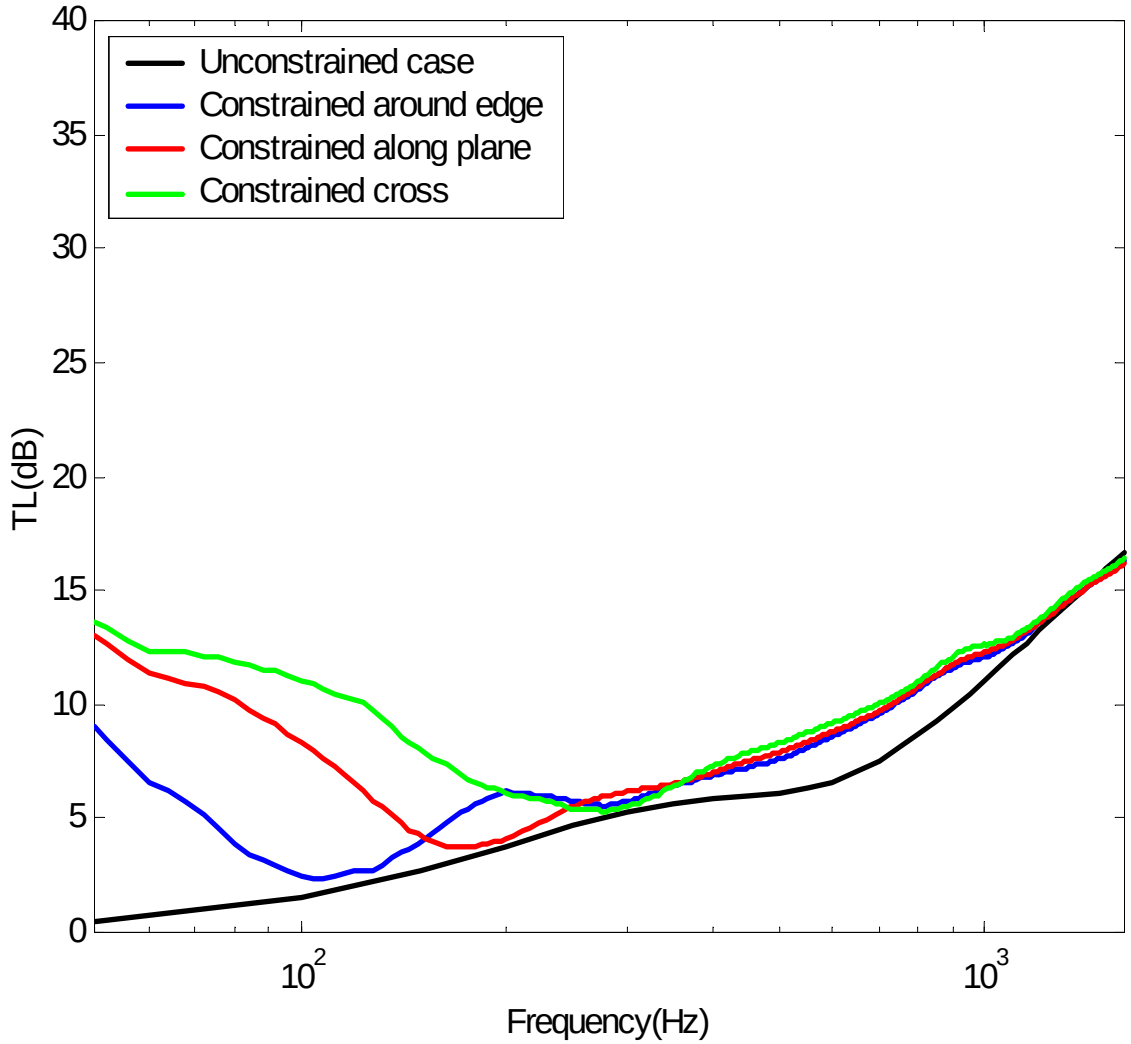
Constrained along Plane (50 Hz - 1600 Hz)



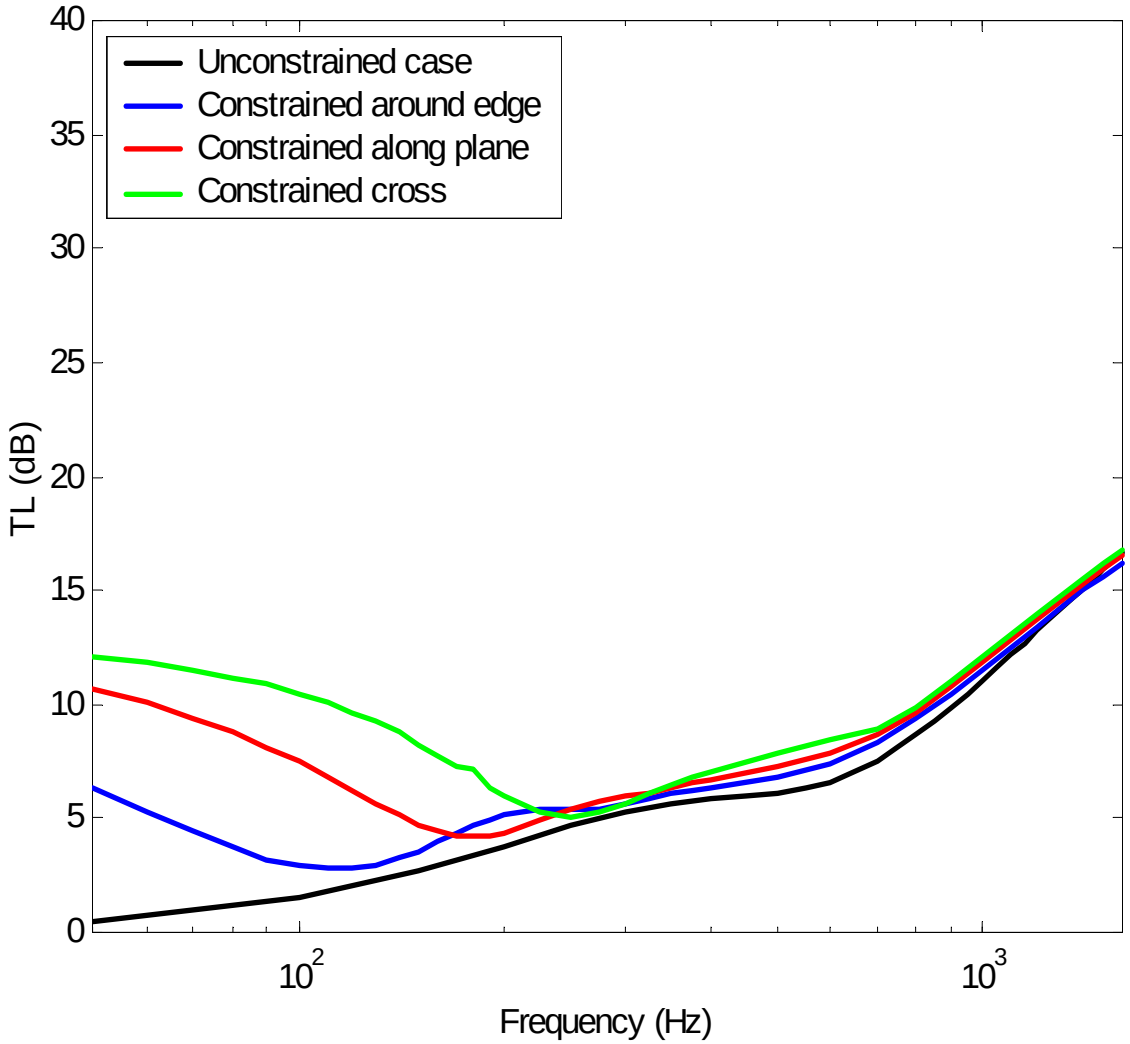
Constrained Cross (50 Hz - 1600 Hz)



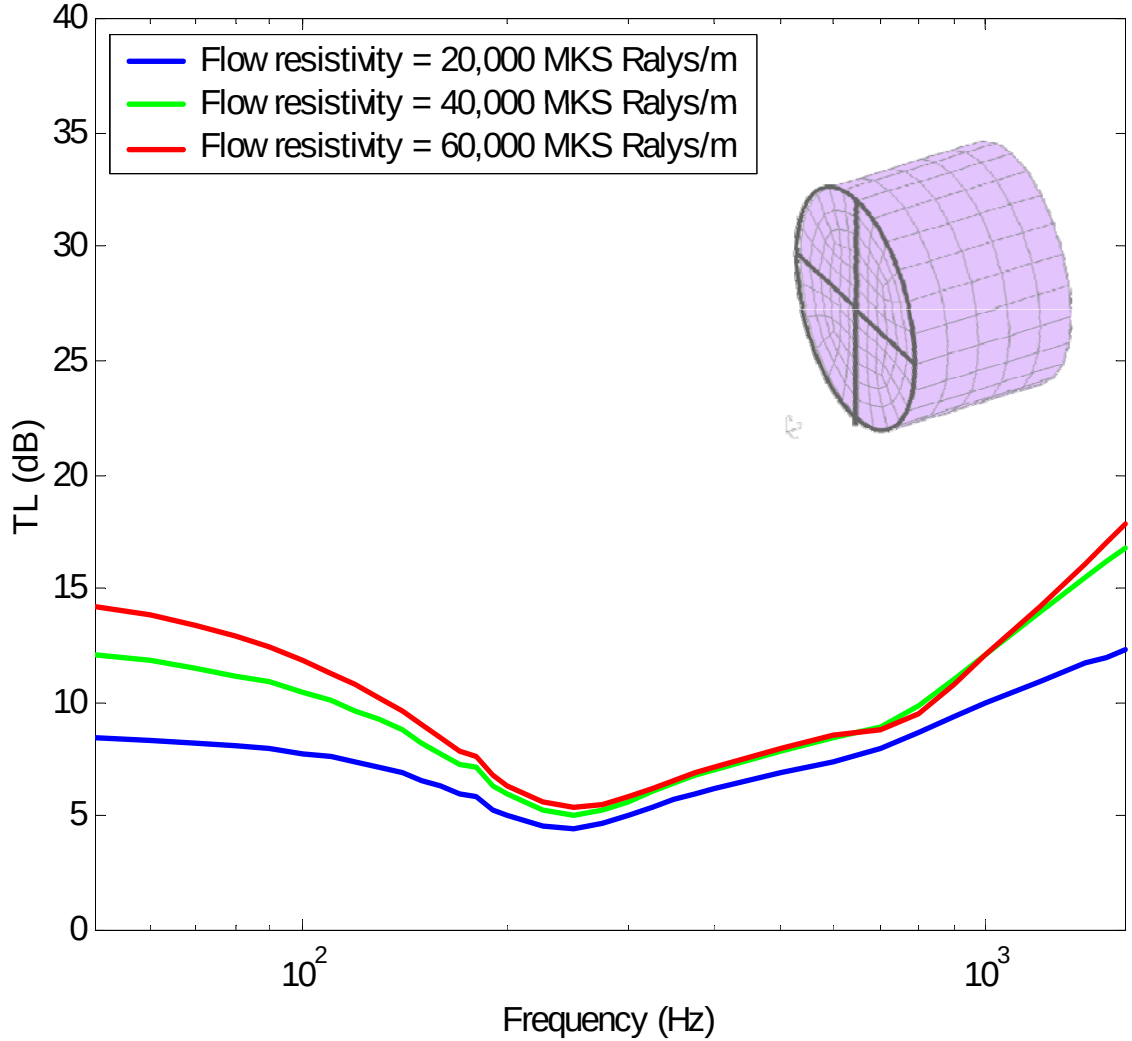
Transmission Loss (Experiment)



Transmission Loss (FEM)

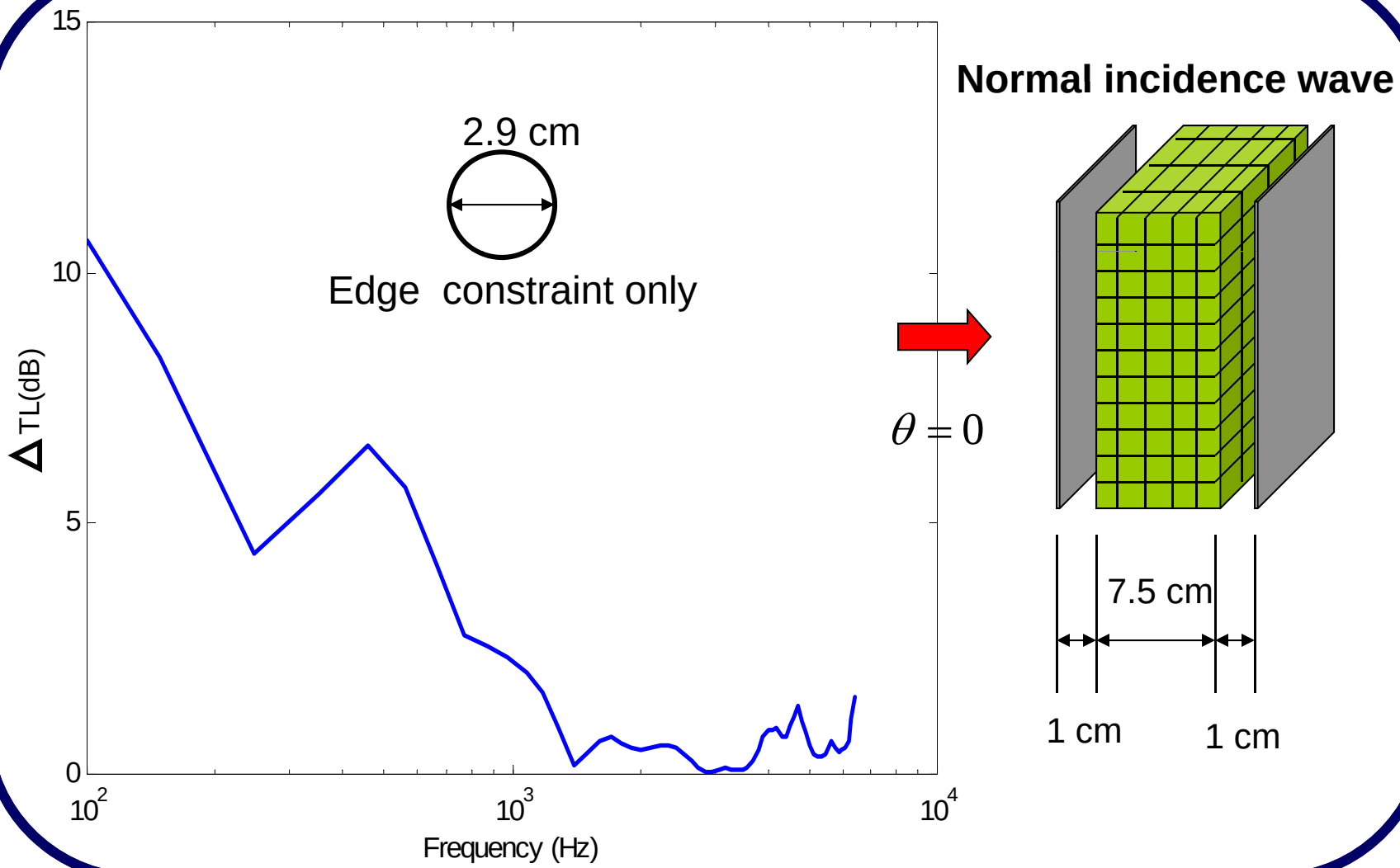


Effect of flow resistivity on TL for cross constrained case



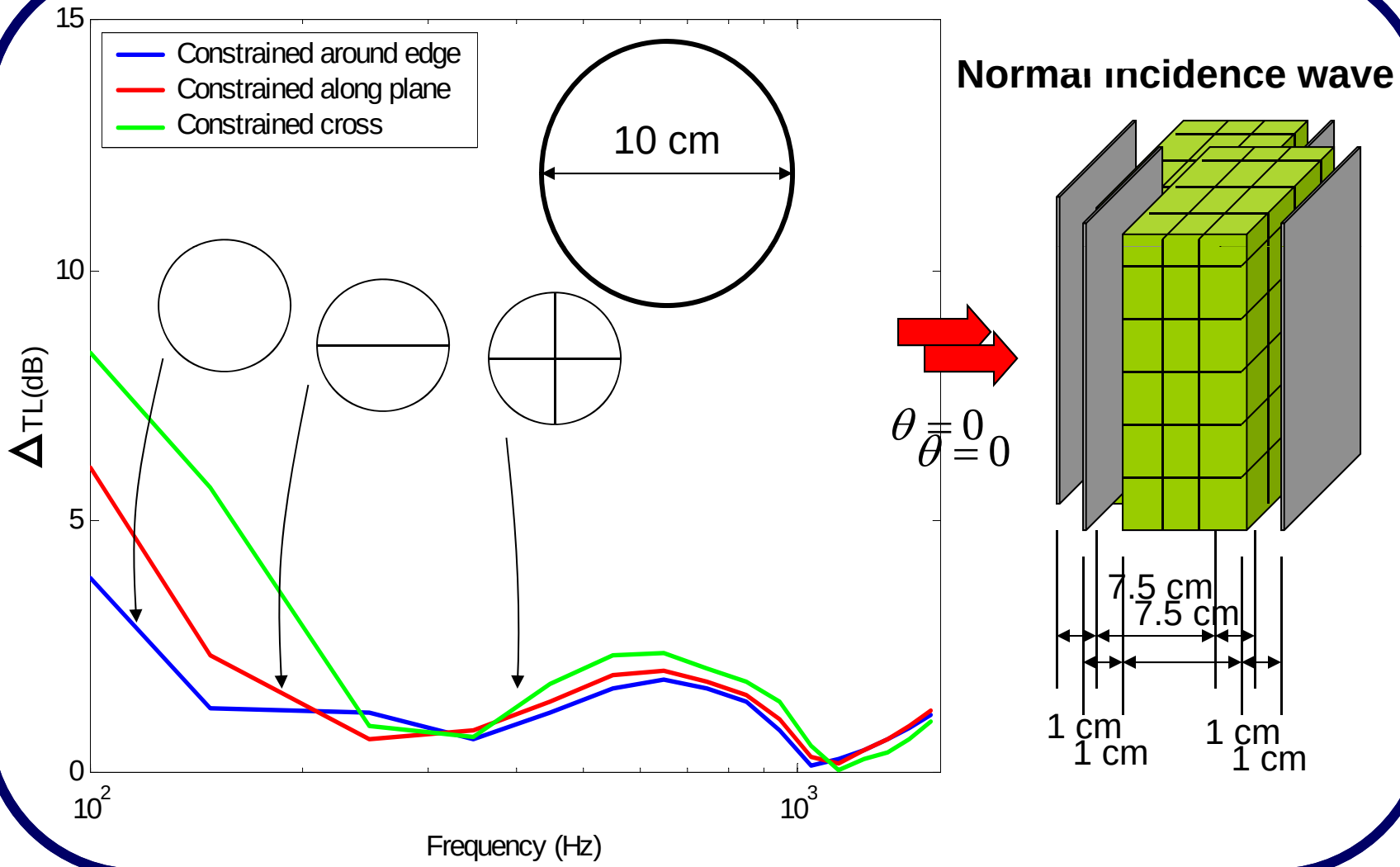
Δ TL constrained and unconstrained cases

[Panel (Al, 0.762 mm)+Air+Glass fiber (7.5 cm)+Air+panel (Al, 0.762 mm)]



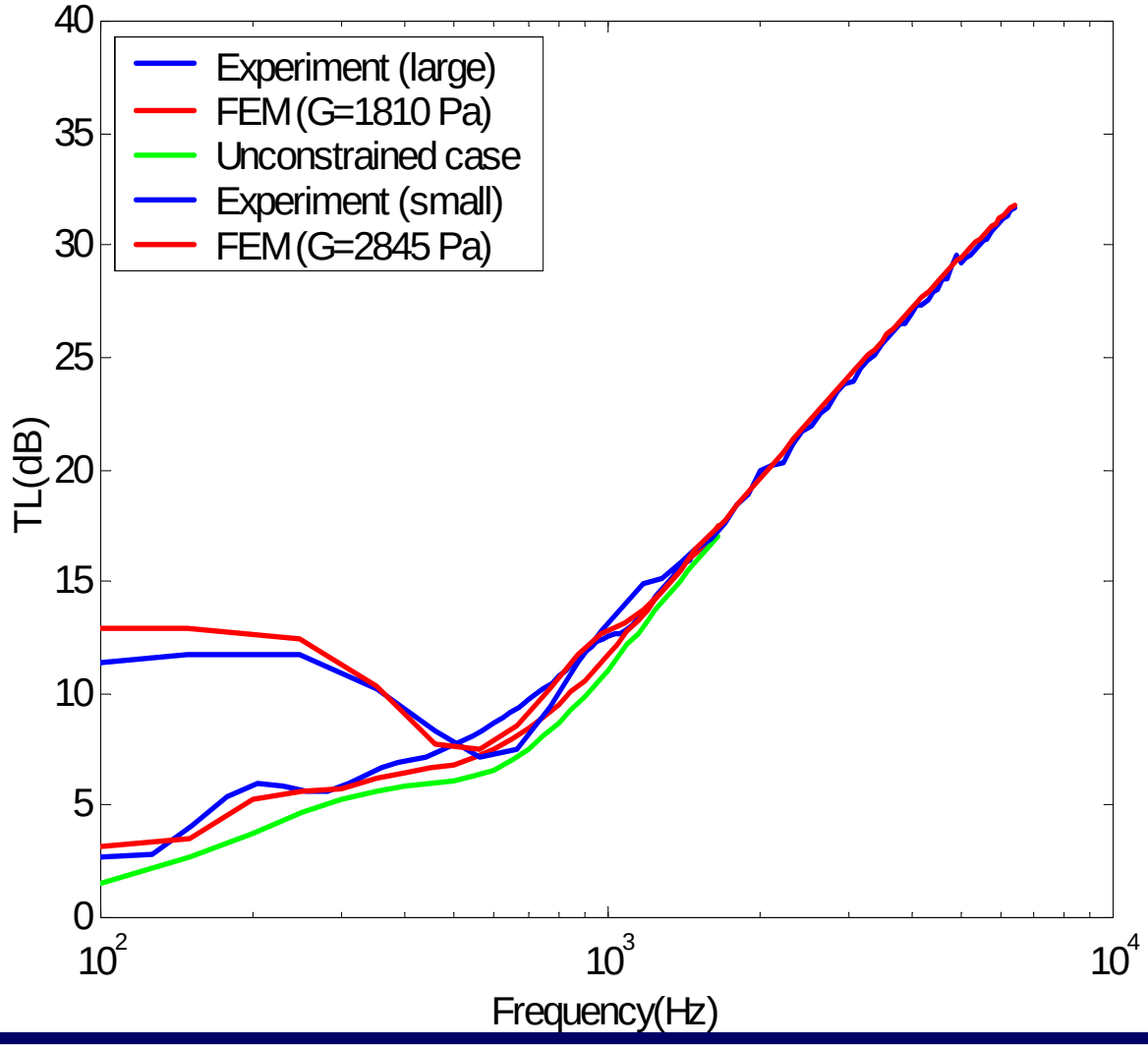
Δ TL constrained and unconstrained cases

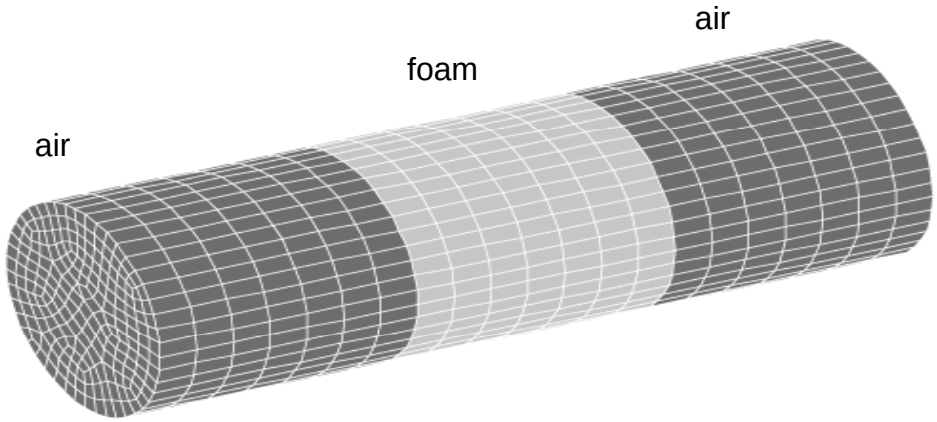
[Panel (Al, 0.762 mm)+Air+Glass fiber (7.5 cm)+Air+panel (Al, 0.762 mm)]



Transmission Loss (100 Hz - 6400 Hz)

(10 cm samples very nearly approximates unconstrained case)





Conclusions

- **Acoustical performances of fibrous layers such as transmission loss and absorption coefficient are affected by constraint on the boundary of the samples.**
- **The various constrained effects are well predicted by using poroelastic FEM model (COMET/SAFE).**
- **<u>Light and stiff fibrous materials</u> combined with edge and internal constraint mechanisms can be used to design, light, high performance low frequency noise control barriers.**