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Evaluation of the sound insulation of roofing systems

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ABSTRACT

The transmission of noise from the outside environment into dwellings is often a concern for the inhabitants. However, the transmission of the noise through the roof is often overlooked when the sound insulation of the dwelling is being assessed unless the dwelling is located near an airport. The transmission of noise through the roof system depends not only on the performance of the roof cladding, but also on the structure-borne noise attenuation of the trusses, the ceiling and the ceiling insulation. In this investigation, the sound insulation of different configurations of roofing systems were evaluated in the laboratory. The configurations tested included variations in the cladding, the sarking installed under the cladding, the thickness of the insulation installed between the ceiling joists and the ceiling construction. The outcome of the study will help to improve the acoustic performance of roofing systems as well as to assist architects in the selection of roofing systems.

INTRODUCTION

The New Zealand Metal Roofing Manufacturers Inc. have commissioned a study at the University of Canterbury to benchmark the acoustic qualities of existing roofing products and to evaluate the potential for improvements to the acoustic performance of roofing systems. The evaluation will be conducted in two phase.

The first phase which is presented in this paper includes the evaluation of the sound reduction index of different roofing systems. The roofing systems will include different combinations of cladding, sarking, insulation between the ceiling joists and ceiling constructions. The laboratory testing will allow for the evaluation of the effect of changes to the roofing system on the sound reduction index without the effect of outside influences such as different construction techniques or different connecting structures as would be the case in actual dwellings. Preliminary results of the testing will be included when the paper is presented.

The second phase which will be initiated after the conclusion of the laboratory testing will include field testing in a dedicated test house. The roof system of the test house will be modified or replaced as needed to evaluate different roofing systems. The use of the dedicated test house will have an advantage over testing the roofing systems of different houses which may be exposed to different levels of traffic noise or have different constructions.

PRIOR WORK

The most extensive, published study of noise attenuation of roofs was published in three parts in 1980 by Cook [1-3]. Part one of the study was a laboratory investigation of the sound reduction index of just the ceiling components. The ceiling was tested both by itself and with different configurations of fiberglass infill between the ceiling joists as well as sarking of 0.23mm thick aluminum which was laid across the ceiling joists. It was found that the infill had little effect on the sound reduction index of the ceiling components at the low frequencies. Part two of the study investigated the sound reduction index of the roof cladding. The claddings included concrete tiles and steel decking. Part three of the study investigated the sound reduction index of the roof system inclusive of the cladding, the ceiling components and the trusses between them. Cook found that the highest single number ratings for each combination of cladding and ceiling were achieved when high surface density infills were added between the ceiling joists.

Cook attempted to predict the sound reduction index of the roof system based on the sound reduction indices which had been measured for the individual cladding and the ceiling components, but found that the predictions did not match the measured values. One reason for the difference between the predictions and the measurements was that the trusses act as pathways for structure-borne sound between the cladding and the ceiling components. Cook concluded that the sound reduction index of the roof system inclusive of the roof, ceiling and the connections between them could not be predicted from the sound reduction index of the roof or ceiling measured separately from the roof system. Therefore, specifying a higher sound reduction index rating for one part of the roof system, for example the cladding without considering the system as a whole may not be effective.

A separate study by Scholes [4] regarding the transmission of aircraft noise into dwellings near Heathrow also found that the addition of mineral wool insulation between the ceiling joists to be more effective at reducing the noise in the dwelling than the addition of sheets of lead under the roof. The study by Scholes differed from that by Cook in that the measurements were made in actual dwellings and therefore included the effect of flanking transmission.

METHOD

Following from the work of Cook, the sound reduction index of the roof system as well as just the cladding will be measured in the laboratory. Variations in the cladding, sarking, infill thickness and ceiling construction will be evaluated as part of the study.

The measurement of the sound reduction index will be made using sound intensity according to ISO 15186-1 [5] for the 1/3 octave bands between 100 Hz and 5000 Hz and according to ISO 15186-3 [6] for the 1/3 octave bands between 50 Hz and 100 Hz. Each roof system to be evaluated will be built in-situ by a professional roofer in the 11.5 m^2 opening between a reverberation room and a receiving room, both of which are in compliance with ISO 15186 as shown in Figure 1.

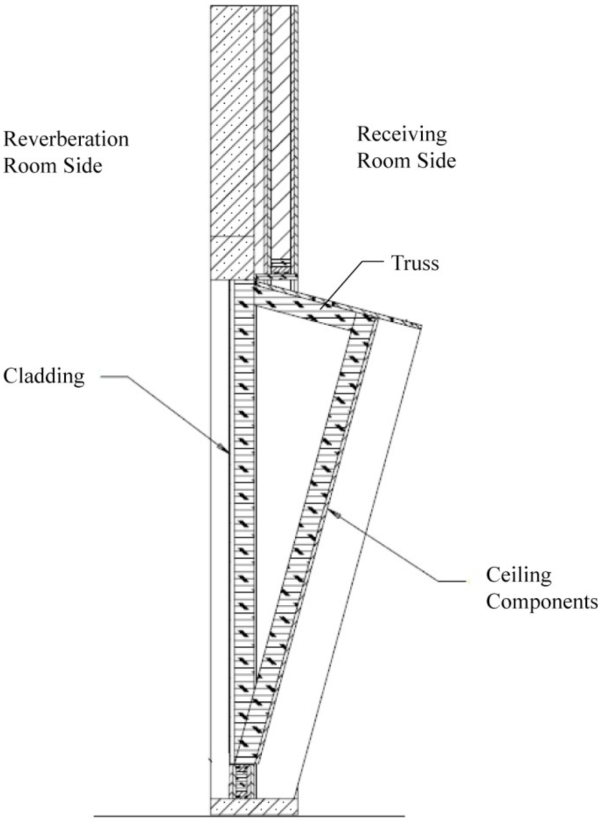

Figure 1. Cross section of the roof system in the opening between the reverberation and receiving rooms.

In addition to the measurements of the sound reduction index, the vibration reduction index of several of the roofing systems will be measured according to ISO10848-1 [7]. The measurement of the vibration reduction index will allow for future work on the prediction of the sound reduction index of the roofing systems using statistical methods.

DISCUSSION

Any improvement in the sound reduction index of the roof system will only be beneficial to the occupants of the dwelling if the dominant transmission paths for outdoor noise are addressed first. The dominant transmission paths for outdoor noise are commonly the doors and windows [8]. In New Zealand, the use of double-glazed windows became mandatory in 2008 for most new residences [9]. However, the majority of the windows in residences built in New Zealand prior to 2008 have single glazing. Therefore, the replacement of single glazed windows should be considered before modifications to the roof system purely for acoustic reasons.

A second consideration is the exposure of roofs to environmental noise. In urban areas, the primary source of noise annoyance is road traffic [10]. The exposure of roofs to road traffic noise can differ from vertical facades, depending on the height of the building and the pitch of the roof [11]. The shape of the roof can also affect the incident sound levels [10]. The affect of the shape and height of the roof will be addressed in a separate study at the University of Canterbury.

CONCLUSIONS

Based on the work of Cook, the sound reduction index of a roof system can not be determined from the sound reduction indices of the individual components, but must be determined from the complete system. The study currently underway at the University of Canterbury will quantify the effect on the sound reduction index due to changes in the roof system and will be an aid to the design of future roofing systems. The inclusion of measurements of the vibration reduction index as well as the intensity sound reduction index will allow for the development of models to predict the sound reduction index of future roofing systems.

ACKNOLOGEMENTS

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