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Universitatea Tehnică de Construcții București

REHVA
Federation of European Heating, Ventilation and Air-conditioning Associations

ASOCIAȚIA INGINERILOR DE INSTALAȚII DIN ROMÂNIA
AIIR

Innovative Acoustic Approach for Building Air Permeability Estimation using Experimental and Numerical Study

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Coordinators : Tiberiu Catalina & Vlad Iordache

REHVA STUDENT COMPETITION 2018 - BRUSSELS

About us

Alexandra ENE (ANGELESCU)

1ST year Master Student

Implication in multiple national and European research programs "*Innovative strategies for designing the HVAC systems for a superior quality inside a vehicle's cabin*" and "*Smart Radon - Measurements and Solutions in Energy Efficient Dwellings*"

Publications:

Romanian Journal of Acoustics and Vibration: *"ACOUSTIC MEASUREMENTS INSIDE A VEHICLE WITH DIFFERENT AIR PROTOTYPE DIFFUSERS"*

Romanian Journal of Acoustics and Vibration: *"IMPROVING SPEECH INTELLIGIBILITY IN A HIGH SCHOOL CLASSROOM USING SOUND ABSORBING PANELS"*

About us

Claudiu STANCIU

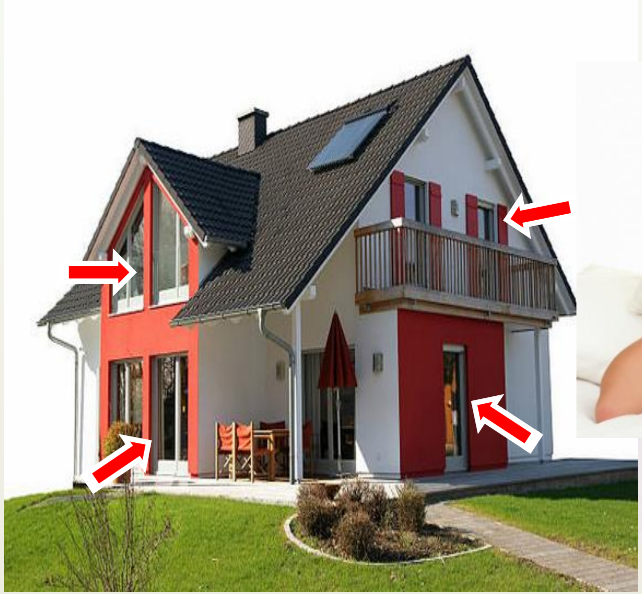
1St Year Master Student

Member of the **Solar Decathlon Romania** in the EFdeN project *(Paris 2014)* and **Over4** project *(Hungary 2019)*

Involvement in multiple technical projects

Participant in different national competitions “Distrigaz ENGIE” – Energy efficient mobile office

INTRODUCTION



Impact of air infiltration on

- BMS errors

Standards and Norms:

ISO 7730, Romanian Norm - I5

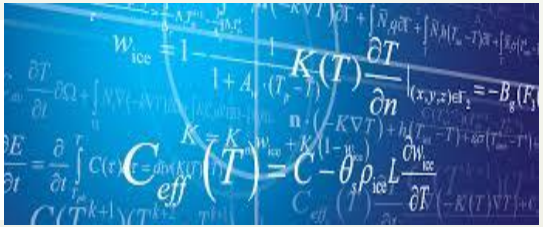
The **major need to estimate correctly the air infiltration rate**

INTRODUCTION – CURRENT SOLUTIONS

1. ***Prediction models*** (LBL, AIM-2, Montoya, Chan, McWilliams et al.)

Advantages:
- Easy and simple;
- Fast.

Disadvantages:
- **Low precision** – up to **100% errors** in some cases – **Unacceptable**



References:
Wang W, Beausoleil-Morrison I, Reardon J, Evaluation of the Alberta air infiltration model using measurements and inter-model comparisons, Building and Environment, 2009, 44, 309– 318
McWilliams J, Jung M. Development of a mathematical air-leakage model from measured data. Report LBNL-59041. Berkley, CA: Lawrence Berkley National Laboratory; 2006
Montoya M, Pastor E, Carrié F, Guyot G, Planas E. Air leakage in Catalan dwellings: developing an airtightness model and leakage airflow predictions. Building Environment 2010
Chan WR, Nazaroff WW, Price PN, Sohn MD, Gadgil AJ. Analyzing a database of residential air leakage in the United States.Atmos Environ 2005

INTRODUCTION – CURRENT SOLUTIONS

2. Blower Door *- EN13829*

Advantages:

- High precision because is an experimental approach.

Disadvantages:

- Weather dependent;
- Time consuming (pressurization and depressurization determination);
- Large and expensive equipment.

References

Raman G, Prakash M,Ramachandran R, Patel H, Chelliah K, Remote detection of building air infiltration using a compact microphone array and advanced beamforming methods, 5th Berlin Beamforming Conference 2014

Górzeński R, Szymański M, Górka A, Mróz T, Airtightness of Buildings in Poland, International Journal of Ventilation 2014, Volume 12 No 4 March

INTRODUCTION – CURRENT SOLUTIONS

3. Tracer gas method - *E741 Standard*

Advantages:

- Good precision because is an experimental approach.

Disadvantages:

- Complex and expensive equipment;
- Weather dependent;
- Time consuming;
- Special gas needed.

References:

Patel T, Miller J, Mitsingas C, Newell T, Comparison of blower door and tracer gas testing methods for determination of air infiltration rates through building envelopes at normal operating conditions, 5th International Conference on Energy Sustainability, Washington, USA, August 7-10, 2011

Air change rates at night in northeast Chinese homes, Jing Hou, Yufeng Zhang, Yuexia Sun, Pan Wang, Qingnan Zhang, Xiangrui Kong, Jan Sundell, Building and Environment, 2018

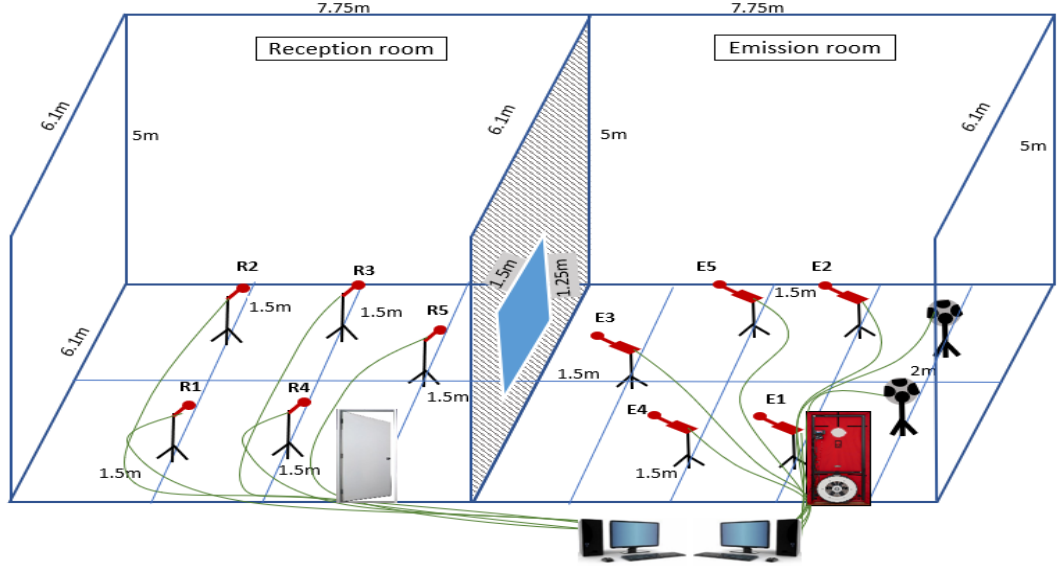
OBJECTIVES

Is there a compromise solution between inaccurate prediction models and the more complex experimental measurements ?

- To prove the correlation between air and sound transfer phenomena;
- Develop **a novel acoustic method** for determining the air permeability - **FASTER and SIMPLER;**
- Determining **a nomogram and finally to develop and easy tool** to quickly estimate air permeability.

Full scale experimental facility

EN 717 compliance



Experimental stand:
Length: 7.75 m
Width: 6.13 m
Height: 5 m

Volume: 234.47 m^3

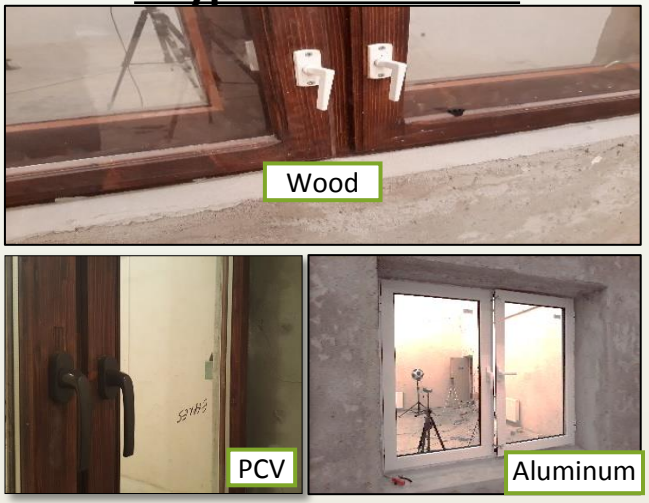
Tested window:
Length: 1.5 m
Height: 1.25 m

We performed **simultaneously two experimental campaigns**: acoustical & permeability

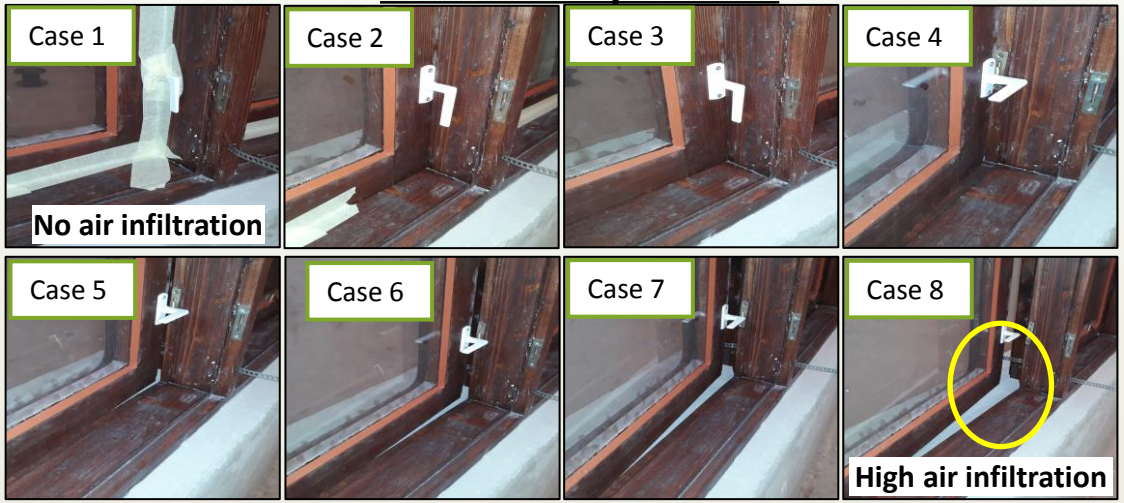
The measurement campaign was conducted in a controlled environment at the ***National Building Institute of Research – INCERC*** from Bucharest

Full scale experimental facility

9 types of windows



8 window apertures



The analyzed windows were: simple, double, coupled and triple wood pane windows, double-glazing wood pane windows and a double-glazing aluminum pane window and a simple, double and triple glazing PVC pane window.

We have studied **144 complex experimental campaign** (72 acoustic + 72 permeability)

Experimental study 1 - Permeability measurements

Equipment

Testo 480 –temperature, humidity and air velocity

Minneapolis Blower Door System

PC with the Tectite software v.5

High precision equipment

Standards and norms:

- EN13829
- ISO9972

Experimental study 2 - Acoustic measurements

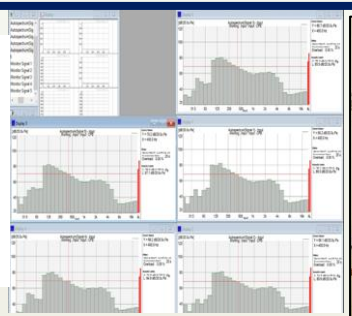
Equipment

2 x Omnipower sound source "4929-L" - from Bruel&Kjaer

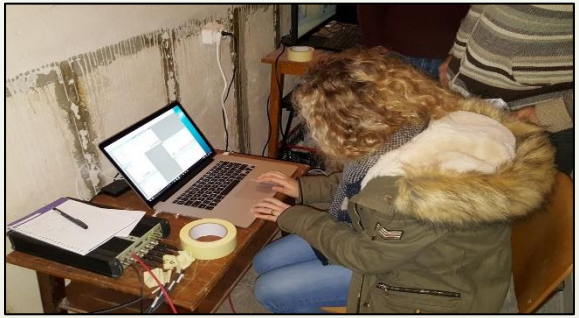
Soundmeters
3 x 2250
1 x 2270
Bruel&Kjaer Class precision 1

Multipoint station "Pulse 3560-B-020"

MacBook which connected all the sound meters and the noise sources



Labshop software used for data acquisition multipoint station



Measurements were performed in a **standardized room**

Standards and norms:

- EN717
- SR616

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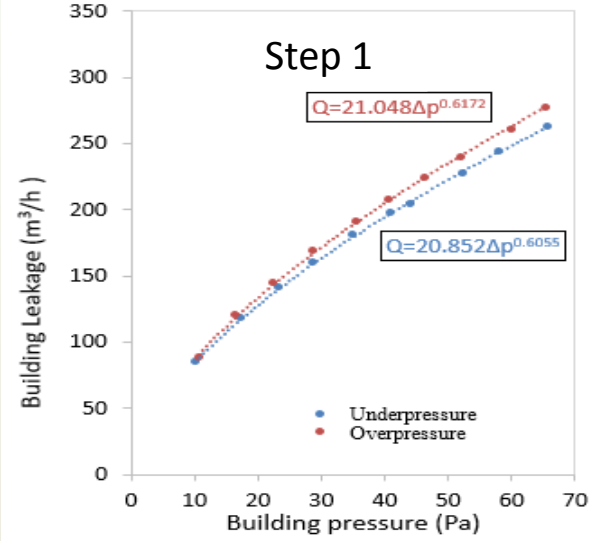
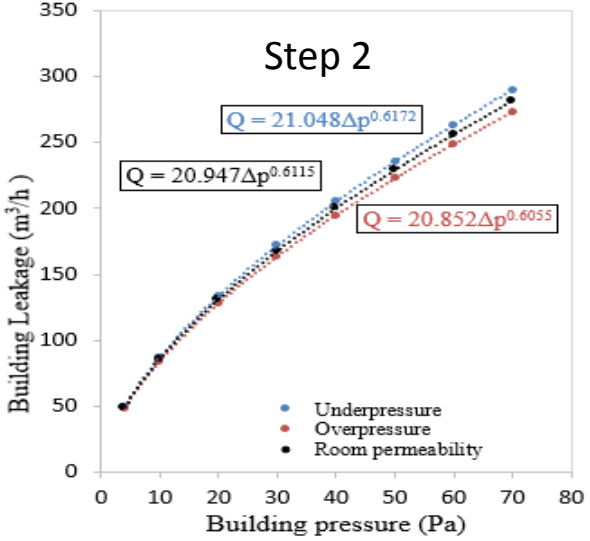
Experimental study 1

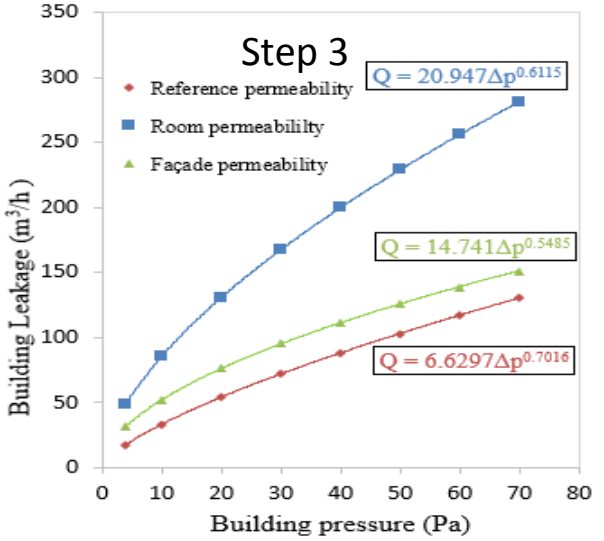
Air flow measurements

Example for **case 1 – simple wood pane window** (in total 72 cases)

More than 200 charts







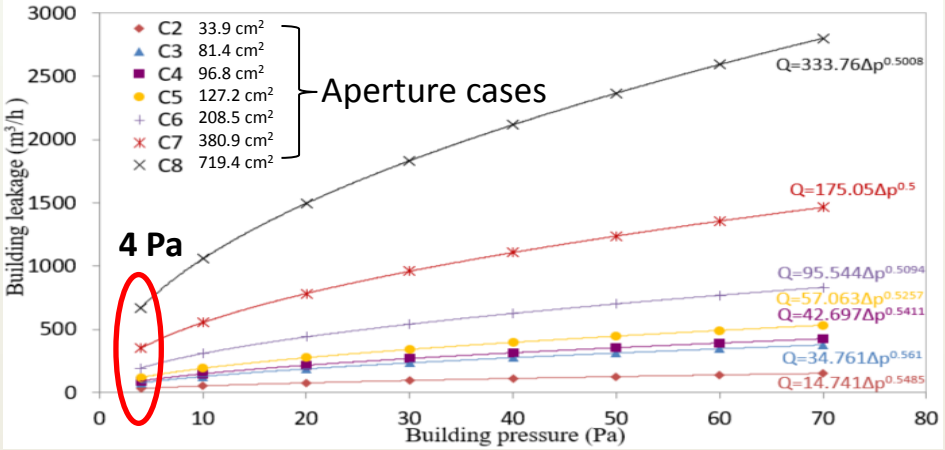
Two situations: **over and under-pressure**

Average permeability law

Extracting the **façade permeability law**

Experimental study 1

Example of façades permeability for all cases – **single wood pane window**



The **curves of the facades** were determined **for each case** and **for each type of window**

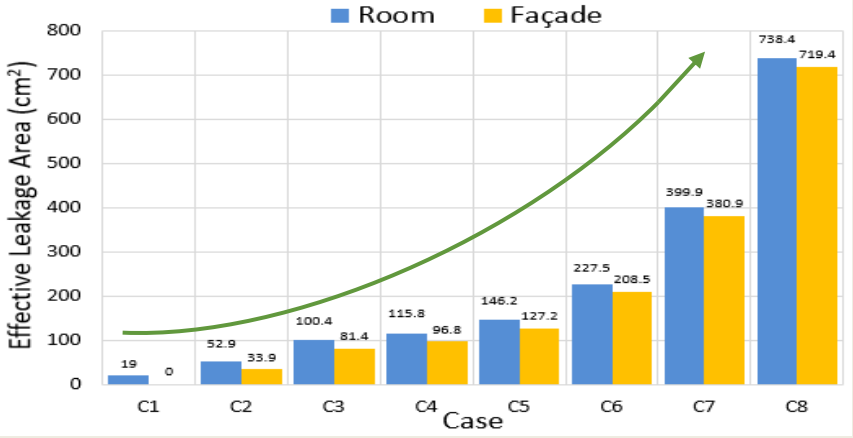
Air flow measurements

72 façades permeability laws

4 Pa Outdoor/Indoor pressure difference

Effective leakage area

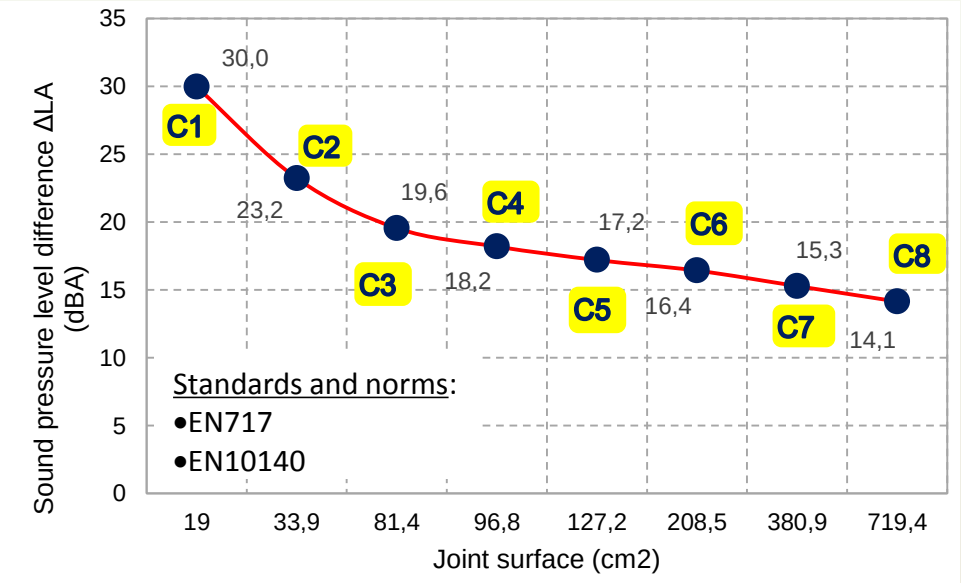
Example– **single wood pane window**



Experimental study 2

Acoustic measurements

Example of sound pressure difference level– **simple wood pane window**

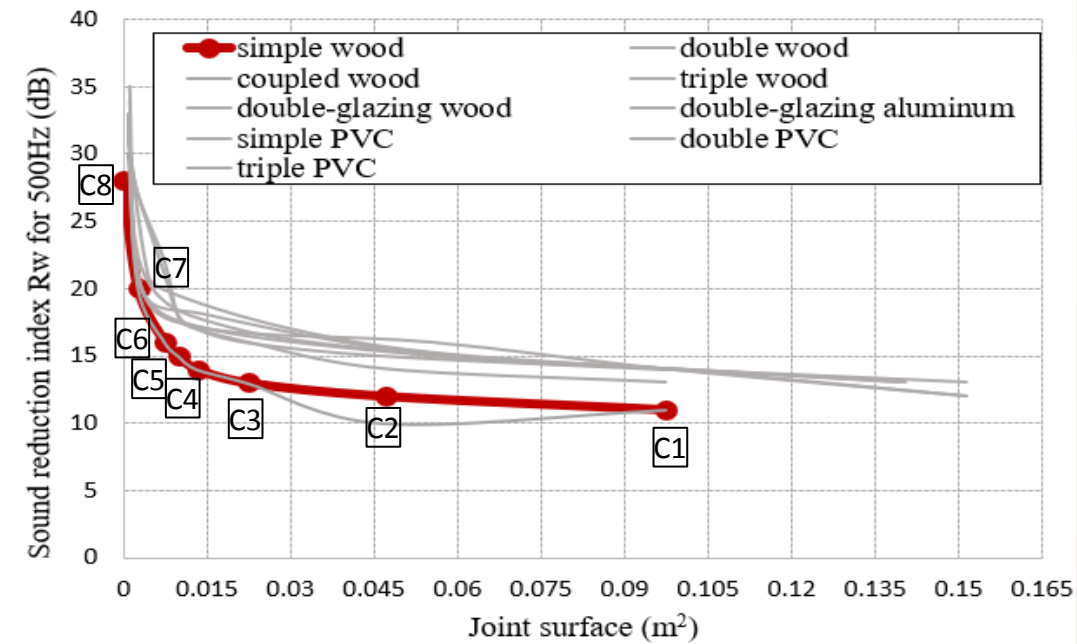


The sound pressure level difference is dropping as the joint surface is growing

First step of proving the correlation

Experimental study 2

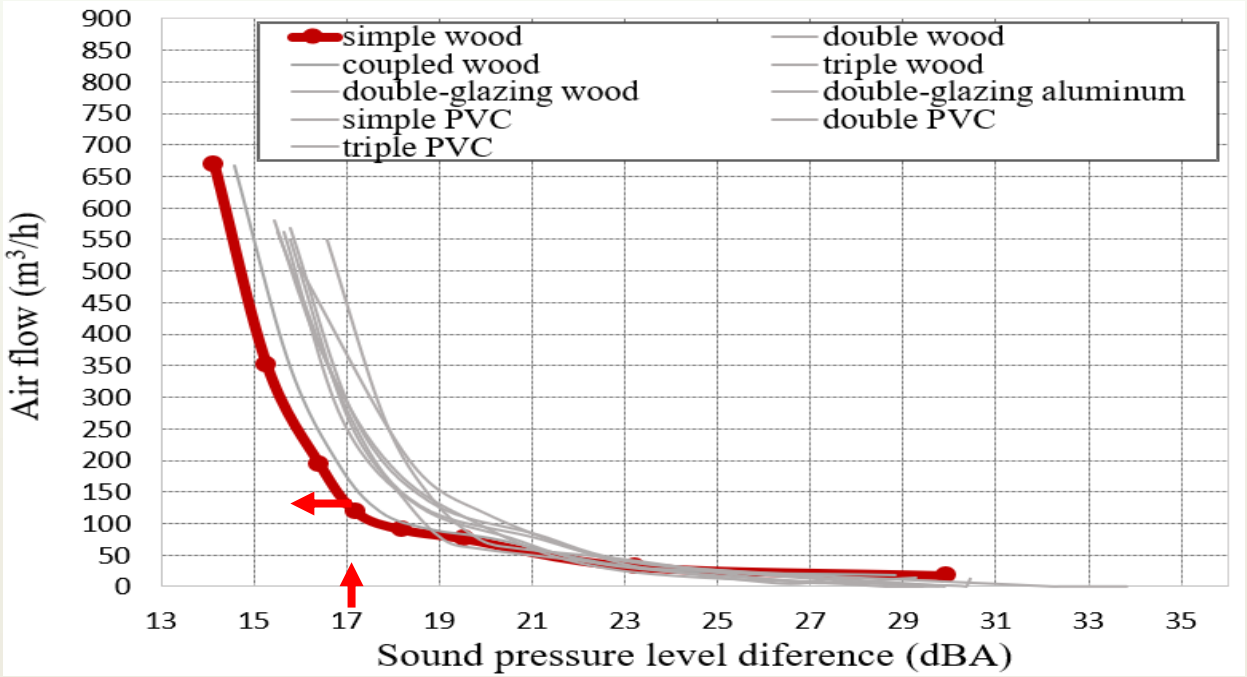
Acoustic measurements



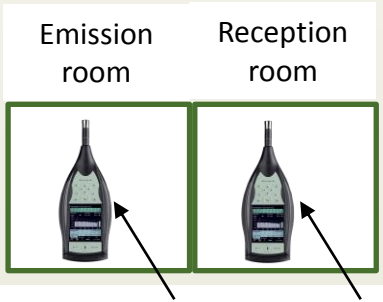
← The relationship between sound reduction coefficient R_w and joint's surface – All types of windows

The analyzed frequency range: between 100 – 5000 Hz

Correlation between air and sound phenomena



We have treated more than **1 million values** to obtain the correlation between air flow and acoustic pressure level for all the 72 scenarios



$$\Delta LA = LP_{emission} - LP_{reception}$$

Numerical simulation study

Calibration

a) $R_{windows}$ ——————> *according to EN 717*

b) $\alpha_{emission}$ ——————> *to match* $RT^{experiment}_{emission\ room}$

c) *Sound sources –> to match* $SPL^{experiment}_{emission\ room}$

d) $\alpha_{reception}$ ——————> *to match* $RT^{experiment}_{reception\ room}$

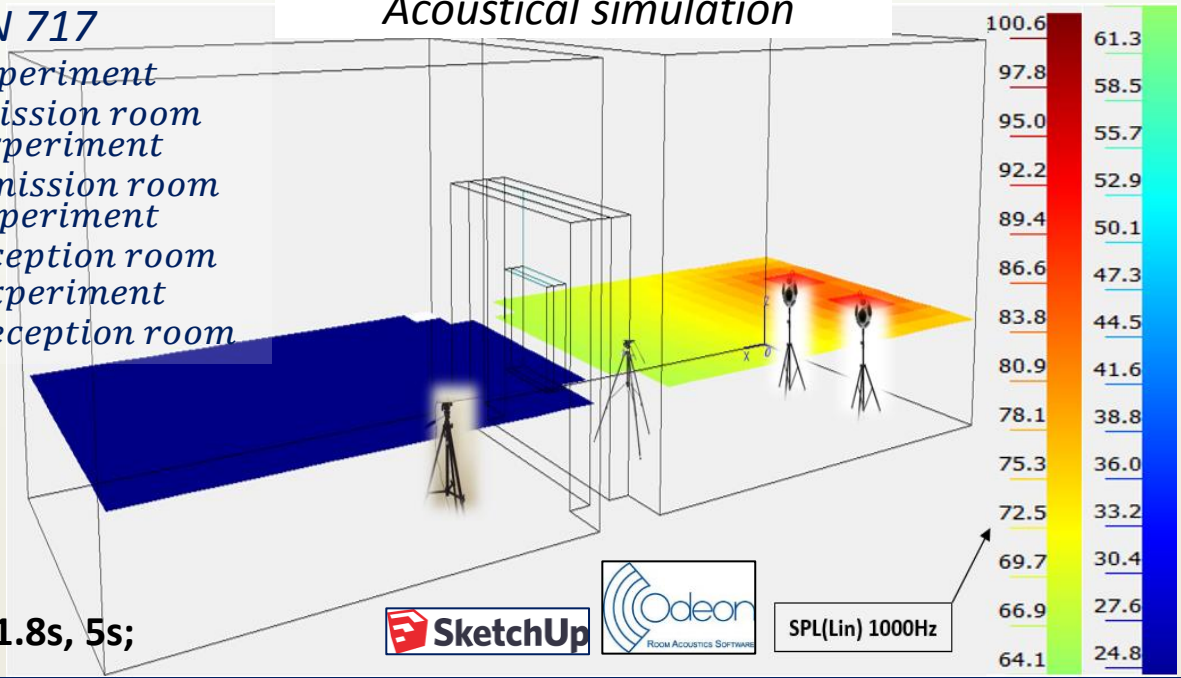
e) R_{walls} ——————> *to match* $SPL^{experiment}_{reception\ room}$

Necessity of lower reverberation times (<2sec)

Experimental RT = 5s

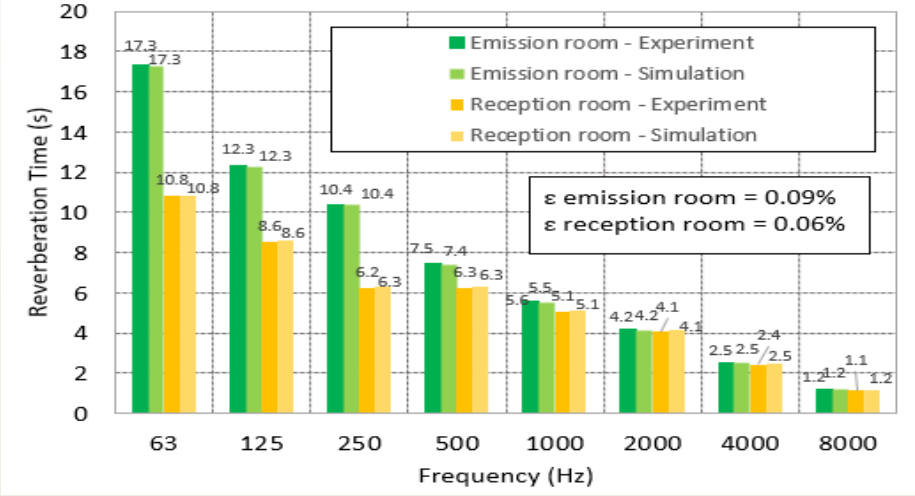
Different reverberation time: 0.6s, 1.2s, 1.8s, 5s;

Acoustical simulation



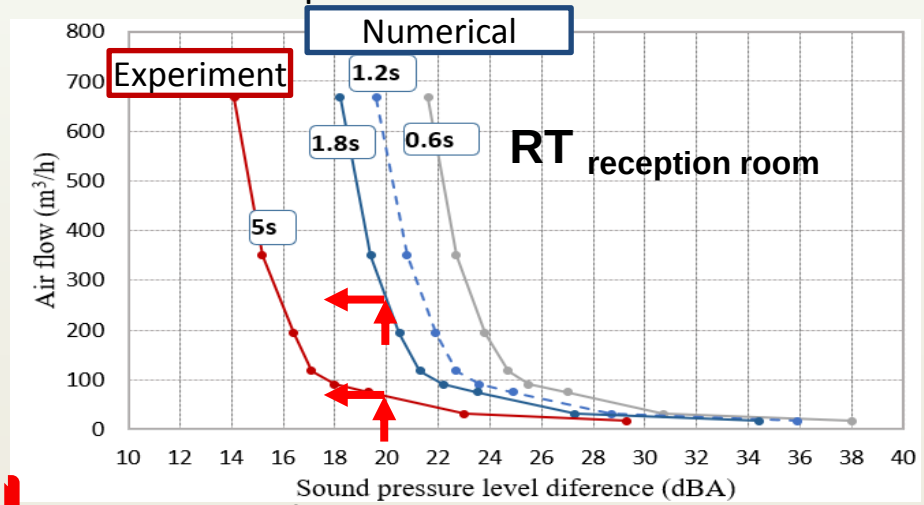
Numerical simulation software

Example for **simple wood pane window**



The **calibration** of the model was **successfully** done presenting **errors less than 1%.**

The graphic shows the impact of the reverberation time to the sound pressure level difference.

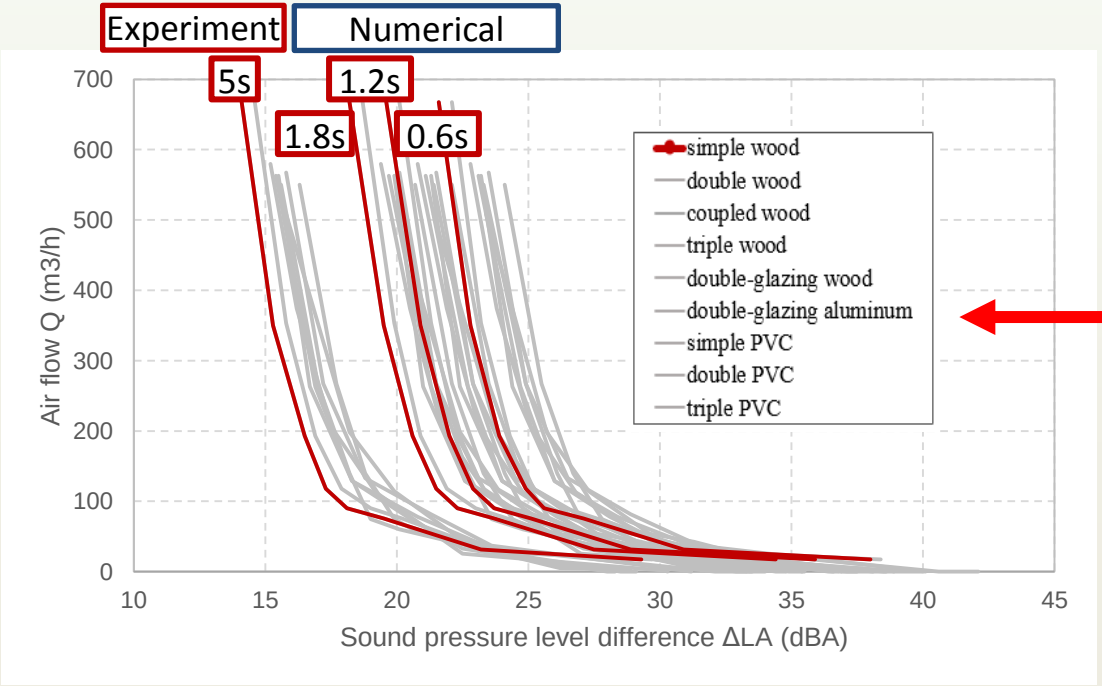


Example for **simple wood pane window**

Calibration

Simulation

Final results



144 experimental cases

Total equipment value (acoustic and permeability) : **210.000 €**

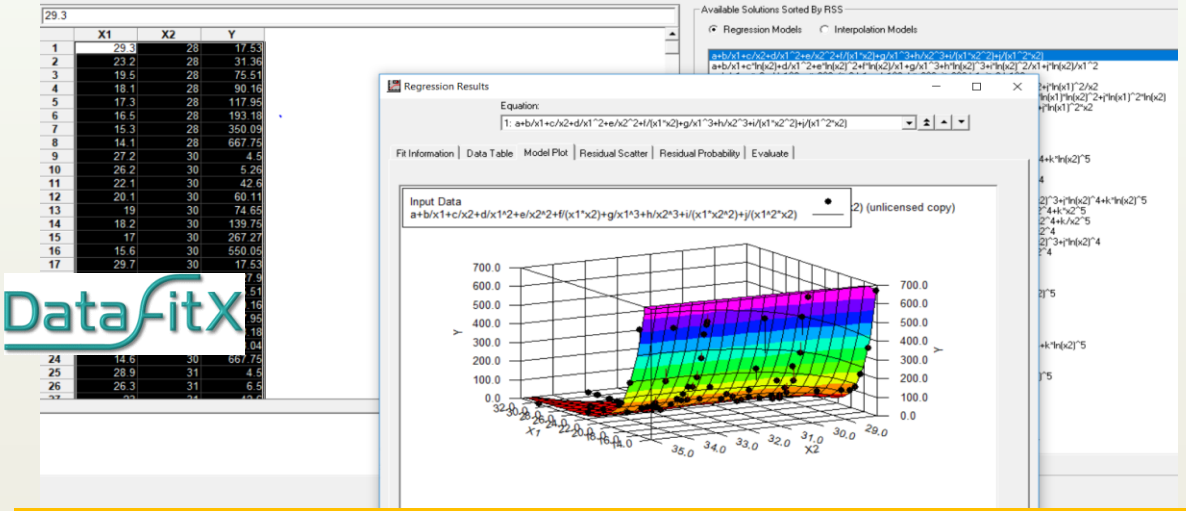
288 simulated cases

36 obtained curves

8 months of work

Nomogram for multiple types of windows and for different reverberation time

Implementation in an easy tool



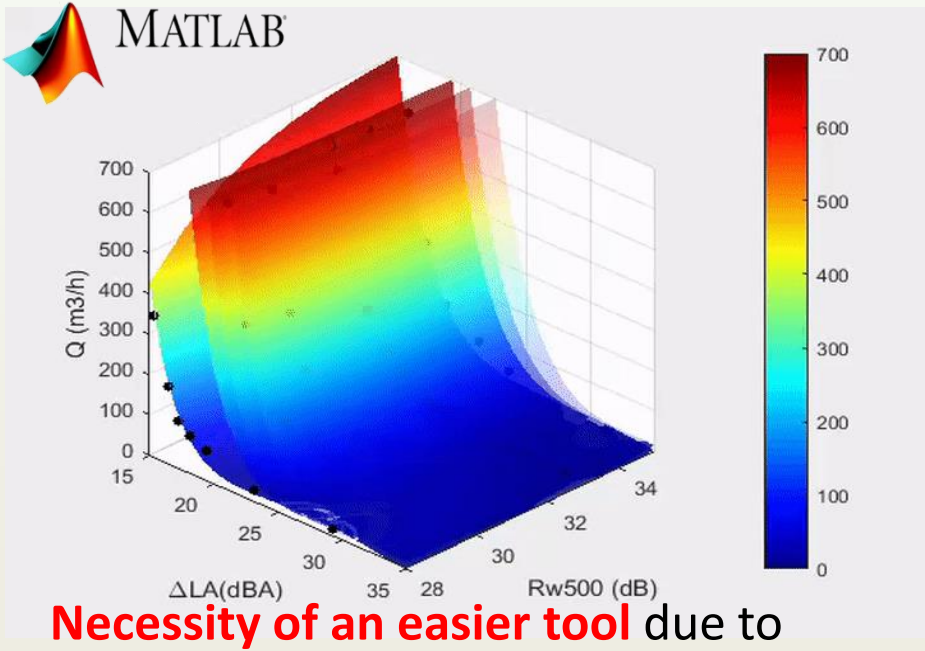
Model example for RT=5 sec

DataFit models for easy calculation of the permeability

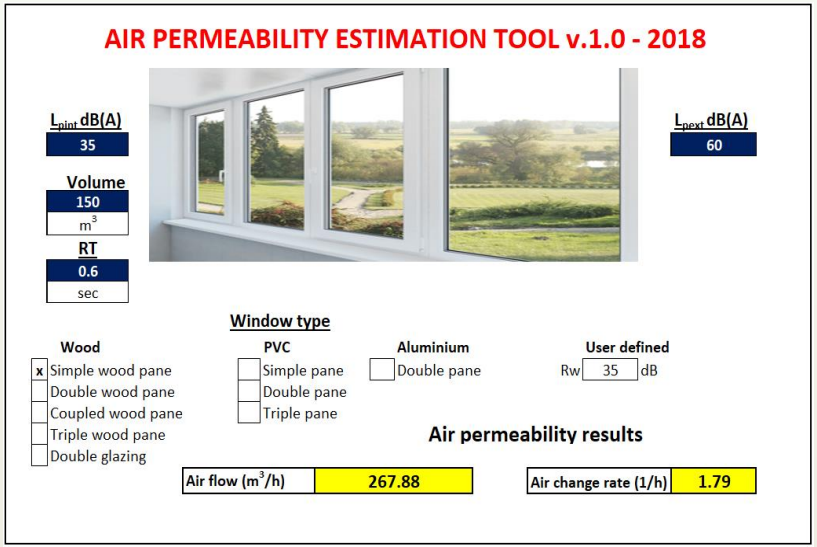
4 models (RT 5 sec.,1.8,1.2 and 0.6 sec) implemented in a software for faster calculation

$$Q=20512-199355/\Delta LA-1690816/R_w-1423230/\Delta LA^2+429999083/R_w^2+16140168/(\Delta LA \cdot R_w)+2425700/\Delta LA^3-36259569/R_w^3-203125570/(\Delta LA \cdot R_w^2)-42489811/(\Delta LA^2 \cdot R_w)$$

Implementation in an easy tool



Necessity of an easier tool due to the reading errors



Inputs : $Lp_{outdoor}$ dB(A) / Lp_{indoor} dB(A) and Type of window/R_w

Output: Air flow in m^3/h

Conclusions

Scientific

- Two full scale experiments

(air and sound measurements)

Valid and accurate results

- Numerical simulations for different RT
- Development of 4 correlation air/sound models

Innovative acoustic method

Building and environment journal

Article under submission

Technical

- Independent on the weather;
- Easy method;
- Light equipment - two sound meters and a noise source;
- Fast solution – less than 1 hour;
- Price of the system approx. 600 €;
- Good precision using a personalized tool.

High importance for: energy certification, commissioning, thermal rehabilitation, real estate.

THANK YOU FOR THE ATTENTION!

REHVA Student Competition 2018 - Brussels 22 April 2018