Summary report for Consortium on Fire Resistance and Sound Insulation of Floors: sound transmission and impact insulation data

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Summary Report for Consortium on Fire Resistance and Sound Insulation of Floors: Sound Transmission and Impact Insulation Data.

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Foreword

This project was a continuation of an earlier project [1,2] to determine the factors that are important in determining the degree of sound transmission through floors. Studies of fire resistance of floors carried out in this joint project are dealt with in other IRC internal reports.

The report presents measurements of airborne and impact sound transmission through 67 floor assemblies—wood joists, wood trusses, wood I-joists, and cold-formed C-shape steel joists. Three types of sound-absorbing material were used and two thicknesses of Type X gypsum board.

The results of this phase of the project were combined with those from Phase I and used to refine a regression model for estimating sound transmission class, impact insulation class and some other single-number ratings. The regression model was used to create a small program for estimating these ratings for a restricted set of common floors.

The National Research Council of Canada is indebted to the partners in this Joint Research Project for their technical and financial contributions. The partners include

- Canada Mortgage and Housing Corporation
- Canadian Steel Construction Council
- Canadian Wood Council
- Cellulose Insulation Manufacturers Association of Canada
- Cellulose Insulation Manufacturers Association (US)
- Forintek Canada Corporation
- Gypsum Association (US)
- Gypsum Manufacturers of Canada
- Ontario Ministry of Municipal Affairs and Housing
- Owens-Corning Canada
- Roxul Inc.
- Truss Plate Institute of Canada
- Truss Plate Institute (US)

Two other partners contributed in the early part of the project – Johns Manville International and Louisiana Pacific Corporation – and their assistance is also acknowledged.

Table of Contents

Project Summary

Airborne and impact sound transmission were measured through 67 floor assemblies in accordance with ASTM standards. The project was a continuation of an earlier, more extensive study[1,2]. The data obtained in this second phase were combined with the data from Phase I and used to refine an empirical model for estimating single number ratings from the physical properties, dimensions and arrangement of the materials used to build the floor. No attempt was made to develop models to predict transmission loss or impact sound spectra; such models will require work beyond the scope of the project.

The regression equations are provided in the report and were incorporated into a computer program for predicting sound transmission class (STC)[3].

Complete information for each floor tested is given in an appendix.

The main conclusions drawn from inspection of the data and from the regression analysis from both projects are the following:

- The total mass of the subfloor and the ceiling layers are the most important variables determining sound attenuation.
- The analysis of the data for specimens tested did not reveal any significant dependence of sound attenuation on joist type.
- Increasing the distance between joists had a slight positive effect on STC. A change in spacing of 200 mm is needed to change the STC by 1 point. IIC did not depend on joist spacing.
- On average, deeper cavities gave better sound attenuation; STC increases by about 1 point when the cavity depth increases by 160 mm. IIC did not depend on cavity depth.
- Increasing the thickness of the sound-absorbing material installed in the floor increases STC and IIC.
- STC values showed no dependence on the type of sound-absorbing material although some comparisons made with a few floor systems did. The three other airborne sound ratings all showed a dependence on the type of sound-absorbing material as did all of the impact sound ratings. This remains a confusing issue.
- Increasing the spacing between resilient metal channels tended to increase sound attenuation but the increments are fairly small.
- Because of differing densities for the 13 and 16 mm gypsum board used, substituting one thickness for the other made very little difference to the sound attenuation.

Introduction

An earlier phase of this project[1,2] to study airborne and impact sound transmission through floors led to a good understanding of the factors that influence sound attenuation. Factors varied included

- joist type, depth and spacing
- type, thickness and disposition of sound-absorbing material
- type, thickness and number of layers of sub-floor
- type, thickness and number of layers of gypsum board, and
- resilient channel spacing.

About 200 floor assemblies were tested in the first phase and a multi-variate regression model was developed for floors incorporating resilient metal channels and sound-absorbing material. The presence of both of these elements was clearly shown to be essential for good sound attenuation with minimum material.

While the first phase[1,2] provided a good deal of new and valuable information, some questions remained un-answered. In particular, it was not clear whether the different types of sound-absorbing material – rock, cellulose and glass fibre – gave consistently different sound attenuation ratings in otherwise identical floor systems. Also, the few results available with 13 mm thick gypsum board seemed to be somewhat higher than expected. While the first phase of the project was extensive, not all material types were included to the same degree. Hence, this second phase of the project was undertaken.

This report describes the measurements made in this second phase of the project. The same parameters as above were varied except that only Type X gypsum board was used in this phase. The first three sections of the report describe measurement procedures, a coding system to simplify description of the specimens, and the single-number ratings for each tested construction. The multi-variate regression analyses are described and an appendix gives all the one-third octave data measured during the project.

Another appendix describes alternative single-number ratings that have been developed as a result of research at NRC and in Europe. These ratings are thought to be more useful, especially for impact sound, than the traditional ratings — sound transmission class (STC) and impact insulation class (IIC) — based on contour fitting. and The appendix shows how they relate to STC and IIC.

Measurement procedures

The facility for measuring sound transmission through floors is housed in building M59 of the Institute for Research in Construction (IRC), Ottawa, Canada. It comprises two rooms with volumes of about 175 m^3. The bottom room is constructed of 30 cm thick poured concrete and is supported on steel springs and neoprene placed under the floor. The upper room is constructed from steel studs and layers of particleboard. It is supported on steel columns that in turn rest on steel springs and neoprene supports. Floor specimens are constructed in one of two concrete test frames that can be inserted between the reverberation rooms or removed and lifted by a crane to a storage or work area.

A more detailed description of the floor test facility is given in reference [1]; the standard measurement procedures and instrumentation are also described there. Airborne sound transmission and impact sound transmission were measured according to ASTM standards as follows.

Airborne Sound — ASTM E90

Laboratory measurements of airborne sound transmission were made in accordance with ASTM E90[4]. In the M59 floor test facility sound is generated in one room using four loudspeaker systems, each with its own noise generator and amplifier. The movable microphone in each room measures the sound pressure levels and sound decay rates at frequencies from 50 to 6300 Hz. Measurements are made with each room in turn serving as the source room and the two sets of results are averaged. The information collected in the frequency range 125 to 4000 Hz is used to calculate sound transmission loss (TL) and sound transmission class (STC) according to ASTM E413[5]. The data are also used to calculate the ratings defined in ISO 717-1[6] — the weighted sound reduction index, R_w, and the spectrum adaptation term, C.

Impact Sound — ASTM E492

Transmission of impact sound through floors is measured in accordance with ASTM E492[7]. A standardized tapping machine incorporating 5 steel-faced hammers is placed on the floor under test in four specified positions. The hammers are driven by a motor so they impact the floor surface twice per second each for a total rate of 10 impacts per second. Sound pressure levels and decay rates are measured in the room below. In this project, measurements were made from 50 to 6300 Hz. The information collected is used to calculate the normalized impact sound pressure level and the impact insulation class (IIC) according to ASTM E989[8]. The data are also used to calculate the ratings defined in ISO 717-2[9] —weighted normalized impact sound pressure level, $L_{n,w}$, and the spectrum adaptation terms, C_I.

Coding System for Specimen Description

To avoid the tedium of reading long descriptions of floor constructions a coding system is used throughout the report. Each layer in a floor is coded as follows:

- an integer representing the number of sheets of material
- a sequence of letters to indicate the material in the layer (See Table 1 below)
- a number representing the thickness in mm of each sheet or element in the layer.

If the number of sheets in a layer is one, the leading 1 is omitted. Underscores separate layers. The coding system is also applied to horizontal floor elements that do not constitute layers, such as joists, trusses and resilient metal channels. For such elements, the number following the letters is the depth of each element—the dimension along the axis perpendicular to the plane of the floor—and the number in parentheses following the depth code is the separation between the mid-plane of each element.

Thus the code OSB15_WJ235(406)_GFB150_RC13(610)_2G16 describes the following floor:

- A 15 mm thick oriented strandboard subfloor.
- 38 x 235 mm wood joists, 406 mm on centres (o.c.)
- 150 mm thick glass fibre batts in the joist cavities.
- 13 mm deep resilient metal channels screwed to the joists, 610 mm o.c. and perpendicular[♪] to the joists
- Two layers of gypsum board, 16 mm thick, attached to the resilient metal channels.

This coding system is used in the detailed tables at the end of this report and in the accompanying computer files. The coding system simplifies computer searches for particular constructions. Note that the coding system is a convenience and actual dimensions may not be exactly as coded. For example, the nominal 15 mm thick OSB was not always exactly 15 mm thick. Other details are given for each specimen in Appendix 1.

Sprayed-on cellulose fibre insulation was applied to the surfaces of the joists and to the underside of the subfloor. The thickness given for sprayed-on cellulose fibre insulation is the equivalent average thickness in the plane parallel to the ceiling — the thickness that a uniform batt of the material would have. Use of this average permits comparisons of sprayed-on cellulose with fibrous batts or blown-in cellulose. The average thickness of the coating on the vertical face of the joists was about 90 mm.

[♪] In the project, all resilient metal channels were applied at right angles to the joists.

In some instances in figures comparing specimens, n or xxx is used to indicate that a parameter is being varied. Thus nOSB15 indicates that the number of layers of oriented strandboard varies and RC13(xxx) indicates that the spacing between resilient metal channels varies.

Where the resilient metal channel spacing is followed by a + sign in the table, this signifies that additional channels were installed to support the non-tapered, short edges of the sheets of gypsum board. These additional channels have been found necessary for obtaining good fire resistance ratings with single layers of gypsum board.

Table 1: Codes used to identify materials and describe constructions.

Code	Material
CAR	Carpet
CFL	Blown-in cellulose fibre
CFS	Sprayed-on cellulose fibre insulation (to underside of subfloor and sides of joists)
CON	Concrete
FOMRUB	Foam rubber carpet underlay
G	Gypsum board
GCB	Gypsum/cellulose board
GCON	Gypsum concrete
GFB	Glass fibre batts
OSB	Oriented strandboard
PLY	Plywood
RC	Resilient metal channels
RFB	Rock fibre batts
SJ	Cold-formed steel C-joists (steel C-joists)
SWWT	Steel web wood trusses
CORSTE	Corrugated steel deck
WI	Wood I-joists
WJ	Wood joists
WT	Wood trusses

Summary Rating Tables

This section gives a brief description of all the floors tested together with airborne and impact sound ratings for each. The one-third octave band data and material information are given in an appendix. Floor and ceiling layers and the absorptive materials are described using the coding system above. The one-third octave band data for any particular assembly can be found as explained at the beginning of the appendix by using the TL Test ID as an index.

In addition to STC and IIC, the tables present two other ratings, ALD50 and IR50. These ratings are explained later in Appendix 2. They are provided as general information with the thought that they may eventually replace STC and IIC. They can be ignored if so desired. Both ratings include low frequency data down to 50 Hz. ALD50 represents the attenuation of music-like sounds and IR50 is the total energy of the sound generated by the tapping machine below the floor in the frequency range 50 to 2500 Hz.

Wood joist floors

Table 2 summarizes the construction and ratings for all the floors in this project where solid wood joists were used to form the frame. Included in the table are the ratings for the reference floor (Mean Ref) that was constructed several times in the first phase[1] of the project.

The material coded as GCB in row 3 of the table was a proprietary board product made from a combination of gypsum and cellulose. The 13 mm thick panels weighed 12.7 kg/m^2. The addition of this extra mass considerably improved all the sound attenuation ratings as might be expected. This test and that in row 2 were part of a small IRC research project. The data are included here for interest.

The selection of wood joist floors in Table 2 is such that any useful direct comparisons are evident from reading the table.

Table 2: Wood joists, 406 mm o.c. A + sign following the resilient channel spacing signifies that additional channels were installed to support the non-tapered, short edges of the sheets of gypsum board as shown in Figure 1. Mean Ref is the reference floor from Phase I[1].

	Floor Layer	Sound Absorption Material	RC o.c.	Ceiling	TL Test ID TLF- . .	STC	ALD50	Impact test ID IIF- . .	IIC	IR50
235 mm wood joists, 406 mm o.c.										
1	OSB15	GFB150	610	G16	Mean Ref	52	45	Mean Ref	46	41
2	OSB19	RFB180	406	G16	03-065a	52	45	03-029	43	41
3	2GCB13_ OSB19	RFB180	406	G16	03-067a	61	51	03-030	50	47
4	PLY16	CFL235	610	2G13	04-001a	57	50	04-001	49	42
5	2PLY16	GFB180	406+	G16	03-061a	51	44	03-027	42	39
6	2PLY16	RFB180	406+	G16	03-063a	52	45	03-028	43	41
7	GCON25_ PLY16	GFB90	610	2G13	04-003a	65	56	04-002	34	49
8	GCON25_ PLY16	GFB90	406	2G13	04-007a	64	55	04-004	33	48
235 mm wood joists, 610 mm o.c.										
9	PLY19	RFB90	610	G13	03-057a	49	44	03-025	42	39
10	PLY19	RFB90	610	2G13	03-055a	54	47	03-024	48	43
184 mm wood joists, 406 mm o.c.										
11	PLY16	GFB90	406	2G13	03-033a	52	46	03-011	45	42

Wood I-joist floors

The wood I-joists used in this phase of the project had laminated veneer lumber flanges and oriented-strandboard webs. The flanges for the I-joists used in most of the assemblies measured 44 x 38 mm and the web was 10 mm thick. They are shown installed on 610 mm centers in Figure 1. A frame was also constructed with the I-joists spaced on 406 mm centers. In two cases the flanges measured 58 x 38 mm. The ratings for the I-joist floors are summarized in Table 3.

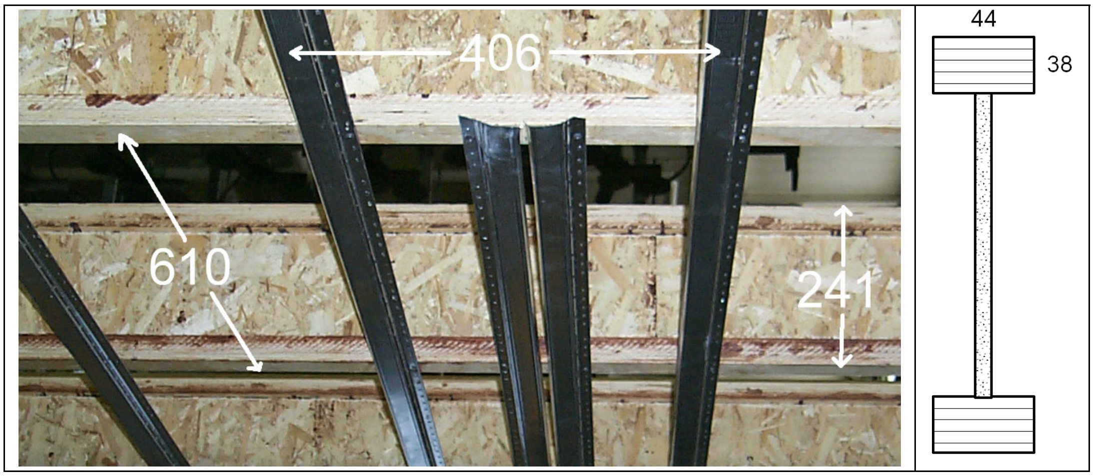

Figure 1: View and cross section of 241 mm deep I-joist. The joists were spaced 610 mm o.c. in this case.

The impact test for the floor in row 1 was rejected because the spectrum of impact sound levels was clearly atypical and, consequently, the IIC rating obtained was several points too high. The concrete slab was merely laid on top of the plywood subfloor resulting in poor contact between the slab and the subfloor. The poor contact reduced high frequency sound transmission much more than a bond-breaking layer of plastic or paper would. This assembly was deemed to be unrepresentative of a real application where the concrete is poured on the subfloor and allowed to set.

Rows 2 to 4 of the table show no significant differences when the type of sound-absorbing material was changed. The same is true for rows 8 to 10 where two layers were used in the subfloor and the ceiling.

Rows 6 and 7 show no change when the thickness of the single layer of gypsum board was changed.

Rows 12 to 14 show increased sound attenuation when the thickness of glass fibre was doubled and that the loose-fill cellulose fibre insulation gave significantly better sound attenuation values at the same thickness as the glass fibre.

Row 16 gives the ratings for the case when three layers of 90 mm thick rock fibre were compressed into the joist cavity. There is a slightly increased sound attenuation relative to the results in row 15 where the cavity was filled with blown-in cellulose fibre.

Table 3: 241 mm deep, wood I-joists 406 and 610 mm o.c. A + sign following the resilient channel spacing signifies that additional channels were installed to support the non-tapered, short edges of the sheets of gypsum board as shown in Figure 1.

	Floor Layer	Absorption	RC o.c.	Ceiling	TL Test ID TLF- . .	STC	ALD50	Impact test ID IIF- . .	IIC	IR50
44 x 38 mm flanges, 406 mm o.c.										
1	CON38_PLY16	GFB90	406	2G13	02-045a	69	59			
2	PLY16	RFB90	406+	G13	01-063a	45	42	01-030	41	39
3	PLY16	GFB90	406+	G13	01-065a	44	41	01-031	40	38
4	PLY16	CFL90	406+	G13	01-077a	46	41	01-037	41	38
5	2PLY16	RFB90	406+	G13	01-061a	48	43	01-029	43	40
44 x 38 mm flanges, 610 mm o.c.										
6	OSB19	RFB90	406+	G13	02-009a	49	43	02-008	42	39
7	OSB19	RFB90	406+	G16	02-015a	49	43	02-013	41	38
8	2OSB19	RFB90	406	2G13	02-017a	57	49	02-014	49	44
9	2OSB19	GFB90	406	2G13	02-019a	58	49	02-015	50	43
10	2OSB19	CFL90	406	2G13	02-023a	58	49	02-017	50	45
11	2OSB19	CFS150	406	2G13	02-027a	62	52	02-020	52	46
12	OSB19	GFB90	406	2G13	02-043a	53	46	02-027	46	41
13	OSB19	GFB180	406	2G13	02-021a	55	48	02-016	48	43
14	OSB19	CFL180	406	2G13	02-025a	59	50	02-018	51	46
58 x 38 mm flanges, 406 mm o.c.										
15	2PLY16	CFL240	305	G16	04-009a	52	45	04-005	45	40
16	2PLY16	RFB270	305	G16	04-005a	54	45	04-003	45	40

Wood truss floors

Two views of the metal-plate-connected truss framework are given in Figure 2. The trusses were spaced 406 mm o.c. except in one case noted in Table 4 which gives the ratings obtained.

Figure 2: Metal-plate-connected wood truss framework. The trusses were formed from 38 x 89 mm lumber. The truss depth was 305 mm.

The impact test result for the assembly in row 1 was rejected as was done above in the section on I-joists because of the atypical results ascribed to poor contact between the slab and the subfloor.

Rows 2 to 4 give results for three types of sound-absorbing material. They are not significantly different.

Rows 5 and 7 are tests on two nominally identical but completely rebuilt specimens. For practical purposes the ratings are the same. Row 6 adds a carpet and underpad to this particular assembly. This typically gives very high impact insulation class ratings. Note that the IR50 rating shows a lesser improvement.

The result in Row 15 differs from the two tests in rows 5 and 7 in that the trusses used had solid wood top and bottom plates and steel webs. (See Figure 3) The three test results give results that are the same within the limits of the test measurement repeatability.

Rows 8 to 10 compare three types of sound-absorbing material, all giving the same ratings. Row 11 changes the thickness of the gypsum board with no significant change to the ratings.

Rows 12 to 14 show rating changes as the total mass of the layers in the floor changes but show no change when the thickness of the gypsum board is changed.

Table 4: 305 mm deep wood trusses, 406 and 610 mm o.c. A + sign following the resilient channel spacing signifies that additional channels were installed to support the non-tapered, short edges of the sheets of gypsum board as shown in Figure 1.

	Floor Layer	Absorption	RC o.c.	Ceiling	TL Test ID TLF- . .	STC	ALD 50	Impact test ID IIF- . .	IIC	IR50
Trusses 406 mm o.c.										
1	CON38_ PLY16	GFB90	406	2G13	03-003a	66	58			
2	PLY16	CFL90	406+	G13	01-031a	48	43	01-014	41	38
3	PLY16	GFB90	406+	G13	01-045a	47	42	01-021	39	37
4	PLY16	RFB90	406+	G13	01-047a	47	43	01-022	41	38
5	PLY16	GFB90	406	2G13	01-041a	52	47	01-019	44	42
6	CAR_ FOMRUB9.5_ PLY16	GFB90	406	2G13	01-043a	53	48	01-020	73	54
7	PLY16	GFB90	406	2G13	03-001a	52	46	03-001	43	40
8	2PLY16	CFL90	406	2G16	01-033a	54	49	01-015	45	44
9	2PLY16	GFB90	406	2G16	01-035a	55	50	01-016	45	44
10	2PLY16	RFB90	406	2G16	01-037a	55	50	01-017	47	45
11	2PLY16	RFB90	406	2G13	01-039a	55	50	01-018	46	43
12	OSB16	RFB90	406	2G13	01-057a	55	48	01-027	47	43
13	2OSB16	RFB90	406	2G13	01-051a	57	50	01-024	47	44
14	2OSB16	RFB90	406	2G16	01-059a	56	51	01-028	47	45
15	PLY16*	GFB90	406	2G13	04-037a	51	45	04-020	43	41
Trusses 610 mm o.c.										
16	PLY19	GFB90	406	2G13	02-049a	54	48	02-031	45	42

*Steel web trusses

Figure 3: Steel web wood trusses with 65 x 40 mm wood flanges.

C-shape steel joist floors with plywood or oriented-strandboard flooring

Table 5 summarizes the results for steel C-joist floors that incorporated plywood or oriented-strandboard flooring. All the steel C-joists used in this project were formed from 18 gauge steel with a measured thickness of 1.22 mm.

Rows 1 to 3 demonstrate the effects of increasing the number of layers on the floor or on the ceiling.

Rows 4 and 5 are two tests that were done to quantify the effects of having resilient metal channels 203 mm on center. It was thought that this separation might give improved fire resistance ratings. Comparing rows 2 and 4 and rows 3 and 5 shows that the STC decreases by 2 to 3 points and the IIC decreases by 1 to 3 points.

Rows 6 to 9 show that changing from 13 mm to 16 mm gypsum board in this case had no significant effect on the ratings.

Rows 10 to 12 show the effects of changing the type of sound-absorbing material. In this case, there are definite differences among the three types of material.

Table 5: 203 mm deep, steel C-joists 406 and 610 mm o.c.

	Floor Layer	Absorption	RC o.c.	Ceiling	TL Test ID TLF- . .	STC	ALD50	Impact test ID IIF- . .	IIC	IR50
	Joists 406 mm o.c.									
1	PLY16	GFB90	406	2G13	01-003a	49	45	00-036	39	39
2	2PLY16	GFB90	406	G13	01-009a	48	44	01-003	38	37
3	2PLY16	GFB90	406	2G13	01-007a	53	47	01-002	42	41
4	2PLY16	GFB90	203	G13	01-013a	46	41	01-005	35	35
5	2PLY16	GFB90	203	2G13	01-015a	50	46	01-006	41	40
6	OSB16	GFB90	406	2G13	01-017a	51	46	01-007	43	42
7	OSB16	GFB90	406	2G16	01-025a	50	46	01-011	43	41
8	2OSB16	GFB90	406	2G13	01-019a	56	50	01-008	45	44
9	2OSB16	GFB90	406	2G16	01-021a	55	50	01-009	44	43
10	2OSB16	GFB90	406	G16	01-023a	50	46	01-010	40	39
11	2OSB16	RFB90	406	G16	01-027a	52	46	01-012	42	40
12	2OSB16	CFL90	406	G16	01-029a	54	47	01-013	44	40
13	2PLY16	CFS120	406	G16	04-029a	51	44	04-016	45	41
	Joists 610 mm o.c.									
14	PLY19	CFS130	610	2G13	04-011a	57	51	04-007	51	47

C-shape steel joist floors with concrete on corrugated steel deck

Two sets of floors constructed using cold-formed steel C-joists (steel C-joists) were tested. The results summarized in Table 6 are for the cases where a concrete topping was poured onto a corrugated steel deck. A portion of the cross section of the deck is shown in Figure 4. The maximum depth of concrete was nominally 50 mm, thus the nominal minimum depth was 35 mm. The average thickness of the concrete was calculated from the dimensions in Figure 4 to be 39 mm. The density of the concrete was 2260 kg/m^3. Measurements during demolition of the thickness of small pieces of the concrete showed that the average thickness was around 40 mm.

In this set of measurements, the blown-in cellulose fibre insulation gives ratings that are slightly higher than those for the other sound-absorbing materials, including the sprayed-on cellulose fibre insulation. Note, however, that the blown-in material has the greatest thickness. The photograph in Figure 5 shows how the sprayed-on cellulose fibre insulation was applied; it adhered to the underside of the subfloor and the surfaces of the joists. The average thickness of the coating on the joists was intended to be 90 mm.

The ratings in row 1 of the table show that omitting the sound-absorbing material leads to significant reductions in sound attenuation, but the reduction is not as great as seen in some other cases in Phase I[1] of the project.

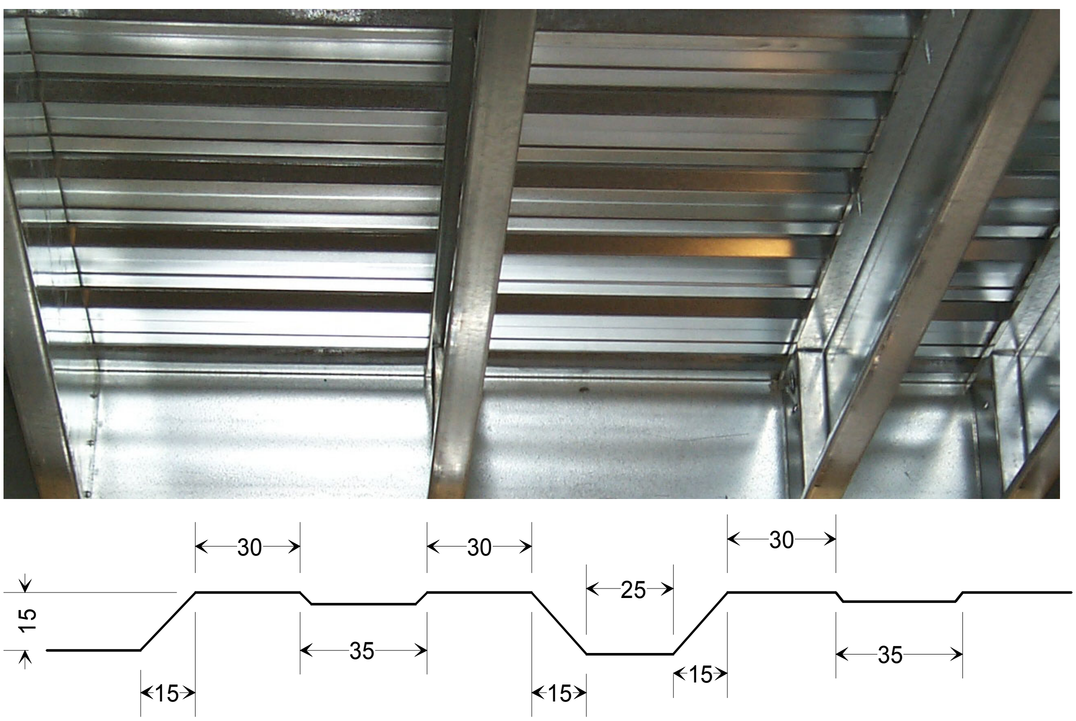

Figure 4: Steel C-joists and cross section of corrugated steel deck, thickness 0.41 mm.

Table 6: 203 mm deep steel C-joists, 406 and 610 mm o.c. with concrete topping poured onto 0.41 mm thick corrugated steel deck. A + sign following the resilient channel spacing signifies that additional channels were installed to support the non-tapered, short edges of the sheets of gypsum board as shown in Figure 1.

	Absorption	RC o.c.	Ceiling	TL Test ID TLF- . .	STC	ALD50	Impact test ID IIF- . .	IIC	IR50
	Joists 406 mm o.c.								
1	none	406	2G13	03-011a	62	59	03-005	32	48
2	GFB90	406	2G13	03-005a	68	63	03-003	36	52
3	RFB90	406	2G13	03-007a	68	63	03-004	37	52
4	CFL200	406	2G13	03-031a	70	65	03-010	38	54
5	CFS150	406	2G13	03-039a	68	63	03-016	39	54
6	GFB90	610	2G13	02-051a	66	63	02-032	34	50
	Joists 610 mm o.c.								
7	CFS130	610	G16	04-031a	64	58	04-017	32	48
8	CFS130	610+	G16	04-033a	64	58	04-018	32	49

Figure 5: Sprayed-on cellulose applied to steel C-joist floor.

The results for the constructions in rows 2 and 6 of Table 6 should be noted. These constructions differ only in the spacing of the resilient channels. In fact, the same joists, flooring and sound-absorbing material was used in each case. Only the channels and gypsum board were changed. Increasing the distance between channels *decreased* the STC and IIC ratings. This result is in marked contrast to the effects seen in the first phase[1] of the project where increasing the distance between channels attached to wood joists clearly led to *increased* sound attenuation. No explanation has been found for this difference.

Factors affecting airborne sound transmission

In this section, the effects on STC and IIC of changing some of the variables are discussed in general terms using information from regression analyses. The comments apply only to floors with resilient metal channels supporting the ceiling and with sound-absorbing material in the floor cavity. Using these regression equations to estimate the effects of changes to the floor structure is more reliable than comparing entries in the tables. The random variations in materials, construction, and measurement can give confusing if not erroneous conclusions.

From experience and simple theory, certain factors can be expected to have an effect on the sound transmission through a floor. Densities and stiffnesses of materials are known to be important. The spacing between elements such as joists and resilient metal channels is important; these determine the number of connections per unit area among other things. The type and thickness of sound-absorbing material, its density and airflow resistance are also thought to be important. Analytical and empirical models have been created by several authors, but they tend to predict transmission loss values that are too high or the models are too complex to be used easily. The approach in this and the previous project has been to use simple multi-variate regression analysis to estimate single number ratings. The details are discussed later in the section Multi-Variate Regression Analysis.

Mass of layers

Simple theory for a single layer of solid material predicts that transmission loss will increase 6 dB each time the mass per unit area is doubled. Thus transmission loss is proportional to 20 $\log_{10}$(mass per unit area). For cavity constructions, transmission loss still depends on mass but other factors are also important. The regression analyses show strong logarithmic dependencies on mass for all of the ratings; it is the most important variable determining the sound attenuation.

According to the regression equations, adding a second layer of gypsum board to the ceiling results in an increase of 5 STC points on average. The corresponding increase for a second layer of oriented strandboard or plywood is 4.

For impact sound, if the increase in mass of the floor layer is accompanied by an increase in surface hardness, the IIC may actually decrease. This detrimental effect can easily be dealt with by adding a resilient layer on top of the hard layer, below it, or both.

Joist Type

No statistically significant dependence on joist type (wood, I-joists, trusses or steel C-joists) was found in the regression analysis. Separate analyses were made for each joist type. The predictions made using the regression equations for each type were not significantly different from the predictions made by treating all joists as equivalent.

Joist spacing

Increasing the distance between joists had a slight positive effect on STC. A change in spacing of 200 mm is needed to change the STC by 1 point. Thus increasing joist spacing from 406 to 610 mm results in only a one point increase in STC on average. IIC did not depend on joist spacing.

Cavity depth

There are theoretical reasons to expect that deeper cavities will give better sound attenuation. In Phase I of the project, increasing the cavity depth increased the sound attenuation and the same result was found when the data from Phase II were included in the regression analysis. On average, STC increases by about 1 point when the cavity depth increases by 160 mm. IIC did not depend on cavity depth.

Thickness of sound-absorbing material

The thickness of the sound-absorbing material installed in the floor was shown to have a significant effect on the STC in the first phase of this project. Thickness is again important in this analysis; STC and IIC increase by about 1 point when the thickness of the sound-absorbing material is increased by 50 mm.

Type of sound-absorbing material

The presence of sound-absorbing material in the cavity of a floor is very beneficial when the floor and ceiling layers are adequately isolated one from the other by means of resilient metal channels or some other resilient support. Three types of sound-absorbing material were used in this project: glass fibre batts, rock fibre batts and cellulose fibre. The latter was applied in two ways: blown into the floor cavity loosely and supported by wire mesh or the gypsum board below, or sprayed-on to the underside of the floor system and the sides of the joists as shown earlier in Figure 5.

Several floor systems were tested during Phase I and Phase II with different types of sound-absorbing material in the cavity to try to establish whether there was a significant effect on the STC. The data were averaged where necessary and are summarized in Table 7 where changes are shown relative to the case where the cavity contained the same thickness of glass fibre batts. This table suggests that on average there will be a slight increase in STC when rock fibre is substituted for glass fibre. The change for rock fibre is so small, however, as to be of no practical significance.

The blown-in cellulose fibre insulation gives more variable results due perhaps to the manual installation of this material; the range in differences in the last column of the table is 5 dB. While the average increase in STC is larger for this material and in some cases might be practically significant, the variability in the data means that significant improvements can not be relied on.

There were not enough cases with sprayed-on cellulose fibre insulation to allow direct comparisons with other sound-absorbing materials.

Table 7: Change in STC for floors differing only in the type of sound-absorbing material. The change is relative to the case with glass fibre batts in the cavity.

	Rock Fibre batts	Blown-in cellulose fibre
Steel C-joists		
OSB16_SJ203(406)_xFx152_RC13(610)_G16	0	1
2OSB16_SJ203(406)_xFx90_RC13(406)_G16	2	4
CON40_CORSTE0.4_SJ203(406)_xFx90_RC13(406)_2G13	0	
Wood I-joists		
PLY16_WI241(406)_RFB90_RC13(406+)_G13	1	2
2OSB19_WI241(610)_xFx90_RC13(406)_2G13	-1	0
OSB15_WI457(406)_xFx456_RC13(610)_G16	2	
OSB15_WI457(406)_xFx90_RC13(610)_G16	1	
OSB19_WI241(610)_xFx180_RC13(406)_2G13		4
Wood joists		
OSB15_WJ235(406)_xFx90_RC13(610)_G16	0	
2PLY16_WJ235(406)_xFx180_RC13(406)_G16	1	
OSB15_WJ235(406)_xFx202_RC13(610)_G16	1	
Wood trusses		
PLY16_WT305(406)_xFx90_RC13(406+)_G13	0	1
2PLY16_WT305(406)_xFx90_RC13(406)_2G16	0	-1
Average difference	0.6	1.6

STC gives only a broad estimate of the sound transmission. The data in Figure 6 give one example of the effects of different sound-absorbing materials on the transmission loss at different frequencies. In general, changes at low frequencies are small. Changes at high frequencies can be larger, as they are in this figure, but they usually do not affect STC, which is controlled by the low frequency transmission loss values.

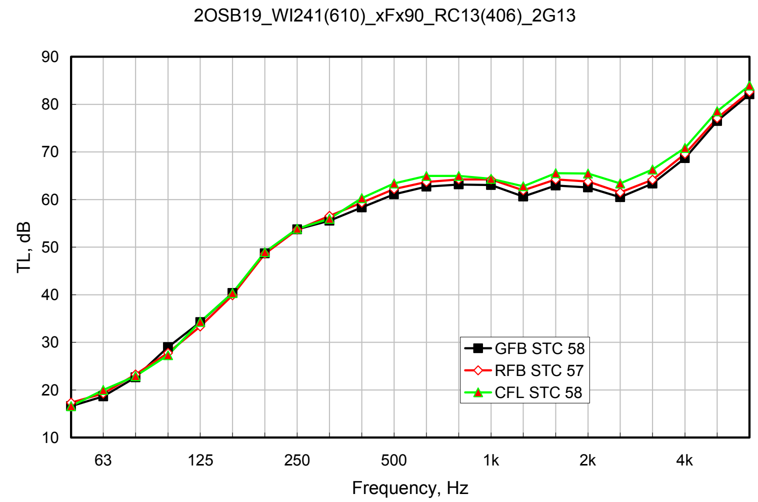

Figure 6: Transmission losses for a wood I-joist floor with three different types of sound-absorbing material in the cavity.

A more reliable estimate of the average effect of different sound-absorbing materials is found through regression analysis described later in the report. STC showed no significant dependence on the density of the sound-absorbing material; the three other airborne ratings used did. IIC and the other impact sound ratings all showed significant dependence on the density of the sound-absorbing material. The change in IIC predicted when cellulose fibre insulation is substituted for glass fibre batts of the same thickness is about 1.5 dB. Density was chosen as the variable to describe the sound-absorbing materials because it is known from other work that, for the fibrous materials used in this project, it correlates highly with airflow resistance, the material property that is expected to effect the sound attenuation.

Spacing of resilient channels

Results obtained in phase 1 showed that decreasing the spacing between the resilient metal channels used to support the ceiling, resulted in decreased sound attenuation. Adding additional channels to support the non-tapered edges of single layers of gypsum board resulted in further reductions in sound attenuation. The regression analysis in this project also showed that STC and IIC depend on channel spacing.

In practice, the channel spacing is likely to be either 406 or 610 mm with 406 mm being preferred to obtain adequate fire resistance ratings.

Thickness of gypsum board

In the previous phase of the project, most of the measurements were made using 16 mm thick gypsum board. The few measurements that were made with 13 mm gypsum board gave sound attenuation values somewhat higher than expected. This project used predominantly 13 mm gypsum board to determine the reason for this and, in general, to obtain more test data for the thinner boards. Figure 7 and Figure 8 show typically what happens. The major changes in transmission loss occur around 2000 Hz at the coincidence frequency for the 16 mm gypsum board.

At frequencies below 1000 Hz, there is little difference between the results for the two thicknesses. One might expect some difference based on weight, assuming that the weight of the thicker boards increases by the ratio of the thicknesses — 16/13, an increase of 23%. However, the densities of the two boards are not the same. The average density of the 13 mm board used in the project was 742 kg/m^3 (9.4 kg/m^2) while the average for the 16 mm board was 686 kg/m^3 (10.9 kg/m^2). Thus the increase in surface weight is only 10.9/9.4, or 16%.

The different behavior around the coincidence frequency occasionally caused a change in STC or IIC due to the application of the 8 dB rule in ASTM E413 or E989 in that region. The regression equations predict that the 13 mm gypsum board will give STC values about 1 point less than the 16 mm board. The impression gained by comparing tests where only the gypsum board was changed is that there was no significant effect due to changing the thickness of the gypsum board; the 13 mm thick board gave about the same STC and IIC ratings as the 16 mm board.

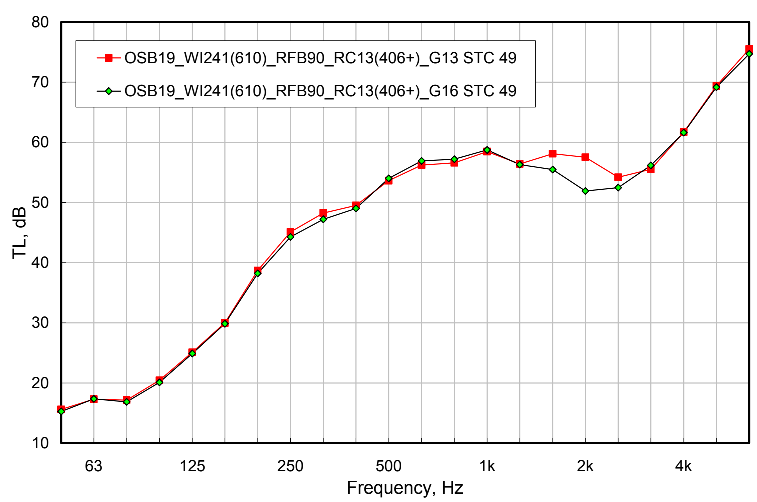

Figure 7 Transmission loss for two floors differing only in type of gypsum board used for the ceiling.

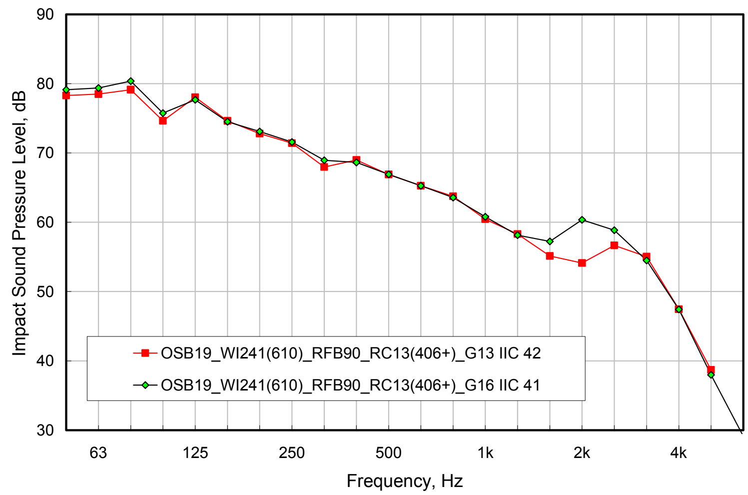

Figure 8: Impact sound pressure levels for two floors differing only in type of gypsum board used for the ceiling

Multi-Variate Regression Analysis

As in the previous project, attempts were made to try to relate STC[5] and IIC[8] to the material properties of the floor components. The data from this project were combined with the data from the Phase I[1] and regression analyses were carried out as in Phase I. More complicated analytical modeling is beyond the scope of the project and the predictions from the regression analysis are good enough for most practical purposes. Predictive algorithms were also derived for the ISO 717[6,9] ratings R_w and $L_{n,w}$ and the alternative rating systems derived from the spectrum adaptation terms defined in ISO 717. The alternative ratings used are described in Appendix 2. They are ALD50, ALD100, IR50, and IR100. This section gives more details about the regression analyses; the analyses and charts were obtained using the R language[10].

The object in using regression analysis is to find algorithms that predict sound ratings from a set of physical parameters. The algorithms predict results that have a certain error associated with them. This is inevitable and the analysis provides estimates of the uncertainty of the predictions. The standard error of the estimate that follows each regression equation gives a measure of how well the predicted values agree with measured values. Approximately two-thirds of the measured values lie within plus or minus one standard error from the regression line. A smaller value of standard error means the predictions are more precise. The adjusted square of the correlation coefficient, R^2, tells what fraction of the variations in the measured data is explained by the regression fit: the larger the value of R^2, the better the fit.

Comparing two or a few results from a dataset and trying to relate these individual results to the predictions from regression analysis can lead to apparent contradictions and confusion. Any sound transmission measurement has an associated uncertainty due to measurement, material, and installation variations. The combined dataset from both phases of this project has examples where nominally identical floors had STC values differing by 2 points. Errors are compounded when comparisons are made. Thus, differences seen when comparing table entries might be random or they might be due to some undiscovered real effect. The only way to resolve such anomalies is through further research.

The reader is reminded that variables used in regression equations should not have values significantly beyond the bounds of the variables used to derive the equations. If this principle is not followed, predictions from the equations can be seriously in error.

Airborne sound

All floors in this analysis incorporated sound absorbing material and resilient metal channels. Floors that did not contain sound-absorbing material or have resilient metal channels were not included. Such floors give poor sound attenuation and very few were included in the project. The range of construction parameters for the 170 floors from Phase I and Phase II used for analysis of airborne sound is shown in Table 8.

Table 8 : Range of construction parameters for all 170 floors used in the analysis of airborne sound.

	Floor Layers (kg/m^2)	Frame Mass (kg)	Cavity Depth (mm)	Joist o.c. (mm)	Absorption Thickness (mm)	Absorption Density (kg/m^3)	RC o.c. (mm)	Ceiling Mass (kg/m^2)
min	114.6	120.8	197	305	59	6.9	200	129.8
max	2237	415.5	623	610	456	58.4	610	415

The range of the airborne noise ratings for these floors is given in Table 9.

Table 9: Range of single number ratings for 170 floors used in the analysis of airborne sound ratings.

	STC	ALD50	ALD100	R_w
min	44	41	41	44
max	70	65	68	69

The regression equations obtained for estimating airborne sound ratings are only valid for floors containing sound absorbing material and resilient metal channels. They are:

$$STC = 15.5 \log M_{Ceil} + 14.2 \log M_{flr} + 0.006\,Cav + 0.005\,JstSpace + 0.019\,AbsThick + 0.011\,RCoc + 8.6$$

Residual standard error: 1.5, adjusted R^2: 0.92

$$ALD50 = 14.5 \log M_{Ceil} + 12.5 \log M_{flr} + 0.0069\,Cav - 0.0042\,JstSpace + 0.0118\,AbsThick + 0.022\,AbsDens + 0.011\,RCoc + 9.9$$

Residual standard error: 1.6, adjusted R^2: 0.89

$$ALD100 = 16.4 \log M_{Ceil} + 14.9 \log M_{flr} + 0.0073\,Cav + 0.0037\,JstSpace + 0.0156\,AbsThick + 0.022\,AbsDens + 0.014\,RCoc + 1.82$$

Residual standard error: 1.6, adjusted R^2: 0.92

$$R_w = 17.1 \log M_{Ceil} + 14.1 \log M_{flr} + 0.007\,Cav + 0.0079\,JstSpace + 0.017\,AbsThick + 0.026\,AbsDens + 0.011\,RCoc + 4.6$$

Residual standard error: 1.6, adjusted R^2: 0.92

where

M_{flr}	is the total mass of the floor layers per unit area, kg/m^2
M_{Ceil}	is the total mass of the ceiling layers, kg/m^2
Cav	is the distance from the underside of the subfloor to the upper surface of the gypsum board, mm
JstSpace	is the separation between joist mid-planes, mm
AbsThick	is the thickness of the sound absorbing material, mm
AbsDens	is the density of the sound absorbing material, kg/m^3
RCoc	is the distance between mid-lines of the resilient metal channels, mm

In Phase I analysis, STC depended on the type of sound-absorbing material. Adding the data from Phase II removes that dependence. The equations above for the other three airborne sound ratings do have a term for the density of the sound-absorbing material. This result is in accord with the earlier discussion of the effects of sound-absorbing material; any change in STC caused by substituting one type of sound-absorbing material for another might or might not cause a change in the STC rating and, except for a few cases, the change is small (See Table 7).

For all the floors in the dataset Figure 9, Figure 10 and Figure 11 show

- values calculated using the regression equations plotted against measured values,
- scatterplots of the residuals (measured value minus calculated value), and
- histograms of the residuals.

Limitations of the software used to create these plots mean that R_w appears as Rw.

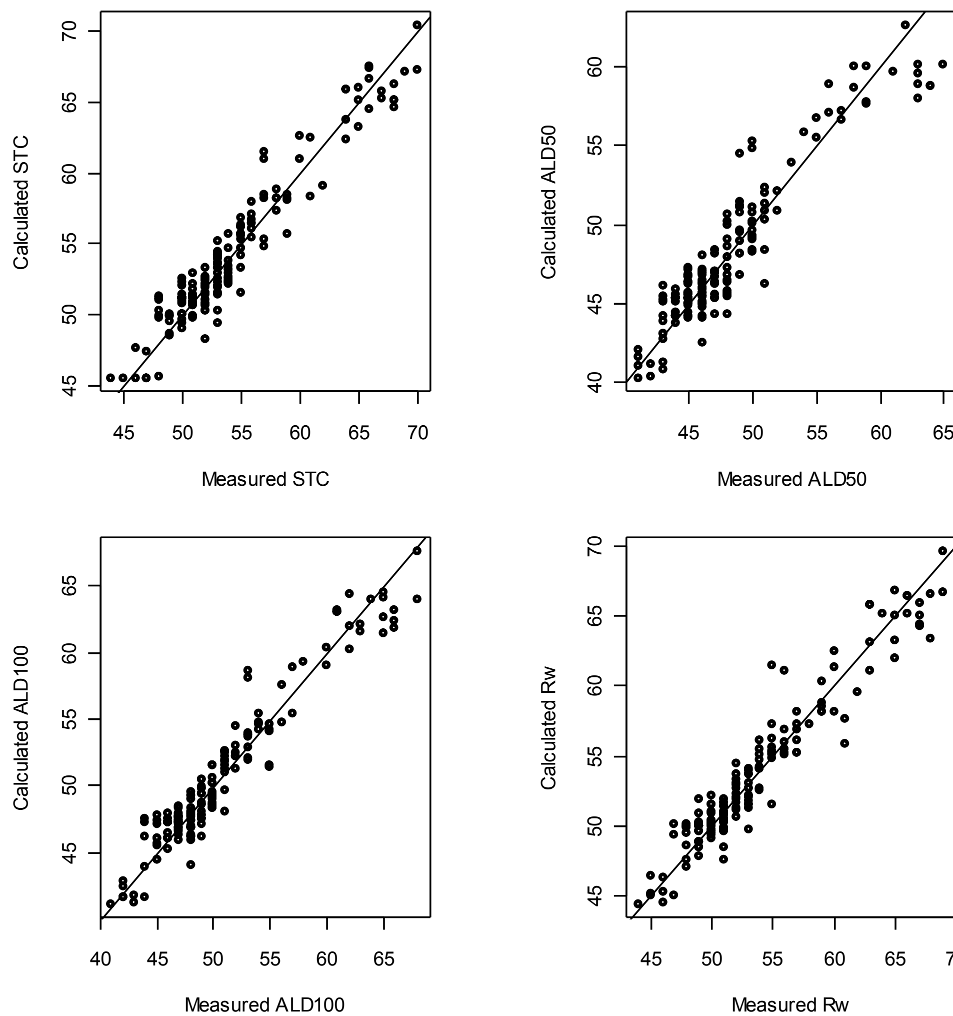

Figure 9: Measured versus calculated airborne sound ratings for the set of floor data.

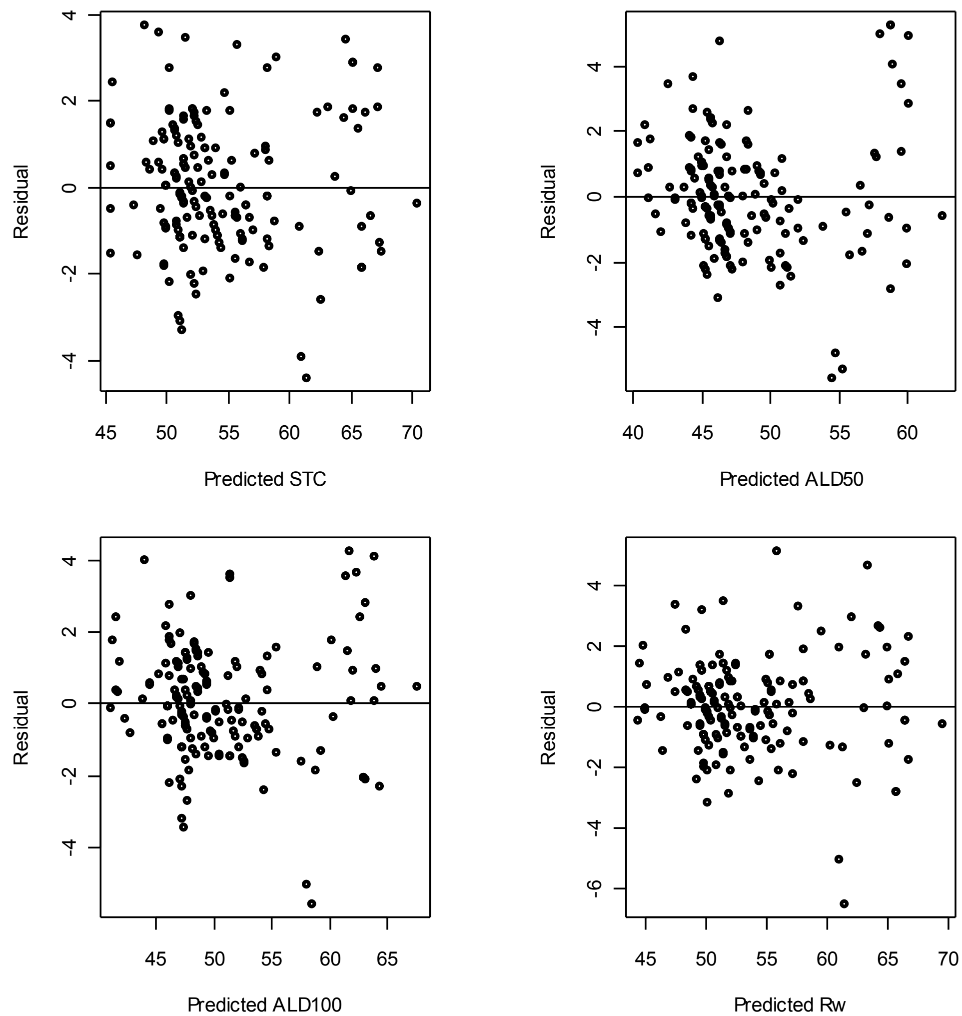

Figure 10: Residuals (error in prediction) versus predicted airborne ratings.

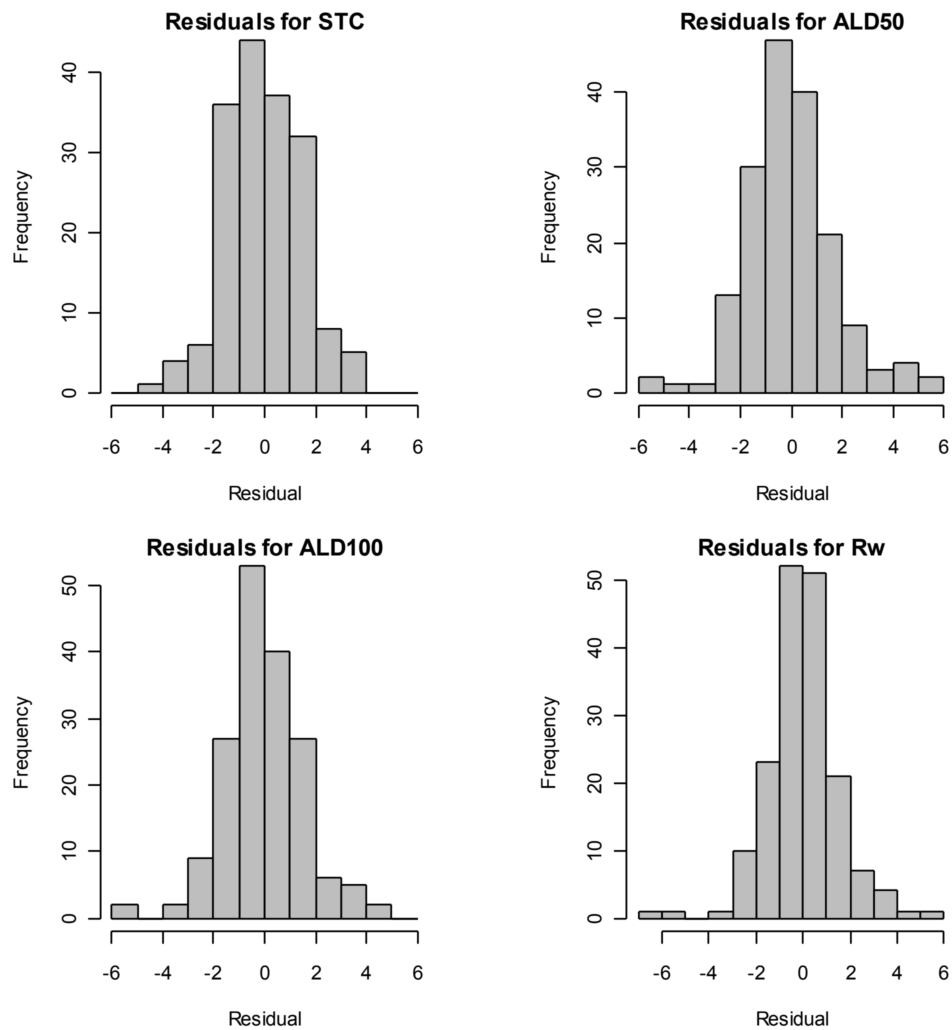

Figure 11: Histogram of residuals for the airborne sound ratings.

Impact sound

Impact sound ratings for floors are strongly influenced by the floor finish. Almost all of the floors in both phases of the project were tested with no finishing surface – bare OSB or plywood and bare concrete. Leaving the floors with no finishing surface was necessary to control the cost of the project and keep the number of tests within reasonable bounds. The effects of different finishes can be estimated to some extent but there are so many variations possible that most floor finishes need to be evaluated separately.

Adding a concrete or gypsum concrete layer to a joist floor increases the mass and so reduces the level of low frequency impact sound below the floor. However, the increase in surface hardness due to the concrete leads to increased high frequency levels and poor IIC ratings. For analysis, the floors were separated into those with concrete-based toppings and those with OSB or plywood surfaces.

Wood surfaces

The data set comprised only those floors having a wood top surface and no concrete included. There were 144 such floors.

Table 10: Range of construction parameters for 144 floors with wood top layers used in the analysis of impact sound.

	Total Mass of layers and frame, kg	Cavity Depth (mm)	Joist o.c. (mm)	Absorption Thickness (mm)	Absorption Density (kg/m^3)	RC o.c. (mm)	Ceiling Mass (kg/m^2)
Min	301	197	305	59	6.9	200	129.8
Max	486	623	610	456	58.4	610	415

The range of impact noise ratings for these floors is given in Table 11

Table 11: Range of single number ratings for 144 floors used in the analysis of impact sound ratings.

	IIC	IR50	IR100	$L_{n,w}$
min	35	35	35	56
max	53	47	54	75

The regression equations for joist floors with wood surfaces are as follows.

$$IIC = 14.6 \log M_{Ceil} + 6.0 \log M_{flr} + 0.019\, AbsThick + 0.062\, AbsDens + 0.014\, RCoc + 11.7$$

Residual standard error: 1.75, adjusted R^2: 0.66

$$IR50 = 13.8 \log M_{Ceil} + 4.4 \log M_{flr} + 0.0118\, AbsThick + 0.041\, AbsDens + 0.0065\, RCoc + 15.4$$

Residual standard error: 1.25, adjusted R^2: 0.71

$$IR100 = 15.1 \log M_{Ceil} + 6.3 \log M_{flr} + 0.020\, AbsThick + 0.068\, AbsDens + 0.015\, RCoc + 10.3$$

Residual standard error: 1.8, adjusted R^2: 0.67

$$L_{n,w} = 99 - 15.1 \log M_{Ceil} - 6.9 \log M_{flr} - 0.021\, AbsThick - 0.077\, AbsDens - 0.0133\, RCoc$$

Residual standard error: 1.8, adjusted R^2: 0.67

where the symbols have the same meaning as defined above.

For all the floors in this dataset, Figure 12, Figure 13 and Figure 14 show

- values calculated using the regression equations plotted against measured values,
- scatterplots of the residuals (measured value minus calculated value), and
- histograms of the residuals.

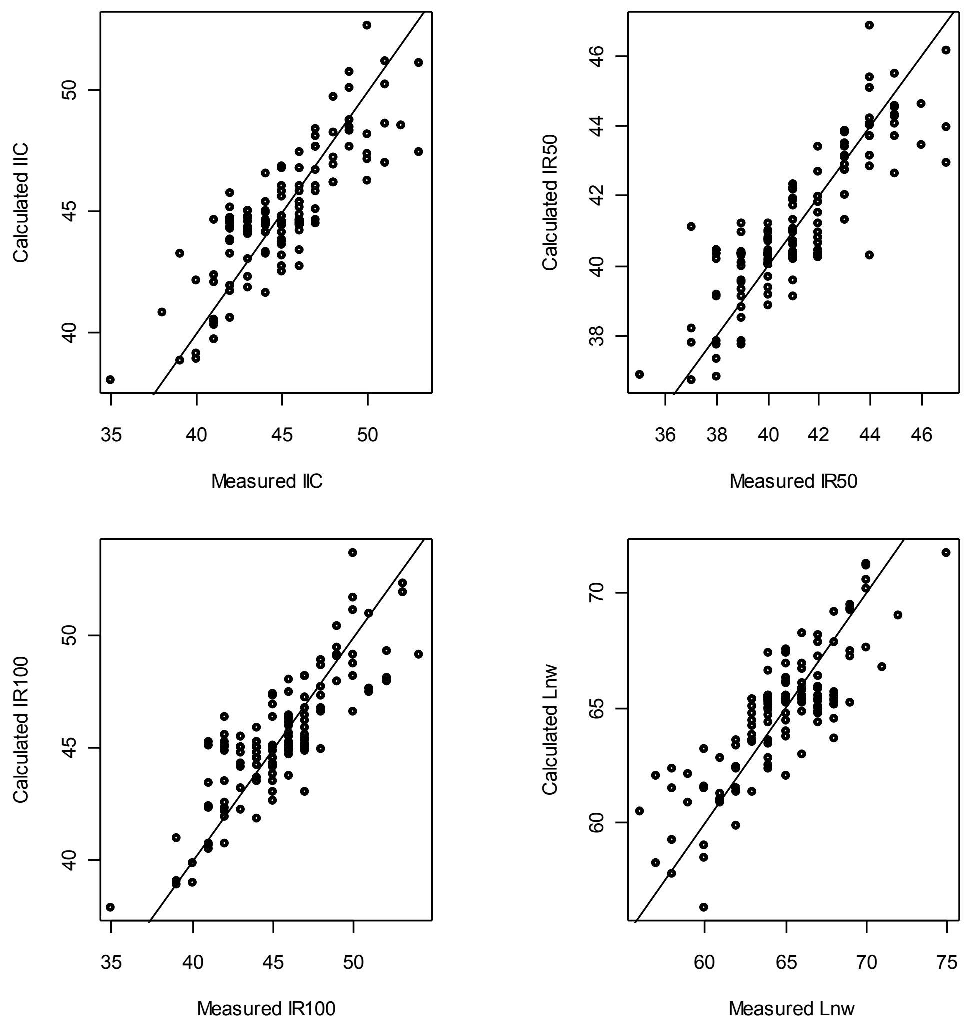

Figure 12:Calculated versus measured impact ratings for floors with joists of all types and with bare wood subfloors.

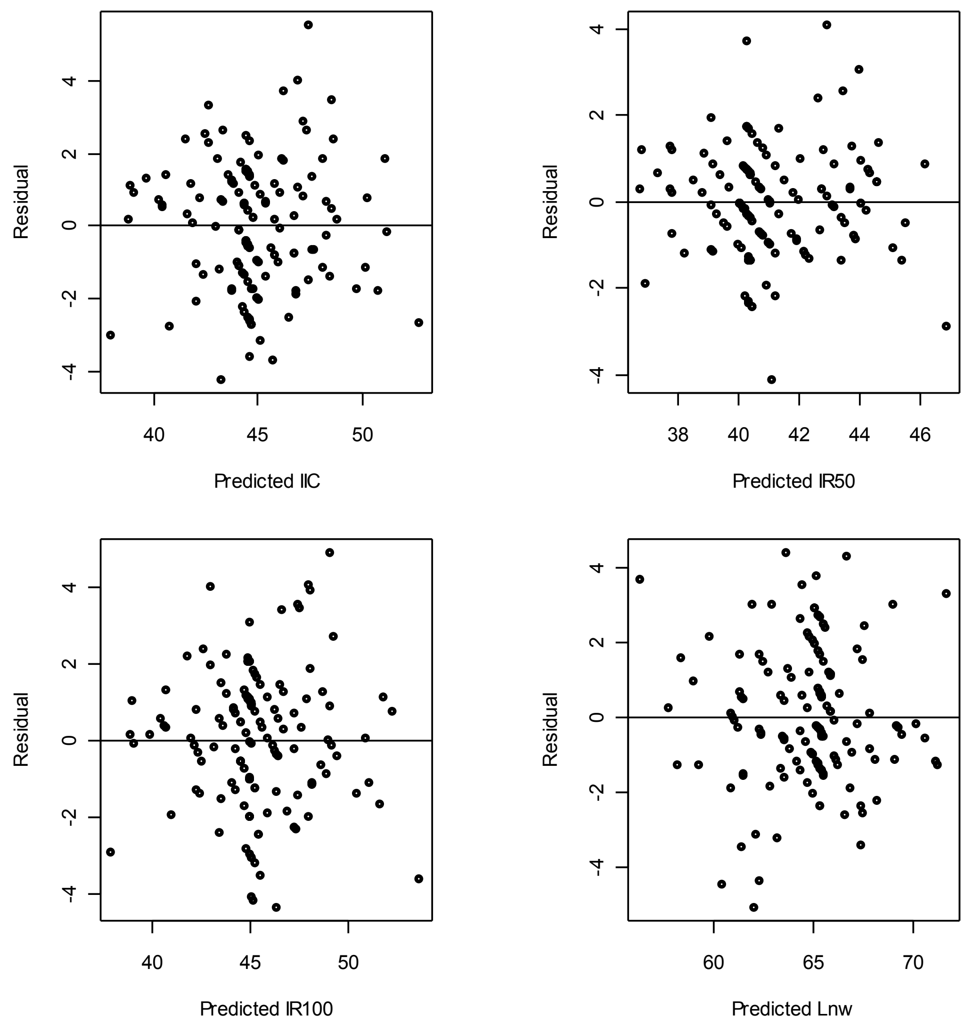

Figure 13:Residuals for four impact ratings for joist floors with wood subfloors.

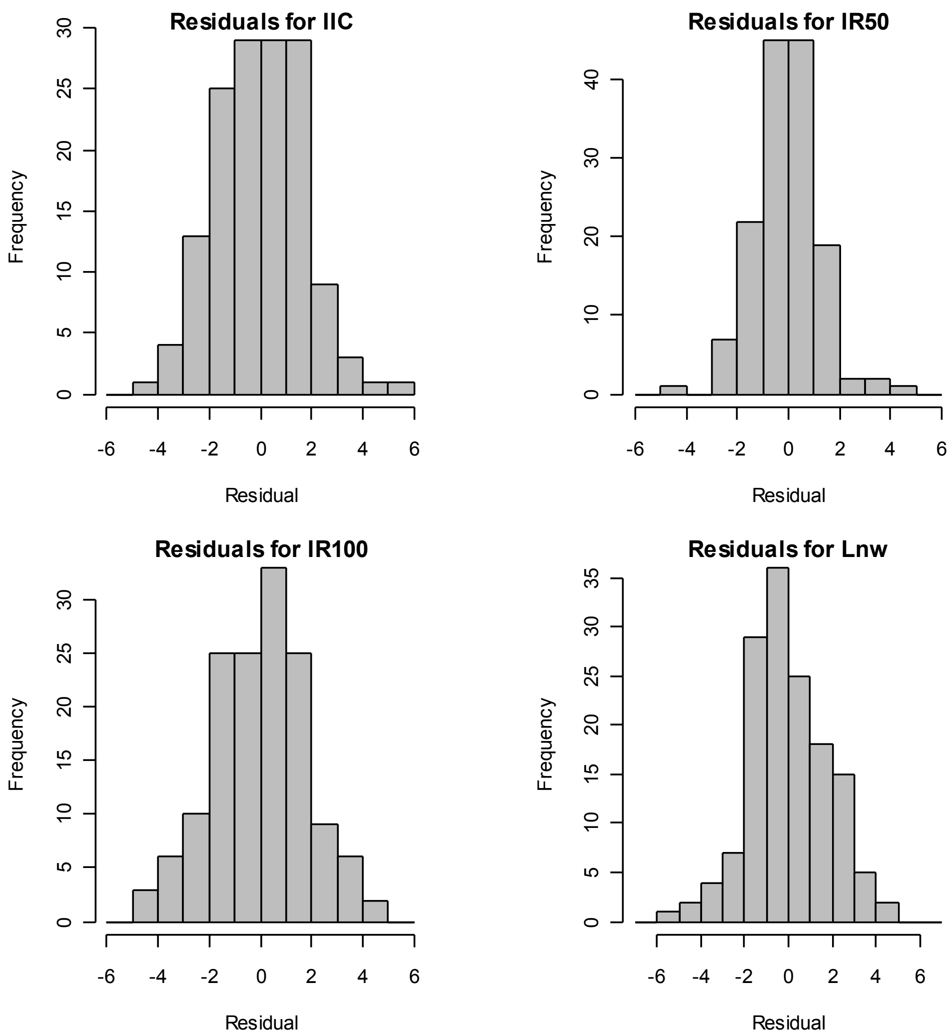

Figure 14: Histograms of residuals for four impact ratings: joist floors with wood subfloors.

Floors with concrete gypsum concrete toppings

Fifteen floors with concrete or gypsum concrete toppings were analyzed separately. The range in relevant material properties is shown in Table 12 and the range in impact ratings in Table 13.

Table 12: Range of construction parameters for the fifteen floors with concrete toppings used in the analysis of impact sound.

	Joist Depth (mm)	Cavity Depth (mm)	Joist o.c. (mm)	Absorption Thickness (mm)	Absorption Density (kg/m^3)	RC o.c. (mm)	Total mass of ceiling and floor (kg/m^2)
Min.	203	216	406	89	10.1	406	76
Max.	457	470	610	200	37.8	610	125

Table 13: Range of single number ratings for the fifteen floors with concrete toppings used in the analysis of impact sound.

	IIC	IR50	IR100	$L_{n,w}$
Min.	28	43	44	60
Max.	46	56	59	77

The analysis led to these regression equations.

$IIC = 43.6 \log M_{all} + 0.04\ Cav - 0.025\ JstSpace + 0.041\ AbsThick - 55.7$
Residual standard error: 2.6, adjusted R^2: 0.62

$IR50 = 34.6 \log M_{all} - 0.014\ Cav - 0.016\ JstSpace + 0.026\ AbsThick - 12.6$
Residual standard error: 1.26, adjusted R^2: 0.87

$IR100 = 40.4 \log M_{all} - 0.02\ JstSpace + 0.041\ AbsThick - 25.6$
Residual standard error: 1.94, adjusted R^2: 0.74

$L_{n,w} = 160.7 - 46.1 \log M_{all} - 0.029\ Cav + 0.03\ JstSpace - 0.04\ AbsThick$
Residual standard error: 2.38, adjusted R^2: 0.69

where M_{all} is the sum of the weights per unit area of the subfloor and the ceiling layers, kg/m^2.

Figure 15 to Figure 17 show that the regression equations do not predict well for floors with concrete or hard surfaces. There are not enough data points to allow a thorough analysis.

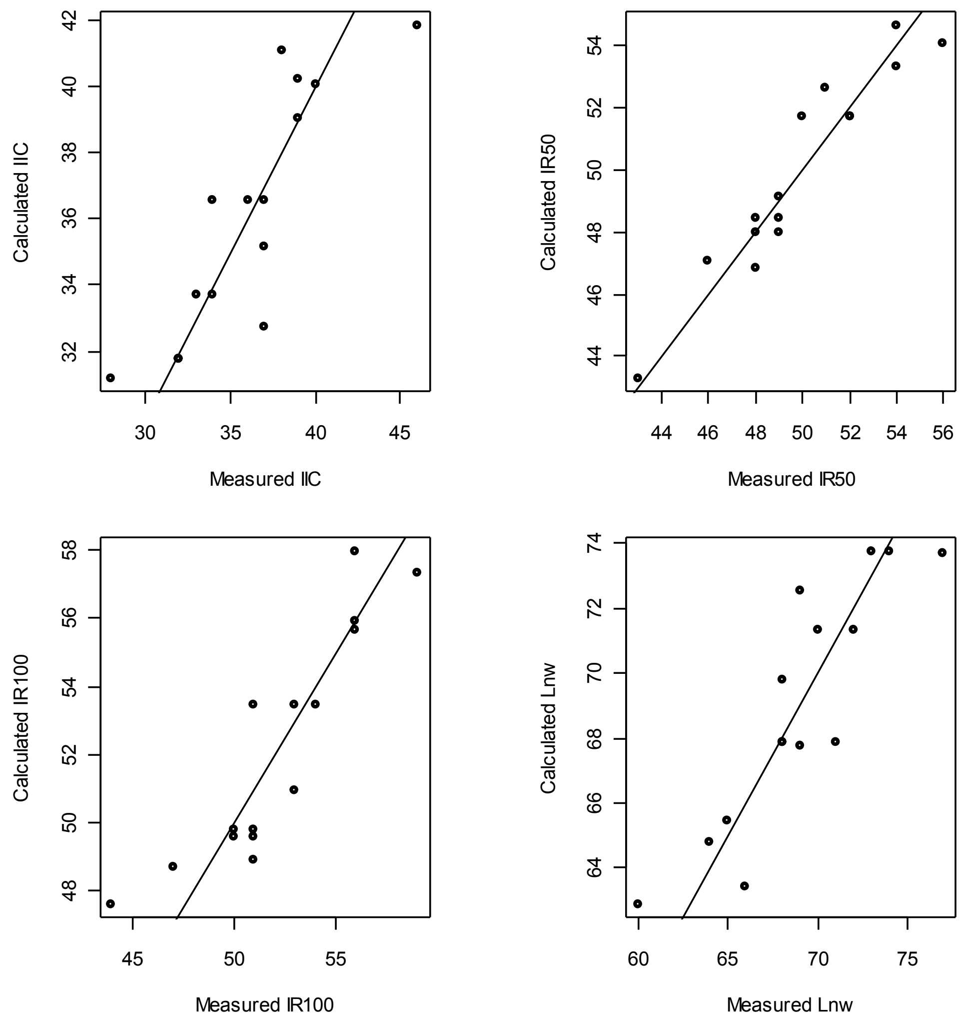

Figure 15: Calculated versus measured impact ratings for joist floors with concrete based toppings.

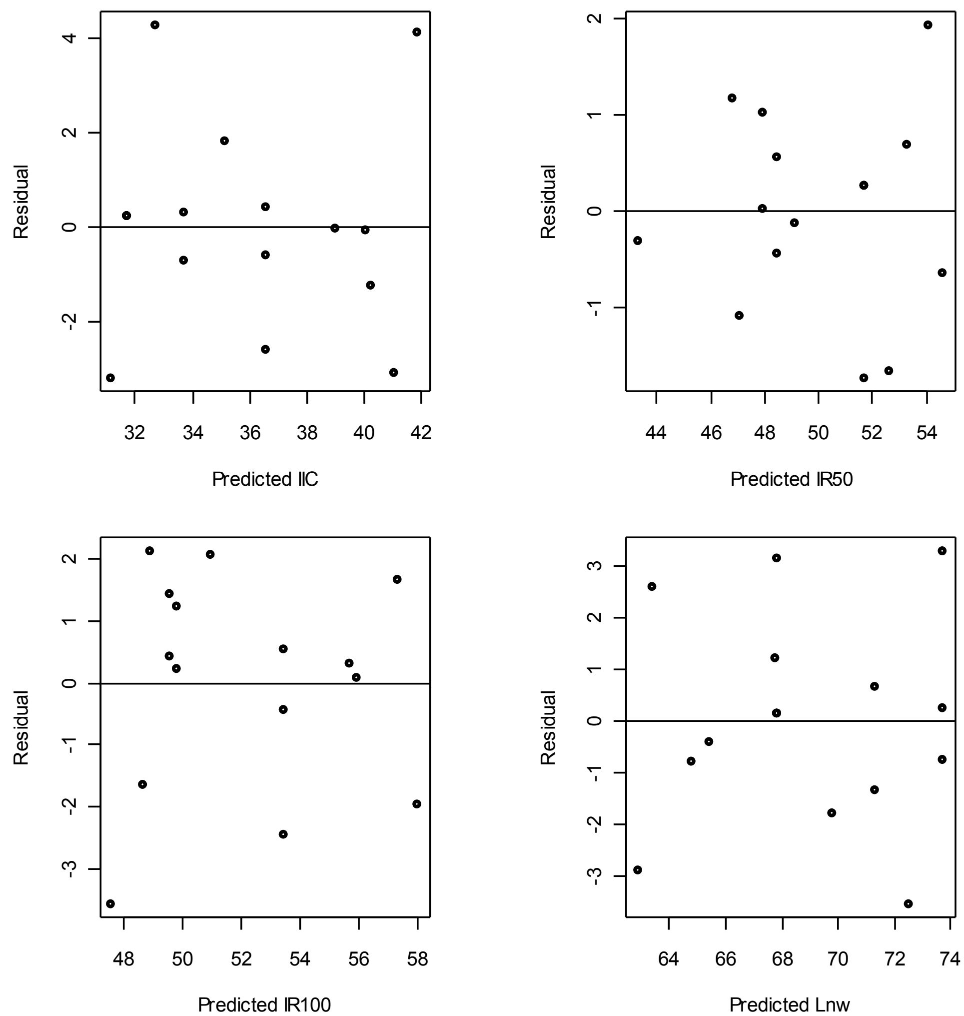

Figure 16: Residuals for four impact ratings for joist floors with concrete based toppings.

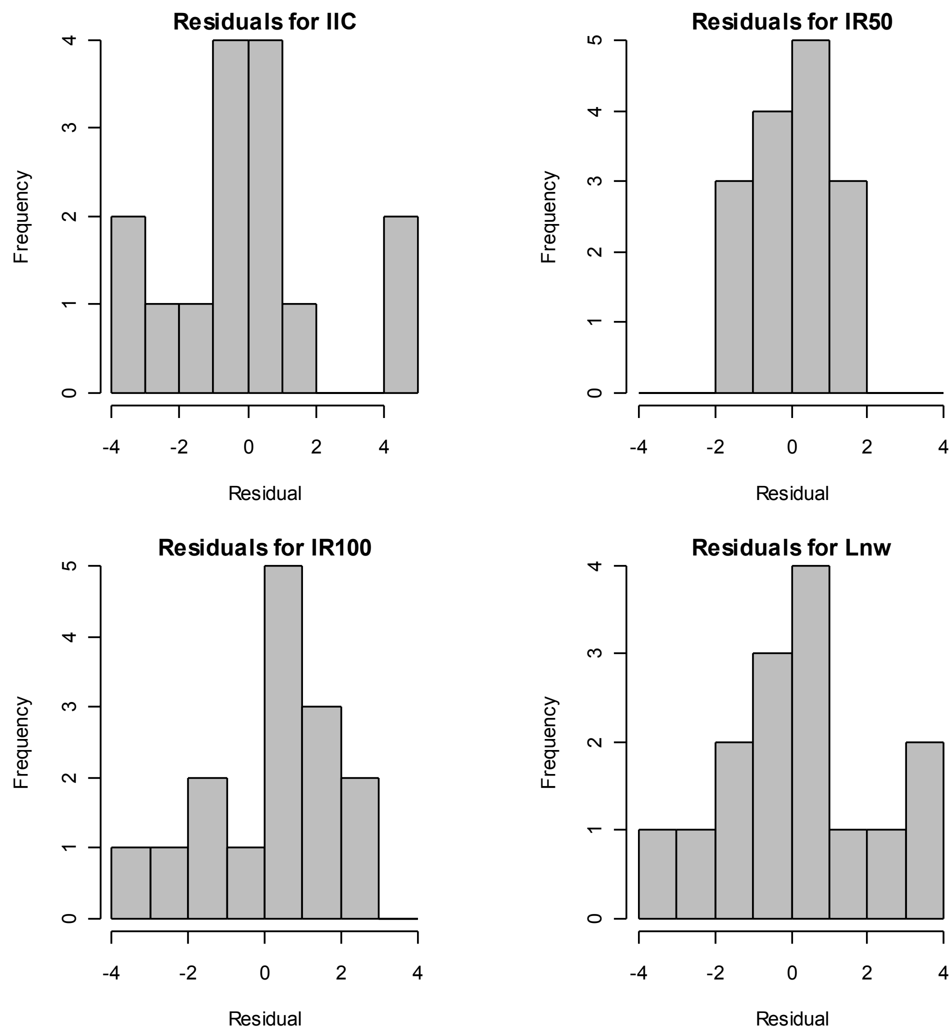

Figure 17: Histograms of residuals for four impact ratings for joist floors with concrete based toppings.

The effects of adding resilient coverings, such as carpets or vinyl, or floating floors were not examined in this project. General effects are known from other work,[11] but no prediction schemes have been developed to predict the resultant impact sound levels.

The regression equations show that the most important variables are the masses of the floor and ceiling layers. The full benefit of a deeper cavity is not obtained because of transmission by way of the joists and the resilient metal channels to the ceiling.

Construction details and Materials

Except as otherwise indicated, the construction details given in reference [1] for the layout of subfloor panels and gypsum board, application of screws and other materials apply to the constructions used in this project.

Floors with only a single layer of gypsum board usually had additional short pieces of resilient metal channels attached to the joists to support the un-tapered, short edges of the gypsum board. A + sign following the separation for resilient metal channels indicates that these additional channels were installed. These additional pieces of channel were not present when double layers of gypsum board were applied.

The standard procedure used by IRC for finishing gypsum board uses a non-hardening acrylic caulking applied to the joints between the sheets, which is then covered by an aluminum tape. Joints between the specimen and the test frame are finished in a similar manner. A series of measurements[12] showed that this technique gives sound attenuation values that are negligibly different from those obtained when the gypsum board is finished using joint compound and tape. This technique allows more frequent testing without having to wait for joint compound to cure.

The average densities of the materials used in the project were as follows:

oriented-strandboard – 580 kg/m^3 ± 3.5 %

plywood – 440 kg/m^3 ± 3.1%

13 mm gypsum board – 742 kg/m^3 ± 2.6 %, 9.4 kg/m^2

16 mm gypsum board – 686 kg/m^3 ± 2.1 %, 10.9 kg/m^2

glass fibre batts – 9.8 kg/m^3 ± 15.4 %

rock fibre batts – 36.4 kg/m^3 ± 5.4 %

cellulose fibre, blown-in – 25.2 kg/m^3 ± 12.5%

cellulose fibre, sprayed-on – 34 kg/m^3

gypsum/cellulose boards – 973 kg/m^3, 12.65 kg/m^2

concrete on corrugated steel deck – 2260 kg/m^3

gypsum concrete – 1890 kg/m^3

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[3] SOCRATES – Sound Classification Rating Estimator. Contact alf.Warnock@nrc-cnrc.gc.ca for the latest version.

[4] ASTM E90. *Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions*.*

[5] ASTM E413. *Classification for Rating Sound Insulation*.*

[6] ISO 717-1. *Acoustics, Rating of sound insulation in buildings and of building elements —Part 1: Airborne sound insulation*.

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[8] ASTM E989. *Standard Classification for Determination of Impact Insulation Class*.*

[9] ISO 717-2. *Acoustics, Rating of sound insulation in buildings and of building elements —Part2: Impact sound insulation.*

[10] R Development Core Team (2003). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-00-3, http://www.R-project.org.

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[12] J.D. Quirt, A.C.C. Warnock, J.A. Birta. Summary Report for Consortium on Gypsum Board Walls : Sound Transmission Results, Internal Report (IRC-IR-693), Institute for Research in Construction, National Research Council Canada, October 1995. http://irc.nrc-cnrc.gc.ca/fulltext/ir693/

*http://www.astm.org. In all cases, the current version of the ASTM test method was used. ASTM standards are available from ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA, 19428-2959 USA.

** http://www.iso.org/iso/en/prods-services/ISOstore/store.html

Appendix 1 - Summary Data Sheets

The summary pages that follow are ordered chronologically. The test identifiers are at the top of the page and the coded description follows immediately. The first two digits following the first hyphen give the year the test was performed. The three digits following the second hyphen give the number of the test. Thus, TLF-03-010 is the identifier for the 10^{th} transmission loss test performed in the year 2003 and IIF-02-021 is the 21^{st} impact sound transmission test made in 2002.

Each page tabulates the transmission loss and normalized impact sound pressure levels. The single number ratings shown in the table are sound transmission class (STC), impact insulation class (IIC), weighted sound reduction index (R_w), and the weighted normalized impact sound pressure level ($L_{n,w}$). In addition to these standardized ratings, the tables also give the ALD50 and IR50 ratings defined in Appendix 2.

Dimensions are in mm unless otherwise noted.

Several of the plots in this appendix show abrupt changes in slope and the transmission loss or impact sound pressure level apparently goes to zero. This is an artifact of the automated procedure used to produce this section of the report. Corresponding values in the table of transmission loss and impact sound pressure level are blank, indicating that valid measurements could not be made at those frequencies. Such values and the corresponding sections of the charts should be ignored.

The standard procedure used by IRC for finishing gypsum board uses a non-hardening acrylic caulking applied to the joints between the sheets, which is then covered by an aluminum tape. Joints between the specimen and the test frame are finished in a similar manner. Unless otherwise noted in the following pages, this is how gypsum board joints were finished. All gypsum board used was Type X.

During the project, two tests were carried out to determine whether there was significant sound leakage through the joints between OSB or plywood panels. There was none. Nevertheless, in all tests the joints between the subfloor panels were taped as a precaution. In actual installations, these boards would always be covered so sound leakage would not be significant.

A few of the specimens in this section had no ceiling installed. These results are not used in the main body of the report but are included here as information useful to researchers.

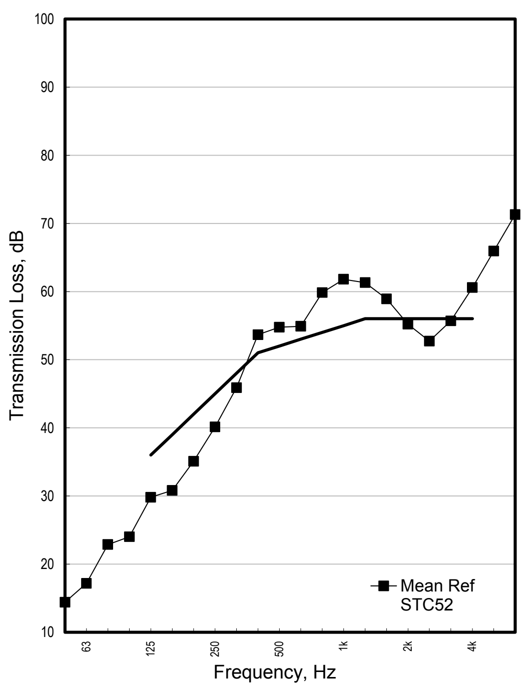
Mean Ref / Mean Ref
OSB15_WJ235(406)_GFB150_RC13(610)_G16

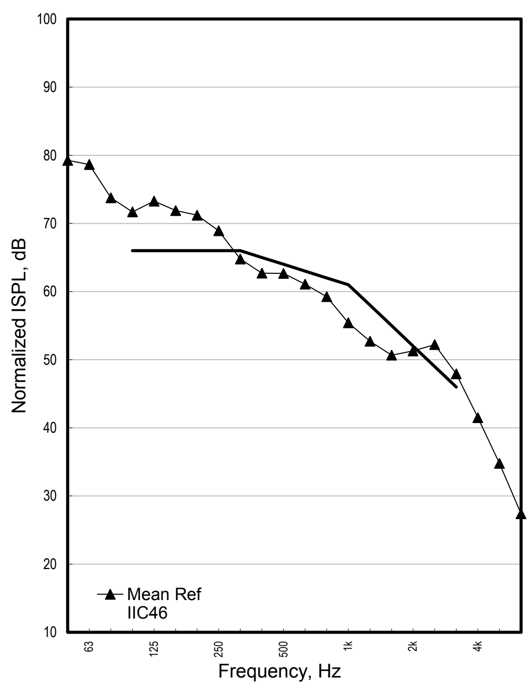
Freq. Hz	Mean Ref	Mean Ref
50	14	79
63	17	79
80	23	74
100	24	72
125	30	73
160	31	72
200	35	71
250	40	69
315	46	65
400	54	63
500	55	63
630	55	61
800	60	59
1000	62	55
1250	61	53
1600	59	51
2000	55	51
2500	53	52
3150	56	48
4000	61	42
5000	66	35
6300	71	27
STC/IIC	**52**	**46**
$R_w/L_{n,w}$	**50**	**65**
ALD50/IR50	45	41

Material	N	Thick.	Spac.
Oriented strandboard	1	15	
Wood joists		235	406
Glass fibre batts		152	
Resilient metal channels		13	610
Gypsum board	1	16	

	Mass, kg	
Frame	224.0	
Floor layers	182.4	9.1 kg/m^2
Ceiling layers	202.0	11.3 kg/m^2

This is the arithmetic average of several re-builds of the same floor construction from Phase I of the project. TLF-95-043a, TLF-95-059a, TLF-95-093a, TLF-95-121a, TLF-95-151a, TLF-96-047a, TLF-96-079a, TLF-96-095a.
38 x 235 x 3924 mm joists. Gypsum board layer screwed 305 oc. OSB screwed 150 oc around edges, 305 oc in the field. One set of 19 x 64 mm cross bridging.





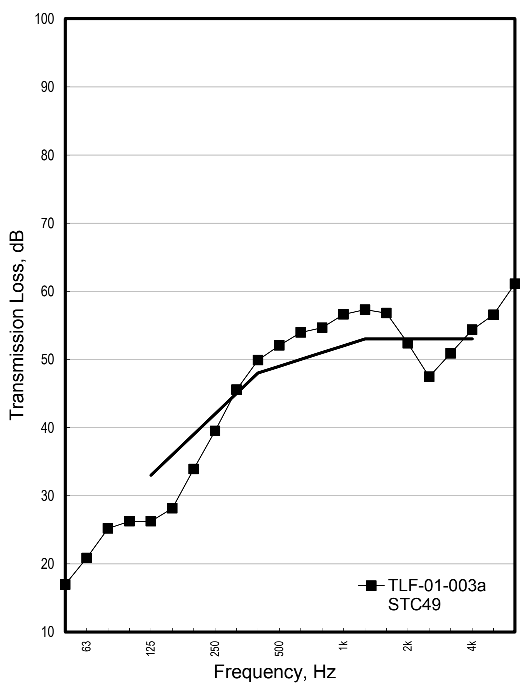
TLF-01-003a / IIF-00-036
PLY16_SJ203(406)_GFB90_RC13(406)_2G13

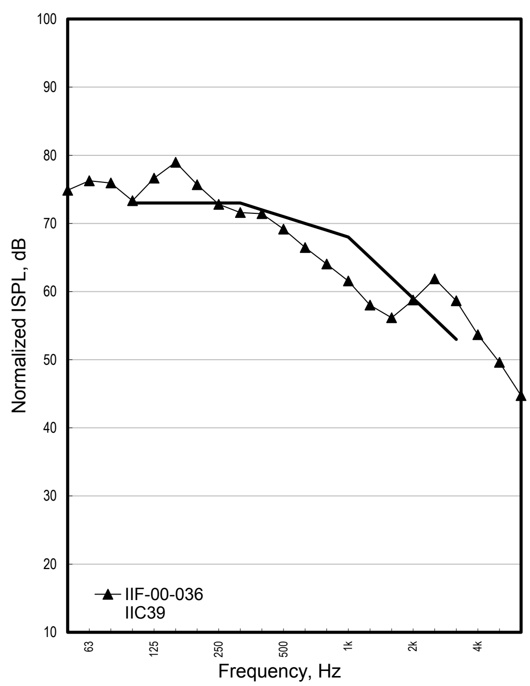
Freq. Hz	TLF-01-003a	IIF-00-036
50	17	75
63	21	76
80	25	76
100	26	73
125	26	77
160	28	79
200	34	76
250	40	73
315	46	72
400	50	71
500	52	69
630	54	66
800	55	64
1000	57	62
1250	57	58
1600	57	56
2000	52	59
2500	47	62
3150	51	59
4000	54	54
5000	57	50
6300	61	45
STC/IIC	**49**	**39**
$R_w/L_{n,w}$	**48**	**71**
ALD50/IR50	45	39

Material	N	Thick.	Spac.
Plywood	1	16	
Steel C-joists		203	406
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	169.1	
Floor layers	147.9	7.4 kg/m^2
Ceiling layers	344.9	19.4 kg/m^2

Steel C-joists (1.22 mm thick steel). Gypsum board joints covered with drywall tape and joint compound.





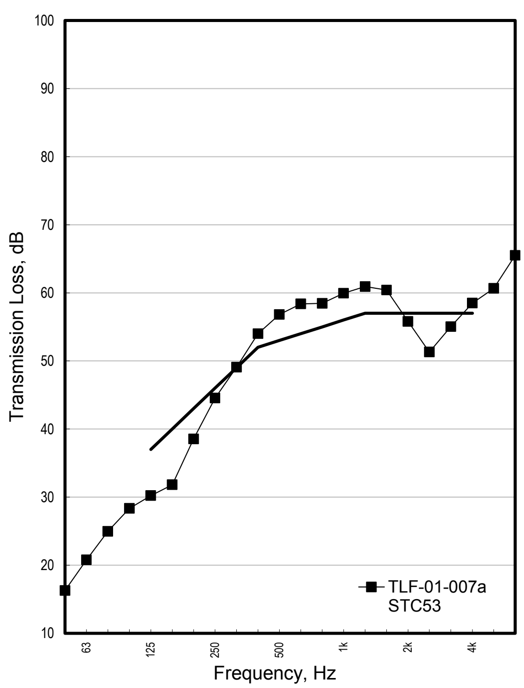
TLF-01-007a / IIF-01-002
2PLY16_SJ203(406)_GFB90_RC13(406)_2G13

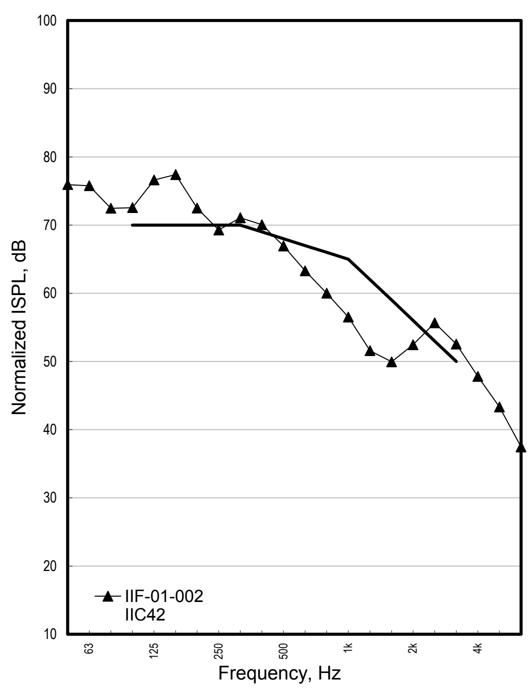
Freq. Hz	TLF-01-007a	IIF-01-002
50	16	76
63	21	76
80	25	72
100	28	73
125	30	77
160	32	77
200	39	72
250	45	69
315	49	71
400	54	70
500	57	67
630	58	63
800	58	60
1000	60	57
1250	61	52
1600	60	50
2000	56	52
2500	51	56
3150	55	53
4000	58	48
5000	61	43
6300	66	37
STC/IIC	**53**	**42**
$R_w/L_{n,w}$	**52**	**68**
ALD50/IR50	47	41

Material	N	Thick.	Spac.
Plywood	2	16	
Steel C-joists		203	406
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	169.1	
Floor layers	293.3	14.6 kg/m^2
Ceiling layers	344.9	19.4 kg/m^2

Steel C-joists (1.22 mm thick steel). Gypsum board joints covered with drywall tape and joint compound.





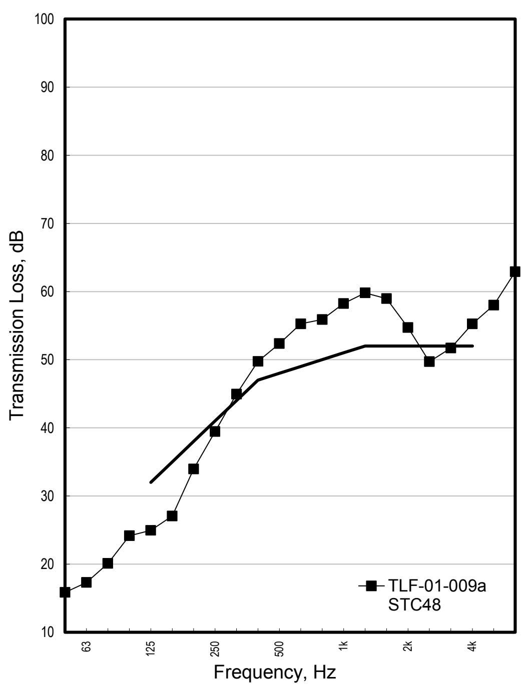
TLF-01-009a / IIF-01-003
2PLY16_SJ203(406)_GFB90_RC13(406)_G13

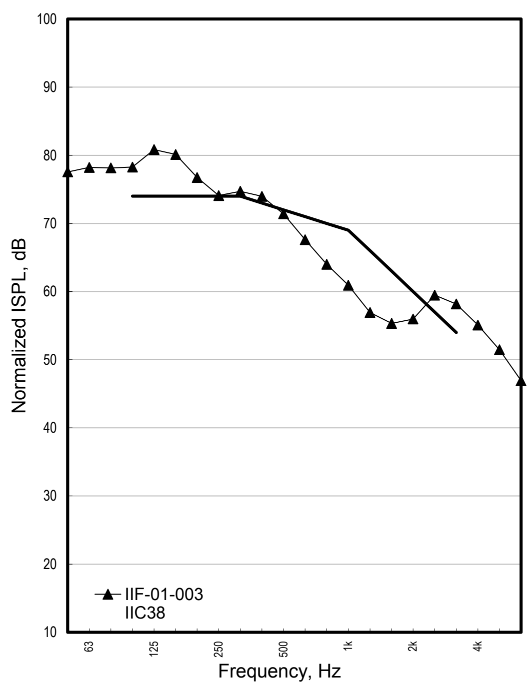
Freq. Hz	TLF-01-009a	IIF-01-003
50	16	78
63	17	78
80	20	78
100	24	78
125	25	81
160	27	80
200	34	77
250	39	74
315	45	75
400	50	74
500	52	71
630	55	68
800	56	64
1000	58	61
1250	60	57
1600	59	55
2000	55	56
2500	50	59
3150	52	58
4000	55	55
5000	58	51
6300	63	47
STC/IIC	**48**	**38**
$R_w/L_{n,w}$	**48**	**72**
ALD50/IR50	44	37

Material	N	Thick.	Spac.
Plywood	2	16	
Steel C-joists		203	406
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	1	13	

	Mass, kg	
Frame	169.1	
Floor layers	293.3	14.6 kg/m^2
Ceiling layers	173.2	9.7 kg/m^2

Steel C-joists (1.22 mm thick steel). Gypsum board joints covered with drywall tape and joint compound.





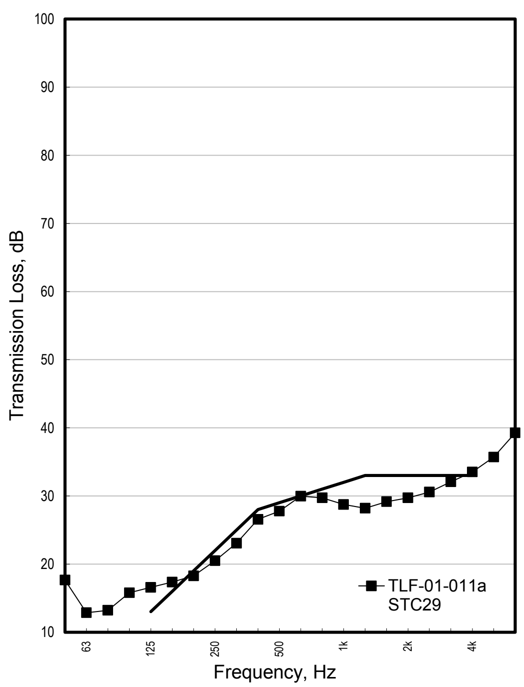
TLF-01-011a / IIF-01-004
2PLY16_SJ203(406)_RC13(406)

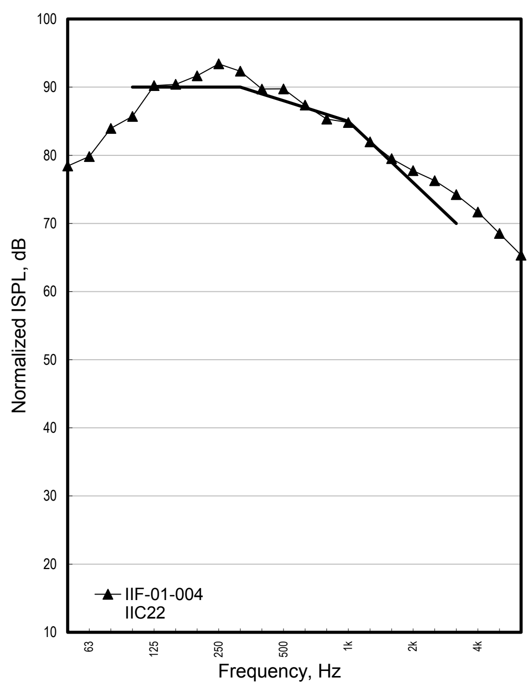
Freq. Hz	TLF-01-011a	IIF-01-004
50	18	78
63	13	80
80	13	84
100	16	86
125	17	90
160	17	90
200	18	92
250	20	93
315	23	92
400	27	90
500	28	90
630	30	87
800	30	85
1000	29	85
1250	28	82
1600	29	79
2000	30	78
2500	31	76
3150	32	74
4000	34	72
5000	36	69
6300	39	65
STC/IIC	**29**	**22**
$R_w/L_{n,w}$	**29**	**88**
ALD50/IR50	28	24

Material	N	Thick.	Spac.
Plywood	2	16	
Steel C-joists		203	406
Resilient metal channels		13	406

	Mass, kg	
Frame	169.1	
Floor layers	293.3	14.6 kg/m^2

Steel C-joists (1.22 mm thick steel). No ceiling installed.





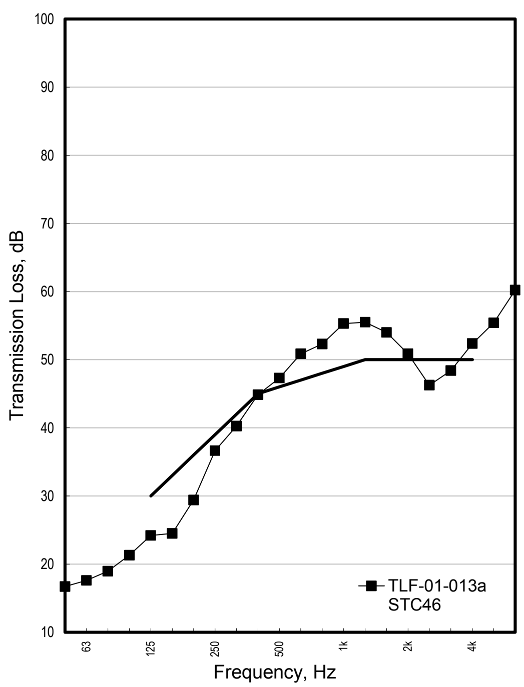
TLF-01-013a / IIF-01-005
2PLY16_SJ203(406)_GFB90_RC13(203)_G13

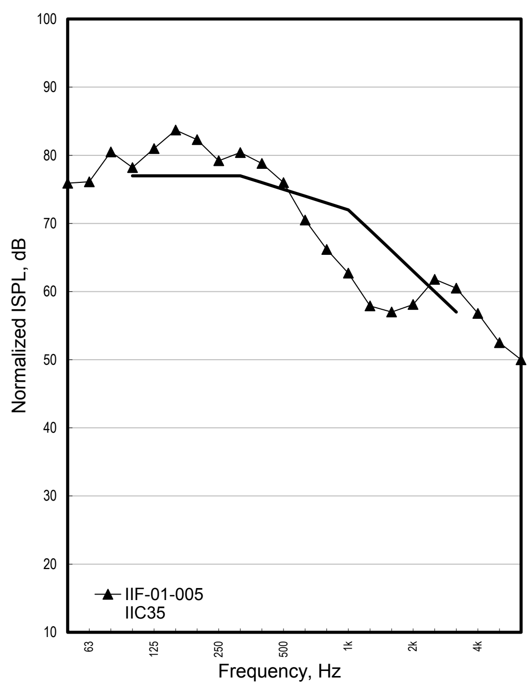
Freq. Hz	TLF-01-013a	IIF-01-005
50	17	76
63	18	76
80	19	81
100	21	78
125	24	81
160	25	84
200	29	82
250	37	79
315	40	80
400	45	79
500	47	76
630	51	71
800	52	66
1000	55	63
1250	56	58
1600	54	57
2000	51	58
2500	46	62
3150	48	61
4000	52	57
5000	55	53
6300	60	50
STC/IIC	**46**	**35**
$R_w/L_{n,w}$	**45**	**75**
ALD50/IR50	41	35

Material	N	Thick.	Spac.
Plywood	2	16	
Steel C-joists		203	406
Glass fibre batts		90	
Resilient metal channels		13	203
Gypsum board	1	13	

	Mass, kg	
Frame	169.1	
Floor layers	293.3	14.6 kg/m^2
Ceiling layers	173.2	9.7 kg/m^2

Steel C-joists (1.2 mm thick steel).





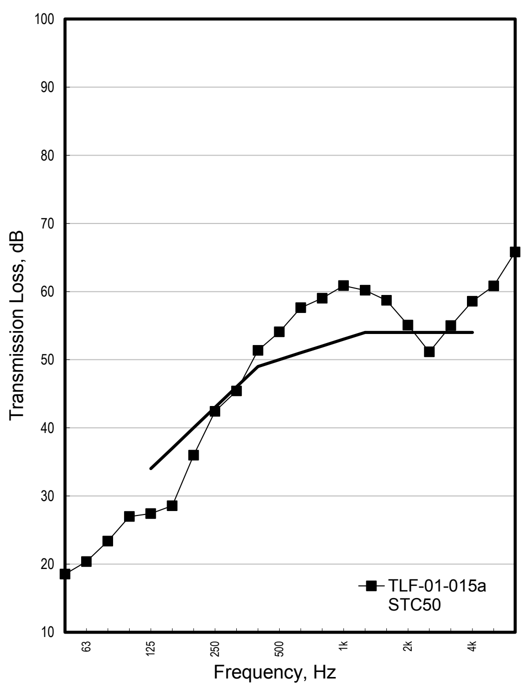
TLF-01-015a / IIF-01-006
2PLY16_SJ203(406)_GFB90_RC13(203)_2G13

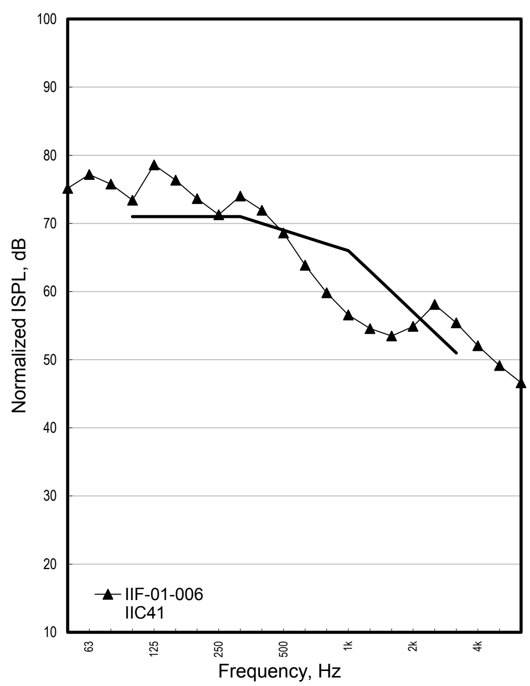
Freq. Hz	TLF-01-015a	IIF-01-006
50	19	75
63	20	77
80	23	76
100	27	73
125	27	79
160	29	76
200	36	74
250	42	71
315	45	74
400	51	72
500	54	69
630	58	64
800	59	60
1000	61	57
1250	60	55
1600	59	53
2000	55	55
2500	51	58
3150	55	55
4000	59	52
5000	61	49
6300	66	47
STC/IIC	**50**	**41**
$R_w/L_{n,w}$	**50**	**69**
ALD50/IR50	46	40

Material	N	Thick.	Spac.
Plywood	2	16	
Steel C-joists		203	406
Glass fibre batts		90	
Resilient metal channels		13	203
Gypsum board	2	13	

	Mass, kg	
Frame	169.1	
Floor layers	293.3	14.6 kg/m^2
Ceiling layers	344.1	19.3 kg/m^2

Steel C-joists (1.22 mm thick steel).





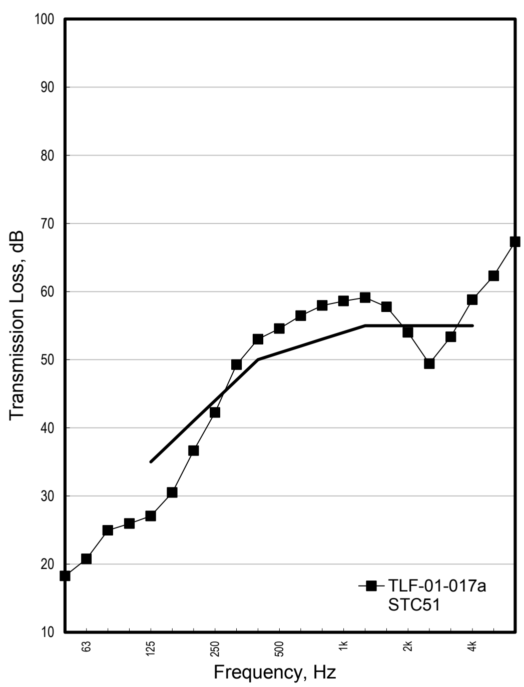
TLF-01-017a / IIF-01-007
OSB16_SJ203(406)_GFB90_RC13(406)_2G13

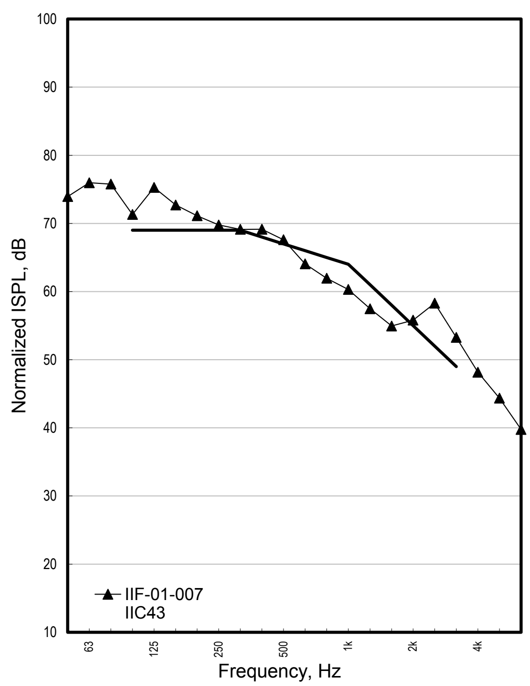
Freq. Hz	TLF-01-017a	IIF-01-007
50	18	74
63	21	76
80	25	76
100	26	71
125	27	75
160	31	73
200	37	71
250	42	70
315	49	69
400	53	69
500	55	68
630	56	64
800	58	62
1000	59	60
1250	59	57
1600	58	55
2000	54	56
2500	49	58
3150	53	53
4000	59	48
5000	62	44
6300	67	40
STC/IIC	**51**	**43**
$R_w/L_{n,w}$	**50**	**67**
ALD50/IR50	46	42

Material	N	Thick.	Spac.
Oriented strandboard	1	16	
Steel C-joists		203	406
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	169.1	
Floor layers	189.6	9.4 kg/m^2
Ceiling layers	344.1	19.3 kg/m^2

Steel C-joists (1.22 mm thick steel).





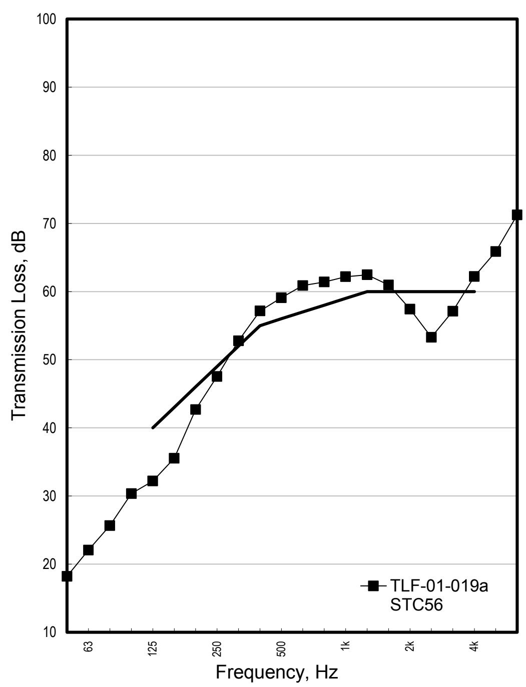
TLF-01-019a / IIF-01-008
2OSB16_SJ203(406)_GFB90_RC13(406)_2G13

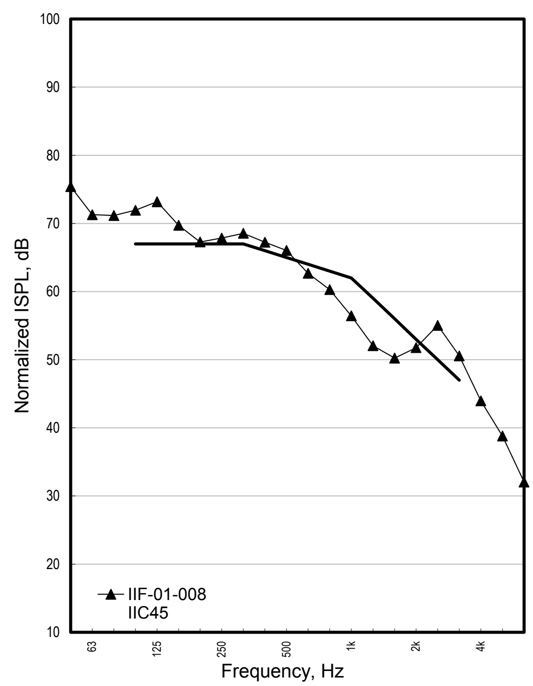
Freq. Hz	TLF-01-019a	IIF-01-008
50	18	75
63	22	71
80	26	71
100	30	72
125	32	73
160	36	70
200	43	67
250	48	68
315	53	69
400	57	67
500	59	66
630	61	63
800	61	60
1000	62	56
1250	62	52
1600	61	50
2000	57	52
2500	53	55
3150	57	51
4000	62	44
5000	66	39
6300	71	32
STC/IIC	**56**	**45**
$R_w/L_{n,w}$	**55**	**65**
ALD50/IR50	50	44

Material	N	Thick.	Spac.
Oriented strandboard	2	16	
Steel C-joists		203	406
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	169.1	
Floor layers	380.1	18.9 kg/m^2
Ceiling layers	344.1	19.3 kg/m^2

Steel C-joists (1.22 mm thick steel).





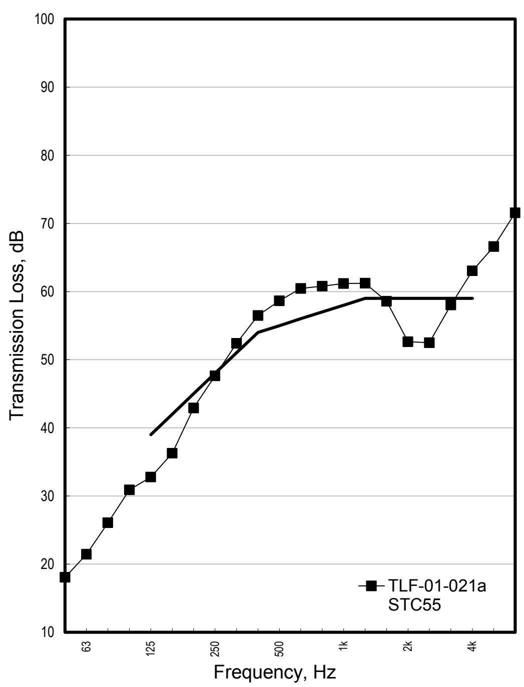
TLF-01-021a / IIF-01-009
2OSB16_SJ203(406)_GFB90_RC13(406)_2G16

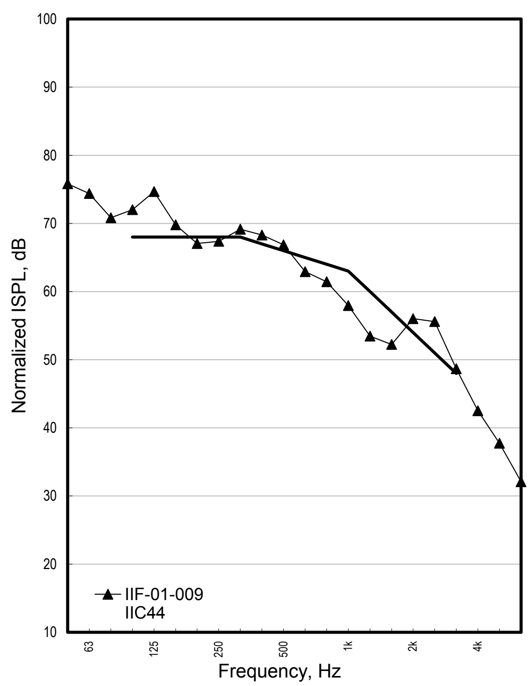
Freq. Hz	TLF-01-021a	IIF-01-009
50	18	76
63	21	74
80	26	71
100	31	72
125	33	75
160	36	70
200	43	67
250	48	67
315	52	69
400	56	68
500	59	67
630	60	63
800	61	61
1000	61	58
1250	61	53
1600	59	52
2000	53	56
2500	52	56
3150	58	49
4000	63	43
5000	67	38
6300	72	32
STC/IIC	**55**	**44**
R_w/$L_{n,w}$	**54**	**66**
ALD50/IR50	50	43

Material	N	Thick.	Spac.
Oriented strandboard	2	16	
Steel C-joists		203	406
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	16	

	Mass, kg	
Frame	169.1	
Floor layers	380.1	18.9 kg/m^2
Ceiling layers	385.2	21.6 kg/m^2

Steel C-joists (1.22 mm thick steel).





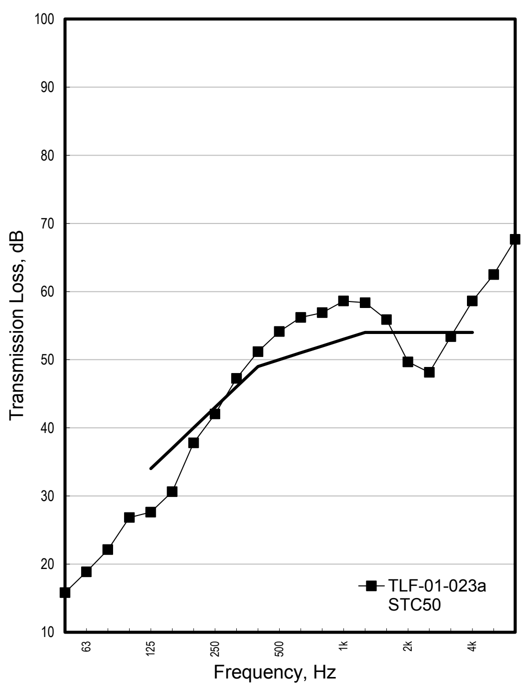
TLF-01-023a / IIF-01-010
2OSB16_SJ203(406)_GFB90_RC13(406)_G16

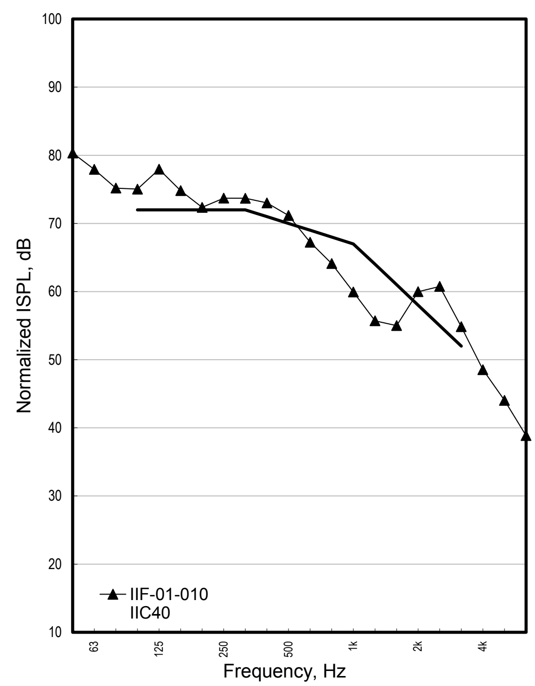
Freq. Hz	TLF-01-023a	IIF-01-010
50	16	80
63	19	78
80	22	75
100	27	75
125	28	78
160	31	75
200	38	72
250	42	74
315	47	74
400	51	73
500	54	71
630	56	67
800	57	64
1000	59	60
1250	58	56
1600	56	55
2000	50	60
2500	48	61
3150	53	55
4000	59	49
5000	62	44
6300	68	39
STC/IIC	**50**	**40**
$R_w/L_{n,w}$	**50**	**70**
ALD50/IR50	46	39

Material	N	Thick.	Spac.
Oriented strandboard	2	16	
Steel C-joists		203	406
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	1	16	

	Mass, kg	
Frame	169.1	
Floor layers	380.1	18.9 kg/m^2
Ceiling layers	191.1	10.7 kg/m^2

Steel C-joists (1.22 mm thick steel).





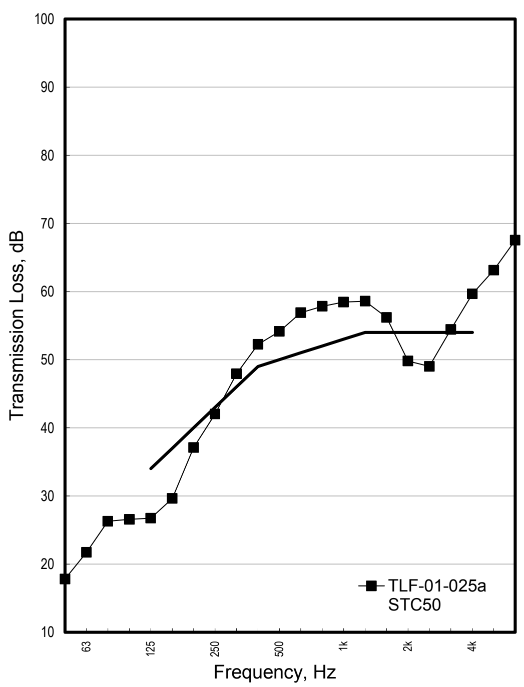
TLF-01-025a / IIF-01-011
OSB16_SJ203(406)_GFB90_RC13(406)_2G16

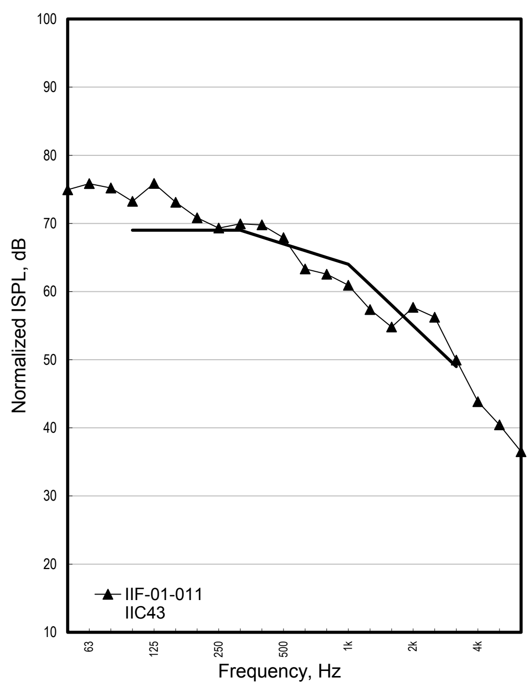
Freq. Hz	TLF-01-025a	IIF-01-011
50	18	75
63	22	76
80	26	75
100	27	73
125	27	76
160	30	73
200	37	71
250	42	69
315	48	70
400	52	70
500	54	68
630	57	63
800	58	63
1000	58	61
1250	59	57
1600	56	55
2000	50	58
2500	49	56
3150	54	50
4000	60	44
5000	63	40
6300	68	37
STC/IIC	**50**	**43**
$R_w/L_{n,w}$	**49**	**67**
ALD50/IR50	46	41

Material	N	Thick.	Spac.
Oriented strandboard	1	16	
Steel C-joists		203	406
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	16	

	Mass, kg	
Frame	169.1	
Floor layers	189.6	9.4 kg/m^2
Ceiling layers	385.2	21.6 kg/m^2

Steel C-joists (1.22 mm thick steel).





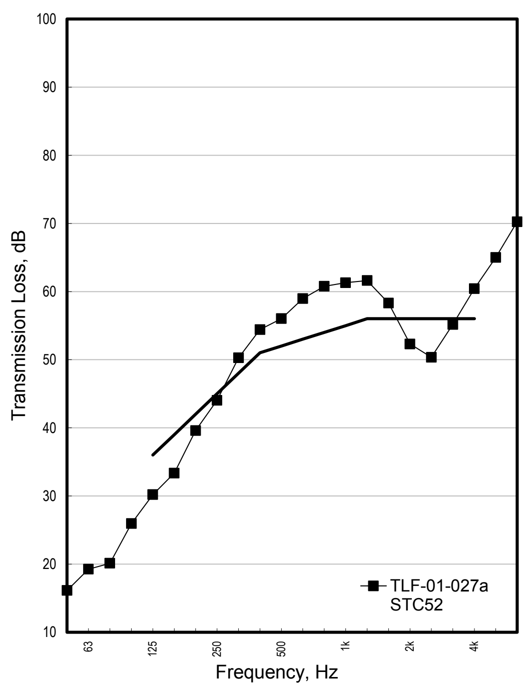
TLF-01-027a / IIF-01-012
2OSB16_SJ203(406)_RFB90_RC13(406)_G16

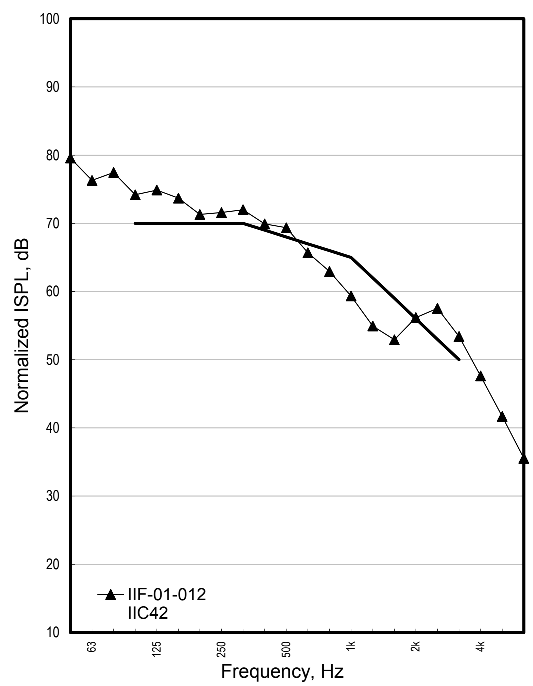
Freq. Hz	TLF-01-027a	IIF-01-012
50	16	80
63	19	76
80	20	77
100	26	74
125	30	75
160	33	74
200	40	71
250	44	72
315	50	72
400	54	70
500	56	69
630	59	66
800	61	63
1000	61	59
1250	62	55
1600	58	53
2000	52	56
2500	50	58
3150	55	53
4000	60	48
5000	65	42
6300	70	36
STC/IIC	**52**	**42**
$R_w/L_{n,w}$	**51**	**68**
ALD50/IR50	46	40

Material	N	Thick.	Spac.
Oriented strandboard	2	16	
Steel C-joists		203	406
Rock fibre batts		90	
Resilient metal channels		13	406
Gypsum board	1	16	

	Mass, kg	
Frame	169.1	
Floor layers	380.1	18.9 kg/m^2
Ceiling layers	191.1	10.7 kg/m^2

Steel C-joists (1.22 mm thick steel).





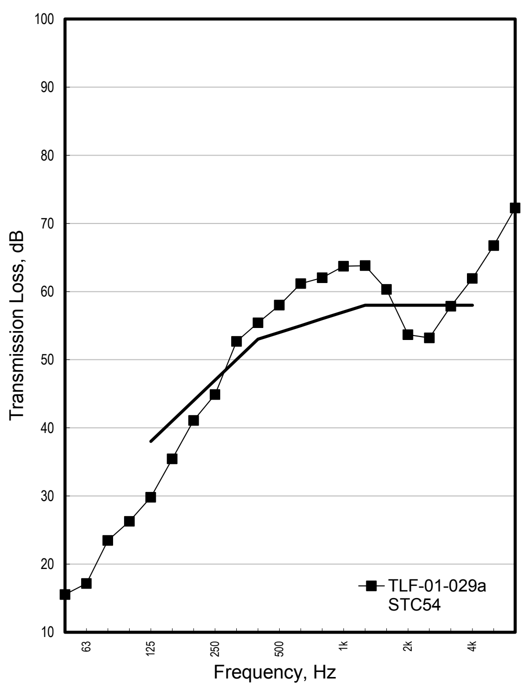
TLF-01-029a / IIF-01-013
2OSB16_SJ203(406)_CFL90_RC13(406)_G16

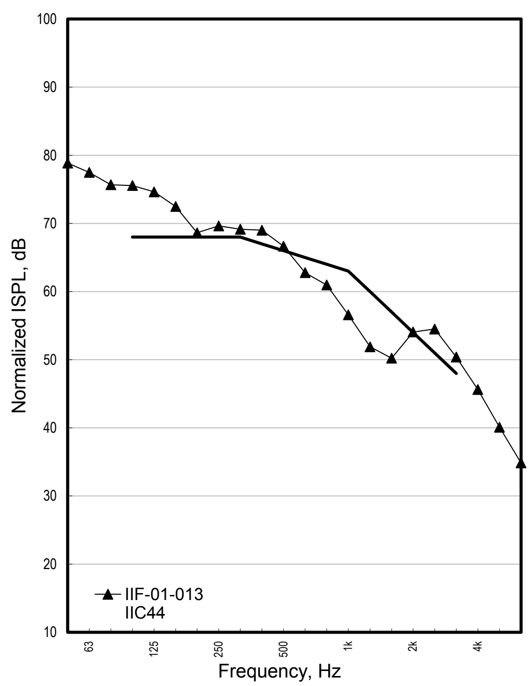
Freq. Hz	TLF-01-029a	IIF-01-013
50	16	79
63	17	77
80	23	76
100	26	76
125	30	75
160	35	72
200	41	69
250	45	70
315	53	69
400	55	69
500	58	67
630	61	63
800	62	61
1000	64	57
1250	64	52
1600	60	50
2000	54	54
2500	53	55
3150	58	50
4000	62	46
5000	67	40
6300	72	35
STC/IIC	**54**	**44**
$R_w/L_{n,w}$	**53**	**66**
ALD50/IR50	47	40

Material	N	Thick.	Spac.
Oriented strandboard	2	16	
Steel C-joists		203	406
Blown-in cellulose fibre		90	
Resilient metal channels		13	406
Gypsum board	1	16	

	Mass, kg	
Frame	169.1	
Floor layers	380.1	18.9 kg/m^2
Ceiling layers	196.2	11 kg/m^2

Steel C-joists (1.22 mm thick steel). Dry cellulose, blown in from the top.





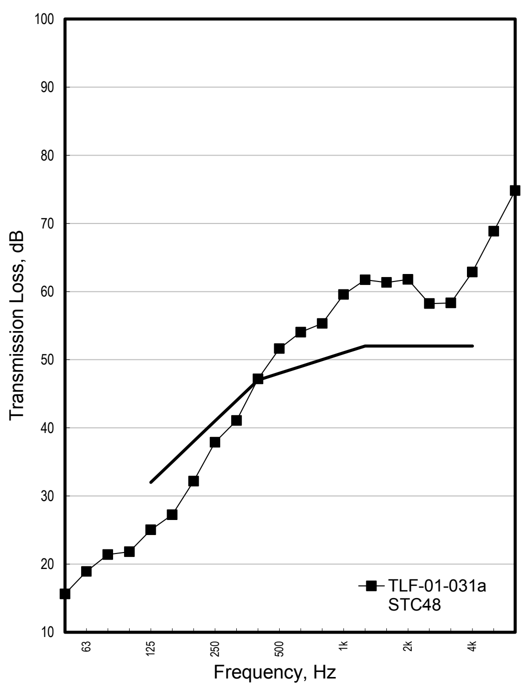
TLF-01-031a / IIF-01-014
PLY16_WT305(406)_CFL90_RC13(406+)_G13

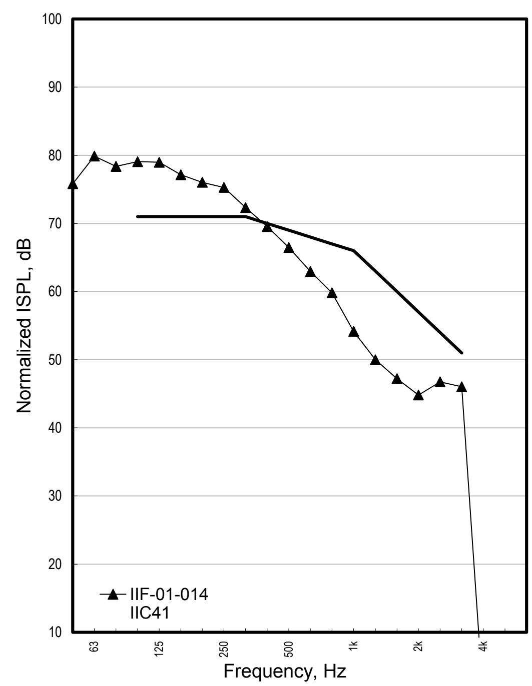
Freq. Hz	TLF-01-031a	IIF-01-014
50	16	76
63	19	80
80	21	78
100	22	79
125	25	79
160	27	77
200	32	76
250	38	75
315	41	72
400	47	70
500	52	66
630	54	63
800	55	60
1000	60	54
1250	62	50
1600	61	47
2000	62	45
2500	58	47
3150	58	46
4000	63	0
5000	69	0
6300	75	0
STC/IIC	**48**	**41**
$R_w/L_{n,w}$	**47**	**70**
ALD50/IR50	43	38

Material	N	Thick.	Spac.
Plywood	1	16	
Wood trusses		305	406
Blown-in cellulose fibre		90	
Resilient metal channels		13	406+
Gypsum board	1	13	

	Mass, kg	
Frame	397.5	
Floor layers	135.6	6.7 kg/m^2
Ceiling layers	171.9	9.7 kg/m^2

Dry cellulose, blown in from the top. Additional short pieces of RCs at gypsum board butt joints.





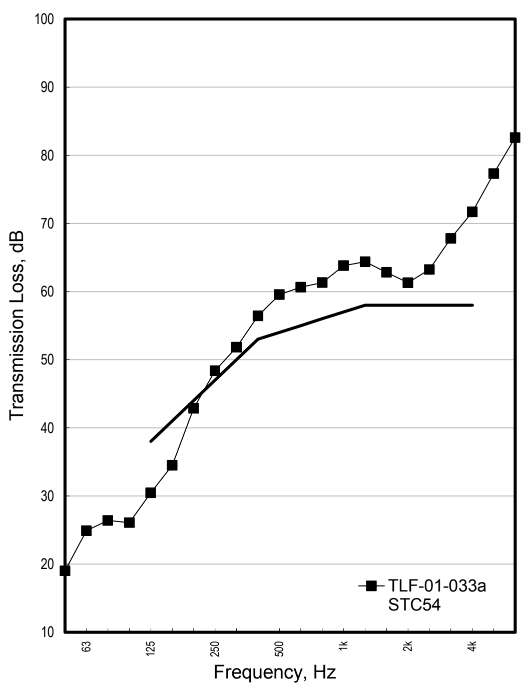
TLF-01-033a / IIF-01-015
2PLY16_WT305(406)_CFL90_RC13(406)_2G16

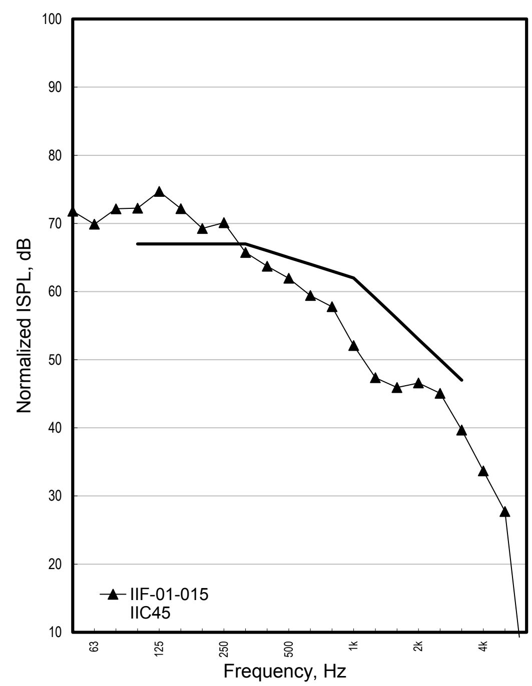
Freq. Hz	TLF-01-033a	IIF-01-015
50	19	72
63	25	70
80	26	72
100	26	72
125	30	75
160	35	72
200	43	69
250	48	70
315	52	66
400	56	64
500	60	62
630	61	59
800	61	58
1000	64	52
1250	64	47
1600	63	46
2000	61	47
2500	63	45
3150	68	40
4000	72	34
5000	77	28
6300	83	0
STC/IIC	**54**	**45**
$R_w/L_{n,w}$	**55**	**64**
ALD50/IR50	49	44

Material	N	Thick.	Spac.
Plywood	2	16	
Wood trusses		305	406
Blown-in cellulose fibre		90	
Resilient metal channels		13	406
Gypsum board	2	16	

	Mass, kg	
Frame	397.5	
Floor layers	279.3	13.9 kg/m^2
Ceiling layers	396.0	22.2 kg/m^2

Dry cellulose, blown in from the top.



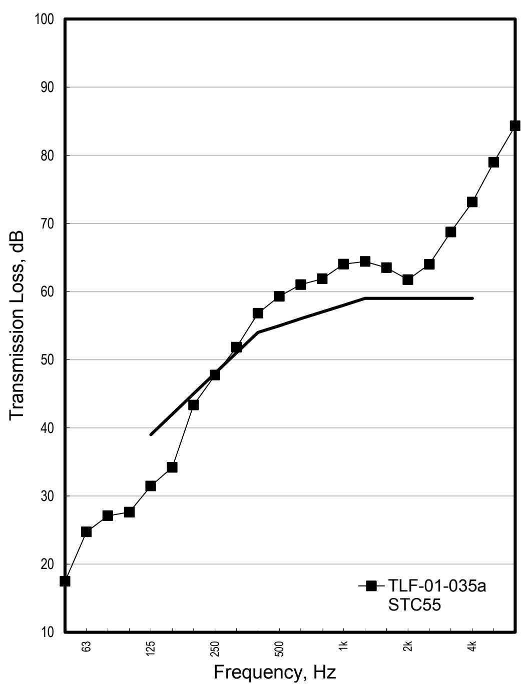


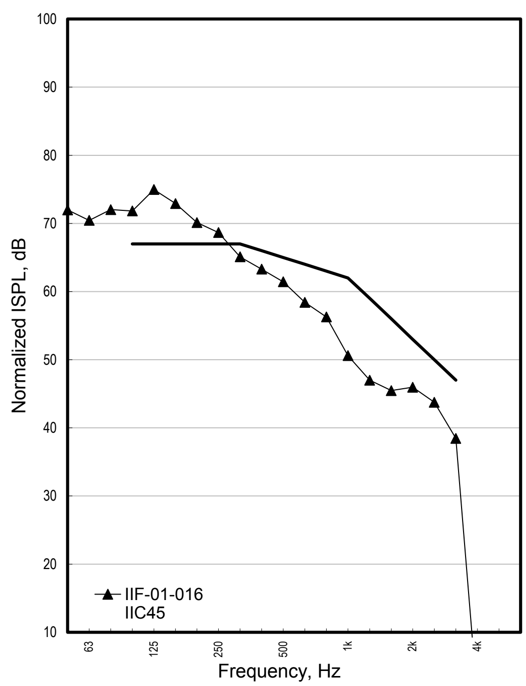
TLF-01-035a / IIF-01-016
2PLY16_WT305(406)_GFB90_RC13(406)_2G16

Freq. Hz	TLF-01-035a	IIF-01-016
50	17	72
63	25	70
80	27	72
100	28	72
125	31	75
160	34	73
200	43	70
250	48	69
315	52	65
400	57	63
500	59	61
630	61	58
800	62	56
1000	64	51
1250	64	47
1600	63	45
2000	62	46
2500	64	44
3150	69	38
4000	73	0
5000	79	0
6300	84	0
STC/IIC	**55**	**45**
$R_w/L_{n,w}$	**56**	**64**
ALD50/IR50	50	44

Material	N	Thick.	Spac.
Plywood	2	16	
Wood trusses		305	406
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	16	

	Mass, kg	
Frame	397.5	
Floor layers	279.3	13.9 kg/m^2
Ceiling layers	396.0	22.2 kg/m^2



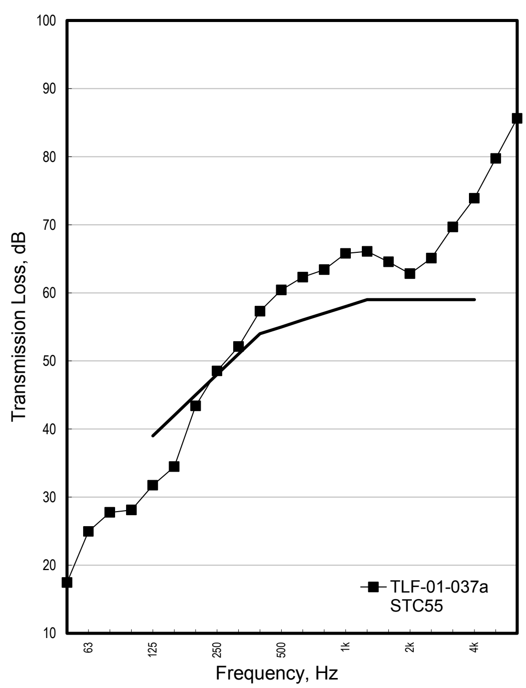


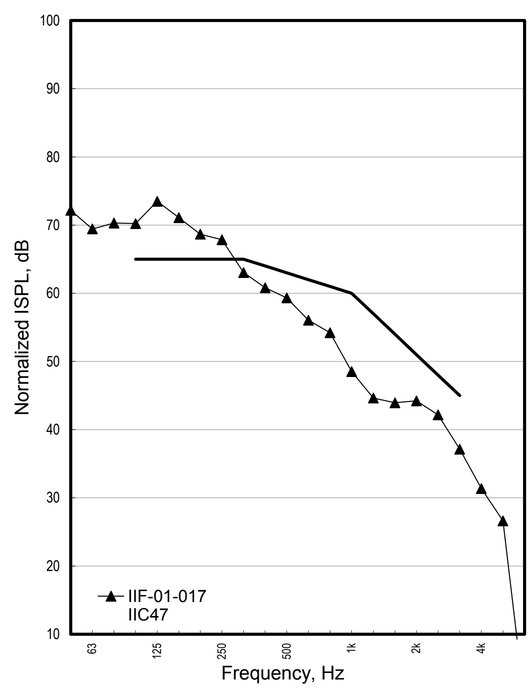
TLF-01-037a / IIF-01-017
2PLY16_WT305(406)_RFB90_RC13(406)_2G16

Freq. Hz	TLF-01-037a	IIF-01-017
50	17	72
63	25	69
80	28	70
100	28	70
125	32	73
160	34	71
200	43	69
250	49	68
315	52	63
400	57	61
500	60	59
630	62	56
800	63	54
1000	66	49
1250	66	45
1600	65	44
2000	63	44
2500	65	42
3150	70	37
4000	74	31
5000	80	27
6300	86	0
STC/IIC	**55**	**47**
R_w/$L_{n,w}$	**56**	**62**
ALD50/IR50	50	45

Material	N	Thick.	Spac.
Plywood	2	16	
Wood trusses		305	406
Rock fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	16	

	Mass, kg	
Frame	397.5	
Floor layers	279.3	13.9 kg/m^2
Ceiling layers	396.0	22.2 kg/m^2



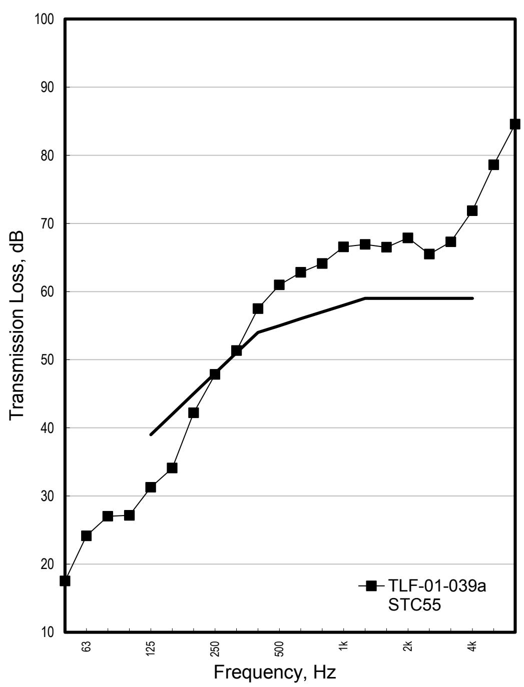


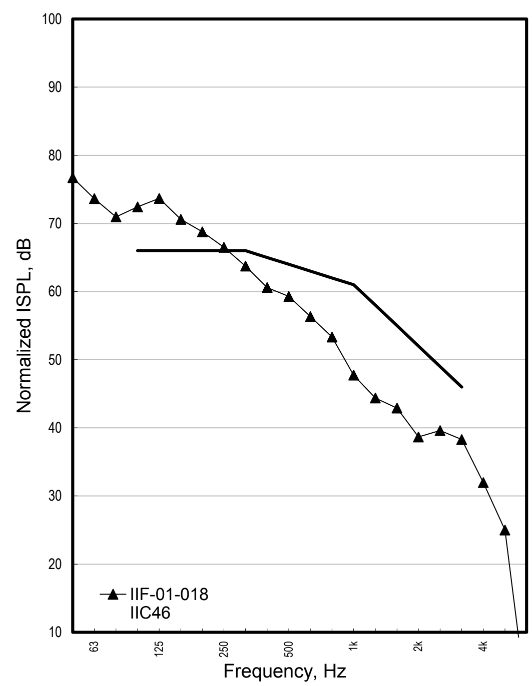
TLF-01-039a / IIF-01-018
2PLY16_WT305(406)_RFB90_RC13(406)_2G13

Freq. Hz	TLF-01-039a	IIF-01-018
50	18	77
63	24	74
80	27	71
100	27	72
125	31	74
160	34	71
200	42	69
250	48	66
315	51	64
400	57	61
500	61	59
630	63	56
800	64	53
1000	67	48
1250	67	44
1600	66	43
2000	68	39
2500	65	40
3150	67	38
4000	72	32
5000	79	25
6300	85	0
STC/IIC	**55**	**46**
$R_w/L_{n,w}$	**55**	**62**
ALD50/IR50	50	43

Material	N	Thick.	Spac.
Plywood	2	16	
Wood trusses		305	406
Rock fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	397.5	
Floor layers	279.3	13.9 kg/m^2
Ceiling layers	343.7	19.3 kg/m^2



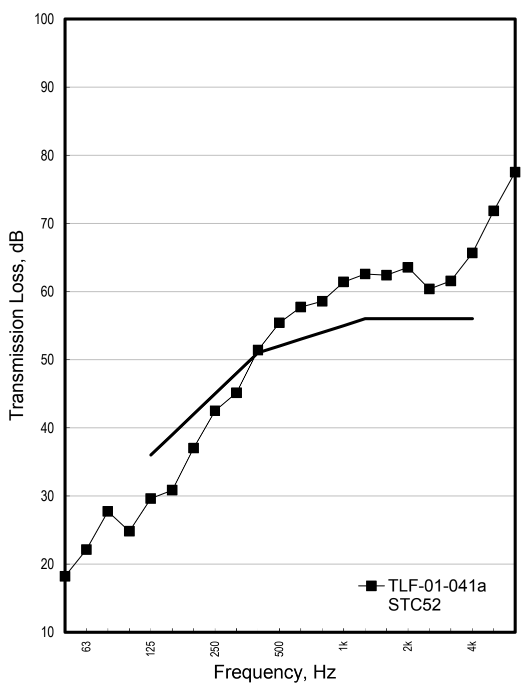


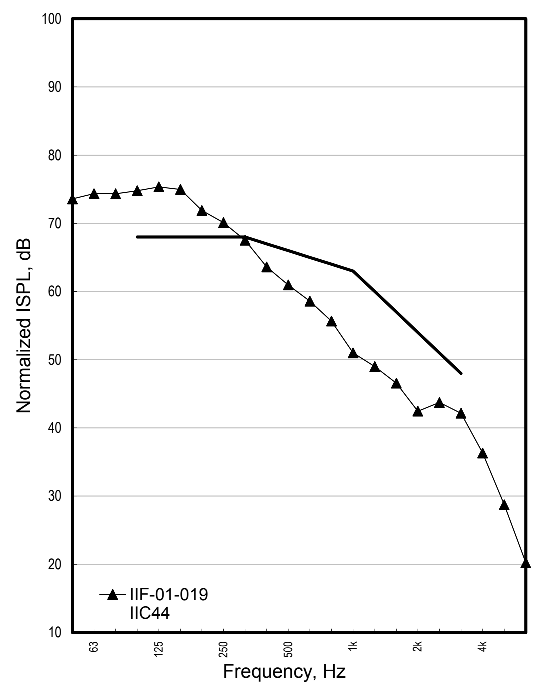
TLF-01-041a / IIF-01-019
PLY16_WT305(406)_GFB90_RC13(406)_2G13

Freq. Hz	TLF-01-041a	IIF-01-019
50	18	74
63	22	74
80	28	74
100	25	75
125	30	75
160	31	75
200	37	72
250	42	70
315	45	68
400	51	64
500	55	61
630	58	59
800	59	56
1000	61	51
1250	63	49
1600	62	47
2000	64	42
2500	60	44
3150	62	42
4000	66	36
5000	72	29
6300	78	20
STC/IIC	**52**	**44**
$R_w/L_{n,w}$	**51**	**66**
ALD50/IR50	47	42

Material	N	Thick.	Spac.
Plywood	1	16	
Wood trusses		305	406
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	397.5	
Floor layers	135.6	6.7 kg/m^2
Ceiling layers	343.7	19.3 kg/m^2





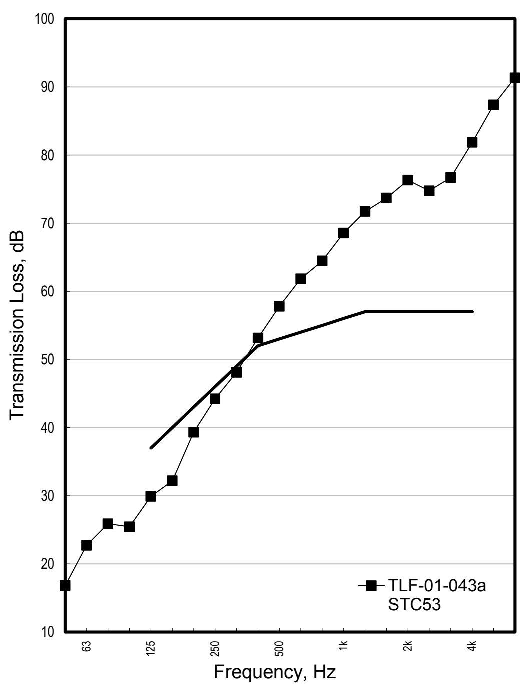
TLF-01-043a / IIF-01-020
CAR_FOMRUB9.5_PLY16_WT305(406)_GFB90_RC13(406)_2G13

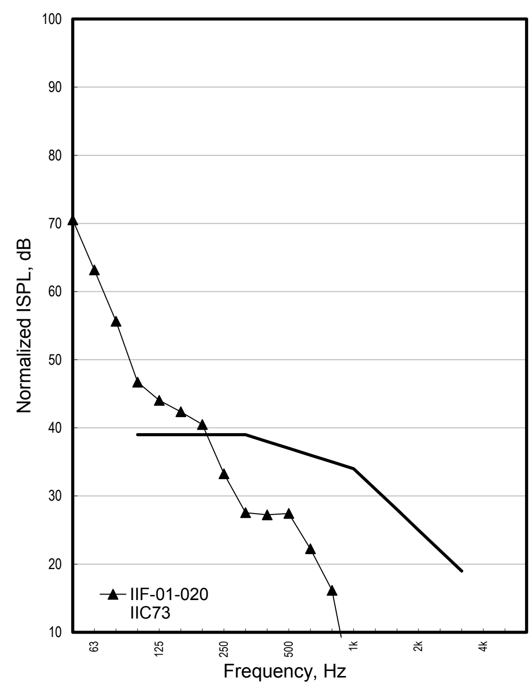
Freq. Hz	TLF-01-043a	IIF-01-020
50	17	71
63	23	63
80	26	56
100	25	47
125	30	44
160	32	42
200	39	40
250	44	33
315	48	28
400	53	27
500	58	27
630	62	22
800	64	16
1000	69	0
1250	72	0
1600	74	0
2000	76	0
2500	75	0
3150	77	0
4000	82	0
5000	87	0
6300	91	0
STC/IIC	**53**	**73**
R_w/$L_{n,w}$	**53**	**34**
ALD50/IR50	48	54

Material	N	Thick.	Spac.
Carpet			
Foam rubber underlay		9.5	
Plywood	1	16	
Wood trusses		305	406
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	397.5	
Floor layers	135.6	6.7 kg/m^2
Ceiling layers	343.7	19.3 kg/m^2

Carpet and underpad installed.





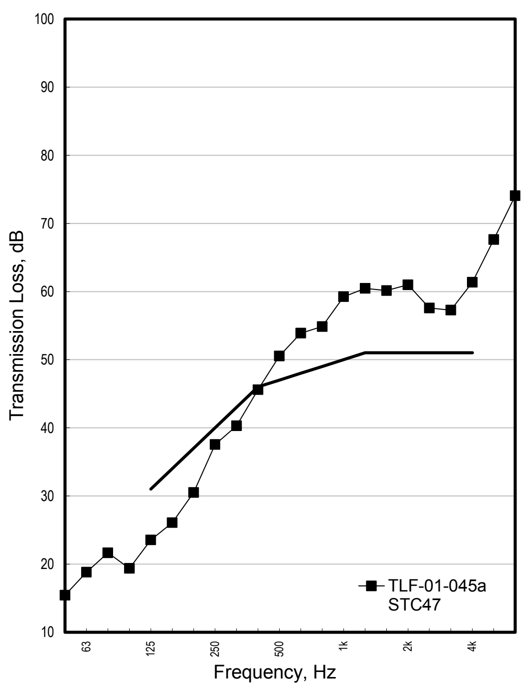
TLF-01-045a / IIF-01-021
PLY16_WT305(406)_GFB90_RC13(406+)_G13

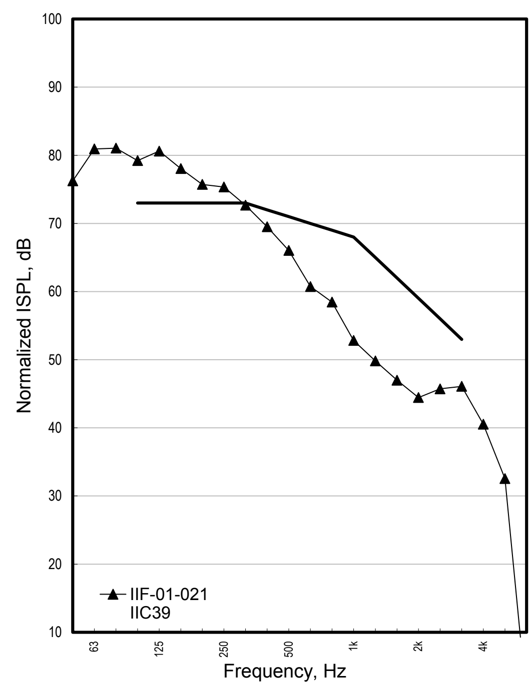
Freq. Hz	TLF-01-045a	IIF-01-021
50	15	76
63	19	81
80	22	81
100	19	79
125	24	81
160	26	78
200	30	76
250	38	75
315	40	73
400	46	70
500	51	66
630	54	61
800	55	58
1000	59	53
1250	60	50
1600	60	47
2000	61	44
2500	58	46
3150	57	46
4000	61	41
5000	68	33
6300	74	0
STC/IIC	**47**	**39**
$R_w/L_{n,w}$	**46**	**70**
ALD50/IR50	42	37

Material	N	Thick.	Spac.
Plywood	1	16	
Wood trusses		305	406
Glass fibre batts		90	
Resilient metal channels		13	406+
Gypsum board	1	13	

	Mass, kg	
Frame	397.5	
Floor layers	135.6	6.7 kg/m^2
Ceiling layers	170.7	9.6 kg/m^2

Additional short pieces of RCs at gypsum board butt joints.





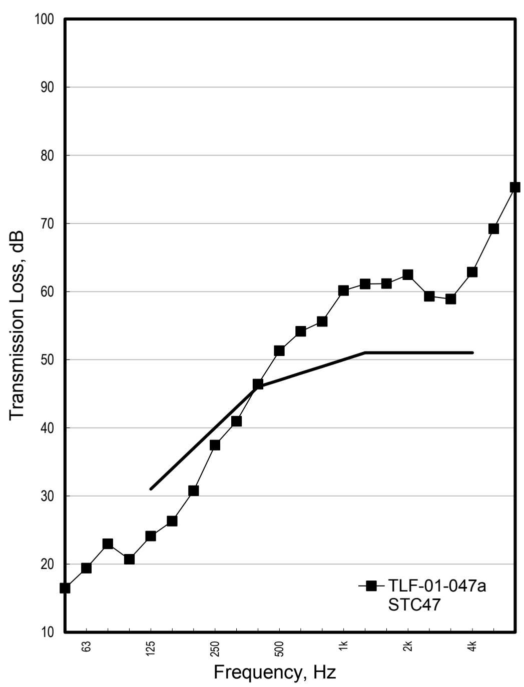
TLF-01-047a / IIF-01-022
PLY16_WT305(406)_RFB90_RC13(406+)_G13

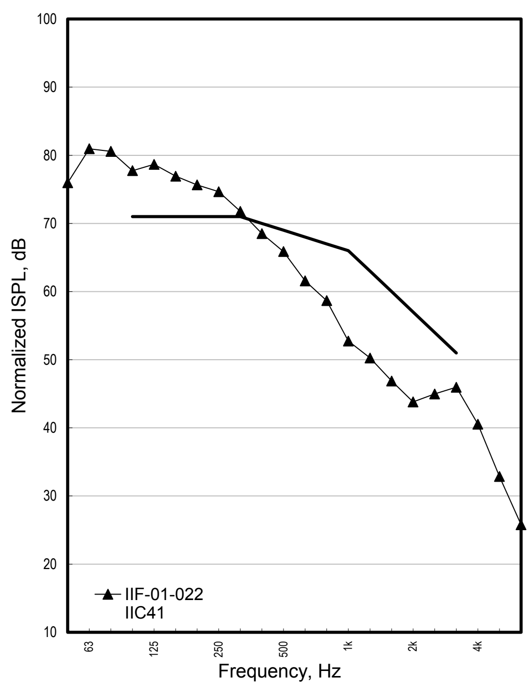
Freq. Hz	TLF-01-047a	IIF-01-022
50	16	76
63	19	81
80	23	81
100	21	78
125	24	79
160	26	77
200	31	76
250	37	75
315	41	72
400	46	69
500	51	66
630	54	62
800	56	59
1000	60	53
1250	61	50
1600	61	47
2000	62	44
2500	59	45
3150	59	46
4000	63	41
5000	69	33
6300	75	26
STC/IIC	**47**	**41**
R_w/$L_{n,w}$	**46**	**69**
ALD50/IR50	43	38

Material	N	Thick.	Spac.
Plywood	1	16	
Wood trusses		305	406
Rock fibre batts		90	
Resilient metal channels		13	406+
Gypsum board	1	13	

	Mass, kg	
Frame	397.5	
Floor layers	135.6	6.7 kg/m^2
Ceiling layers	170.7	9.6 kg/m^2

Additional short pieces of RCs at gypsum board butt joints.



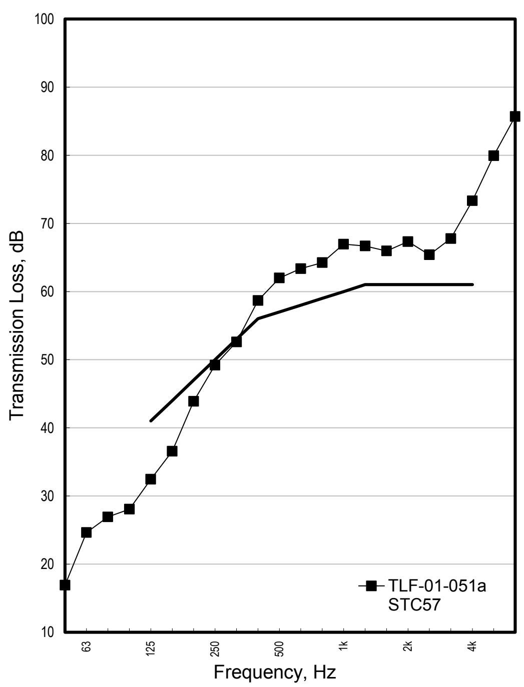


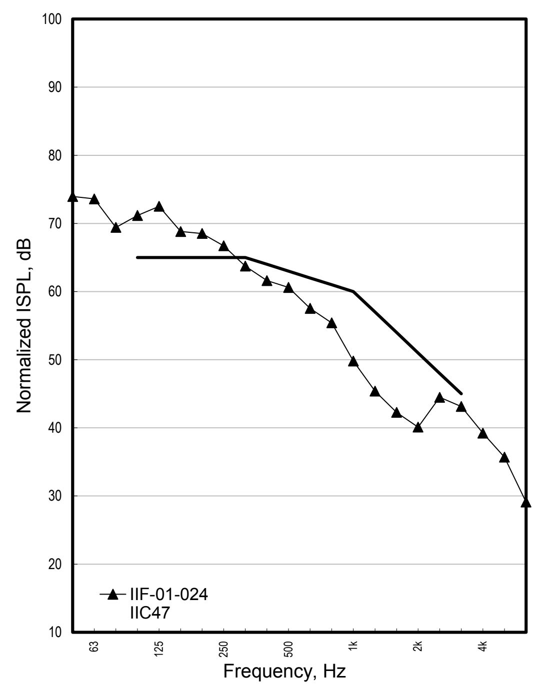
TLF-01-051a / IIF-01-024
2OSB16_WT305(406)_RFB90_RC13(406)_2G13

Freq. Hz	TLF-01-051a	IIF-01-024
50	17	74
63	25	74
80	27	69
100	28	71
125	32	73
160	37	69
200	44	69
250	49	67
315	53	64
400	59	62
500	62	61
630	63	58
800	64	55
1000	67	50
1250	67	45
1600	66	42
2000	67	40
2500	65	44
3150	68	43
4000	73	39
5000	80	36
6300	86	29
STC/IIC	**57**	**47**
$R_w/L_{n,w}$	**57**	**62**
ALD50/IR50	50	44

Material	N	Thick.	Spac.
Oriented strandboard	2	16	
Wood trusses		305	406
Rock fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	397.5	
Floor layers	385.9	19.2 kg/m^2
Ceiling layers	344.9	19.4 kg/m^2



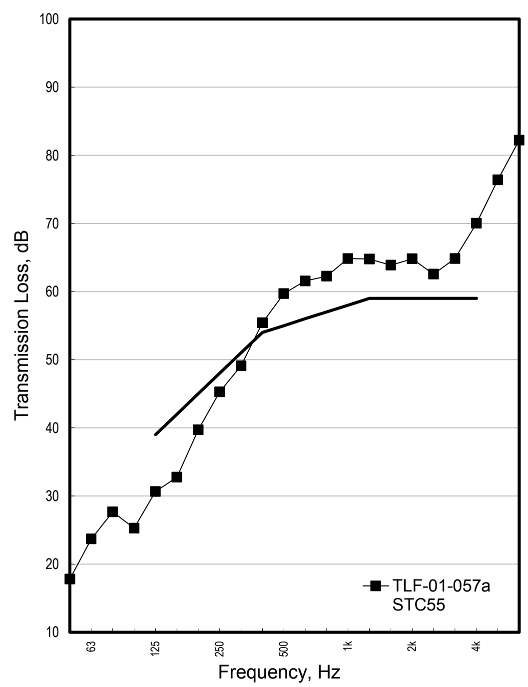


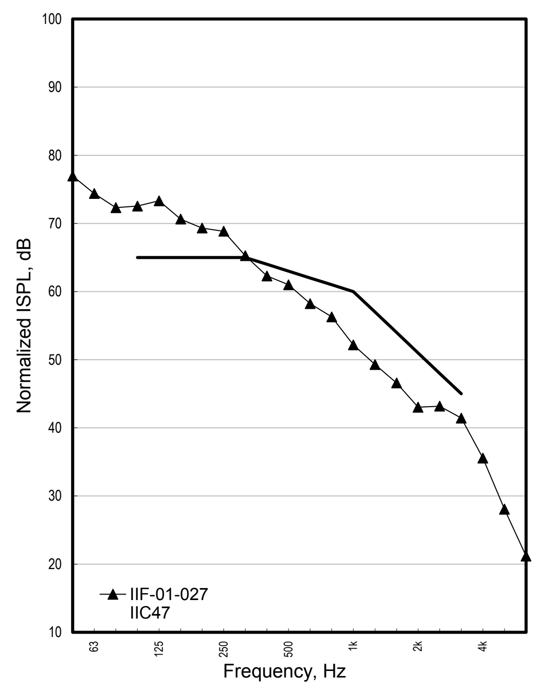
TLF-01-057a / IIF-01-027
OSB16_WT305(406)_RFB90_RC13(406)_2G13

Freq. Hz	TLF-01-057a	IIF-01-027
50	18	77
63	24	74
80	28	72
100	25	73
125	31	73
160	33	71
200	40	69
250	45	69
315	49	65
400	55	62
500	60	61
630	62	58
800	62	56
1000	65	52
1250	65	49
1600	64	47
2000	65	43
2500	63	43
3150	65	41
4000	70	36
5000	76	28
6300	82	21
STC/IIC	**55**	**47**
$R_w/L_{n,w}$	**53**	**63**
ALD50/IR50	48	43

Material	N	Thick.	Spac.
Oriented strandboard	1	16	
Wood trusses		305	406
Rock fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	397.5	
Floor layers	193.4	9.6 kg/m^2
Ceiling layers	344.9	19.4 kg/m^2



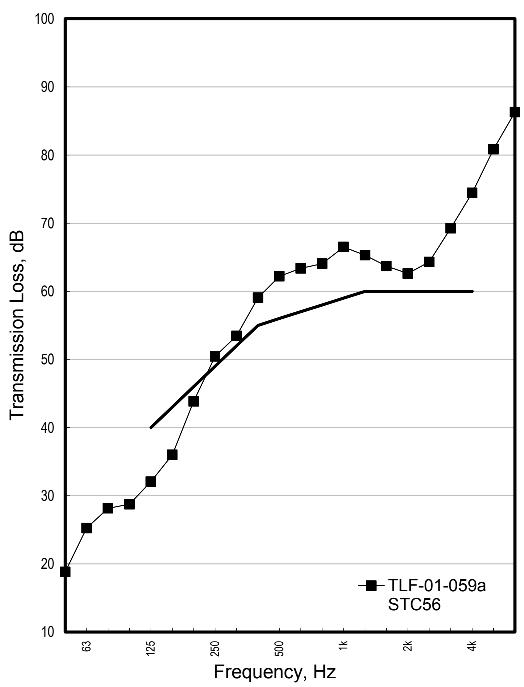


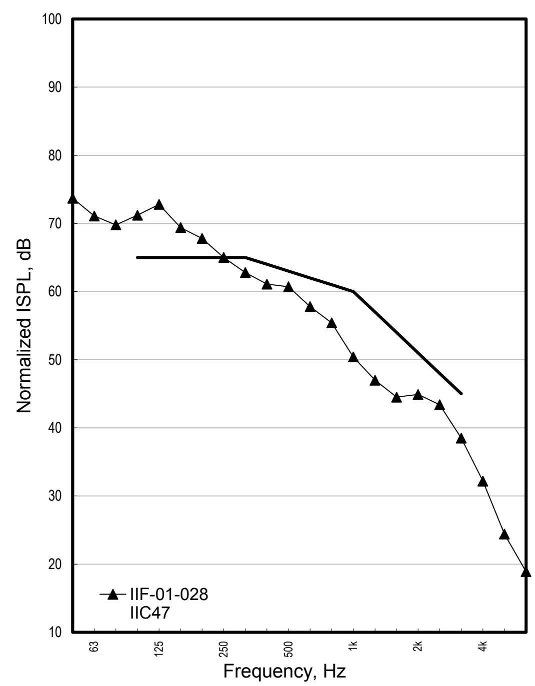
TLF-01-059a / IIF-01-028
2OSB16_WT305(406)_RFB90_RC13(406)_2G16

Freq. Hz	TLF-01-059a	IIF-01-028
50	19	74
63	25	71
80	28	70
100	29	71
125	32	73
160	36	69
200	44	68
250	50	65
315	53	63
400	59	61
500	62	61
630	63	58
800	64	55
1000	67	50
1250	65	47
1600	64	45
2000	63	45
2500	64	43
3150	69	39
4000	74	32
5000	81	24
6300	86	19
STC/IIC	**56**	**47**
R_w/$L_{n,w}$	**57**	**61**
ALD50/IR50	51	45

Material	N	Thick.	Spac.
Oriented strandboard	2	16	
Wood trusses		305	406
Rock fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	16	

	Mass, kg	
Frame	397.5	
Floor layers	358.9	17.9 kg/m^2
Ceiling layers	384.0	21.6 kg/m^2





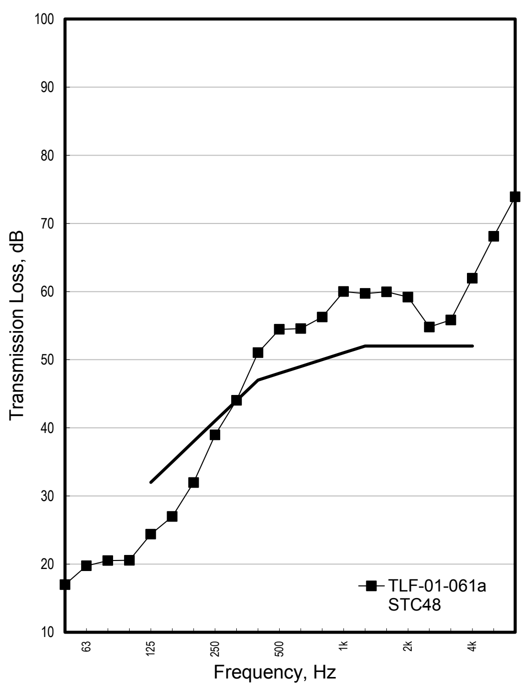
TLF-01-061a / IIF-01-029
2PLY16_WI241(406)_RFB90_RC13(406+)_G13

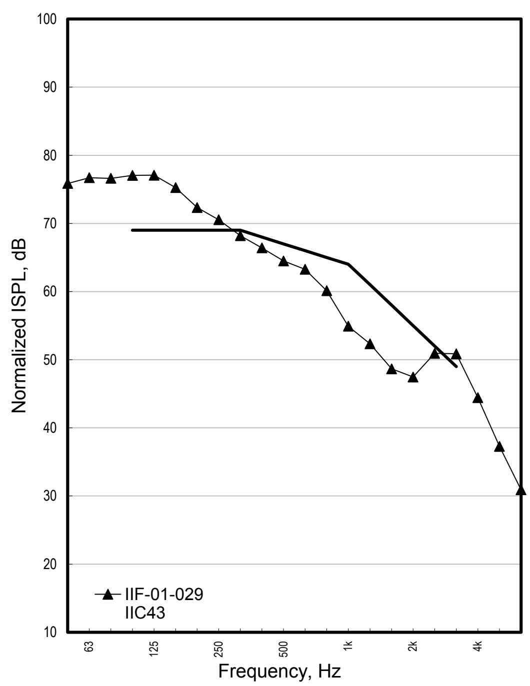
Freq. Hz	TLF-01-061a	IIF-01-029
50	17	76
63	20	77
80	21	77
100	21	77
125	24	77
160	27	75
200	32	72
250	39	71
315	44	68
400	51	66
500	54	64
630	55	63
800	56	60
1000	60	55
1250	60	52
1600	60	49
2000	59	47
2500	55	51
3150	56	51
4000	62	44
5000	68	37
6300	74	31
STC/IIC	**48**	**43**
$R_w/L_{n,w}$	**47**	**67**
ALD50/IR50	43	40

Material	N	Thick.	Spac.
Plywood	2	16	
Wood I-joists		241	406
Rock fibre batts		90	
Resilient metal channels		13	406+
Gypsum board	1	13	

	Mass, kg	
Frame	204.8	
Floor layers	287.1	14.3 kg/m^2
Ceiling layers	172.6	9.7 kg/m^2

Additional short pieces of RCs at gypsum board butt joints.





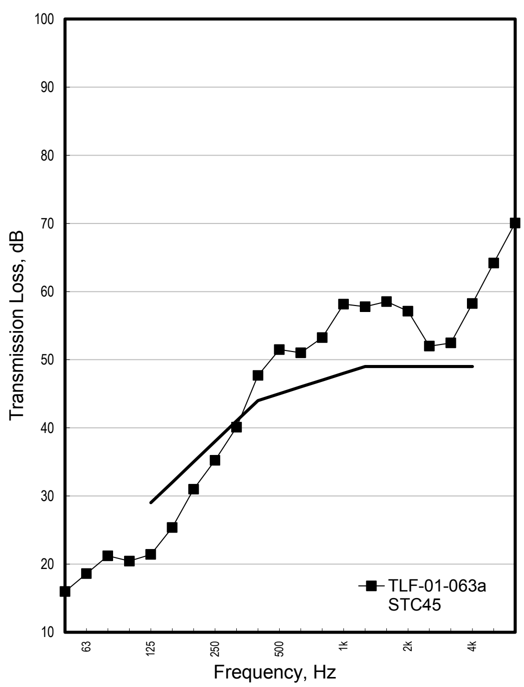
TLF-01-063a / IIF-01-030
PLY16_WI241(406)_RFB90_RC13(406+)_G13

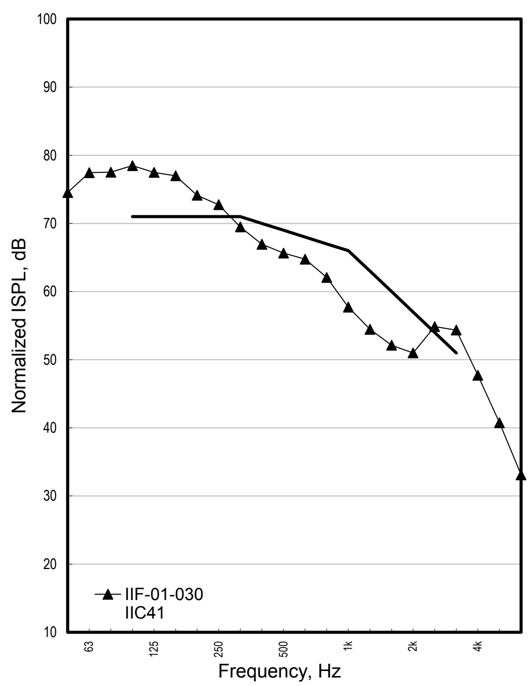
Freq. Hz	TLF-01-063a	IIF-01-030
50	16	75
63	19	77
80	21	78
100	20	78
125	21	77
160	25	77
200	31	74
250	35	73
315	40	69
400	48	67
500	51	66
630	51	65
800	53	62
1000	58	58
1250	58	54
1600	59	52
2000	57	51
2500	52	55
3150	52	54
4000	58	48
5000	64	41
6300	70	33
STC/IIC	**45**	**41**
$R_w/L_{n,w}$	**45**	**69**
ALD50/IR50	42	39

Material	N	Thick.	Spac.
Plywood	1	16	
Wood I-joists		241	406
Rock fibre batts		90	
Resilient metal channels		13	406+
Gypsum board	1	13	

	Mass, kg	
Frame	204.8	
Floor layers	142.5	7.1 kg/m^2
Ceiling layers	172.6	9.7 kg/m^2

Additional short pieces of RCs at gypsum board butt joints.





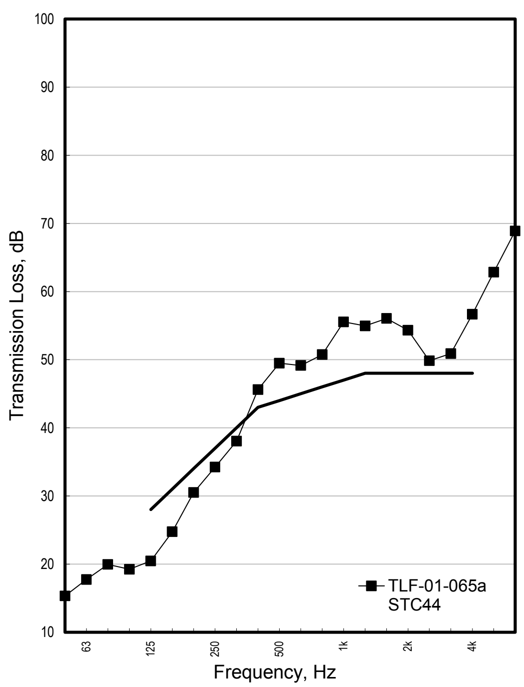
TLF-01-065a / IIF-01-031
PLY16_WI241(406)_GFB90_RC13(406+)_G13

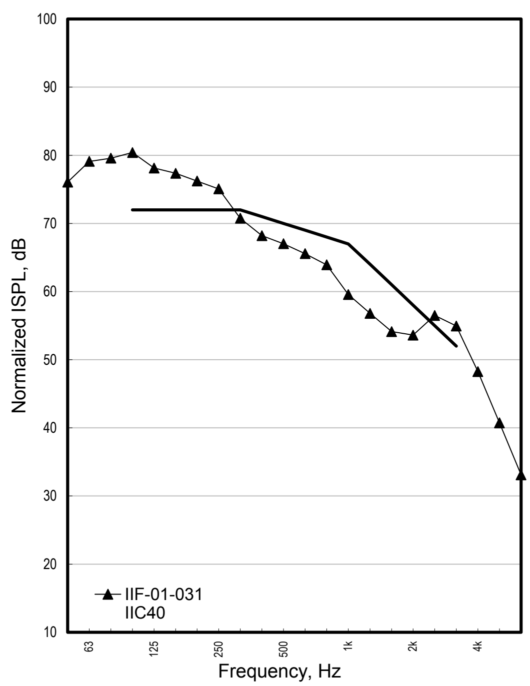
Freq. Hz	TLF-01-065a	IIF-01-031
50	15	76
63	18	79
80	20	80
100	19	80
125	20	78
160	25	77
200	30	76
250	34	75
315	38	71
400	46	68
500	49	67
630	49	66
800	51	64
1000	56	60
1250	55	57
1600	56	54
2000	54	54
2500	50	56
3150	51	55
4000	57	48
5000	63	41
6300	69	33
STC/IIC	**44**	**40**
$R_w/L_{n,w}$	**44**	**70**
ALD50/IR50	41	38

Material	N	Thick.	Spac.
Plywood	1	16	
Wood I-joists		241	406
Glass fibre batts		90	
Resilient metal channels		13	406+
Gypsum board	1	13	

	Mass, kg	
Frame	204.8	
Floor layers	142.5	7.1 kg/m^2
Ceiling layers	172.6	9.7 kg/m^2

Additional short pieces of RCs at gypsum board butt joints.





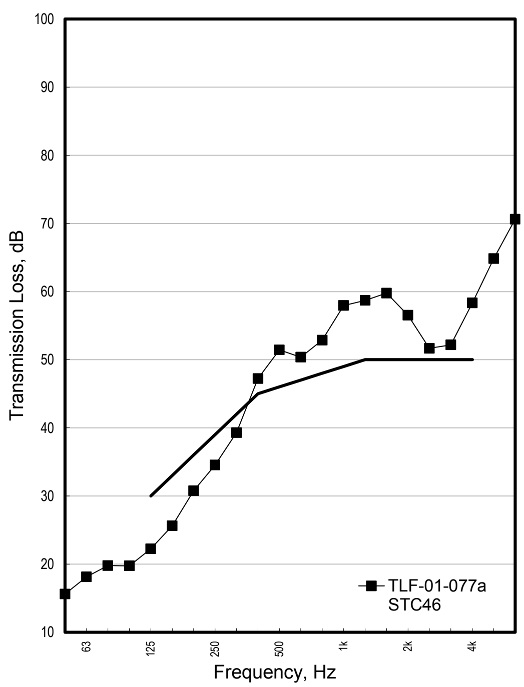
TLF-01-077a / IIF-01-037
PLY16_WI241(406)_CFL90_RC13(406+)_G13

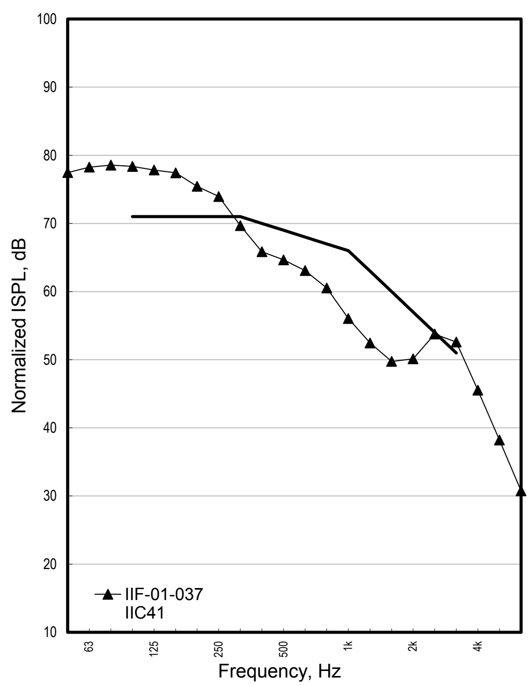
Freq. Hz	TLF-01-077a	IIF-01-037
50	16	77
63	18	78
80	20	79
100	20	78
125	22	78
160	26	77
200	31	75
250	35	74
315	39	70
400	47	66
500	51	65
630	50	63
800	53	61
1000	58	56
1250	59	52
1600	60	50
2000	57	50
2500	52	54
3150	52	53
4000	58	46
5000	65	38
6300	71	31
STC/IIC	**46**	**41**
$R_w/L_{n,w}$	**45**	**69**
ALD50/IR50	41	38

Material	N	Thick.	Spac.
Plywood	1	16	
Wood I-joists		241	406
Blown-in cellulose fibre		90	
Resilient metal channels		13	406+
Gypsum board	1	13	

	Mass, kg	
Frame	204.8	
Floor layers	142.5	7.1 kg/m^2
Ceiling layers	172.6	9.7 kg/m^2

Additional short pieces of RC at gypsum board butt joints.





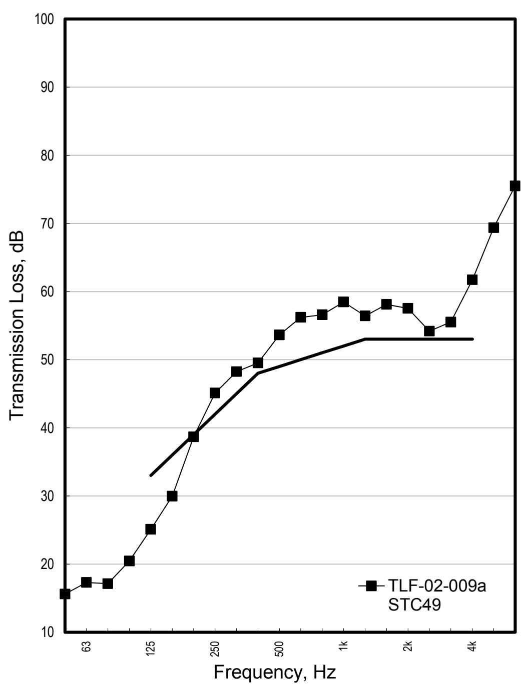
TLF-02-009a / IIF-02-008
OSB19_WI241(610)_RFB90_RC13(406+)_G13

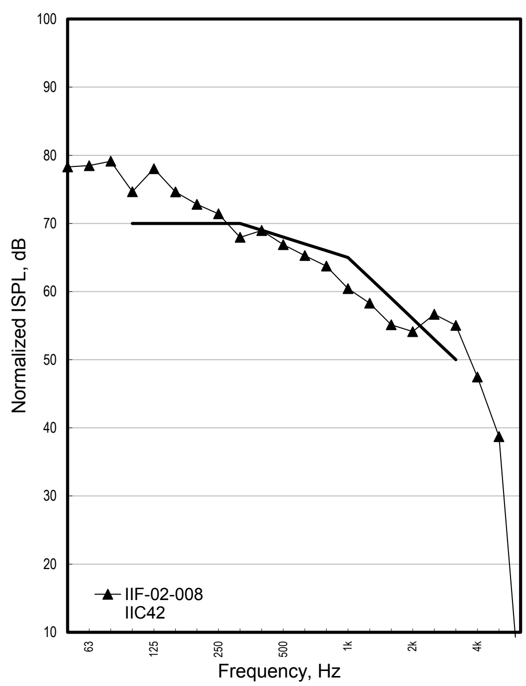
Freq. Hz	TLF-02-009a	IIF-02-008
50	16	78
63	17	78
80	17	79
100	20	75
125	25	78
160	30	75
200	39	73
250	45	71
315	48	68
400	50	69
500	54	67
630	56	65
800	57	64
1000	58	60
1250	56	58
1600	58	55
2000	58	54
2500	54	57
3150	56	55
4000	62	47
5000	69	39
6300	76	0
STC/IIC	**49**	**42**
$R_w/L_{n,w}$	**50**	**68**
ALD50/IR50	43	39

Material	N	Thick.	Spac.
Oriented strandboard	1	19	
Wood I-joists		241	610
Rock fibre batts		90	
Resilient metal channels		13	406+
Gypsum board	1	13	

	Mass, kg	
Frame	199.9	
Floor layers	225.8	11.2 kg/m^2
Ceiling layers	177.1	9.9 kg/m^2

Additional short pieces of RC at gypsum board butt joints.





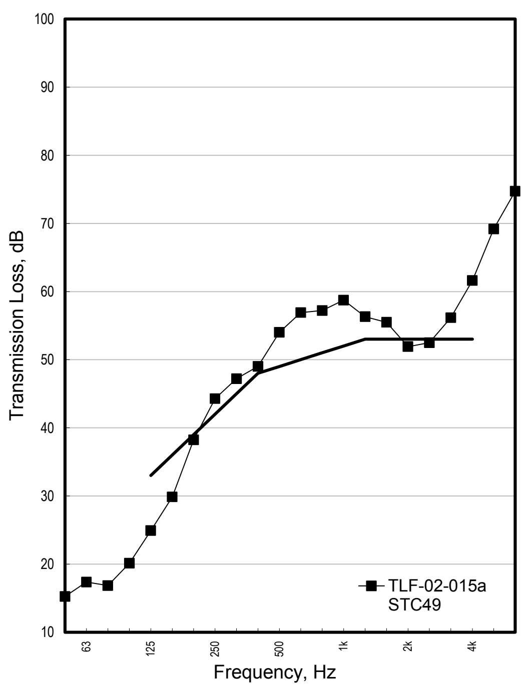
TLF-02-015a / IIF-02-013
OSB19_WI241(610)_RFB90_RC13(406+)_G16

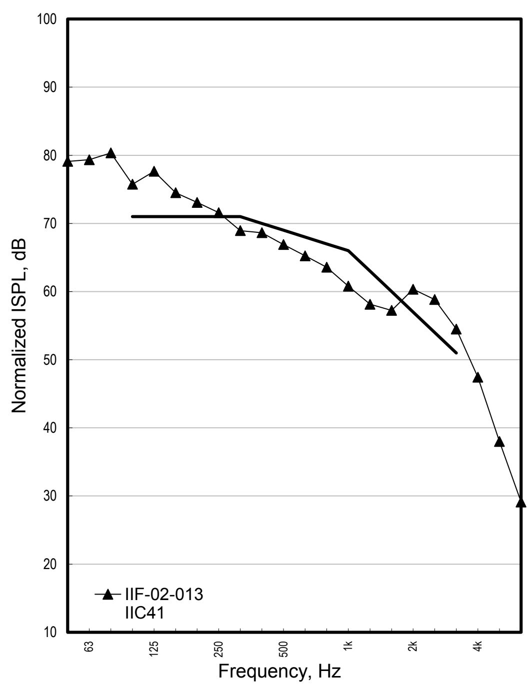
Freq. Hz	TLF-02-015a	IIF-02-013
50	15	79
63	17	79
80	17	80
100	20	76
125	25	78
160	30	75
200	38	73
250	44	72
315	47	69
400	49	69
500	54	67
630	57	65
800	57	64
1000	59	61
1250	56	58
1600	55	57
2000	52	60
2500	52	59
3150	56	54
4000	62	47
5000	69	38
6300	75	29
STC/IIC	**49**	**41**
R_w/$L_{n,w}$	**49**	**69**
ALD50/IR50	43	38

Material	N	Thick.	Spac.
Oriented strandboard	1	19	
Wood I-joists		241	610
Rock fibre batts		90	
Resilient metal channels		13	406+
Gypsum board	1	16	

	Mass, kg	
Frame	199.9	
Floor layers	225.8	11.2 kg/m^2
Ceiling layers	188.4	10.6 kg/m^2

Additional short pieces of RC at gypsum board butt joints.



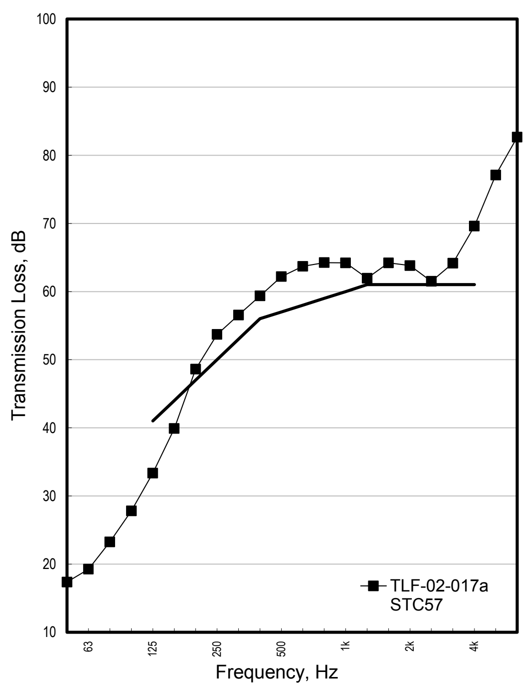


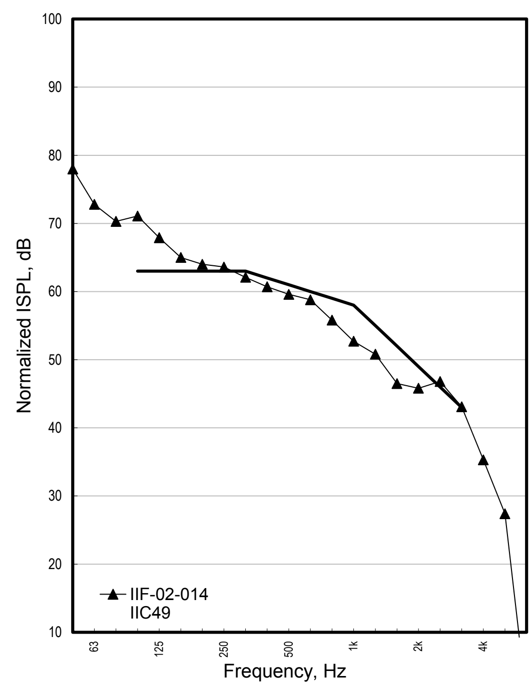
TLF-02-017a / IIF-02-014
2OSB19_WI241(610)_RFB90_RC13(406)_2G13

Freq. Hz	TLF-02-017a	IIF-02-014
50	17	78
63	19	73
80	23	70
100	28	71
125	33	68
160	40	65
200	49	64
250	54	64
315	57	62
400	59	61
500	62	60
630	64	59
800	64	56
1000	64	53
1250	62	51
1600	64	47
2000	64	46
2500	62	47
3150	64	43
4000	70	35
5000	77	27
6300	83	
STC/IIC	**57**	**49**
$R_w/L_{n,w}$	**59**	**60**
ALD50/IR50	49	44

Material	N	Thick.	Spac.
Oriented strandboard	2	19	
Wood I-joists		241	610
Rock fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	199.9	
Floor layers	448.6	22.3 kg/m^2
Ceiling layers	343.0	19.3 kg/m^2



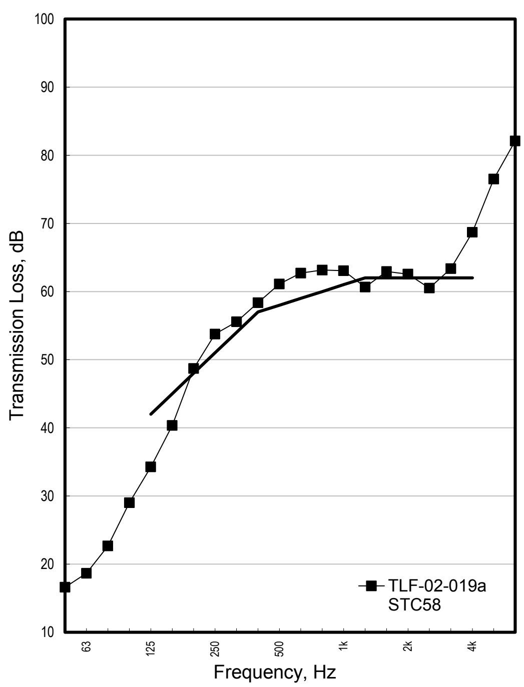


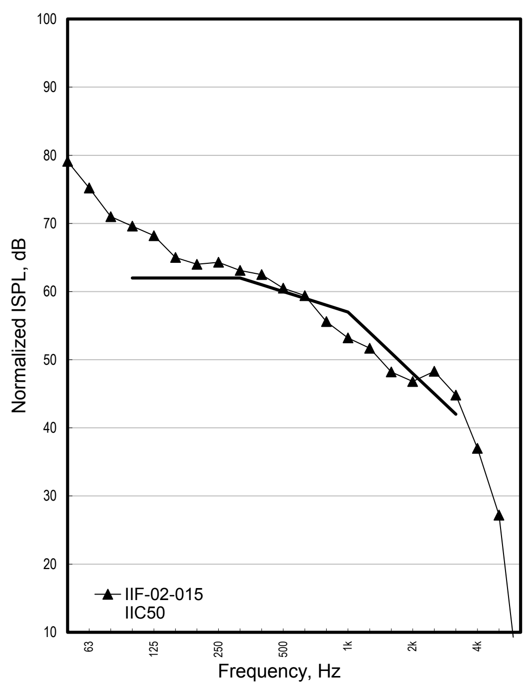
TLF-02-019a / IIF-02-015
2OSB19_WI241(610)_GFB90_RC13(406)_2G13

Freq. Hz	TLF-02-019a	IIF-02-015
50	17	79
63	19	75
80	23	71
100	29	70
125	34	68
160	40	65
200	49	64
250	54	64
315	56	63
400	58	63
500	61	61
630	63	59
800	63	56
1000	63	53
1250	61	52
1600	63	48
2000	63	47
2500	61	48
3150	63	45
4000	69	37
5000	77	27
6300	82	
STC/IIC	**58**	**50**
R_w/$L_{n,w}$	**59**	**60**
ALD50/IR50	49	43

Material	N	Thick.	Spac.
Oriented strandboard	2	19	
Wood I-joists		241	610
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	199.9	
Floor layers	448.6	22.3 kg/m^2
Ceiling layers	343.0	19.3 kg/m^2



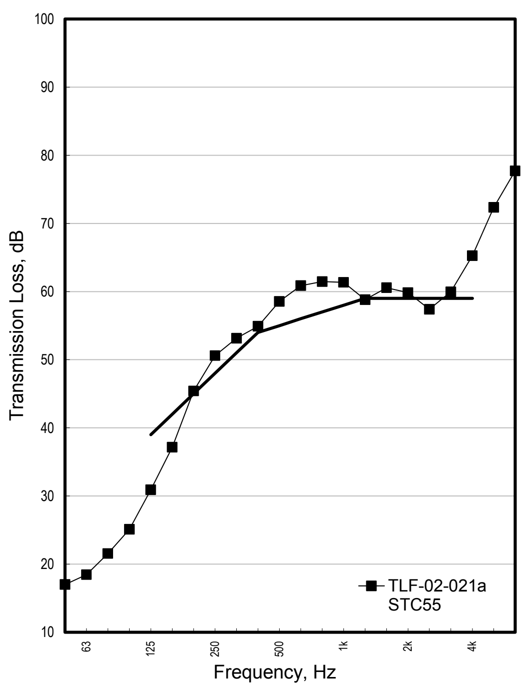


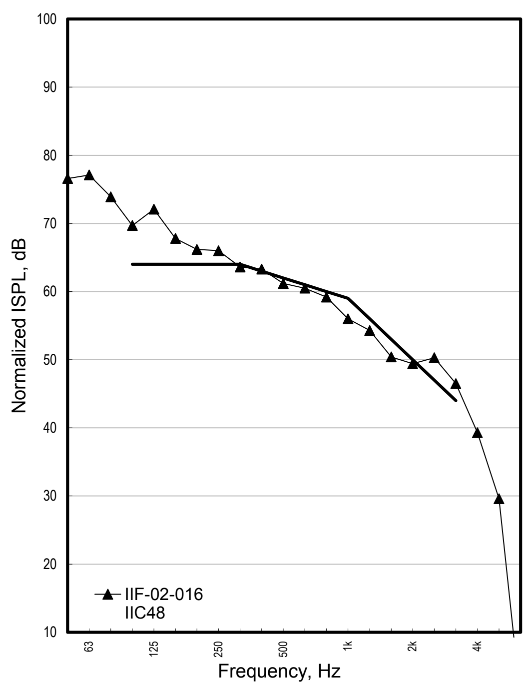
TLF-02-021a / IIF-02-016
OSB19_WI241(610)_GFB180_RC13(406)_2G13

Freq. Hz	TLF-02-021a	IIF-02-016
50	17	77
63	18	77
80	22	74
100	25	70
125	31	72
160	37	68
200	45	66
250	51	66
315	53	64
400	55	63
500	59	61
630	61	61
800	61	59
1000	61	56
1250	59	54
1600	61	50
2000	60	49
2500	57	50
3150	60	47
4000	65	39
5000	72	30
6300	78	
STC/IIC	**55**	**48**
$R_w/L_{n,w}$	**56**	**62**
ALD50/IR50	48	43

Material	N	Thick.	Spac.
Oriented strandboard	1	19	
Wood I-joists		241	610
Glass fibre batts		180	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	199.9	
Floor layers	225.8	11.2 kg/m^2
Ceiling layers	343.0	19.3 kg/m^2



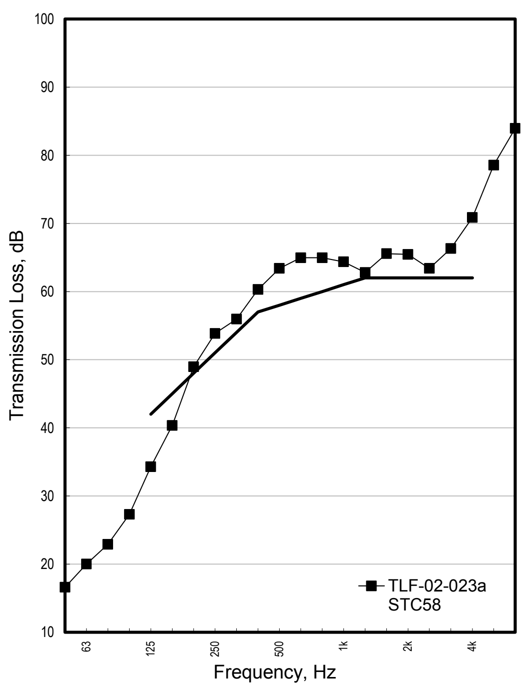


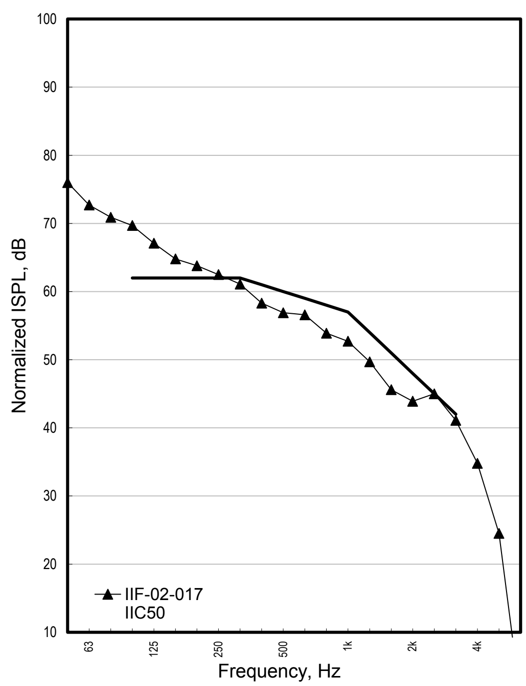
TLF-02-023a / IIF-02-017
2OSB19_WI241(610)_CFL90_RC13(406)_2G13

Freq. Hz	TLF-02-023a	IIF-02-017
50	17	76
63	20	73
80	23	71
100	27	70
125	34	67
160	40	65
200	49	64
250	54	63
315	56	61
400	60	58
500	63	57
630	65	57
800	65	54
1000	64	53
1250	63	50
1600	66	46
2000	65	44
2500	63	45
3150	66	41
4000	71	35
5000	79	25
6300	84	
STC/IIC	**58**	**50**
$R_w/L_{n,w}$	**59**	**59**
ALD50/IR50	49	45

Material	N	Thick.	Spac.
Oriented strandboard	2	19	
Wood I-joists		241	610
Blown-in cellulose fibre		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	199.9	
Floor layers	451.6	22.5 kg/m^2
Ceiling layers	343.0	19.3 kg/m^2



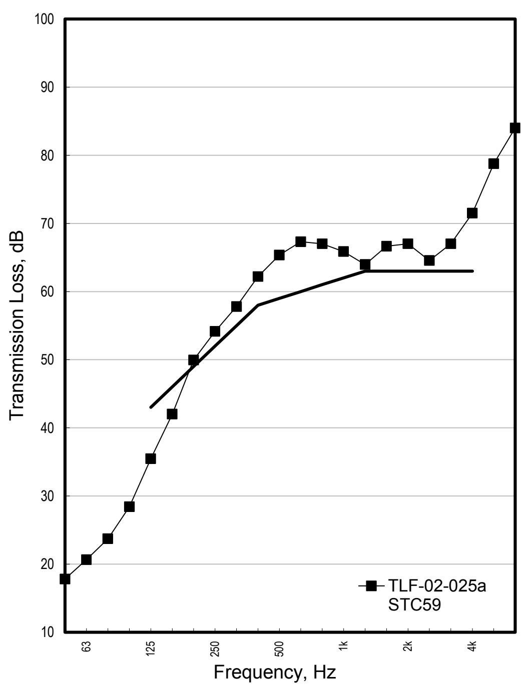


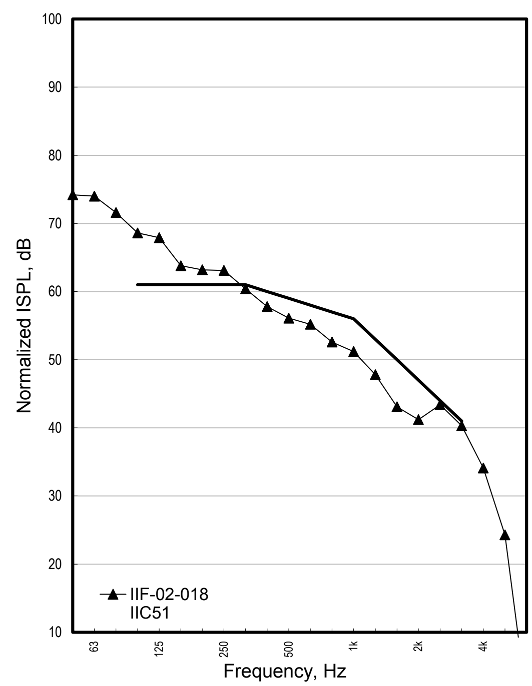
TLF-02-025a / IIF-02-018
OSB19_WI241(610)_CFL180_RC13(406)_2G13

Freq. Hz	TLF-02-025a	IIF-02-018
50	18	74
63	21	74
80	24	72
100	28	69
125	35	68
160	42	64
200	50	63
250	54	63
315	58	60
400	62	58
500	65	56
630	67	55
800	67	53
1000	66	51
1250	64	48
1600	67	43
2000	67	41
2500	65	43
3150	67	40
4000	72	34
5000	79	24
6300	84	
STC/IIC	**59**	**51**
$R_w/L_{n,w}$	**61**	**58**
ALD50/IR50	50	46

Material	N	Thick.	Spac.
Oriented strandboard	1	19	
Wood I-joists		241	610
Blown-in cellulose fibre		180	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	199.9	
Floor layers	225.8	11.2 kg/m^2
Ceiling layers	343.0	19.3 kg/m^2



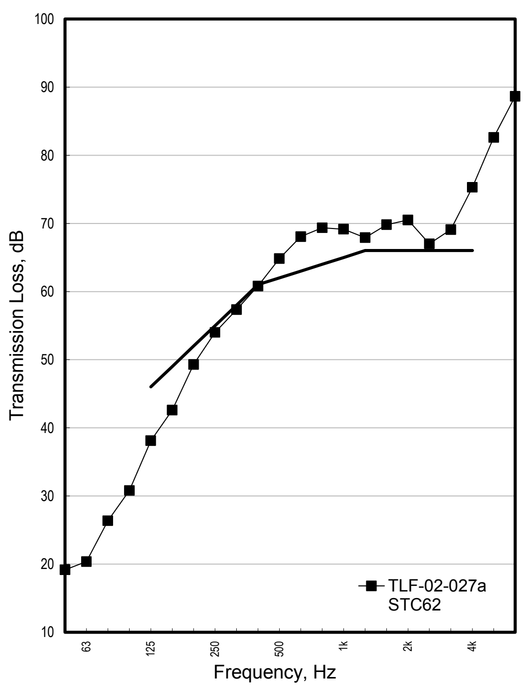


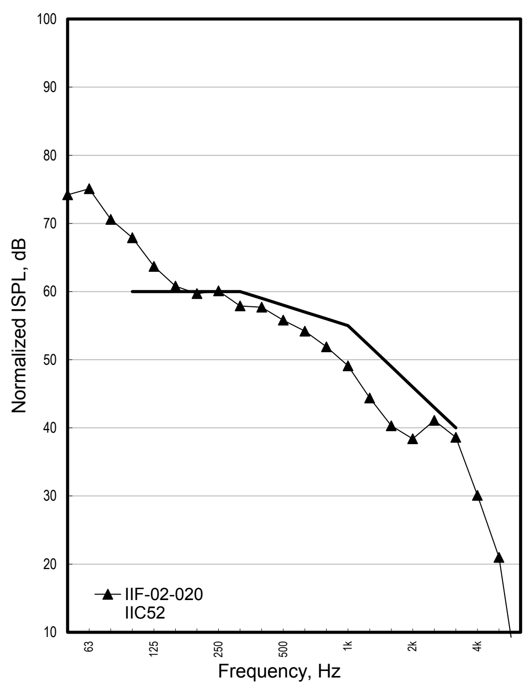
TLF-02-027a / IIF-02-020
2OSB19_WI241(610)_CFS150_RC13(406)_2G13

Freq. Hz	TLF-02-027a	IIF-02-020
50	19	74
63	20	75
80	26	71
100	31	68
125	38	64
160	43	61
200	49	60
250	54	60
315	57	58
400	61	58
500	65	56
630	68	54
800	69	52
1000	69	49
1250	68	44
1600	70	40
2000	71	38
2500	67	41
3150	69	39
4000	75	30
5000	83	21
6300	89	
STC/IIC	**62**	**52**
$R_w/L_{n,w}$	**62**	**56**
ALD50/IR50	52	46

Material	N	Thick.	Spac.
Oriented strandboard	2	19	
Wood I-joists		241	610
Sprayed-on cellulose fibre		150	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	199.9	
Floor layers	451.6	22.5 kg/m^2
Ceiling layers	343.0	19.3 kg/m^2



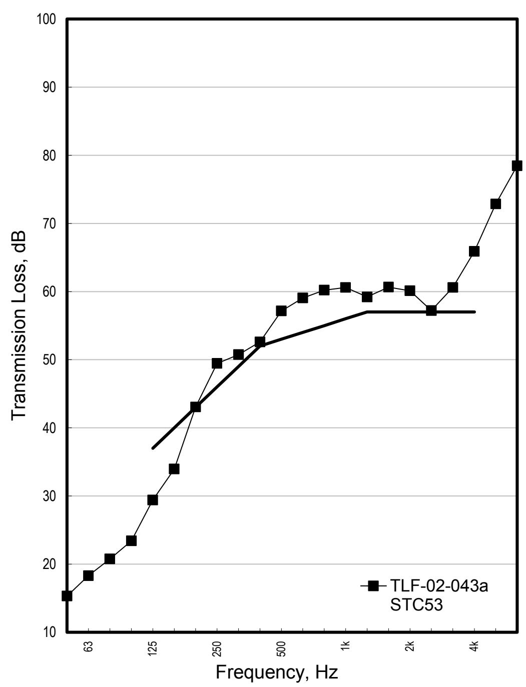


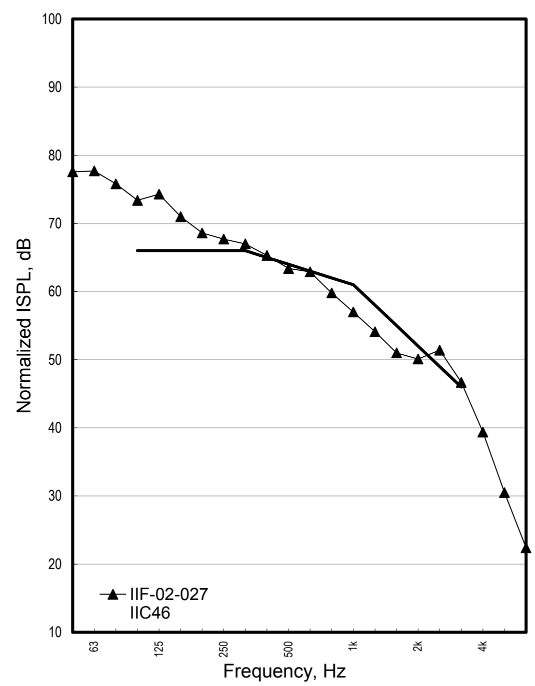
TLF-02-043a / IIF-02-027
OSB19_WI241(610)_GFB90_RC13(406)_2G13

Freq. Hz	TLF-02-043a	IIF-02-027
50	15	78
63	18	78
80	21	76
100	23	73
125	29	74
160	34	71
200	43	69
250	49	68
315	51	67
400	53	65
500	57	63
630	59	63
800	60	60
1000	61	57
1250	59	54
1600	61	51
2000	60	50
2500	57	51
3150	61	47
4000	66	39
5000	73	31
6300	78	22
STC/IIC	**53**	**46**
$R_w/L_{n,w}$	**54**	**64**
ALD50/IR50	46	41

Material	N	Thick.	Spac.
Oriented strandboard	1	19	
Wood I-joists		241	610
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	215.7	
Floor layers	231.0	11.5 kg/m^2
Ceiling layers	344.0	19.3 kg/m^2





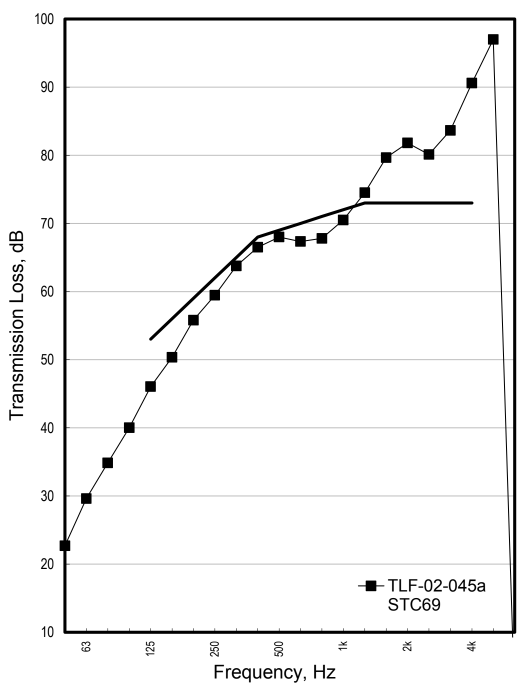
TLF-02-045a
CON38_PLY16_WI241(406)_RC13(406)_GFB90_2G13

Freq. Hz	TLF-02-045a	
50	23	
63	30	
80	35	
100	40	
125	46	
160	50	
200	56	
250	59	
315	64	
400	67	
500	68	
630	67	
800	68	
1000	71	
1250	75	
1600	80	
2000	82	
2500	80	
3150	84	
4000	91	
5000	97	
6300		
STC/IIC	**69**	
$R_w/L_{n,w}$	**68**	
ALD50/IR50	59	

Material	N	Thick.	Spac.
Concrete		38	
Plywood	1	16	
Wood I-joists		241	406
Resilient metal channels		13	406
Glass fibre batts		90	
Gypsum board	2	13	

	Mass, kg	
Frame	251.7	
Floor layers	2235.8	111.2 kg/m^2
Ceiling layers	344.0	19.3 kg/m^2

NRC 38mm concrete slab laid on floor.



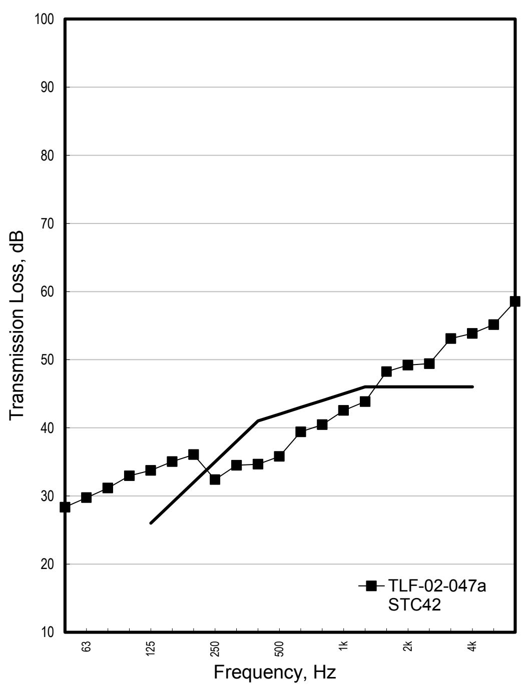
TLF-02-047a / IIF-02-030
CON40_CORSTE0.4_SJ203(406)

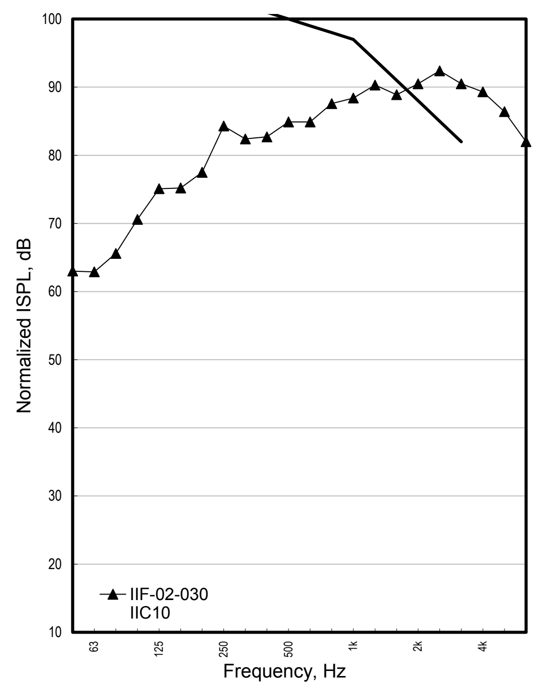
Freq. Hz	TLF-02-047a	IIF-02-030
50	28	63
63	30	63
80	31	66
100	33	71
125	34	75
160	35	75
200	36	78
250	32	84
315	35	82
400	35	83
500	36	85
630	39	85
800	40	88
1000	43	88
1250	44	90
1600	48	89
2000	49	91
2500	49	92
3150	53	91
4000	54	89
5000	55	86
6300	59	82
STC/IIC	**42**	**10**
R_w/$L_{n,w}$	**42**	**97**
ALD50/IR50	41	26

Material	N	Thick.	Spac.
Concrete		40	
corrugated steel deck		0.4	
Steel C-joists		203	406

	Mass, kg	
Frame	182.0	
Floor layers	1969.5	98 kg/m^2

Average concrete thickness 39 mm. No ceiling installed.





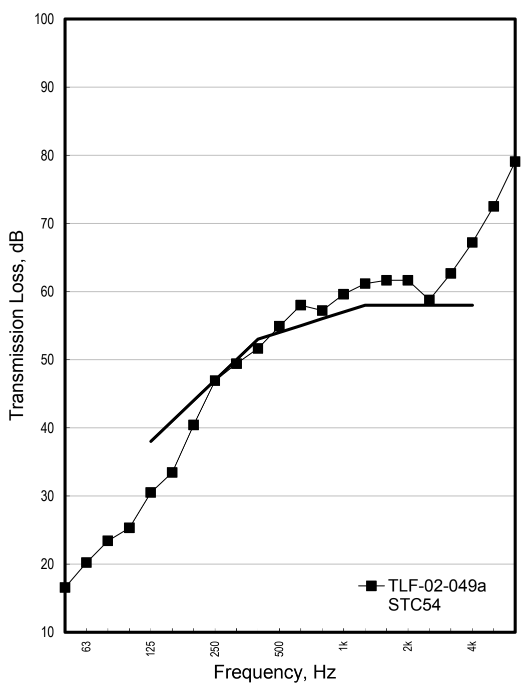
TLF-02-049a / IIF-02-031
PLY19_WT305(610)_GFB90_RC13(406)_2G13

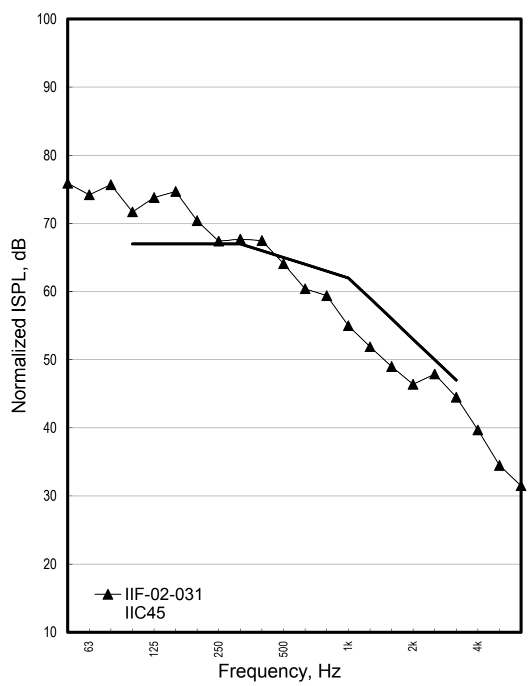
Freq. Hz	TLF-02-049a	IIF-02-031
50	17	76
63	20	74
80	23	76
100	25	72
125	31	74
160	33	75
200	40	70
250	47	67
315	49	68
400	52	68
500	55	64
630	58	60
800	57	59
1000	60	55
1250	61	52
1600	62	49
2000	62	46
2500	59	48
3150	63	45
4000	67	40
5000	73	35
6300	79	32
STC/IIC	**54**	**45**
$R_w/L_{n,w}$	**54**	**65**
ALD50/IR50	48	42

Material	N	Thick.	Spac.
Plywood	1	19	
Wood trusses		305	610
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	371.8	
Floor layers	169.5	8.4 kg/m^2
Ceiling layers	341.8	19.2 kg/m^2

Alpha - Forintek Wood Truss.



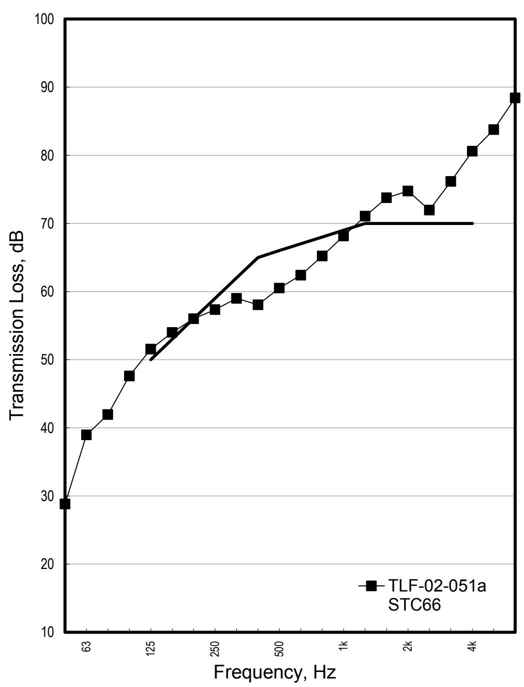


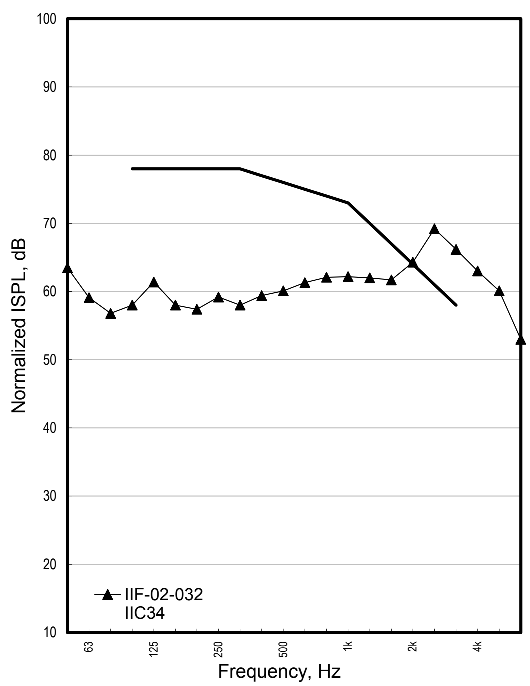
TLF-02-051a / IIF-02-032
CON40_CORSTE0.4_SJ203(406)_GFB90_RC13(610)_2G13

Freq. Hz	TLF-02-051a	IIF-02-032
50	29	64
63	39	59
80	42	57
100	48	58
125	52	61
160	54	58
200	56	57
250	57	59
315	59	58
400	58	59
500	61	60
630	62	61
800	65	62
1000	68	62
1250	71	62
1600	74	62
2000	75	64
2500	72	69
3150	76	66
4000	81	63
5000	84	60
6300	88	53
STC/IIC	**66**	**34**
R_w/$L_{n,w}$	**66**	**71**
ALD50/IR50	63	50

Material	N	Thick.	Spac.
Concrete		40	
Corrugated steel deck		0.4	
Steel C-joists		203	406
Glass fibre batts		90	
Resilient metal channels		13	610
Gypsum board	2	13	

	Mass, kg	
Frame	195.0	
Floor layers	1769.6	88 kg/m^2
Ceiling layers	326.2	18.3 kg/m^2





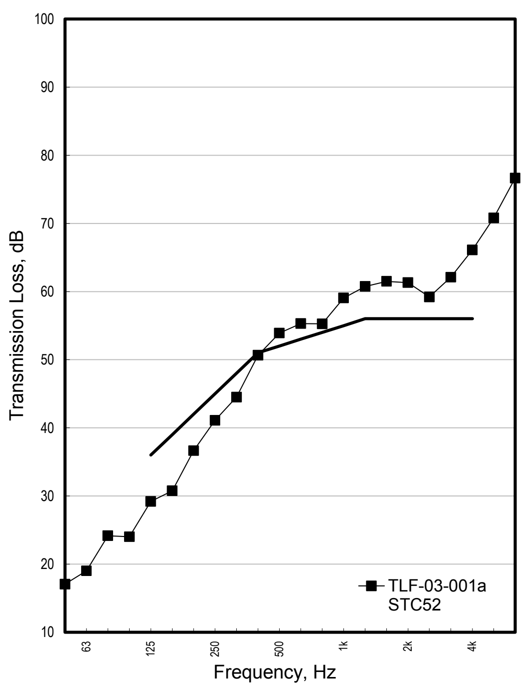
TLF-03-001a / IIF-03-001
PLY16_WT305(406)_GFB90_RC13(406)_2G13

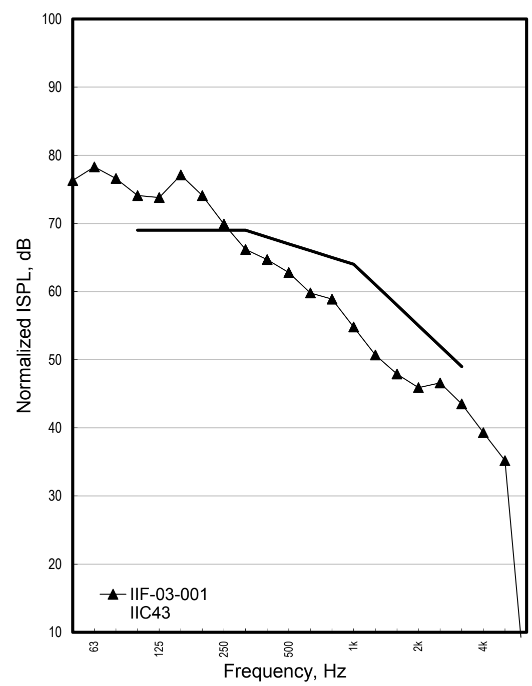
Freq. Hz	TLF-03-001a	IIF-03-001
50	17	76
63	19	78
80	24	77
100	24	74
125	29	74
160	31	77
200	37	74
250	41	70
315	45	66
400	51	65
500	54	63
630	55	60
800	55	59
1000	59	55
1250	61	51
1600	62	48
2000	61	46
2500	59	47
3150	62	44
4000	66	39
5000	71	35
6300	77	
STC/IIC	**52**	**43**
$R_w/L_{n,w}$	**51**	**66**
ALD50/IR50	46	40

Material	N	Thick.	Spac.
Plywood	1	16	
Wood trusses		305	406
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	415.5	
Floor layers	135.6	6.7 kg/m^2
Ceiling layers	341.8	19.2 kg/m^2

Alpha - Forintek Wood Truss.





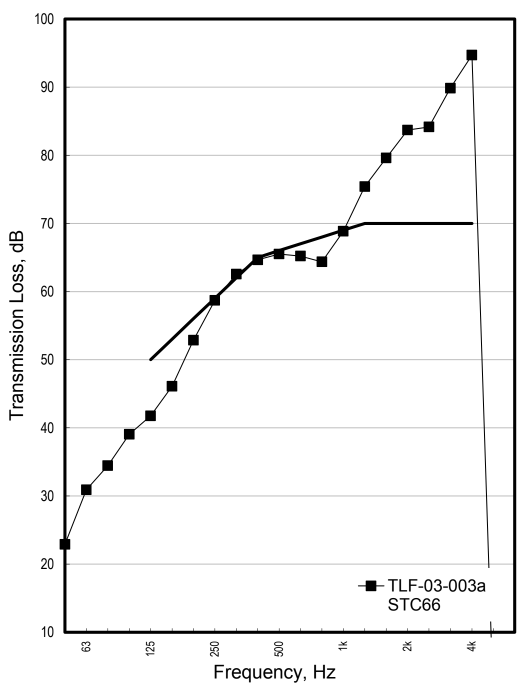
TLF-03-003a
CON38_PLY16_WT305(406)_GFB90_RC13(406)_2G13

Freq. Hz	TLF-03-003a	
50	23	
63	31	
80	34	
100	39	
125	42	
160	46	
200	53	
250	59	
315	63	
400	65	
500	66	
630	65	
800	64	
1000	69	
1250	75	
1600	80	
2000	84	
2500	84	
3150	90	
4000	95	
5000		
6300		
STC/IIC	**66**	
$R_w/L_{n,w}$	**65**	
ALD50/IR50	58	

Material	N	Thick.	Spac.
Concrete		38	
Plywood	1	16	
Wood trusses		305	406
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	415.5	
Floor layers	2236.7	111.3 kg/m^2
Ceiling layers	341.8	19.2 kg/m^2

38mm NRC concrete slab. Alpha - Forintek Wood Truss.



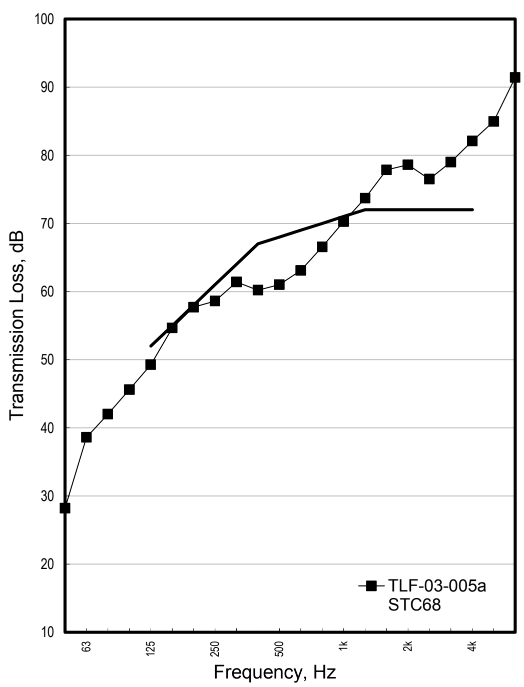
TLF-03-005a / IIF-03-003
CON40_CORSTE0.4_SJ203(406)_GFB90_RC13(406)_2G13

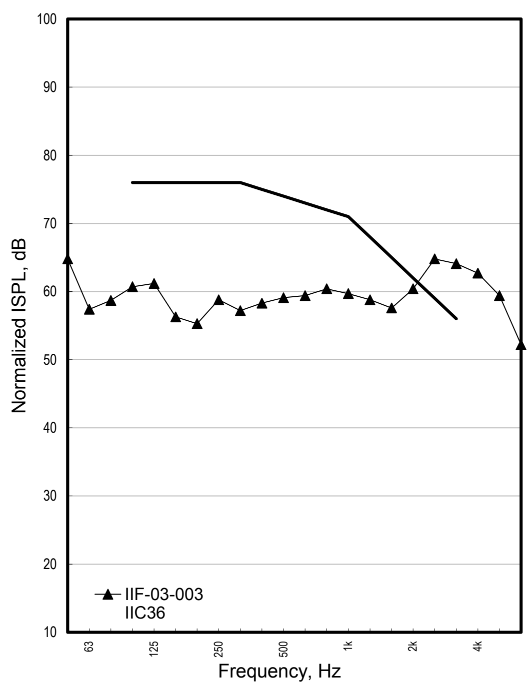
Freq. Hz	TLF-03-005a	IIF-03-003
50	28	65
63	39	57
80	42	59
100	46	61
125	49	61
160	55	56
200	58	55
250	59	59
315	61	57
400	60	58
500	61	59
630	63	59
800	67	60
1000	70	60
1250	74	59
1600	78	58
2000	79	60
2500	77	65
3150	79	64
4000	82	63
5000	85	59
6300	91	52
STC/IIC	**68**	**36**
$R_w/L_{n,w}$	**67**	**68**
ALD50/IR50	63	52

Material	N	Thick.	Spac.
Concrete		40	
Corrugated steel deck		0.4	
Steel C-joists		203	406
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	195.0	
Floor layers	1769.6	88 kg/m^2
Ceiling layers	326.2	18.3 kg/m^2

Concrete poured on ribbed steel deck. Average concrete thickness 39 mm.



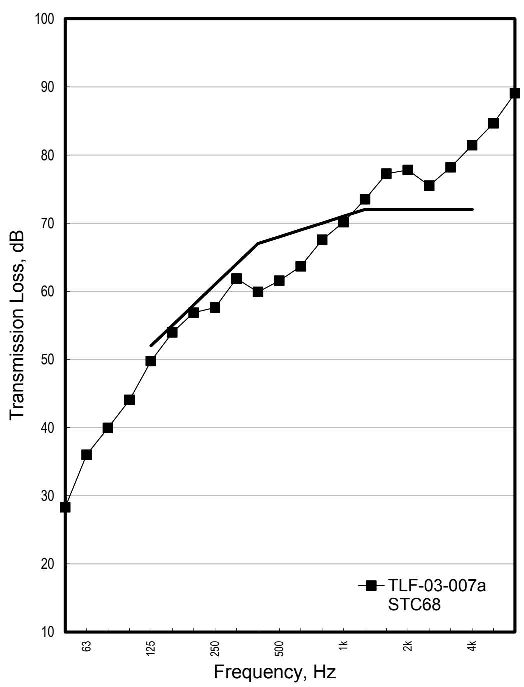


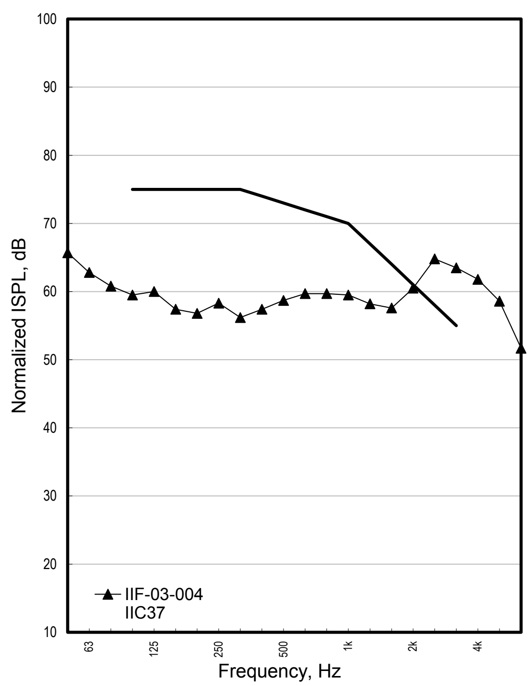
TLF-03-007a / IIF-03-004
CON40_CORSTE0.4_SJ203(406)_RFB90_RC13(406)_2G13

Freq. Hz	TLF-03-007a	IIF-03-004
50	28	66
63	36	63
80	40	61
100	44	60
125	50	60
160	54	57
200	57	57
250	58	58
315	62	56
400	60	57
500	62	59
630	64	60
800	68	60
1000	70	60
1250	74	58
1600	77	58
2000	78	61
2500	76	65
3150	78	64
4000	81	62
5000	85	59
6300	89	52
STC/IIC	**68**	**37**
R_w/$L_{n,w}$	**67**	**68**
ALD50/IR50	63	52

Material	N	Thick.	Spac.
Concrete		40	
Corrugated steel deck		0.4	
Steel C-joists		203	406
Rock fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	195.0	
Floor layers	1769.6	88 kg/m^2
Ceiling layers	326.2	18.3 kg/m^2



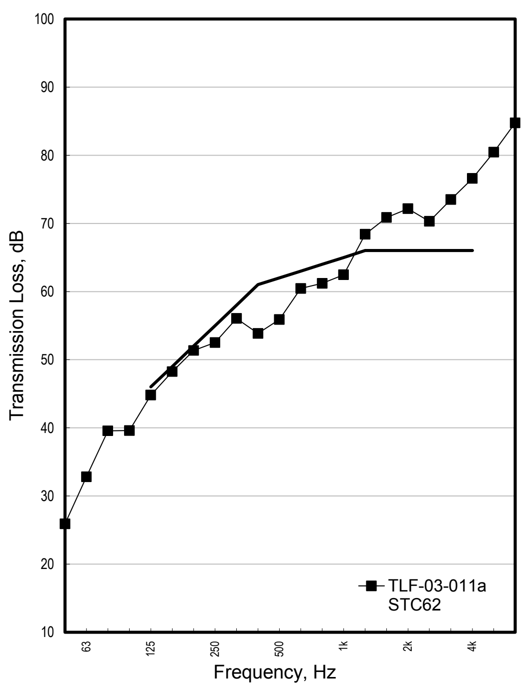


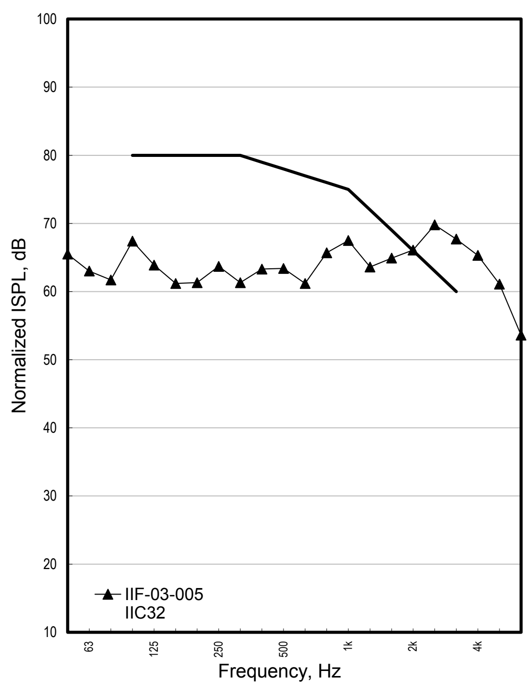
TLF-03-011a / IIF-03-005
CON40_CORSTE0.4_SJ203(406)_RC13(406)_2G13

Freq. Hz	TLF-03-011a	IIF-03-005
50	26	66
63	33	63
80	40	62
100	40	67
125	45	64
160	48	61
200	51	61
250	53	64
315	56	61
400	54	63
500	56	63
630	60	61
800	61	66
1000	62	68
1250	68	64
1600	71	65
2000	72	66
2500	70	70
3150	74	68
4000	77	65
5000	80	61
6300	85	54
STC/IIC	**62**	**32**
$R_w/L_{n,w}$	**62**	**73**
ALD50/IR50	59	48

Material	N	Thick.	Spac.
Concrete		40	
Corrugated steel deck		0.4	
Steel C-joists		203	406
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	195.0	
Floor layers	1769.6	88 kg/m^2
Ceiling layers	326.2	18.3 kg/m^2





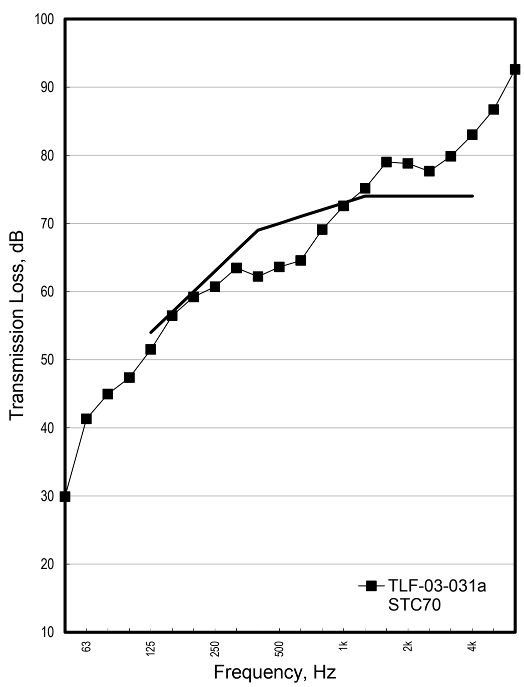
TLF-03-031a / IIF-03-010
CON40_CORSTE0.4_SJ203(406)_CFL200_RC13(406)_2G13

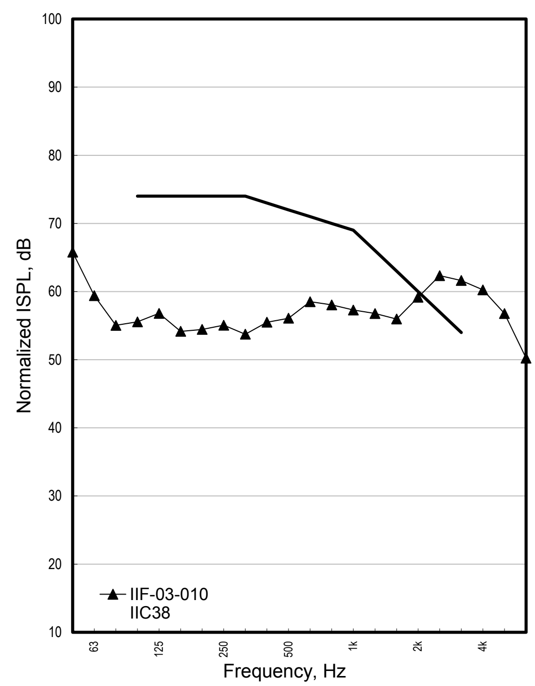
Freq. Hz	TLF-03-031a	IIF-03-010
50	30	66
63	41	59
80	45	55
100	47	56
125	52	57
160	56	54
200	59	54
250	61	55
315	63	54
400	62	56
500	64	56
630	65	59
800	69	58
1000	73	57
1250	75	57
1600	79	56
2000	79	59
2500	78	62
3150	80	62
4000	83	60
5000	87	57
6300	93	50
STC/IIC	**70**	**38**
R_w/$L_{n,w}$	**69**	**66**
ALD50/IR50	65	54

Material	N	Thick.	Spac.
Concrete		40	
Corrugated steel deck		0.4	
Steel C-joists		203	406
Blown-in cellulose fibre		200	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	196.0	
Floor layers	1769.6	88 kg/m^2
Ceiling layers	326.2	18.3 kg/m^2

Cellulose fibre blown in from below and supported by wire mesh



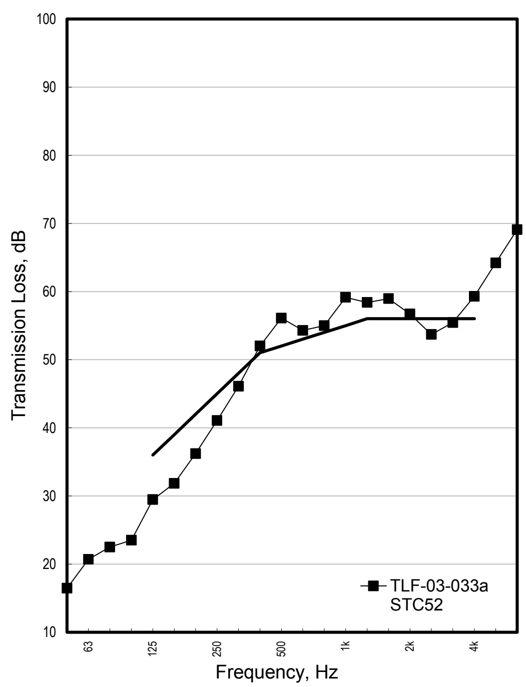


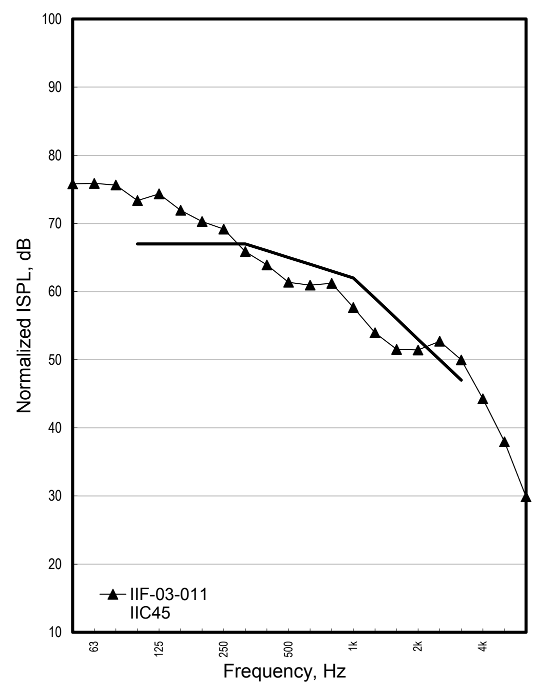
TLF-03-033a / IIF-03-011
PLY16_WJ184(406)_GFB90_RC13(406)_2G13

Freq. Hz	TLF-03-033a	IIF-03-011
50	16	76
63	21	76
80	23	76
100	24	73
125	29	74
160	32	72
200	36	70
250	41	69
315	46	66
400	52	64
500	56	61
630	54	61
800	55	61
1000	59	58
1250	58	54
1600	59	52
2000	57	51
2500	54	53
3150	55	50
4000	59	44
5000	64	38
6300	69	30
STC/IIC	**52**	**45**
$R_w/L_{n,w}$	**51**	**65**
ALD50/IR50	46	42

Material	N	Thick.	Spac.
Plywood	1	15	
Wood joists		184	406
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	186.1	
Floor layers	134.5	6.7 kg/m^2
Ceiling layers	330.7	18.6 kg/m^2





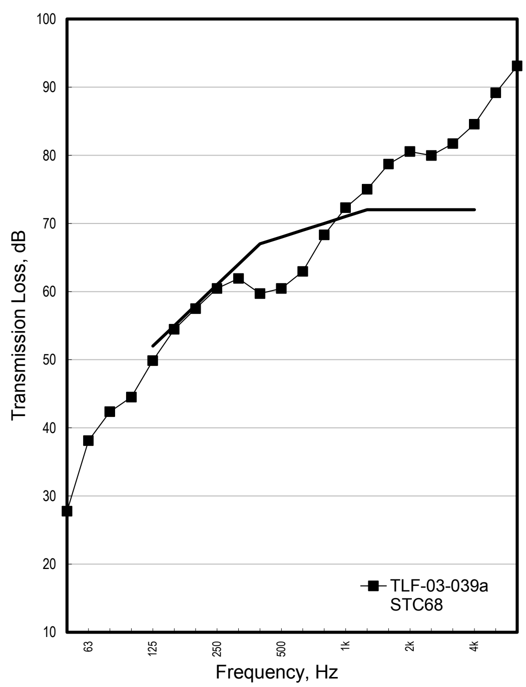
TLF-03-039a / IIF-03-016
CON40_CORSTE0.4_SJ203(406)_CFS150_RC13(406)_2G13

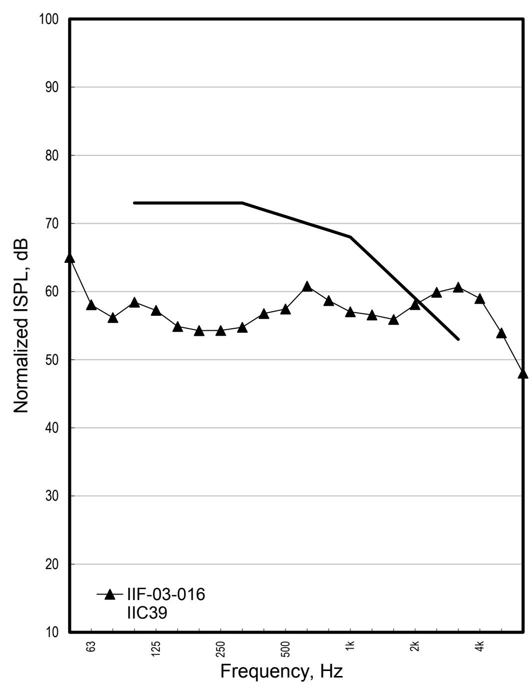
Freq. Hz	TLF-03-039a	IIF-03-016
50	28	65
63	38	58
80	42	56
100	45	58
125	50	57
160	54	55
200	58	54
250	60	54
315	62	55
400	60	57
500	60	57
630	63	61
800	68	59
1000	72	57
1250	75	57
1600	79	56
2000	81	58
2500	80	60
3150	82	61
4000	85	59
5000	89	54
6300	93	48
STC/IIC	**68**	**39**
R_w/$L_{n,w}$	**67**	**65**
ALD50/IR50	63	54

Material	N	Thick.	Spac.
Concrete		40	
Corrugated steel deck		0.4	
Steel C-joists		203	406
Sprayed-on cellulose fibre		150	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	195.0	
Floor layers	1769.6	88 kg/m^2
Ceiling layers	326.2	18.3 kg/m^2

Sprayed-on cellulose.



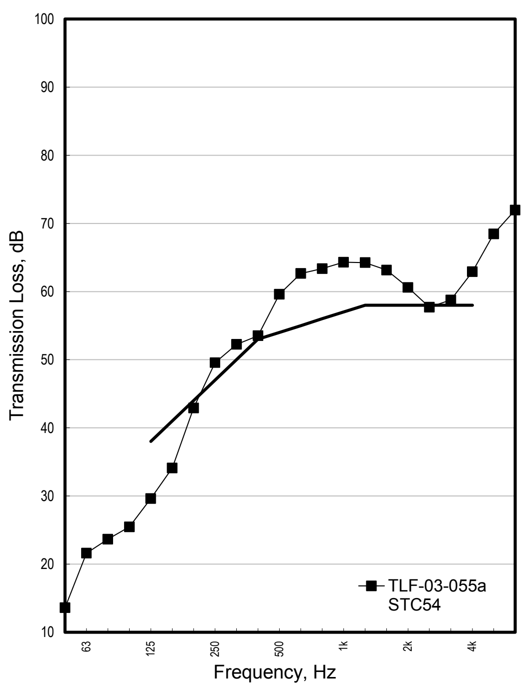


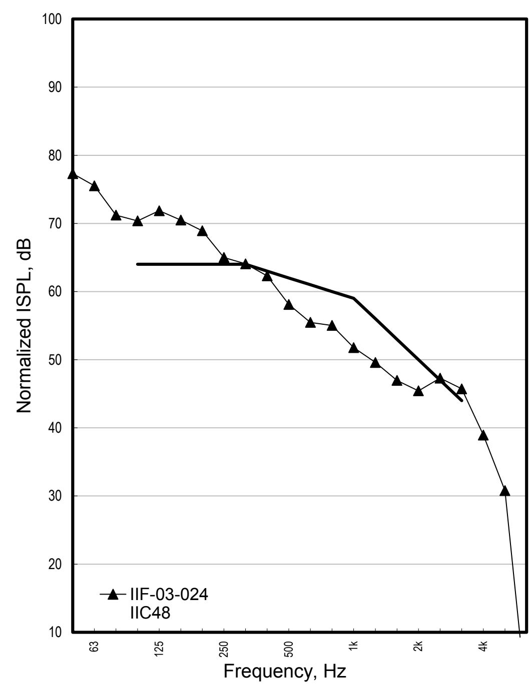
TLF-03-055a / IIF-03-024
PLY19_WJ235(610)_RFB90_RC13(610)_2G13

Freq. Hz	TLF-03-055a	IIF-03-024
50	14	77
63	22	76
80	24	71
100	25	70
125	30	72
160	34	70
200	43	69
250	50	65
315	52	64
400	54	62
500	60	58
630	63	55
800	63	55
1000	64	52
1250	64	50
1600	63	47
2000	61	45
2500	58	47
3150	59	46
4000	63	39
5000	68	31
6300	72	
STC/IIC	**54**	**48**
$R_w/L_{n,w}$	**55**	**62**
ALD50/IR50	47	43

Material	N	Thick.	Spac.
Plywood	1	19	
Wood joists		235	610
Rock fibre batts		90	
Resilient metal channels		13	610
Gypsum board	2	13	

	Mass, kg	
Frame	164.1	
Floor layers	172.0	8.6 kg/m^2
Ceiling layers	352.9	19.8 kg/m^2



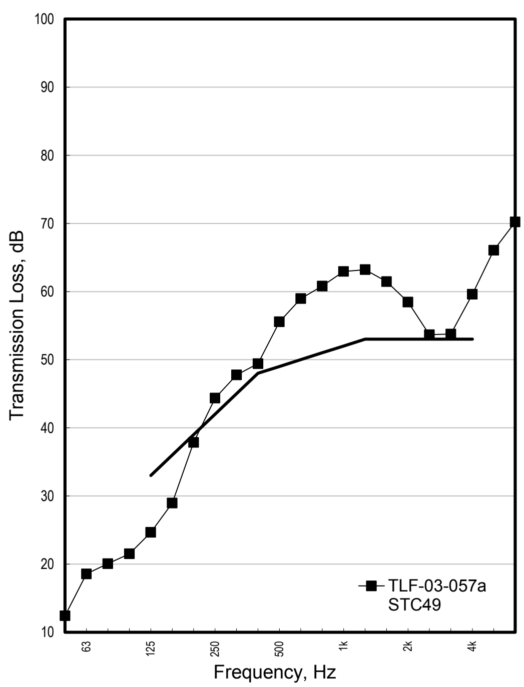


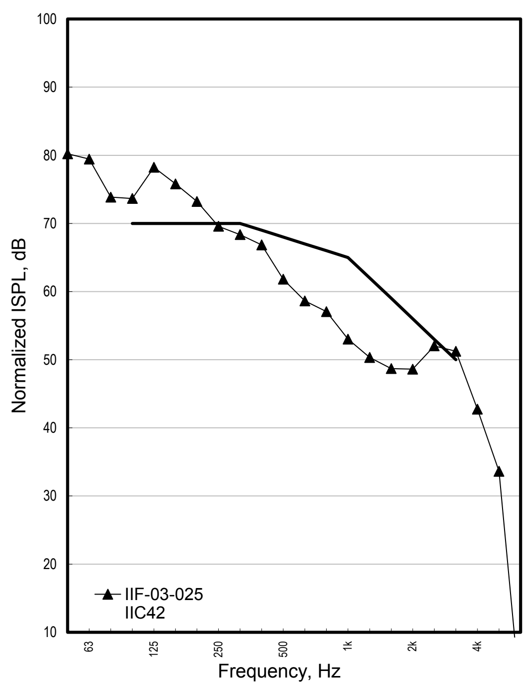
TLF-03-057a / IIF-03-025
PLY19_WJ235(610)_RFB90_RC13(610)_G13

Freq. Hz	TLF-03-057a	IIF-03-025
50	12	80
63	19	79
80	20	74
100	22	74
125	25	78
160	29	76
200	38	73
250	44	70
315	48	68
400	49	67
500	56	62
630	59	59
800	61	57
1000	63	53
1250	63	50
1600	61	49
2000	58	49
2500	54	52
3150	54	51
4000	60	43
5000	66	34
6300	70	
STC/IIC	**49**	**42**
$R_w/L_{n,w}$	**50**	**67**
ALD50/IR50	44	39

Material	N	Thick.	Spac.
Plywood	1	19	
Wood joists		235	610
Rock fibre batts		90	
Resilient metal channels		13	610
Gypsum board	1	13	

	Mass, kg	
Frame	164.1	
Floor layers	172.0	8.6 kg/m^2
Ceiling layers	174.8	9.8 kg/m^2





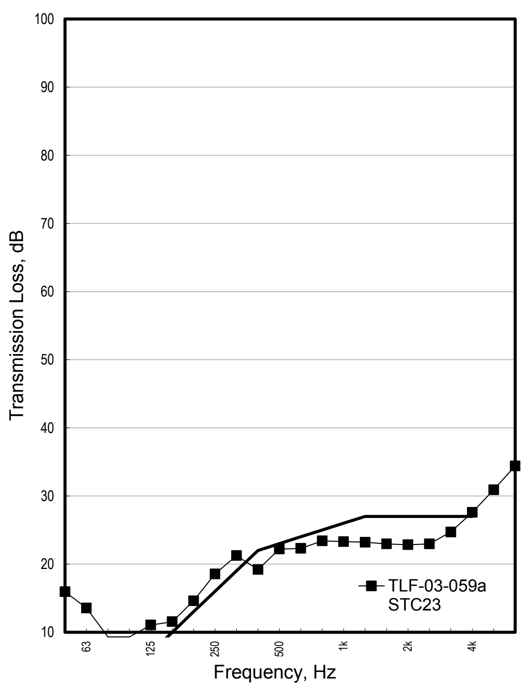
TLF-03-059a / IIF-03-026
PLY19_WJ235(610)

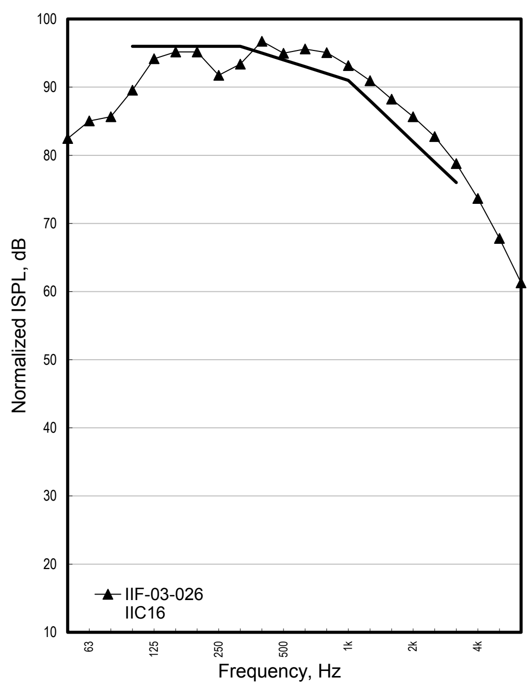
Freq. Hz	TLF-03-059a	IIF-03-026
50	16	82
63	14	85
80	9	86
100	9	90
125	11	94
160	12	95
200	15	95
250	19	92
315	21	93
400	19	97
500	22	95
630	22	96
800	23	95
1000	23	93
1250	23	91
1600	23	88
2000	23	86
2500	23	83
3150	25	79
4000	28	74
5000	31	68
6300	34	61
STC/IIC	**23**	**16**
$R_w/L_{n,w}$	**23**	**94**
ALD50/IR50	22	20

Material	N	Thick.	Spac.
Plywood	1	19	
Wood joists		235	610

	Mass, kg	
Frame	164.1	
Floor layers	172.0	8.6 kg/m^2

No ceiling installed.



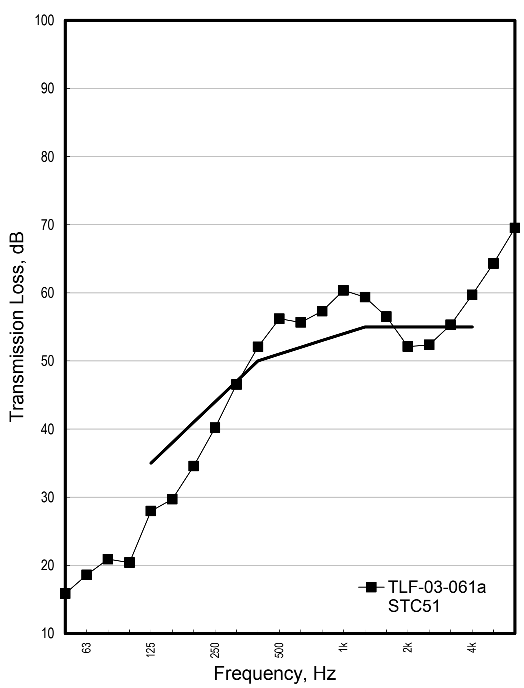


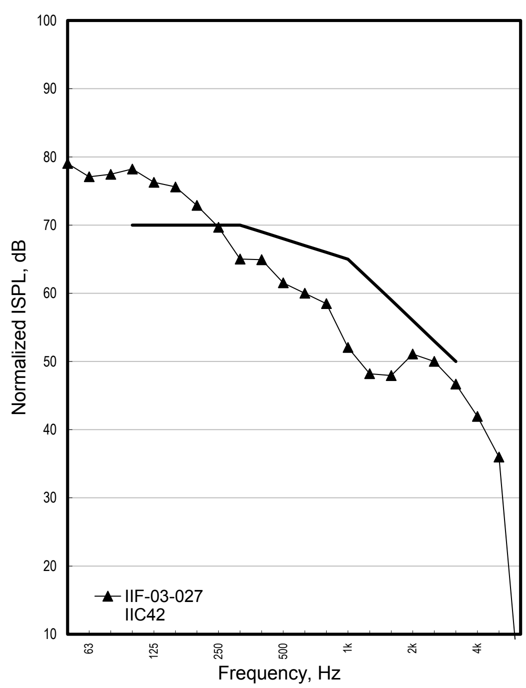
TLF-03-061a / IIF-03-027
2PLY16_WJ235(406)_GFB180_RC13(406)_G16

Freq. Hz	TLF-03-061a	IIF-03-027
50	16	79
63	19	77
80	21	77
100	20	78
125	28	76
160	30	76
200	35	73
250	40	70
315	47	65
400	52	65
500	56	62
630	56	60
800	57	58
1000	60	52
1250	59	48
1600	57	48
2000	52	51
2500	52	50
3150	55	47
4000	60	42
5000	64	36
6300	70	
STC/IIC	**51**	**42**
$R_w/L_{n,w}$	**49**	**67**
ALD50/IR50	44	39

Material	N	Thick.	Spac.
Plywood	2	15	
Wood joists		235	406
Glass fibre batts	2	90	
Resilient metal channels		13	406
Gypsum board	1	16	

	Mass, kg	
Frame	217.1	
Floor layers	270.3	13.4 kg/m^2
Ceiling layers	199.7	11.2 kg/m^2



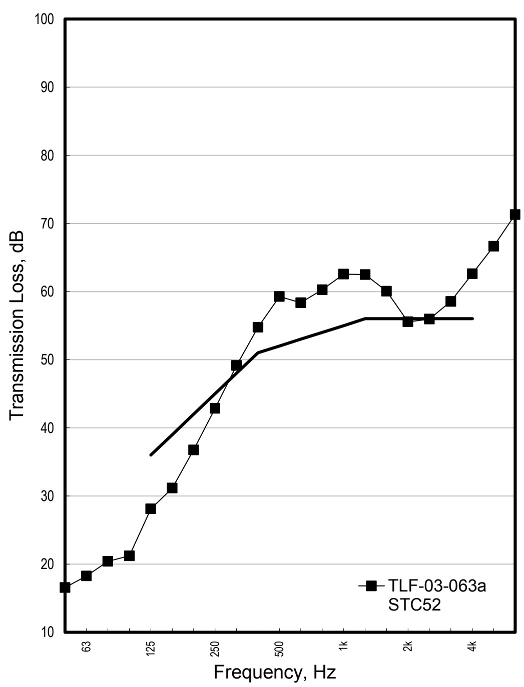


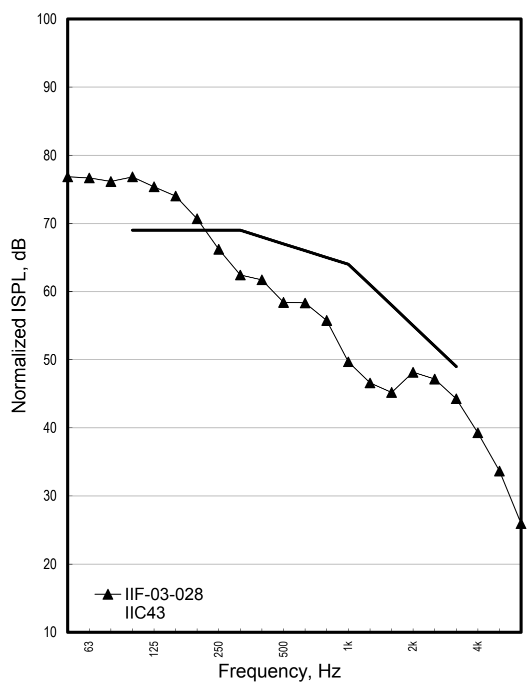
TLF-03-063a / IIF-03-028
2PLY16_WJ235(406)_RFB180_RC13(406)_G16

Freq. Hz	TLF-03-063a	IIF-03-028
50	17	77
63	18	77
80	20	76
100	21	77
125	28	75
160	31	74
200	37	71
250	43	66
315	49	62
400	55	62
500	59	58
630	58	58
800	60	56
1000	63	50
1250	63	47
1600	60	45
2000	56	48
2500	56	47
3150	59	44
4000	63	39
5000	67	34
6300	71	26
STC/IIC	**52**	**43**
$R_w/L_{n,w}$	**51**	**65**
ALD50/IR50	45	41

Material	N	Thick.	Spac.
Plywood	2	16	
Wood joists		235	406
Rock fibre batts		178	
Resilient metal channels		13	406
Gypsum board	1	16	

	Mass, kg	
Frame	217.1	
Floor layers	270.3	13.4 kg/m^2
Ceiling layers	199.7	11.2 kg/m^2



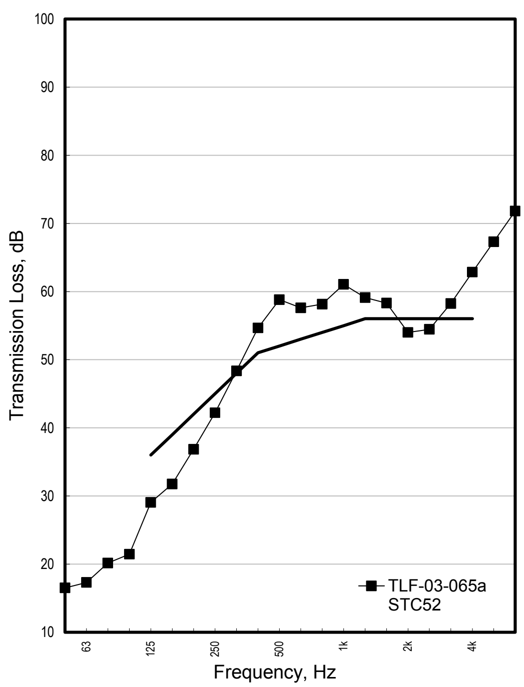


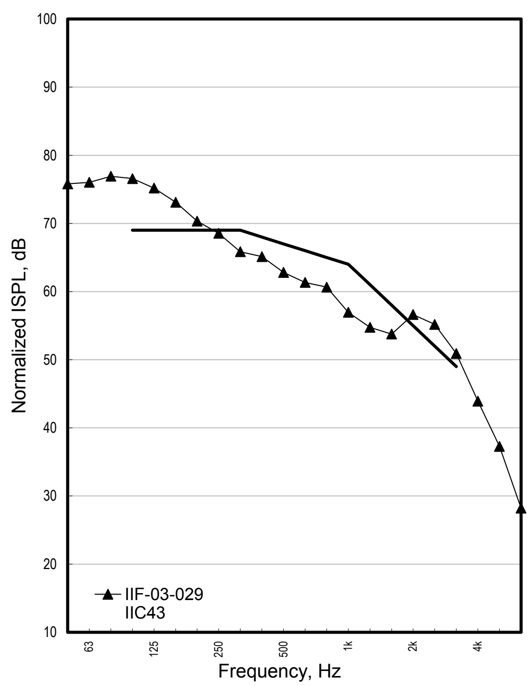
TLF-03-065a / IIF-03-029
OSB19_WJ235(406)_RFB180_RC13(406)_G16

Freq. Hz	TLF-03-065a	IIF-03-029
50	17	76
63	17	76
80	20	77
100	21	77
125	29	75
160	32	73
200	37	70
250	42	69
315	48	66
400	55	65
500	59	63
630	58	61
800	58	61
1000	61	57
1250	59	55
1600	58	54
2000	54	57
2500	54	55
3150	58	51
4000	63	44
5000	67	37
6300	72	28
STC/IIC	**52**	**43**
R_w/$L_{n,w}$	**51**	**67**
ALD50/IR50	45	41

Material	N	Thick.	Spac.
Oriented strandboard	1	19	
Wood joists		235	406
Rock fibre batts		178	
Resilient metal channels		13	406
Gypsum board	1	16	

	Mass, kg	
Frame	217.1	
Floor layers	225.6	11.2 kg/m^2
Ceiling layers	199.7	11.2 kg/m^2





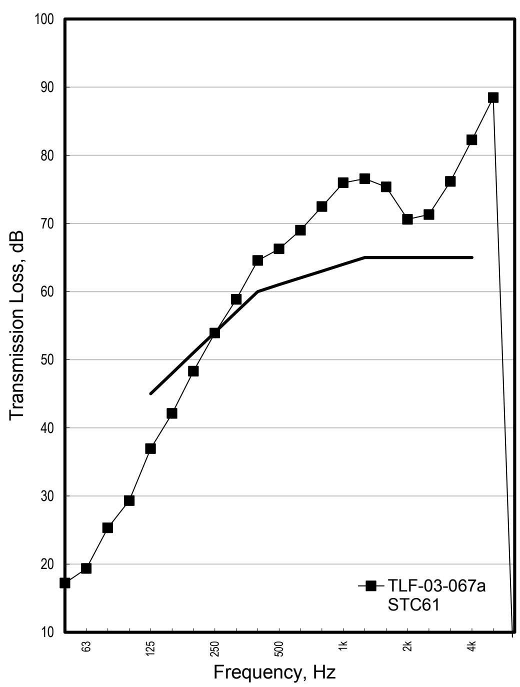
TLF-03-067a / IIF-03-030
2GCB13_OSB19_WJ235(406)_RFB180_RC13(406)_G16

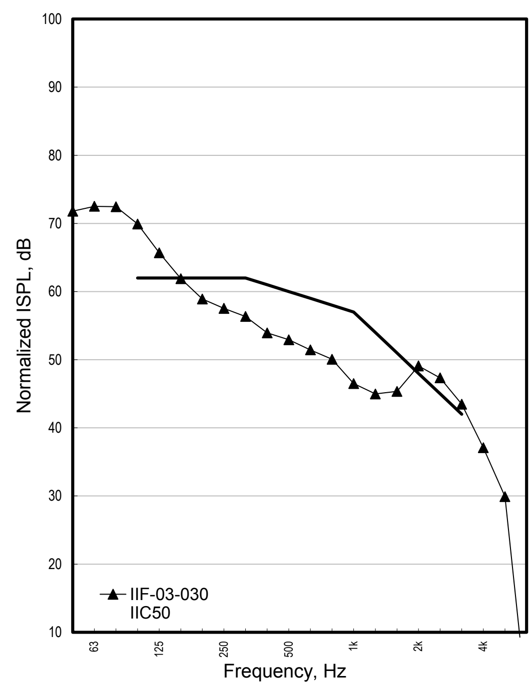
Freq. Hz	TLF-03-067a	IIF-03-030
50	17	72
63	19	73
80	25	72
100	29	70
125	37	66
160	42	62
200	48	59
250	54	58
315	59	56
400	65	54
500	66	53
630	69	51
800	72	50
1000	76	46
1250	77	45
1600	75	45
2000	71	49
2500	71	47
3150	76	43
4000	82	37
5000	88	30
6300		
STC/IIC	**61**	**50**
R_w/$L_{n,w}$	**61**	**58**
ALD50/IR50	51	47

Material	N	Thick.	Spac.
Gypsum/cellulose board	2	13	
Oriented strandboard	1	19	
Wood joists		235	406
Rock fibre batts		178	
Resilient metal channels		13	406
Gypsum board	1	16	

	Mass, kg	
Frame	217.1	
Floor layers	731.8	36.4 kg/m^2
Ceiling layers	199.7	11.2 kg/m^2

2 layers of gypsum/cellulose board. First layer laid down on top of the OSB, second layer glued and stapled to the first layer.



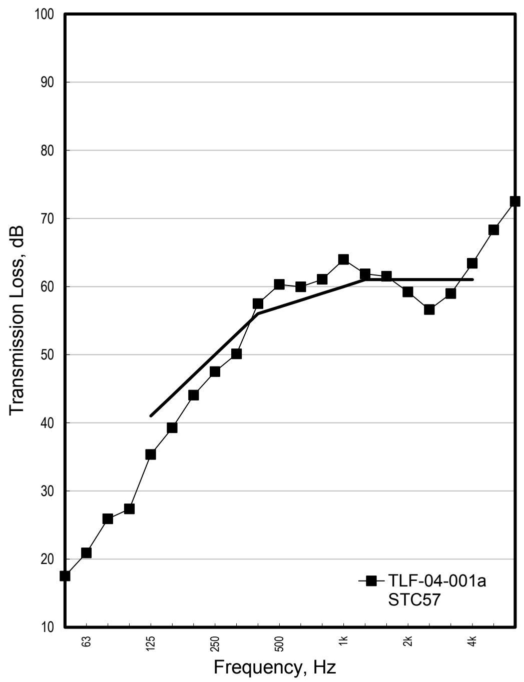


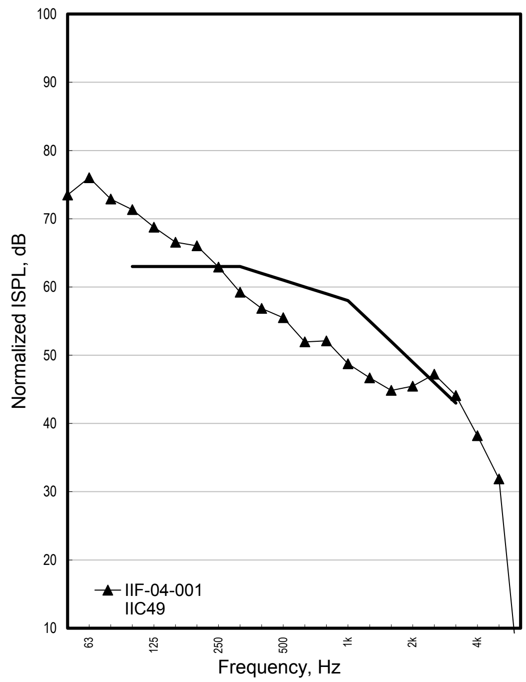
TLF-04-001a / IIF-04-001
PLY16_WJ235(406)_CFL235_RC13(610)_2G13

Freq. Hz	TLF-04-001a	IIF-04-001
50	18	73
63	21	76
80	26	73
100	27	71
125	35	69
160	39	67
200	44	66
250	48	63
315	50	59
400	58	57
500	60	55
630	60	52
800	61	52
1000	64	49
1250	62	47
1600	62	45
2000	59	45
2500	57	47
3150	59	44
4000	63	38
5000	68	32
6300	73	
STC/IIC	**57**	**49**
R_w/$L_{n,w}$	**56**	**60**
ALD50/IR50	50	44

Material	N	Thick.	Spac.
Plywood	1	16	
Wood joists		235	406
Blown-in cellulose fibre		235	
Resilient metal channels		13	610
Gypsum board	2	13	

	Mass, kg	
Frame	217.1	
Floor layers	141.1	7 kg/m^2
Ceiling layers	355.1	19.9 kg/m^2



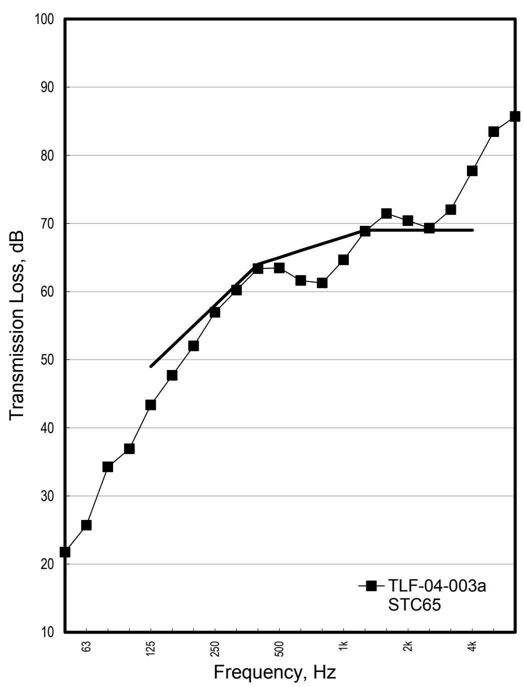


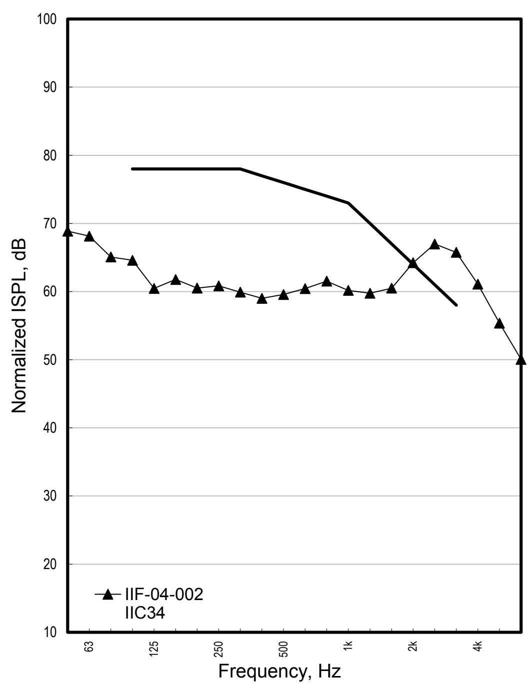
TLF-04-003a / IIF-04-002
GCON25_PLY16_WJ235(406)_GFB90_RC13(610)_2G13

Freq. Hz	TLF-04-003a	IIF-04-002
50	22	69
63	26	68
80	34	65
100	37	65
125	43	60
160	48	62
200	52	61
250	57	61
315	60	60
400	63	59
500	63	60
630	62	60
800	61	62
1000	65	60
1250	69	60
1600	71	61
2000	70	64
2500	69	67
3150	72	66
4000	78	61
5000	83	55
6300	86	50
STC/IIC	**65**	**34**
$R_w/L_{n,w}$	**64**	**70**
ALD50/IR50	56	49

Material	N	Thick.	Spac.
Gypsum concrete		25	
Plywood	1	16	
Wood joists		235	406
Glass fibre batts		90	
Resilient metal channels		13	610
Gypsum board	2	13	

	Mass, kg	
Frame	217.1	
Floor layers	1252.2	62.3 kg/m^2
Ceiling layers	355.1	19.9 kg/m^2



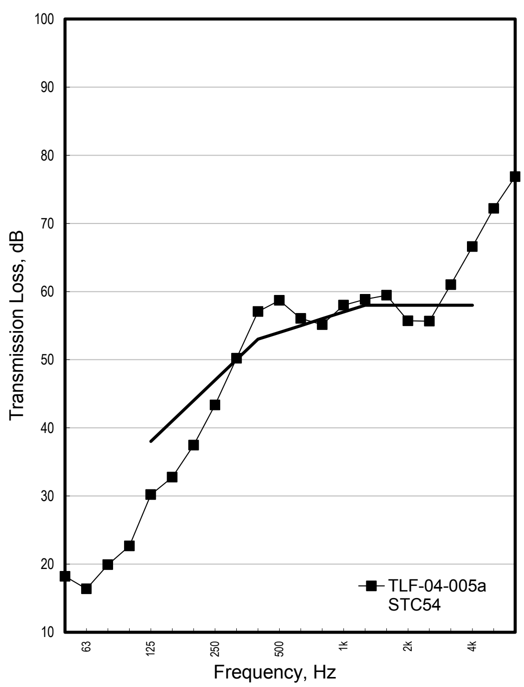


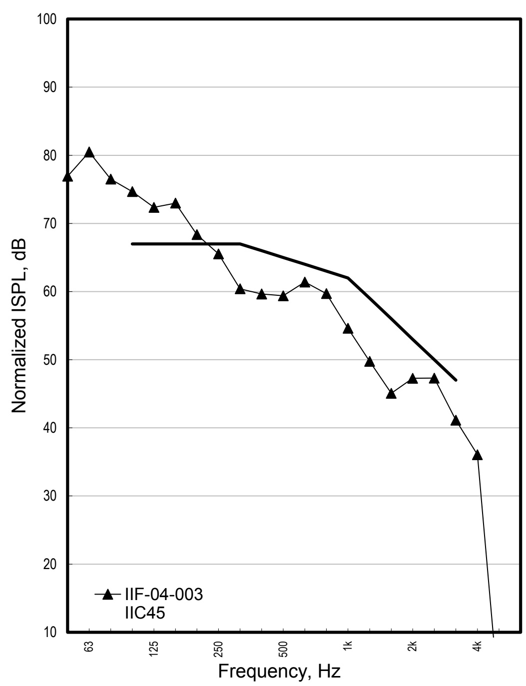
TLF-04-005a / IIF-04-003
2PLY16_WI241(406)_RFB267_RC13(305)_G16

Freq. Hz	TLF-04-005a	IIF-04-003
50	18	77
63	16	80
80	20	77
100	23	75
125	30	72
160	33	73
200	37	68
250	43	66
315	50	60
400	57	60
500	59	59
630	56	61
800	55	60
1000	58	55
1250	59	50
1600	59	45
2000	56	47
2500	56	47
3150	61	41
4000	67	36
5000	72	
6300	77	
STC/IIC	**54**	**45**
$R_w/L_{n,w}$	**52**	**63**
ALD50/IR50	45	40

Material	N	Thick.	Spac.
Plywood	2	16	
Wood I-joists		241	406
Rock fibre batts		267	
Resilient metal channels		13	305
Gypsum board	1	16	

	Mass, kg	
Frame	246.3	
Floor layers	286.0	14.2 kg/m^2
Ceiling layers	191.6	10.8 kg/m^2



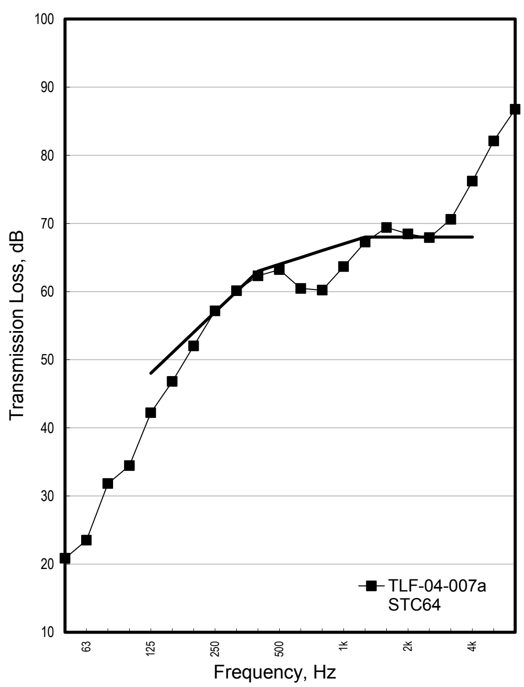


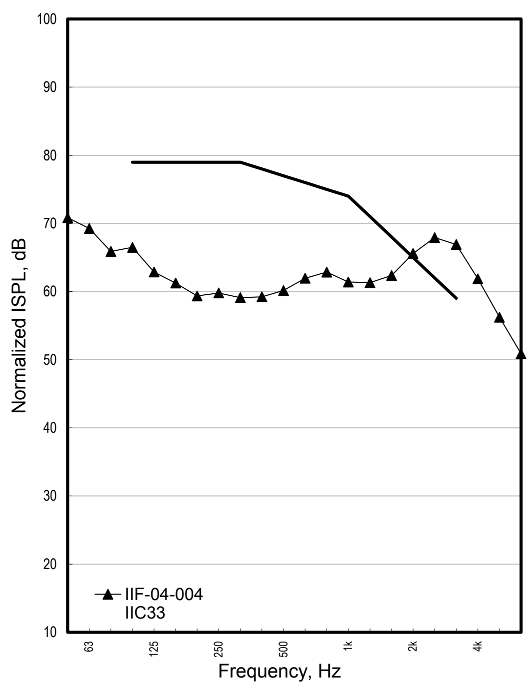
TLF-04-007a / IIF-04-004
GCON25_PLY16_WJ235(406)_GFB90_RC13(406)_2G13

Freq. Hz	TLF-04-007a	IIF-04-004
50	21	71
63	24	69
80	32	66
100	34	66
125	42	63
160	47	61
200	52	59
250	57	60
315	60	59
400	62	59
500	63	60
630	60	62
800	60	63
1000	64	61
1250	67	61
1600	69	62
2000	68	66
2500	68	68
3150	71	67
4000	76	62
5000	82	56
6300	87	51
STC/IIC	**64**	**33**
R_w/$L_{n,w}$	**63**	**72**
ALD50/IR50	55	48

Material	N	Thick.	Spac.
Gypsum concrete		25	
Plywood	1	16	
Wood joists		235	406
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	217.1	
Floor layers	1252.2	62.3 kg/m^2
Ceiling layers	355.1	19.9 kg/m^2



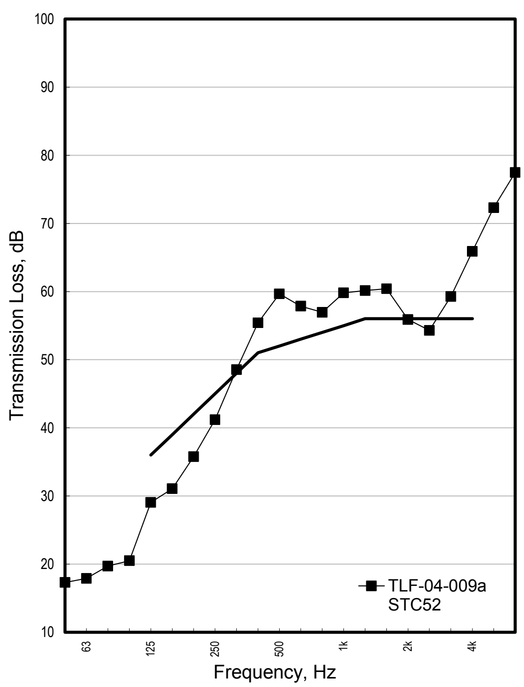


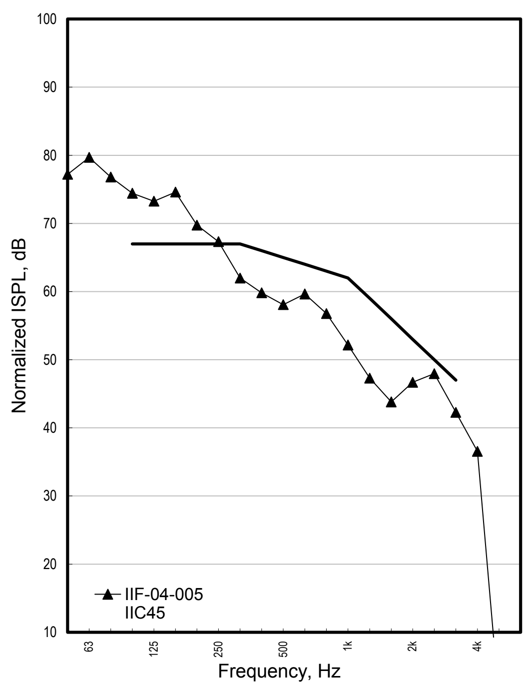
TLF-04-009a / IIF-04-005
2PLY16_WI241(406)_CFL241_RC13(305)_G16

Freq. Hz	TLF-04-009a	IIF-04-005
50	17	77
63	18	80
80	20	77
100	21	74
125	29	73
160	31	75
200	36	70
250	41	67
315	49	62
400	55	60
500	60	58
630	58	60
800	57	57
1000	60	52
1250	60	47
1600	60	44
2000	56	47
2500	54	48
3150	59	42
4000	66	37
5000	72	
6300	77	
STC/IIC	**52**	**45**
$R_w/L_{n,w}$	**50**	**64**
ALD50/IR50	45	40

Material	N	Thick.	Spac.
Plywood	2	16	
Wood I-joists		241	406
Blown-in cellulose fibre		241	
Resilient metal channels		13	305
Gypsum board	1	16	

	Mass, kg	
Frame	246.3	
Floor layers	286.0	14.2 kg/m^2
Ceiling layers	191.6	10.8 kg/m^2



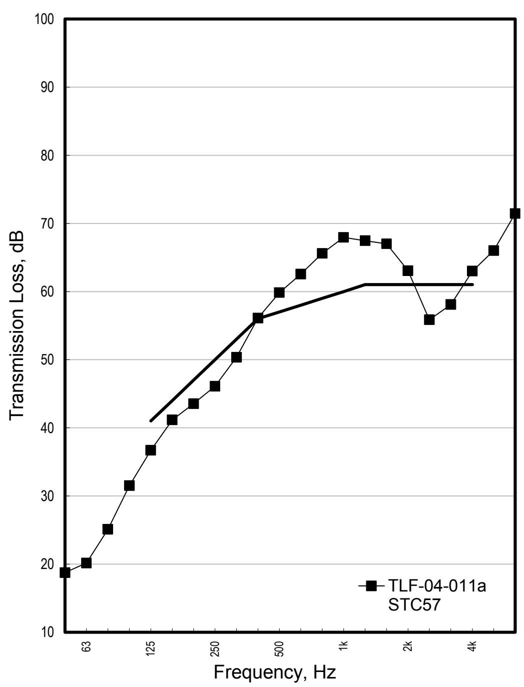


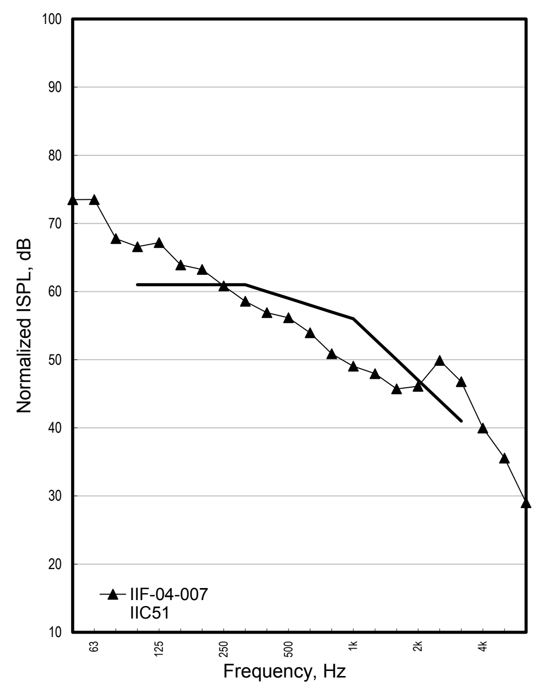
TLF-04-011a / IIF-04-007
PLY19_SJ203(610)_CFS130_RC13(610)_2G13

Freq. Hz	TLF-04-011a	IIF-04-007
50	19	73
63	20	74
80	25	68
100	32	67
125	37	67
160	41	64
200	44	63
250	46	61
315	50	59
400	56	57
500	60	56
630	63	54
800	66	51
1000	68	49
1250	67	48
1600	67	46
2000	63	46
2500	56	50
3150	58	47
4000	63	40
5000	66	36
6300	71	29
STC/IIC	**57**	**51**
$R_w/L_{n,w}$	**57**	**59**
ALD50/IR50	51	47

Material	N	Thick.	Spac.
Plywood	1	19	
Steel C-joists		203	610
Sprayed-on cellulose fibre		130	
Resilient metal channels		13	610
Gypsum board	2	13	

	Mass, kg	
Frame	135.6	
Floor layers	166.4	8.3 kg/m^2
Ceiling layers	354.2	19.9 kg/m^2



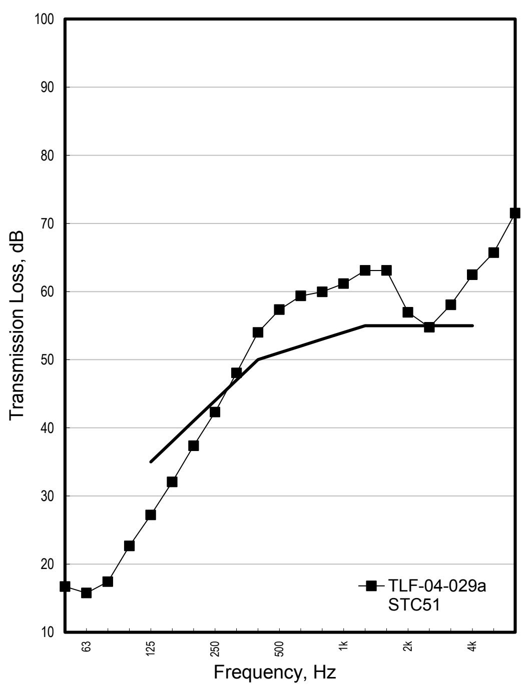


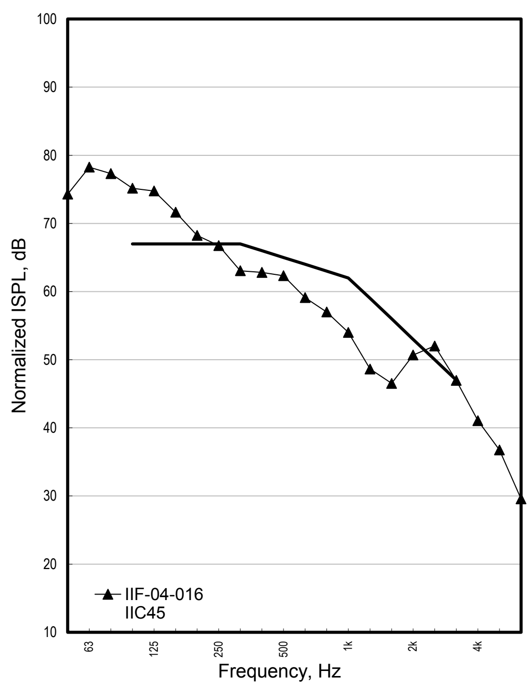
TLF-04-029a / IIF-04-016
2PLY16_SJ203(406)_CFS120_RC13(406)_G16

Freq. Hz	TLF-04-029a	IIF-04-016
50	17	74
63	16	78
80	17	77
100	23	75
125	27	75
160	32	72
200	37	68
250	42	67
315	48	63
400	54	63
500	57	62
630	59	59
800	60	57
1000	61	54
1250	63	49
1600	63	47
2000	57	51
2500	55	52
3150	58	47
4000	62	41
5000	66	37
6300	72	30
STC/IIC	**51**	**45**
R_w/$L_{n,w}$	**51**	**64**
ALD50/IR50	44	41

Material	N	Thick.	Spac.
Plywood	2	16	
Steel C-joists		203	406
Sprayed-on cellulose fibre		120	
Resilient metal channels		13	406
Gypsum board	1	16	

	Mass, kg	
Frame	145.8	
Floor layers	289.9	14.4 kg/m^2
Ceiling layers	198.8	11.2 kg/m^2



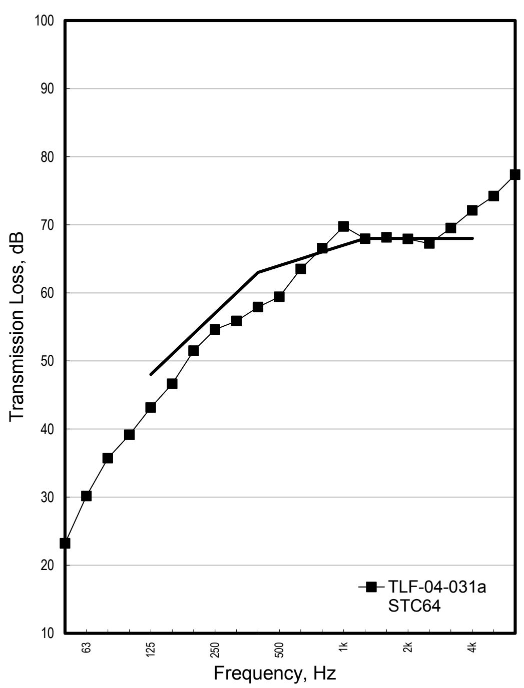


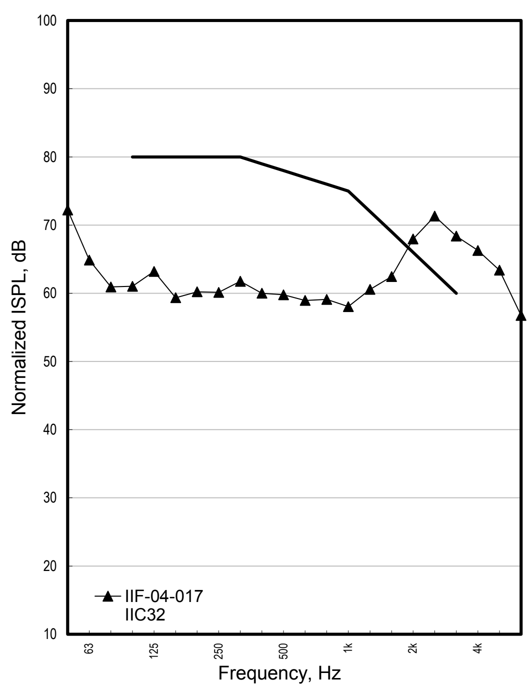
TLF-04-031a / IIF-04-017
CON40_CORSTE0.4_SJ203(610)_CFS130_RC13(610)_G16

Freq. Hz	TLF-04-031a	IIF-04-017
50	23	72
63	30	65
80	36	61
100	39	61
125	43	63
160	47	59
200	52	60
250	55	60
315	56	62
400	58	60
500	59	60
630	64	59
800	67	59
1000	70	58
1250	68	61
1600	68	62
2000	68	68
2500	67	71
3150	70	68
4000	72	66
5000	74	63
6300	77	57
STC/IIC	**64**	**32**
$R_w/L_{n,w}$	**63**	**74**
ALD50/IR50	58	48

Material	N	Thick.	Spac.
Concrete		40	
Corrugated Steel deck		0.4	
Steel C-joists		203	610
Sprayed-on cellulose fibre		130	
Resilient metal channels		13	610
Gypsum board	1	16	

	Mass, kg	
Frame	145.8	
Floor layers	1950.0	97 kg/m^2
Ceiling layers	198.4	11.1 kg/m^2





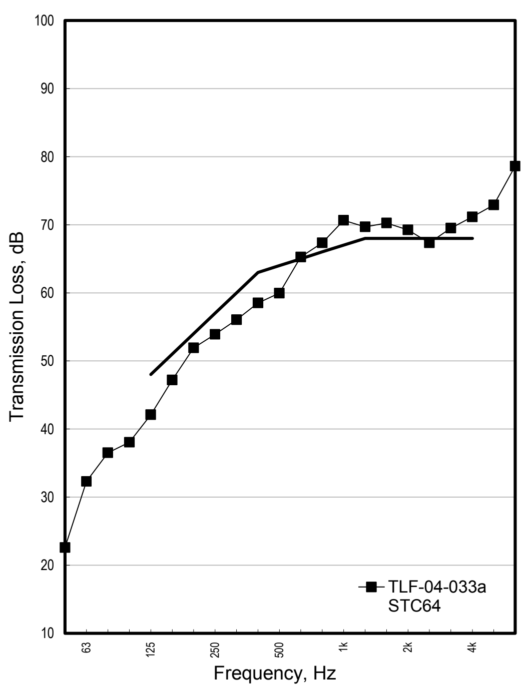
TLF-04-033a / IIF-04-018
CON40_CORSTE0.4_SJ203(610)_CFS130_RC13(610+)_G16

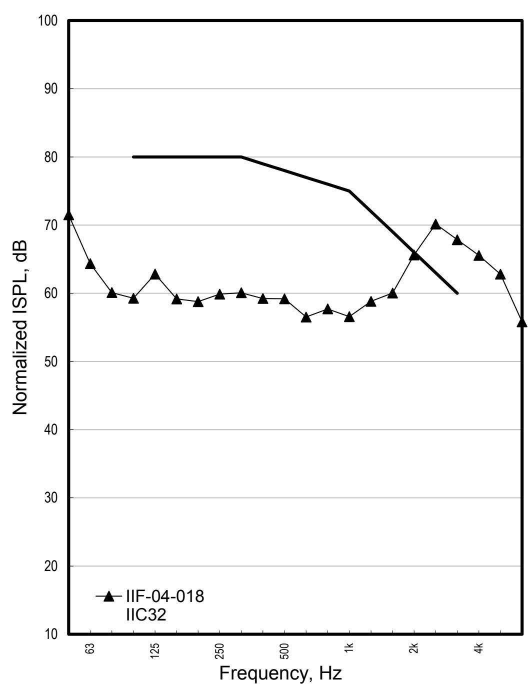
Freq. Hz	TLF-04-033a	IIF-04-018
50	23	72
63	32	64
80	37	60
100	38	59
125	42	63
160	47	59
200	52	59
250	54	60
315	56	60
400	59	59
500	60	59
630	65	57
800	67	58
1000	71	57
1250	70	59
1600	70	60
2000	69	66
2500	67	70
3150	70	68
4000	71	66
5000	73	63
6300	79	56
STC/IIC	**64**	**32**
$R_w/L_{n,w}$	**63**	**73**
ALD50/IR50	58	49

Material	N	Thick.	Spac.
Concrete		40	
Corrugated Steel deck		0.4	
Steel C-joists		203	610
Sprayed-on cellulose fibre		130	
Resilient metal channels		13	610+
Gypsum board	1	16	

	Mass, kg	
Frame	145.8	
Floor layers	1950.0	97 kg/m^2
Ceiling layers	198.4	11.1 kg/m^2

Additional short pieces of RCs at gypsum board butt joints.





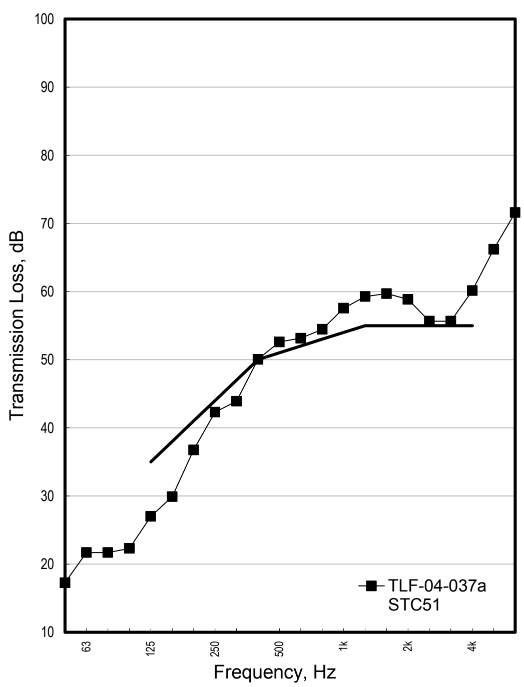
TLF-04-037a / IIF-04-020
PLY16_SWWT305(406)_GFB90_RC13(406)_2G13

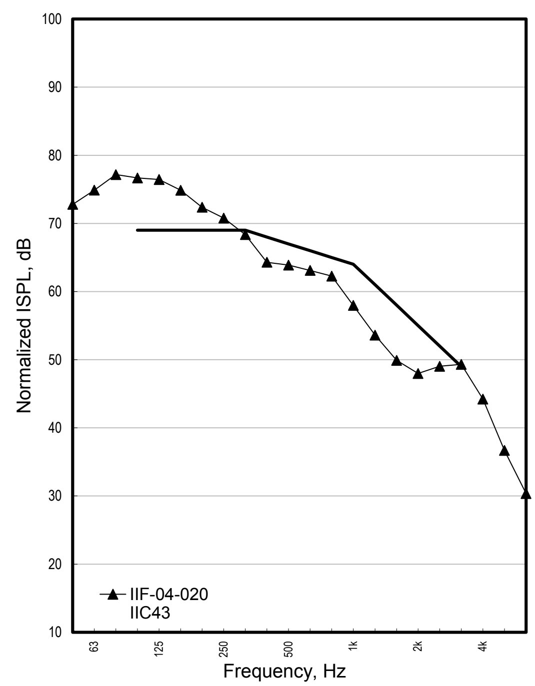
Freq. Hz	TLF-04-037a	IIF-04-020
50	17	73
63	22	75
80	22	77
100	22	77
125	27	76
160	30	75
200	37	72
250	42	71
315	44	68
400	50	64
500	53	64
630	53	63
800	54	62
1000	58	58
1250	59	54
1600	60	50
2000	59	48
2500	56	49
3150	56	49
4000	60	44
5000	66	37
6300	72	30
STC/IIC	**51**	**43**
$R_w/L_{n,w}$	**50**	**67**
ALD50/IR50	45	41

Material	N	Thick.	Spac.
Plywood	1	16	
Steel Web Wood trusses		305	406
Glass fibre batts		90	
Resilient metal channels		13	406
Gypsum board	2	13	

	Mass, kg	
Frame	269.7	
Floor layers	148.1	7.4 kg/m^2
Ceiling layers	343.0	19.3 kg/m^2

Flanges are 65 x 40 mm wood. Web is formed from 1 mm thick steel.





Appendix 2: Alternative Sound Ratings

Airborne Sound

New rating systems have been introduced in ISO 717-1[1] that are meant to deal with low frequency sound such as might be created by a home music system. An additional spectrum adaptation term, C, must be calculated and presented together with the weighted sound reduction index, R_w. The sum R_w + C is proposed in ISO 717-1 as a new single number rating for use in building codes. C can be calculated over the frequency range 100 to 3150 or from 50 to 3150 Hz. In either case, R_w + C is the same as the difference in A-weighted sound level for pink* noise attenuated by the transmission loss spectrum. In this report the terms ALD50 and ALD 100 are used instead of R_w + C. Thus

$$\mathrm{R_w} + \mathrm{C} = \mathrm{ALD100} = -10\log \sum_{f=100}^{f=3150} \left(10^{(W_f - TL_f)/10}\right)$$

$$\mathrm{R_w} + \mathrm{C}_{50\text{-}3150} = \mathrm{ALD50} = -10\log \sum_{f=50}^{f=3150} \left(10^{(W_f - TL_f)/10}\right)$$

where W_f is a weighting factor given in ISO 717 and TL_f is the transmission loss for the one-third octave band with mid-band frequency f. While the ALD terms have no official status they are exactly equivalent to the ISO 717-1 ratings.

Impact Sound

ISO 717-2[2] also proposes a spectrum adaptation term, C_I, for impact sound. The sum $L_{n,w} + C_I$ is proposed in ISO 717-2 as a new single number rating for use in building codes. This sum is the same as the energy sum over a specified frequency range. While its use is not mandatory, research[3,4,5,6,7] strongly suggests that this energy sum correlates better with occupant reactions or A-weighted impact levels created by walkers than does IIC or $L_{n,w}$. In this report, the terms IR50 and IR100 are used instead of $L_{n,w} + C_I$. In addition, the constant 125 is introduced so the IR ratings increase as the sound attenuation for the floor increases in the same way that IIC does. Thus

$$\mathrm{IR100} = 110 - \mathrm{L_{n,w}} - C_I = 125 - 10\log \sum_{f=100}^{f=2500} 10^{L_f/10}$$

$$\mathrm{IR50} = 110 - \mathrm{L_{n,w}} - C_{I,50-2500} = 125 - 10\log \sum_{f=50}^{f=2500} 10^{L_f/10}$$

where L_f is the impact sound level at frequency f. Note that the upper frequency is 2500 Hz, not 3150 as used to calculate IIC and $L_{n,w}$. For many floors, the IR ratings will have about the same numerical value as IIC.

It is important to note that IR50 and IR100 have no official status and are provided here as additional information only.

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* The spectrum of music is very similar to that of pink noise.

Lightweight joist floors can generate high levels of sound at frequencies below 100 Hz and the IR50 rating provides a method for rating these sounds. However, measurements in rooms at these lower frequencies are strongly influenced by the room size and other properties, so comparisons among different laboratories can be problematic. Measurements made in a single laboratory avoid effects due to laboratory differences and should reliably rank assemblies at low frequencies.

Correlations between rating pairs

The newer ratings have been introduced because they are expected to correlate better with subjective evaluations of sound transmission. In some cases the differences between STC and other ratings are small; in other cases, they are not so small. In the following, charts are presented that show the relationships for about 2600 tests carried out over several years in the NRC facilities.

STC versus R_w

STC[8] and R_w have been standardized for many years. The numerical values of the ratings differ for two reasons: the difference in the frequency range and the use of the "8 dB rule" in ASTM E413[8]. STC is calculated from the transmission loss values from 125 to 4000 Hz; R_w is calculated from the transmission loss values from 100 to 3150 Hz. Figure A2-1 and Figure A2-2 show the relationship between the two ratings. In most cases the difference between them is 2 dB or less. At first inspection, Figure A2-1 suggests that there can be large differences between the two ratings. This is true but Figure A2-2 makes it clear that the frequency of occurrence of such differences is small.

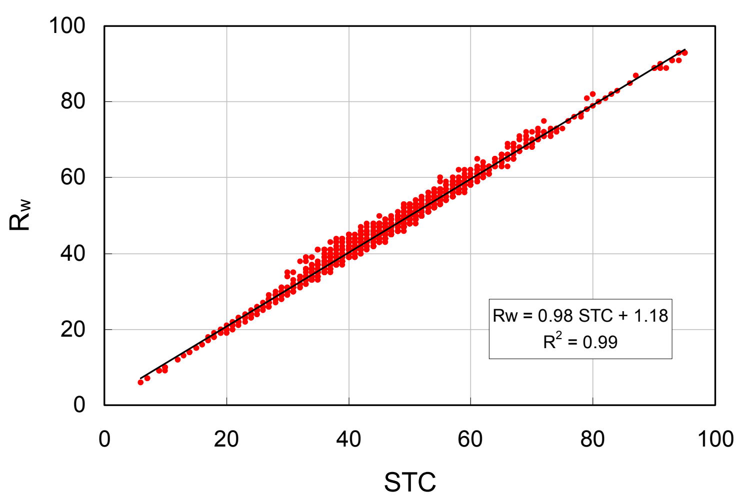

Figure A2-1: Chart showing relationship between R_w and STC for 2600 tests.

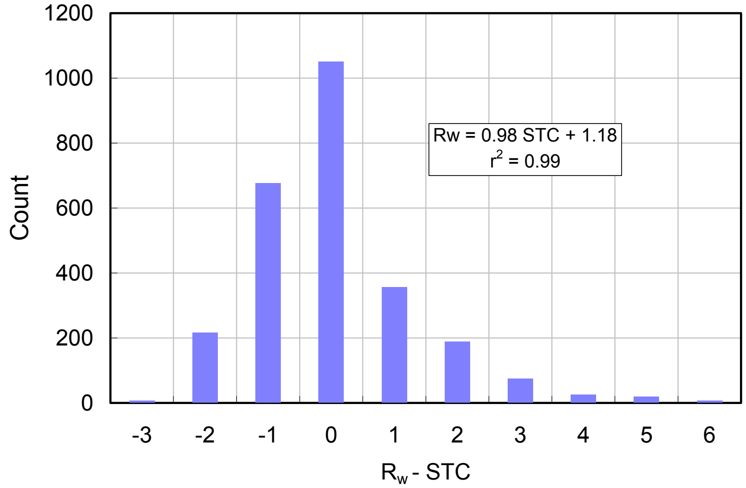

Figure A2-2: Histogram showing the distribution of differences between R_w and STC.

STC versus ALD

The ALD50 rating is calculated from 50 to 3150 Hz. If low frequency intrusive sound in buildings is deemed important, it is necessary to include low frequency transmission loss values in calculations of ratings so ALD50 would seem to be preferable to ALD100. The same set of 2600 test records was used as in the previous section to examine the correlation between the ALD ratings and STC. Figure A2-3 shows that the ALD100 ratings are on average about two or three points lower than STC and there is considerable scatter. ALD100 is only calculated down to 100 Hz, one band less than the lower limit for the STC calculation, so this plot illustrates the differences due to the different calculation procedures: the STC contour fit versus the weighted approach of ALD100. Figure A2-4 shows even greater scatter for the ALD50 rating. The ALD50 rating will penalize walls or floors with poor sound attenuation below 125 Hz, a frequency range ignored by STC. Large differences mean that the specimen has very poor low frequency sound attenuation.

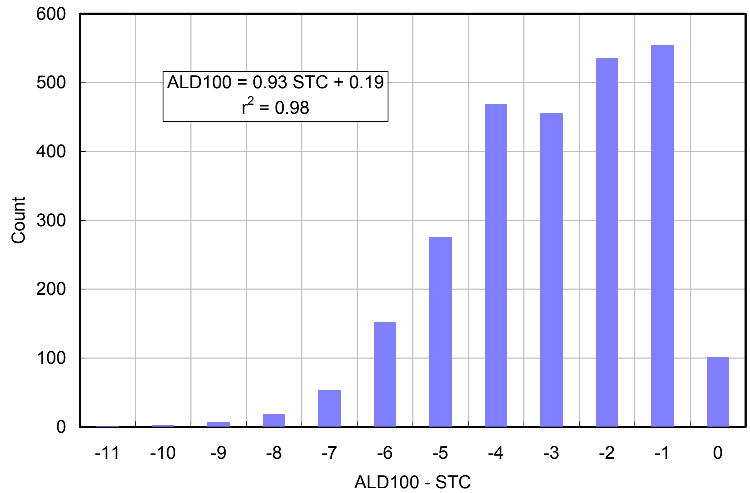

Figure A2-3: Histogram showing the distribution of differences between ALD100 and STC for 2600 tests. The ALD100 rating is calculated from 100 to 3150 Hz.

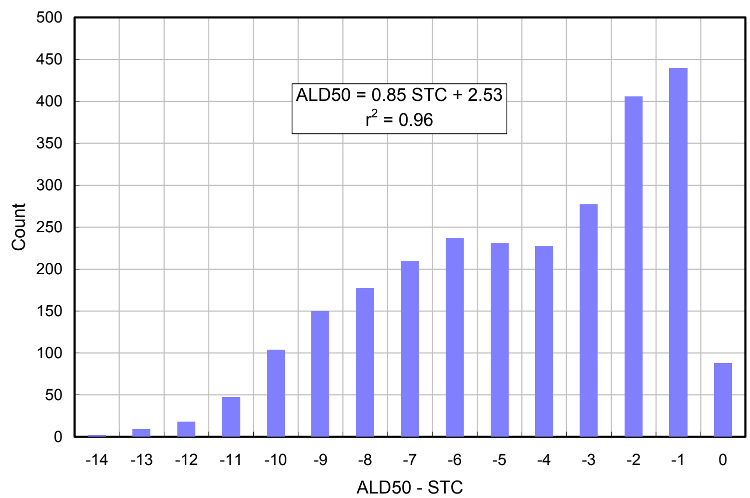

Figure A2-4: Histogram showing the distribution of differences between ALD50 and STC. The ALD50 rating is calculated from 50 to 3150 Hz.

IIC versus $L_{n,w}$

The impact ratings, IIC and $L_{n,w}$ use the same frequency range and reference contour and are thus very similar. The rules for rounding data are slightly different, but this has negligible effect on the numerical value of the rating obtained. More important is the requirement in ASTM E989 that the maximum deviation above the reference contour be limited to 8 dB. This leads to significant rating differences in some cases. Once the fitting process is complete, ASTM E989 subtracts the level of the reference contour at 500 Hz from 110 so the IIC rating increases as the attenuation of impact sound by the floor increases. Thus to compare IIC with $L_{n,w}$, it is convenient to use the variable

110 - IIC. Figure A2-5 shows differences between 110 - IIC and $L_{n,w}$. Non-zero differences are almost all due to the application of the 8 dB rule.

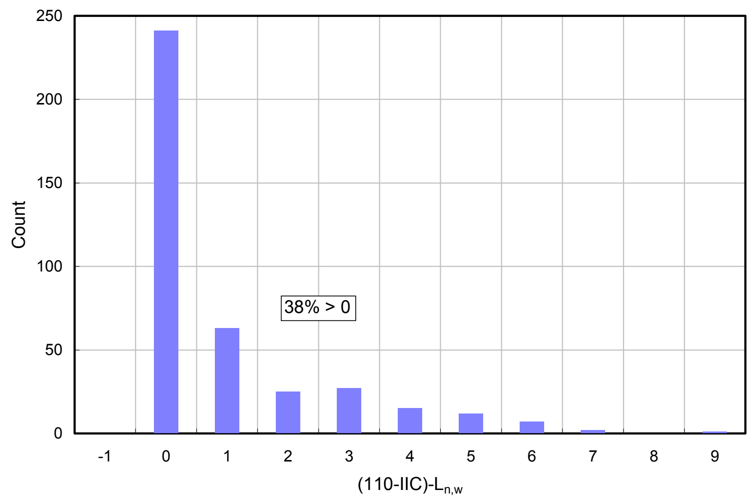

Figure A2-5: Histogram showing the distribution of differences between 110-IIC and $L_{n,w}$.

IIC versus IR

Differences between the IR ratings and IIC are much greater because of the different calculation procedures and because of the inclusion of low frequency information in IR50. Figure A2-6 shows that the correlation of IIC with IR100 is poor. The distribution of differences in Figure A2-7 shows a one-sided distribution with some very large values of IR100 - IIC. Differences of four or more correspond to floors where the upper surface is hard—concrete, gypsum concrete or ceramic tiles. There are cases where IR100 is more than 10 points higher than the IIC. This arises because the IIC rating places too much importance on the high frequencies for such floors. The steel faces of the hammers of the tapping machine produce excessive amounts of high frequency energy, more than is typically produced by a walker wearing normal shoes.

The corresponding plots for IR50 are shown in Figure A2-8 and Figure A2-9. The histogram of differences now has some large negative differences in addition to the positive ones — IR50 is less than the IIC value. These correspond to cases where a carpet was installed on the floor. Carpets very effectively reduce high frequency impact sound but are less effective at frequencies below 100 Hz. The IR50 rating takes account of the sound at low frequencies. So, carpeted floors are not rated as highly as they are under the IIC system.

The differences between IIC and the IR ratings seem to be in accord with practical experience. Carpets, for example, do not usually reduce low frequency footfall sound by very much. The IR rating is supported by research work done at NRC[5,6,7] and in Europe[3] but more investigation of listener reactions to footstep noises would be very useful to aid in the development of reliable impact ratings. While the IR ratings may not be the best possible rating systems, the research shows that they are superior to the IIC and $L_{n,w}$ ratings.

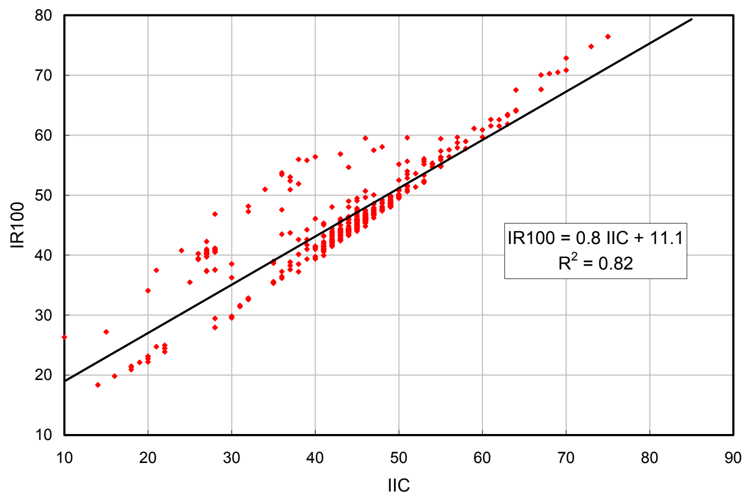

Figure A2-6: Scatterplot comparing IR100 and IIC for 407 tests.

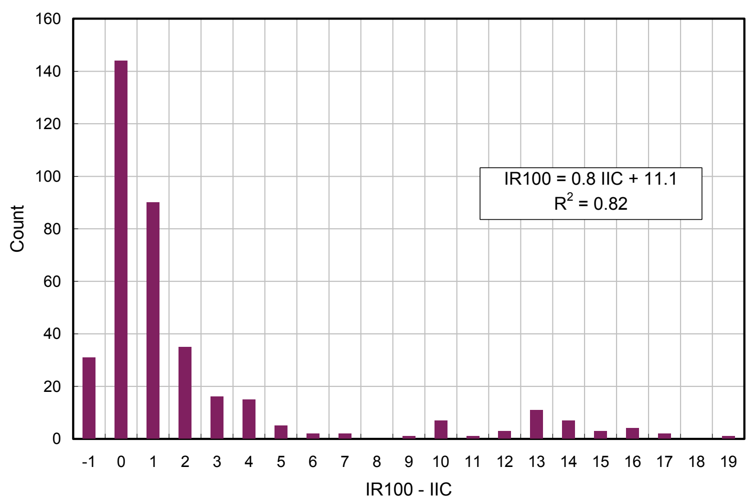

Figure A2-7: Histogram showing the distribution of differences between IR100 and IIC for 407 tests.

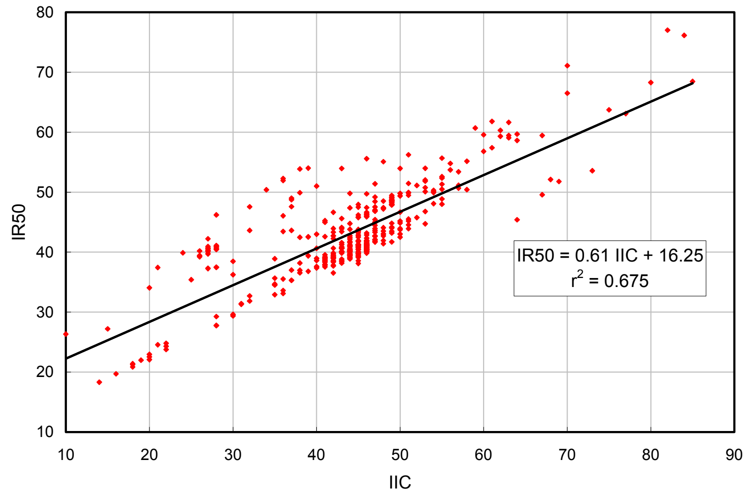

Figure A2-8: Scatterplot comparing IR50 and IIC for 407 tests.

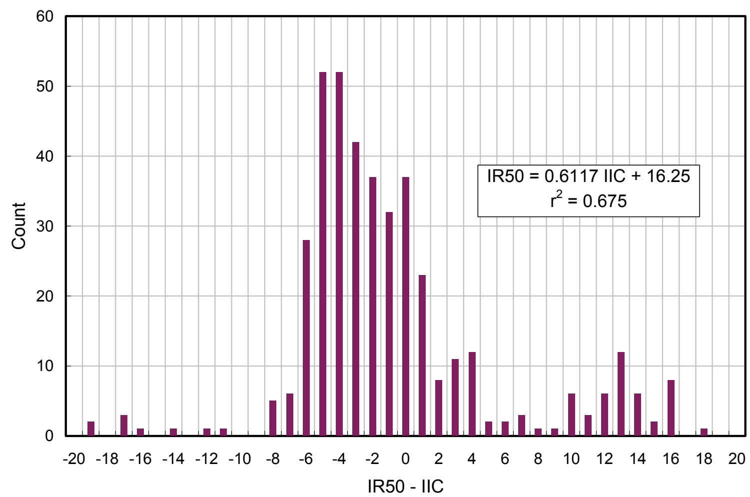

Figure A2-9: Histogram showing the distribution of differences between IR50 and IIC for 407 tests.

References

[1] ISO 717-1. *Acoustics, Rating of sound insulation in buildings and of building elements, Airborne sound insulation in buildings and of interior building elements***.

[2] ISO 717-2. *Acoustics, Rating of sound insulation in buildings and of building elements, Impact sound insulation***.

[3] K. Bodlund. *Alternative Reference Curves For Evaluation of the Impact Sound Insulation Between Dwelling.* J. Sound and Vibration. 102(3), p381, 1985

[4] E. Gerretsen. *A New System for Rating Impact Sound Insulation.* Applied Acoustics, Vol. 9, p247, 1976.

[5] Warnock, A.C.C. *Investigation of Use of the Tire Impact Machine as Standard Device for Rating Impact Sound Transmission of Floors*. September 01, 2000. (NRCC-44301). URL: http://irc.nrc-cnrc.gc.ca/fulltext/nrcc44301.pdf.

[6] Warnock, A.C.C. *Low-frequency impact sound transmission through floor systems*. InterNoise 2000 (NRCC-44211) URL: http://irc.nrc-cnrc.gc.ca/fulltext/nrcc44211.pdf.

[7] Warnock, A.C.C. *Floor research at NRC Canada*. Acoustic Performance of Medium-Rise Timber Buildings (Dublin, Ireland, 1998). URL: http://irc.nrc-cnrc.gc.ca/fulltext/nrcc42815.pdf

[8] ASTM E413. *Classification for Rating Sound Insulation**.

*http://www.astm.org. ASTM standards are available from ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA, 19428-2959 USA.

** http://www.iso.org/iso/en/prods-services/ISOstore/store.html