ACA – New Research and Testing Competence for Timber Constructions with a focus on low frequencies in Austria

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Summary

A new research project in building acoustics has been started in Austria in 2014. The overall goal of ACA is to establish the required infrastructure and concentrate the competence of three institutions (HFA, TGM, TU Vienna) with different approaches to building acoustics. This cooperative project will lead to acoustic test facilities for lightweight components where attention is drawn to the research topics "low frequencies" and "subjective perception". Therefore, installation of two transmission suites is intended, taking into account experience of several leading European laboratories, current research results and ongoing worldwide discussion process on this topic. To get an idea about the optimal dimensions of the transmission suites to fulfill the conditions for reproducible building acoustic measurements in the extended frequency range below 100 Hz, a parametric study was carried out. The indicators of diffusivity of the sound field like eigenmode density, distribution and shapes where calculated by an FEM Model. The Model was validated by a comparison of the calculated and measured sound pressure field in the source- and receiving room of the test facility at TGM during a sound transmission loss measurement. This paper shows the comprehensive considerations which led to the design of two transmission suites for lightweight building components and describes the scientific approach within numerous opposing poles that have to be respected in the planning process.

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1. Introduction

Timber frame and solid timber construction methods, commonly used for single family houses, have been established as standard construction modes for multi-storey buildings and terraced houses as well. To give consideration to the particular sound insulation issues of timber and light-weight constructions, a new research project in building acoustics has been launched in Austria in 2014 with the overall goal to establish infrastructure and concentrate expertise of HFA, TGM and TU Vienna, each of them representing a different approach to building acoustics. This cooperative research project will lead to the construction of a laboratory for building acoustics with focus on lightweight building components where the research topics "low frequencies" and "subjective perception" are investigated in particular.

2. Methodology

Besides research the prospective laboratory will be used for research carrying out certified measurements of sound insulation of building components as well, facilities have to comply with respective standards. Therefore, all relevant normative documents, in particular EN ISO 10140 and EN ISO 10848 series, have been analysed in order to ensure accordance of the transmission suites with current standards.

Since a lot of expertise already exists on this topic, a journey to different leading acoustic laboratories in Austria and Europe was organized to increase knowledge, learn from different approaches and, last but not least, avoid mistakes which have been committed already. Collected information was processed and analysed by assigning visited test facilities to types of laboratories with certain properties and identification of assets and drawbacks.

2.1 Preliminary investigation: sound field diffusivity - methodology

Aware of the fact that not only size, but proportions of test boxes influence the uniformity and density of the eigenmode distribution, which is crucial for location independent sound pressure measurements and for low frequency results reproducibility, an investigation of variations and combinations of test chamber geometries was carried out. As software environment for this research the finite element method tool "COMSOL-Multiphysics" with the acoustic-solid interaction interface was used. This interface combines the calculation possibilities of the pressure acoustic module and the structural mechanics module and couples the acoustic sound pressure variations on the border of the structure to the elastic deformations of the solid domain.

2.2 Preliminary investigation: coupling loss factor – methodology

According to EN ISO 10140-5 [1], a minimum loss factor η_{min} for heavy test elements is required. To determine the coupling loss factor of the prospective test facilities, different coupling methods in combination with sealing systems were developed. Since all other terms of the respective calculation of EN 12354-1 [2] are known, velocity level differences have to be measured to specify the coupling loss factor of the junction between test element and transmission suite. An experimental setup is built and measurements according EN ISO 10848-1 [3] are carried out.

3. Contradictory specifications in standards, research and practise

Different, recently revised standards give guidance on requirements of acoustic test facilities and sound insulation measurements. Looking closely, it appears that some of these requirements are contradictory, in particular when it comes to the preconditions for accurate measurements at low frequencies. On one hand, a minimum room volume for transmission suites of 50 m^3 with a difference of 10 % (55 m^2) is recommended in [1] with appropriate dimensions between 50 to 60 m^3. The reason can be found in the request for a full test opening to avoid niches [1]. On the other hand, Annex A of EN ISO 10140-4 [4] states that the sound field in these test rooms is not diffuse for low frequency bands below 400 Hz and the general requirement of the room dimensions to be at least one wavelength cannot be fulfilled. To comply with requirements for better low frequency measurement reproducibility, a significant increase of room dimensions is necessary.

Large rooms lead to large test openings in order to achieve the full opening request of [1], since proportions between surfaces have to be chosen in a way, that eigenmodes of low frequencies appear numerously and uniformly. However, the sound reduction index depends on size of the test object and room conditions as well.

Downsizing of the test opening inevitably leads to niches. Their impact on measurement results of the sound reduction index is directly related to niche dimensions and element position as pointed out by Hopkins in [5] and demonstrated by Dijckmans in [6]. Oblique angled rooms with the objective to reduce size of the test object are not advantageous either und should be avoided [7] as well.

A further aspect to be considered is the manageability during the test procedure in the laboratory. Larger test objects lead to higher costs for delivery, storage, assembly and handling equipment and for the testing process in general.

4. Analysis of existing laboratories for building acoustics

Since a lot of expertise on sound insulation measurements already exists, a journey to different leading building acoustic laboratories in Austria and Europe was carried out. Aim was to increase knowledge and learn from different approaches in order to avoid mistakes. Table 1 shows as a result a typology of laboratories that was also used as a starting point for further analyses on assets and disadvantages. Each one of the different types of transmission suites has its benefits and drawbacks. Transmission suites of type 1 are limited in size of test objects and mounting of prefabricated components, but the time consuming installation procedure seems to be the best method to ensure the required minimal loss factor. Modern transmission suites (type 3) usually have the opportunity to deal with prefabricated test elements, since they are installed in spacious laboratories where delivery of large objects and handling within the building has been considered during design process. The given selection of laboratories shows that approach to design of transmission suites can be very different. Although there is no right or wrong, per se the decisions made, result in certain characteristics, which usually cannot be changed later on.

Two important properties seem to be crucial because they are not fulfilled in every transmission suite. On one hand, the minimal loss factor according to EN ISO 10140-5 seems to be hard to achieve, although it is of importance for heavy test objects [1]. On the other hand, niches can be found in several facilities though their impact has already been studied comprehensively e.g. in [5, 6 and 7], and it is agreed within the scientific community that they should be avoided. In general it can be concluded that all analysed examples show the complexity of design of transmission suites with the intention to fulfil all respective requirements.

5. Preliminary investigations

5.1 Sound field diffusivity

The diffusivity of the sound field in the test chambers is highly related to the existing eigenmode density in the investigated frequency band. Since the eigenmode density is rapidly decreasing with the increasing wave length at low frequencies, properly designed room geometries are highly recommended. In a functional test facility infrastructure, the maximum size of the test boxes, and the overall economic design of the facility of the model, was used to investigate the eigenmode density of different geometries and combinations of dimensions of the test chambers at the low frequency range. The following parameters were modified in the variation, with each possible combination of parameters examined.

Table I. Typology and properties of transmission suites.

Typology[1]	*Arrangement*	*Akkreditation*	*Loss factor*	*Volume* m^3	*Opening* m^2	*Combination wall/floor*	*Prefab objects*	*Flexibility*	*Niche*
wall transmission suite									
1	part of structure	yes/no	fix connection	standard+	approx 10	yes/no	no	low	yes/no
2	detached mobile	yes	sealing	standard	approx 10	separate	yes/no	low	yes/no
3	cluster and mobile	yes	sealing and gypsum	standard and up to 100	10 and more	separate	yes	test frame crane	yes/no
floor transmission suite									
1	part of structure	yes/no	elastomer, bear on	standard+	10+	yes/no	no	low, internal crane	yes/no
2*	seperate building	yes	air spring	standard	approx 10	separate	yes	forklift	large and damped
3	cluster and mobile	yes	bear on with load, elastomere	standard+	10-20	separate and mobile box	yes	tub and crane	yes/no

[1] Typology: 1 - Transmission suites are integral part of building structure. 2 - Transmission suites built in existing buildings with constricted room or limited growing opportunities. 2* - Transmission suites are a separate building. 3 - Transmission suites built in exclusively designed buildings. Yes/no – some laboratories yes, some of them no

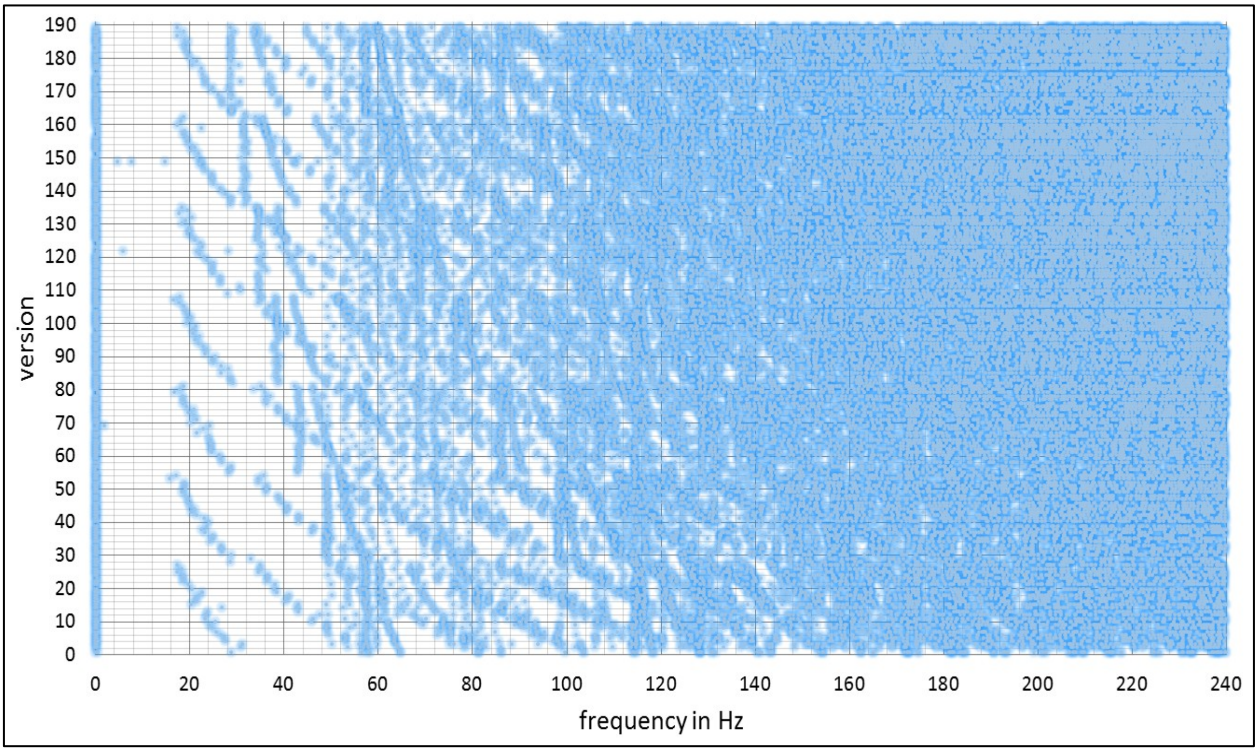

Figure 1. Illustration of the eigenmode distribution of all investigated variations of test box geometries as point cloud. One version constitutes one line in x-direction in which one point represents one eigenfrequency.

- Length: 6-10 m in steps of 0.5 m
- Width: 3-6m in steps of 0.5 m
- Height: 3-3.5m in steps of 0.25 m

Figure 1 shows all eigenmodes in the frequency spectrum 0-240 Hz of all analysed geometry variations in the parametric study. Due to the combination of all possible variations of lengths and widths of the test boxes, groups of variations with the same room height are pictured in Figure 2. As expected, the tightest eigenmode distribution over the low frequency spectrum below 100 Hz in one geometry group with the same height is observed for the geometry with the widest and longest dimensions. This group of variants shows that there are combinations of room dimensions with smaller size and volumes but nevertheless superior eigenmode density in the low frequency bands caused by more advantageously distributed diagonal spatial modes. Considering eigenmode distribution and boundary conditions from ACA research project, ideal dimensions of the projected transmission suites were identified.

5.2 Coupling loss factor

For the identification of the required minimum loss factor mentioned in [1], a test setup with two concrete plates with different coupling methods and materials is foreseen. By means of measurement of the respective coupling loss factors, minimum loss factors can be calculated with equation 1 according to annex C of [2], since remaining parameters are already well known.

$$\eta_{tot} = \eta_{int} + \frac{2 \cdot \rho_0 \cdot c_0 \cdot \sigma}{2 \cdot \pi \cdot f \cdot m'} + \frac{c_0}{\pi^2 \cdot S \cdot \sqrt{f \cdot f_c}} \cdot \sum_{k=1}^{4} l_k \cdot \alpha_k \quad (1)$$

η_{tot} total loss factor; f 1/3rd octave band frequency; η_{int} internal loss factor; m' mass per unit area; σ radiation efficiency; f_c critical frequency; S area; α_k absorption coefficient for bending waves on the edge; l_k length of the edge; c_0 phase velocity of sound in air, c_0 = 340 m/s; ρ_0 density of air

Due to the fact that coupling methods have a significant impact on manipulation of test elements and transmission suites, practicability is an important parameter when it comes to selection of materials and methods for analysis. The aim of this preliminary investigation is to define crucial properties of projected transmission suites as accurate as possible in order to avoid unexpected findings after the building phase has been completed.

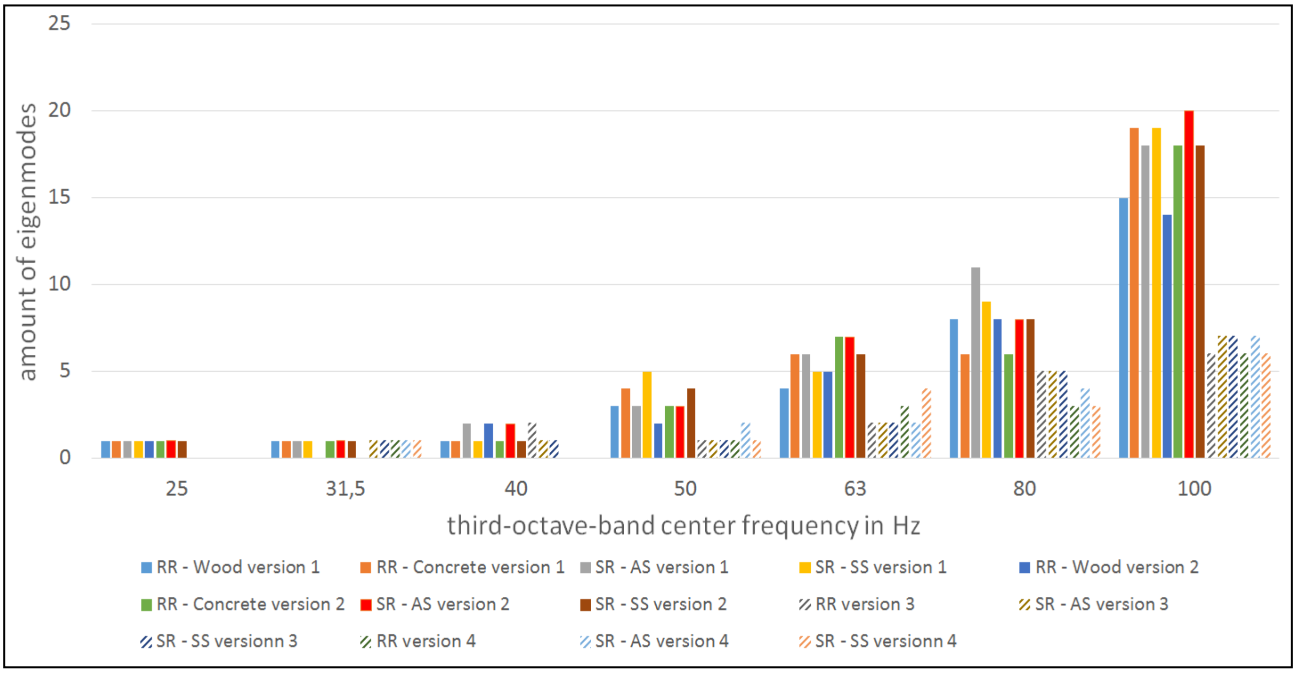

Figure 2. Amount of eigenmodes of final variations of test boxes in third-octave bands from 25 to 100 Hz.

6. Conclusions

Design of transmission suites from the scratch requires a comprehensive strategy, particularly considering contradictory design recommendations in standards, research and current practise is challenging. Therefore, analysis and comparison of existing laboratories was the first step which led to fundamental decisions in the design process. The result of these comprehensive considerations was the intention to build two transmission suites with different sizes: a standard sized one for testing and a bigger one for research, taking into account repeatability of sound measurement results with the implication of the need of a downscaling model.

Several preliminary investigations, like sound field diffusivity in test boxes and transmission loss factor, have been carried out in order to have the capability to predict behaviour of transmission suites in a comprehensive way and to avoid unexpected findings during calibration of the test facilities.

Acknowledgement

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