Modeling of Field Sound Insulation for Multi-Layered CLT Floor Assemblies Using Artificial Neural Networks

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1 Introduction

Despite the advantages of wood as a constructional material, it has a lower subjective quality of sound insulation, due to its relatively low stiffness and mass, compared with heavy structural materials, such as concrete [1]. The sound insulation measurements are cost and time-demanding due to the large construction efforts of full-size assemblies. In addition, the acoustic performance of tested structures is sometimes varied between laboratory to on-site measurements. This paper aims to develop a prediction model based on the ANN approach to estimate the field sound insulation of multi-layered CLT-based floor systems.

2 Method

2.1 On-site sound insulation measurements

The database collection comprises 104 acoustic field measurements implemented on multi-layered CLT-based floor systems for different buildings in Europe that are reported in one-third-octave bands ($50\ \text{Hz} - 5\ \text{kHz}$). Fifty-one of them are airborne insulation measurements, and fifty-three are impact curves. Measurements were carried out according to ISO 16283 (Part 1 & 2) [2, 3] and ISO 717 (Part 1 & 2) [4, 5]. The database includes several structural parameters of each measured floor, such as linked walls and specific information about junctions (T or X-junction, the thickness of visco-elastic interlayer). For each acoustic measurement, the structural materials of each floor and wall and their installation orders, thickness, densities, floor construction system, and wall type are considered in the modeling. In addition, each test floor's area and the receiving room's volume are included in the classification.

2.2 Artificial neural networks modeling

This study developed a multi-layer perceptron ANN model with three hidden layers. Cross-validation and dropout techniques were employed to avoid overfitting and validate the network model. LeakyReLU (Leaky Rectified Linear Unit) is used as an activation function for the three hidden layers. The data is split into three subsets: training, validation, and testing set with percentages of 80%, 10%, and 10%, respectively. The root-mean-square error (RMSE) function is used as the cost function to calculate the difference between each measured and predicted curve in one-third-octave bands from 50 Hz to 5 kHz. The same model is used to predict the acoustic performance of floors by using each measurement type separately (airborne, impact insulation curves).

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3 Results

3.1 Prediction of airborne and impact sound insulation

Five measurements related to different buildings are used to test the model's accuracy. Figure 1 shows each test floor's plan view and construction material. Errors are viewed for each measured curve against its prediction in each 1/3-octave band. Figure 2 shows the five test floor systems' measured and predicted insulation curves. The gray area in the background of each sub-figure represents the mean and standard deviation values used to train the network model. The single number quantities and RMSE values for each acoustic curve are presented in Tables 1 and 2.

Table 1: Predicted and measured weighted standardized level differences of test floors (in dB).

Floor no.	RMSE	D_{nTw}	$D_{nTwPred}$
1	3.44	54	54
2	3.56	58	58
3	2.97	51	51
4	2.90	54	55
5	3.34	60	60

Table 2: Predicted and measured weighted standardized impact sound pressure level of test floors (in dB).

Floor no.	RMSE	L'_{nTw}	$L'_{nTwPred}$
1	4.58	45	47
2	1.61	51	52
3	2.90	53	55
4	2.26	50	49
5	3.34	54	53

4 Discussion

The estimations for both airborne and impact sound were found to be close to measured ones; see Figure 2. Compared to other study [6], a good agreement was found in estimations near both the fundamental (below 200 Hz) and critical frequencies (1.25 - 3 kHz). This is likely due to multiple measurements on the same floor composition but with different connected walls, floor surfaces (and therefore room volume), and junctions, allowing the model to capture the structure's

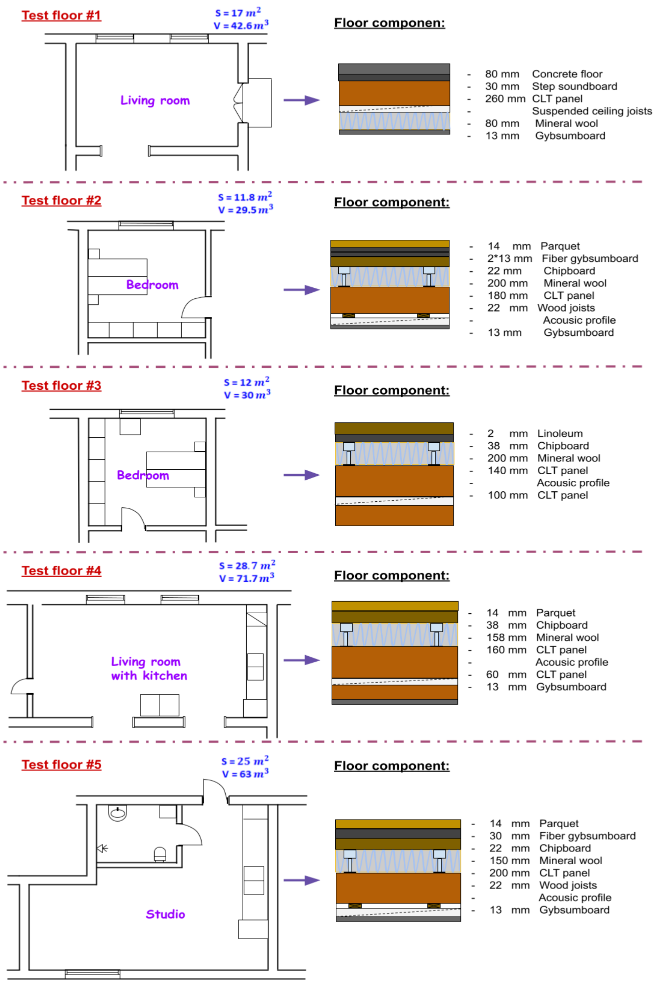

Figure 1: A schematic layout and section drawing of each test floor assembly.

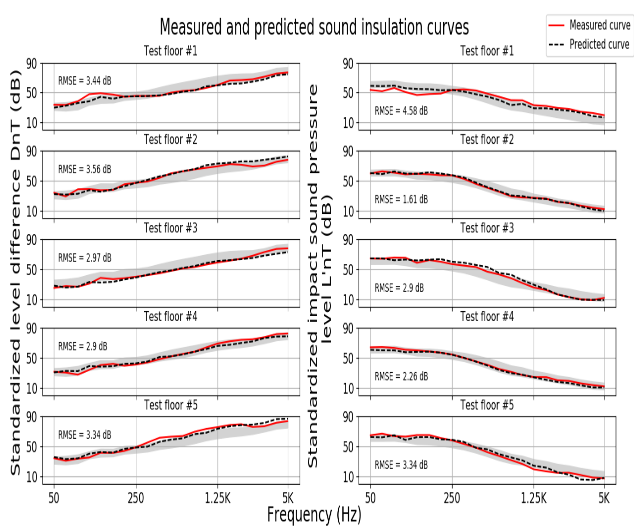

Figure 2: Airborne and impact sound insulation predictions.

insulation behavior around these frequencies accurately. In certain cases, discrepancies are observed between the predicted and measured curves at mid and high frequencies. The latter can be explained due to sound flanking transmission paths, which usually exist in those ranges in field measurements. The highest discrepancy in the prediction of D_{nTw} (Table 1) was 1 dB (test floor #4). However, it is 2 dB in the prediction of L'_{nTw} (test floor #1 and #3).

5 Conclusions

The present publication reveals a potential means of predicting on-site acoustic insulation curves for CLT-based floor systems using an ANN approach. The network model is developed using various structural parameters for 104 field acoustic insulation curves. The highest deviation is 1 dB in the estimation of weighted standardized level differences D_{nTw}, while it is 2 dB for weighted standardized impact pressure level L'_{nTw}. The results encourage acoustic designers to adapt the network model in practical engineering works, especially differences up to 2 dB are less than noticeable human differences in noise level.

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