DISPUTATION

VIBRATION TRANSMISSION IN LIGHTWEIGHT BUILDINGS
Numerical prediction models

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Academic thesis which, by due permission of the Faculty of Engineering at Lund Univesity, will be publicly defended for the degree of Doctor of Philosophy in Engineering, on Friday 20th of January, 2017, at 10.15 a.m. in lecture hall V:C, in the V-building, Lund University, Faculty of Engineering, John Ericssons väg 1, Lund, Faculty opponent: Prof. Dr.-Ing. habil. Frank Ihlenburg, Hamburg University of Applied Sciences.

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Abstract

Wood buildings currently account for 10-15% of the newly produced multi-family housings in Sweden and their construction is increasing rapidly. Although modern wood buildings fulfil the requirements for sound insulation specified in building regulations, studies have shown that residents in wood buildings are more disturbed by noise and vibrations than are residents in conventional concrete buildings. Especially problematic is the transmission of low-frequency structure-borne sound between storeys and rooms. During the last few decades, the vibroacoustic comfort of residents has improved as a result of the efforts to reduce noise and vibration transmission. However, there are no reliable models for predicting the noise and vibration transmission in the buildings. If accurate and efficient numerical models were available, they would facilitate the optimisation of existing measures for noise and vibration reduction and the development of novel types of measures. The objective of the research presented in this thesis is to develop such models.

The thesis work focuses on the numerical modelling of low-frequency vibration transmission from a source to a receiving room. Accurate models of the structural vibrations are valuable for predicting structure-borne sound as well as floor vibrations. Two main topics are discussed in the thesis: model validation to ensure accurate predictions and dynamic substructuring to improve the computational efficiency. The studies were performed using example cases representing parts of timber volume element buildings. Such buildings are constructed by stacking pre-fabricated volume elements with elastomeric vibration isolators between storeys to reduce vibration transmission. The timber volume element buildings account for a large part of the construction of multi-storey wood buildings in Sweden.

An important step towards validating the numerical models is to perform model correlations to unveil errors and update the models. In the thesis, a model correlation study for the low-frequency vibration transmission in an experimental wooden building structure is presented. It was found that deterministic methods are relevant for creating the models provided that measurement data for calibration purposes is available. Based on the observations made in the correlation studies, important modelling parameters are discussed and modelling guidelines are presented. The studies presented in the thesis also consider the modelling of air and insulation in cavities of wood buildings, which were found to have appreciable effect on the vibration transmission.

A strategy for dynamic substructuring of wood buildings is suggested in the thesis. It involves methods for model order reduction and for interface reduction of substructure models, and uses coupling elements to represent elastomeric vibration isolators between building elements. It was shown that by performing the model reduction in the suggested manner, the computation times of numerical analyses can be reduced significantly without having an appreciable effect on the accuracy of the model predictions.

Several uncertainties in the modelling remain, but the results and conclusions presented in the thesis are important steps towards enabling the prediction of vibration transmission by use of numerical models.

Keywords

vibration transmission, structure-borne sound, wood buildings, numerical modelling, finite element method, structure-acoustic coupling, model validation, model calibration, dynamic substructuring, model order reduction

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