Prediction of Noise Transmission in Lightweight Building Structures

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BACKGROUND

Lightweight building techniques are currently progressing faster than the development of prediction tools for the acoustic behavior of such structures. In order to ensure that the increasing demands to sound insulation between dwellings are being accommodated, reliable prediction tools are needed at an early stage of the building design.

According to a recently published Swedish state-of-the-art report concerning acoustics in wooden buildings [Forssen et al., 2008], a great variance in the sound insulation of lightweight wood constructions is observed. Such unpredictable behavior calls for over-qualifying constructions in the design, which contradicts the idea of a simple design keeping expenses at a minimum. Without reliable prediction methods building with lightweight structures combined with high acoustic quality demands is associated with a large risk. Thus, the state-of-the-art report concludes that it is crucial to have reliable prediction tools in the early stage of a building project.

The noise transmission between adjacent rooms in a building occurs directly through separating constructions as well as over different paths that include flanking building elements.

The standard EN12354 describing a simplified statistical energy analysis (SEA) subsystem approach provides a valuable tool to predict the flanking transmission of air-borne and structure-borne sound already in the stage of design [EN12354-1:2000, Lyon & DeJong, 1996]. The losses that occur at the junctions, where different building elements are interconnected, play a key role in the EN12354 standard, since they dominate the sound insulation of flanking paths. However lightweight building constructions typically do not meet the requirements for ideal SEA subsystems and therefore applying the EN12354 standard to lightweight building constructions may result in imprecise predictions.

STATE-OF-THE-ART

Currently there is an increasing focus on the transmission of low frequency noise, as sources like road and air traffic or even home theater subwoofers become part of everyday life for many people. Recently, research has been presented where sound transmission in the low frequency range through lightweight structures has been predicted with numerical methods [Brunskog & Davidsson, 2004, Davidsson, 2004, Sonnerup et al, 2008]. However, only a limited number of applications have been evaluated.

The construction of a lightweight structure is fairly complex and many variables belonging to material models, junction types and coupling phenomenons between structure and acoustic medium have to be modeled in a proper way.

Ongoing research is concerned with the loss factors in the different types of couplings that occur in lightweight structures including both different types of beams [Craik & Smith, 2000, Galbrun, 2010] as well as line coupling versus point coupling [Fahy & Gardonio, 2007, Craik & Smith, 2000, Galbrun, 2010].

OBJECTIVE

In the present project typical structures of modern lightweight building techniques are investigated by means of numerical simulations. This should help clarifying the reason for the large variances between the acoustic behavior of lightweight structures.

The project will include an investigation of the effects of several structural properties like material damping, viscoelastic slippage in beam/plate couplings, spatial periodicity, sealing of enclosed volumes, etc. The method of investigation will primarily be based on readily available elements in the commercial FEM software package Abaqus. Experimental verification of the results will be conducted continuously by starting with simple well-defined structures and then increasing the complexity of the modeled structure in steps.

The approach in the present PhD project is using the commercial finite element software ABAQUS to investigate the fluid/structure coupling occurring in junctions of lightweight structures while continuously verifying the model experimentally. This approach will reveal the weaknesses of the model at an early stage of the design. If possible, an SEA approach may be investigated.

The objective of the present research project is to obtain a better knowledge of noise transmission for junctions of lightweight building elements and derive more precise prediction models, either as an extension of the SEA approach or based on finite element (FEM) solutions.

CURRENT STATUS

Currently, the fluid/structure coupling related to the enclosed volumes of air inside a single-stud double-plate lightweight panel is being investigated. A finite element model has been utilized in which solid continuum elements are adopted for the structure and fluid continuum elements for the air-inclusions. The model is based on readily avaible elements in the commercial finite element package ABAQUS.

The structure is excited by an approximated diffuse field on one side and the response is evaluated at the plate at the other side. The calculations are performed in the low frequency range 50-250 Hz, but the frequency range will be extended upwards in the near future.

The goal of this preliminary study is to investigate the effect of the air inclusions in the model while at the same time gaining experience regarding how to model such structures for future investigations.

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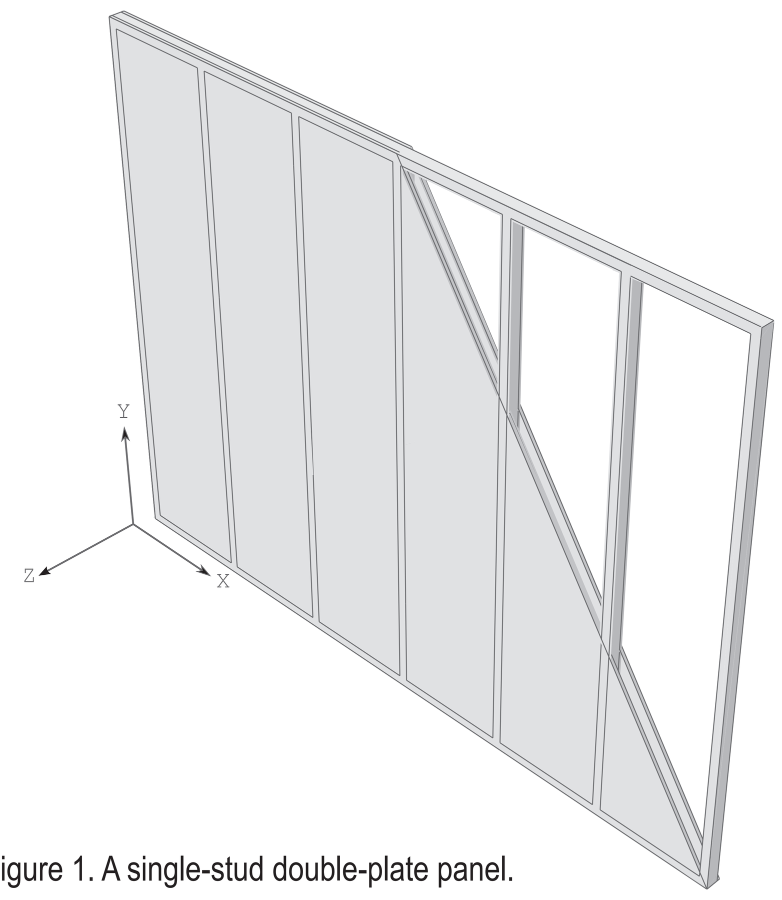

Figure 1. A single-stud double-plate panel.

SILENT SPACES

An ongoing project at the Universities in Lund and Aalborg. The project is part of Interreg IVA program which is funded by the European Union.

The project aims to help economic growth in the Øresund-Kattegat Region while creating a more sustainable environment by reducing noise and vibrations in buildings and dwellings.

To reach the goal of reduced noise and vibration in dwellings and office buildings, both the building design and the noise sources must be taken into consideration.

The project aims to develop and validate new, innovative, optimization-based design tools that include both methods to minimize noise and vibration generated by, e.g., HVAC systems in the buildings and methods of designing buildings and dwellings protected against sound and vibration from sources outside the building.

While the current trend towards lightweight constructions may be of both economical and environmental benefit, the trade-off between reduction of structural weight and reduction of the level of sound and vibration is an important issue that must be dealt with by optimizing the designs.

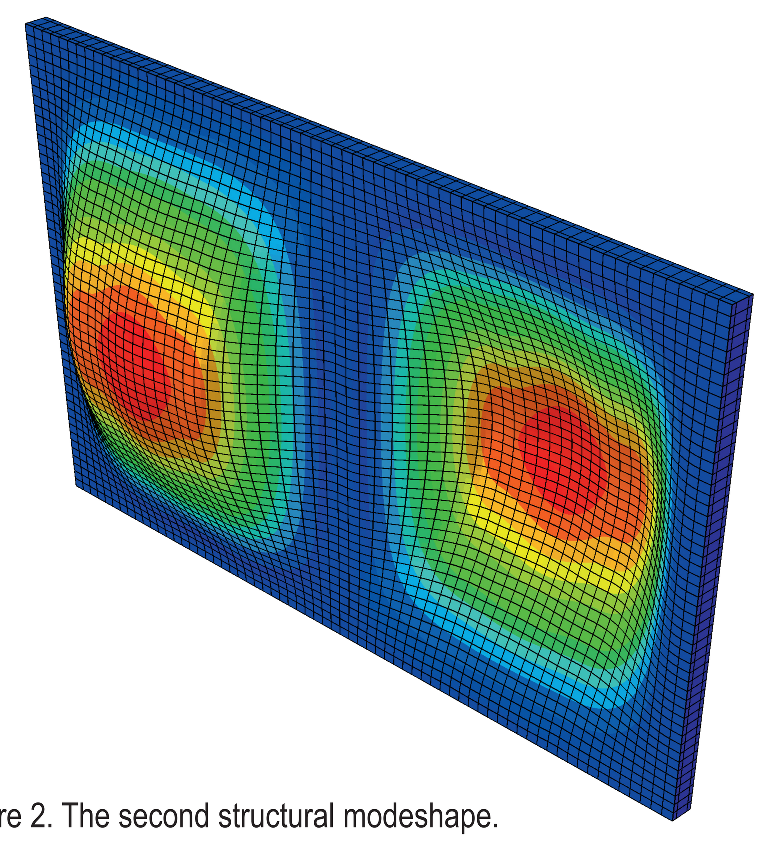

Figure 2. The second structural modeshape.

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