Standardized prediction methods for estimating sound insulation in buildings

Trevor Nightingale, Institute for Research in Construction, National Research Council Canada, K1A 0R6
Thomas Alber, Fachhochschule Stuttgart-Hochschule für Technik, Department of Building Physics, 70174 Stuttgart Germany

Introduction

In Europe, "objective" or "performance" based building codes have spurred the development of standardized methods to predict the sound insulation of buildings. These models are reviewed and their suitability for North American constructions discussed. In this summary we retain the terminology used in the standards and note that "sound reduction" is synonymous with "transmission loss".

Using either measured sound reduction data or information on the material properties, a model should be able to predict "apparent sound reduction" which determines the subjective perception of sound privacy. The apparent sound reduction, R', is the sum of all the transmission paths and includes the direct transmission through the nominally separating wall or floor as well as indirect transmission paths or flanking paths. Figure 1 shows some of the common flanking paths that can exist. In the following sections the ability of three European models to predict the sound reduction of these paths is discussed.

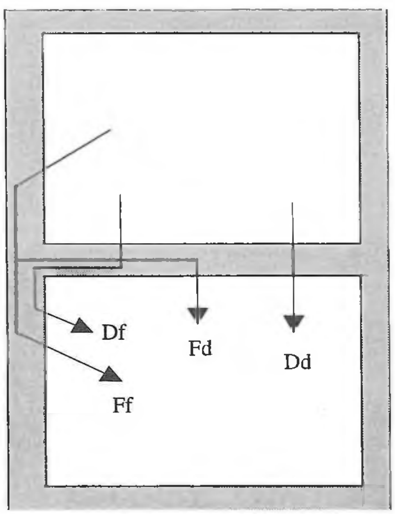

Figure 1: Direct (Dd) and possible flanking transmission paths for a joint.

CEN method

The CEN model (prEN 12354-1) was published as a draft standard in April 1996. It is based on the principle of energy balance[1] and enables calculation of sound insulation of all flanking paths that involve only a single joint. This means that there can be 12 flanking paths and one direct path between rooms separated by a floor or a wall. Figure 1 shows the flanking paths for a single junction. The sound reduction of the individual flanking paths can be calculated using,

$$R_{ij} = \frac{R_i + R_j}{2} + K_{ij} + 10\lg\frac{S_{Partition}}{l_0 \cdot l_{ij}} \qquad (1)$$

where the subscript i indicates the source surface and j the receive surface, R is the one-third octave band sound reduction, K_{ij} is the vibration reduction index describing the joint attenuation between plates i and j, S is the area of the partition and l is the joint length.

Values of the joint vibration reduction index, K, can be obtained from Annex E of the standard which lists seven joint details and provides an empirical value based on measured data. Alternately, the K_{ij} will have to be computed from measured quantities using,

$$K_{ij} = \frac{D_{v,ij} + D_{v,ji}}{2} + 10\log\frac{l_{ij}}{\sqrt{a_i a_j}} \qquad (2)$$

where D_v is the velocity level difference and $a_{i,j}$ is the equivalent absorption length of element. The apparent sound reduction index R' for the assembly is determined by the sum of the direct path plus all flanking paths which is given by:

$$R' = -10\log\left[10^{-R_{Dd,w}/10} + \sum_{F=f=1}^{n}10^{-R_{Ff,w}/10} + \sum_{f=1}^{n}10^{-R_{Df,w}/10} + \sum_{F=1}^{n}10^{R_{Fd,w}/10}\right] \qquad (3)$$

Thus, in theory, the CEN model provides a reasonably general description of flanking transmission between two rooms. However it is restricted to paths involving only a single joint.

Normally, equations 1 and 2 are evaluated for all possible paths and at all one-third octave band frequencies of interest and inserted in equation 3 to obtain the apparent one-third octave sound reduction. The standard refers to this as the "detailed model." A "simplified model" is also given that uses only single number ratings for the sound reduction. The simplified model has been widely used in heavy, monolithic constructions and typically exhibits good agreement with measured results. Unfortunately, the simplified method is only valid for heavy monolithic constructions where the single number ratings are determined by resonant transmission through the assembly (i.e., the critical frequency is at or below the lowest frequency of interest). In North American buildings employing double-leaf construction, the single number ratings are often determined by transmission in the 125 and 160 Hz one-third octave bands, namely non-resonant transmission, since the critical frequency for lightweight building materials (OSB, plywood and gypsum board) is usually in the range 1600 and 3150 Hz. Consequently, the CEN "simplified model" is not appropriate for wood frame constructions and will not be considered further.

DIN method

The German standard DIN 4109 includes both a prediction model for heavy, monolithic constructions in "Beiblatt 1" as well as a calculation procedure for wood-frame linings that may be used as partition walls in heavy monolithic buildings.

Unlike the CEN model, the DIN method considers only the flanking path Ff (Figure 1) and assumes that paths Df and Fd that involve the partition wall are insignificant. This assumption may be a reasonable approximation for junctions between lightweight interior partition walls and heavy monolithic concrete floors and exterior walls. In this case, joint attenuation between a lightweight wall and a monolithic wall (Df and Fd) will be very large with respect to the almost negligible attenuation for the monolithic element (Ff). This means that the velocity level difference between plates F and f will be near zero and leads to a very simplified model given by,

$$R'_{L,w,R,i} = R_{L,w,R,i} + 10\lg\frac{S_T}{S_0} - 10\lg\frac{l_i}{l_0}dB \qquad (4)$$

where $R'_{L,w,R,i}$ is the sound reduction for the flanking path Ff expressed as a single number rating and $R_{L,w,R,i}$ is the sound reduction for the flanking path obtained from a listing in the standard (again a single number rating), S_T is the area of the partition element, S_0 is the reference area (for walls $S_0 = 10m^2$),

l_l is the common length of the partition and flanking element and l_0 is the reference length (for floors and ceilings $l_0 = 4{,}5$m; for walls $l_0 = 2{,}8$m). This is in essence the same result that one would get if the CEN K_{ij} were set to zero (which would happen if walls F and f were identical and very massive with respect to wall D).

In lightweight wood frame constructions, it is not likely that paths Fd and Df will be insignificant with respect to Ff. This may be viewed as significant impediment if the DIN standard where applied to wood frame constructions. The second impediment is that it assumes all flanking paths past a floor/ceiling assembly have a sound reduction of 65 dB.

ÖNorm method

The ÖNORM 8115 is the national standard of Austria for the prediction of the sound insulation offered by heavy masonry or cast-in-place constructions. This model will be of limited use for North American wood frame constructions due to the very different behaviour of the constructions.

Application of the CEN Model to a Wood Frame Construction

Two of the more serious difficulties of the CEN model are discussed by examining the flanking sound reduction for the paths from the floor and party wall in Room B to the party wall of room D of the assembly shown in Figure 2. Figure 3 shows the measured and predicted K_{ij}'s for these paths. The measured K_{ij}'s were calculated from measured velocity level differences and structural decay times while the predictions were obtained from the listed assemblies in Annex E of the standard.

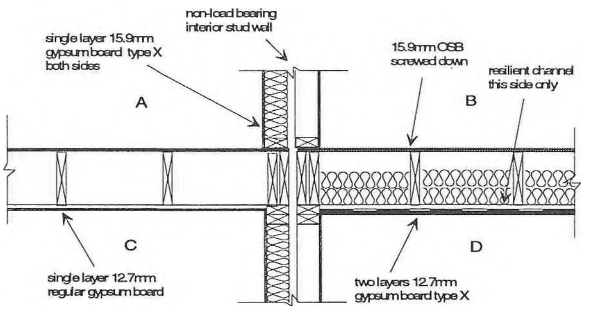

Figure 2: Section through a potentially common wood frame construction.

Figure 3 indicates that Annex using either equation E7 or E8 would grossly underestimate the vibration reduction index for these paths. The error could be in excess of 35 dB. Equation 1 shows that the underestimation in K will cause a corresponding underestimation in the sound reduction for the flanking path. Thus, it is possible to underestimate the flanking sound reduction by as much as 35 dB. Fortunately model codes in Canada have standardized building material dimensions and practices making it possible to create a catalogue of common joint details and Kij's for wood frame constructions.

Another difficulty occurs in determining the correct value of the sound reduction for the building elements involved in the flanking paths. It has been shown[2] that only the resonant component of the sound reduction should be used in equation 1. An estimate of the error that can occur if the sound reduction contains non-resonant transmission can be seen in Figure 4 by comparing the predicted resonant and non-resonant transmission for the OSB subfloor. It can also be seen that ASTM E90 or E336 data can not be used as transmission is dominated by non-resonant transmission below the critical frequency (about 2000 Hz) and would also lead to a significant underestimation of the flanking sound reduction. Computing the resonant components of the OSB or gypsum board surfaces involved in the flanking paths between Rooms B and D is quite simple. However, computing the resonant transmission through the party wall is very difficult and would be required in determining the sound reduction of the flanking paths between Rooms A and B. The standard does not give a method for predicting resonant transmission through a wall.

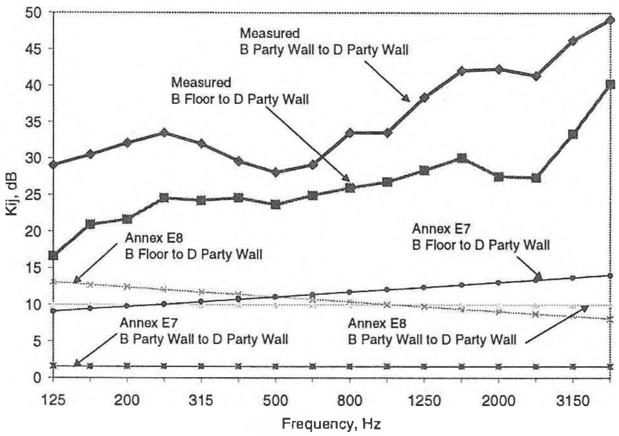

Figure 3: K_{ij}'s obtained from measured results and from Annex E of the CEN standard.

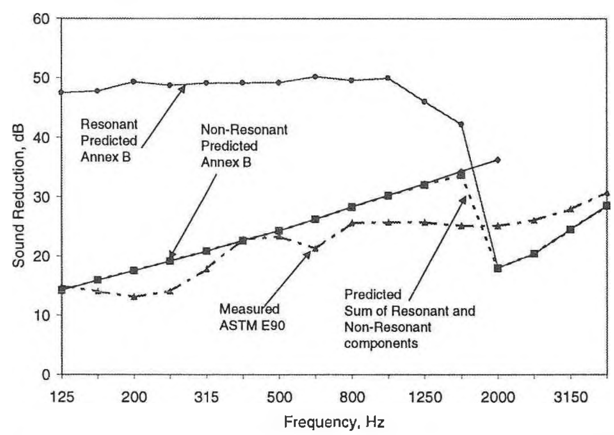

Figure 4: Sound reduction data obtained by measurement and calculation according to Annex B for the OSB floor decking.

Conclusions

Wood frame constructions are considerably more difficult to model than the heavy monolithic assemblies commonly found in Europe. Consequently, the three prediction models examined would be of limited use in their present form. The CEN model is perhaps best equipped to be adapted for wood frame construction but this will require considerable effort.

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[1] Gerretsen, E., "Calculation of Airborne and Impact Sound Insulation between dwellings," Applied Acoustics **19** (1986) 245-264.

[2] Nightingale, T.R.T., "Application of the CEN draft building acoustics model to a lightweight double leaf construction," Applied Acoustics **46** (1995) 265-284.