

Prediction of airborne sound transmission across a timber–concrete composite floor using Statistical Energy Analysis



Claire Churchill^a, Carl Hopkins^{b,*}

^a EMPA, Laboratory for Acoustics/Noise Control, Überlandstrasse 129, 8600 Dübendorf, Switzerland

^b Acoustics Research Unit, School of Architecture, University of Liverpool, Liverpool L69 7ZN, UK

ARTICLE INFO

Article history:

Received 16 December 2015

Received in revised form 21 March 2016

Accepted 23 March 2016

Keywords:

Airborne sound insulation

Statistical energy analysis

Timber

Concrete

Composite floor

ABSTRACT

This paper concerns the development and experimental validation of prediction models using Statistical Energy Analysis (SEA) to calculate the airborne sound insulation of a timber–concrete composite floor. The complexity in modelling this floor is due to it having (1) a multilayer upper plate formed from concrete and Oriented Strand Board (OSB), (2) multiple types of rigid connector between the upper plate and the timber joists and (3) a resiliently suspended ceiling. A six-subsystem model treats the concrete–OSB plate as a single subsystem and three different five-subsystem models treat the combination of concrete, OSB and timber joists as a single orthotropic plate subsystem. For the orthotropic plate it is suggested that bending stiffnesses predicted using the theories of Huffington and Troitsky provide a more suitable and flexible approach than that of Kimura and Inoue. All SEA models are able to predict the weighted sound reduction index to within 2 dB of the measurement. The average difference (magnitude) between measurements and predictions in one-third octave bands is up to 4 dB. These results confirm that SEA can be used to model direct transmission across relatively complex floor constructions. However, this requires the inclusion of measured data in the SEA model, namely the dynamic stiffness of the resilient isolators and the cavity reverberation time.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Timber-frame buildings have potential advantages over traditional masonry and concrete buildings in terms of reduced construction times and higher quality due to pre-fabricated, factory-engineered products. However, traditional timber-frame buildings are not always sufficient for the occupants [1] as they can have inadequate low-frequency airborne and impact sound insulation [2,3], excessive deflection, and excessive vibration [4]. There is the potential to overcome these issues through the use of timber–concrete composite floors which are essentially a hybrid type of lightweight and heavyweight construction [5]. This paper concerns the development and validation of a prediction model for airborne sound insulation across such a timber–concrete composite floor.

When assessing building performance at the design stage it is important to have validated models to predict the sound insulation for direct and flanking transmission. A recent review of the acoustical state-of-the-art for timber buildings concluded that

there is no general model available for the prediction of airborne sound insulation for direct transmission across individual walls and floors that has acceptable accuracy [6]. This is primarily because many structures are multilayer structures which incorporate resilient isolators and have relatively complex junctions between the walls and/or floors. However, a model by Guigou-Carter et al. [7] has been developed to incorporate laboratory measurements on timber-frame walls and floors to calculate the sound insulation *in situ* due to both direct and flanking transmission.

Prediction models based on Statistical Energy Analysis (SEA) models have previously been used to predict airborne sound insulation for timber joist floors [8] or timber stud walls [9,10] where the components were rigidly connected with screws/nails. These showed close agreement with measurements. When the direct and flanking walls are formed from stud walls, SEA has also been used to extend the prediction capability from direct transmission to flanking transmission [11,12]. However, these were basic timber-frame walls or floors without floating floors, resilient isolators and suspended ceilings. Basic timber joist floors are usually used as an internal floor within dwellings; hence they typically have low airborne sound insulation (<40 dB R_w). In contrast, the timber–concrete composite floor considered in this paper has

* Corresponding author.

E-mail address: carl.hopkins@liverpool.ac.uk (C. Hopkins).

significantly higher sound insulation (58 dB R_w) and with the addition of a floating floor to provide impact sound insulation it could be used as a separating floor between dwellings.

This paper develops and experimentally validates different prediction models based on SEA for the direct airborne sound insulation across a timber–concrete composite floor. Compared to modelling a basic timber joist floor, the timber–concrete composite floor has the added complexity of having (1) a multilayer upper plate formed from concrete and Oriented Strand Board (OSB), (2) multiple types of rigid connector between the upper plate and the timber joists and (3) a resiliently suspended ceiling. Whilst it is relatively straightforward to identify beam and plate subsystems for an SEA model of a basic timber joist floor, the timber–concrete composite floor is sufficiently complex that it is necessary to consider different approaches to describe the dynamic behaviour of the structural elements.

2. Timber–concrete composite floor construction

A timber–concrete composite floor is built into a sound transmission laboratory in order to measure the airborne sound insulation. This defines the construction to be considered for the SEA modelling in this paper.

A cross-section through the floor construction is shown in Fig. 1. The dimensions of the full floor are 5670 mm $\times$ 4590 mm. The base floor is formed from two factory-built composite slabs which consist of 70 mm concrete cast on top of 12 mm OSB. Each slab is supported by solid timber joists (5670 mm long, 260 mm deep, 80 mm wide) with a joist spacing of 440 mm. For structural reasons, the two slabs are rigidly connected using two welded steel plates (120 mm $\times$ 60 mm) with a gap of $\approx$ 20 mm between the slabs. Circular foam tubes (40 mm diameter) are compressed into this gap and a cement skim is applied on top. Before the concrete is cast,

nails are used to connect the OSB to the timber joists at 100 mm centres. There are additional “shear” connecting strips ($\approx$ 180 mm long, 90 mm wide) formed from 2 mm thick perforated metal connecting the concrete slab to the timber joists (seven strips per joist). These strips are aligned along the centre line of the joist as shown in Fig. 2 and penetrate the concrete by $\approx$ 40 mm and the joists by $\approx$ 40 mm. Fig. 3 shows that the concrete slab is in contact with one-third of the top of the joist.

The suspended ceiling consisted of 12.5 mm plasterboard which is screwed to 24 mm thick, 48 mm wide, timber noggins at 200 mm centres. These noggins are spaced at a distance of 500 mm to 550 mm (except at the edges where a smaller spacing is needed to support the plasterboard). The noggins are connected to the joists using resilient hangers (Ampack Ampaphon) as shown in Fig. 4. The hanger comprised two metal brackets isolated from each other by 6.5 mm of rubber where the rubber is in compression under static load. The majority of hangers are fixed at 440 mm centres (except where the two slabs are connected where this increased to $\approx$ 520 mm). This resulted in a total of 56 hangers. In the cavities above the plasterboard, 120 mm rock wool (38 kg/m³) is installed between the joists just above the plasterboard by cutting it to a size such that it is held in place by friction.

2.1. Laboratory measurement of airborne sound insulation

The test floor is built into a laboratory in order to measure the airborne sound insulation. The two test rooms either side of the floor have volumes of 64 m³ and 69 m³. The sound reduction index is measured in both directions according to ISO 10140-2 [13] and the direction-average value is used for comparison with the SEA models.

The laboratory walls are lined in order to suppress flanking transmission. The flanking limit of the laboratory is assessed in

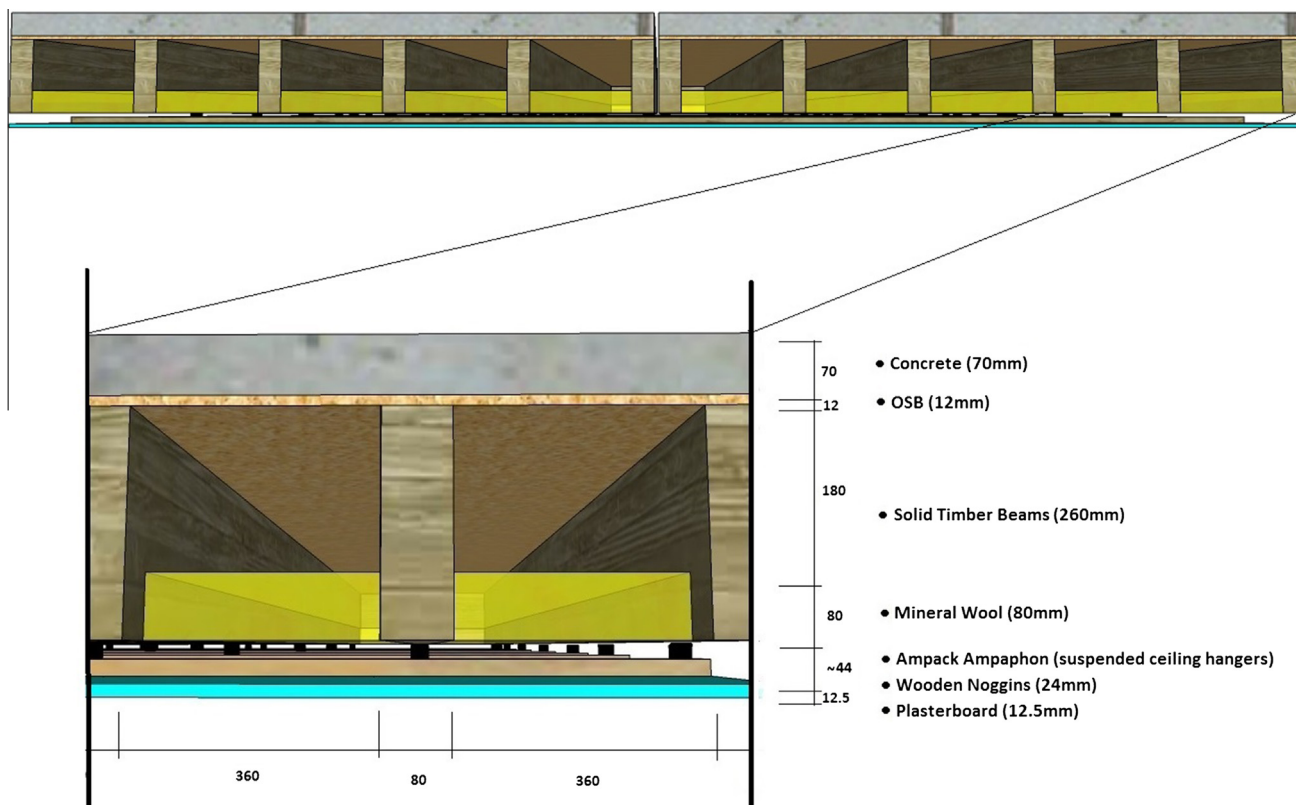


Fig. 1. Cross section through the floor construction.

Download English Version:

<https://daneshyari.com/en/article/7152497>

Download Persian Version:

<https://daneshyari.com/article/7152497>

[Daneshyari.com](https://daneshyari.com)