Exploring sound solutions

Representing the SP Swedish Research Institute, **Klas Hagberg** is the project leader of AkuLite: the Swedish research group hoping to increase the collective knowledge of how we experience sound in different structures

Firstly, can you explain why lightweight multi-storey family houses are particularly susceptible to vibration disturbances?

They are light and normally less stiff than a concrete structure. If the span increases, the vibration issue becomes more evident, even for daily activities. The supports are 'weaker' and the risk for flanking transmission through mechanical connections is obvious. To avoid flanking transmission the acoustic designer strives for no mechanical connections between different building parts – walls and floors – while the static designer wants to keep everything together. Imagine jumping from a sofa onto a light structure compared to a homogenous concrete – it will be more 'painful' when you hit the concrete! This is due to the high 'impedance' of the concrete compared to a light floor. If not properly designed the light floor becomes weak; it starts to move or vibrate.

How is the 'Sound, vibrations and springiness in lightweight buildings' (AkuLite) project engaging with this issue? What are its core goals?

There is a lack of knowledge about how humans experience vibration in their homes. Current evaluation principles for sound insulation (sound attenuation between flats) are based on old knowledge presupposing that all buildings are made of concrete. I would say that this is due to historical tradition, but also the fact that all acousticians realise technical problems to measure low frequencies with high enough security. Nevertheless, the human ear (and body) experiences low frequency sound and vibrations. AkuLite will result in proper evaluation guidelines that consider a frequency range adapted to 'light' structures. In the future, the measurement technique and prediction models have to be adapted to these new guidelines.

From a personal angle, what drew you to this area of research?

I am particularly fascinated with the challenging aspects of how humans experience sound, particularly low frequency sound, but also the huge complexity of light structures. It is an area that is 'outside' the traditional statistical methods

used in building acoustics. Concrete structures, for instance, are more simple and predictable. The frequencies for disturbances in light structures are normally below the limit of where statistical methods can be used, and this is both very challenging and interesting. For light structures the annoyance is concentrated towards the very low frequencies (below 200 Hz).

In what ways is the project contributing to efforts to increase cooperation between actors in the innovation system – namely, universities, institutes, consultants and industry?

The project comprises almost all Swedish manufacturers of wooden building systems and light steel floor structures, as well as a number of consultant companies and all Swedish universities. The industry uses the project results to develop building systems continuously. Furthermore, cooperation with the parallel European project AcuWood extends the AkuLite network. Internationally, cooperation within European networks, such as the COST Actions, 'TU 0901 – Integrating and Harmonizing Sound Insulation Aspects in Sustainable Urban Housing Constructions' and 'FP 0702 – Net-Acoustics for Timber based Lightweight Buildings and Elements', also increases the cooperation with European universities and research institutes, aiding the dissemination of results from AkuLite.

Can you detail what your present activities involve?

Present activities involve extensive measurements in several buildings to complete the objective measurements in buildings. Questionnaire studies have been completed on the same buildings. There are also ongoing listening tests in the laboratory, where individuals are asked to compare and judge various sounds from different floor structures (solid concrete and wood). The structures have identical measured sound insulation according to Swedish minimum regulations. It is now time to compile the results from the laboratory tests, field studies and earlier vibration surveys in laboratory, in order to find the most proper evaluation criteria.

Have you encountered any unusual or particularly striking findings thus far?

So far it is very clear that a it is important to focus on vibrations and low frequency walking sound in very low frequencies when designing floor structures in light material. In questionnaire studies and laboratory tests the results are similar. However, the more striking findings will follow during 2012. At present, we are analysing a lot of data and the final report will conclude this analysis. We hope to have a clear view of future ratings of sound insulation and vibration that is applicable for light constructions. It is worth mentioning that the methods developed within AkuLite are now implemented throughout Europe, mainly through the parallel project AcuWood and the aforementioned COST actions.

How and by whom do you anticipate AkuLite's findings to be used?

The findings will be very useful for the industry in developing buildings and building systems that are more aligned with correct evaluation criteria. They will help to further develop the 'light' building industry and equalise wood and light steel with concrete, as very competitive structural materials, for instance in high-rise residential buildings. Furthermore, the findings are useful for authorities throughout Europe in terms of harmonising regulations and therefore promoting increased trade within the building industry in the future.

Sounding out the future

Sweden has witnessed a remarkable surge in the building of lightweight family houses, and this has led to the reassessment of the measurement of sound, vibrations and springiness. **AkuLite** aims to support the growing forest and construction industries through the refinement of sound and vibration criteria

THE VAST EXPANSE of forestland in the Nordic region is renowned for its outstanding natural beauty. However, these forests are also increasingly considered a valuable resource for the construction industry. Sweden in particular has seen a rapid increase in multi-storey lightweight houses in recent years, due in part to the 1994 removal of the legislative demand on non-combustible materials and the introduction of the national strategy, 'Mer trä i byggandet' (greater use of wood in the building sector).

A SURGE IN POPULARITY

Made with timber frames, this lightweight type of construction is more ecologically friendly than the heavyweight-build, concrete family houses that have dominated the European construction industry over the past century. The possible lower costs of lightweight builds is another appealing factor in their increasing popularity, along with the recognised sustainability of utilising renewable materials. Klas Hagberg, leader of the Swedish project, 'Sound, vibrations and springiness in lightweight buildings' (Akulite), is keenly aware of this: "It is the fast and successful industrial building technology within this area that makes it successful, not only in Sweden, but also in our neighbouring countries".

However, the rapid growth of the lightweight build industry has its challenges. The economic viability of any build lies in the speed with which it can be built. At present, special design attention and knowledge is needed to ensure that the requirements for a comfortable sound and living experience are met. Yet as the building of lightweight houses becomes ever more widespread, it is increasingly urgent to provide the industry with the right knowledge.

Since 2009, AkuLite has been investigating the regulated measurement of sound and vibrations in close comparison with the human experience of acoustics in lightweight houses. Noise and vibrational disturbances are a potential problem in these houses – even when the building code requirements have been fulfilled. It is clear that the system of sound and vibrational measurement needs work to be fair to all building types. Publicly funded by Vinnova and Formas (and also funded by a collected industry), the aim of AkuLite is to eliminate the present disadvantages with regard to acoustic evaluation of lightweight multi-storey houses, and increase their competitiveness in a national and European market.

AT A DISADVANTAGE

The current system of sound and vibration measurement for the fulfilment of code requirements and regulations throughout Europe is based on heavyweight structures. It has been observed that the system of sound assessment often does not match the subjective human

experience of sound, especially in lightweight houses which are prone to more vibrational movement due to the nature of the materials with which they are made. Currently the vibrational experiences of residents in these multi-storey buildings can be disturbing even if the building code requirements are met with some margin. Hence, if not carefully designed the sound insulation in lightweight houses might become poor compared to heavier structures – particularly for lower frequency sounds such as washing machines on floors, people walking and powerful hi-fi systems. AkuLite believes that the results of sound testing must match the human sound experience of residents who occupy such premises. With this approach it is possible to form the basis for an advantageous and long-lasting modern 'light' building technique.

The Swedish Government made some adjustments to sound regulations in 1999, in an attempt to incorporate a consideration of lighter weight houses, most significantly the lowering the the frequency range down to 50 Hz for official sound evaluation. This compares to the 100 Hz lower limit used in most European countries which, although ample for heavyweight builds, has been proven (by the research of AkuLite) not to suffice for light structures. Yet extended research is needed for this sustainable approach to extend into construction and living. Hagberg outlines the main concern: "If we continue to develop new building systems and issue European technical guidelines based on current legislation, then there is an obvious risk that the development and acceptance of new structural materials in buildings will decrease and confirm the building industry as a non-developing industry".

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CORRESPONDING MEASUREMENTS

Involving all active research institutions in the field in Sweden, the AkuLite project aims to develop objective criteria of sound insulation, impact noise, vibrations and springiness so as to make possible an evaluation of acoustic quality that stands apart from the type of frame a building has. The focus is on objective evaluation of measurements that correspond with the subjective experience of sound. Evaluation of existing methods of measurements has already revealed the uncertainty in the ISO standardised tapping machine system currently in place, and the shortcomings in corresponding evaluation. Yet the tapping machine is most likely to be used as the primary method of sound testing of impact sound for the foreseeable future, even if new methods are proposed in upcoming standards. The decision of AkuLite has been to develop methods for evaluation both when using the current tapping machine, but also with other impact methods that can possibly improve the correlation between objective measurements and subjective experience.

A RANGE OF METHODS

AkuLite have been combining the results from subjective questionnaire surveys with objective measurements of sound transmissions in new builds, and laboratory listening tests. The questionnaire survey methods are spread throughout Europe: the questionnaire has been translated into six languages and an electronic version is now available. "The methods for field questionnaire surveys are developed, not only for use in Sweden, but also for future and deeper knowledge of residents' experience of sound and vibration in the rest of Europe," Hagberg observes.

For the gathering of objective data, physical models are currently being designed to account for the interaction between an impact source and the floor. The focus here is on the sound of human walking – the main source of impact noise which is still not understood as an acoustic source, particularly in lightweight structures. Modelling a tapping machine and a human foot, floor vibration and contact models, the testing of this interaction will occur in a laboratory, providing a full description of the acoustic connection between the tapping machine and human feet.

The resulting psychoacoustic models of many modes of research and the correlation of objective and subjective results will provide the basis for the formulation of new requirements for sound insulation, vibrations and springiness.

WHAT'S TO COME?

Wood is generally considered to be more 'alive' than concrete in that it can contribute to better acoustic comfort, with less echoes and reverberation. The technologies and methods of sound assessment are rising to meet this potential. Linked to international projects such as AcuWood and Silent Spaces, the AkuLite team is outward-thinking in its hopes for the success of the project. The suggestions for change in standards of evaluation will probably start in the Nordic countries, but it is believed the discoveries will feed into the progression of the rest of Europe in regard to sound criteria, especially through the European network COST TU 0901 Indeed, as the fundamental changes to the system solidify the competitiveness of lightweight houses, international trade looks set to provide more sustainable, cost effective and peaceful family homes throughout Europe.

INTELLIGENCE

AKULITE

ACOUSTICS AND VIBRATION IN LIGHTWEIGHT BUILDINGS

OBJECTIVES

To develop sound and vibration criteria that fit better with human experience in lightweight buildings. The project will strengthen the competitiveness of lightweight structures compared to heavyweight structures and remove hinders for international trade. It will also build long-term competence among participating research and industry partners.

KEY COLLABORATORS

Chalmers University of Technology • SP Acoustics • Lund University • ÅF Sound & Vibration • WSP Acoustics • Luleå Technical University • SP Wood Technology • Linné University

FUNDING

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KLAS HAGBERG has been a building acoustician for more than 20 years and during this time has developed a particular interest in acoustics in light constructions. He graduated as a civil engineer from Chalmers (1988) and continued with research at Lund University. Hagberg has also worked for the Swedish National Authority in building regulations and standardisation. He is now employed part-time at the Swedish research institute, SP, as project leader for two projects (AkuLite and AcuWood), while maintaining his role as head of the Swedish Acoustic business within WSP Acoustics.