Method to predict airborne flanking through concrete floors with nibs at the base of lightweight walls using ISO 12354-1

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Abstract

Typically in the New Zealand residential market, concrete floor systems with lightweight walls are the preferred construction method. As floor slabs become progressively thinner, what consistently effects the achievement of the airborne acoustic design targets between adjacent residential units is the noise flanking transmission through the floor.

A solution to limiting flanking is identified in this paper for when it is not possible to have a slab of sufficient overall thickness, or when a floating floor or floating screed is not a cost effective option. The solution, utilising the introduction of a concrete nib along the wall line, reduces the floor to floor flanking noise transmission and promotes the achievement of better sound insulation ratings onsite.

The objective of the research is to determine whether the scientific prediction method contained within ISO 12354-1:2000 - "Building acoustics - Estimation of acoustic performance in buildings from the performance of elements – Part 1: Airborne sound insulation between rooms" can be adapted to accurately predict the flanking reduction achieved through the introduction of a concrete nib into a heavy-floor/ lightweight-wall system. The standard is under review, but from the draft available, the prediction approach for this specific application has not changed and the proposed method in this paper is still valid.

Comparisons of predicted results with several field test results are made to verify the accuracy of the methodology. Incorporating a concrete nib into the wall-floor junction appears to effectively reduce the vibration transmission through the floor slab by introducing a secondary dissipation path for the sound energy running through the floor slab.

Additional testing should be done to validate the theoretical model, however, based on the analysed data to-date, it appears that ISO 12354-1:2000 gives good correlation between the predicted and field-measured weighted sound reduction index when a nib is introduced at the wall-floor junction.

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1. Introduction

The New Zealand Building Code (NZBC) clause G6 "*Airborne and Impact Sound*" stipulates that "*Building elements which are common between occupancies, shall be constructed to prevent undue noise transmission from other occupancies or common spaces, to the habitable spaces of household units.*"

The NZBC calls for the Sound Transmission Class (STC) of walls, floors and ceilings between apartments to be a minimum standard of STC 55 when tested in the laboratory situation. The code then allows for a reduction in performance of 5 dB for the same construction when tested in the field situation, i.e. FSTC 50 in-situ. Both the laboratory rating and in-situ performance must be achieved in order to meet the NZBC requirements.

Historically, floor thicknesses have been sufficient to limit noise flanking to an acceptable level, but as floor slabs become progressively thinner (in part due to New Zealand seismic event design considerations), the proposed slabs compromise the achievement of the acoustic design targets.

A solution to limiting flanking is indentified in this paper for when is not possible to have a sufficient overall thickness of the floor slab, or when a floating floor or floating screed is not a cost effective option. This solution, utilising the introduction of a concrete up-stand or "*Nib*" along the wall line, reduces the floor to floor flanking noise transmission and promotes the achievement of better values on site.

It should be noted that the ASTM standard used in the NZBC does not propose an ISO equivalent prediction method for flanking transmission, and slight differences (maximum 2 dB) between the FSTC (Field Sound Transmission Class) parameter proposed by the ASTM and the R'_w (Apparent Sound Reduction Index) proposed by the ISO standard are expected. For the purposes of the remainder of this paper, R'_w will be used in place of FSTC to enable direct application of the ISO methodology.

2. Case studies

Three combinations of slab system and separating walls have been tested on different sites and the results have been compared to predictions using ISO 12354-1. In all cases, the floor-wall junction incorporated a concrete nib.

Norman Disney & Young proprietary software was used for the ISO prediction, with the software making use of the "simplified method" generally, but using the "detailed method" in the prediction of the flanking through the floor.

In all three analyzed cases, separating walls with high Rw ratings have been proposed.

A plasterboard ceiling on both sides of the wall was installed to reduce the flanking through the upper slab, and the wall/facade junction has been designed to not transmit a significant amount of energy from one unit to the other.

The following image schematically represents the cases of study. The primary transmission paths are through the separating wall and flanking through the bottom floor.

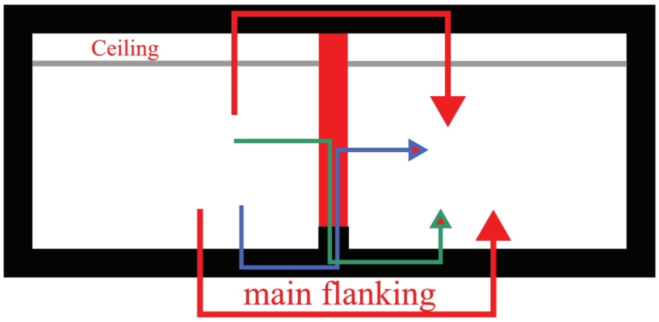


Figure 1: Schematic of flanking noise paths

The three case study combinations are described below.

2.1 Case 1 - Precast concrete T slab

In this case, the project brief was to maximise the wall sound insulation rating (R'_w essentially maximized), limited, of course, by construction practicalities. The following floors and walls were proposed.

2.1.1 Floor

- Precast concrete T slab (200mm overall depth) + 100mm concrete topping
- Minimum thickness of the concrete: 150mm
- Total weight: 410 kg/m^2
- Laboratory R_w: 54 dB

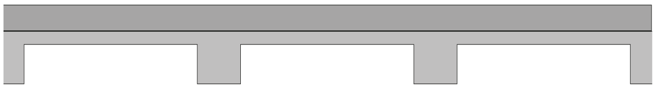


Figure 2: Diagram of Case 1 floor construction - Precast concrete T slab

2.1.2 Separating Wall

- Double steel frame (64mm + 64mm studs) wall, studs at 600mm centres, 20mm gap between frames
- 2 layers of 13mm plasterboard (≈13 kg/m^2 per layer) on each side
- 90mm layer of polyester insulation (≈10 kg/m^3) in the cavity
- Total weight: 52 kg/m^2
- Laboratory Rw: 63 dB

The precast concrete T slab was orientated with the beams perpendicular to the separating wall as shown in the following sketch.

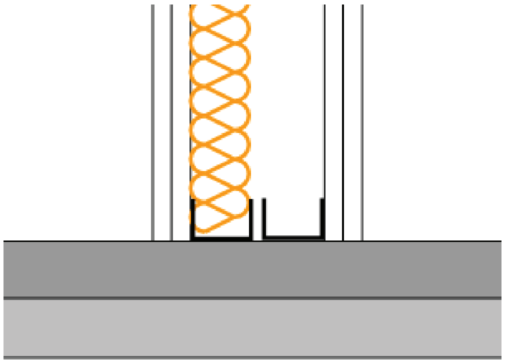
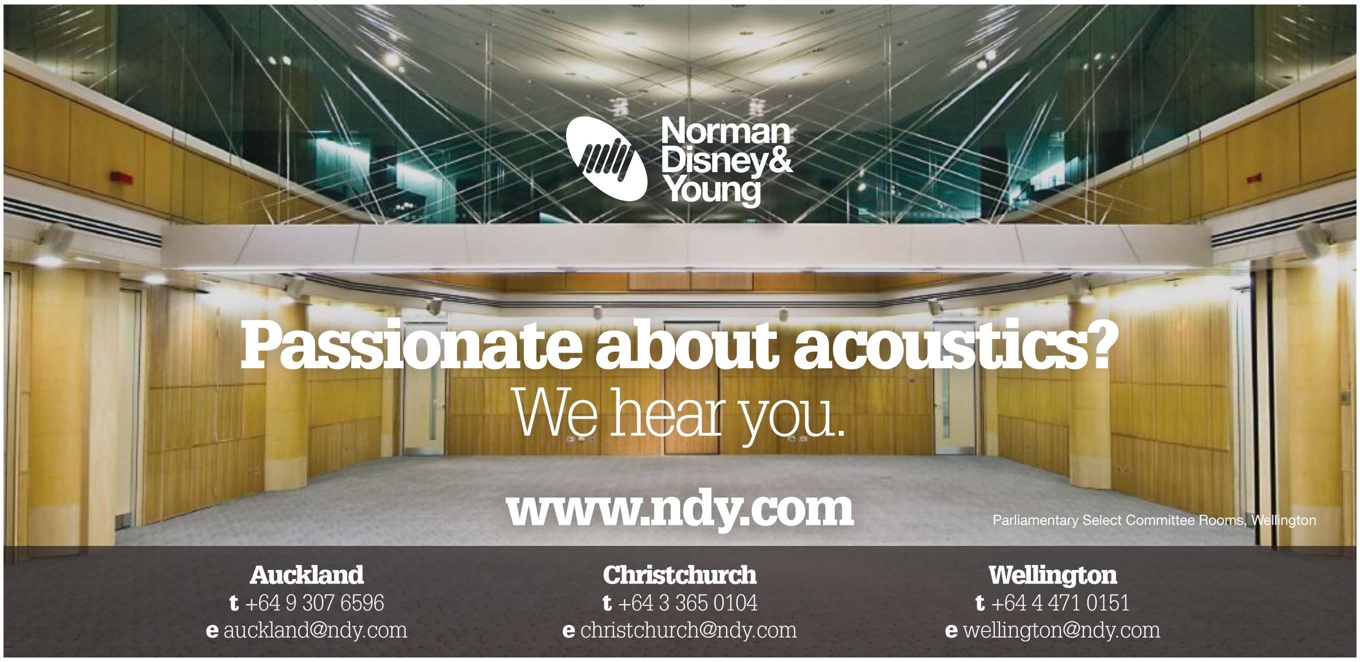


Figure 3: Vertical cross section orientation of the Case 1 floor

2.2 Case 2 - Corrugate steel deck slab

In this case, the project brief was to achieve the minimum NZBC rating (essentially R'_w = 50 dB) with the proposed wall and floor construction. The following floors and walls were proposed.



2.2.1 Floor

- Corrugated steel deck with 120mm thick concrete topping
- Minimum thickness of the concrete: 65mm
- Total weight: 230 kg/m^2
- Laboratory R_w: 45 dB

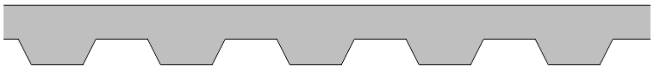


Figure 4: Diagram of Case 2 floor construction - Corrugate steel deck

2.1.2 Separating Wall

- Double steel frame (64mm + 64mm studs), studs at 600mm centres, 20 gap between frames
- 2 layers of 13mm plasterboard on one side and 1 layer of 13mm plasterboard on the other side (≈10.5 kg/m^2 each), fixed vertically at 600 centres in each row
- 75 mm layer of polyester insulation (≈10 kg/m^3) in the cavity
- Total weight: 33 kg/m^2
- Laboratory R_w: 58 dB

The corrugated steel deck slab was orientated with tray profile perpendicular to the separating wall as shown in the following sketch.

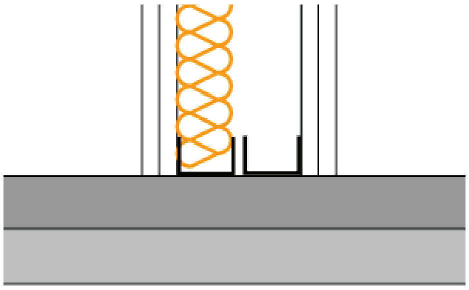


Figure 5: Vertical cross section orientation of Case 2 floor

2.3 Case 3 – Suspended concrete flooring system

In this case, the project brief was to achieve the minimum NZBC rating (essentially R'_w = 50 dB) with the proposed wall and floor construction. The following floors and walls were proposed.

2.3.1 Floor

- 400mm joist system floor with 90mm concrete topping
- Minimum thickness of the concrete: 90mm
- Total weight: 220 kg/m^2
- Laboratory R_w: 48 dB

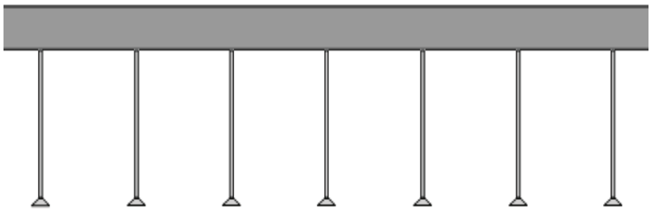


Figure 6: Diagram of Case 3 floor construction - Joist system floor

2.3.2 Separating Wall

- Double timber frame wall (90mm + 90mm studs), studs at 600mm centres, 20mm gap between frames
- 2 layers of 13mm plasterboard (≈10.5 kg/m^2 each layer) on both sides
- 90 mm layer of polyester insulation (≈10 kg/m^3) in the cavity
- Total weight: 45 kg/m^2
- Laboratory R_w: 61 dB

The suspended concrete flooring slab was orientated with the beams perpendicular to the separating wall as shown in the following sketch.

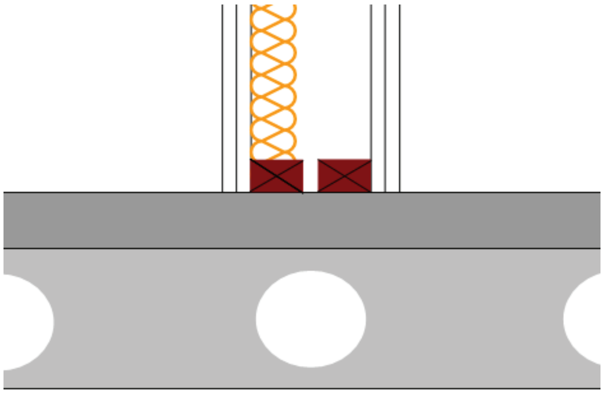


Figure 7: Vertical cross section orientation of Case 3 floor

3. Proposed solution - Concrete nib at wall base

In the absence of traditional flanking-reduction treatments to the bottom floor (floating floor or floating screed) - considered too expensive - the required airborne rating is not possible to achieve in-situ as the sound energy transmitted through the bottom slab, in the absence of sufficient thickness, produces a short-circuit in the wall performance.

The solution adopted to reduce the floor transmission onsite consists of the introduction of a 200mm x 200mm (WxH) concrete nib at the base of the separating wall, extended across the entire length of the wall. The separating wall was then constructed on, and around, the nib, as shown in the following sketch.

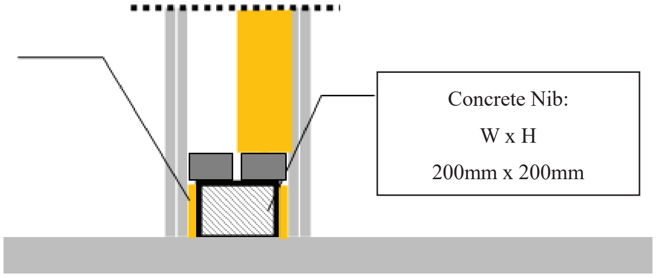


Figure 8: Nib configuration to limit flanking

The following photos show how the nib and wall were constructed onsite.

Figure 9: Photos onsite of the nib solution

3.1 Flanking transmission prediction between non-homogenous constructions ISO 12354-1

ISO 12354-1:2000 proposes a predictive method for calculating flanking transmission in section 4.4.1, in which the following mathematical formula is applied:

$$R_{Ff,w} = \frac{R_{F,w} + R_{f,w}}{2} + \Delta R_{Ff,w} + K_{Ff} + 10\lg\frac{S_s}{l_0 l_f}\ \text{dB} \qquad (1)$$

Where:

$R_{Ff,w}$ is the weighted sound reduction index of the F_f element, in decibels

$R_{F,w}$ is the weighted sound reduction index of the flanking element F in the source room, in decibels;

$R_{f,w}$ is the weighted sound reduction index of the flanking element f in the receiving room, in decibels;

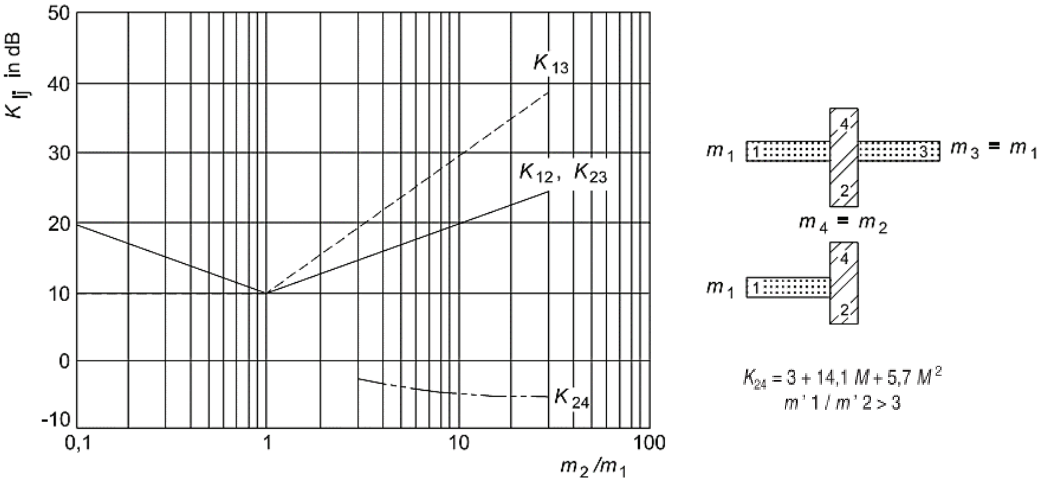


Figure 10: Junction of lightweight double leaf wall and homogeneous elements – ISO 12354-1:2000

$\Delta R_{Ff,w}$ is the total weighted sound reduction index improvement by additional lining on the source and/or receiving side of the flanking element, in decibels;

K_{Ff} is the vibration reduction index for transmission path *Ff*, in decibels;

S_s is the area of the separating element, in square metres;

l_f is the common coupling length of the junction between separating element and the flanking elements *F* and *f*, in metres;

l_o is the reference coupling length; l_o = 1 m.

The most effective parameter of the equation is the vibration reduction index K_{Ff}. Annex E of ISO 12354-1:2000 proposes several combinations for this junction.

The parameter K_{Ff} is related to the mass per unit area of the elements connected at the junction, m_1 and m_2 according to the following equation:

$$M = 10\lg \frac{m'_{\perp i}}{m'_i} \qquad (2)$$

Where:

$m'i$ is the mass per unit area of the element *i* in the transmission path *Ff*, in kilograms per square metre;

$m'_{\perp}i$ is the mass per unit area of the other, perpendicular, element making up the junction, in kilograms per square metre.

ISO 12354-1:2000 proposes different types of connections, but in this case of study, only the following junctions are considered:

1. Junction of lightweight double leaf wall and homogeneous elements
2. Rigid T-junction

The main junction between the dividing wall and the bottom floor slab is schematically represented by the ISO standard as the junction of a lightweight double leaf wall and a homogeneous element (equation E7). As illustrated earlier in Figure 10, this is the main noise flanking path.

In the case of junctions between heavy floors and lightweight walls, the "simplified" method proposed by ISO 12354-1:2000 has been shown, from testing comparisons, to underestimate the R_{Ff} flanking sound reduction index, therefore, our calculations were implemented with the "*detailed*" ISO approach. On this basis, the previous simplified formula (1) was replaced for this junction with formula 25a of the ISO 12354-1:2000:

$$R_{Ff} = \frac{R_{F,situ}}{2} + \Delta R_{F,situ} \frac{R_{f,situ}}{2} + \Delta R_{f,situ} + \overline{D_{v,Ff,situ}} + 10\lg \frac{S_s}{\sqrt{S_F S_f}} \quad \text{dB} \qquad (3)$$

All the parameters are similar to those in formula (1), except for the in-situ transmission $\overline{D_{v,Ff,situ}}$ and the source and receiving room floor surface areas, S_i and S_j, respectively.

The in-situ transmission is calculated using formula 21 of the ISO 12354-1:2000:

$$\overline{D_{v,Ff,situ}} = K_{Ff} - 10\lg \frac{l_{Ff}}{\sqrt{a_{F,situ} a_{f,situ}}} \quad \text{dB}$$

$$\overline{D_{v,Ff,situ}} \geq 0 \text{ dB} \qquad (4)$$

Where $a_{F,situ}$ and $a_{f,situ}$ are functions of the structural reverberation time of the elements and K_{Ff} is the vibration reduction index.

3.2 Modelling variation of the wall-floor junction - Concrete nib at wall base

Incorporating a concrete nib into the wall-floor junction changes the vibration transmission behaviour through the floor slab by introducing a secondary dissipation path for the sound energy running through the floor.

This in turn alters the way in which we should apply the ISO 12354-1:2000 junction calculation from a lightweight

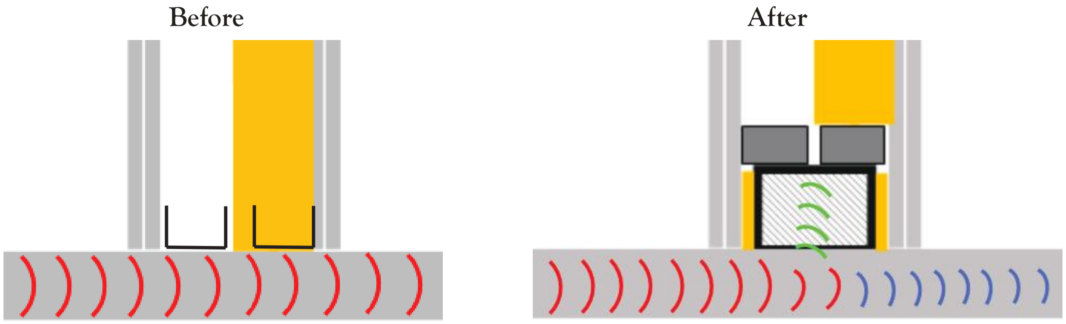


Figure 11: Vibrational energy dissipation at the wall-floor junction in the absence and presence of a concrete nib

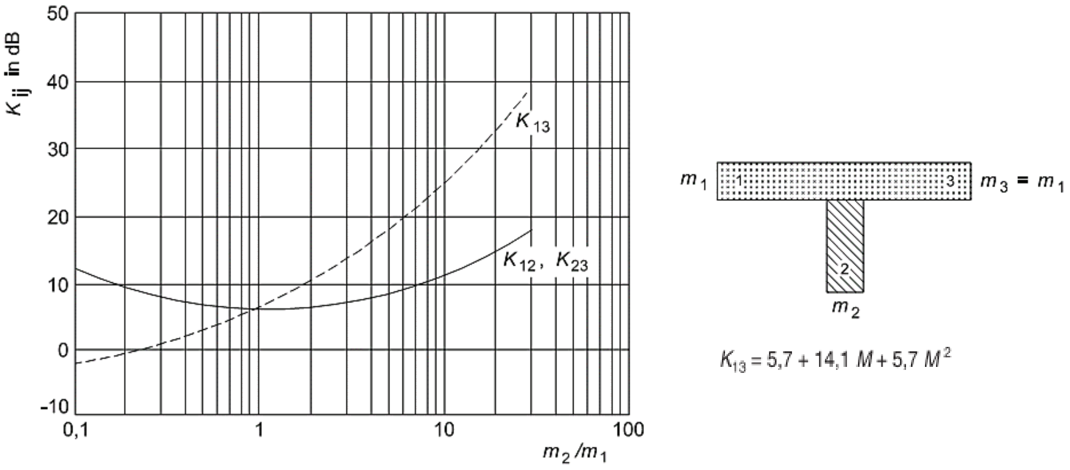


Figure 12: Rigid T-junction equation – ISO 12354-1:2000

double leaf wall and homogeneous elements connection, to a rigid junction. The bottom wall-floor junction is replaced with a rigid T junction as proposed in the equation E.4 of ISO 12354-1 (see figure 12).

The mass per square metre of the concrete nib is considered for the connection at the bottom wall-floor junction only, while at the other junctions (wall-ceiling, wall-sidewall_1 and wall-sidewall_2), the original mass of the plasterboard wall is considered.

In this case, the simplified model (formula (1)) was applied at the bottom wall-floor junction, because as demonstrated by the NRC publication, "*Guide to calculating airborne sound transmission in buildings*" [6], the simplified and detailed method give the almost identical results for rigid connections.

A mass per square metre of 400 has been assumed only at the bottom junction wall/floor where the nib is introduced. The other junctions maintain the original M (formula 2) value.

The figure 13 below illustrates the mass that is assumed for the separating wall at the four junctions.

3.3 Results

The proposed flanking prediction method described above has been employed and compared to onsite test data obtained for the three case studies. Table 1 shows the results, inclusive of the estimated performance had the concrete hob not been installed.

The prediction of the ISO 12354-1 appears to be accurate in a range of ± 2 dB and in most of the case the results differs by 1 point.

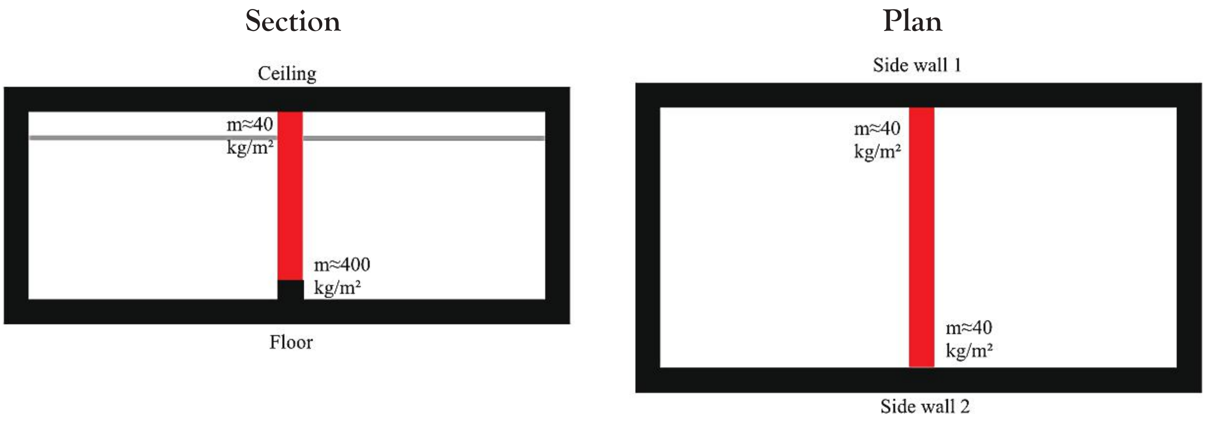


Figure 13: Mass per square metre assumed at each junction

Table 1: Comparison between predicted and Measured R'_w

Location	R_w wall (dB)	Predicted R'_w (dB) ISO 12354-1 Without Nib	Predicted R'_w (dB) ISO 12354-1 With Nib	R'_w (dB) Measured Onsite	Nominal R'_w Target
Test 1 Apt 15-Apt 16 (Case 1: R_w 54 dB floor)	63	55	58	57	Max Possible
Test 2 Apt 11-Apt 10 (Case 1: R_w 54 dB floor)	63	54	57	58	Max Possible
Test 3 Apt 13-Apt 14 (Case 1: R_w 54 dB floor)	63	55	58	57	Max Possible
Test 4 Apt 2-Apt 1 (Case 1: R_w 54 dB floor)	63	54	58	60	Max Possible
Test 5 Apt 1716-1717 (Case 2: R_w 45 dB floor)	58	48	53	54	50
Test 6 Apt 1202-1203 (Case 2: R_w 45 dB floor)	58	47	52	50	50
Test 7 Apt 1501-1502 (Case 3: R_w 45 dB floor)	58	46	51	52	50
Test 8 Apt 1602-1603 (Case 2: R_w 45 dB floor)	58	48	52	54	50
Test 9 Apt 214-215 (Case 3: R_w 48 dB floor)	61	50	56	57	50

Using this prediction method, it can be shown that when the thickness of the floor slab is insufficient, wall ratings below R'_w 50 dB can be expected onsite due to flanking via the floor.

A clear demonstration of this is that the increase obtained with the introducing of the nib is more perceptible when the mass/thickness of the floor is lower. In presence of a massive floor, the increment of performance given by the nib is 3 dB, in presence of lighter slabs the increment can achieve 7 dB.

4. Conclusions

Nine different combinations of floors and walls with a concrete nib at the base have been analyzed using a modified approach of ISO 12354-1 and the results have been compared with onsite testing of the same analyzed constructions. Although only a small set of experimental data was available to completely validate the theoretical model, it appears that the modified approach of the ISO Standard gives relatively accurate correlation between the predicted and field-measured weighted sound reduction index (R'_w) when a nib is introduced at the wall-floor junction.

The introduction of the rigid concrete nib at the base of the lightweight wall appears to change the vibration transmission behaviour through the floor slab by introducing a secondary dissipation path for the sound energy running through the floor. It is interesting to observe how, with some adaption, it is possible to use the ISO 12354-1 methodology to predict the nib effect. The validation of this method could be an interesting improvement of the ISO standard, introducing an additional design tool.

In New Zealand, the use of the nib at the base of the light weight walls is common practice when the floor system appears to have insufficient capability to reduce the flanking transmission, however there is not a developed scientific method to predict how effective the nib may be.

An extension of this experimental campaign is proposed in addition to the work contained in this paper, investigating other similar cases using the same methodology.

A review of the draft of the new ISO 12354 confirms that the prediction approach for this specific application has not changed and the proposed method in this paper will still be valid.

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The Project report looks at each of these areas in further detail.

3. Regulations

The industry feedback indicated there is certainly support across all sectors to improve NZ's regulations related to building acoustics. The report urges that efforts actively continue in this direction. In the meantime, it is hoped that the introduction of an information hub would help people become more familiar with what can and cannot be easily achieved and avoid unnecessary mistakes, which should help drive a general improvement in quality. Hopefully, any future shift in regulations will then come more easily.

7. Conclusions

This Project has collated a large amount of information on the current state of play and the most relevant information resources, needs and gaps as they relate to noise control and acoustics in NZ medium-density housing. The extensive industry survey and other consultation includes qualitative and quantitative data covering the full range of perceptions in this topic from across NZ industry.

The suggested online Quiet Housing Hub format should be able to utilize this information to help provide an invaluable expandable resource to deliver technical information to industry, to support better noise control for medium-density housing and any future changes to acoustic regulations. Information from the research areas highlighted can also be better fed back to industry via the hub.

However, building acoustics cannot be considered alone - for quality, affordable, desirable medium-density housing, careful integration is needed with other areas of planning, design and construction.

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