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Flanking transmission at impact sound excitation - Calculation according to DIN 4109 and prEN ISO 12354 –2-

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ABSTRACT

Compared to buildings in masonry and concrete construction, the planning of a timber building is a significantly greater challenge. The reasons for this can be found, among others, in the lack of proven designs and planning tools for noise control and serviceability check. The new German standard DIN 4109 will now offer the possibility to perform the proof of impact sound insulation for timber floors on basis of a much larger collection of construction-examples and application of a simple prediction model for flanking transmission on basis of single number values. In addition to this simple single number model, a more detailed SEA- based calculation in general accordance with prEN ISO 12354-2 is applicable. The detailed prediction procedure offers the possibility to consider additional measures, such as additional sheetings, which are needed for fire protection, or decoupling materials in the junction between floor and wall. However an accurate description of the flanking transmission in timber construction requires an extension of this model.

The paper compares the results of prediction calculations with measurements for the different transmission paths. An additional transmission path for impact flanking sound transmission is modeled in the context of prEN ISO 12354-2 which clearly increases the accuracy of prediction.

Keywords: SEA- based calculation, Flanking transmission, prEN ISO 12354-2, timber construction

I-INCE Classification of Subjects Number: 76.3

1. INTRODUCTION

The prediction of airborne and impact sound transmission by separating and flanking building elements is usual done in accordance with EN 12354-2: 2000 [2] and prEN ISO 12354-2: 2016 [3]. While in the basing SEA-theory all transmission paths of the building elements are taken into account, the EN approach reduces the transmission paths on the direct transfer (Dd or d) and the flanking transmission Df (see Figure 1).

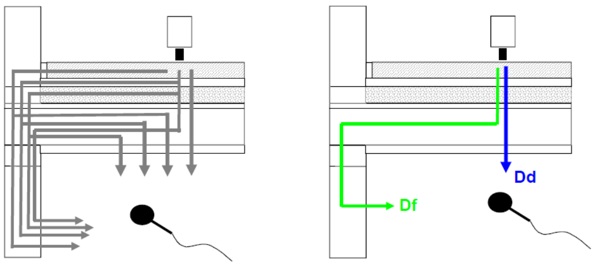

Figure 1 – Flanking transmission paths for impact sound excitation of a floor (divided in its typical subsystems) for the complete SEA model (left) or the simplified model with the transmission path Df according to EN 12354 (right).

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To proof the applicability of the prediction model according to EN 12354-2 for timber buildings several measurements of the flanking transmission paths have been carried out. Therefore the transmission paths were separated under laboratory conditions as shown in Figure 2.

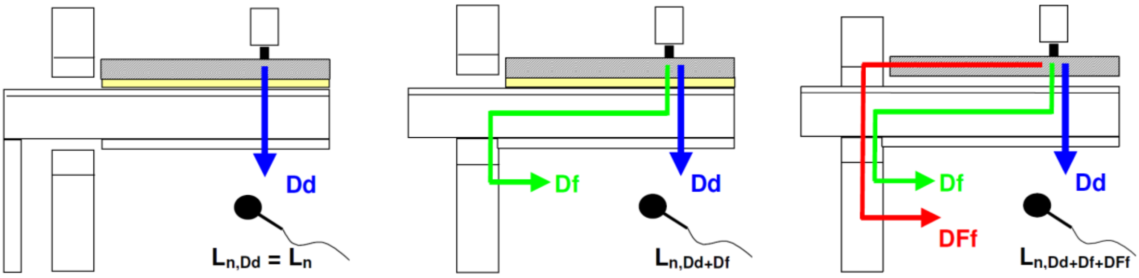

Figure 2 – Separating of the transmission paths under laboratory conditions

The measurement results show the influence of an additional sound transmission path via the edge of the floating floor screed and the insulation strips. This path becomes significant when the direct transmission und the flanking transmission via path Df is reduced by a floating screed and additional ballasting (gravel, crushed stones or sand) on top of the floor element. The sound transmission via the path Df shows a noticeable influence for floors with decoupled suspended ceilings (see Figure 3).

Construction:

140 mm vertically laminated timber element

150 mm decoupled suspended ceiling

Construction:

50 mm floating floor screed

40 mm impact insulation, sd = 6 MN/m³

120 mm grit as ballasting, m‘ = 180 kg/m²

140 mm vertically laminated timber element

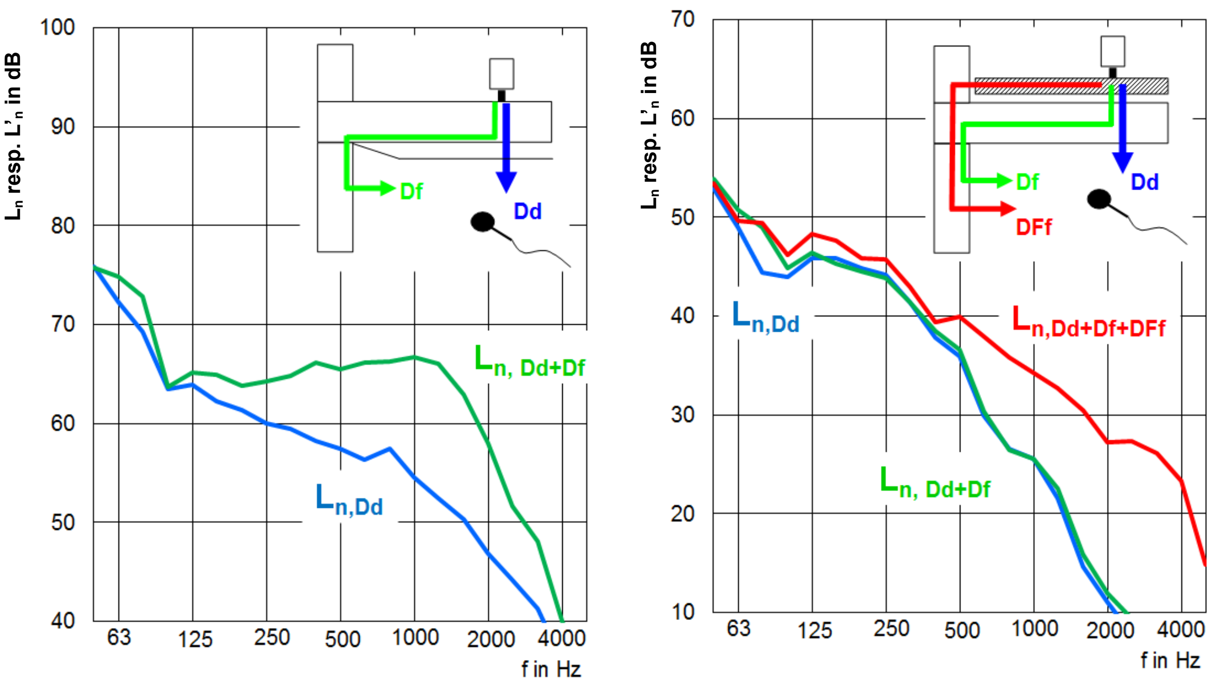

Figure 3 – Normalized impact sound level for different transmission paths

2. PREDICTION ACCORDING to DIN 4109

2.1 Single rating prediction for the proof of evidence

The proof of performance for impact sound insulation in timber buildings according to the new German standard DIN 4109 [6] is done by employing eq.(1). Corrections K_1 and K_2 represents the effects of flanking sound transmission via path Df and DFf.

$$L'_{n,w} = L_{n,w} + K_1 + K_2 \quad (1)$$

The correction terms K_1 and K_2 were evaluated from the measurement results (see e.g. in Figure 3) for different timber floor- and wall-constructions:

$$K_1 = L_{n,Dd+Df,w} - L_{n,w}\,; \;\; K_2 = L'_{n,w} - L_{n,Dd+Df,w} \quad (2)$$

The tables of the correction terms K_1 and K_2 are shown in the appendix.

2.2 Validation of the single number model

The validation of the prediction method and the input data were performed by comparing the predicted normalized impact sound levels with the results of on-site measurements. Therefore the input data of the new DIN4109-2 and DIN4109-33 were used. The standard deviation between the predicted weighted normalized impact sound levels and the measured values was σ = 1.7 dB (23 measurements). The mean difference between predicted and the measured $L'_{n,w}$ was 0.4 dB.

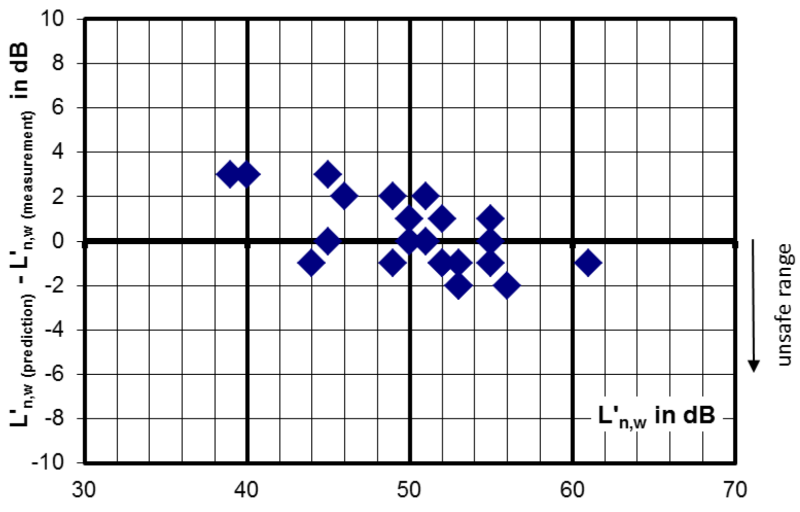

Figure 4 – Difference between calculated and measured $L'_{n,w}$ in 23 situations

3. PREDICTION ACCORDING TO prEN ISO 12354-2

3.1 Application of prEN ISO 12354-2 on massive wood elements

The normalized impact sound pressure level in situ can be predicted from the direct transmission $L_{n,d}$ ($L_{n,Dd}$) and the flanking transmission $L_{n,ij}$:

$$L'_n = 10\log\left(10^{L_{n,d}/10} + \sum_{j=1}^{n} 10^{L_{n,ij}/10}\right) \tag{3}$$

$L_{n,d}$ represents the direct impact sound transmission for on-site condition and can be estimated for the result of a laboratory measurement L_n with a correction via total loss factor according to eq. (4) and (5)

$$L_{n,d} = L_{n,situ} = L_n + 10\log\left(\frac{\eta_{tot,lab}}{\eta_{tot,situ}}\right) \tag{4}$$

$$\eta_{tot,situ} = \eta_{\text{int}} + \frac{m'}{300\sqrt{f}} \qquad \eta_{tot,lab} = \eta_{\text{int}} + \frac{m'}{485\sqrt{f}} \tag{5}$$

The prediction of the flanking transmission on path ij requires the $L_{n,situ}$ of the bare floor, the reduction of the impact sound pressure level of the floor covering (ΔL_{situ}), the airborne sound insulation of the floor without floating screed ($R_{i,situ}$) and the flanking element in the receiving room ($R_{j,situ}$). The velocity level difference on transmission path ij, can be calculated from the vibration reduction index K_{ij}.

$$L_{n,ij} = L_{n,situ} - \Delta L_{situ} + \frac{R_{i,situ} - R_{j,situ}}{2} - \overline{D_{v,ij,situ}} - 10\log\sqrt{\frac{S_i}{S_j}} \tag{6}$$

$$\overline{D_{v,ij,situ}} = K_{ij} - 10\log\frac{l_{ij}}{\sqrt{a_{i,situ}a_{j,situ}}} \tag{7}$$

The vibration reduction index K_{ij} can be predicted according prEN ISO 12354-2: 2016 [3],[4] or taken from measurements [1],[5].

In Figure 5 the comparison of calculated and measured results are shown for a massive timber floor slab (see also Figure 3). As flanking element a thick oriented strand board (80 mm OSB) was used. The measurements were done in a test facility with a T-junction under same mounting conditions as in situ. All other walls of the test facility had no rigid connection to the tested wall and floor.

Tests on a massive wood floor element with decoupled suspended ceiling (Figure 5, left) showed the strong influence of the transmission path ij = Df and a good match between calculation and measurement. This indicates that the model is, in principle, applicable for massive wood elements. For the same floor element with floating floor screed and additional ballasting on the element (Figure 5, right), the transmission on path Df was reduced similar to the effect on the direct transmission and can be practically neglected compared to $L_{n,d}$. The calculation shows a poor correlation with the measurement and is nearly identical with the $L_{n,d}$ ($L_{n,Dd}$). As shown by the measurements in section 1, an additional transmission path via the edge of the floating floor screed and the insulation strips has a significant influence when the direct transmission and the flanking transmission via path Df is reduced by a floating floor screed and additional ballasting (gravel, crushed stones or sand) on the floor element. In order to achieve a satisfactory agreement between computation and measurement, the consideration of this transmission path in the prediction model is necessary.

Construction:		Construction:	
140 mm	vertically laminated timber element	50 mm	floating floor screed
150 mm	decoupled suspending ceiling	40 mm	impact insulation, sd = 6 MN/m³
		120 mm	grit as ballasting, m‘ = 180 kg/m²
		140 mm	vertically laminated timber element

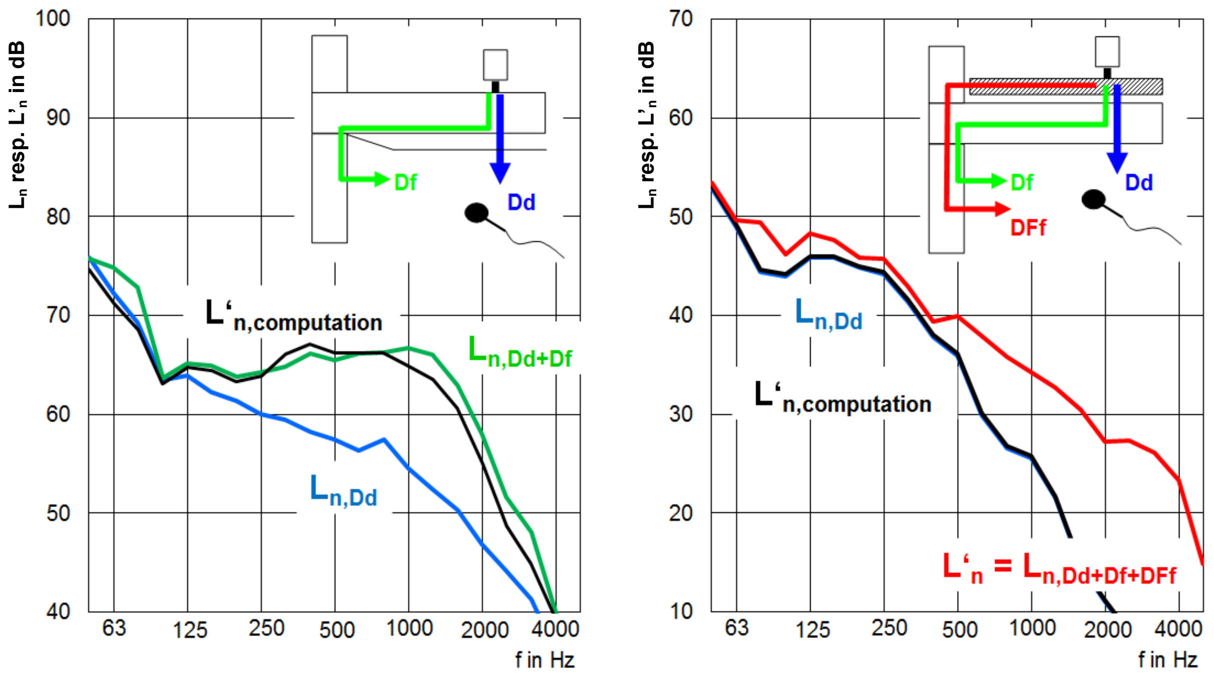

Figure 5 – Comparison between measured and predicted impact sound level according to prEN ISO 12354-2

3.2 Extension of the prediction model with the transmission path DFf

The computation of the transmission path DFf can be realized in the framework of prEN ISO 12354. The calculation requires a $L_{n,F,situ}$ (theoretical impact sound pressure level for excitation of flanking wall in emission room), the impact sound reduction over the edge of the floating screed ΔL_{edge}, the vibration reduction index K_{Ff} and the airborne sound insulation ($R_{f,situ}$) of the flanking element in the receiving room (see Figure 6 and eq. (8)).

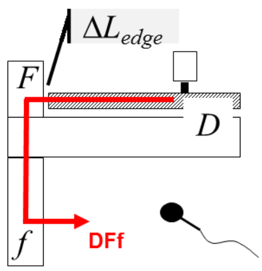

Figure 6 – Transmission path DFf

$$L_{n,DFf} = L_{n,F,situ} - \Delta L_{edge} + \frac{R_{F,situ} - R_{f,situ}}{2} - \overline{D_{v,Ff,situ}} - 10\log\sqrt{\frac{S_F}{S_f}} \quad (8)$$

$L_{n,F,situ}$ and $R_{f,situ}$ can be calculated according to prEN ISO 12354. ΔL_{edge} has to be obtained from measurements. As no rules or standards for measurement of this property exist, it is proposed to use measurements of velocity level difference. Therefore the velocity level $L_{v,0}$ was measured on the wall in the emission room (element F) while directly excited by a shaker. In the second measurement, the excitation was done on the floating screed with unchanged positions of the accelerometer on the wall (see Figure 7). The impact sound reduction over the floor edge is then obtained from the difference between the velocity levels.

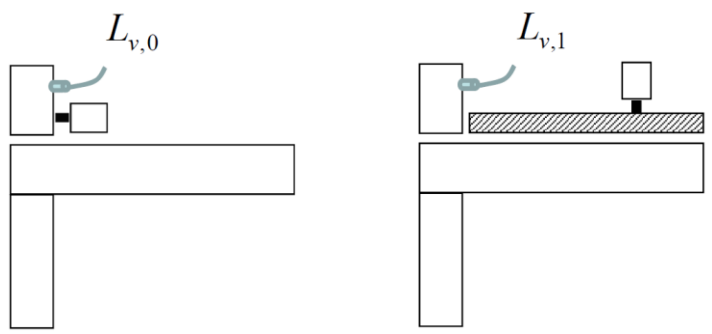

Figure 7 – Measurement of impact sound reduction over the floating screed edge

$$\Delta L_{edge} = L_{v,0} - L_{v,1} \tag{9}$$

The measurement results of ΔL_{edge} for different edge insulation strips and impact insulation boards are shown in Figure 8.

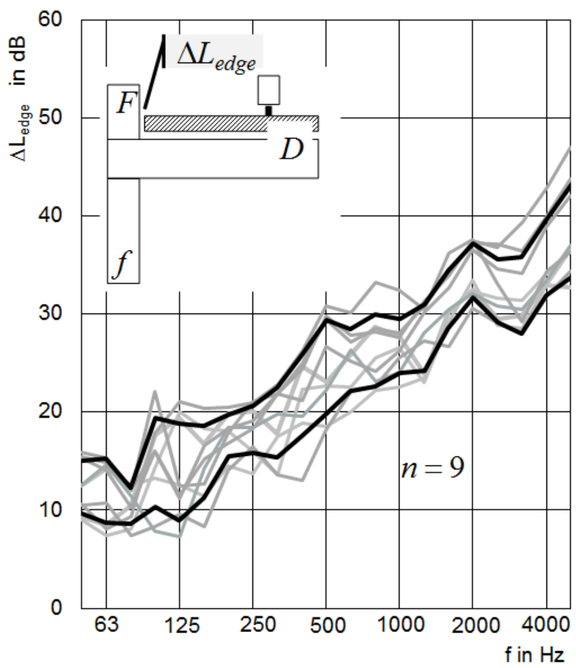

Figure 8 – Measurement data of ΔL_{edge} for different impact insulations and insulation strips.

3.3 Comparison between measurement and computation for the extended model

The described model was used for the computation of the impact noise level for a T-junction under laboratory conditions. The floor and wall construction are the same as displayed in Figure 2. The modified calculation (Figure 9, right) shows a significantly better agreement between measurement and calculation at middle and high frequencies than before (Figure 9, left).

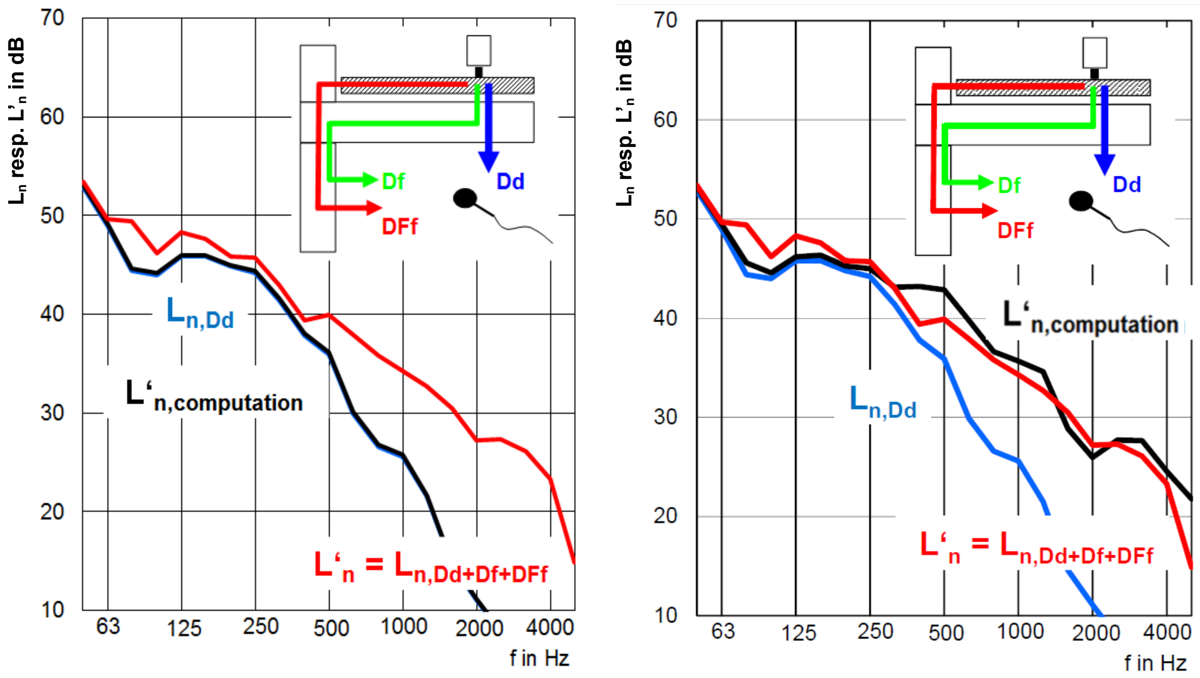

Figure 9 – Calculation and measurement for original (left) and extended (right) EN 12354-model

Figure 10 shows the results of calculation applied to a construction project in Germany (four-storey timber building) compared with on-site measurement results. Massive wood elements were used as floor and wall elements (see Figure 10).
The described wall structure was used as a load-bearing interior wall and the separating wall. The exterior walls have an additional exterior thermal insulation layer and a timber cladding for weather protection.

Following input data were used for the computation of the impact sound level of the separating floor:

- L_n of the floor structure (laboratory data)
- R of the floor without screed (from laboratory data)
- R of the flanking walls (according to EN 12354-1, Appendix B)
- K_{ij} of the junctions (according to prEN ISO 12354-1, 2016)
- ΔL_{edge} (from laboratory data, see e.g. Figure 8)
- L_n of the upper flanking wall (Theoretical data calculated according to EN 12354-2, Appendix B)

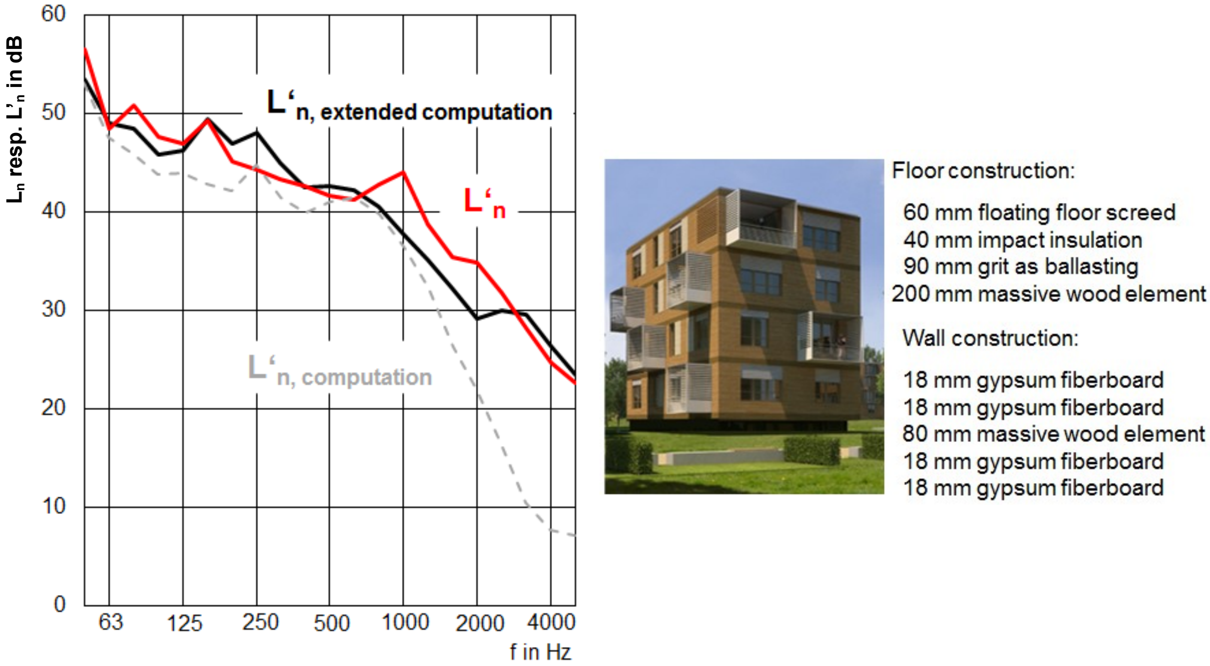

Figure 10 – Calculation and measurement for the party floor within a four-storey timber building

4. CONCLUSIONS

Within the project [1], the applicability of the prediction according to EN 12354-2 has been tested for solid wood elements. Besides a general suitability, the prediction model showed deficits for certain configurations, which could be corrected by taking into account sound transmission via a transmission path DFf. First validations of the proposed calculation procedure for T-junctions under laboratory conditions and a four-storey timber building showed a good agreement between measurement and computation. These validations shall now be carried out for further building projects and other types of screed (dry screed).

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APPENDIX

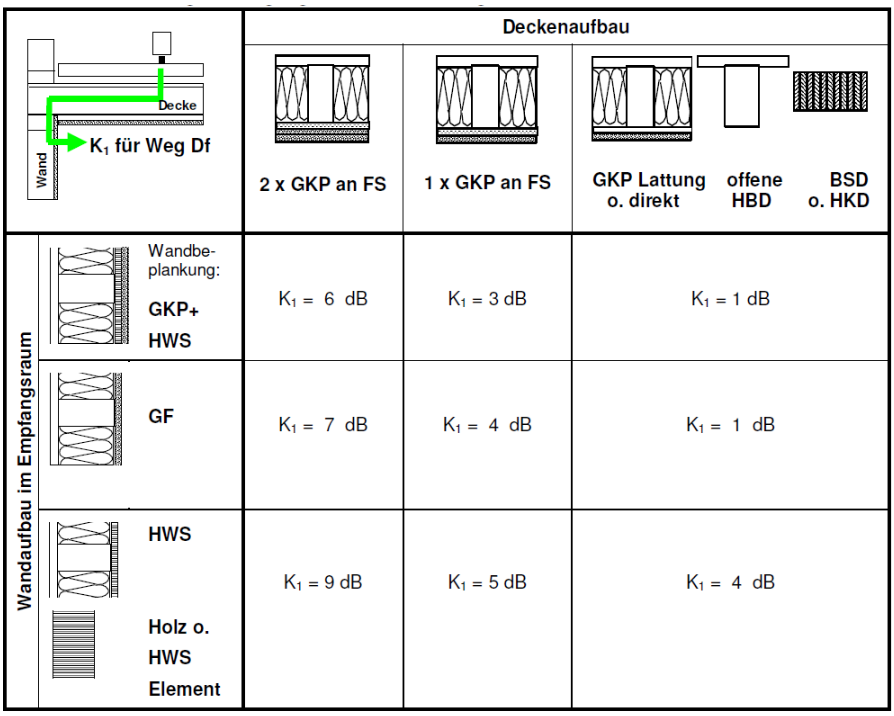
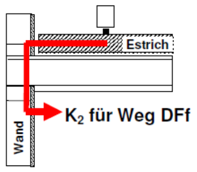


Figure 11 – Correction term K_1 [7]

Table 1 – Legend of abbreviations in Figure 11

abbreviation	English meaning
GKP	gypsum plaster board
HWS	wooden particle board
GF	gypsum fiberboard
Holz o. HWS Element	massive wood or wooden particle element
GKP an FS	suspended ceiling (GKP) with resilient channel
Lattung	suspended ceiling (GKP) mounted on battens
offene HBD	Timber beam floor without suspended ceiling
BSD o. HKD	Massive wood floor elements



Trittschallübertragung auf dem Weg Dd + Df : $L_{n,w} + K_1$ in dB

Wandaufbau im Sende- und Empfangsraum	Estrichaufbau	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
GKP + HWS / GF	a) ZE/HWF	10	9	8	7	6	5	5	4	4	3	3	2	2	1	1	1	1	1	1	0	0
	b) ZE/MF	6	5	5	4	4	3	3	2	2	1	1	1	1	1	1	0	0	0	0	0	0
	c) TE	5	4	4	3	3	2	2	1	1	1	1	1	1	0	0	0	0	0	0	0	0
HWS / Holz- o. HWS-Element	a) ZE/HWF	11	10	10	9	8	7	6	5	5	4	4	3	3	2	2	1	1	1	1	1	1
	b) ZE/MF	10	10	9	8	7	6	5	5	4	4	3	3	2	2	1	1	1	1	1	1	0
	c) TE	8	7	6	5	5	4	4	3	3	2	2	1	1	1	1	1	1	0	0	0	0

Figure 12 – Correction term K_2 [7]

Table 2 – Legend of abbreviations in Figure 12

abbreviation	English meaning
GKP	gypsum plaster board
HWS	wooden particle board
GF	gypsum fiberboard
Holz o. HWS Element	massive wood or wooden particle element
ZE	cement-based floating floor screed
HWF	wood fiber impact sound insulation board
MF	mineral fiber impact sound insulation board
TE	dry screed element