

ICC G2-2010

GUIDELINE FOR ACOUSTICS



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ICC G2 – 2010 Guideline for Acoustics

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Preface

Introduction

The principal purpose of the ICC Guideline series is to provide a state-of-the-art volume of knowledge that will contribute to the public health, safety, and general welfare in the built environment. Guideline projects are established based on market relevancy, demand, and the realization that existing technical information, regulations, or standards, if any, do not adequately address the subject or that such existing technical information needs to be enhanced, clarified and made more user friendly. ICC Guidelines are in-depth, topic specific technical publications that have global relevancy and may be used internationally. They are different from codes or standards in that they will generally use nonmandatory language.

Development

Development of the ICC Guideline series was approved by the ICC Board of Directors in September of 2008. ICC Policy GP

33-08 governs the development of ICC guidelines and can be viewed on the ICC website at www.iccsafe.org. ICC Guidelines are developed with the establishment of a Guideline Development Committee (GDC). The GDC is made up of a diverse stakeholder population and the participants are focused on ensuring high-quality and timely technical information for the built environment's usage. Upon the GDC reaching consensus the final draft is posted for a "Public Comment" period for 30 days. The GDC considers all public comments, revises the public comment draft as appropriate and sends its recommendations to ICC for publication.

Maintenance

ICC Guidelines are not required to be updated on a specific cycle; however, they will be reviewed periodically and may be updated through a GDC-established process as needed based on changing trends, technology or relevant technical information.



About This Guideline

ICC G2-2010 Guideline for Acoustics

Sound isolation in construction systems separating occupied spaces in all types of buildings is a necessity. This guideline calls for “improved acoustical analysis of assemblies, components and installation methods, and a more detailed inspection process beyond the minimum requirements traditionally found in building codes.”

ICC G2–2010 provides recommendations to solve issues such as:

- The need to upgrade the current level and approach to sound isolation requirements in the building code. These are currently insufficient to meet occupant needs. This guide provides two grades of acoustical performance: *acceptable* and *preferred* performance levels for airborne and structure-borne noise. Both recommendations exceed the current code minimum.
- As sound-rated assemblies are installed in buildings, flanking paths and sound leaks can degrade their acoustical performance. Specific design and evaluation techniques for managing this potential degradation are provided in this guideline.

About the International Code Council

The International Code Council (ICC), a membership association dedicated to building safety, fire prevention and energy efficiency, develops the codes used to construct residential and commercial buildings, including homes and schools. The mission of ICC is to provide the highest quality codes, standards, products and services for all concerned with the safety and performance of the built environment. Most United States cities, counties and states choose the International Codes, building safety codes developed by the International Code Council.

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Other Guidelines of the Series

ICC G1-2010 Guideline for Replicable Buildings



Guideline for Acoustics Development Committee

The following GDC individuals participated in this ICC G2 – 2010 *Guideline for Acoustics* development process and reached consensus on the guidelines content:

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Introduction

The purpose of this guideline is to recommend suitable sound isolation performance for construction systems that separate occupied spaces in commercial and multiple-family buildings such as offices, hospitals, schools, condominiums, apartments, dormitories, hotels and mixed-use buildings. The recommendations in this guideline call for improved acoustical analysis of assemblies, components and installation methods, and a more detailed inspection process beyond the minimum requirements traditionally found in building codes. The intent is to reflect the findings of extensive acoustical research, to better match expectations for acoustical comfort of the building occupants and to prepare for anticipated code changes regarding sound isolation.¹

The guideline addresses three main issues:

1. The need to upgrade the current level and approach to sound isolation requirements in the building code. These are currently insufficient to meet occupant needs.
2. The technical reference materials that are used as a basis of acoustical design need to describe accurately the sound-rated wall or floor/ceiling assemblies. Ideally, such data should not be more than 20 years old.
3. When sound-rated assemblies are installed in buildings, flanking paths and sound leaks can degrade their acoustical performance. This potential degradation should be evaluated by one or more of the following techniques:

- a. Employ analytical or mathematical models during the design phase based on reference materials and resources.
- b. Verify the as-built acoustical performance of the assembly at the project itself.
- c. Verify the as-built acoustical performance of a mock-up assembly surrounded by its proposed construction elements.

Scope

This guideline addresses the acoustical performance of walls and floor/ceiling assemblies used to separate occupied spaces. This guideline gives recommendations for adequate and preferred levels of performance for both airborne and structure-borne noise. These performance requirements are specified in terms of the appropriate American Society of Testing and Materials (ASTM) test method and/or classification procedure. These recommendations may be applied to all types of assemblies and should be referenced during both the design and commissioning phases of the project.

This guideline recommends that the acoustical performance criteria be considered for use in multiple-family dwellings, and for certain commercial and health care settings such as closed offices, courtrooms and examination rooms for which acoustical privacy is necessary or expected.

¹ References to research that supports these conclusions and recommendations can be found in Appendix B.

Terminology

Airborne sound, n—sound that arrives at the point of interest, such as one side of a partition, by propagation through air.

Apparent sound transmission class, ASTC, n—a single-number rating obtained by applying the classification procedure of ASTM E 413 to apparent transmission loss data. The apparent sound transmission class provides a measure of the sound reduction provided by the complete building system, including flanking but not receiving room absorption.

Apparent impact insulation class, AIIC, n—a single number rating obtained by applying the classification procedure of ASTM E 989 to apparent impact transmission loss data. The apparent impact insulation class provides a measure of the impact sound reduction provided by the complete floor/ceiling system, including flanking.

Field impact insulation class, FIIC, n—a single-number rating derived from measured values of normalized one-third octave band impact sound pressure levels in accordance with ASTM Classification E 989. The transmitted tapping sound levels are normalized to the equivalent of 10 m² (108 sabins) of absorption found in a laboratory test chamber. The use of field impact insulation class is intended to determine the impact sound reduction of a floor/ceiling assembly, including the effects of flanking.

Flanking transmission, n—airborne or structure-borne sound transmission that bypasses the separating wall or floor/ceiling and travels through other building elements such as the floor, ceiling or walls abutting the separating wall or ceiling. Flanking transmission can also occur through joints or penetrations in the assembly.

Impact insulation class, IIC, n—a single-number rating derived from measured values of normalized impact sound pressure levels, in accordance with Annex A1 of ASTM E 492, when measured under controlled laboratory conditions. It provides

an estimate of the impact sound insulating performance of a floor/ceiling assembly. This is the amount that impact sound produced by a standard tapping machine striking the top surface of a floor/ceiling assembly is reduced when it is measured in the room below.

Noise isolation class, NIC, n—a single-number rating calculated in accordance with ASTM Classification E 413 using measured values of noise reduction. It provides a measure of the sound isolation (including flanking) between two enclosed spaces that are acoustically connected by one or more paths. The NIC includes the sound reduction provided by the assembly being tested, the effects of absorption in the receiving room and the effects of flanking. For field testing of airborne noise isolation, a measurement of noise isolation class should be performed.

Normalized impact sound rating, NISR, n—the impact sound rating normalized to a reference absorption equivalent to a receiving room that has a reverberation time of 0.5 seconds. For field testing of impact sound insulation where no furnishings are present, a measurement of normalized impact sound rating test should be performed. The NISR includes the sound reduction provided by the partition, the effects of absorption in the receiving room (assuming that the receiving room had a reverberation time of 0.5 seconds) and the effects of flanking.

Normalized noise isolation class, NNIC, n—a single-number rating for noise isolation between two rooms both less than 150 cubic meters calculated in accordance with ASTM Classification E 413 using measured values of normalized noise reduction. The noise reduction values are normalized to an equivalent receiving room absorption that would be achieved with a reverberation time of 0.5 seconds. The NNIC includes the sound reduction provided by the partition, the effects of absorption in the receiving room (assuming that the receiving room had a reverberation time of 0.5 seconds) and the effects of flanking. For field test-



ing of airborne noise isolation where no furnishings are present, a measurement of normalized noise isolation class should be performed.

Sound transmission class, STC, n—a single-number rating calculated in accordance with Classification E 413 using values of sound transmission loss. It provides an estimate of the sound reduction provided by an assembly tested in a laboratory.

Structure-borne sound, n—sound that arrives at the point of interest, such as the edge or face of a partition, by propagation through a solid structure.

Traditional Construction Practices

Section 1207 of the *International Building Code* (code or IBC) addresses the sound isolation of “common interior walls, partitions, and floor/ceiling assemblies . . .” that are used to separate dwellings from one another in multiple-family buildings (and also to separate dwellings from public or service areas). The code specifies that such assemblies shall have a sound transmission class (STC) of not less than 50 (45 if field tested) in accordance with ASTM E 90. Design professionals have generally interpreted the “field-tested” quantity to mean an apparent sound transmission class (ASTC), as defined in ASTM E 336.

Similarly, the code specifies that floor/ceiling assemblies used to separate dwellings shall have an impact insulation class (IIC) rating of not less than 50 (45 if field tested) in accordance with ASTM E 492. The acoustical consulting profession has interpreted the “field-tested” quantity to mean a normalized field impact insulation class (FIIC) or the proposed apparent impact insulation class (AIIC), as defined in ASTM E 1007.

Recommendations for Acceptable or Preferred Performance

Practical experience in combination with research² involving surveys of occupants in multiple-family dwellings indicates that these minimum code requirements, even if attained, do not always satisfy the acoustical privacy expectations of all building occupants.

With the current level of performance specified by the building code, a large percentage of people are highly annoyed by noises from their neighbors, leading to a reduced quality of life and possibly to negative health effects.³

This guide recommends two grades of acoustical performance beyond the current code minimum—*acceptable* and *preferred*, both which exceed the current code minimum. Grade B is acceptable and Grade A is preferred. These criteria are expressed in terms of the acoustical performance as found in a completed building. Numerical values for the two performance grades are shown below in Table 1. Airborne noise performance is measured per normalized noise isolation class (NNIC), as detailed in ASTM test method E 336. Impact noise per performance is measured in accordance with normalized impact sound rating (NISR), as detailed in ASTM test method E 1007.

Table 1: Grades of Field Acoustical Performance

Field Sound Rating	Acceptable Performance (Grade B Performance)	Preferred Performance (Grade A Performance)
Airborne Noise (NNIC per ASTM E 336)	52	57
Impact Noise (NISR per ASTM E 1007)	52	57

² See Appendix B for supporting research.

³ See Appendix B for supporting research.

In addition to the field performance shown in Table 1, Table 2 summarizes the recommended Grade A and Grade B performance of sound-rated assemblies as determined in an acoustical laboratory. If the selected sound-rated assembly does not attain the values in Table 2, it is unrealistic to expect that the field acoustical values in Table 1 will be achieved. Therefore, the performance of the sound-rated assemblies in Table 2 should be considered the minimum allowable in order to meet the room-to-room field performance presented in Table 1.

Table 2: Grades of Laboratory Acoustical Performance

Laboratory Sound Rating	Acceptable Performance (Grade B Performance)	Preferred Performance (Grade A Performance)
Airborne Sound (STC per ASTM E 90)	55	60
Impact Sound (IIC per ASTM E 492)	55	60

Once the separating wall or floor/ceiling element has been selected, the second step is to design the entire building system so that flanking transmission involving other building elements will not compromise the overall performance of the system. Reduction or elimination of flanking is critical to meet the final performance goals. Designers and code officials should review not only the actual assembly but also adjacent areas of the assembly that could compromise the acoustical performance. It is best to have a qualified acoustical design professional perform this function, but there are some basic steps that can be taken to minimize flanking. These are presented in Appendix C.

When accounting for low-frequency noises associated with amplified music, transportation noise and mechanical hum, special attention should be paid to select a building assembly with high sound transmission loss values in the 63 Hz, 125 Hz and 250 Hz octave bands.

Design and/or Performance Verification

The traditional approach to designing for noise control in modern construction focuses almost exclusively on the separating wall or floor. Usually, separating dwelling units fails to address important aspects of how sound is transmitted. Figure 1 shows that this approach does not ensure satisfactory sound insulation between units because it fails to consider flanking transmission, which is structure-borne sound transmission that bypasses the separating wall and travels through other building elements such as the floor, ceiling or walls abutting the separating wall (also known as sidewalls).

Transmission Paths in Real Buildings

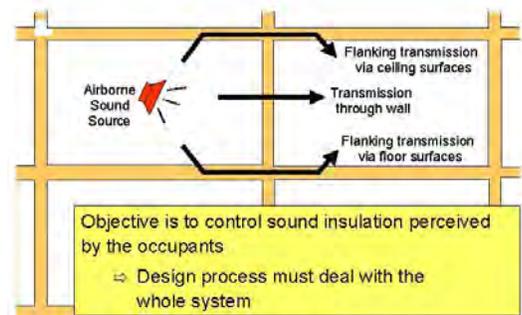


Figure 1: Transmission paths in buildings include both direct transmission through the separating assembly and flanking transmission involving adjacent wall and floor assemblies.

Flanking sound transmission can lead to a reduction in the installed acoustical performance of an assembly. For this reason, the building must be treated as a system of multiple sound transmission paths; when establishing acoustical performance goals, the entire system needs to



be addressed and not just the separating assembly. For this reason, building acoustical performance that is predicted through an analysis of the whole building system, including flanking, during design and then verified by field testing is preferred over solely prescriptive designs based on laboratory testing.

For the purposes of this guideline, the expected performance of the system should be demonstrated by one of the following options (in order of decreasing reliability):

- A. Field verification
- B. Mock-up testing
- C. Analytic design (with consideration of flanking) with the support of acceptable reference materials (e.g., detailed laboratory tests).

A. Field Verification

This guideline encourages post-construction field tests to verify the in-situ acoustical performance of the system. Acoustical field testing should be considered one component of building commissioning. Field testing conducted during or immediately following construction limits the risks to parties who are involved in the success of the building project. Although every wall or floor/ceiling assembly in a building project need not be tested, some type of acoustical quality control program should be implemented, preferably by a qualified expert in architectural acoustics.

The typical acoustical performance within a residential building project should be determined by testing a minimum of five unit-pairs, or five percent of the total, whichever is less (though not less than one acoustical test). This requirement applies to the total units in a project regardless of the number of separate buildings. Field tests should be performed during the early stages of the project so that any deficient assemblies can be remedied and modifications implemented for the remaining portion of the project.

B. Mock-Up Testing

One alternative to a field-testing program is to verify the performance of a specific assembly by constructing a mock-up suite of rooms. A representative dwelling suite is constructed using project labor and typical construction techniques. Following construction of one or more mock-up rooms, the acoustical performance is measured between the critical spaces. Acceptable performance helps validate the assembly for use throughout the project. Marginal acoustical performance in the mock-up suite may lead to a modification of installation techniques and/or design changes. The goal is to instill confidence that the installed assemblies will meet the requirements of the project.

C. Analytical Design and Reference Materials for Sound Ratings

During the design phases of a project, a two-step process is required for selection of sound-isolating assemblies and systems. The first step is to select individual building assemblies that meet the STC and IIC requirements shown in Table 2. The second step is to design the connections between the individual assemblies and conduct acoustical analysis of the building systems comprised of the individual assemblies, as described in Appendix C, to evaluate the effects of flanking transmission on the performance of the whole building system. Values for building system performance and field measurements where flanking has been evaluated must be greater than the values shown in Table 1 for airborne and impact sound transmission.

Sound-rated assemblies need to be properly designed and specified to perform as expected. A sound-rated assembly is more likely to perform consistently when constructed as described in its laboratory test report. An acoustical laboratory test report is supposed to contain a comprehensive description of assembly details, along with acoustical data measured at all the standard frequencies.



Reference materials with inadequate descriptions or data are sometimes cited as a means to show compliance with the code. Such generic assemblies could be either nonrepresentative or misleading, thereby causing inconsistent performance when a variant of the assembly is installed in a building. In a similar vein, one should use caution when considering apparently identical assemblies that are assigned a range of laboratory sound ratings in various references.

Extensive literature and test data are available to assist professionals (acoustical consultants, architects, owners and building trades) in selecting materials and specifying the proper construction techniques. Certain classes of reference materials are considered more credible and reliable than others. Credible sources of data include the following:

1. Detailed third-party research reports for generic assemblies that do not employ proprietary materials and systems (e.g., International Code Council Evaluation Services [ICC-ES], National Research Council and Institute for Research in Construction [NRC-IRC]).
2. Contemporary test reports from an acoustical testing laboratory that is accredited by the National Voluntary Laboratory Accredited Program (NVLAP)⁴ or International Accreditation Service (IAS).⁵
3. Field test reports from qualified acoustical professionals. Construction details, materials, testing methods and a discussion of flanking sound should be included in the report.

Other reference materials are considered less accurate or credible. In particular, designers should avoid relying on sources with certain limitations in performance data.

⁴ <http://ts.nist.gov/nvlap>

⁵ <http://www.iasonline.org>

For example:

1. Avoid reference sources where the focus is specific to fire ratings or other nonacoustical issues.
2. Avoid test summaries that do not include data at all the standard test frequencies.
3. Avoid test summaries where the acoustical performance is summarized as a single-number rating within a range of other single-number ratings (e.g., STC 50-54).
4. Avoid test summaries where the descriptions of acoustically significant material components are given as generic elements (e.g., resilient channel, isolation clip and underlayment/pad),^{6,7,8} rather than specific components with relevant material characteristics (model number, density, dimensions, mounting procedure, etc.).
5. Avoid referencing small-sample field tests (e.g., 1 m by 1 m) and field tests with loosely laid materials (unfastened or not permanently affixed) or those that have not cured for ASTM-specified time periods.

⁶ LoVerde and Dong, "Measurement and Evaluation of Low Frequency Impact Noise in Lightweight Wood Floor Ceiling Assemblies," INCE Inter-Noise 2004 Proceedings, 167 (2004).

⁷ LoVerde and Dong, "Quantitative comparisons of resilient channel designs and installation methods," INCE Inter-Noise Proceedings, in09_737 (2009).

⁸ Jerry Lilly, "Update on the use of steel resilient channels for constructing sound rated walls," Sound and Vibration 36, 8-9 (2002).



REPORTING

The following information should be reported in the building design package:

1. *Statement of conformance to standard*—the design professional should state to which grade of performance the demising assembly is designed to and confirm which method of performance assurance is (to be) conducted.
2. *Description of test specimen*—give a complete description of the test specimen, including the dimensions, thickness and all of the constructional elements. The description should as far as practicable be based upon measurement and examination of the specimen itself, rather than upon general descriptions of generic wall types. The description should also list any restrictions in materials or construction techniques.
3. *Additional considerations*—list any additional considerations that the general contractor or building inspector should be aware of when reviewing or approving the design or installation.





Appendix A – Acoustical Review Checklist

When using laboratory performance data,

1. Verify the number and type of different demising wall assemblies from the plans,
2. Verify the number and type of different demising floor/ceiling assemblies from the plans,
3. Verify the number and type of conditions of demising wall assemblies that are both parallel, and perpendicular, to the structure for both wood and metal frame buildings,
4. Verify the sound ratings provided on the detail sheets, project manual or specifications for each interdwelling party wall and floor/ceiling assembly,
5. Verify that the acoustical laboratory sound ratings are commensurate with code requirements,
 - a. Check that the source of the acoustical data comes from an accredited acoustical laboratory.
 - b. Check the original test report that contains a full description of construction assembly.
 - c. Confirm that the age of the test report is 20 years or less.
 - d. As an alternative to a laboratory test report, review the submitted acoustical field tests for similar construction in existing buildings
6. Confirm the analysis of flanking sound transmission for the whole building system.

When using field performance data,

1. Verify the qualifications of the agency performing the acoustical field test (e.g., it is on the list of approved test agencies);
2. Verify that the details of the proposed sound-rated construction assembly conform to the description in submitted acoustical test report; and
3. Verify item by item that each construction assembly described in the construction documents matches the assemblies shown in the test reports: joist type and spacing, stud type and spacing, type and spacing of fasteners, thickness and surface weight of layers such as gypsum board and plywood, finishes, sealants and other details.

Additional guidance

In case of perceived conflicts between the submitted construction documents and the available library of sound ratings, the building official may consider two or more actions:

1. Request more documentation to help verify that the assembly shown in the submitted construction documents accurately reflects the assembly tested by an accredited acoustical laboratory, or
2. Require field testing of the submitted assembly to help verify that it will provide the necessary acoustical performance in the completed building.



The acoustical field testing may be performed either on an approved mock-up assembly or at some later date within the partially completed building that is under review. If the review process is left incomplete pending field testing, the building's Certificate of Occupancy may be withheld until a) the field testing has been completed in a manner satisfactory to the building official, and b) the acoustical test results satisfy the project requirements.



Appendix B – Research Supporting Recommendations

According to a 1995 British report, *Building Regulation and Health*,⁹ the number of extremely severe health risks that are due to noise (suicides or assaults attributed to noise from neighbors) in British homes is between one and 10 per year. The number of less severe problems (such as stress, migraines, etc.) is estimated to be about 10,000 per year.

Practical experience, in combination with research involving surveys of occupants in multiple-family dwellings, indicates that these minimum code requirements, even if attained, do not always satisfy the acoustical privacy expectations of all building occupants. Based on a study conducted in three large Canadian cities involving over 600 families living in multifamily housing, Bradley¹⁰ concluded,

Noise from neighbours in multi-unit buildings is a serious problem that degrades the quality of life of the residents. Many of their spontaneous and directly elicited responses are strongly related to the measured [A]STC values of the walls between their homes.

It is only when sound isolation is approximately [A]STC 55 or greater, that sound isolation is effective in minimizing the negative effects on residents. [A]STC 55 is therefore recommended as a realistic goal for acceptable sound isolation and [A]STC 60 as a more ideal goal that would practically eliminate the negative effects of neighbour's noises.

Note that this study predates home theater and sound systems with subwoofers, so these results might be considered rather optimistic given these sources, which generate significant low-frequency power.

9 British Building Research Establishment (BRE), *Building Regulations and Health*, BRE Report 289, G.J. Raw and R.M. Hamilton, 1995.

10 Bradley, J.S., *Deriving Acceptable Values for Party Wall Sound Insulation from Survey Results*, *Inter Noise Proceedings*, pp. 1505–1510, The Hague, Netherlands, 2001 [also reprinted in a longer version as No. NRCC 45177 available in electronic format from the Institute for Research in Construction, National Research Council Canada <www.nrc.nrc.gc.ca>]. A summary document from the same research program is entitled, *Acceptable party wall sound insulation criteria*, *Canadian Acoustics*, v. 29, no. 3, September 2001, pp. 56-57, also available in electronic format as No. NRCC 44774].



Appendix C – System Performance and Flanking Transmission

As noted in the main body, the sound that people hear is determined by the sum of direct transmission and all flanking transmission noise between the source and receiver. Because it is this actual sound insulation that determines the perception of the occupants, it is vital to make certain that sound insulation offered by the nominally separating wall or floor is not compromised by flanking transmission via the building elements to which it is connected.

Flanking transmission exists in all buildings—it cannot be completely eliminated, but it can be controlled through good design—and its importance typically increases with the design goal. Controlling flanking transmission is the topic of much study that has resulted in many design documents for the practitioner. This appendix provides a reference to some of those documents and provides a basic design approach.

First, poor design can have devastating consequences. A recent study¹¹ has shown how two rooms separated by an STC 67 wall could experience a performance reduction of 10 or more STC points because of poor design. The problem was not with construction of the wall, which achieved the expected performance. Flanking transmission through the floor completely controlled and undermined the sound insulation. As a result, the final dwelling-to-dwelling performance would be unacceptable, and any remedial treatments applied to the wall would be largely ineffective.

Second, the same study showed that the commonly applied approach of overdesigning the nominally separating element as a hedge against flanking would not have helped. The approach of overdesigning is acoustically ineffective in some cases and not required in others. As a result, the approach is often not cost-effective.

Considering flanking at the design stage should lead to better, more cost-effective performance of the complete system. Because the flanking mechanisms for heavy monolithic assemblies (e.g., concrete and masonry) are different than for light-framed assemblies (light steel and wood-frame construction), the appropriate design tools are different as well. Therefore it is necessary to address them separately.

Concrete and Masonry

An internationally recognized and standardized flanking prediction approach has been developed for buildings employing these materials. ISO 15712 Parts 1 and 2¹² can be used effectively to predict the airborne sound and impact sound insulation performance, respectively. Commercially available computer software developed by companies in Europe greatly simplifies the prediction process.

11 Nightingale, T.R.T.; Quirt, J.D.; King, F., Halliwell, R.E., "Flanking Transmission in Multi-Family Dwellings Phase IV," NRC-IRC Research Report IRC-RR-218, March 2006. (<http://www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/rr/rr218/rr218.pdf>).

12 Building acoustics -- Estimation of acoustic performance of buildings from the performance of elements -- Part 1: Airborne sound insulation between rooms, Part 2: Impact sound insulation between rooms. These standards may be found online at http://www.iso.org/iso/catalogue_detail.htm?csnumber=37595 and http://www.iso.org/iso/catalogue_detail.htm?csnumber=37598.

Light Steel and Wood Frame

Although these materials can satisfy the acoustical recommendations of this guideline, the performance and anticipated flanking for types of assemblies are not accurately predicted by ISO 15712. For wood-frame construction, the National Research Council of Canada has developed from a series of studies¹¹ a design guide¹³ that provides a basic introduction and a series of design solutions and construction details. Except where required for wind and seismic loads, building elements (OSB, gypsum board, joists, etc.) should not be continuous across or under a partition, because they can introduce strong flanking paths.

The following examples are taken from the NRC *Guide to Sound Insulation in Wood Frame Construction*:

- Whether the room pairs are separated by a partition floor or a wall, unless the floor has a massive and resiliently isolated topping, the dominant flanking path typically involves the top surface of the floor and the flanking junction formed by intersection of the wall and floor. One of the most important factors in determining the magnitude of the floor flanking path(s) is joist orientation (parallel versus perpendicular to the flanking junction). Joists parallel to the wall or flanking junction are greatly preferred to those perpendicular to the wall or flanking junction.
- In comparison to the effects associated with continuity and joist orientation, other details (junction blocking details at the wall/floor junction, solid lumber versus wood I joists, oriented strand board versus plywood subfloor) were not particularly important. Wall type (single versus double stud) was important for horizontally (side-by-side) and diagonally separated rooms, but not as important for one room above the other.
- Flanking paths involving the floor can be significantly suppressed by adding a floor topping, but joist orientation remains a factor because the effectiveness of a topping depends on the floor to which it is applied. In general, a topping affects airborne and impact sources differently. It also affects direct and flanking transmission paths, such that:
 - For airborne sound insulation, the most important factor is the mass of the applied topping. Topping installation (bonded, placed or floating on a resilient material) is also significant but less important.
 - For impact sound insulation, there are three important factors—topping mass, topping installation and hardness of the exposed topping surface. A significant increase in mass is required to improve low-frequency impact sound insulation. Resilient support of a topping tends to improve performance. A hard subfloor or topping surface (such as concrete) tends to worsen impact noise and lower the (apparent) IIC, but addition of a floor covering tends to mask this in practice.
- Floor coverings can significantly improve the apparent impact sound insulation when the floor covering reduces the hardness of the floor surface. Thus, carpet is more effective than vinyl, and both tend to be more effective when applied over hard concrete or gypsum concrete surfaces than over comparatively soft surfaces like OSB.
- Flanking paths involving gypsum board surfaces can be significantly suppressed by mounting the gypsum board on resilient channels. Adding resilient channels between the framing member (joist or stud) and the base layer of gypsum is more effective than directly attaching another layer of gypsum board.

13 Quirt, J.D.; Nightingale, T.R.T.; King, F., "Guide for Sound Insulation in Wood Frame Construction," Research Report, NRC Institute for Research in Construction, 219, p. 104 2006-03-01. (<http://www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/rr/rr219/rr219.pdf>).



The approach to controlling flanking transmission depends on the type of construction, but in all cases it is important to avoid elements that are continuous across the nominally separating element. Where continuous elements are required for structural integrity or fire resistance, a rough estimate of the severity of the flanking involving this surface can be obtained by examining the transmission loss (for example, an STC rating or frequency specific data) of the element that is continuous. For example, a continuous 200 mm concrete slab may not pose significant problems if the design goal of the system is an apparent STC of 45 but would likely be an issue if the goal is an apparent STC of 60. Specific guidance cannot be given here, because the magnitude of flanking is a complex function of the flanking elements and their junction to the nominally separating wall or floor, as well as the nominally separating assembly.

Airborne flanking can be introduced by fire stops and blocks,¹⁴ as well as penetrations to an assembly for a duplex electrical, data or other electrical boxes. It is best to avoid penetrations in wall assemblies for both acoustic and fire resistance reasons, but solutions are available.¹⁵

The material given here should only be considered basic information providing background and guidance that can be used during discussions with a trained professional who will be either creating the design or evaluating a proposed design.

14 Nightingale, T.R.T., "Effect of Electrical Outlet Boxes on Sound Insulation of a Double Leaf Wall," Internal Report, Institute for Research in Construction, National Research Council Canada, 772, p. 22. 1998-10-01. (<http://www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/ir772/ir772.pdf>).

15 Richardson, J.K.; Quirt, J.D.; Hlady, R., "Best Practice Guide on Fire Stops and Fire Blocks and their Impact on Sound Transmission," Report, Institute for Research in Construction, National Research Council Canada, NRCC-49677, p. 232. 2007-06-01. (<http://www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/nrcc49677/nrcc49677.pdf>).

Also see Nightingale, T.R.T.; Sultan, M.A., "Sound Isolation and Fire Resistance of Assemblies with Fire Stops," Construction Technology Update, 16, p. 6. 1998-07-01 (<http://www.nrc-cnrc.gc.ca/eng/ibp/irc/ctus/ctus-n16.html>).



Appendix D – Other Occupancies with Acoustical Requirements

There are a number of other building types that have recommendations or requirements for acoustical performance that are not specifically covered in the IBC. These are listed below.

The American Institute of Architects (AIA) and the American Hospital Association provide acoustical design guidelines for hospital and health care occupancies.¹⁶ The guidelines include recommendations for exterior building skins to reduce outside noise from being transmitted inside the building, STC ratings for walls and floor/ceiling assemblies, vibration criteria, background noise levels from building equipment, and recommended reverberation times and alpha bars for interior finish materials.

The American National Standards Institute (ANSI) standard, S12.60-2002 (R2009) *American National Standard Acoustical/Performance Criteria, Design Requirements, and Guidelines for Schools*, covers K-12 educational occupancies¹⁷, specifying maximum reverberation times for spaces, STC ratings for wall and floor/ceiling assemblies, maximum levels of background noise from building equipment and criteria for exterior sound transmission through the building skin.

The American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) provides recommended sound and vibration levels from building equipment for various occupancies in the chapter “Sound and Vibration Control” of their *Applications Handbook*, which is updated every four years.¹⁸

The Department of Housing and Urban Development (HUD) provides criteria for maximum levels on residential building sites, maximum interior noise levels, and criteria for building skin assemblies to meet these requirements. www.HUD.gov is the official HUD web site. www.hudnoise.org contains a third-party summary of HUD criteria with links to the *Code of Federal Regulations* (CFR) sections that contain the legal requirements.

The General Services Administration (GSA) provides criteria for federal courthouses and office buildings.¹⁹ The design criteria and guidelines are included in the section “Special Design Considerations” and include reduction of exterior noise, achieving speech privacy between different areas, STC ratings of partitions, criteria for interior finishes, and background noise levels from building equipment.

THX provides acoustical requirements for reverberation times within theaters, STC ratings for wall assemblies, and background noise levels for THX-certified theaters.²⁰

¹⁶ www.speechprivacy.org

¹⁷ <http://asa.aip.org>

¹⁸ www.ASHRAE.org

¹⁹ www.gsa.gov

²⁰ www.THX.com

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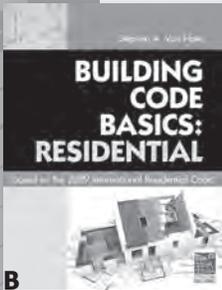
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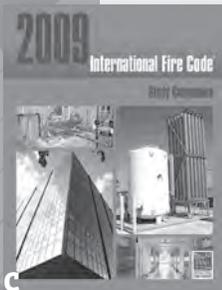
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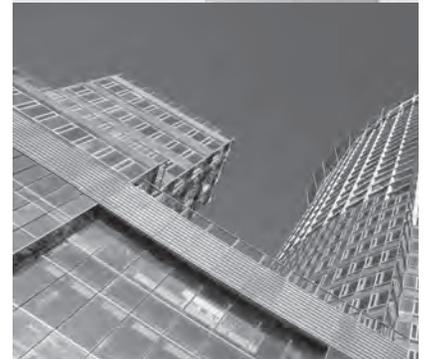
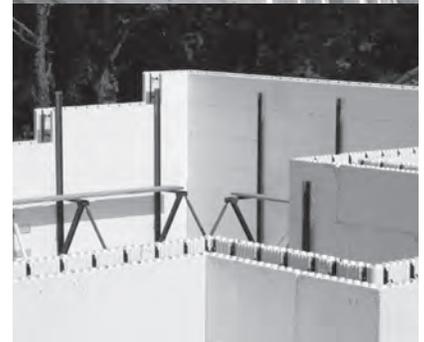
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