Design and implementation of a transmission suite in order to characterise the vibro-acoustic properties of lightweight structures

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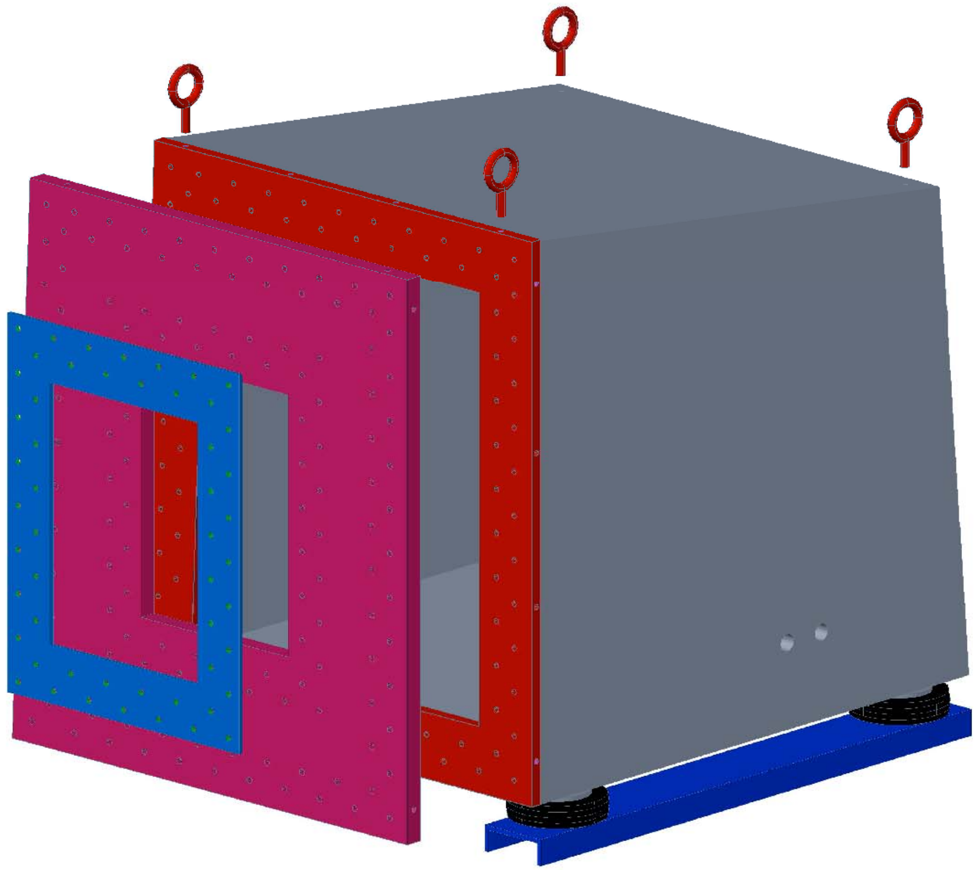
Overview

- Motivation and goal
- Construction and design considerations
- Shape optimization
- Walls thickness influence
- Front wall influence
- Final model description
- Conclusion and future work

Motivations and Goal

- Design and build a "transmission suite" (acoustic research facility) to study lightweight structures:
  - Honey comb panels/Sandwichpanels
- The transmission suite has to be flexible:
  - Different shapes and dimensions/thickness of samples; should have different front walls
  - Provide both a mechanical and acoustic excitations
    - Airborne excitation
    - Structural-borne excitation
  - Measurements:
    - Sound Power Level (SPL) Sound Power Intensity
    - Transmission Loss (TL) & Insertion Loss (IL)

Design



Construction considerations

- Solid Masonry
  - Heavy
  - Permanent
  - High degree of room sound isolation
- Prefabricated acoustic panel rooms
  - Can be removed and relocated/reinstalled at another site
  - High degree of sound transmission loss performance
  - More expensive than the solid masonry
- Lightweight traditional building material
  - Lower cost
  - Constructed on situ

Design considerations

- **Schroeder frequency;** frequency above which the sound field is diffuse for a steady-state sound level
- **Room dimensions;** the spacing uniformity of the modal frequencies is governed by the ratio of room dimensions; preferred proportion: 1.25:1.5:1.75 {Blaszak},1.59:1.26:1 {SAE}

$$f_{n_x,n_y,n_z} = \frac{c}{2}\sqrt{\left(\frac{n_x}{L_x}\right)^2 + \left(\frac{n_y}{L_y}\right)^2 + \left(\frac{n_z}{L_z}\right)^2}$$

- **Optimization** of the shape in order to get the smoothest frequecy response (no-parallel walls)
- **Mass-Size** of the test rig

Shape optimization

$$\Psi = \frac{\sum_{i=1}^{n-1} \varepsilon_i^2}{(n-1)\delta^2} + 1$$

$$\Omega = \frac{\sum_{i=1}^{n-1} \left(|\varepsilon_i| - \Gamma \right)^2}{(n-1)\Gamma^2}, \quad \Gamma = \sqrt{\Psi - 1}$$

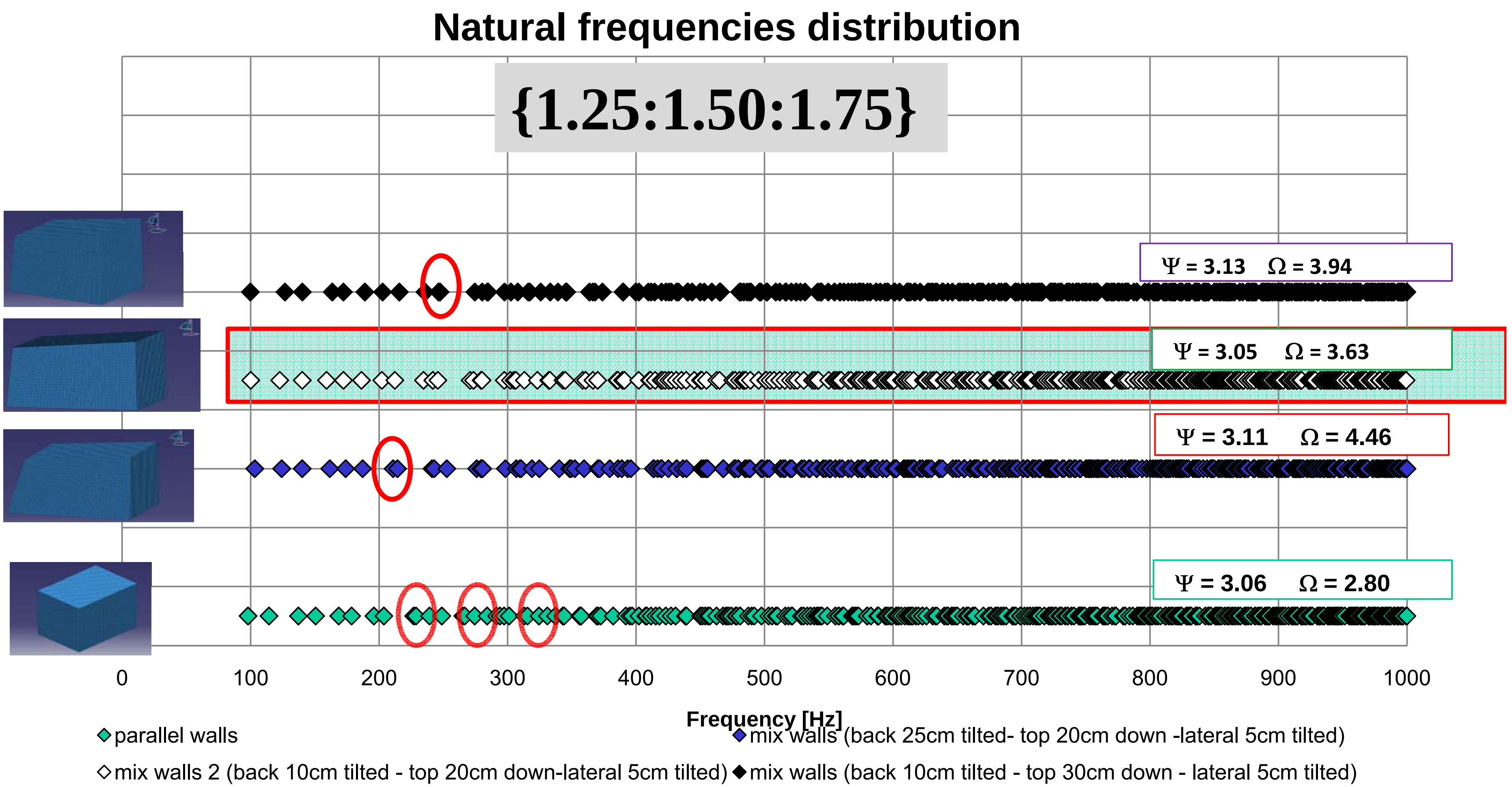
The **mean square of the deviation** of the actual distances between subsequent modes from the mean value.

The higher the value of Ψ, the larger the fluctuations in the frequency spacing.

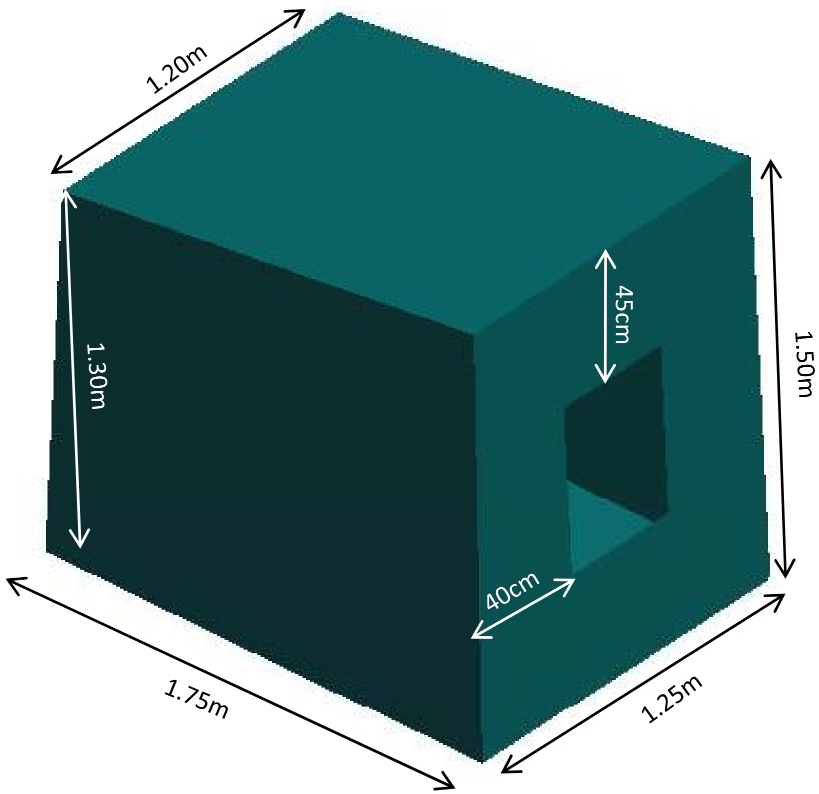
The higher the value of Ω, the larger the gaps in the characteristics.

1.25:1.5:1.75 {Blaszak}, 1.59:1.26:1 {SAE}

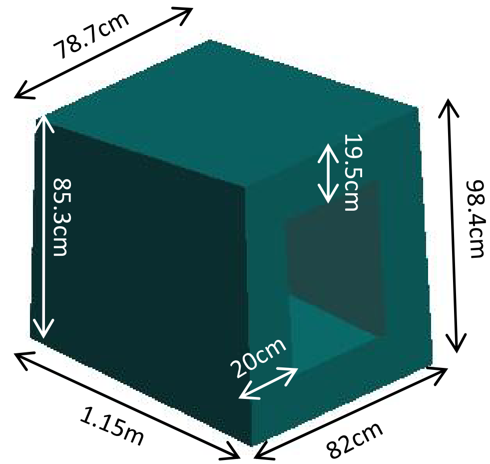
Performed Analysis (Blaszak ratio)



Scaled models – inner volume

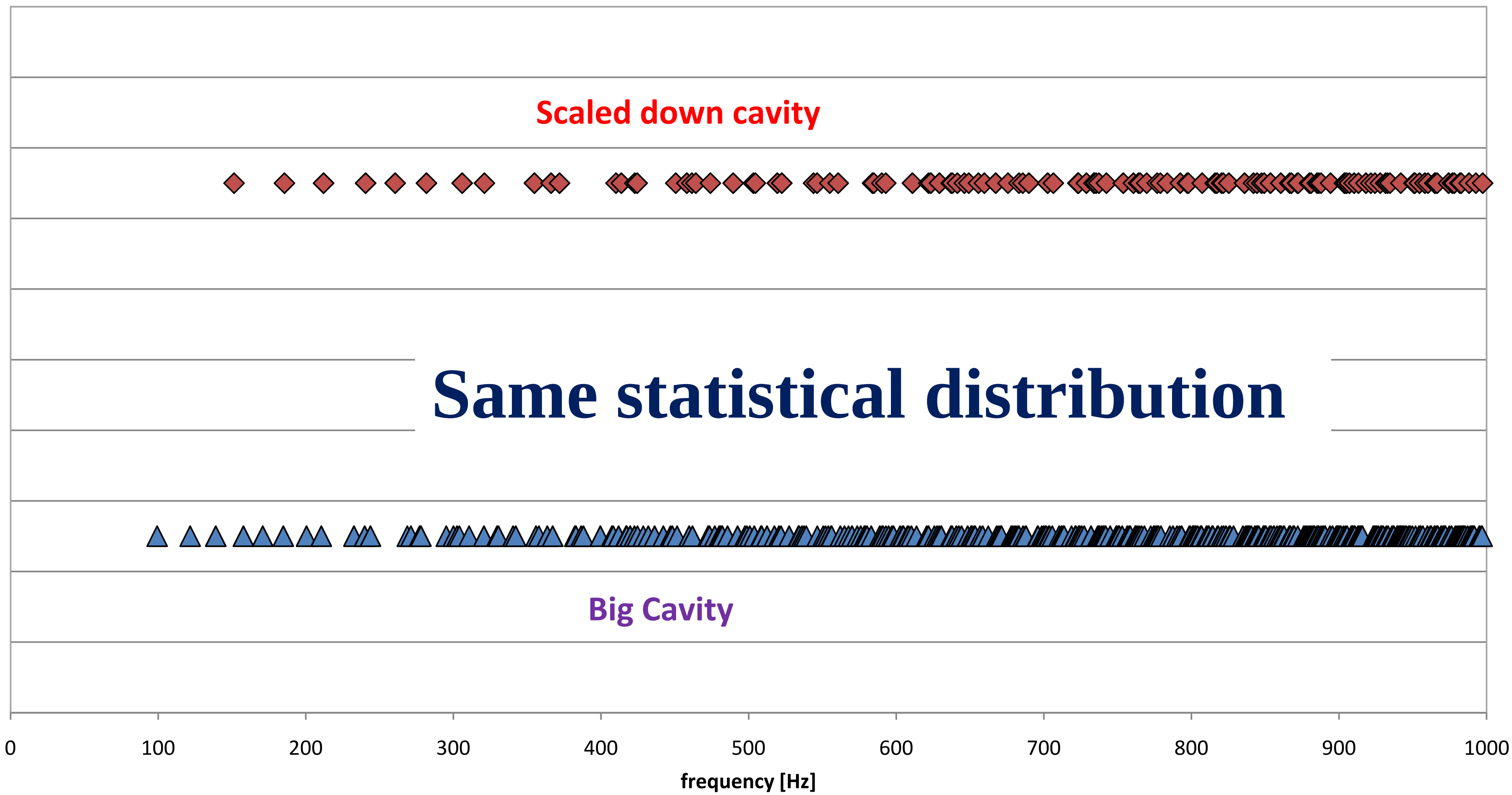


<starting model>



<scaled model>

Big and Scaled models – cavity modes

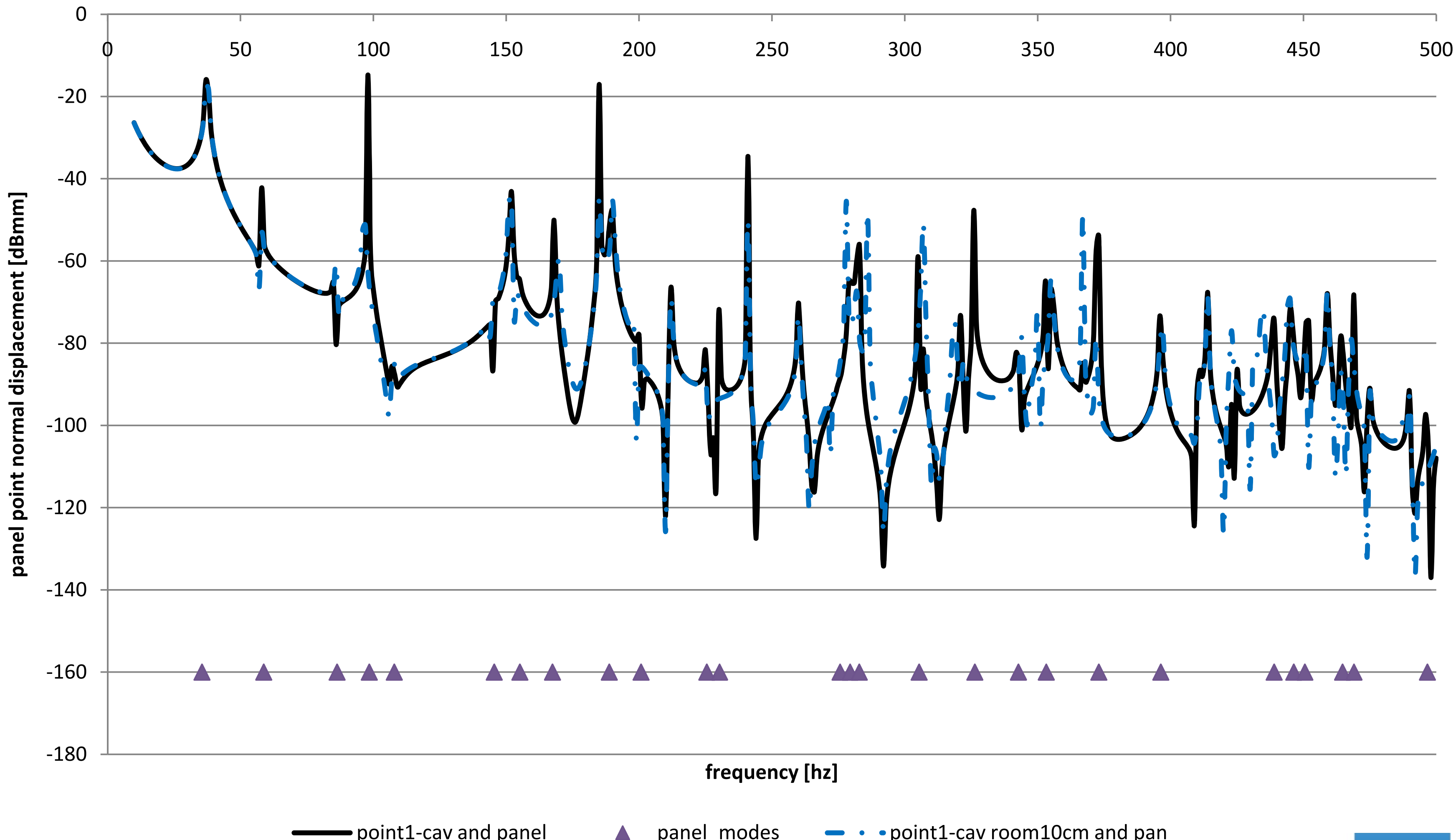


Walls thickness influence

Comparison between displacement amplitude on two test panel points using:

- same test panel – aluminum; 1mm; A2 size; clamped
- same reference case – coupled cavity-panel system, considering infinitely rigid walls
- same test acoustic source (and in the same location)
- different wall thicknesses – 10cm; 12cm; 14cm

10cm Walls



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-100
-120
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-160
-180
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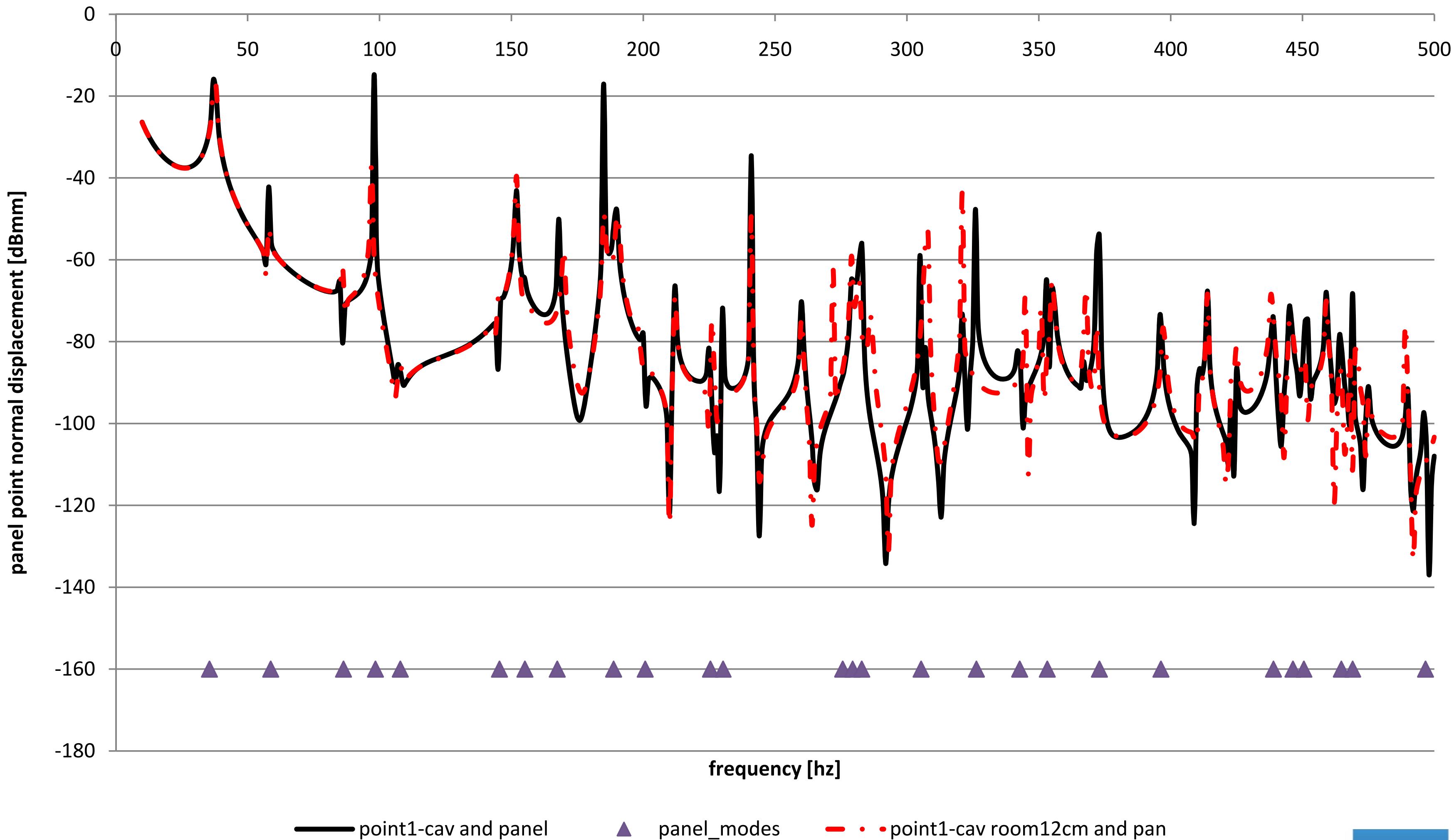
50
100
150
200
250
300
350
400
450
500
panel point normal displacement [dBmm]
frequency [hz]
point1-cav and panel
panel_modes
point1-cav room10cm and pan

12cm Walls



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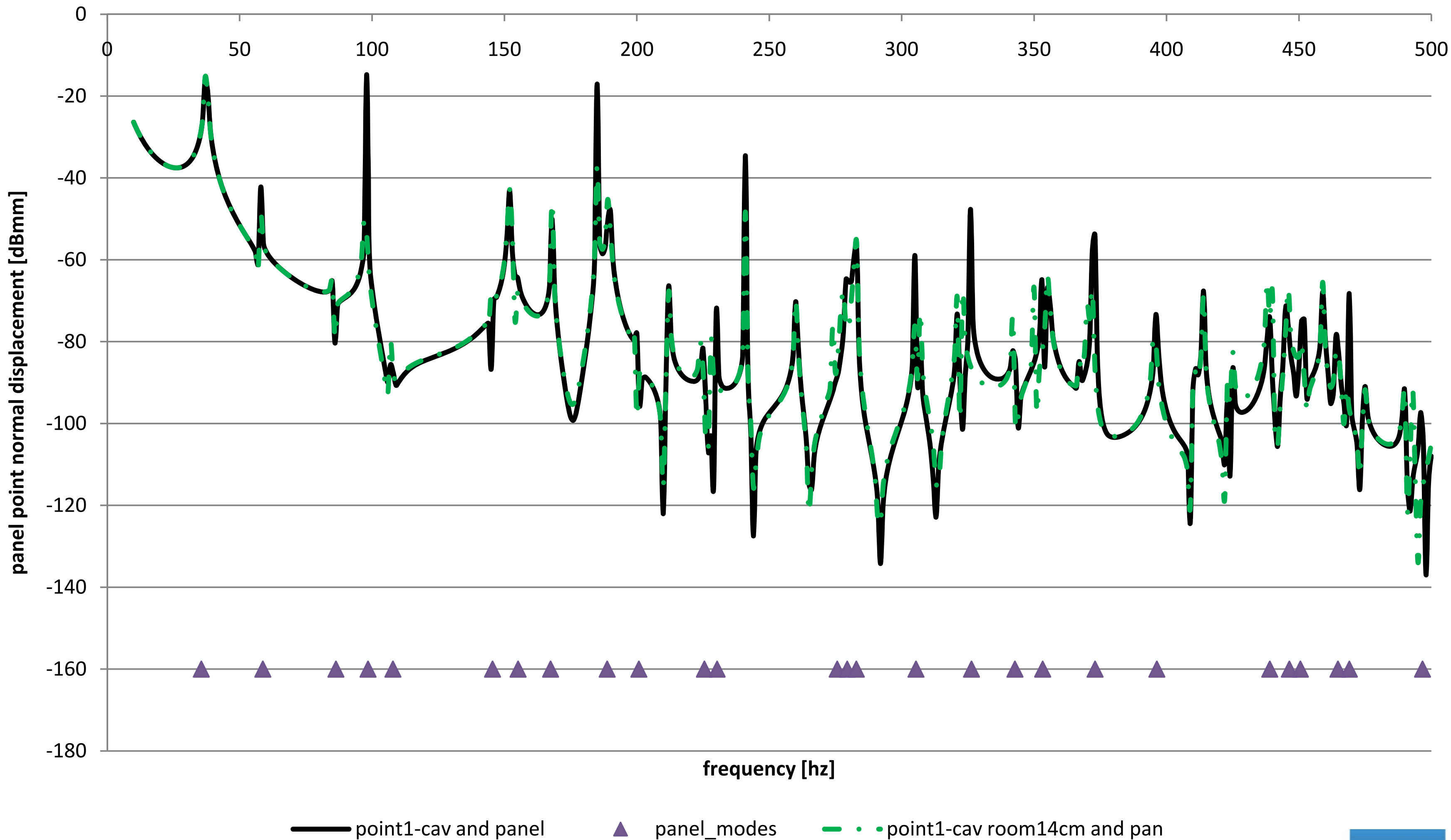
panel point normal displacement [dBmm]
frequency [hz]
point1-cav and panel
panel_modes
point1-cav room12cm and pan

14cm Walls



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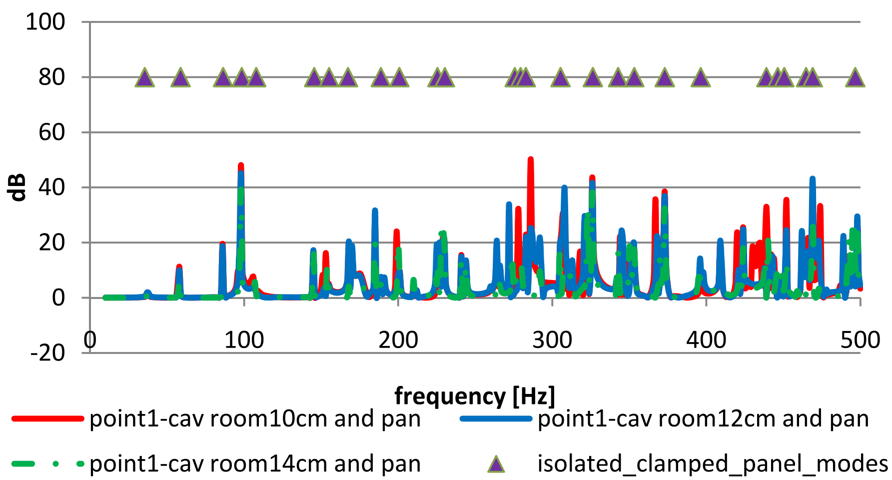
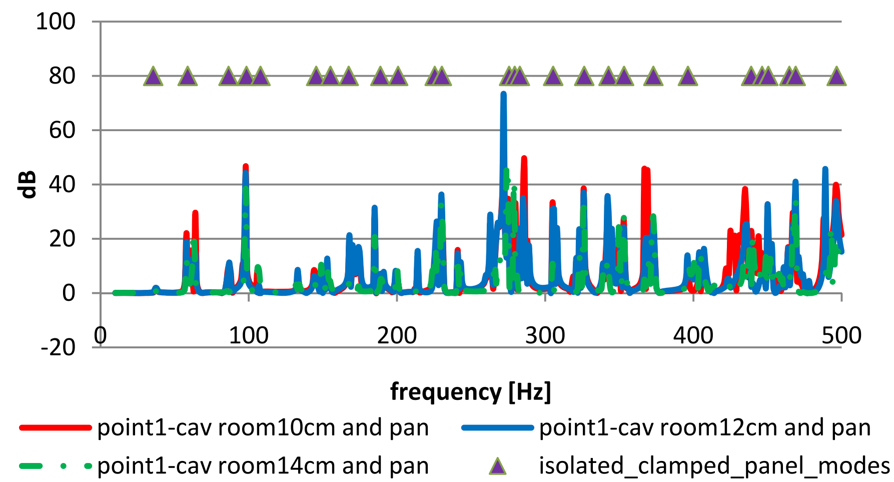
panel point normal displacement [dBmm]
frequency [hz]
point1-cav and panel
panel_modes
point1-cav room14cm and pan

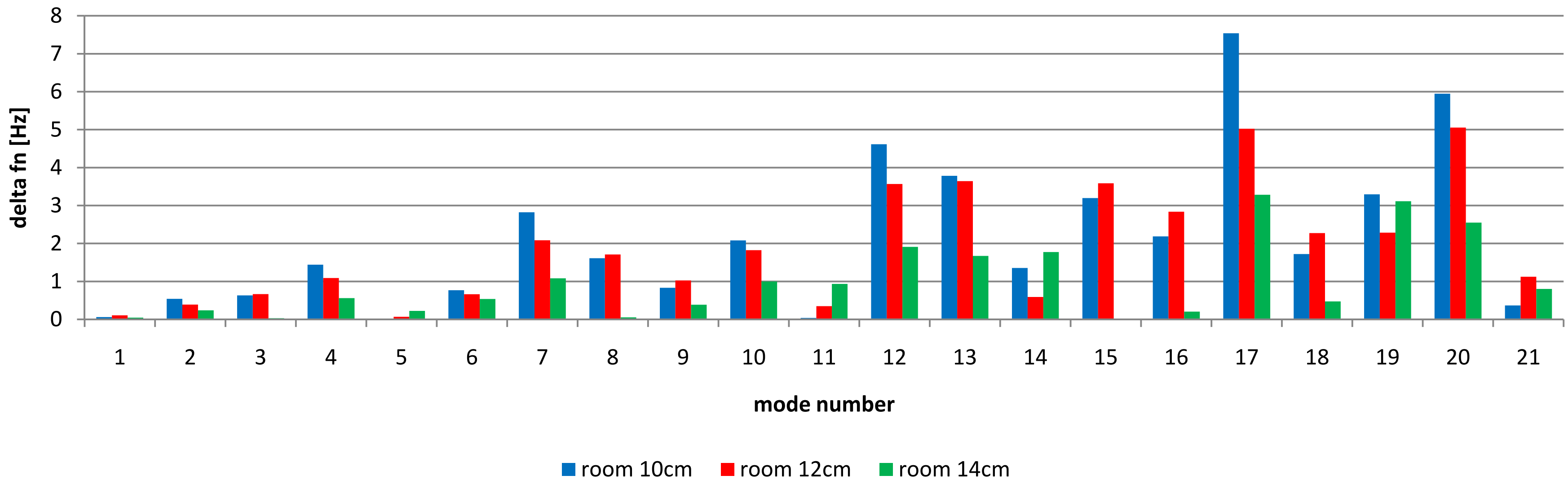
Walls thickness – mean abs. amplitude error

	mean abs(DA), [0-500]Hz [dB]	
	P1	P2
10cm	5	6
12cm	5	6
14cm	3	4



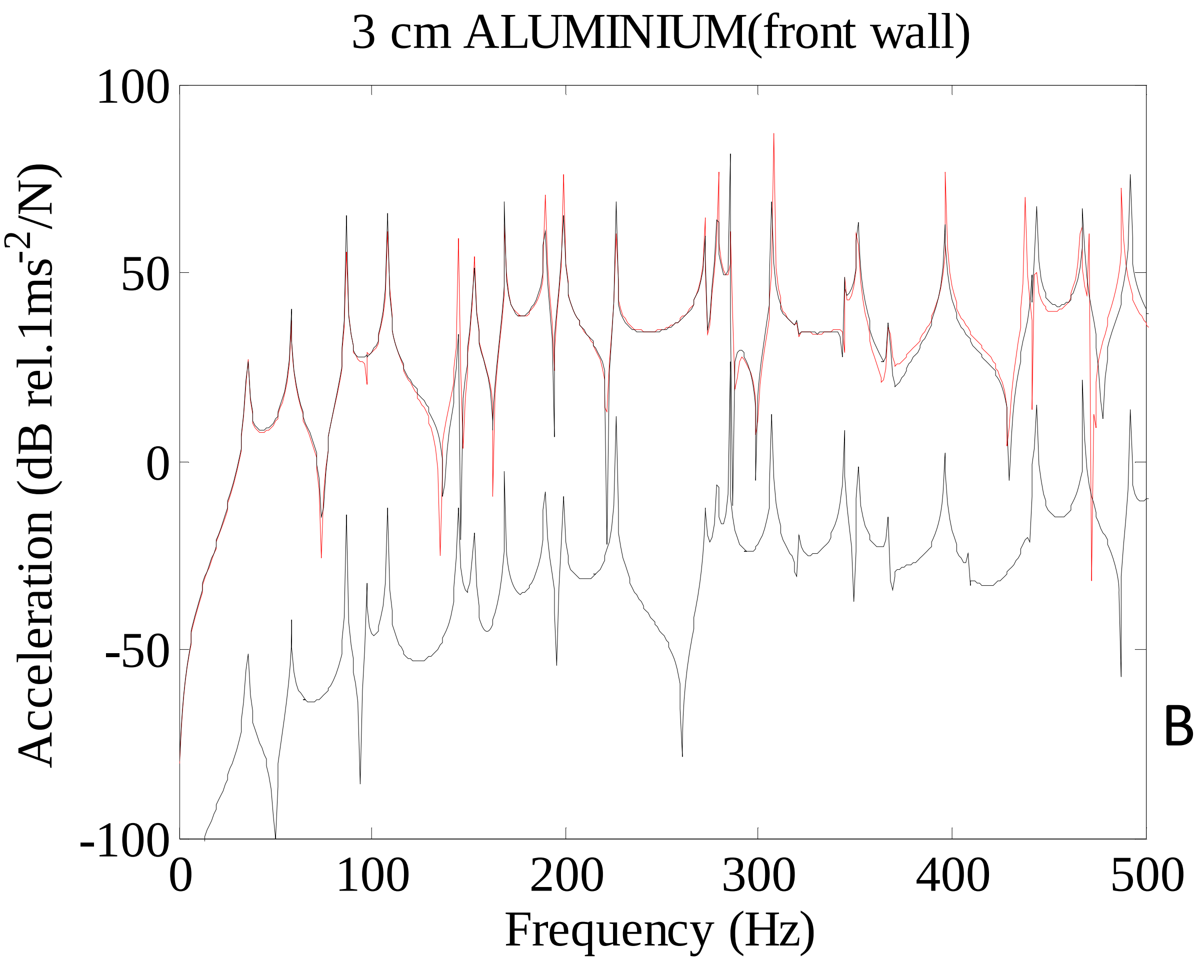


Walls thickness effect – panel natural freq.



	Over the first 20 modes of the test panel [0-400Hz]	
	Dfn [Hz] <1Hz	**Dfn [Hz] <2Hz**
10cm	8times	12times
12cm	8times	12times
14cm	13times	18times

Front wall infruence



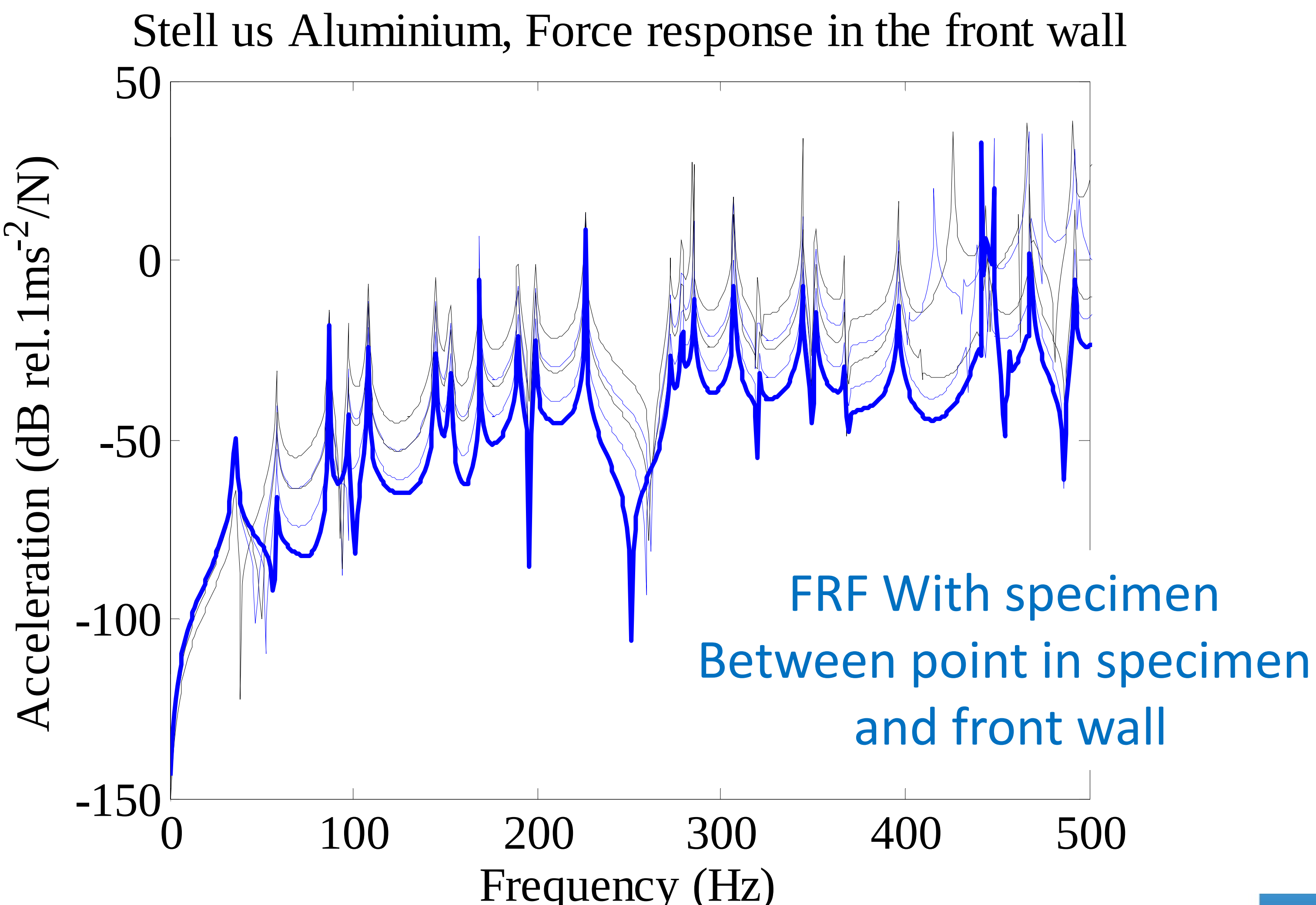
Isolated clamped panel

Vs

Panel installed in the box

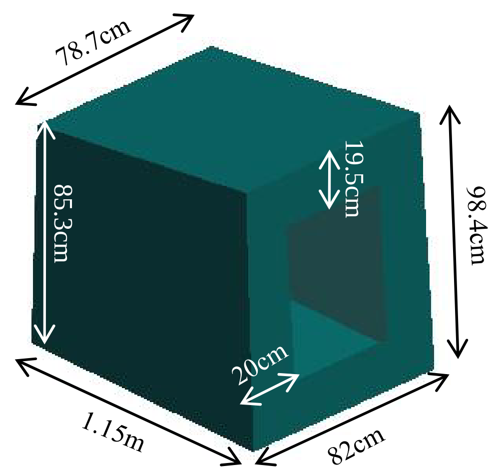
FRF With specimen Between point in specimen and front wall

Front wall influence



Final model - description

- Internal volume: 1.15m x 82cm x 98.4cm
- Wall thickness: 15cm
- Reinforced concrete: 2500kg/m^3 - E=40GPa
- Total mass ~ 2.1Ton + front wall (aluminium wall)
- Several Test windows
  - A2, A3, A4 window size
  - Fully closed



Conclusion & Future work

- A optimum geometric proportion has been found;
  - Taking into account the eigenfrequencies
  - Absorption coefficient (α)
- The wall thickness and front wall influence has been studied
- A final model has been designed and ordered

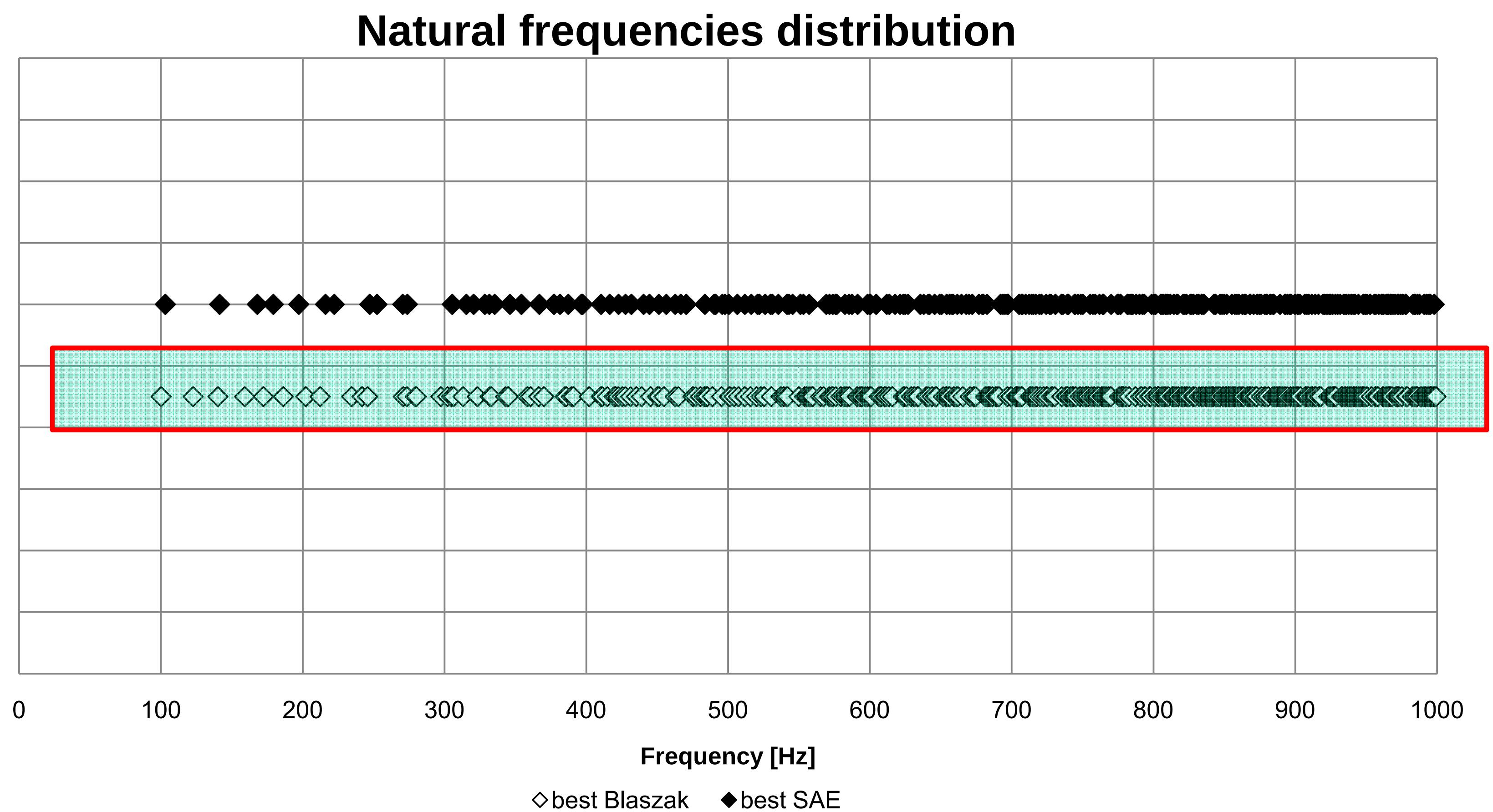
- Experimental validation
- Clamped mechanisms

Thank you!!!

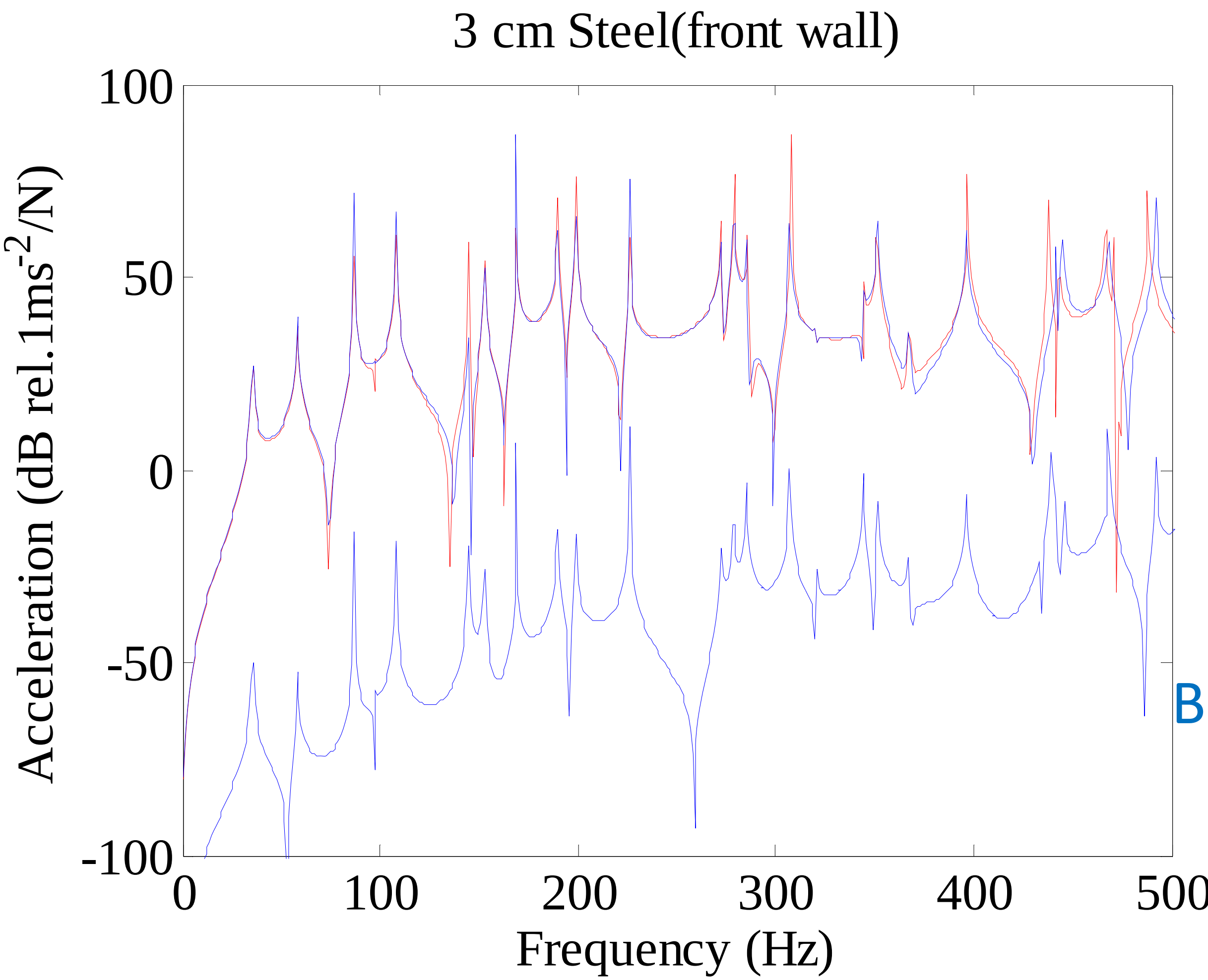
Acknowledgement

Marianna Vivolo

Performed Analysis
{Blaszak & SAE} ratios



Forced response:box and panel



Isolated clamped panel

Vs

Panel installed in the box

FRF With specimen Between point in specimen and front wall

Panel	Structure	Structure - Panel	Acoustic	Coupled Structure - Plate
35.6539		35.6211		37.4634
58.3569		58.2878		57.5926
87.12		86.988		86.224875
97.2741		97.2804		96.816455
108.1463		107.9279		107.46288
144.9707		144.8309		144.55517
			151.3813	151.60583
152.7912		152.7531		152.58681
169.1599		169.0142		169.58475
			185.5101	185.19042
190.132		189.6923		190.27906
198.9342		198.7782		198.6321
			212.0006	212.13338
226.1933		225.9862		225.85168
226.5034		226.8157		226.65679
			240.5112	240.95988
			260.4894	260.25305
272.2245		272.4606		272.48793
278.8863		278.4897		278.46766
			281.6943	281.64799
285.814		285.3157		285.30034
			305.9175	306.48068
307.9851		307.2438		307.10575
			320.9529	320.29709
320.5771		320.5617		321.25601