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Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/40002844
Construction Technology Update; no. 25, 1999-05-01

Construction Technology Update No. 25

Controlling the Transmission of Airborne Sound through Floors

by A.C.C. Warnock

This Update explains how to best control airborne sound transmission through floor systems in multi-family dwellings. Focusing largely on joist floors, the information derives primarily from an industry-supported research project conducted by NRC's Institute for Research in Construction (IRC).[1,2]

Construction Technology Update No. 20 presented the key finding of a comprehensive study of the fire resistance of floor assemblies. The same floor assemblies were also studied for acoustic performance since good fire resistance is sometimes achieved at the expense of good sound isolation.

While the research project focused mainly on joist floors, a few concrete slabs were included in the test series. Both airborne and impact sound transmission were measured in the project, but this Update deals only with airborne sound.

The research demonstrated that, as for stud-wall systems, the key factor in increasing sound isolation in joist floors is the independent or resilient support of the gypsum board ceiling from the joists. If the gypsum board is not supported in this way, sound-absorbing material in the floor cavity is rendered ineffective. In practice, independent supports (separate ceiling joists) are seldom used in North America and the most common way of resiliently supporting gypsum board ceilings is to use 25 ga. resilient metal channels.

Table 1. Research variables

Floor variables	Characteristics
Joist types	solid wood joists, wood I-joists, wood trusses, and steel joists
Joist depth	from 200 to 610 mm
Joist spacing	from 305 to 610 mm; I-joists and trusses with different flange widths were tested.
Thickness of sound-absorbing material	from 60 mm for sprayed-on cellulose fibre to 450 mm for glass- and rock-fibre batts
Spacing for resilient metal channels	203, 305, 406, and 610 mm Additional channels were used in special cases to support the butt ends of the gypsum board.
Subfloors	single and double layers of oriented strand board (OSB) or plywood
Toppings	Concrete or gypsum concrete was added in a few cases.
Gypsum board	primarily a fire-rated type in thicknesses of 12.7 and 15.9 mm; One lightweight, non-fire-rated type was included for some floors.
Application of gypsum board	directly on the joists, and on furring strips, but mostly on resilient metal channels

Sound Attenuation in Joist Floors

The variables examined included joist type, joist depth, joist spacing, type and thickness of sound-absorbing material, type and arrangement of furring used to support the gypsum board, type and thickness of the subfloor, and type and thickness of the gypsum board (see Table 1).

Factors controlling STC in joist floors without resilient metal channels

In floors without resilient metal channels, acoustical energy transfers from one surface of the floor to the

Published by
Institute for Research in Construction
IRC

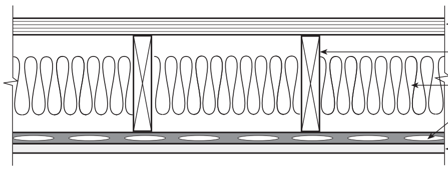

Figure 1. A generic joist floor. Resilient metal channels support one or more layers of gypsum board below the joist, which can be of any type. The sound-absorbing material in the cavity increases the sound isolation when resilient channels are present.

other primarily through the joists. Thus, adding sound-absorbing material to the cavity has little effect on the sound isolation.

STC ratings for floors with the gypsum board ceiling rigidly attached to the joists are presented in Table 2. When the gypsum board is directly attached, the ratings are clearly worse than when wood furring or 22-mm-deep 25 ga. steel U-channels are used. While furring systems provide an improvement over the direct application of gypsum board, they are still too rigid and not as effective as resilient metal channels, where the flange supporting the gypsum board is free to bend.

Adding a 35-mm concrete topping to the basic floor increases the sound attenuation because of the increased weight, but none of the floors listed in the table achieve an STC of 50 or more. It is quite likely that the combination of any one of the furring types listed in Table 2 together with a concrete topping would give an STC of 50 or more, but this combination was not tested in the project.

Table 2. STC ratings for floors comprising 38- x 235-mm wood joists (406 mm o.c.), a 15-mm OSB (oriented strand board) subfloor, and 15.9-mm fire-rated gypsum board using different methods of attachment, both with and without sound-absorbing material in the cavity.

Furring type	**152-mm-thick glass-fibre batts in cavity**	**Layers of gypsum board**	**STC**
No furring	No	1	33
No furring	Yes	1	34
19- x 64-mm wood furring, 610 mm o.c	No	1	39
19- x 64-mm wood furring, 610 mm o.c	Yes	1	42
22-mm-deep 25 ga. steel U-channels, 610 mm o.c.	Yes	1	43
35-mm concrete on top of subfloor			
None	No	1	46
None	No	2	47
None	Yes	1	48

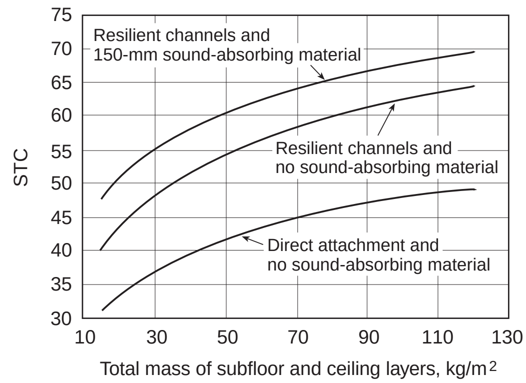

Figure 2. Dependence of STC on total mass per square metre of subfloor and ceiling layers for uniformly spaced resilient metal channels (610 mm o.c.)

Factors controlling STC in joist floors <u>with</u> resilient metal channels

In joist floors with resilient metal channels attached to the underside to support the gypsum board ceiling (Figure 1), several factors determine the airborne sound isolation and thus the STC rating.

The most important factor is the total mass per unit area of the subfloor and ceiling layers. The mass of the joists was not found to be a significant variable. Other variables that have an effect on STC include the thickness of the sound-absorbing material, the arrangement of the resilient metal channels, and the depth and spacing of the joists.

Mass

The influence of mass on STC for floors with joists 240 mm deep and 406 mm apart, and resilient metal channels 610 mm apart is shown in Figure 2. These three cases illustrate the importance of mass and of using resilient metal channels and sound-absorbing material in the floor cavity. The graph is based on the average results of many tests. Apart from its educational value, it can be used to estimate changes in STC that will occur when the thickness or number of sheets of a material in the floor or ceiling is changed. See Table 3 for list of weights/area for common materials.

Figure 2 shows clearly that an STC of 50 or more can be attained with a mass of about 20 kg/m^2 and that an STC of 55 can be reached with a mass of about 30 kg/m^2. It is also clear that without resilient metal channels or the equivalent, an STC of 50 can only be attained with a mass of approximately 130 kg/m^2.

The research showed that putting sound-absorbing material in the cavity of a joist floor with a ceiling that is directly attached to the joists provides no significant increase in sound isolation. Consequently, only one curve (bottom) is shown in the figure for such floors.

Table 3. Area weights for common materials

Material	Area weight, kg/m^2
15-mm OSB	8.8
19-mm OSB	10.3
13-mm plywood	5.7
15-mm plywood	7.1
25-mm plywood	12.1
12.7-mm lightweight gypsum board	7.4
12.7-mm fire-rated gypsum board	9.1
15.9-mm fire-rated gypsum board	11.3
35-mm concrete	77.0

Some specific examples in Table 4 further illustrate the effect on STC of changing the total mass of the combined floor and ceiling. The table has been arranged to allow comparisons among floors with the same type of ceiling but different subfloors. It shows that the STC ratings for assemblies with plywood subfloors are consistently lower than the ratings for assemblies with OSB subfloors. While the plywood used was lighter than the OSB, the difference in weight alone was not enough to account for the measured differences in STC. There are other material properties, such as stiffness, that also influence sound transmission. Table 4 provides a general indication of what happens to the STC when one material is substituted for another; however, for precise information, it is best to use measured STC ratings.

Thickness and type of sound-absorbing material

Three types of sound-absorbing material were used in the study: glass, rock and cellulose fibre. The glass fibre and rock fibre were installed as batts; the cellulose fibre was applied by spraying in two cases, and by blowing it in as a loose fill in two others. The influence of sound-absorbing material in the floor cavity can be summarized as follows:

- Increasing the thickness of the sound-absorbing material increased the STC; similarly, decreasing the thickness decreased the STC.
- Each change in thickness of about 65 mm changes the STC by 1 point.
- There is some indication that for the same thickness of material, rock and cellulose fibres give an STC that is higher than that of glass fibre by about 1 point. This result needs to be verified.

Arrangement of resilient metal channels

Only two spacings for resilient metal channels are commonly in use: 406 mm and 610 mm. Changing from 610 to 406 mm lowers the STC by about 1 point.

Table 4. STC ratings for floors with 38- x 235-mm wood joists (406 mm o.c.), 152-mm glass-fibre batts in the cavity, uniformly spaced resilient channels (610 mm o.c.), and fire-rated gypsum board (except where noted)

Gypsum board thickness, mm	Subfloor	STC	Subfloor	STC
12.7*	15-mm OSB	49		
12.7	15-mm OSB	51		
15.9	15-mm OSB	52	15-mm plywood	50
15.9	19-mm OSB	52	25-mm plywood	52
2 layers, 12.7*	15-mm OSB	54		
2 layers, 12.7	15-mm OSB	56		
2 layers, 15.9	15-mm OSB	55	15-mm plywood	55
2 layers, 15.9			25-mm plywood	56
15.9	2 layers 15-mm OSB	55	2 layers 15-mm plywood	53
15.9			2 layers 13-mm plywood	51
2 layers, 15.9	2 layers 15-mm OSB	60	2 layers 15-mm plywood	58
2 layers, 15.9			2 layers 13-mm plywood	58
15.9	35-mm concrete on top of 15-mm OSB	68		
2 layers, 15.9	35-mm concrete on top of 15-mm OSB	70		

* Lightweight

To maintain the fire resistance of ceilings consisting of *single* layers of gypsum board, additional pieces of resilient metal channel were added to support the butt ends of the gypsum board. These additional channels reduced the STC by 1–2 points.

These two effects (spacing and the addition of extra channels) are cumulative and STC values in Figure 2 or Table 4 need to be altered to suit the particular assembly under consideration.

Joist depth and spacing

Increasing the depth of the joists increases the STC, but the effect is not very pronounced. On average, an increase in depth of about 100 mm is needed to increase the STC by 1 point. Increasing the spacing between joists also increases the STC but the effect is even less pronounced and very variable. A change in spacing of approximately 200 mm will change the STC by 1 point.

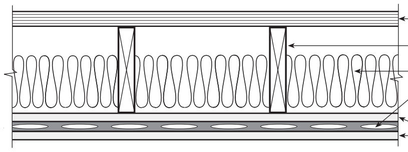

Figure 3. Resilient metal channels between two layers of 15.9-mm fire-rated gypsum board in the ceiling give this construction an STC of only 38. As shown in Table 4, removing the internal layer of gypsum board gives an STC of 52 for an OSB subfloor. Putting both layers below the resilient metal channels gives an STC of 55.

Both of these effects should be taken into account when extrapolating from Figure 2 or Table 4.

Joist type

For practical purposes, the type of joist (solid wood joists, wood I-joists, wood trusses, and steel joists) does not significantly affect the sound isolation.

Other Findings

- Attaching the subfloor to the joists using both construction adhesive and nails gave the same sound isolation as attaching it using only screws.
- Changing the gauge of steel joists through a range of 14 to 18 had no effect on the STC.
- Changing the width of the I-beam or truss flange in contact with the subfloor did not affect the STC.
- Placing resilient metal channels between two layers of gypsum board in the ceiling significantly reduces the sound isolation. This construction should never be used when good sound isolation is important (see Figure 3).

Sound Attenuation in Concrete Slab Floors

The sound attenuation provided by concrete floor slabs is determined mainly by the weight of the slab. Only three floor slabs were measured during the project but the data were supplemented with published information to produce Table 5, which gives typical laboratory STC ratings for a number of concrete slabs. The flow of acoustical energy in buildings, from concrete slabs to the surrounding structure, can be quite different from that found in a laboratory. This can lead to differences in measured sound attenuation for nominally identical slabs for these two different settings. The explanation of these differences is beyond the scope of this Update. Thus, for purposes of comparison, it is best to use laboratory data.

A gypsum board ceiling suspended resiliently below a concrete slab can increase the sound isolation considerably. The increase depends on the mass of the gypsum board, the depth of the cavity between the gypsum board and the concrete slab, and the thickness of the sound-absorbing material in the cavity. The effects of these variables were not investigated in the project. While little information is available for floors, Construction Technology Update No. 13 provides some data for concrete block walls that can be applied when adding gypsum board ceilings to concrete floors. As pointed out in that Update, a cavity depth that is too small can reduce the sound isolation and the STC. Increasing the cavity depth and placing sound-absorbing material in it increases the sound isolation.

Table 5. Typical STC ratings for concrete slabs

Thickness, mm	Mass, kg/m^2	STC
	Solid slabs	
50	115	43
70	160	46
100	230	47
150	350	53
200	460	58
80-150 ribbed	272	51
	Hollow-core slabs	
150	220	48
200	280	50
250	310	50

Implications for the Construction Industry

The data obtained during the project are being used to generate new tables of STC ratings for inclusion in the National Building Code of Canada.

References

1. "Summary Report For Consortium On Fire Resistance And Sound Insulation Of Floors: Sound Transmission Class And Impact Insulation Class Results," A.C.C. Warnock and J.A. Birta, Internal report IRC-IR-766, April 1998.
2. The project was supported by a consortium that included Boise Cascade Corporation, Canada Mortgage and Housing Corporation (CMHC), Canadian Home Builders' Association, Canadian Portland Cement Association, Canadian Sheet Steel Building Institute, Canadian Wood Council, Cellulose Insulation Manufacturers Association of Canada, Forintek Canada Corporation, Gypsum Association, Gypsum Manufacturers of Canada, Louisiana-Pacific Incorporated, Nascor Inc., Ontario New Home Warranty Program, Ontario Ministry of Municipal Affairs and Housing, Owens Corning Canada, Roxul Inc., Trus Joist MacMillan, Willamette Industries.

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May 1999
ISSN 1206-1220

"Construction Technology Updates" is a series of technical articles containing practical information distilled from recent construction research.

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