Acoustic modeling of airborne sound insulation of wooden facade systems using artificial neural networks

WOOD RISE-2022
Portorož, Slovenia

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WOOD RISE 2022
RENOVATION, RESTORATION & REHABILITATION

Table of Content

1- Introduction

- What is special about wood?

Prefabricated

- Quick & easy installation

Eco-Friendly

- Renewable

Time saving

- Faster than conventional materials

Fire-resistant

- Charring provides longer resistance

Less carbon footprint

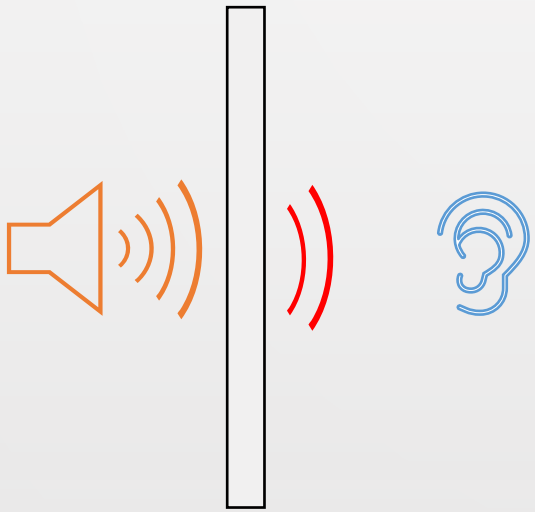
- Less carbon emission

Thermal insulation

- Better insulation than concrete

1- Introduction

- What is special about wood?
  - **But…**



- Wooden constructions have **lower** subjective sound insulation compared to heavy structures [1]

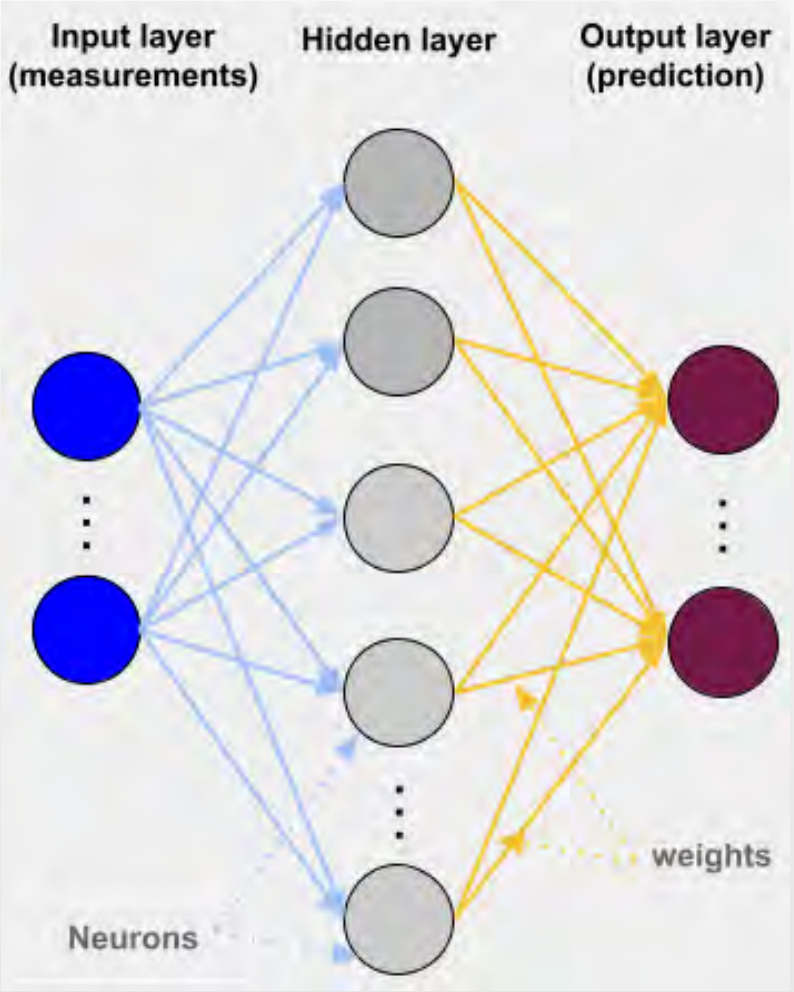
- Wood has poor sound insulation due to its lightweight comparing to concrete [2]
- Acoustic measurements are time and cost demanding
- Many challenges face developing a reliable tool:
  - the standardized method
  - the variety of construction materials,
  - measurements cannot be generalized

[1]- Guigou-Carter, C.; Villot, M.; Wetta, R. Prediction method adapted to wood frame lightweight constructions. Build. Acoust. 2018, 13, 173–188.
[2]- Zhou, Jianhui, and Zijian Zhao. "Apparent impact sound insulation performance of cross laminated timber floors with floating concrete toppings." *INTER-NOISE and NOISE-CON Congress and Conference Proceedings*. Vol. 263. No. 1. Institute of Noise Control Engineering, 2021.

2- Materials and Methods

2.1. Artificial Neural Networks (ANN)

- Machine learning applications have been widely used in complex problems in various fields [3-5]
- Comprises of input layer, hidden, and output layer(s)
- Errors that are made by ANN are viewed to evaluate the values of weights



[3]- Chattopadhyay, A.; Manupriya, P.; Sarkar, A.; Balasubramanian, V.N. Neural network attributions: A causal perspective. In Proceedings of the International Conference on Machine Learning, PMLR, Long Beach, CA, USA, 9–15 June 2019.
[4]- Thai, L.H.; Hai, T.S.; Thuy, N.T. Image classification using support vector machine and artificial neural network. Int. J. Inf. Technol. Comput. Sci. 2012, 4, 32–38.
[5]- Serpilli, F.; Di Nicola, G.; Pierantozzi, M. Airborne sound insulation prediction of masonry walls using artificial neural networks. Build. Acoust. 2021, 28, 391–409

2- Materials and Methods

2.2 Acoustic Measurements

- 100 lab-based measurements
- The measurement sources: Lund University and CNRC [6]

Database		ANN model		
Air-borne meas. no.	100	100		
		trainning set	validation set	testing set
		80	10	10

[6]- Bradley, J.S.; Birta, J.A. Laboratory Measurements of the Sound Insulation of Building Facade Elements; Institute for Research in Construction, National Research Council Canada: Ottawa, ON, Canada, 2000.

2- Materials and Methods

2.2 Acoustic Measurements

- Physical and geometric parameters:
  - material types and their installation order
  - thickness and density of constructional elements
  - total and group thickness and density of the structure
  - facade area
  - volume of the structure
  - studs' depth and spacing between them

[6]- Bradley, J.S.; Birta, J.A. Laboratory Measurements of the Sound Insulation of Building Facade Elements; Institute for Research in Construction, National Research Council Canada: Ottawa, ON, Canada, 2000.

2- Materials and Methods

2.2 Acoustic Measurements

- Split **into three**: Exterior, main, and interior parts

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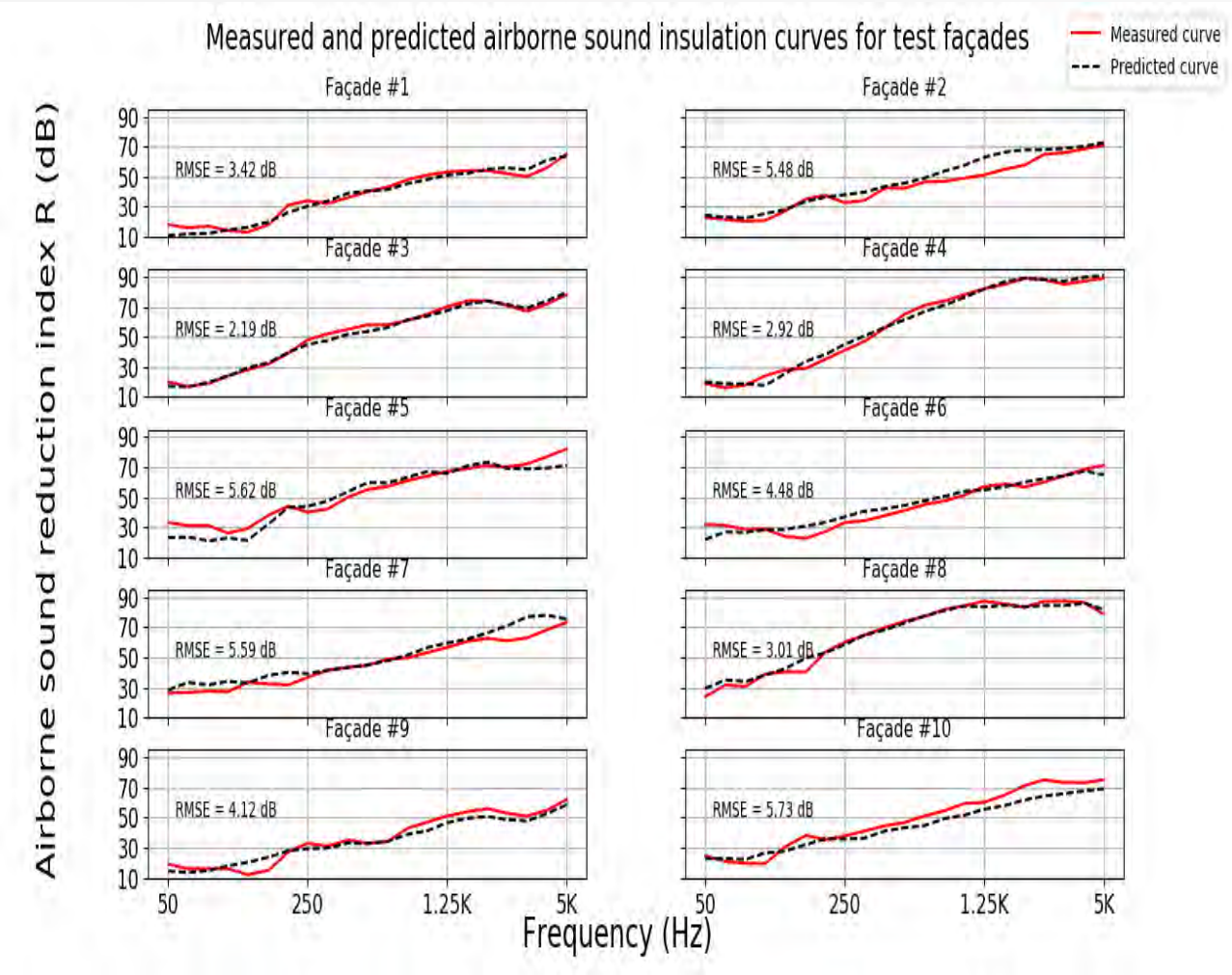
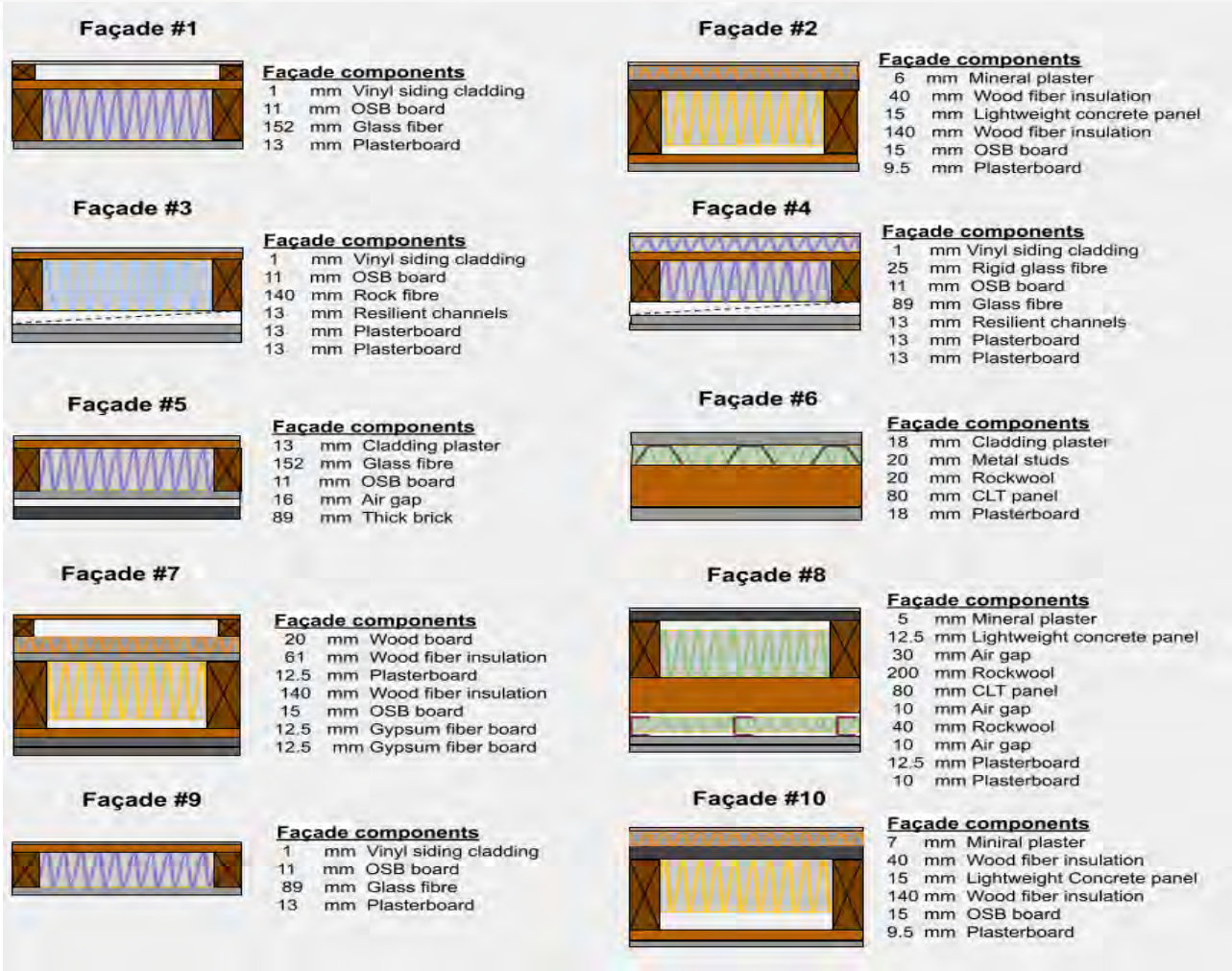
3- Results and discussion

3.1. Comparison between measured and predicted airborne

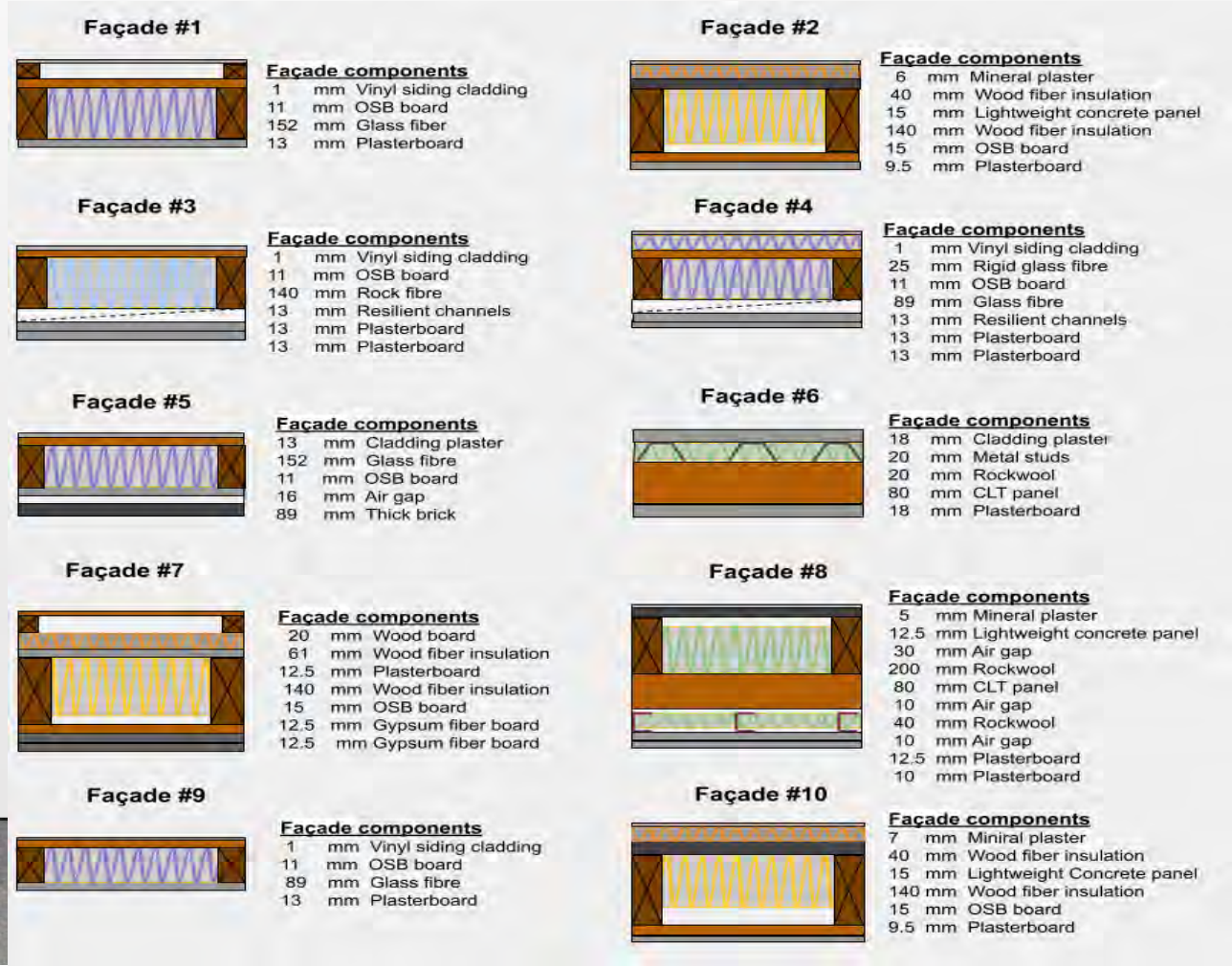




3- Results and discussion

3.1. Comparison between measured and predicted airborne curves

Floor no.	RMSE (dB)	Rw (dB)	Rw Pred (dB)
1	3.42	39	40
2	5.48	46	48
3	2.19	53	53
4	2.92	50	51
5	5.62	52	51
6	4.48	55	55
7	5.59	48	51
8	3,01	65	67
9	4,12	37	38
10	5.73	49	47



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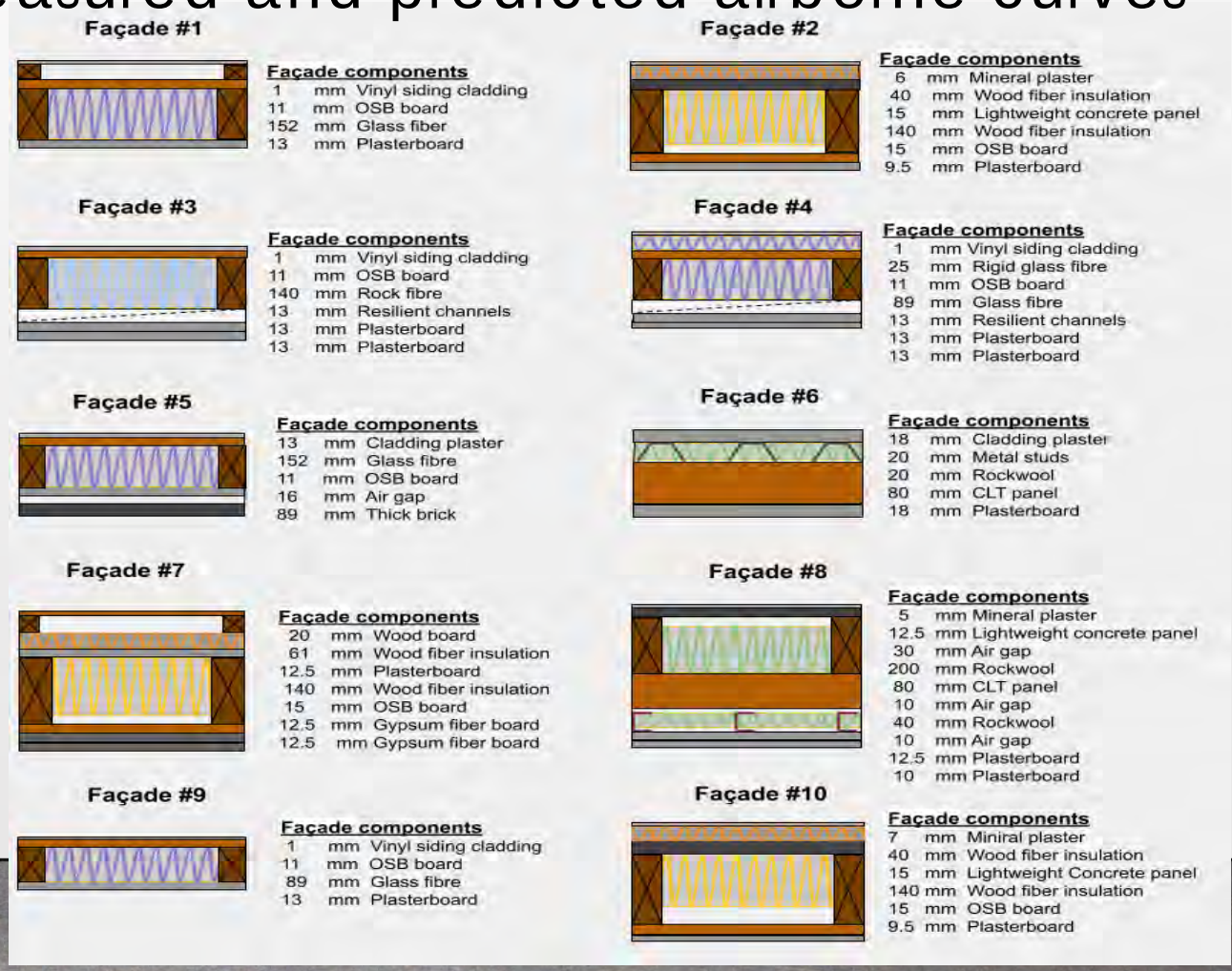

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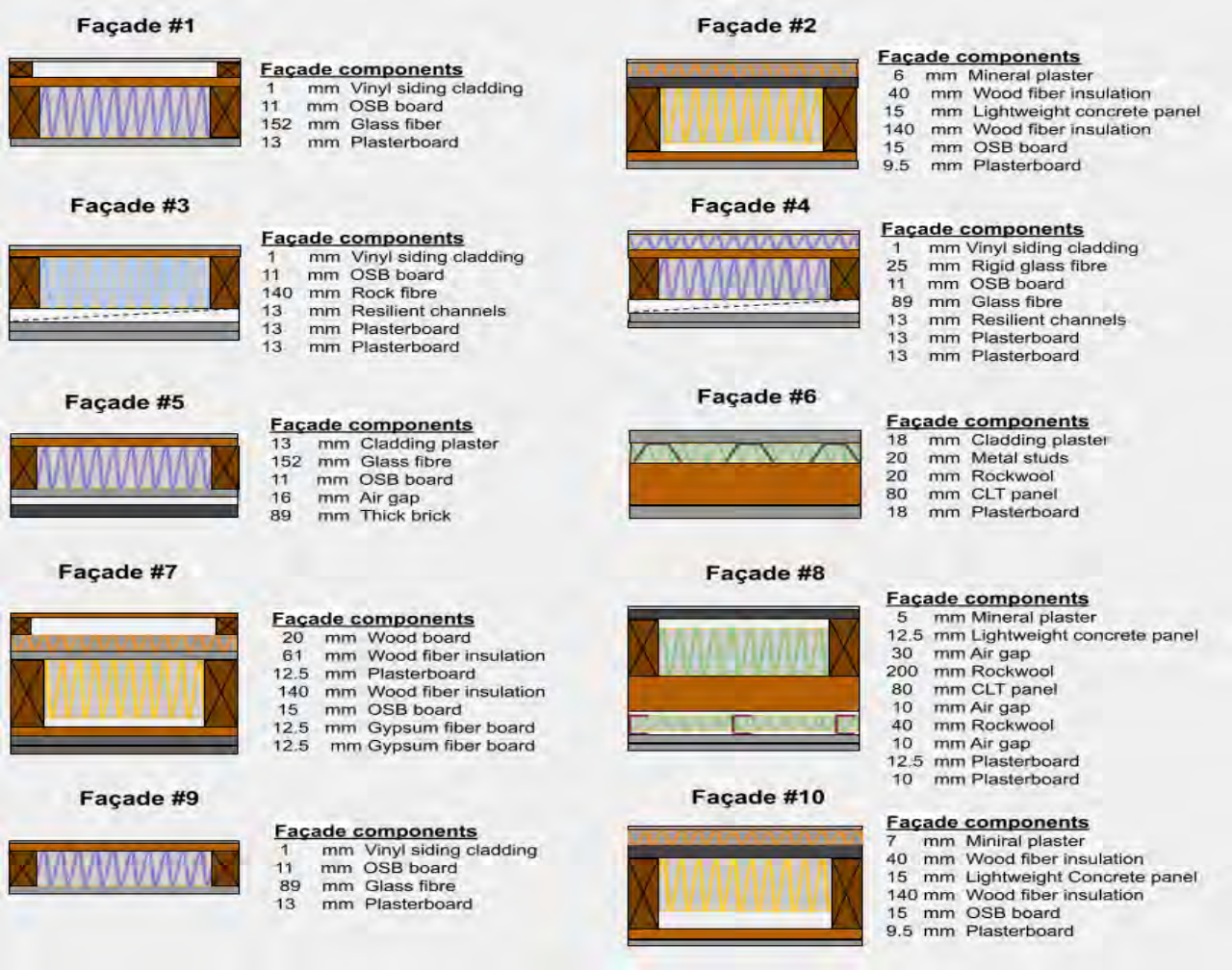
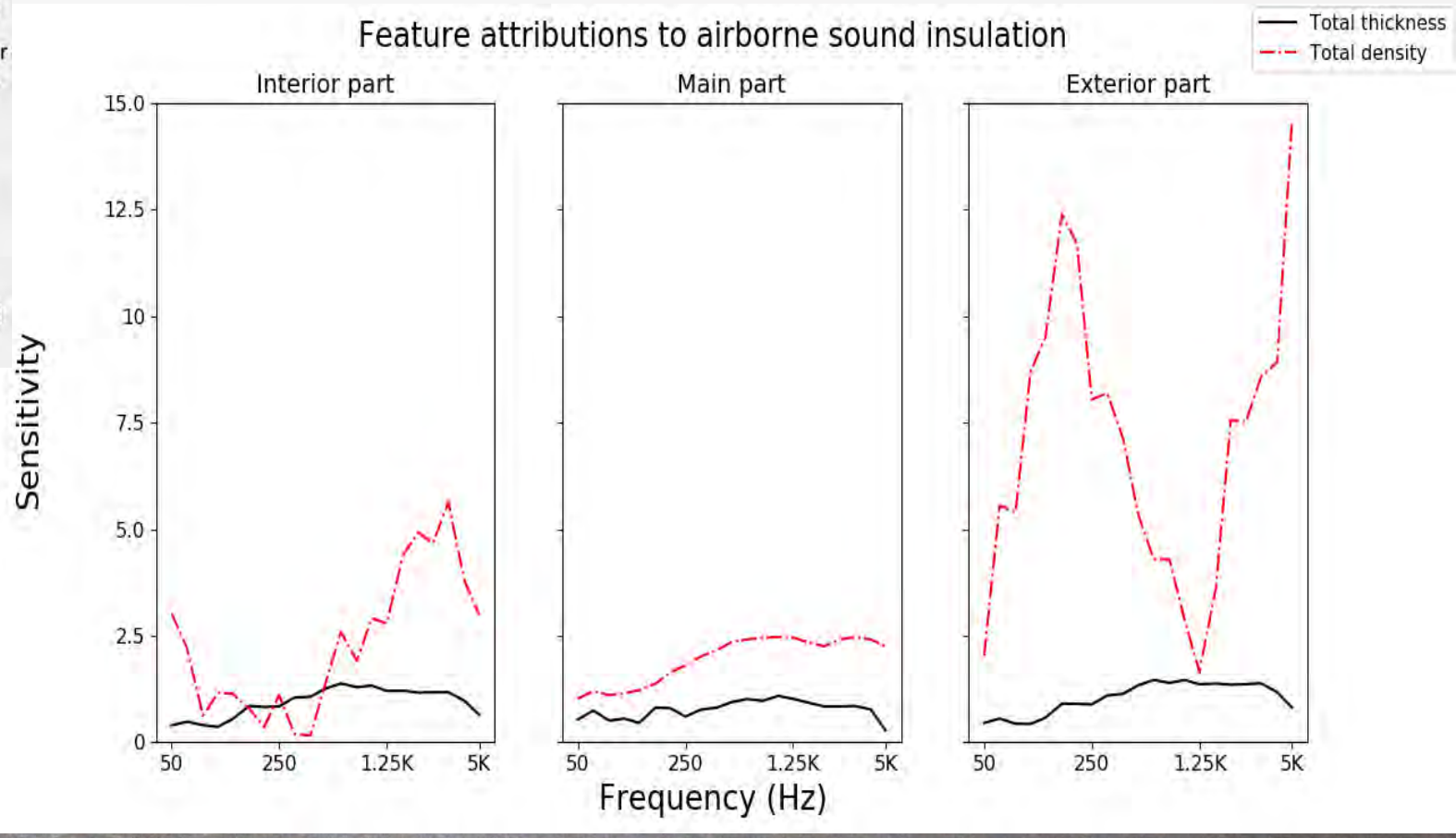


3- Results and discussion

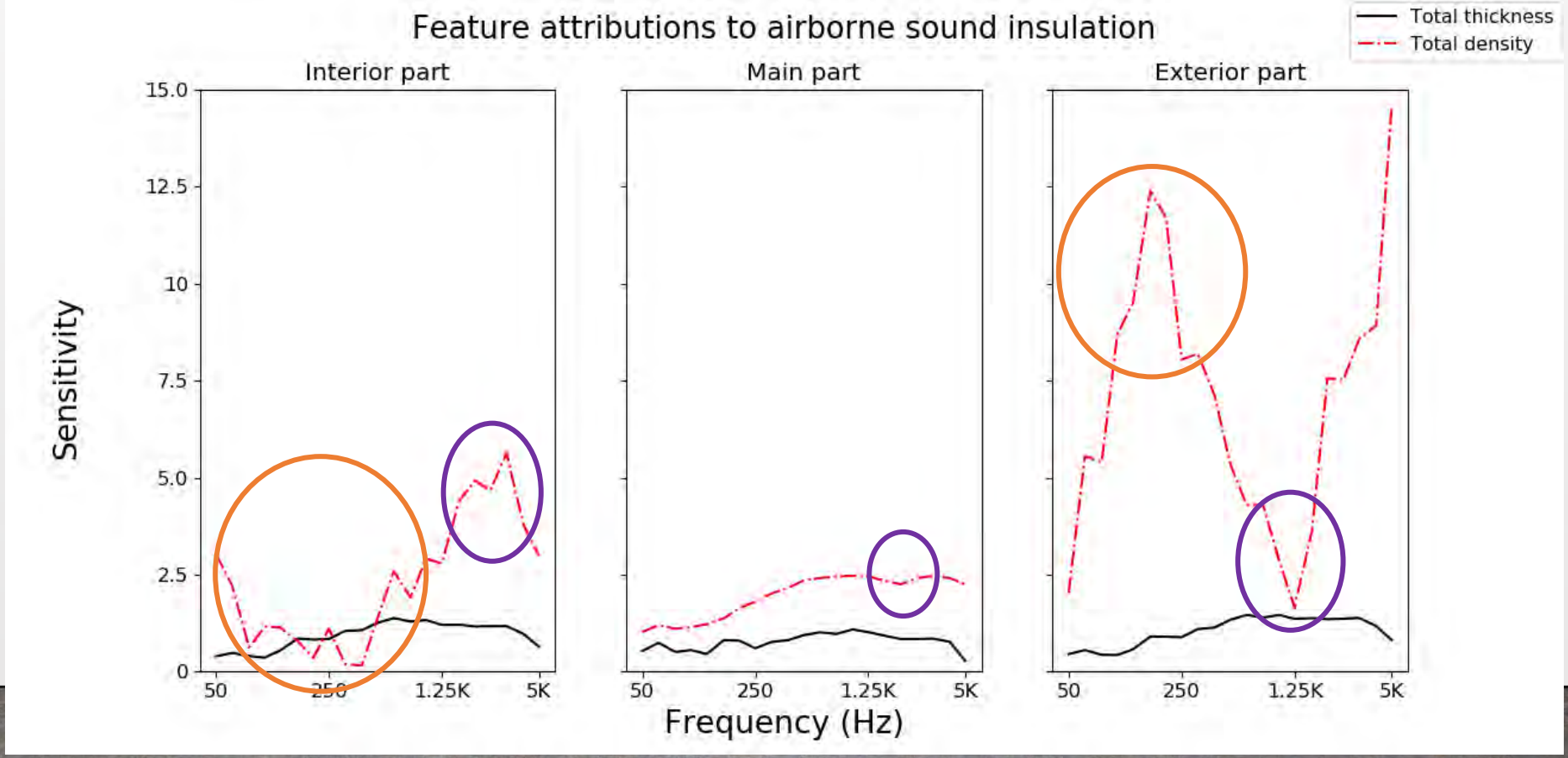
3.3. Sensitivity analysis



3- Results and discussion

3.3. Sensitivity analysis

- **Effect of resonance frequency**
- **Effect of critical frequency**



4- Conclusion

- The present article demonstrates a potential of ANN model in prediction airborne sound insulation curves for façade walls
- The model can predict Rw within a maximum error of 3 dB
- In many cases the prediction is difficult around the fundamental and the critical frequencies
- The total thickness and total density of interior, main and exterior parts of façades have remarkable effects at all frequencies
- The total density of the exterior part has higher attribution on the predictions

5- References

[1]- Guigou-Carter, C.; Villot, M.; Wetta, R. Prediction method adapted to wood frame lightweight constructions. Build. Acoust. 2018, 13, 173–188.

[2]- Zhou, Jianhui, and Zijian Zhao. "Apparent impact sound insulation performance of cross laminated timber floors with floating concrete toppings." *INTER-NOISE and NOISE-CON Congress and Conference Proceedings*. Vol. 263. No. 1. Institute of Noise Control Engineering, 2021.

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