DOI: 10.61782/fa.2023.0479

forum acusticum 2023

CONSTRUCTION LEVEL MEASUREMENTS IN CLT-BUILDINGS FOR VALIDATION OF PREDICTION MODELS FOR AIRBORNE- AND IMPACT SOUND INSULATION

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ABSTRACT

The prediction of flanking transmission of solid wood elements in CLT buildings is a major subject of several studies and papers. Important parameters in prediction models are the vibration reduction index (K_{ij}) and the sound reduction index (R_i, R_j) of the elements involved, related to the resonant transmission only. Because laboratory values of direct sound reduction R involve forced transmission as well, ISO 12354-1:2017 proposes a correction value for this difference (annex B2). Peutz Consultants has implemented these prediction tools to predict the sound insulation in CLT buildings in the design phase and uses delivery measurements to validate the predictions. In this validation process in situ construction level measurements are an important tool. Determining the partial insulations from the construction levels measured with an accelerometer on several radiating surfaces in the receiving room due to the sound source in the source room gives a valuable indication of the priority between the different partial sound insulations and are also useful to validate prediction calculations of the sound insulation and their input data. This method gives useful information to improve the accuracy of the predictions in the design phase and to consult on the most efficient provisions needed for a certain sound insulation demand. Several examples for airborne sound reduction and lessons learned will be treated.

Keywords: *CLT-buildings, validation, calculations, airborne-sound, construction level measurements).*

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1. INTRODUCTION

In the consulting practice on wooden CLT-buildings reliable prediction models for sound insulation are a key factor. The present ISO 12354 [1] standard gives SEA-based prediction tools and distinguishes between a detailed, frequency dependent model and a simplified model working with single values as input data. In our engineering work on air borne noise insulation the simplified model has proven to be the most practical one so far. The accuracy of the prediction calculations depends on reliable input data, such as values for the vibration reduction index (K_{ij}) for different junction types and values for the flanking sound reduction index (R_i, R_j) of the elements involved, related to the resonant transmission only.

In the present ISO 12354-1 [1] the amount of input data for the vibration reduction index K_{ij} for different CLT-junctions is still rather limited. In 2019 an expanded collection of input and planning data for CLT-junctions regarding K_{ij}-values and their frequency dependance has become available [2]. These data are based on an overall analysis of measured K_{ij}-values by different institutes in different CLT-mock-up settings, using structure born excitation as well as the indirect method (flanking sound reduction) according to ISO 10848 [3].

This expanded set of input data regarding K_{ij}-values for CLT-junctions is a valuable addition to the data already present in ISO 12354-1, because it covers a wider range of different CLT-junction types and therefore can give a better prediction and a better agreement with measurement results for certain situations. For wooden buildings with a so-called post & beam construction however there still is a lack of available input data for (direct and flanking) sound reduction calculations, such as K_{ij}-values for different junction types and values for the direct and flanking sound reduction index (R_d, R_i, R_j) of columns and beams.

2. PARTIAL SOUND REDUCTION

2.1 Determination of partial sound reduction by construction level measurements

In addition to standard sound level measurements needed to determine the airborne sound reduction index R'_w between adjoining rooms, construction level measurements can be performed. With this method partial sound reduction values for each surface are determined from the construction levels - measured by an accelerometer on several radiating surfaces in the receiving room - due to a sound source in the sending room. Based on these individual partial sound reduction values of the different surfaces the priority between the contributions of different (flanking) surfaces to the overall sound reduction can be determined, which can be valuable to advice on future improvements. Additionally, each individual partial sound reduction measured can be used to validate prediction calculations and related input data - such as used by the simplified model - for the sound reduction contribution of individual flanking paths. Several examples hereof will be discussed in chapter 3.

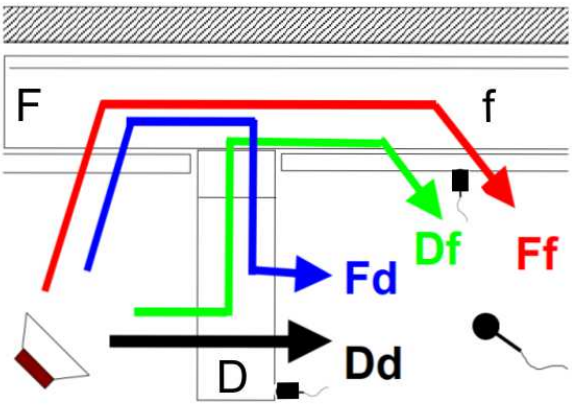

Figure 1. Schematic representation of contributions to airborne sound insulation in wooden buildings. Direct sound transmission path (Dd) and three flanking paths (Ff, Fd, Df) for one of four junctions (ceiling, floor, wall, façade) between horizontally adjoining rooms.

Figure 1 shows in a schematic way the different contributions to the airborne sound transmission between horizontally adjoining rooms, both the direct path (Dd) as three relevant flanking paths (Ff, Fd and Df). In this case the junction of the separation wall with the ceiling is given, but in total there are usually four flanking elements (ceiling, floor, façade and inner wall) so four different junctions. For airborne sound transmission each junction covers three flanking sound tranmission paths (Ff, Fd and Df), as can be seen in figure 1, and therefore 12 flanking transmission paths and one direct transmission path can be distinguished, so 13 paths in total.

Figure 1 also illustrates that if construction level measurements are performed to determine the partial insulation of each surface, using an accelerometer on each surface in the receiving room, only two flanking paths (Ff, Df) will contribute to the sound radiation of the flanking element. The third flanking path (Fd) will contribute to the sound radiation of the separation wall and therefore reduces the partial sound reduction of the separation wall. In case of four junctions, the partial sound reduction of the direct separation wall consists of five contributing sound reductions (R_{ij}): the direct sound reduction (R_d) and four flanking sound reductions ($R_{ceiling,Fd}$, $R_{facade,Fd}$, $R_{floor,Fd}$, $R_{innerwall,\ Fd}$).

2.2 Deduction of target values for partial sound reductions and for flanking paths

In order to achieve a certain criterium value $R'_{w,crit}$ for the overall sound reduction index in wooden CLT-buildings, the laboratory value for the air borne sound reduction of the direct separation should preferably be at least 7 dB higher ($R_{w,s} \geq R'_{w,crit}$+7 dB) [4]. A similar increment of at least 7 dB above the criterium value should be set for the flanking contribution of each junction ($\Sigma R_{ij}=R_{Ff}+R_{Df}+R_{Fd} \geq R'_{w,crit}+7$ dB).

For example, if the demand for the weighted sound reduction index is $R'_w \geq 52$ dB, the laboratory value of the direct sound reduction of the separation should be at least $R_{w,s} \geq 59$ dB and the contribution of each of the four flanking elements should also be also at least 59 dB. This means that the average sound reduction of each individual flanking sound transmission path (R_{ij}) should be at least 64 dB. In that case the partial sound reduction of each flanking element should be at least $R'_w \geq 61$ dB and the partial sound reduction of the direct separation wall should be at least $R'_w \geq 55$ dB (including four flanking contributions of R_{ij}=64 dB each).

3. PROJECT RESULTS

Recent experience with a multi-storey apartment building (project X) will be treated to illustrate how construction level measurements can be used in the validation process of CLT-buildings. In this building measurements of the air borne sound reduction and the impact sound insulation have been performed. Several measurement results of the horizontal airborne sound reduction between adjoining

dwellings will be discussed in this paper. Experiences with the impact sound insulation measurements and their validation will be treated in a separate paper.
In the project the horizontal sound reduction indices measured between living rooms of adjoining apartments on the upper level appeared to be 3 dB lower than the results on the middle level, with yet a fully identical separation wall. Therefore, additional detailed measurements of the partial sound reduction contributions of the direct and flanking elements in the receiving rooms were performed using construction level measurements, to analyse possible reasons for this difference. The resulting partial sound reductions measured are summarised in the 2nd column of table 1 (upper level) and table 2 (middle level) and are discussed thereafter.
Additionally, calculations of the flanking sound contributions of individual sound paths have been performed according to the calculation formulas of the simplified model [1], using mostly - unless stated otherwise - input data regarding K_{ij}- and R_i-values from [2] and [4]. For specific situations, a comparison with K_{ij}-values from ISO 12354-1 has been made. The results of these calculations are summarised in the 3rd column of the same tables 1 and 2 – and discussed thereafter – to allow for a direct comparison between the calculated flanking sound reduction values and the measured partial sound reduction values. This also gives an opportunity to validate the calculations and input values used.
Relevant data on the build-up of the direct and flanking elements concerned is summarised in the last column of both tables.

Table 1. Partial horizontal sound reduction index values (R'_w in dB) measured (based on construction level measurements) vs. calculated values (flanking paths calculations) in project X between two adjoining living rooms on <u>upper</u> floorlevel

Surface	Measured R'_w (dB)	Calculated R_{ij} (dB)	Diff. (dB)	Description and input data
Roof	52	R_{Ff} = 46/52 R_{Df} = 73 ΣR = 46/52	-6/-2/0	140 CLT (66 kg/m^2, continuous) + insulation (145 mm PIR) + 2 layers of 4 mm bitumen, total mass 79 kg/m^2 ($R_{f,w}$=38 or 45).
Floor	64	R_{Ff} = 81 R_{Df} = 85 ΣR = 79	+15	70 screed + 40 MW (s'=15) + 200 CLT (94 kg/m^2, dilatated, elastomer top/bottom) ($R_{Dd,w}$=57 dB, $R_{s,w}$=43 dB, $\Delta R_{Dd,w}$=14 dB)
Façade	57	R_{Ff} = 49/57 R_{Df} = 73 ΣR = 49/57	-8/0	100 CLT (47 kg/m^2, $R_{f,w}$=35 dB or 43 dB fitting value) + insulation (145 mm PIR) + rooftiles
Rear wall	61	-		100 CLT (no direct connection to separation wall)
Side wall	73	-		80 CLT (no direct connection to separation wall)
Separation wall (hxb=2.6x4m)	<u>54</u>	R_{Dd} = 57 $R_{roof,Fd}$ =53/57 $R_{facade,Fd}$ =54/58 $R_{floor,Fd}$ =72 ΣR = 50/53	-4/-1	120 CLT (56 kg/m^2) with one sided planking of 2 x 12,5 mm gypsumboard (24 kg/m^2) on free standing metal profiles (50 mm with 40 MW) on 10 mm distance ($R_{Dd,w}$=57 dB, $R_{s,w}$=37 dB, $\Delta R_{Dd,w}$=20 dB)
Summation of partial insulations:	49	ΣR_{ij} =43/49	-6/0	
Measured value (appararent sound reduction) R'_w	47		-4/+2	
difference	-2			

Table 2. Partial horizontal sound reduction index values (R'$_w$ in dB) measured (construction level measurements) vs. calculated (flanking paths calculations) in project X between two adjoining living rooms on middle floor level

Surface	Measured R'$_w$ (dB)	Calculated R_{ij} (dB)	Diff. (dB)	Description and input data
Ceiling	59	R_{Ff} = 59 R_{Df} = 78 ΣR = 59	0	200 CLT (94 kg/m^2) dilatated, elastomer top/bottom ($R_{f,w}$=43 dB)
Floor	63	R_{Ff} = 81 R_{Df} = 85 ΣR = 79	+16	70 screed + 40 MW (s'=15) + 200 CLT (94 kg/m^2, dilatated, elastomer top/bottom) ($R_{Dd,w}$=57 dB, $R_{s,w}$=43 dB, $\Delta R_{Dd,w}$=14 dB)
Façade	57	R_{Ff} = 50/57 R_{Df} = 75/79 ΣR = 50/57	-7/0	100 CLT (47 kg/m^2, $R_{f,w}$=35 dB or42 dB fitting value) + insulation (160 mm MW) + brickwork
Rear wall	72	-		100 CLT (no direct connection to separation wall)
Side wall	74	-		80 CLT (no direct connection to separation wall)
Separation wall (hxb=2.6x5.3m)	56	R_{Dd} = 57 $R_{ceiling,Fd}$ =58 $R_{facade,Fd}$ =55/59 $R_{floor,Fd}$ =72 ΣR = 51/53	-5/-3	120 CLT (56 kg/m^2) with one sided planking of 2 x 12,5 mm gypsumboard (24 kg/m^2) on free standing metal profiles (50 mm with 40 MW) on 10 mm distance ($R_{Dd,w}$=57 dB, $R_{s,w}$=37 dB, $\Delta R_{Dd,w}$=20 dB)
Summation of partial insulations:	52	ΣR_{ij} =47/51	-5/-1	
Measured value (appararent sound reduction) R'$_w$	50		-3/+1	
difference	-2			

3.1 Explanation on the results of measured partial sound reductions

With respect to the partial sound reduction contributions as measured between adjoining living rooms and summarised in table 1 and 2, the following conclusions can be drawn:

From the measured values of the partial weighted sound reduction in table 1, the following priority for the contributions to the total weighted horizontal sound reduction index measured of R'_w=47 dB on the upper level can be deduced:

- 1st: roof
- 2nd: separation wall
- 3rd: façade
- 4th: rear wall
- 5th: floor
- 6th: side wall

On the upper level the roof has the lowest partial sound reduction value and therefore is a main contributor to the horizontal sound reduction measured. This is because the CLT-plate (140 mm) used for the roof is continuous at the (rigid) connection to the bearing separation wall, without a dilatation or ballast layer, as is shown in the cross-section detail in figure 2.

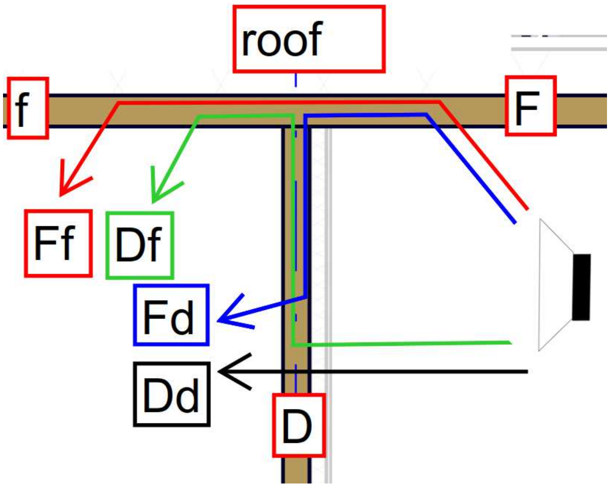

Figure 2. Cross-section at the junction of separation wall (with one-sided cladding) and continuous CLT-roof, with schematic indication of the contributions to the airborne sound reduction in the measurement direction, with direct sound transmission path (Dd) and three flanking paths (Ff, Fd, Df).

From the measured values of the partial weighted sound reduction in table 2, the following priority for the contributions to the total weighted horizontal sound reduction index measured of R'_w=50 dB on the middle level can be deduced:

- 1st: separation wall
- 2nd: façade
- 3rd: ceiling
- 4th: floor
- 5th: rear wall
- 6th: side wall

In this case the 200 mm CLT-ceiling has a 7 dB higher partial insulation value measured (R'_w=59 dB) than that of the continuous 140 mm CLT-roof plate (R'_w=52 dB). This is mainly due to the discontinuity in the ceiling by a separation cut that has been applied in the CLT-ceiling at the junction with the separation wall, and partly due to its higher mass and a limited additional decoupling effect (elastomer at the top and bottom (conventional screws)).

When significant higher values for the apparent sound reduction than those measured in this example project are aimed for, thorough attention and advice on possible improvements in an early design phase will be needed for at least the first three elements in both priority lists (roof/ceiling, separation wall, façade). In this process validated prediction calculations with the simplified model regarding the effect of possible adaptations are useful.

The next paragraphs will explain how the measured values can be used to validate calculations and their input data.

3.2 Explanation on the results of calculated partial sound reductions

With respect to the different calculated values for the sound reduction contributions of several sound paths through flanking elements as given in table 1 and table 2 and the differences, if any, with the partial sound reduction values measured, the following explanatory remarks and interpretations can be given.

3.2.1 Roof

For a continuous 140 mm CLT roof with insulation the partial sound reduction measured (R'_w=52 dB) – based on a single measuring point on the middle of the CLT-ceiling and a assumed radiation factor σ of 1 – is 6 dB higher than the sum of the calculated contributions of both flanking paths radiating from the roof (R_{Ff}+R_{Df}=46 dB), see table 1.

These first calculations are based on a vibration reduction index of K_{Ff}=3 for a continuous floor (T-or X-junction) [2] as well as on a flanking sound reduction of the CLT-roof of $R_{f,w}$=38 dB (25log(m)-7 [4]) for which at first only the mass of the CLT-layer (66 kg/m^2) of the roof is considered.

If the sound reduction of the flanking CLT-roof is considered to be determined by the total effective mass of the CLT including the added mass of the (stiff) thermal insulation plates (PIR) (4.5 kg/m^2) and the bituminous layers (8 kg/m^2) the total mass becomes 79 kg/m^2 which – if based on mass - results in a 2 dB higher sound reduction ($R_{f,w}$=40 dB) and reduces the difference with the measured value down to 4 dB. However, this slight increase of mass cannot account for the total difference.

If the sound reduction index for the flanking CLT-roof is assumed to be at least equal to the measured laboratory value of the direct sound reduction (including resonant and forced transmission) of the total roof build-up – which may be tempting but can be judged as a valid assumption because of the rather stiff (PIR) thermal insultation plates that are attached with rigid connectors to the CLT-roof plate - a value of $R_{f,w}$=45 dB can be interpolated for the total roof build-up, based on available laboratory data – on direct sound reduction values of several roof types - in a building catalogue [4]. In that case the sum of the calculated contributions of both flanking paths radiating from the ceiling (R_{Ff}+R_{Df}=52 dB) matches exactly the measured value of the partial sound reduction of the ceiling (R'_w=52 dB).

However, if the calculation for the flanking of the continuous CLT-roof would be performed based on the vibration reduction index values in ISO 12354-1 (E.3.2.3) [1] - with an additional assumption that K_{Ff}-values for T-junctions are almost the same as for X-junctions - a 6 dB higher value of K_{Ff} =9,3 dB would result. In that case an exact match of the calculated values (R_{Ff}+R_{Df}=52 dB) with the measured value can also obtained in case $R_{f,w}$=38 dB is used as input for the flanking sound insulation based on the mass of a 140 mm CLT-plate of the roof itself, without any increasing influence of attached PIR-insulation or bituminous roofing.

3.2.2 Ceiling

For the 200 mm thick dilatated ceiling the sum of the calculated contributions of both flanking paths radiating from the ceiling (R_{Ff}+R_{Df}=59 dB) exactly matches the partial reduction value of the ceiling, as measured on the middle floor level, see table 2. In that case the calculations are based on a vibration reduction index of K_{Ff}=10.3 for the dilatated ceiling [2], a flanking sound reduction of the CLT-ceiling of $R_{f,w}$=43 dB (25log(m)-7[4]) based on the surface mass of 94 kg/m^2 of the CLT-layer itself, as well as on a limited decoupling effect of ΔK=2 dB (elastomer at top/bottom with conventional fasteners)

3.2.3 Floor

For the floor, the partial horizontal sound reduction index measured is similar on both levels (R'_w=63-64 dB) and is 15-16 dB lower than the sum of the calculated contributions of both flanking paths radiating from the floor (R_{Ff}+R_{Df}=79 dB). These calculation results are based on a vibration reduction index of K_{Ff}=10.3 for the dilatated CLT-floor [2], a sound reduction improvement of $\Delta R_{Dd,w}$=14 dB for the floating slab and a limited decoupling effect (ΔK=2 dB). This large difference is most likely caused by a missing dilatation in the floating slab under the entrance doors at the time of measurement, which caused a direct coupling between the slabs of both adjoining living rooms via the corridor.

3.2.4 Façade

For the façade, that consists of a 100 mm CLT element placed on the CLT-floor but continuous at the connection to the 120 mm CLT-separation wall, the partial horizontal sound reduction indices measured (R'_w=57 dB)) – based on four to five measuring points on the façade and an assumed radiation factor σ of 1 – are the same at both levels measured, see table 1 and 2. These values are 7-8 dB higher than the sum of the first calculated contributions of both flanking paths radiating from the façade (R_{Ff}+R_{Df}=49-50 dB). These first calculations are based on a vibration reduction index of K_{Ff}=8.3 for continuous facades [2] and on a flanking sound reduction of the CLT-façade of $R_{f,w}$=35 dB (=(25log(m)-7) based on the surface mass of 47 kg/m^2 of the CLT-layer itself.

A possible partial explanation for the significant difference may be that the closed parts of the CLT-façade on both sides of the separation wall up to the intersections with large windows are rather small (0,5 m wide), which is not accounted for in the simplified calculation model.

Another explanation for this large difference of 8 dB may be that the flanking sound reduction of the 100 mm CLT-façade may be raised by the influence of added insulation and/or rather stiff connections with a heavy outer blade. On the top level these elements consist of stiff (PIR) thermal insulation plates attached to the CLT-blade, and directly on this insulation wooden laths with concrete rooftiles (45

kg/m^2). On lower levels an outer façade of 100 mm brickwork is attached to the CLT inner blade for stability by rigid connectors (anchors, point connections) with mineral wool insulation plates in the void against the CLT.
In these cases a fitting value for the effective flanking sound reduction of $R_{f,w}$=42-43 dB can be deduced if the difference between calculations and measured value should be zero, which is not unlikely for a flanking sound reduction index of these façade build-up compared with direct sound reduction values in databases [4], also because this value corresponds with an effective acoustic mass of 90-100 kg/m^2.
The database of ISO 12354-1 does not yet provide data for comparable CLT-junctions with a continuous CLT-façade element, unless the K_{ij}-values for an X-junction according E.3.2.3 in ISO 12354-1 [1] are assumed to be also valid for this T-junction, in which case a 3 dB higher value of K_{Ff} =11 dB would result and the difference with the measured values reduces to 4-5 dB and the fitting value for the effective flanking sound reduction of the façade reduces to $R_{f,w}$=39-40 dB.

3.2.5 Separation wall

For the direct separation wall, consisting of a 120 mm CLT element with one-sided free-standing planking of double gypsum (24 kg/m^2) on 60 mm void (40 mm mineral wool) the partial horizontal sound reduction indices measured– based on a single measuring point on the middle of the CLT-wall and a assumed radiation factor σ of 1 – I are R'_w=54 dB on the top level and R'_w=56 dB on the middle level. This difference is mainly caused by the contribution of the flanking sound reduction R_{Fd} of a continuous CLT-roof vs. a dilatated CLT-ceiling.
The sum of the calculated contributions of the direct path and three flanking paths, all radiating from the CLT-side of the separation wall (R_{Dd} +$R_{roof,Fd}$ + $R_{facade,Fd}$ + $R_{floor,Fd}$) are 4-5 dB below the value of partial sound reduction measured. With adapted values for the effective flanking sound reduction of the roof and the façade – as mentioned above - these differences reduce to 1 -3 dB. These calculation results are based on vibration reduction indices according [2], limited decoupling effect (ΔK=2 dB) as mentioned before, a direct and flanking sound reduction value for the 120 mm CLT-wall of $R_{s,w}$=37 dB and a sound reduction improvement of $\Delta R_{Dd,w}$=20 dB for the free-standing planking, and therefore a direct sound reduction of the separation wall of $R_{Dd,w}$=57 dB.

3.3 Explanation on the results of the overall summations of partial sound reductions measured and calculated

With respect to the results of the overall summations of measured and calculated partial sound reductions between adjoining living rooms as summarised in table 1 and 2, the following remarks are made:

In both situations, on the upper floor as well as on the middle floor, the summed value of all partial horizontal sound reductions measured remains 2 dB above the actual weighted sound reduction indices measured.
A likely explanation for this difference of 2 dB is that apparently not all sound radiating surfaces have been measured or accounted for. This is related to a practical choice on site between efficiency of the measurements vs. the amount of measuring positions for the construction level measurements. In this case for instance no accelerometers were placed against a small part of the roof surface in the dormers (continuous 100 mm CLT), where-as this part may contribute significantly due its smaller thickness compared with the main roof (140 mm CLT).
Another possibility is that the amount of measuring points for the construction level measurements on each surface should have been higher for more accuracy, and/or that the assumed radiation factor (σ=1) has been too low for some surfaces.

In both situations, the summed value of the sound reductions of all calculated sound paths (1 direct path and 9 flanking paths) remains 4 to 5 dB below the summed value of all measured partial sound reductions and remains 3 to 4 dB below the measured apparent sound reduction values of R'_w=47 and R'_w=50 dB, see table 1 and 2. A possible explanation for these (remaining) differences might be the inherent inaccuracy of the simplified model and its limitations [1]. If adapted values for the effective flanking sound reduction of the roof and the façade are applied as described before, these differences reduce to 0 to -1 dB resp. +1 to +2 dB.

4. CONCLUSIONS, DISCUSSION AND RECOMMENDATIONS

Construction level measurements pose a valuable tool to validate calculations of the sound reduction of individual sound paths. In the project example described a significant difference appeared in the horizontal sound reduction measured between adjoining living rooms on top floor level compared with the same separation wall on the middle floor. Detailed measurements of the partial sound reduction combined with calculations of the sound reduction of flanking paths according to the simplified model, have shown that this difference is mainly caused by the differences between the build-up of the roof (as a continuous CLT-element) and the ceiling (dis-continuous CLT-element).

The calculated flanking sound reduction values of the continuous roof give the best agreement with measured values when input data of ISO 12354-1 is used [1]. On the other junctions is this example project no corresponding junction type were available in ISO 12354-1 so far, however input data on these was available in another database [2].

For the continuous CLT-façade the calculated flanking sound reduction values could only be matched with the measured values if an increased sound reduction is assumed corresponding to an assumed increased effective mass due to the type of connection with the heavy outer blades (i.c. brickwork and rooftiles).

If adapted values for the effective flanking sound reduction of the roof and the façade are applied, differences between the total calculated sound reduction and the measured appararent sound reduction values are below 2 dB.

In all cases subtraction of the prediction uncertainty value (u=2 dB) [4] has not yet been applied for the calculated values of the sound reductions of the sound paths, neither for the overall values nor for the individual contributions. This is mainly because in this case the comparison of calculated results with measured values concerns a single measured situation which is more likely to represent an overall average of a natural distributed set of similar situations rather than to belong to the 5% worst case situations. However, when the goal of such calculations is to match a requirement that must be met for at least 95% of all similar cases (measured), this subtraction of u=2 dB should be applied before comparison of the calculated results with the requirement value occurs.

When significant higher values for the apparent sound reduction than those measured in this example project are aimed for, thorough attention and advice on possible improvements in an early design phase will be needed for elements that are most relevant regarding their limited partial sound insulation, in this case roof/ceiling, separation wall and façade. In this process validated prediction calculations with the simplified model regarding the effect of possible adaptations are usefull to consult on the most efficient way to reach the quality level of sound reduction aimed for.

In addition to the existing databases of the airborne sound reduction of CLT-roof structures, such as in [2], it is recommended to add validated data on the flanking sound reduction as well.

It is recommended to expand the ISO 12354-1 database with more recent extended validated data comparable with [2], as well with input data validated for post and beam buildings.

5. REFERENCES

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