ACOUSTICS IN WOODEN BUILDINGS – STATE OF THE ART 2008
SUMMERY OF A SWEDISH COOPERATION PROJECT

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ABSTRACT

Acoustics is an important performance characteristic for building with wood and a prerequisite for the acceptance of wooden buildings by building industry, building owners and consumers. However, the research in this area has been limited in Sweden during recent years.

Therefore, a national consortium was initiated by SP Trätek in 2007 in order to utilize available resources more efficiently and to maintain and develop the competence in the field of Acoustics in wooden buildings. The consortium consists of all national R&D performers, leading industry companies within the building, building materials and wood sectors and leading consultants.

The aim is to present the state of the art, define industrial needs for producing wooden buildings with high acoustic performance and to define further research needs to reach that goal.

A state of the art report is the first result from the new Swedish consortium. The report includes a literature survey, analysis and identification of industrial needs for producing wooden buildings with good acoustic comfort and further research needs to reach that goal.

The aim is also to further develop contacts and cooperation with international actors.

1. INTRODUCTION

Building technique using lightweight structures and in particular, wooden structures, is interesting for a country like Sweden. Sweden has a large area covered with forests which constitute a renewable resource for building materials. But it is also interesting on a European and global level, since sustainability in the building sector is a major challenge worldwide.

Sweden has used wooden structures in dwellings for many years. However, since 1994 it is permitted to use wooden structures in multi-storey (> 2 storeys) buildings. The first years after the revision of the building code some buildings were erected as a result of research within some certain projects. During the last ten years a large number of new systems have entered the market, which is a result of persistent work within industrial companies but also a result of governmental commitments to increase the use of wood in multi-storey housing units. This work has increased the knowledge in Sweden regarding the use of wood in building structures, but still there is a lot left to know until the behavior of wooden structures will be predictable and thus, a material that might be as natural as any other building material in high rise buildings. There is a challenge to convince the market that wood is a natural and obvious structural material and to do this, the knowledge has to increase in particular regarding the acoustic and vibration behavior of wooden structures. To benefit synergism, scientific experience might be shared with other countries which have shown a lot interest in wood as a structural building material, for example Canada, USA, Austria, Norway, Finland and New Zealand.

2. STATE OF THE ART – ACOUSTICS IN WOODEN BUILDINGS

For acoustics in wooden buildings, which concerns both sound and vibration, there are some important features that differ from those in heavy constructions, most commonly by concrete. Over the years, the building industry has become more and more aware that multi-storey residential buildings in wood with high acoustic performance, is complicated and connected to large risks since the acoustic behavior might exhibit large variability. By increasing the knowledge on wood, the risks will be reduced for the use of wood in floors and walls, which will aid the decision process.

Generally, wooden houses can be divided into three main types of constructions:

- Wood frame systems, which acoustically can be treated as double wall constructions
- Solid wood systems, which are described acoustically as single walls when a single board is used and as double walls when higher sound insulation is needed
- Hybrid systems, which are made of combinations of various materials and constructions.

Wooden buildings can also be divided with respect to the various sound sources they are exposed for.

2.1. Air-borne sound insulation

The weight (mass per unit area) of a construction is an important parameter for the air-borne sound insulation properties, especially for the lower frequency range (in general 20–200 Hz). This has the implication that many wood constructions have poor sound insulation at the lower frequencies. Solid wood elements may however show better performance than the lighter wood frame elements at lower frequencies. At higher frequencies, solid wood elements may have poor sound insulation, while wood frame elements and double layer elements can show a good sound insulation. However, the so-called double wall resonance may cause an impaired sound insulation of double layer elements at lower frequencies. Also for façade elements the sound insulation is of importance, and may become increasingly so with the current trends of intensified transportation noise and new apartments being built in central urban areas. Concerning prediction of air-borne sound insulation for single elements, there is no general model available that can be applied to the different types of walls of interest with acceptable accuracy.

2.2. Impact noise

Impact sound from people walking is the most common sound insulation problem for lightweight floors, and the most severe at low frequencies. An important difference between the sound of footsteps and other sources of noise is that, even at low frequencies, footsteps produce a high degree of noise disturbance, which enhances the importance of having a good impact sound insulation. The impact noise is measured with the standardized ISO tapping machine. Although the machine provides no genuine simulation of real footsteps, the obtained test results give valuable information on the dynamic behavior of the floor. Also for impact sound insulation, prediction models are lacking. In addition, the evaluation procedure is known to frequently fail when it comes to the correlation between measured impact sound insulation and perceived acoustic quality; people complain on impact noise even though the building has been classified as fulfilling higher sound classes than (Swedish) minimum requirements according to standardized procedure.

2.3. Flanking transmission

Flanking transmission is yet another very important sound transmission path that causes large problems in lightweight constructions. A typical example of flanking transmission is when the vibrations of the floor spread to the load-bearing walls and result in sound radiation from the walls. The sound radiation from the walls may become larger than that from the floor, especially if the floor is made as a double construction. Flanking transmission constitutes an important practical problem for on-site manufactured lightweight constructions. It is essential to solve the problems of flanking transmission in order to handle the impact sound insulation.

2.4. Noise from installations

Noise from installations is in many cases dominated by low frequencies, whereby special consideration is needed for wooden constructions. Installation equipment may excite vibrations more easily in a wooden floor than in a corresponding concrete element. Test methods are needed, both for estimation of structure-borne input power from installations and for dimensioning of vibration isolation on weaker foundations such as wooden floors.

2.5. Vibrations and springiness

Low-frequency vibration and springiness can be of importance to consider especially for floors of large dimensions. In order to avoid an impaired acoustic quality, it is valuable to know where the lowest resonance frequencies appear.

3. NEEDS FOR RESEARCH AND DEVELOPMENT

By the end of the state of the art report [1], the suggested further work topics are tabulated including the character of the problems involved, from where it can be concluded that there are large similarities between the research and development needs for lightweight buildings in general and wooden buildings in specific.

For the industry, it is important to have improved knowledge concerning current requirements and their shortcomings with regard to light weight structures, as well as easily accessible data on the acoustic properties of building materials that can be used in the early stage of the building project. It is crucial to have reliable prediction tools in the early stage of a building project, in order to avoid severe and costly future changes. There is also a need for an improved quality of foundations. In addition, it is necessary to extend the acoustics knowledge within the different groups involved in the wood building projects as well as to have properly educated acoustic consultants. Moreover, the very low number of acoustic research groups that today deal with building acoustics accentuates the necessity to ensure that the universities can educate the engineers called for by the industry.

Prediction models are important tools for the design of new constructions and building projects. Today, there exist theoretically simplified models, which however are best suited to concrete structures, or similar heavy and homogeneous constructions. This concerns mainly the European prediction standard EN 12354, in which the flanking transmission is modeled, and the total resulting air-borne and impact sound insulation is calculated. Since the prediction models are less applicable to lightweight constructions, this is believed to constitute a severe drawback for building in wood. Still, the industry often use the costly process of using test-buildings even though the obtained measurement results might become less useful when the building constructions changes to fit the needs in real projects. Hence, there is a need to develop a prediction tool for the flanking transmission. In addition, a reliable model for calculating the direct transmission is needed to produce correct input for an engineering prediction tool. The prediction is further complicated due to the periodic build-up of the wood framed floors and walls, and due to that the solid wood constructions contain plates that are not isotropic.

4. CONCLUSIONS AND SUGGESTIONS OF FURTHER WORK

Low-frequency sound insulation needs to be studied with respect to the following aspects: to insulate the impact of human steps and children playing (a problem which may be handled directly by product development in industry), to know how much the low-frequency resonances of rooms and building constructions will affect the sound insulation in individual cases (which, as a first step, can be helped by a design guide), to develop a prediction scheme for flanking transmission at low frequencies (a problem which can be dealt with by theoretical research, possibly aided by experimental work), and concerning vibration isolation of building service equipment. In addition, since there is strong indication that the evaluation methods in use today substantially underrates the influence of low-frequency sound, there is a strong research need to improve the knowledge within this area and ultimately improve the evaluation methods.

The development of an engineering prediction tool is suggested to aim at a prediction tool for buildings of volume elements, since the development of a generic prediction tool is limited by the large complexity of wooden buildings in general. The prediction tool for volume elements is then suggested to focus on mid-frequency transmission over the flanks and low-frequency transmission considering the whole building.

A further development of elastic interlayers is needed, which can be use for multi-storey buildings of volume elements. Concerning building service equipment on wooden floors, the development of vibration isolators, test methods and user guidelines are needed due to the higher mobility of wooden floors compared with the rigid floors usually assumed for today's design. Moreover, there is a general need for noise reducing devices. These can be developed in a process of combined theoretical and experimental work where innovation may be an important part of the solution, whereby education and experience play a central role.

The general problem of variability for the acoustic properties of wooden buildings needs to be investigated as well as the large effects of small construction changes. Such investigations can be made using theoretical high-resolution methods and finite element analysis, with additional contribution from using statistical energy analysis concerning the interaction of elements within a larger part of the structure. In addition, controlled experimental tracking of changing variability properties is also of interest, which is possible in the industrial production of flat blocks and volume elements.

5. ACKNOWLEDGEMENT

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6. REFERENCE

[1] *Acoustics in wooden buildings - State of the art 2008,* SP Report 2008:16, ISBN 978-91-85829-31-6, ISSN 0284-5172, Stockholm 2008