ACOUSTICS IN TALL WOOD BUILDINGS, RECENT RESEARCH AND FUTURE CHALLENGES

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1 INTRODUCTION

Today, state of the art regarding sound insulation of tall wood residential buildings is internationally still based on national building regulations normally not including frequencies below 100 Hz. Results from state of the art studies [1,2], recent research projects such as "AkuLite" ("Acoustics, vibration and springiness in lightweight constructions", Swedish research project finished 2013-05-31) and "AcuWood" (WWN project, "Acoustics in Wooden buildings", finished 2013-10-31) are straight forward, frequencies far below 100 Hz have to be included at least for multi storey residential houses with lightweight structural systems. Therefore, almost all current basis material has limited use in order to further develop and design wooden multifamily residential buildings that perform competitive structural systems. Excluding low frequencies in the evaluation and design imply that new solutions developed by the industrial initiatives and SME´s are optimized completely wrong, which of course will become a weakness when these systems are compared to traditional "heavy" structures. If the development of acoustically competitive light weight structures with good low frequency performance does not start within short, the shortcomings of these structural systems will be further emphasized, especially since new regulations in future are expected to actually include low frequencies [3]. To further develop new criteria for light structures one more Swedish project recently started (2014) – "New improved building technique-neutral criteria for sound insulation evaluation". This work will give further input to previous projects, "AkuLite" and "AcuWood".

It still remains at least yet another challenge for the wooden buildings and their structural components, namely the ability to predict their acoustic performance in the final buildings and their sensitivity in the production phase, on site. For concrete structures, standardized prediction models are available, but it is not the case for wooden structures. In a new WWN+ project, "Silent Timber Build", which has an aim that is closely linked to the intentions from the European workshop held in Stockholm 2011 [4], calculation models will be developed. They will be developed in order to cover a frequency range that is needed to calculate objective values corresponding to subjective experience. In the projects results from recently finished projects "AkuLite" and "AcuWood" will be used and the outcome from the COST actions TU 0901[3] and FP 0702, and finally additional new data from the Swedish new project and other potential ongoing projects. Hence, by using basis from several projects new calculation tools for lightweight (e.g. wooden) structures will be developed.

2 OUTLINE

Due to lack of satisfactory prediction models for various wooden constructions it is not possible to calculate the final acoustical results satisfactory. Instead, each new tall wood project is a new experience and a completely new challenge. In order to promote future development "Silent Timber Build" concentrates on development of prediction tools (see objectives), which is a natural and necessary transition from ongoing and recently finished research projects.

The work is carried out by several European countries (Sweden, Norway, France, Austria, Germany, Switzerland, Finland and Spain) in order to cover a wide range of typical European constructions. It is done by close interaction between all partners (research and industry), and developed in order to adapt to new findings regarding criteria. The aim is also to provide ISO and CEN standardization with new knowledge for wooden structures to further develop current ISO/CEN standards [5]. These standards can then be used as basis for commercial software development, available for consultants throughout Europe. Today commercial reliable software is primarily available for heavy structures. Hence the ambition amongst the project members is to participate in international research and standardization in order to achieve rapid implementation of new knowledge and coordinate activities in Europe but also globally, see figure 1.

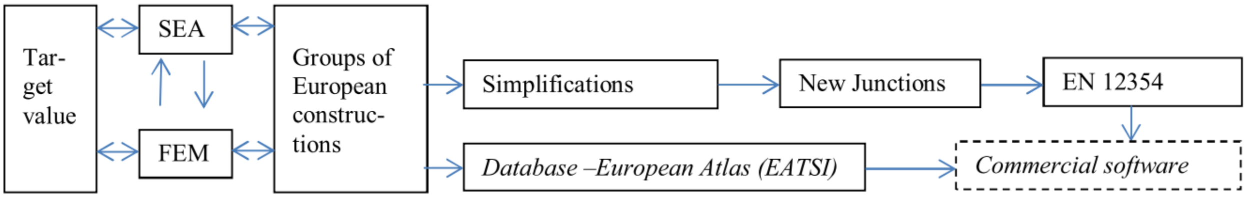


Figure 1. Work “flow chart” for Silent Timber Build

The project includes an analysis of the new proposed sound insulation criteria from “AkuLite” and “AcuWood” [6,7], and also common proposals from the COST actions TU 0901 and FP 0702 [4]. It includes development of calculation models considering both analytical and statistical methods (primarily FEM and SEA), and an idea on how to use different methods and their mutual interaction in order to cover the full frequency range needed for wooden structures. SEA will be used in medium and high frequencies and then also, in order to optimize the FEM model for lower frequencies. Input from earlier work, for example within COST FP 0702 will be further analyzed and developed. Extending the prediction models to include lower frequencies according to recent findings imply that prevailing statistical methods are not always applicable due to long wavelengths (low modal density) in low frequencies.

The first steps regarding new calculation tools for wooden systems have already been introduced in the project “AkuLite”, and in the COST action FP 0702. New FEM models for volume elements show good agreement with the final performance, however still for limited frequency range [10]. Furthermore new foot step models for impact sound is developed within “AkuLite”, ready to use in new prediction models (however not yet published). This implies that “Silent Timber Build” is a very natural transition from what has started, i.e. applying the FEM modelling on other wooden structural systems, adding statistical methods (SEA) to further refine the models and cover the entire frequency range. One main challenge will be to group various structural systems and also to include the wide frequency from 20-5000 Hz and to find the link between different theoretical approaches, i.e. to connect different models to cover all frequencies in the final calculation tool for a wide range of structural systems. Another challenge is to provide correct material characteristics in the models.

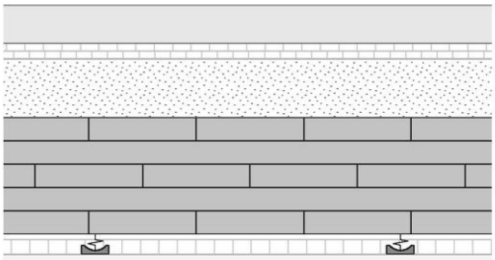
2.1 Wooden structures

Wooden structures are for more complex than concrete structures, making acoustic predictions far more complicated. The number of building materials included in the structural assemblies is normally much higher than for concrete structures and the physical behavior of the material characteristics is not fully known. Starting with basic element, the first challenge appears. Even if elements are homogeneous various elements made of wood have different characteristics in different directions. Their buildups are also different, typical elements are CLT elements or “Brettstapel”, however both with different characteristics in different directions in spite of similar thickness and mass, see figure 2.

Figure 2. A huge amount of various elements complicate the development of stringent models

However, apart from these basic structural elements, it also exist a number of other options, beams (I-joists, square wooden beams) built up in many different ways, hollow core elements (Lignatur), T-elements etc.

Then, to reach the normal target values in dwellings these elements need to be supplied with additional materials. Typical is to add layers both above and below. These additional layers are not always very well specified in terms of their acoustic behavior. Gravel is also used in order to add mass to the system, however very difficult to describe acoustically due to their grain size etc., and then the gravel fill is covered with different material and probably a layer of screed on top, figure 3.



- Screed
- Board
- Gravel
- CLT
- Springs/min.woll
- Gypsum

Figure 3. A common type of floor layout in Europe

Additionally, all systems have different junctions which further complicate the modelling. Hence, it is certainly a challenge to develop prediction models for tall wood buildings, due to the huge amount of various structural assemblies, possible junctions, material characteristics for the materials comprised in the structural assembly etc. Additionally, to make sure that the production process fit to the predicted prerequisites is yet another challenge. Hence there is not only one challenge (e.g. develop models) but also to make sure that the reality corresponds to the theory.

3 SCIENTIFIC CONTENT

In order to move forward and make progress, Silent timber Build project includes several scientific tasks and it is divided into four technical work packages (WP) for efficient handling. Project management and coordination is handled as a separate activity (WP5), since the interdisciplinary structure, the extensive data handling and the international approach of the project requires very special focus. Each work package involves participants with essential knowledge for the specific task and the work packages will not only be handled in a consecutive way. Interdependencies and even iterative loops over the tasks and also between the WP:s are needed and planned. The effort in the different work packages must be well integrated to reach the project final goals. Gender, equal opportunity and diversity and intersectionality aspects will be included in the project. This could for example mean that differences in subjective response found in earlier projects will be analyzed and calculation tools and construction solutions will be adapted to different target groups, for example, students, elderly or families with children. To fully understand different needs close cooperation with the earlier mentioned projects will be needed.

3.1 Technical content

The following work packages are included:

WP1: Prediction tools, low, medium and high frequencies

WP 1 – Prediction tools for low, medium and high frequencies Initial work to state European target values from findings in ongoing and recently finished projects, "state of the art". From existing knowledge develop new prediction models using FEM, SEA and other approaches if necessary and to connect these methods depending on frequency range

WP2: Validation of prediction tools and constructions

WP 2 – Validation of prediction tools and constructions This work package will validate the theoretical models developed in WP 1 by using already available and also new measurements from laboratory and field. Analysis will be made and optimized constructions will be used in validation procedure

WP3: European Timber Sound Insulation Atlas

WP 3 – European Timber Sound Insulation Atlas Pioneer work made by Lignum will be used in order to apply the theories directly in an application for end users. Hence input from WP 1 and WP 2 will be applied in a web based interface for calculation of wooden structural systems

WP4: Dissemination and Exploitation

A project website is available in order to disseminate results in an efficient way, visit it at www.silent-timber-build.com.

WP5: Coordination – managed by SP Wood Technology in Sweden.

4 EXPECTED RESULTS AND FUTURE IMPACT

The economic and ecologic advantages as well as the high residential quality of wooden buildings are well known and widely accepted today. The wooden industry has made tremendous progress in prefabrication processes, reducing material waste to a minimum and improving work conditions. This industrial approach creates basis for future improvements and cost efficiency and is very positive for the building industry in general. Many of the challenges in buildings physics have been solved or at least are "under control", moisture, fire, heat insulation etc. Additionally, increased knowledge regarding the acoustic behaviour of wooden buildings and how the residents experience the sound insulation is gaining the future development. Today it is well known which target values we should aim for. Manufacturers are more and more aware of what they have to achieve and which focus they should have. Nevertheless the lack of knowledge regarding prediction methods for "safe" design procedure is still very unsatisfactory. Now, "Silent Timber Build" will provide basic models in order to give wooden structures systems equal prerequisites as any other system. Possibility to predict and calculate different options in the design stage is the only way to be able to compete with other building techniques. New theoretical models including low frequencies outside the 'normal' frequency range have to be developed for a number of wooden building systems.

The project approach is new and innovative due its interdisciplinary methodology by using new approaches in building acoustics (combining analytical and statistical methods). This integral approach implies that we will aim at the following project results:

- establishing basis for development of standardized engineering calculation methods applicable to lightweight structures
- increased knowledge about calculation methods for multi storey wooden buildings
- increased knowledge about building systems that can be predicted in terms of sound insulation considering future requirements
- possibilities for future optimization of building systems by using prediction tools in the design stage in order to lower the costs and strengthen the competitiveness of the wooden building sector

The expected long term impact from the project is:

- increased knowledge of sound and vibrations in the lightweight building industry, which is necessary for beneficial development of new acoustic solutions for the industry and innovative guidelines in the design stage
- further improve the “sustainability” arguments for the wooden sector. Wooden constructions are fully “sustainable” when sound and vibration properties can be predicted according to modern design criteria, and then as the final results in a building also correspond to the predicted values.

The scientific work and its results will be actively disseminated in order to guarantee a maximum exploitation by broadcasting the results on an open website. The importance of dissemination is emphasized since the project has established one work package (WP4) to secure a structured dissemination. Direct knowledge transfer to the industry are secured by the industrial project partners, and not least from the active contribution that Lignum in Switzerland provides, by setting up a European construction data base comprising wooden construction solutions.

4.1 Industrial, societal and environmental relevance

The economic and ecologic advantages as well as the high residential quality in general of wooden buildings are well known and widely accepted. A number of the challenges in buildings physics have been solved (even if they can still be improved) and the possibilities for high degree of pre-fabrication in the wooden industry are enabling competitive costs and a successful development of the building industry in general. However, in order to optimize the construction assemblies to reduce costs prediction is needed in a ‘full’ frequency range adapted to future requirements in different buildings. This is of growing importance for existing and potential users. One of the main technical aspects that habitants are willing to pay for is “acoustic privacy” in their future home, and hence this has to be secured. These conclusions can be stated worldwide and numerous manufacturers and researchers in Europe, and also other countries are working on technical solutions.

4.2 Environmental and energy impact

Timber based lightweight constructions are seen as good for the environment due to a relatively low life cycle emission of carbon dioxide. The high degree of prefabrication also reduces the waste of material. The wooden constructions are also well suited to give good thermal insulation properties as they generally are designed with timber beams and various types of boards, where the cavities are filled with thermally insulating material. Lightweight façade walls are very effective in order to both fulfil high thermal insulation and high sound insulation, while the floor constructions and the junctions are often ‘critical’ in terms of sound insulation. With these issues solved, wooden constructions can develop further and contribute to major improvement of the overall impact on the environment, caused by the building sector.

4.3 Impact on participating research groups

The project will provide a strong group of national researchers in order to strengthen the research regarding sound and vibration in lightweight buildings. It will produce fruitful collaboration with other researchers worldwide. Valuable know-how will be transferred between different continents through this collaboration.

5 SUMMARY

Silent Timber Build started 2014 and it will give strong impact to the wooden industry. It will facilitate a positive development of wood as structural material which is of big importance for sustainable development of the building sector in general.

The project partners have a strong link to the previous mentioned COST actions (FP0702 “Net-Acoustics for Timber based Lightweight Buildings and Elements” and TU0901 “Integrating and Harmonizing Sound Insulation Aspects in Sustainable Urban Housing Constructions”), regarding sound and vibrations in lightweight buildings and in buildings in general. FP0702 is recently finalized and reported and TU 0901[3] was finalized late 2013 / early 2014. In several European countries there are national projects in the subject and in Sweden a large national program, “AkuLite” was finalized during spring 2013. Furthermore, the European project “AcuWood” was finished in September 2013. The strong “Silent Timber Build” consortium will provide apical research results and the industry will gain access to extensive knowledge and together this will ensure a strong European and International development of the wooden industry.

Finally, the most important thing for the industry is that this project will facilitate the development of new competitive constructions by providing prediction tools and more safe design procedures, which is necessary in order to compete with other structural material. The results will be easily spread due to a big consortium with project partners from all over Europe, all in one single project!

6 REFERENCES

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