Applied Acoustics 91 (2015) 64–72

Contents lists available at ScienceDirect

Applied Acoustics

journal homepage: www.elsevier.com/locate/apacoust

Predicting the sound insulation of plywood panels when treated with decoupled mass loaded barriers ☆

Robin R. Wareing [a,*], John L. Davy [b,1], John R. Pearse [a]

[a] University of Canterbury, Mechanical Engineering, Private Bag 4800, Christchurch 8140, New Zealand
[b] School of Applied Sciences, Royal Melbourne Institute of Technology (RMIT) University, GPO Box 2476V, Melbourne, Victoria 3001, Australia

ARTICLE INFO

Article history:
Received 6 August 2014
Received in revised form 27 November 2014
Accepted 19 December 2014
Available online 8 January 2015

Keywords:
Sound insulation
Sound transmission loss
Mass loaded barrier
Decoupled layer
Noise treatment

ABSTRACT

The addition of mass loaded barriers can be used to improve the sound transmission loss properties of lightweight panels. Decoupling of the mass layer from the panel is achieved using a layer of open celled foam. This treatment causes the panel system to exhibit sound transmission loss behaviour that is similar to conventional double leaf walls. The effects of altering the thickness of the decoupling foam layer, the surface density of the barrier, and the attachment between the treatment and the panel were assessed experimentally. Several analytical prediction methods were combined to develop a model for the transmission loss of the treated system. The material properties of the panel and treatment were measured using static and dynamic methods. These measured values were used in the prediction methods. The prediction methods yielded a range of agreements with the experimental results. The quality of agreement was found to depend on the thickness of the foam decoupling layer, the surface density of the barrier layer and most significantly the attachment method.

1. Introduction

Acoustic treatments can be used to increase the sound transmission loss of a panel in the case where the untreated panel's sound transmission loss is insufficient. Treatments for sound transmission loss can be applied in numerous applications such as machinery enclosures, inter-tenancy walls and bulkheads. Ideally the sound transmission loss of a panel should be improved sufficiently with minimal changes to the thickness and surface density of the panel. The treatment method assessed in this paper consists of limp mass loaded barriers of different weights spaced off a panel by a layer of open celled foam of varying thickness. The thickness of the open celled foam used, and the attachment method between the treatment and the panel were found to have a large effect on the sound transmission loss of the system. A range of different samples were tested to assess the variation in sound transmission loss as the treatment arrangement and construction are altered.

There has been a significant amount of researched focused on predicting the sound transmission loss of single and double leaf walls. Early models such as that presented by London [1,2], Cremer [3], Sharp [4], Sewell [5] and Mulholland [6] used a number of approaches to analytically predict the sound transmission loss of wall systems. A fundamental model is presented by London [1,2], which expresses each panel of the wall as an infinite panel with mechanical bending wave impedance. This model was further developed and modified by future authors in order to achieve better agreement with experimental measurements. In all the prediction methods presented the agreement with experimental results near the coincidence frequency is relatively poor, and a number of these prediction methods also suffer poor agreement above the coincidence frequency.

Davy presented a series of developments to a model [7] based on the model developed by Cremer [3]. The effects of studs on the sound transmission loss behaviour of double leaf walls was included into the original prediction scheme [8,9] following the approach outlined by Fahy [10]. Further modifications were made to the prediction schemes in three following publications [11–13]. These methods are all constructed on the framework presented by Cremer and London. In all cases except the latest model the effect of the finite panel extent on the transmission loss is included by limiting the maximum angle of incidence that the transmission coefficient is integrated over, in general this sits between 78° and 85°. The agreement between measured and predicted results can be very good, but this good agreement often requires the selection of some variable in order to achieve good agreement.

☆ Portions of this work were presented in "Acoustic treatment of panels: Effect of attachment method", Internoise 2013, Innsbruck, Austria, 15–18 September 2013.

* Corresponding author.
E-mail address: robin.wareing@pg.canterbury.ac.nz (R.R. Wareing).
[1] Current address: CSIRO Materials Science and Engineering, PO Box 56 Highett, Victoria 3190, Australia.

http://dx.doi.org/10.1016/j.apacoust.2014.12.006

Other authors have further developed the effect of various components on the sound transmission loss of double and single leaf wall systems. Research on the affects that various connection methods have on the sound transmission loss and the behaviour of porous elastic materials under acoustic excitation was of particular interest. Recent research by Hongisto [14,15] investigated the effectiveness of a number of the current existing prediction models. In general it was found that none of the prediction methods performed well when applied to a wider range of systems. The effectiveness of the prediction methods for the evaluation of studded walls is quite poor in most cases.

Recent research by Vigran [16,17] investigated the application of a transfer matrix scheme with the inclusion of finite stiffness studs for the prediction of sound transmission loss of double leaf walls. A transfer matrix method was presented in [18,19] where it was utilised to predict the impedance and transmission loss of multi-layered porous materials. In the transfer matrix method the system is represented by a set of 2×2 matrices that yield the ratio in velocities between the two plates. In both the research articles presented reasonably good agreement is seen, except near the coincidence region.

Further research into the prediction of multilayer systems was presented by Diaz-Cereceda et al. [20]. The method utilised a finite layer method, which represents the system as a combination of a one dimensional finite element model in the transmission direction combined with trigonometric functions in the panel planes. This method dramatically reduced the computational requirements needed to model the system, although it still requires significantly more computation than an analytical solution. The prediction method was applied to both the sound transmission loss of multi-layered systems and the impact isolation of similar systems. The model predicts the sound transmission loss relatively well, but differs significantly at the coincidence frequency and the mass air mass resonance.

Hongisto also investigated the influence of different wall parameters [15]. This research did not study the influence of absorption location within a wall, the sample size, or studs at frequencies above coincidence. Despite these limitations the research identified the stiffness of the studs as the most important parameter in the transmission loss of double leaf walls. The stud spacing and the presence of absorption within the cavity were also of significant importance.

Further research presented by Hongisto [14] evaluated the effectiveness of 17 different prediction methods. Hongisto took these prediction models from several different authors. The aim of the investigation was to assess if the models performed as well as claimed on a number of different systems. It was found that all of the models investigated did not perform as well as claimed in the original papers. It was also identified that Davy's model was the only one that could predict the sound transmission loss of the four different systems evaluated; with studs and absorption, with studs and without absorption, without studs and with absorption, without studs or absorption. This evaluation indicated that the understanding of the behaviour of double leaf systems is still incomplete and a general model is required.

The measured panel arrangements were modelled using a combination of three analytical models outlined in four publications [11–13,21]. These models require the material properties of the individual components of the system, which were measured using a variety of techniques of varying accuracies. The agreement between the modelled and measured results is presented with a discussion on points of interest. The effect of the fixture method on the accuracy of the predictions is also evaluated.

The model presented attempts to increase the range of applications that Davy's model may be applied to. This prediction method was chosen due to its reliability, wide range of applications and computationally efficient nature. Modifications to a model for the transmission loss of double leaf walls are presented that allow the same analytical model to evaluate the transmission loss of a multi-layer system with two layers separated by acoustic foam.

2. Measurement of the sound transmission loss

The sound transmission loss was measured using a 1550 mm × 950 mm sample, in a common opening between a 200 m^3 reverberation room (source room) and a 10 m^3 semi-anechoic space (receiving room). A sound field was generated within the source room using a Brüel and Kjær Omnipower dodecahedron sound source. This sound source was driven using a power amplifier and a Brüel and Kjær Pulse unit producing a white noise signal. The sound pressure level in the source room was measured according to ISO 10140-4 [22], together with the sound intensity level on the receiving room side of the test sample. The measured and predicted values were determined in the 100–5000 Hz one-third octave bands.

All the tests used an 18 mm thick panel of marine grade plywood with the attached treatment facing towards the reverberation room. The surface density of the plywood was 6 kg/m^2. The tests involved samples with two barrier surface densities (8 kg/m^2 and 4 kg/m^2) and five decoupling layer thicknesses (6 mm, 12 mm, 24 mm, 50 mm and 100 mm). The sound transmission loss of the untreated plywood was also measured to evaluate the change caused by the decoupled treatment. The arrangement of the barrier, foam and plywood is shown schematically in Fig. 1.

The decoupling foam layer is open celled foam that is generally utilised as an acoustic absorption treatment. It has a compressional stiffness of 0.06 MPa, a density of 28 kg/m^3. The mass loaded barrier is a vinyl layer that is approximately 3 mm thick with varying densities as specified by the surface mass. The barrier has a very low bending stiffness, which was unable to be accurately measured in the available testing equipment.

Five different methods of attachment between the panel and the treatment were investigated. Two arrangements, a 300 mm × 400 mm grid and a 500 mm × 600 mm grid, of 150 mm long by 3 mm diameter pins were used to connect the treatment to the panel. Two arrangements of glued samples were constructed; in one case the foam layer was glued to the panel using a layer of

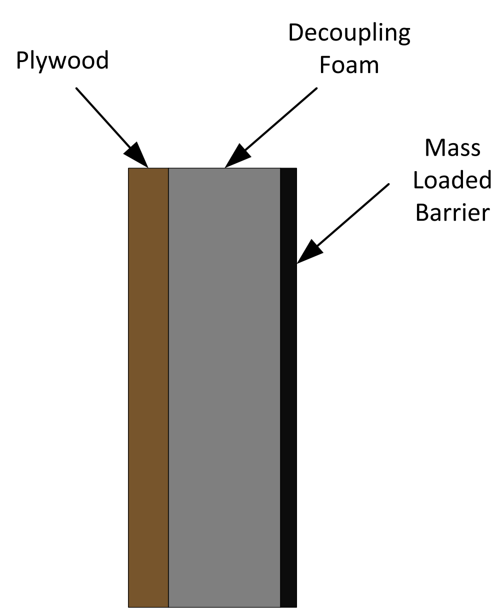

Fig. 1. Layout of test sample.