Apparent sound insulation in precast concrete buildings

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Apparent Sound Insulation in Precast Concrete Buildings

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National Research Council Canada
Conseil national de recherches Canada

Canada

Scope

This Report presents the results from experimental studies of airborne sound transmission, together with an explanation of calculation procedures to predict the apparent airborne sound transmission class (ASTC) rating between adjacent spaces in a building with walls and floors of precast concrete.

This Report was developed in a project established by the National Research Council of Canada and The Canadian Precast/ Prestressed Concrete Institute to support the transition of construction industry practice to using the ASTC rating rather than STC for sound control objectives in the National Building Code of Canada (NBCC). However, the potential range of application goes beyond the minimum requirements of the NBCC. The Report also facilitates design to provide enhanced levels of sound insulation, and should be generally applicable to buildings with precast concrete walls and floors in both Canada and the USA.

Buildings assembled from precast concrete elements commonly have floors of hollowcore precast concrete slabs combined with wall panels of solid reinforced concrete. The building may also include linings on the precast concrete wall, ceiling, or floor surfaces, but this Report focusses primarily on performance of the base constructions of precast concrete.

Acknowledgments

The research studies on which this Report is based were supported by The Canadian Precast/ Prestressed Concrete Institute and the Canadian Concrete Masonry Producers Association. The support is gratefully acknowledged.

Disclaimer

Although it is not repeated at every step of this Report, it should be understood that some variation in sound insulation is to be expected in practice due to changes in the specific design details, workmanship, substitution of "generic equivalents", or simply rebuilding the construction. It would be prudent to allow a margin of error of several ASTC points to ensure that a design will satisfy a specific requirement.

Despite this caveat, the authors believe that methods and results shown here do provide a good estimate of the apparent sound insulation for the types of constructions presented.

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1 Sound Transmission via Many Paths

The simplest approach to controlling sound transmission between adjacent rooms in buildings considers only the sound transmission through the separating wall or floor between the rooms. This approach has been entrenched in North American building codes which for many decades have only included requirements for the single number ratings for the common assembly between dwellings. The single number ratings used by this approach have been the sound transmission class (STC) rating for airborne sources and the impact insulation class (IIC) rating for footstep noise.

Implicit in this approach is the simplistic assumption that sound is only transmitted through the separating assembly between rooms – the separating wall assembly when the rooms are side-by-side (illustrated in Figure 1.1) or the floor/ceiling assembly when rooms are one-above-the-other. Under this approach, if there are noise complaints, the problem is often incorrectly attributed to errors in either the design of the separating assembly or the workmanship of those who built it and remediation focusses on that assembly.

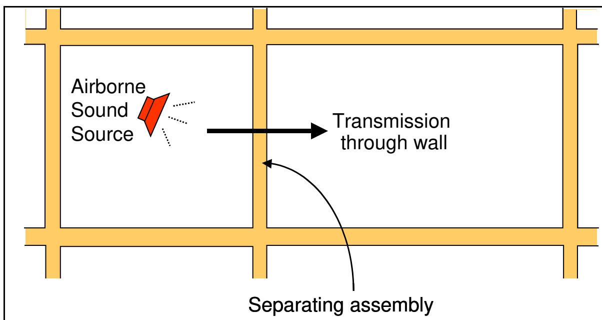

Figure 1.1: A cross-section through two side-by-side rooms of a building showing the historic perspective that sound from an airborne noise source (represented by red loudspeaker in the drawings, which could include anything from a home theatre to people talking loudly) is only transmitted directly through the separating assembly between the rooms (in this case the wall).

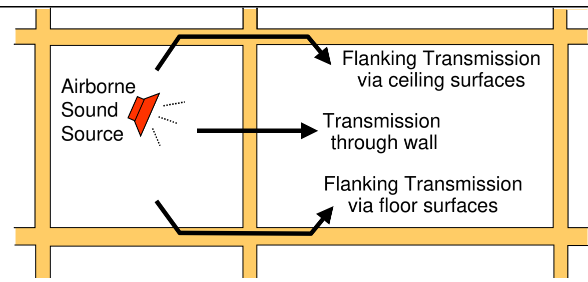

Figure 1.2: This figure shows the reality that in fact there are many paths for sound transmission between adjacent rooms including both direct transmission through the separating assembly and indirect flanking paths, a few of which are indicated here. The flanking paths usually significantly affect the overall sound transmission. See Section 1.4 for more detail about the different paths.

In reality, the technical issue is more complex, as illustrated in Figure 1.2. There is direct transmission of sound through the separating assembly, but that is only part of the story of how sound is transmitted between adjacent rooms. As shown in the figure, the airborne sound source excites all the surfaces in the source room and all of these surfaces vibrate in response. Some of this vibrational energy is transmitted as structure-borne sound across the surfaces abutting the separating assembly, through the junctions where these surfaces join the separating assembly, and into surfaces of the adjoining space. These surfaces in the receiving room then radiate part of the vibrational energy as airborne sound. The sound transmission by these paths is called flanking sound transmission.

The occupants of the adjacent room hear the combination of the radiated sound due to the direct transmission through the separating assembly plus the radiated sounds due to structure-borne flanking transmission involving all the other elements coupled to the separating assembly. There may also be the transmission of sound through leaks (openings) in the walls. Therefore, it follows that in reality, the sound insulation between adjacent rooms is always worse than just the sound insulation of the separating assembly. The importance of including all of the transmission paths has long been recognized in principle and the fundamental science was largely explained decades ago by Cremer et al [8].

Whereas the STC rating is used as the single number rating for sound transmitted only through a wall or floor, there is a single number rating called the apparent sound transmission class (ASTC) rating which includes the contribution of the sound transmitted directly through the separating assembly plus the sound transmitted by all of the flanking paths. Although the measurement of the ASTC rating in a building according to the standard, ASTM E336 is quite straightforward, predicting the ASTC rating of a building is more complex. The challenge has been to reduce the complicated calculation of the sound transmission by multiple paths into manageable engineering that yields trustworthy quantitative estimates and to standardize that process to facilitate its inclusion in a regulatory framework.

For design or regulation, there are standardized frameworks for estimating the overall sound transmission which have been developed and have been in use to support performance-based European building codes. For example, in 2005, the International Organization for Standardization (ISO) published the standard, ISO 15712-1, "Building acoustics — Estimation of acoustic performance of buildings from the performance of elements — Part 1: Airborne sound insulation between rooms" [7]. This standard is one part of four dealing with sound transmission in buildings. In 2017, the four parts of ISO 15712 were replaced by the corresponding parts of ISO 12354. However, this Report continues to reference ISO 15712, for the reasons which will be discussed in Section 1.1.

The standard, ISO 15712-1 outlines a procedure for estimating the weighted apparent sound reduction index (R'_w) of building assemblies. The weighted apparent sound reduction index has a corresponding rating called the apparent sound transmission class (ASTC) rating as described in the standard, ASTM E336 [2]. It is this ASTC rating that is used in the 2015 edition of the National Building Code of Canada as explained in detail in the NRC Report RR-331 [14].

However, there were two significant impediments to applying its methods in a North American context. The first was that although ISO 15712-1 provides reliable estimates for some types of building constructions such as buildings with concrete floors and concrete or masonry walls, the estimates are more difficult to make for the lightweight framed construction widely used for buildings in North America. Secondly, ISO standards for building acoustics have many differences from the ASTM standards used by the construction industry in North America, both in terms of the terminology and in specific technical requirements for measurement procedures and ratings. The following sections of this chapter outline a strategy for dealing with these limitations, both explaining how to merge ASTM and ISO test data and procedures, and providing recommendations for adapting the calculation procedures for precast concrete constructions.

1.1 Predicting Sound Transmission in a Building

The standard, ISO 15712-1 provides reliable estimates for buildings with concrete floors and walls of solid concrete or masonry, but it is less accurate for other common types of construction, especially for constructions whose stiffness is directional, such as wood-frame and steel-frame constructions.

ISO 15712-1 has other limitations as well. For example, especially for light frame construction, the Standard identifies situations where the detailed calculation is not appropriate, but the Standard does not provide specific guidance on how to deal with such limitations. Many of these limitations can be overcome by using measurement data for various combinations of construction types and junctions measured according the four parts of the ISO 10848 standard [6]. The 2015 edition of the National Building Code of Canada (NBCC) addresses these limitation of ISO 15712-1 by specifying the suitable procedures and test data to calculate the ASTC rating for different types of construction, with direct references to ISO 15712-1 and the ISO 10848 series.

The type of attached wall and floor assemblies dictates both the required input data and the steps of the standardized calculation procedures to calculate the ASTC rating. This Report is restricted to the calculation of the ASTC rating for buildings where the walls have a structure of solid precast concrete, and these walls are attached to other walls of precast concrete or to floors of hollowcore precast concrete. The common cases are explained in Chapters 2 to 4 of this Report. This Report indicates which equations from ISO 15712-1 apply in each context and provides key adaptations of the ISO expressions needed to apply the concepts in an ASTM context.

It is important to note that in 2017, the 4 parts of ISO 15712 were replaced by the corresponding parts of ISO 12354. The procedures in ISO 12354-1 are equivalent to those of ISO 15712-1 and resolve most of the concerns identified in the preceding paragraphs. At the time of preparing this Report, the NBCC had not been updated to replace the references to ISO 15712-1 with the corresponding links to the new ISO 12354-1. For consistency with the NBCC, this Report outlines the steps of the standardized calculation procedures with references to ISO 15712-1. Referencing ISO 12354-1 would have negligible impact on the contents of this Report other than the different number of the referenced standard.

1.2 Applying the Concepts of ISO Standards in an ASTM Environment

In Canada, the direct sound transmission loss of building elements is normally tested according to the standard, ASTM E90 [1]. The acoustic requirements in the National Building Code of Canada are given in terms of the apparent sound transmission class (ASTC) determined from the apparent sound transmission loss (ATL) which includes contributions from both the direct sound transmission and the flanking transmission for the set of frequency bands from 125 Hz to 4000 Hz, following the procedure outlined in the standard, ASTM E413 [3].

Although the building acoustics standards developed by ASTM are very similar in concept to the corresponding ISO standards, there are differences in the terminology and the technical requirements which presents numerous barriers to using a mix of standards from the two domains. Although the ASTM standard, E336 recognizes the contribution of flanking sound transmission to the apparent sound transmission, there is neither an ASTM standard for measuring the structure-borne flanking sound transmission that often dominates sound transmission between rooms, nor an ASTM counterpart of ISO 15712-1 for predicting the combination of direct and flanking sound transmission. In the absence of suitable ASTM standards, this Report uses the procedures of ISO 15712-1 and data from the complementary ISO 10848 series for some constructions, but connects this ISO calculation framework to the ASTM terms and test data widely used by the North American construction industry. This methodology combines identifying which data from ASTM laboratory tests can reasonably be used in place of their ISO counterparts, and presenting the results using ASTM terminology (or new terminology for flanking sound transmission that is consistent with existing ASTM terms) to facilitate their use and understanding by a North American audience. Some obvious counterparts in the terminology are presented in Table 1.1.

ISO Designation	Description	ASTM Counterpart
ISO 10140 Parts 1 and 2 [5] (formerly ISO 140-3)	Laboratory measurement of the airborne sound transmission through a wall or floor	ASTM E90
sound reduction index, R (ISO 10140-2)	Fraction of sound power transmitted (in dB) at each frequency, in laboratory test	sound transmission loss, TL (ASTM E90)
weighted sound reduction index, R_w (ISO 717-1 [4])	Single-number rating determined from R or TL values in standard frequency bands	sound transmission class, STC (ASTM E413)
apparent sound reduction index, R' (ISO 16283-1)	Fraction of sound power transmitted (in dB) at each frequency, including all paths in a building	apparent sound transmission loss, ATL (ASTM E336)
weighted apparent sound reduction index, R'_w (ISO 717-1)	Single-number rating determined from R' or ATL values in standard frequency bands	apparent sound transmission class, ASTC (ASTM E413)

Table 1.1: Standards and terms used in ISO 15712-1 for which ASTM has close counterparts

It is important to note that the description “counterpart” does not imply that the ASTM and ISO standards or terms are exactly equivalent. For example, neither the descriptors R_W and STC nor R'_W and ASTC are interchangeable due to systematic differences in the calculation procedures. However, the laboratory tests used to measure the airborne sound transmission through wall or floor assemblies (ASTM E90 and its counterpart ISO 10140-2) are based on essentially the same procedure with minor variants in facility requirements. Therefore, the measured quantities “sound transmission loss” from the ASTM E90 test and “sound reduction index” from the ISO standard are sufficiently similar so that data from ASTM E90 tests can be used in place of data from ISO 10140-2 tests in the calculations of ISO 15712-1 to obtain a sensible answer. Similarly, the simplified calculation of ISO 15712-1 may be performed using STC ratings to predict the ASTC rating. The close parallel between “sound reduction index” and “sound transmission loss” also means that results from ISO 15712-1 calculations (normally expressed as R’ values) can confidently be treated as calculated apparent sound transmission loss (ATL) values and then used in the procedure of ASTM E413 to calculate the ASTC rating, which is the objective for designers or regulators in the North American context. To merge the ASTM terms with the ISO 15712-1 procedures in this Report, the terms “direct sound transmission loss” and “flanking sound transmission loss” have been introduced to provide consistency with ASTM terminology while matching the function of the direct and flanking sound reduction indices defined in ISO 15712-1.

For purposes of this Report, a glossary of new terms with counterparts in ISO 15712-1 and ISO 10848 and using terminology consistent with the measures used in ASTM standards is presented in Table 1.2. In addition, there are other scientific terms that are used at various stages of the calculation in ISO 15712-1 which are used without change in this Report. These terms include: radiation efficiency, velocity level difference, internal loss factor, total loss factor, equivalent absorption length, and transmission factor. These terms are described in the glossary in Annex A of ISO 15712-1.

Terms used in this Report	Description
Structural reverberation time (T_S)	The structural reverberation time is a measure indicating the rate of decay of the vibration energy in an element and can apply either to a laboratory wall or floor assembly, or to a wall or floor assembly in-situ in a building.
Sound transmission loss in-situ (TL_{situ})	The sound transmission loss in-situ is the counterpart of sound reduction index in-situ (R_{situ}) described in ISO 15712-1 as "the sound reduction index of an element in the actual field situation".
Change in sound transmission loss (ΔTL)	The change in sound transmission loss is the difference in sound transmission loss due to the addition of a lining on one side of a wall or floor assembly when measured according to ASTM E90, compared with the sound transmission loss of the same assembly without a lining.
Change in sound transmission class (ΔSTC)	The change in sound transmission class is the difference in the single number rating due to a lining applied on one side of a wall or floor assembly. The calculation procedure for ΔSTC is described in Appendix A2 of this Report.
Vibration reduction index (K_{ij})	The vibration reduction index (K_{ij}) is described in ISO 15712-1 as the "direction-averaged vibration level difference over a junction, normalised to the junction length and the equivalent sound absorption length to make it an invariant quantity". Depending on the type of building element, K_{ij} values may be determined using the equations of Annex E of ISO 15712-1 or the measurement procedures of ISO 10848.
Velocity level difference (VLD)	The velocity level difference (VLD) is described in ISO 15712-1 as the “junction velocity level difference in-situ between an excited element (wall or floor) and the receiving element (wall or floor).” It is calculated by correcting the K_{ij} value to allow for edge loss conditions (identified through structural reverberation times) of the assemblies in-situ.
Flanking sound transmission loss (Flanking TL_{ij})	The flanking sound transmission loss is the counterpart of flanking sound reduction index (R_{ij}) in ISO 15712-1. It is a measure of sound transmission via the flanking path from element i in the source room to element j in the receiving room, normalised like the apparent sound transmission loss.
Flanking sound transmission class (Flanking STC_{ij})	The flanking STC is the single number rating calculated from the flanking sound transmission loss following the STC calculation procedure of ASTM E413.

Table 1.2: Key terms used in this Report to deal with concepts from ISO 15712-1 and ISO 10848 for which current ASTM acoustics standards have no counterparts.

1.3 Combining Sound Transmitted via Many Paths

The calculations of ISO 15712-1 combine the sound power transmitted via the direct transmission path and via a set of flanking paths. To keep track of the sound transmission paths, it is useful to introduce the labeling convention for the paths used in ISO 15712-1 and as shown in Figure 1.3.

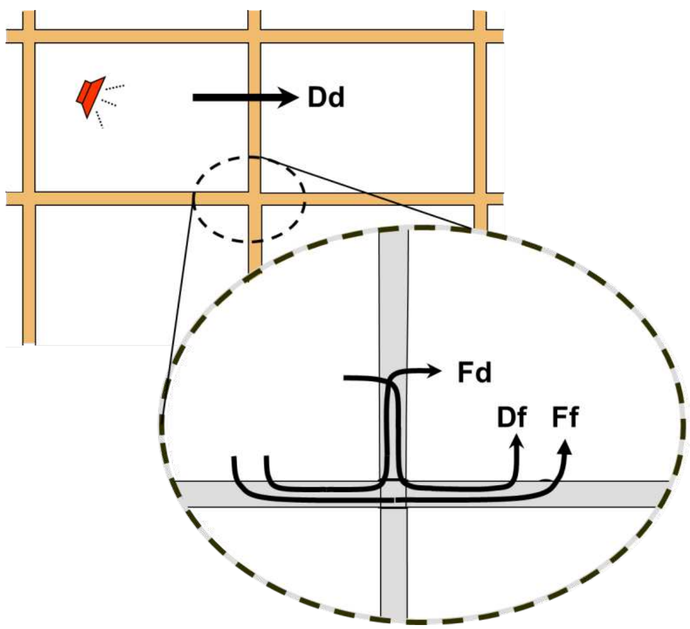

Figure 1.3: This figure shows the labelling convention used for the transmission paths in ISO 15712-1. Consider the transmission of airborne sound from a source room (left) to a receiving room (right). Each transmission path involves one surface in the source room (denoted by a capital letter) and one in the receiving room (denoted by a lower case letter). **D**irect transmission through the separating assembly is path **Dd**. For each edge of the separating assembly there are three flanking paths: **Ff** from flanking surface F to flanking surface f, **Df** from direct surface D to flanking surface f, and **Fd** from flanking surface F to direct surface d.

Note that the letter "F" or "f" denotes **f**lanking surface, and "D" or "d" denotes the surface for **d**irect transmission, i.e. the surface of the separating assembly. These surfaces may be either wall or floor/ceiling assemblies.

The apparent sound transmission loss (ATL) between two rooms (assuming the rectangular room geometry used for examples in Chapter 4, and neglecting sound that is by-passing the building structure, for example sound transmitted through leaks and ducts) is the resultant of the direct sound transmission loss (TL_{Dd}) through the separating wall or floor assembly and the set of flanking sound transmission loss contributions of the three flanking paths ($\mathrm{TL}_{Ff,}$ TL_{Fd}, and TL_{Df}) for each junction at the four edges of the separating assembly as shown in Fig. 1.3. This concept is presented in Equation 1.1.

$$ATL = -10 \cdot \log_{10}\left(10^{-0.1 \cdot TL_{Dd}} + \sum_{edge=1}^{4}\left(10^{-0.1 \cdot TL_{Ff}} + 10^{-0.1 \cdot TL_{Fd}} + 10^{-0.1 \cdot TL_{Df}}\right)\right) \quad \text{Eq. 1.1}$$

Note that this equation differs slightly from the calculation of the apparent sound transmission defined in Equation 14 of ISO 15712-1. Eq. 1.1 of this Report treats the set of paths at each edge of the separating assembly in turn to match the presentation for the examples in this Report. Eq. 1.1 is universally valid for all building systems, so the only remaining challenge is to find the right expressions to calculate the sound transmission via the different paths for the chosen building system and situation.

Each of the flanking sound transmission loss values for a specific path is normalized like the apparent sound transmission loss (ATL), and can be considered as the ATL that would be observed if only this single path were contributing to the sound transmitted into the receiving room. Normalization of the direct and the flanking sound transmission loss input data so that the receiving room absorption is numerically equal to the area of the separating assembly (i.e. using apparent sound transmission loss and the ASTC rating as the measure of system performance) requires suitable corrections to data calculated according to ISO 15712-1, or values of flanking sound transmission loss from laboratory testing according to ISO 10848, so that the set of path sound transmission loss values can be properly combined or compared. This normalization process is described in the calculation procedures in Chapter 4 of this Report.

The standard ISO 15712-1 describes two methods of calculating the apparent sound insulation in a building: the Detailed Method and the Simplified Method. This Report describes both methods to calculate the apparent sound insulation in a building consisting of precast concrete wall assemblies and floor assemblies.

The Simplified Method uses the single number ratings (STC or Flanking STC for each transmission path, as appropriate) instead of the frequency-dependent sound transmission loss values, and yields the ASTC rating directly:

$$ASTC = -10 \cdot \log_{10}\left[10^{-0.1 \cdot STC_{Dd}} + \sum_{edge=1}^{4}\left(10^{-0.1 \cdot STC_{Ff}} + 10^{-0.1 \cdot STC_{Fd}} + 10^{-0.1 \cdot STC_{Df}}\right)\right] \quad \text{Eq. 1.2}$$

The Simplified Method has been widely used by designers in Europe for many years for calculations based on R_W data. Its primary advantage is the simplicity of the procedure, which makes it usable by non-specialists, as illustrated by the worked examples in Section 4.1 and Section 4.3. Although it is less rigorous than the Detailed Method presented in Section 4.2, the differences between the results using the two methods are small, and the calculations for the Simplified Method use approximations that should ensure the results are slightly conservative, especially so if the effect of linings is included in the calculations.

This Report provides both the single number ratings needed to calculate the ASTC rating by the Simplified Method (in tables in Chapters 2 and 3) and the corresponding sets of one-third octave band data needed for the Detailed Method (in the Appendices) for bare precast concrete constructions.

Cautions and limitations to examples presented in this Report:

This Report was developed to support the transition to ASTC ratings for sound control objectives in the National Building Code of Canada. Simplifications were made to meet the specific needs of that application, where sound insulation is addressed only in the context of multi-unit residential buildings. The simplifications include that:

- Transmission around or through the separating assembly due to leaks at its perimeter or penetrations such as ventilation systems are assumed negligible.
- Indirect airborne sound transmission (for example airborne flanking via an unblocked attic or crawl space) is assumed to be suppressed by normal fire blocking requirements.

For adjacent units in a multi-family residential building, these two issues should be dealt with by using normal good practice for fire and sound control between adjoining dwellings.

If this Report is applied to situations other than separation between adjacent units in multi-family residential buildings, some of these issues may have to be explicitly addressed in the calculation process. For example, for adjoining rooms within a single office or home, flanking paths such as ventilation ducts or open shared plenum spaces may be an issue. The flanking sound transmission associated with these additional paths should be determined and included in the calculated ASTC rating. ISO 15712-1 includes specific guidance for such issues, and the examples in this Report allow for such a correction.

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2 Sound Transmission through Wall or Floor Assemblies

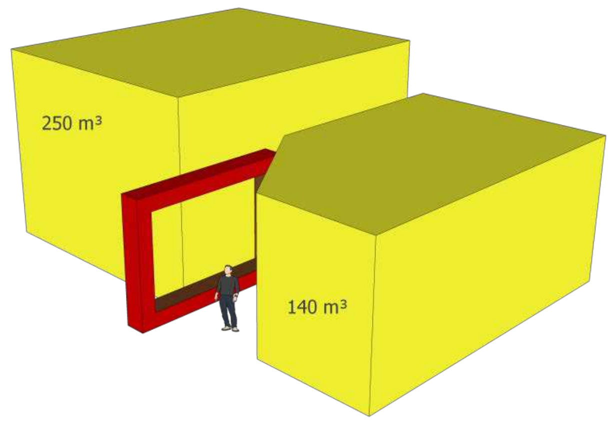
Direct sound transmission loss tests of wall and floor assemblies were conducted in NRC's Wall and Floor Sound Transmission Facilities according to the standard, ASTM E90. Concept drawings of the sound transmission facilities are presented in Figure 2.1.

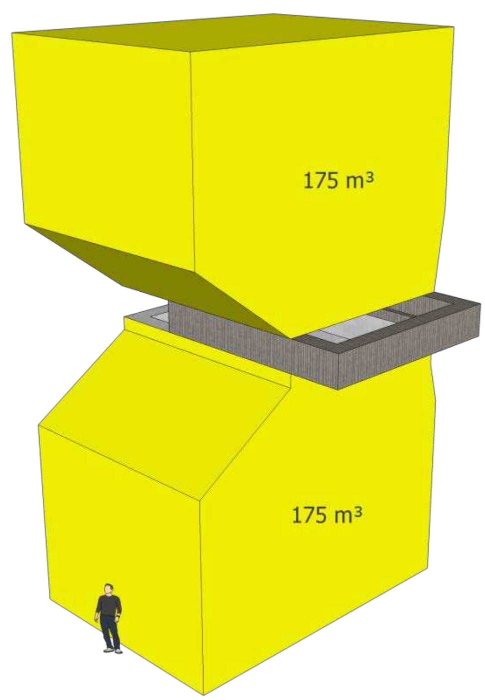
Figure 2.1: A concept drawing of the Wall Sound Transmission Facility at the NRC is presented in the upper drawing. The NRC Floor Sound Transmission Facility, shown in the lower drawing, is similar except that one room is above the other.

In both cases, full scale test assemblies are mounted in the massive, concrete, movable test frames between two reverberation rooms. The test openings are 3.66 m by 2.44 m for walls and 4.70 m by 3.78 m for floors.

For the wall facility, the reverberation rooms (designated "large chamber" and "small chamber") have approximate volumes of 250 m^3 and 140 m^3 respectively. In the floor facility, both chambers have volumes of approximately 175 m^3. All the facility rooms are hard-walled reverberation chambers that are vibration-isolated from each other and from the specimen frame. The rooms have fixed diffusor panels to increase the diffusivity of the sound fields.

The facilities, including instrumentation and the test procedures satisfy or exceed all requirements of ASTM E90.





Measurements of the direct airborne sound transmission loss (TL) were conducted in accordance with the requirements of ASTM E90. The sound transmission loss tests were performed in both transmission directions – from the large chamber to the small chamber and vice-versa for walls, and from the upper chamber to the lower chamber and vice-versa for floors. The results presented in this Report are given as the average of the two transmission directions to reduce measurement uncertainty due to factors such as calibration errors and local variations in the sound fields.

For every measurement, the direct sound transmission loss values were calculated from the average sound pressure levels in the source room and the receiving room and the average reverberation times of the receiving room. One-third octave band sound pressure levels were measured for 32 seconds at nine microphone positions in each room and then averaged to get the average sound pressure level in each room. The average reverberation times were determined from five sound decays measured at each microphone position in the receiving room.

The frequency-dependent direct sound transmission loss was calculated in one-third octave bands in the frequency range from 50 Hz to 5000 Hz. However, only the frequency range between 125 Hz and 4000 Hz is considered in the calculation of the sound transmission class (STC) single number rating in accordance with ASTM E413 [3].

The direct airborne sound transmission loss data is presented as follows in this Report:

- The sets of one-third octave band direct sound transmission loss results from 50 Hz to 5000 Hz are presented in Appendix A1.
- This chapter presents a more compact summary of results in terms of STC ratings.

In addition to the sound transmission loss measurements, measurements were made to characterize the base assemblies. The thickness and mass of the assemblies were determined, and the structural reverberation times were measured in accordance with the requirements in ISO 10140 for thick and heavy wall or floor assemblies. The structural reverberation times are presented in a table in Appendix A1 and the corresponding structural loss factors are presented in Section 2.3.

As explained in Section 2.5 of this Report, the loss factors are pertinent for the calculation of the apparent sound transmission loss following ISO 15712-1. For the precast concrete assemblies evaluated in this study, it was established that the loss factors were too low to ignore corrections for edge losses in the detailed calculations in accordance with Section 4.3 of ISO 15712-1.

2.1 Sound Transmission through Bare Precast Concrete Assemblies

The calculation of the ASTC rating of a building where hollowcore precast concrete floor assemblies are combined with precast concrete walls requires the sound transmission loss data for both the direct transmission through the floor assembly and the direct transmission through the wall assemblies. For the Simplified Method of ISO 15712-1, the required sound transmission loss data is the STC rating for the floor and wall assemblies while the Detailed Method of ISO 15712-1 requires both the one-third octave sound transmission loss values and the corresponding values for the structural reverberation time of the tested floor and wall assemblies.

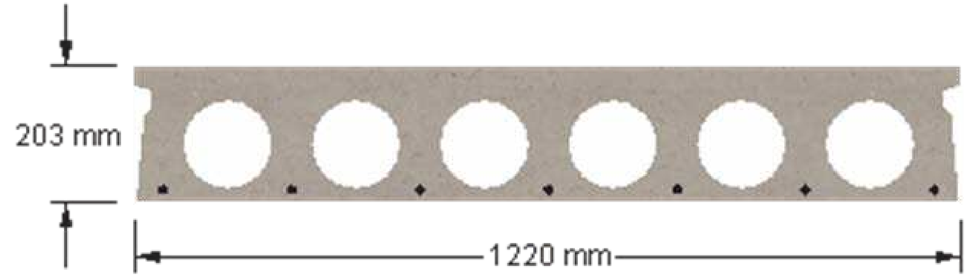
This Report presents the sound transmission data measured for four floor assemblies of hollowcore precast concrete slabs and for one precast concrete wall panel of solid reinforced concrete. Although the panel of solid concrete was tested as a floor assembly, the results are equally applicable for a wall assembly of the same construction. The mass per unit area and STC rating for each of the specimens are presented in Table 2.1.1. Note that the listed value of the mass per unit area for each floor include the mass of the grout at the joints between the slabs.

The test specimens included three floor assemblies with hollowcore precast concrete slabs 203 mm thick, each with different mass per unit area to assess the range of variation possible in practice. Note that the mass per unit area of the hollowcore prestressed concrete floors includes the mass of the grout between the slabs. The cross section of these slabs is illustrated in Figure 2.1.1.

Table 2.1.1: The properties of the tested precast concrete assemblies.

Specimen Code	Specimen Description	Mass / Area (kg/m^2)	STC Rating
CON200	Solid reinforced concrete 200 mm thick	460	59
HCON203(344)	Hollowcore prestressed concrete slabs 203 mm thick, with joints fully grouted	344	56
HCON203(305)	Hollowcore prestressed concrete slabs 203 mm thick, with joints fully grouted	305	54
HCON203(273)	Hollowcore prestressed concrete slabs 203 mm thick, with joints fully grouted	273	55
HCON305	Hollowcore prestressed concrete slabs 305 mm thick, with joints fully grouted	431	57

Figure 2.1.1: Cross-section of a 203 mm thick precast concrete hollowcore slab with nominal dimensions



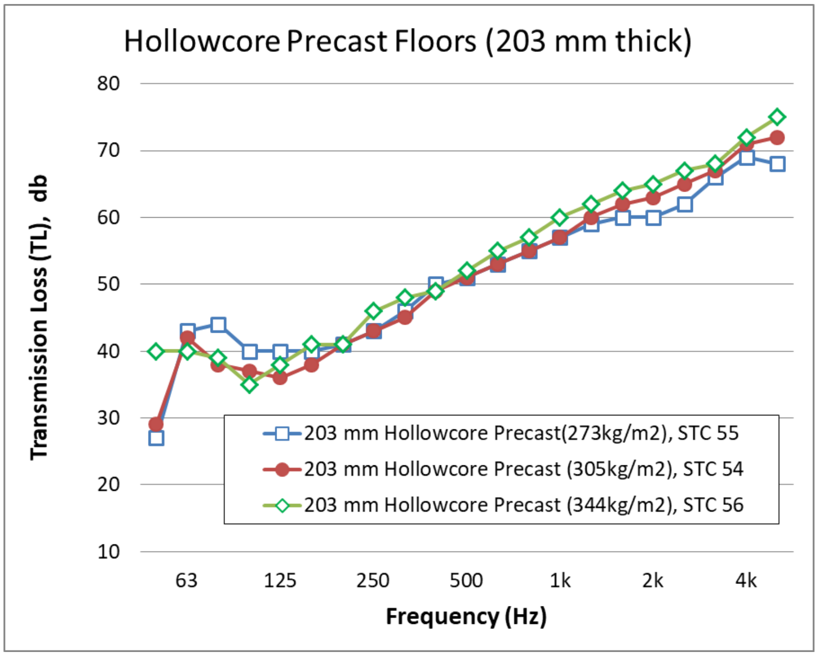
The slabs comprising the 305 mm thick hollowcore precast concrete floor assembly were similar to those illustrated in figure 2.1.1 except that their thickness was greater.

The sound transmission loss values for the precast concrete floors listed in Table 2.1.1 are shown in the following figures and the corresponding one-third octave band data is listed in Table A1.1 in Appendix A1. The corresponding one-third octave data for the structural reverberation times are given in Section 2.3 and in Table A1.3. Additional data for other solid concrete floor assemblies of different mass per unit area and thickness are presented in Report RR-334 - The Apparent Sound Insulation in Concrete Block Buildings [Ref.15.2].

Figure 2.1.2 compares the measured sound transmission loss for the three floor assemblies of 203 mm thick hollowcore precast concrete slabs. The figure shows that while there are some differences in the three curves, the change in sound transmission loss due to the specimen weight of ± 10% is not much greater than the STC changes of ± 1 expected when such specimens are removed and reinstalled.

Figure 2.1.2:

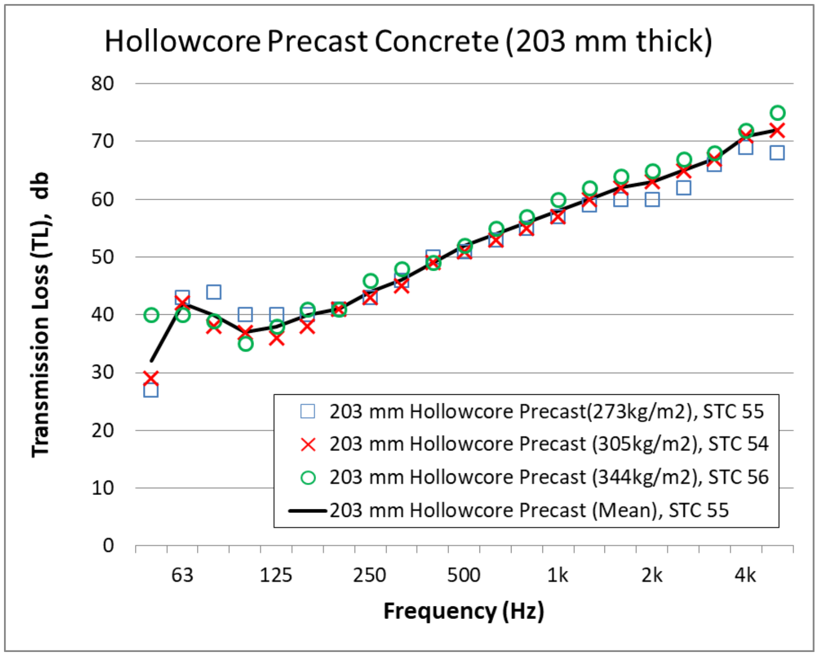
Sound transmission loss for the three tested floor assemblies of 203 mm thick hollow core precast concrete slabs.



The heaviest (344 kg/m^2) of the three floors in Figure 2.1.2 has been used for examples in preceding editions of Guide RR-331. However, for future assessment of such floors, the most useful estimate of sound transmission loss of a typical 203 mm thick hollowcore precast concrete floor is given by the mean value for the three floors which is shown in Figure 2.1.3. **The mean sound transmission loss curve smooths out the fluctuations evident in the individual test specimens and can reasonably be used for a range of mass/area values from about 275 to 350 kg/m^2.**

Figure 2.1.3:

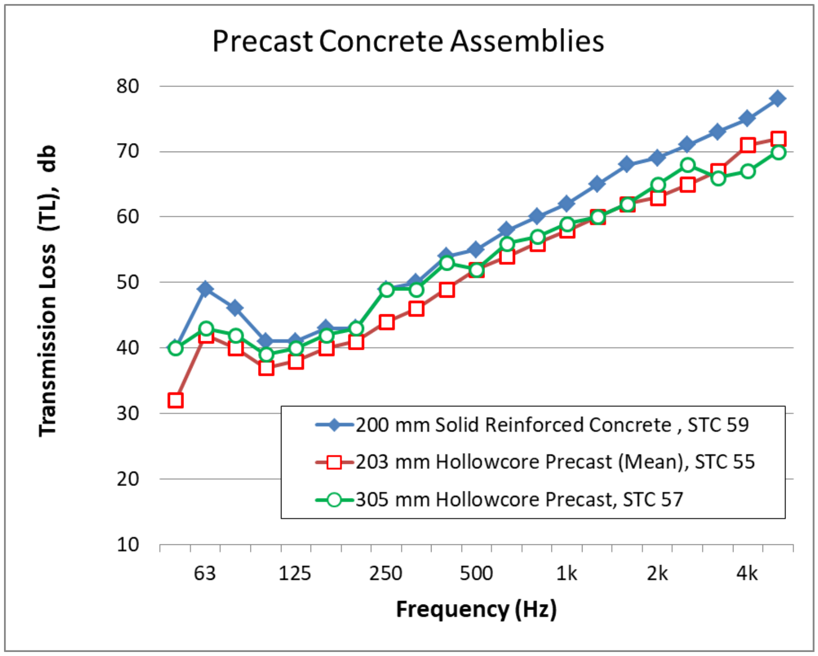
The mean sound transmission loss values based on the measured data for the three floor assemblies of 203 mm thick hollowcore precast concrete slabs is shown by the continuous black curve. Data values for the three specimens are shown by individual symbols at each frequency band.



The mean values for the 203 mm thick hollowcore precast concrete slabs from Figure 2.1.3 is compared with the sound transmission loss for the other (heavier) precast concrete specimens in Figure 2.1.4.

Figure 2.1.4:

A comparison between the mean sound transmission loss for 203 mm thick hollowcore precast concrete slabs with the data for 305 mm thick hollowcore precast concrete and solid reinforced 200 mm concrete.



In Figure 2.1.4, it is evident that the heavier assemblies of 305 mm thick hollowcore precast concrete and solid reinforced 200 mm concrete tend to provide slightly higher sound transmission loss over most of the frequency range and their higher STC values reflect this trend. However, the shape of the sound transmission loss curves is quite consistent.

2.2 Change in Sound Transmission due to Added Linings

It is uncommon in Canada for finished residential buildings to have floors, walls or ceilings of bare concrete without additional linings. However, to date, only a limited number of linings have been tested on precast concrete assemblies. The results of tests for hollow concrete block masonry walls (See report RR-334 [Ref. 15.2].) have shown that some linings added to concrete assemblies may actually decrease the STC rating, so care must be taken in the selection of linings. No data is currently available for common wall and ceiling linings of gypsum board supported by lightweight framing applied to precast concrete walls.

For hollowcore precast concrete floor constructions, data is available for the effect of adding two slightly different generic floor linings as described in Table 2.2.1.

Table 2.2.1: Floor linings evaluated on hollowcore precast concrete floors

Lining Code	Floor Lining Description	Mass / Area (kg/m^2)	∆STC
∆TL-HCON203-F01	25 mm thick gypsum concrete topping applied over hollowcore prestressed concrete slabs 203 mm thick	47	+ 1
∆TL-HCON203-F02	6mm carpet with an underlay installed on a 25 mm thick gypsum concrete topping applied over hollowcore prestressed concrete slabs 203 mm thick	52	+ 1

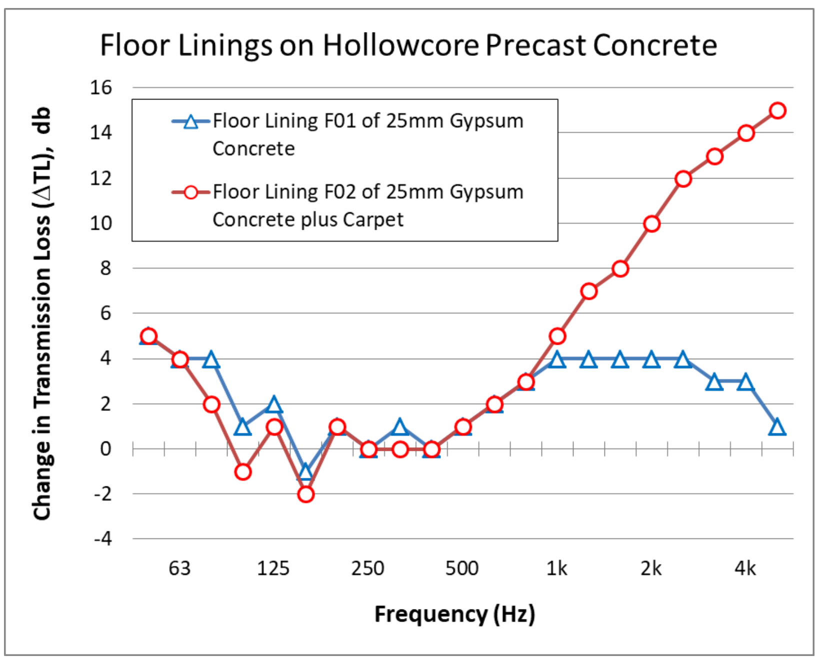
Note: The ∆STC ratings for the linings were calculated as described in Appendix A2 and they apply only when the linings are installed on hollowcore precast concrete floors.

The change in sound transmission loss due to adding the linings over a 203 mm hollowcore precast concrete floor specimen is shown in Figure 2.2.1, and the matching one-third octave band values are included in Table A1.2 in Appendix A1.

Figure 2.2.1:

Change in the sound transmission loss due to adding floor linings ∆TL-HCON203-F01 or ∆TL-HCON203-F02 over a 203 mm thick hollowcore precast concrete floor assembly

The change in the single number rating is ∆STC = +1 in both cases. These were determined from the measured change in sound transmission loss, following the procedure in Appendix A2.



The same change in the transmission loss should apply when these linings are added onto other precast concrete floor assemblies with similar properties.

2.3 Structural Loss Factors for Precast Wall or Floor Assemblies

The structural reverberation times of the bare precast concrete floor and wall assemblies were measured according to ISO 10848 to determine the structural loss factors of the assemblies. The structural loss factors are required for the calculations of the ASTC rating using the Detailed Method.

The structural reverberation times were measured for the bare precast concrete specimens and are listed in Table A1.3 of Appendix A1. Following ISO 10848, the structural loss factor η_{total} was calculated from the reverberation time data using Equation 2.3.1:

$$\eta_{total} = \frac{2.2}{f T_s} \qquad \text{Eq. 2.3.1}$$

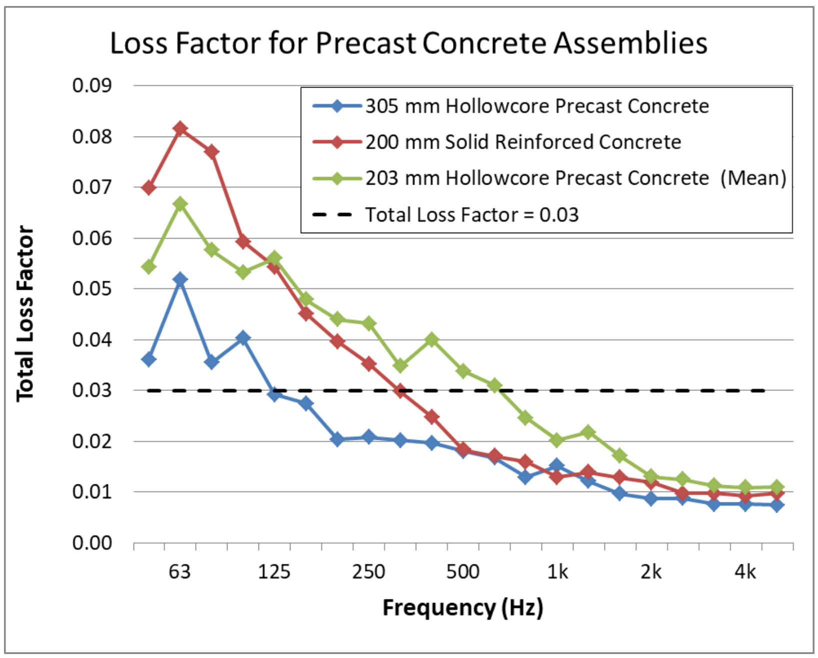
where f is the one-third octave band frequency in Hz and T_s is the structural reverberation time in seconds for that one-third octave band. The resulting loss factors for these assemblies are shown in Figure 2.3.1.

Figure 2.3.1:

Structural loss factors, η_{total} for the precast concrete specimens presented in Section 2.1

These loss factors were calculated from the structural reverberation times which are all listed in Table A1.3 of Appendix A1.

Note that the measured values lower than the rather conservative estimate for "typical specimens" from Annex C of ISO 15712-1



The total loss factor for the hollowcore precast concrete floor specimens are quite similar to the total loss observed for the solid reinforced concrete specimen. Below the 500 Hz one-third octave band which is the range where edge losses become dominant, the total loss factors are greater than 0.03. Above the 500 Hz one-third octave band, the total loss factors are less than 0.03 and at the frequencies above 2000 Hz the total loss factors are around 0.01. For elements with a loss factor less than 0.03, the standard ISO 15712-1 requires that the in situ structural reverberation time be calculated for the estimation of the ASTC rating using the Detailed Method.

3 Vibration Transmission at Precast Concrete Junctions

For building constructions that combine massive, lightly damped constructions such as precast concrete floors or hollow concrete block masonry walls, the ASTC rating is calculated from the measured transmission loss for the wall and floor assemblies (as presented in Chapter 2) and the vibrational power transmission through a junction between structural elements, referred to as the vibration reduction index (K_{ij}). It is common practice to assume that the vibration which is transmitted through the rigid, mortared/grouted junctions of massive constructions may be reliably estimated by using the expressions given in Annex E of ISO 15712-1 which are based on empirical data. The expressions in Annex E for calculating K_{ij} depend only on the junction geometry and the ratio of the mass per unit area of the connected assemblies and therefore can be used for any weight or thickness of the wall and floor constructions.

The expressions in Annex E of ISO 15712-1 have been validated by extensive experimental studies, but the applicability of the expressions to constructions using hollowcore precast concrete floors is not explicitly mentioned in the standard. Hollowcore precast concrete floors do not meet the requirements of ISO 15712-1 of being homogeneous and isotropic elements and therefore the use of the expressions in Annex E could be questioned. Since buildings combining hollowcore precast concrete floors with heavy homogeneous walls are common, a study was devised to determine whether hollowcore precast concrete floor slabs are sufficiently isotropic so that expressions from Annex E can be used for such constructions in the calculation of the ASTC rating, using the procedures of ISO 15712-1.

Section 3.1 of Report RR-334, "Apparent Sound Insulation in Concrete Block Buildings" presents the results of an experimental investigation on a full scale building mock-up comprising hollow concrete block masonry walls connected to hollowcore precast concrete floor assemblies in full accordance with the procedures of standard ISO 10848 to determine the vibration reduction index K_{ij}.

Figure 3.1.:
Mock-up junction between hollowcore precast concrete floor assemblies and hollow concrete block masonry walls above and below the floor.

Details of the test constructions, the measurement procedures and the test results are given in Report RR-334. The key issues for application of the procedures in this Report are given in the following summary.

Summary and Conclusions

The experimental investigation established that junctions between hollowcore precast concrete floor assemblies and \ heavy walls of concrete or concrete block masonry have vibration reduction indices that are at least as high as the values calculated using the expressions of Annex E of ISO 15712-1.

This was found to be the case for all of the flanking paths evaluated and it is therefore concluded that the expressions from Annex E of ISO 15712-1 provide an acceptable basis for calculating the ASTC rating (with a small margin of safety) for buildings where hollowcore precast concrete floor assemblies are combined with heavy walls of concrete or concrete block masonry.

Because of copyright concerns, the drawings and expressions from Annex E are not reproduced in this Report, but copies of the ISO standard are available and the appropriate graphs and equations are readily identified from the associated junction drawings.

4 Calculating the ASTC rating in Buildings with Precast Concrete Walls and Floors

This chapter presents the calculation of the apparent sound transmission loss (ATL), and the apparent sound transmission class (ASTC) rating between adjacent rooms in a building where the walls and floors are precast concrete assemblies. The calculation approaches use the empirical calculation methods that follow the procedures of the standard, ISO 15712-1.

All of the procedures presented in this chapter start from the concepts presented in Chapter 1 of this Report. The sound transmitted between two rooms is calculated from the combination of the airborne sound transmission loss through the separating assembly and the structure-borne sound transmission via the set of first-order flanking paths at each of the edges of the separating assembly where it connects to the flanking assemblies.

The data required for the calculation of the ASTC rating and the details of the calculation procedure depend on the type of wall and floor constructions comprising the building as well as the choice of calculation method (Simplified or Detailed). Each calculation method is explained in the following sections:

- ***Section 4.1*** explains the ASTC rating calculation using the **Simplified Method of ISO 15712-1** for buildings where precast concrete walls are connected to precast concrete floor assemblies. The Simplified Method is less rigorous than the Detailed Method, but also much less complicated. The Simplified Method uses single number values for the sound transmission loss (STC and ΔSTC) and the calculated values of the junction attenuation (K_{ij}) to determine the sound transmission via each transmission path (Dd, Ff, Fd, and Df). This method directly calculates the ASTC rating using Equation 1.2 of this Report to combine the sound energy transmitted by the direct and flanking paths.
- ***Section 4.2*** explains the ASTC rating calculation using the **Detailed Method of ISO 15712-1** for buildings where precast concrete walls are connected to precast concrete floor assemblies. The Detailed Method uses frequency band data for sound transmission loss (TL and ΔTL) for the wall and floor assemblies with calculated values of vibration reduction index (K_{ij}) to determine the sound transmission via each transmission path (Dd, Ff, Fd, and Df). This method directly calculates the apparent sound transmission loss, ATL for each frequency band using Equation 1.1 of this Report to combine the sound energy transmitted by the direct and flanking paths. From the apparent sound transmission loss for the standard set of frequency bands, the ASTC rating can then be calculated using the procedure described in ASTM E413.

Standard Scenario for the Worked Examples in this Report

The prediction of the sound transmitted in buildings depends not only on the construction details of the transmission paths, but also on the size and shape of each of the room surfaces and on the sound absorption in the receiving room. The ability to adjust the calculation to fit the dimensions in a specific building or to normalize the data to different receiving room conditions enables a skilled designer to obtain more accurate predictions of the ASTC rating.

For purposes of this Report, the meaningful comparison of results is facilitated by using a common set of room geometry and dimensions for all of the examples. This is particularly useful where only small changes are made between the construction details in the examples, since any change in the ASTC rating can then be attributed to just the changes that were made in the construction details.

A Standard Scenario has been adopted for all the examples, with the following constraints:

- Sound is transmitted between adjacent rooms, either side-by-side or one-above-the-other.
- The adjacent rooms are mirror images of each other with one side of the separating assembly facing each room and constituting one complete face of each rectangular room.

The Standard Scenario is illustrated in Figures 4.1 and 4.2, for the cases where one room is beside the other and one room is above the other, respectively.

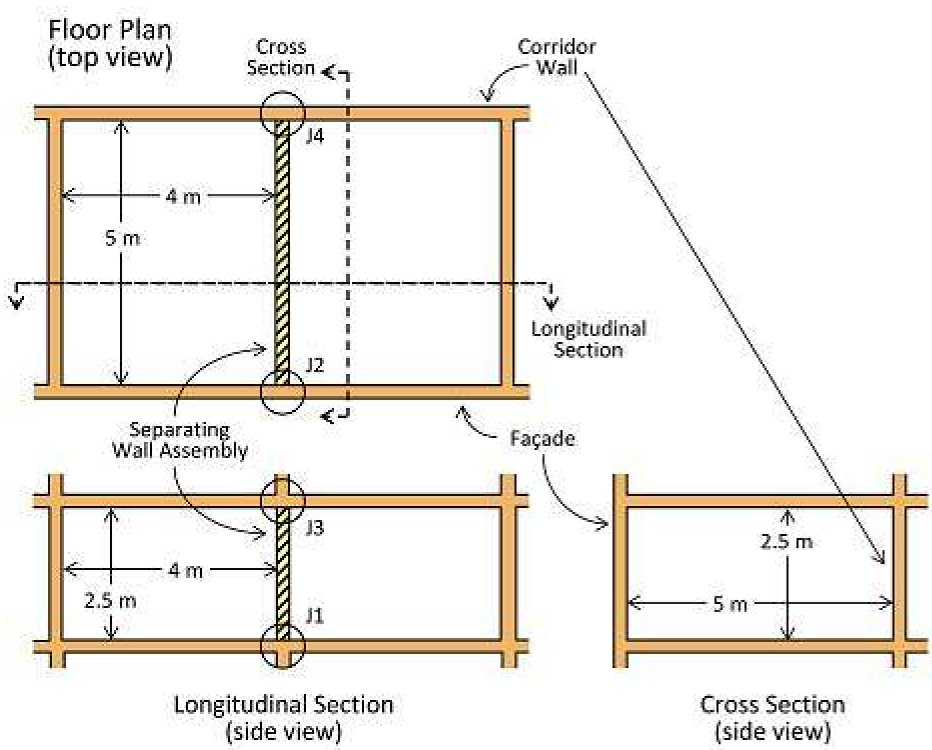
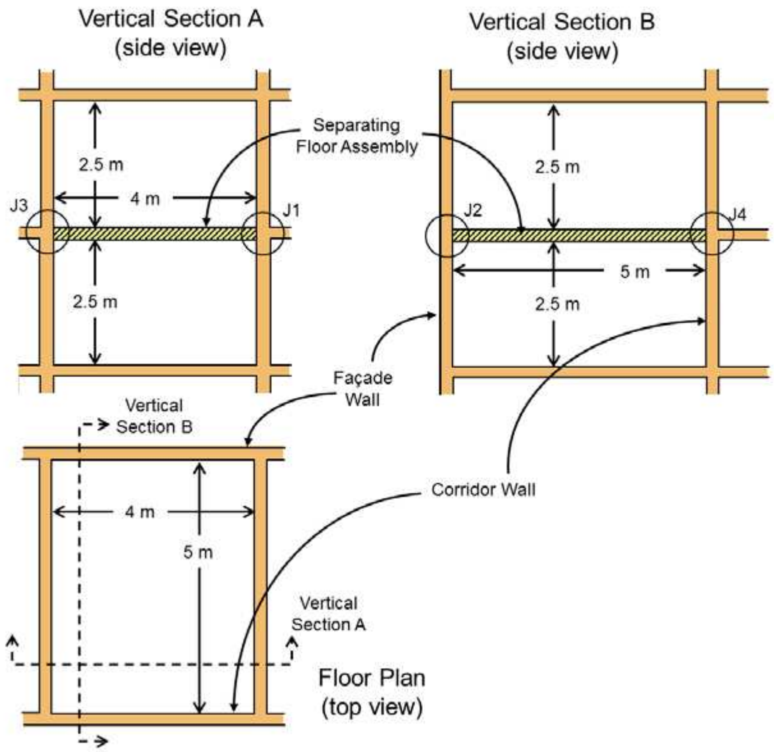


Figure 4.1:

Standard Scenario for the "horizontal room pair" case where the pair of rooms are side-by side with a separating wall assembly between the two rooms.

Figure 4.2:

Standard Scenario for the “vertical room pair” case where one of the pair of rooms is above the other, with the floor/ceiling assembly between the two rooms.



The pertinent dimensions and junction details are shown in Figures 4.1 and 4.2.

- Note that the junctions at the four edges of the separating assembly have been labeled (J1 to J4) in Figures 4.1 and 4.2. These junction designations are used in the examples throughout this Report.
- For the horizontal room pair (the rooms are side-by-side), the separating wall is 2.5 m high by 5 m wide, the flanking floor/ceilings are 4 m by 5 m and the flanking walls are 2.5 m high by 4 m wide.
- For the vertical room pair (one room is above the other) the separating floor/ceiling is 4 m by 5 m wide and the flanking walls in both rooms are 2.5 m high.
- In general, it is assumed that the junctions at one side of the room (at the separating wall if rooms are side-by-side) are cross junctions, while one or both of the other two junctions are T-junctions. This enables the examples to illustrate the typical differences between the two common junction cases.
- For the horizontal room pair, the separating wall has T-junctions with the flanking walls at both the façade and corridor sides and cross-junctions at the floor and ceiling.
- For the vertical room pair, the façade wall has a T-junction with the separating floor, but the opposing corridor wall has a cross-junction, as do the other two walls.

Deviations from the rooms of the Standard Scenario, such as rooms with different dimensions or different junction types (a cross-junction instead of a T-junction, for example) can be calculated by substituting the appropriate room dimensions and junction details in the calculation procedures and in the worked examples in this Report.

Following the labeling convention described in Figure 1.3 of Chapter 1, the labels for the flanking surfaces of the Standard Scenarios are detailed in the following Table 4.1.

Table 4.1: Surfaces (D, d, F and f) for flanking paths at each junction, as in the Standard Scenario.

Room Pair	Surfaces D and d	Flanking Surfaces F and f	Junction
Horizontal (Fig. 4.1)	Separating wall	Junction 1: floor F and f Junction 2: façade wall F and f Junction 3: ceiling F and f Junction 4: corridor wall F and f	Cross-junction T-junction Cross-junction T-junction
Vertical (Fig. 4.2)	Separating floor/ceiling	Junction 1: wall F and f Junction 2: façade wall F and f Junction 3: wall F and f Junction 4: corridor wall F and f	Cross-junction T-junction Cross-junction Cross-junction

Calculation Spreadsheets for the Worked Examples

The calculation of the ASTC rating for each worked example is illustrated step by step in a calculation spreadsheet. Figure 4.3 shows images of two examples of the calculation spreadsheets – one for a calculation using the Simplified Method of ISO 15712-1, and one for a calculation using the Detailed Method.

Color highlights are used to indicate the input and output values in the worked examples:

- Light reddish brown is used to indicate input data values
- Blue is used to indicate the direct sound transmission loss, including the effects of in-situ loss corrections and any added lining(s) added to the separating assembly
- Pale yellow is used to indicate the calculated values of the combined flanking sound transmission lossdue to a set of flanking paths at a junction
- Green is used to indicate the final result for the ASTC rating

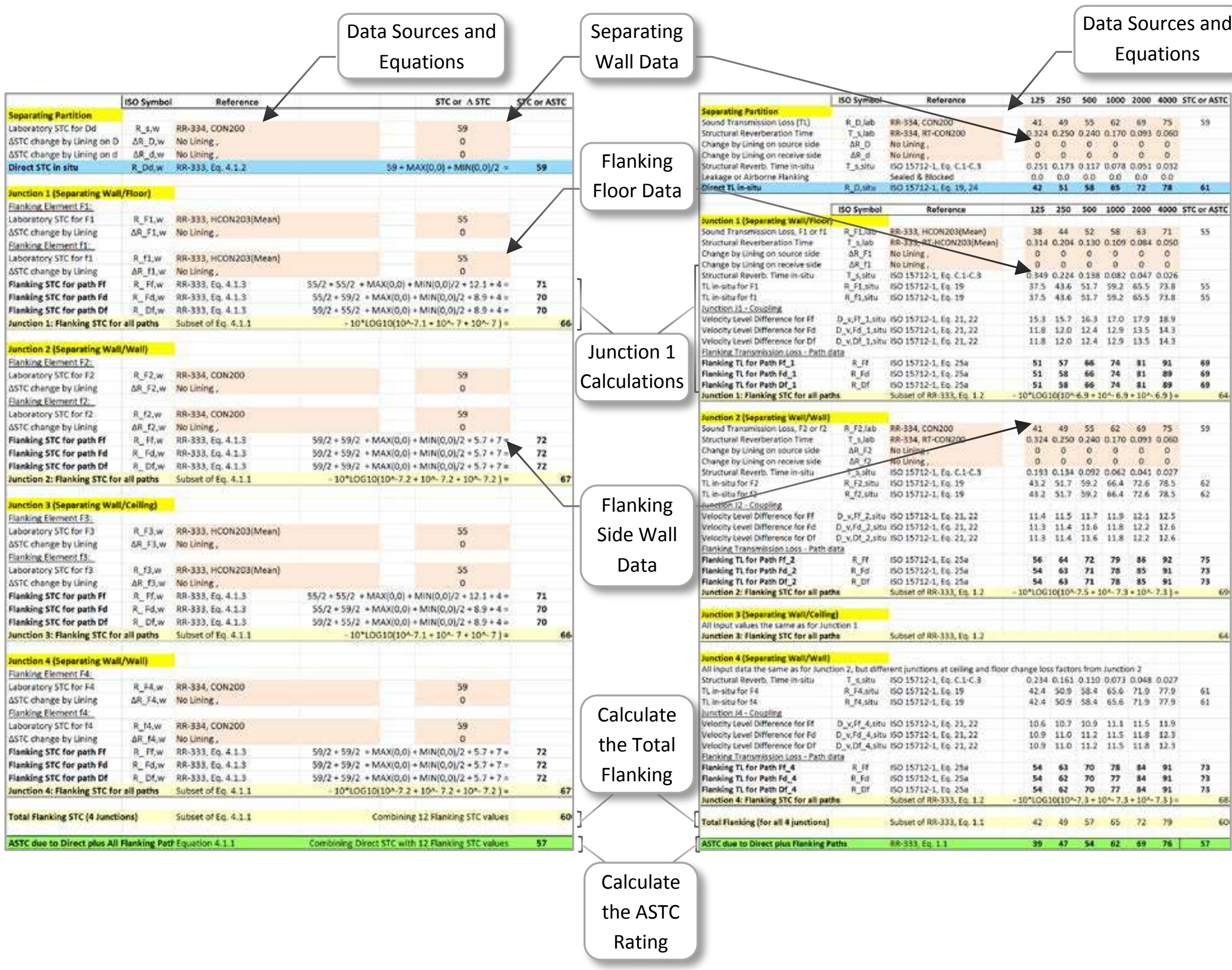


Figure 4.3: Examples of the calculation spreadsheets for the determination of the ASTC rating. The layout is similar for the Simplified Method (on left) and the Detailed Method (on right), but the latter presents more detailed information. Larger (and more legible) versions of these images are given in the following discussion of each method.

Calculation Spreadsheets for Worked Examples using the Simplified Method

Worked examples that demonstrate the calculation of the ASTC rating using the Simplified Method are presented in Section 4.1.

Under the heading "STC or ΔSTC", the examples present input data determined from laboratory tests including the:

- Laboratory measured STC ratings for wall or floor assemblies
- ΔSTC values measured in the laboratory for the change in STC due to adding a lining to the specified wall or floor assembly as explained in Appendix A1 of this Report
- (For lightweight framed construction types, if applicable) flanking STC values for each flanking path at each junction measured following ISO 10848 and re-normalized using Eq. 4.1.3

Under the heading "STC or ASTC", the examples present the calculated values for sound transmission via specific paths including the:

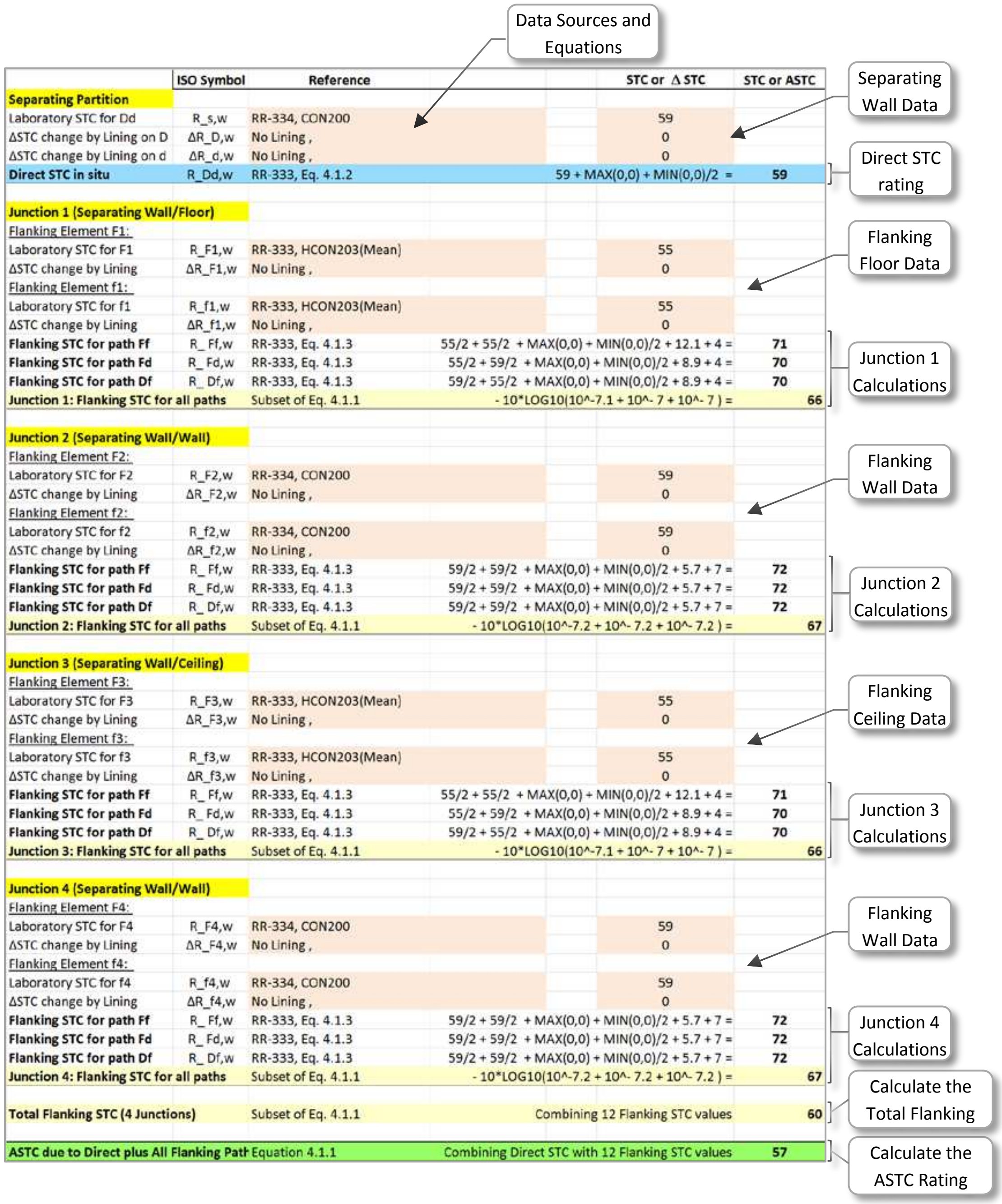
- Direct STC ratings for in-situ transmission through the separating assembly including linings
- ASTC ratings for the combination of direct and flanking sound transmission paths
- (For lightweight framed construction types, if applicable) flanking STC ratings for each flanking transmission path including the change due to linings

The numeric calculations are presented step-by-step in each worked example using compact notation consistent with the spreadsheet expressions. Specifically:

- For the calculation of the Direct STC rating and the Flanking STC ratings, the expressions show the calculation required to take into account linings installed on one or both sides of the bare assembly. These results are rounded to the nearest integer for consistency with the corresponding measured values.
- For combining the sound power transmitted via specific paths, the calculation of Eq. 1.2 is presented in several stages. Note that in the compact notation, a term for transmitted sound power fraction such as $10^{-0.1 \cdot STC_{ij}}$ becomes $10^{-7.4}$, if STC_{ij} = 74.
- At each stage (such as the Flanking STC for the three paths at a given junction) the result is converted into decibel form by calculating $-10 \cdot \log_{10}$ (transmitted sound power fraction) to facilitate comparison of each path or junction with the Direct STC and the final ASTC rating.

For each worked example, the "Reference" column presents the source of the input data. The source may be indicated by a NRC report number and identifier for a laboratory test result or the applicable equations and sections of ISO 15712-1 or their counterparts using ASTM ratings used to determine the input data. Symbols and subscripts identifying the corresponding variable in ISO 15712-1 are given in the adjacent column.

The Simplified Method worksheet of Example 4.1-H1 (for side-by-side rooms separated by a precast concrete wall) is shown in Figure 4.4.



	ISO Symbol	Reference		STC or Δ STC	STC or ASTC
Separating Partition					
Laboratory STC for Dd	R_s,w	RR-334, CON200		59	
ΔSTC change by Lining on D	ΔR_D,w	No Lining ,		0	
ΔSTC change by Lining on d	ΔR_d,w	No Lining ,		0	
Direct STC in situ	R_Dd,w	RR-333, Eq. 4.1.2	59 + MAX(0,0) + MIN(0,0)/2 =		**59**
Junction 1 (Separating Wall/Floor)					
Flanking Element F1:					
Laboratory STC for F1	R_F1,w	RR-333, HCON203(Mean)		55	
ΔSTC change by Lining	ΔR_F1,w	No Lining ,		0	
Flanking Element f1:					
Laboratory STC for f1	R_f1,w	RR-333, HCON203(Mean)		55	
ΔSTC change by Lining	ΔR_f1,w	No Lining ,		0	
Flanking STC for path Ff	R_Ff,w	RR-333, Eq. 4.1.3	55/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 12.1 + 4 =		**71**
Flanking STC for path Fd	R_Fd,w	RR-333, Eq. 4.1.3	55/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 4 =		**70**
Flanking STC for path Df	R_Df,w	RR-333, Eq. 4.1.3	59/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 4 =		**70**
Junction 1: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.1 + 10^- 7 + 10^- 7) =		**66**
Junction 2 (Separating Wall/Wall)					
Flanking Element F2:					
Laboratory STC for F2	R_F2,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_F2,w	No Lining ,		0	
Flanking Element f2:					
Laboratory STC for f2	R_f2,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_f2,w	No Lining ,		0	
Flanking STC for path Ff	R_Ff,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Flanking STC for path Fd	R_Fd,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Flanking STC for path Df	R_Df,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Junction 2: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.2 + 10^- 7.2 + 10^- 7.2) =		**67**
Junction 3 (Separating Wall/Ceiling)					
Flanking Element F3:					
Laboratory STC for F3	R_F3,w	RR-333, HCON203(Mean)		55	
ΔSTC change by Lining	ΔR_F3,w	No Lining ,		0	
Flanking Element f3:					
Laboratory STC for f3	R_f3,w	RR-333, HCON203(Mean)		55	
ΔSTC change by Lining	ΔR_f3,w	No Lining ,		0	
Flanking STC for path Ff	R_Ff,w	RR-333, Eq. 4.1.3	55/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 12.1 + 4 =		**71**
Flanking STC for path Fd	R_Fd,w	RR-333, Eq. 4.1.3	55/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 4 =		**70**
Flanking STC for path Df	R_Df,w	RR-333, Eq. 4.1.3	59/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 4 =		**70**
Junction 3: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.1 + 10^- 7 + 10^- 7) =		**66**
Junction 4 (Separating Wall/Wall)					
Flanking Element F4:					
Laboratory STC for F4	R_F4,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_F4,w	No Lining ,		0	
Flanking Element f4:					
Laboratory STC for f4	R_f4,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_f4,w	No Lining ,		0	
Flanking STC for path Ff	R_Ff,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Flanking STC for path Fd	R_Fd,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Flanking STC for path Df	R_Df,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Junction 4: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.2 + 10^- 7.2 + 10^- 7.2) =		**67**
Total Flanking STC (4 Junctions)		Subset of Eq. 4.1.1	Combining 12 Flanking STC values		**60**
ASTC due to Direct plus All Flanking Path		Equation 4.1.1	Combining Direct STC with 12 Flanking STC values		**57**

Figure 4.4: Image of an example of the worksheet for the calculation of the ASTC rating using the Simplified Method.

Calculation Spreadsheets for Examples using the Detailed Method

Worked examples demonstrating the calculation of the ASTC rating using the Detailed Method are presented in Section 4.2.

The spreadsheets for the Detailed Method use a number of conventions to make the calculations easier to follow and to make it easier to assess the importance of each flanking path. The calculations are made in each of the sixteen one-third octave frequency bands between 125 Hz and 4000 Hz, but presenting all of the data in a spreadsheet that would fit on one page while still readable was a challenge. Therefore, data is only presented in six of the one-third octave bands (125, 200, 500, 1000, 2000 and 4000 Hz) in the spreadsheet. It should be understood that the data presented is just a subset of the actual data.

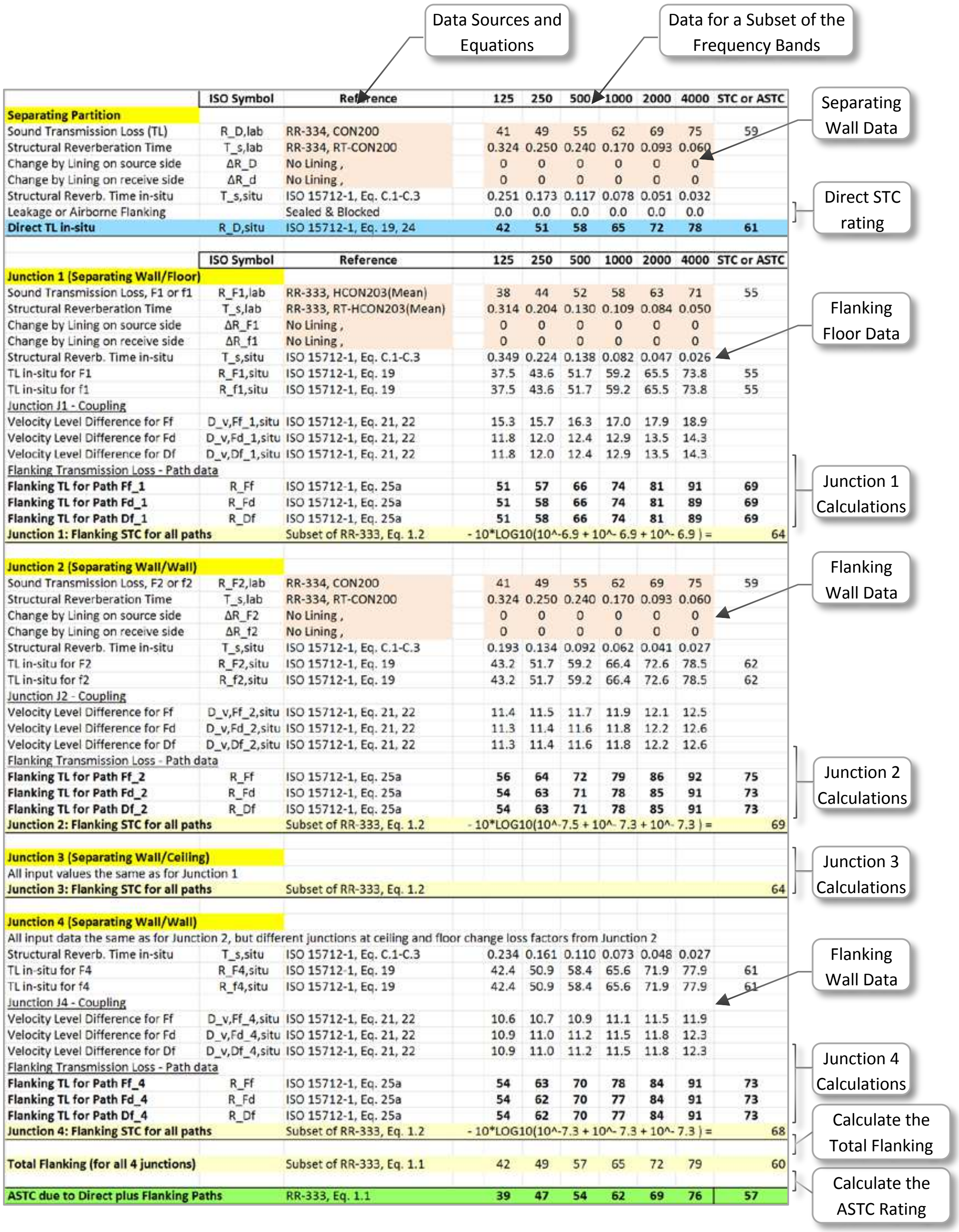
The spreadsheets show the single number ratings at intermediate stages of the calculations, each calculated from a set of one-third octave band data according to ASTM E413 including the:

- STC values for the laboratory sound transmission loss of wall or floor assemblies
- In-situ STC values for the calculated in-situ sound transmission loss of wall and floor assemblies
- Direct STC values for the in-situ sound transmission loss through the separating assembly including the effect of linings
- Flanking STC values calculated for each flanking sound transmission path at each junction including the effect of linings

Note that these single number ratings are only presented as a reference to provide a convenient indication of the relative strength of the 13 sound transmission paths. The actual calculation at each step is performed in the individual one-third octave bands, not from the single number ratings. The sound transmission loss values for the 13 paths are combined to arrive at the overall apparent sound transmission loss (ATL) for each frequency band. The ASTC rating is then calculated from the values for apparent sound transmission loss in the sixteen one-third octave frequency bands between 125 Hz and 4000 Hz.

For each worked example, the "Reference" column presents the source of the input data. The source may be indicated by a NRC report number and identifier for a laboratory test result or the applicable equations and sections of ISO 15712-1 or their counterparts using ASTM ratings used to determine the input data. Symbols and subscripts identifying the corresponding variable in ISO 15712-1 are given in the adjacent column.

The Detailed Method worksheet of Example 4.2-H1 (for side-by-side rooms separated by a precast concrete wall) is shown in Figure 4.5.



	ISO Symbol	Reference	125	250	500	1000	2000	4000	STC or ASTC
Separating Partition									
Sound Transmission Loss (TL)	R_D,lab	RR-334, CON200	41	49	55	62	69	75	59
Structural Reverberation Time	T_s,lab	RR-334, RT-CON200	0.324	0.250	0.240	0.170	0.093	0.060	
Change by Lining on source side	ΔR_D	No Lining ,	0	0	0	0	0	0	
Change by Lining on receive side	ΔR_d	No Lining ,	0	0	0	0	0	0	
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.251	0.173	0.117	0.078	0.051	0.032	
Leakage or Airborne Flanking		Sealed & Blocked	0.0	0.0	0.0	0.0	0.0	0.0	
Direct TL in-situ	R_D,situ	ISO 15712-1, Eq. 19, 24	**42**	**51**	**58**	**65**	**72**	**78**	**61**
	ISO Symbol	**Reference**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**STC or ASTC**
Junction 1 (Separating Wall/Floor)									
Sound Transmission Loss, F1 or f1	R_F1,lab	RR-333, HCON203(Mean)	38	44	52	58	63	71	55
Structural Reverberation Time	T_s,lab	RR-333, RT-HCON203(Mean)	0.314	0.204	0.130	0.109	0.084	0.050	
Change by Lining on source side	ΔR_F1	No Lining ,	0	0	0	0	0	0	
Change by Lining on receive side	ΔR_f1	No Lining ,	0	0	0	0	0	0	
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.349	0.224	0.138	0.082	0.047	0.026	
TL in-situ for F1	R_F1,situ	ISO 15712-1, Eq. 19	37.5	43.6	51.7	59.2	65.5	73.8	55
TL in-situ for f1	R_f1,situ	ISO 15712-1, Eq. 19	37.5	43.6	51.7	59.2	65.5	73.8	55
Junction J1 - Coupling									
Velocity Level Difference for Ff	D_v,Ff_1,situ	ISO 15712-1, Eq. 21, 22	15.3	15.7	16.3	17.0	17.9	18.9	
Velocity Level Difference for Fd	D_v,Fd_1,situ	ISO 15712-1, Eq. 21, 22	11.8	12.0	12.4	12.9	13.5	14.3	
Velocity Level Difference for Df	D_v,Df_1,situ	ISO 15712-1, Eq. 21, 22	11.8	12.0	12.4	12.9	13.5	14.3	
Flanking Transmission Loss - Path data									
Flanking TL for Path Ff_1	R_Ff	ISO 15712-1, Eq. 25a	**51**	**57**	**66**	**74**	**81**	**91**	**69**
Flanking TL for Path Fd_1	R_Fd	ISO 15712-1, Eq. 25a	**51**	**58**	**66**	**74**	**81**	**89**	**69**
Flanking TL for Path Df_1	R_Df	ISO 15712-1, Eq. 25a	**51**	**58**	**66**	**74**	**81**	**89**	**69**
Junction 1: Flanking STC for all paths		Subset of RR-333, Eq. 1.2	- 10*LOG10(10^-6.9 + 10^- 6.9 + 10^- 6.9) =						64
Junction 2 (Separating Wall/Wall)									
Sound Transmission Loss, F2 or f2	R_F2,lab	RR-334, CON200	41	49	55	62	69	75	59
Structural Reverberation Time	T_s,lab	RR-334, RT-CON200	0.324	0.250	0.240	0.170	0.093	0.060	
Change by Lining on source side	ΔR_F2	No Lining ,	0	0	0	0	0	0	
Change by Lining on receive side	ΔR_f2	No Lining ,	0	0	0	0	0	0	
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.193	0.134	0.092	0.062	0.041	0.027	
TL in-situ for F2	R_F2,situ	ISO 15712-1, Eq. 19	43.2	51.7	59.2	66.4	72.6	78.5	62
TL in-situ for f2	R_f2,situ	ISO 15712-1, Eq. 19	43.2	51.7	59.2	66.4	72.6	78.5	62
Junction J2 - Coupling									
Velocity Level Difference for Ff	D_v,Ff_2,situ	ISO 15712-1, Eq. 21, 22	11.4	11.5	11.7	11.9	12.1	12.5	
Velocity Level Difference for Fd	D_v,Fd_2,situ	ISO 15712-1, Eq. 21, 22	11.3	11.4	11.6	11.8	12.2	12.6	
Velocity Level Difference for Df	D_v,Df_2,situ	ISO 15712-1, Eq. 21, 22	11.3	11.4	11.6	11.8	12.2	12.6	
Flanking Transmission Loss - Path data									
Flanking TL for Path Ff_2	R_Ff	ISO 15712-1, Eq. 25a	**56**	**64**	**72**	**79**	**86**	**92**	**75**
Flanking TL for Path Fd_2	R_Fd	ISO 15712-1, Eq. 25a	**54**	**63**	**71**	**78**	**85**	**91**	**73**
Flanking TL for Path Df_2	R_Df	ISO 15712-1, Eq. 25a	**54**	**63**	**71**	**78**	**85**	**91**	**73**
Junction 2: Flanking STC for all paths		Subset of RR-333, Eq. 1.2	- 10*LOG10(10^-7.5 + 10^- 7.3 + 10^- 7.3) =						69
Junction 3 (Separating Wall/Ceiling)									
All input values the same as for Junction 1									
Junction 3: Flanking STC for all paths		Subset of RR-333, Eq. 1.2							64
Junction 4 (Separating Wall/Wall)									
All input data the same as for Junction 2, but different junctions at ceiling and floor change loss factors from Junction 2									
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.234	0.161	0.110	0.073	0.048	0.027	
TL in-situ for F4	R_F4,situ	ISO 15712-1, Eq. 19	42.4	50.9	58.4	65.6	71.9	77.9	61
TL in-situ for f4	R_f4,situ	ISO 15712-1, Eq. 19	42.4	50.9	58.4	65.6	71.9	77.9	61
Junction J4 - Coupling									
Velocity Level Difference for Ff	D_v,Ff_4,situ	ISO 15712-1, Eq. 21, 22	10.6	10.7	10.9	11.1	11.5	11.9	
Velocity Level Difference for Fd	D_v,Fd_4,situ	ISO 15712-1, Eq. 21, 22	10.9	11.0	11.2	11.5	11.8	12.3	
Velocity Level Difference for Df	D_v,Df_4,situ	ISO 15712-1, Eq. 21, 22	10.9	11.0	11.2	11.5	11.8	12.3	
Flanking Transmission Loss - Path data									
Flanking TL for Path Ff_4	R_Ff	ISO 15712-1, Eq. 25a	**54**	**63**	**70**	**78**	**84**	**91**	**73**
Flanking TL for Path Fd_4	R_Fd	ISO 15712-1, Eq. 25a	**54**	**62**	**70**	**77**	**84**	**91**	**73**
Flanking TL for Path Df_4	R_Df	ISO 15712-1, Eq. 25a	**54**	**62**	**70**	**77**	**84**	**91**	**73**
Junction 4: Flanking STC for all paths		Subset of RR-333, Eq. 1.2	- 10*LOG10(10^-7.3 + 10^- 7.3 + 10^- 7.3) =						68
Total Flanking (for all 4 junctions)		Subset of RR-333, Eq. 1.1	42	49	57	65	72	79	60
ASTC due to Direct plus Flanking Paths		RR-333, Eq. 1.1	**39**	**47**	**54**	**62**	**69**	**76**	**57**

Figure 4.5: Image of an example of the worksheet for the ASTC rating calculation using the Detailed Method.

Rounding and Precision in the Worked Examples

The value of the ASTC rating obtained in each worked example slightly depends on the precision of the input data and on rounding of results at each stage of the calculation. There is no rounding approach explicitly specified in ISO 15712-1, but the worked examples in the ISO standard show input and calculated sound reduction index values rounded to 0.1 dB which is consistent with the requirements for presentation of results in the ISO standards for measuring laboratory sound transmission loss. The ASTM standards for the measurement of sound transmission loss in the laboratory and in the field (ASTM E90 and ASTM E336, respectively) specify that sound transmission loss values should be rounded to the nearest integer, which is arguably more representative of meaningful precision of the result.

The examples in this document follow the ASTM convention of rounding to the nearest integer for input sound transmission loss data from laboratory tests of wall or floor assemblies, for measured or calculated values of flanking sound transmission loss for individual paths and for the apparent sound transmission loss calculated from the combination of direct and flanking paths. For input values measured according to ISO standards for which there is no ASTM counterpart, specific rounding rules were used as noted below:

- Structural reverberation times measured for laboratory wall or floor specimens or calculated for laboratory results according to Annex C of ISO 15712-1 were rounded to 3 decimal places.
- Values of the vibration reduction index (K_{ij}) at junctions between a separating assembly and each attached assembly were rounded to the nearest 0.1 dB, both for results measured according to ISO 10848 and for those calculated using the equations from Annex E of ISO 15712-1.

Between the input values and the flanking transmission loss results for each path (which were rounded to the nearest integer), the worked examples are calculated to the full precision of the spreadsheet and interim values are presented to slightly higher precision to permit detailed comparisons for users treating these examples as benchmarks for their own worksheets.

When the calculated Flanking TL or the Flanking STC rating for a given path exceeds 90 dB, the value is limited to 90 dB to allow for the inevitable effect of higher order flanking paths which make the higher calculated value unrepresentative of the true situation. Further enhancements to elements in these paths will give negligible benefit. The consequence of this limit is that the Junction STC rating for the set of 3 paths at each edge of the separating assembly cannot exceed 85 dB, and the Total Flanking STC value for all 4 edges cannot exceed 79 dB.

The rounding and limiting approaches used in this Report provide a reasonable representation of data precision, and should permit unambiguous interpretation of the worked examples presented here. However, it is possible that a jurisdiction could specify other rounding approaches. Other rounding approaches could change the calculated ASTC ratings by ± 1.

4.1 Simplified ASTC Rating Calculation for Precast Concrete Walls and Floors

The standard, ISO 15712-1 presents a Simplified Method for calculating structure-borne transmission. This Simplified Method has some clearly stated limitations, and some implicit cautions. ISO 15712-1 states that the application of the Simplified Method "is restricted to primarily homogeneous constructions", further restricted here to homogeneous, lightly-damped structural assemblies. Here, "lightly-damped" implies a reverberant vibration field that can be characterized by a mean vibration level and "homogeneous" implies similar bending stiffness in all directions across the surface. These definitions result in wood-framed and steel-framed assemblies being excluded from calculations using the Simplified Method, but typical precast concrete floor assemblies and precast concrete wall assemblies are appropriate for the Simplified Method.

The Simplified Method uses two main simplifications:

- The losses to connected assemblies are dealt with "in an average way," ignoring the difference between the losses for laboratory specimens and the (usually higher) in-situ sound transmission loss due to edge losses to adjoining wall and floor constructions in the building.
- The inputs for the calculation of the ASTC rating according to Eq. 4.1.1 are only single number quantities, STC ratings for the wall and floor assemblies, ΔSTC values for any linings, and mean K_{ij} values for the junction attenuation.

These simplifications eliminate much of the calculation process required to use the Detailed Method. However, a drawback of the Simplified Method is that it tends to predict an ASTC rating which is slightly lower than that calculated using the Detailed Method described in Section 4.2 of this Report, especially if linings are applied to the assemblies.

Summary of the Calculation Process

The ASTC rating between two rooms (neglecting sound that is by-passing the building structure, e.g. through leaks or ducts) is estimated using the Simplified Method from the logarithmic expression of the combination of the STC rating (STC_{Dd}) of the separating wall or floor assembly and the combined flanking STC ratings of the three flanking paths for every junction at the four edges of the separating assembly according to Eq. 4.1.1.

$$ASTC = -10\log_{10}\left[10^{-0.1\cdot STC_{Dd}} + \sum_{edge=1}^{4}\left(10^{-0.1\cdot STC_{Ff}} + 10^{-0.1\cdot STC_{Fd}} + 10^{-0.1\cdot STC_{Df}}\right)\right] \qquad \text{Eq. 4.1.1}$$

Eq. 4.1.1 is appropriate for all types of building systems with the geometry of the Standard Scenario and is equivalent to Equation 1.2 in Section 1.4 of this Report and to Eq. 26 in Section 4.4 of ISO 15712-1. This procedure is summarized in Figure 4.1.1 and outlined in the steps that follow the figure.

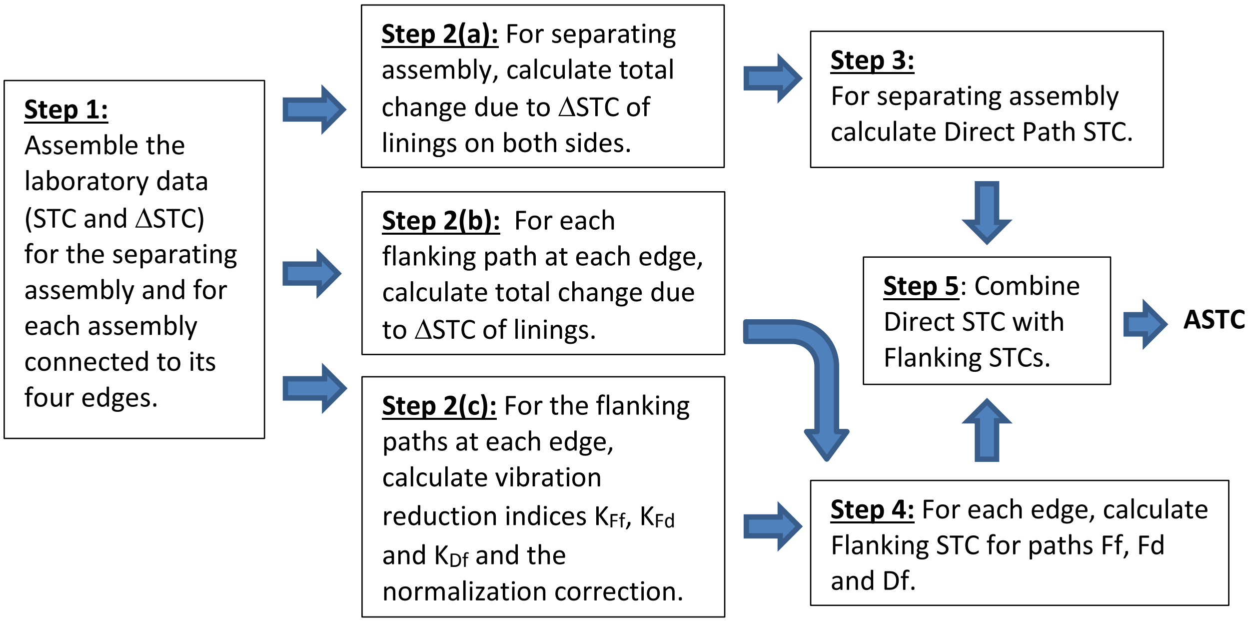


Figure 4.1.1: Steps to calculate the ASTC rating using the Simplified Method.

<u>Step 1</u>: Assemble the required laboratory test data for the constructions:

- Laboratory sound transmission class (STC) values based on direct sound transmission loss data measured according to ASTM E90 for the bare floor and wall assemblies
- Mass per unit area for the unlined wall and floor assemblies
- Measured change in sound transmission class (ΔSTC) determined according to Sections 2.2 and 2.3 for each lining that will be added to the base floor or wall assemblies.

<u>Step 2:</u> Calculate the following:

a) Correction to the separating assembly due to linings. For linings applied to the separating assembly, the correction ΔSTC_{Dd} is the sum of the larger of the ΔSTC values for the linings plus half of the smaller ΔSTC value.

b) Correction to the flanking elements due to linings. For each flanking path ij, the correction ΔSTC_{ij} for linings on the source surface i and/or the receiving surface j is the sum of the larger of the ΔSTC values for these two linings plus half of the smaller ΔSTC value.

c) For each edge of the separating assembly, calculate the vibration reduction indices K_{Ff}, K_{Fd}, and K_{Df} for the flanking paths between the assembly in the source room (D or F) and the attached assembly in the receiving room (f or d) using the appropriate case from Annex E of ISO 15712-1. These values depend on the junction geometry and the ratio of the mass per unit area for the connected assemblies. Also calculate the normalization correction, which depends on the length of the flanking junction and the area of the separating assembly.

Step 3: Calculate the Direct STC rating for the direct sound transmission through the separating assembly (STC_{Dd}) including the correction for the linings according to Eq. 4.1.2 (Eq. 27 and Eq. 30 of ISO 15712-1) using the laboratory STC rating of the unlined assembly and any correction for linings ΔSTC_{Dd} from Step 2(a) due to linings on source "D" and/or receiving side "d" of the separating assembly such that:

$$STC_{Dd} = STC_{lab} + \max(\Delta STC_D, \Delta STC_d) + \frac{\min(\Delta STC_D, \Delta STC_d)}{2} \quad \text{Eq. 4.1.2}$$

Note that if a lining is applied to only one side of the separating assembly then $\min(\Delta STC_D, \Delta STC_d) = 0$.

Step 4: For each of the flanking paths, calculate the Flanking STC rating, STC_{ij} using Eq. 4.1.3 (Eq. 28a of ISO 15712-1) where index i and j refer to the coupled flanking assemblies; thus, "i" can either be "D" or "F" and "j" can be "f" or "d".

$$STC_{ij} = \frac{STC_i}{2} + \frac{STC_j}{2} + K_{ij} + \max(\Delta STC_i, \Delta STC_j) + \frac{\min(\Delta STC_i, \Delta STC_j)}{2} + 10 \cdot \log_{10} \frac{S_S}{l_0 \cdot l_{ij}} \quad \text{Eq. 4.1.3}$$

The equation uses the following inputs:

- The laboratory STC rating for each of the unlined assemblies (STC_i and STC_j) plus the lining corrections (ΔSTC_i and ΔSTC_j) from Step 2(b), if applicable
- The K_{ij} value and the normalization correction for this path from Step 2(c).

Step 5: The ASTC rating between two rooms (neglecting sound that is by-passing the building structure, e.g. through leaks or ducts) is estimated from the logarithmic expression of the combination of the STC rating (STC_{Dd}) of the separating wall or floor assembly and the combined flanking STC ratings (STC_{ij}) of the three flanking paths for every junction at the four edges of the separating assembly according to Eq. 4.1.1.

EXAMPLE 4.1-H1: (SIMPLIFIED METHOD)

- **Rooms side-by-side**
- **Loadbearing solid precast concrete walls and hollowcore precast concrete floors with rigid junctions**

Separating wall assembly (loadbearing) with:
- solid reinforced precast concrete wall (i.e.- normal weight concrete, wall thickness 200 mm and mass/area 460 kg/m^2 including grout at joints) with no linings

Junction 1: Bottom Junction (separating wall / floor) with:
- floor of hollowcore precast concrete slabs (i.e.- normal weight concrete, floor thickness 203 mm and mass/area 300 kg/m^2 including grout at joints) with no lining on top
- rigid grouted cross junction with precast concrete wall

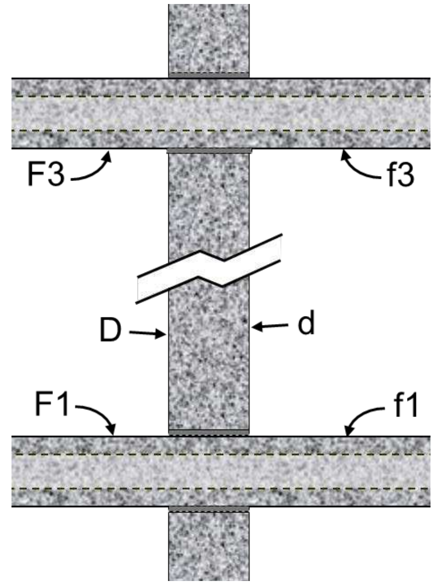
Junction 2 or 4: T-junction of separating wall / abutting side wall:
- side wall and separating wall of solid reinforced precast concrete (i.e.- normal weight concrete, 200 mm thick, mass/area 460 kg/m^2 including grout at joints) with no linings
- rigid grouted T-junctions

Junction 3: Top Junction (separating wall / ceiling) with:
- floor of hollowcore precast slabs (i.e.- normal weight concrete, 203 mm thick, mass/area 300 kg/m^2 including grout at joints) with no ceiling lining below
- rigid grouted cross junction with solid precast concrete wall

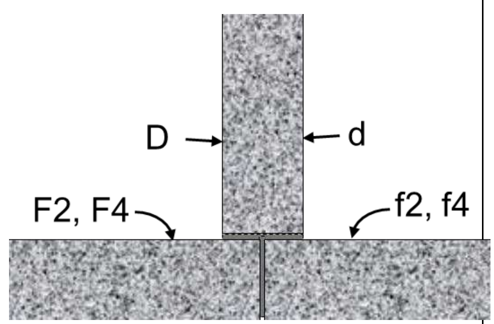
Acoustical Parameters:

For 200 mm solid precast concrete walls:			
Mass/unit area (kg/m^2) =	460	(Separating wall)	
	460	(Flanking wall)	
For 203mm hollowcore precast concrete floor:			
Mass/unit area (kg/m^2) =	300		
Separating partition area (m^2) =	12.5		
Floor/wall junction length (m) =	5.0		
Separating partition height (m) =	2.5		
10*log(S_Partition/l_junction 1&3) =	4.0		
10*log(S_Partition/l_junction 2&4) =	7.0		

Illustration for this case



Junction of separating wall of 200 mm-thick solid reinforced precast concrete with floor and ceiling of 203 mm thick hollowcore precast concrete.
(Side view of Junctions 1 and 3)



Junction of separating wall with side wall, both of 200 mm solid reinforced precast concrete. (Plan view of Junction 2 or 4).

Junction		Mass ratio	Path Ff Kij (in dB) =	Path Fd	Path Df	Reference
1	Rigid-Cross junction	1.53	12.1	8.9	8.9	ISO 15712-1, Eq. E.3
2	Rigid T-junction	1.00	5.7	5.7	5.7	ISO 15712-1, Eq. E.4
3	Rigid-Cross junction	1.53	12.1	8.9	8.9	ISO 15712-1, Eq. E.3
4	Rigid T-junction	1.00	5.7	5.7	5.7	ISO 15712-1, Eq. E.4

	ISO Symbol	Reference		STC or Δ STC	STC or ASTC
Separating Partition					
Laboratory STC for Dd	R_s,w	RR-334, CON200		59	
ΔSTC change by Lining on D	ΔR_D,w	No Lining ,		0	
ΔSTC change by Lining on d	ΔR_d,w	No Lining ,		0	
Direct STC in situ	R_Dd,w	RR-333, Eq. 4.1.2	59 + MAX(0,0) + MIN(0,0)/2 =		**59**
Junction 1 (Separating Wall/Floor)					
Flanking Element F1:					
Laboratory STC for F1	R_F1,w	RR-333, HCON203(Mean)		55	
ΔSTC change by Lining	ΔR_F1,w	No Lining ,		0	
Flanking Element f1:					
Laboratory STC for f1	R_f1,w	RR-333, HCON203(Mean)		55	
ΔSTC change by Lining	ΔR_f1,w	No Lining ,		0	
Flanking STC for path Ff	R_ Ff,w	RR-333, Eq. 4.1.3	55/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 12.1 + 4 =		**71**
Flanking STC for path Fd	R_ Fd,w	RR-333, Eq. 4.1.3	55/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 4 =		**70**
Flanking STC for path Df	R_ Df,w	RR-333, Eq. 4.1.3	59/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 4 =		**70**
Junction 1: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.1 + 10^- 7 + 10^- 7) =		**66**
Junction 2 (Separating Wall/Wall)					
Flanking Element F2:					
Laboratory STC for F2	R_F2,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_F2,w	No Lining ,		0	
Flanking Element f2:					
Laboratory STC for f2	R_f2,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_f2,w	No Lining ,		0	
Flanking STC for path Ff	R_ Ff,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Flanking STC for path Fd	R_ Fd,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Flanking STC for path Df	R_ Df,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Junction 2: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.2 + 10^- 7.2 + 10^- 7.2) =		**67**
Junction 3 (Separating Wall/Ceiling)					
Flanking Element F3:					
Laboratory STC for F3	R_F3,w	RR-333, HCON203(Mean)		55	
ΔSTC change by Lining	ΔR_F3,w	No Lining ,		0	
Flanking Element f3:					
Laboratory STC for f3	R_f3,w	RR-333, HCON203(Mean)		55	
ΔSTC change by Lining	ΔR_f3,w	No Lining ,		0	
Flanking STC for path Ff	R_ Ff,w	RR-333, Eq. 4.1.3	55/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 12.1 + 4 =		**71**
Flanking STC for path Fd	R_ Fd,w	RR-333, Eq. 4.1.3	55/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 4 =		**70**
Flanking STC for path Df	R_ Df,w	RR-333, Eq. 4.1.3	59/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 4 =		**70**
Junction 3: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.1 + 10^- 7 + 10^- 7) =		**66**
Junction 4 (Separating Wall/Wall)					
Flanking Element F4:					
Laboratory STC for F4	R_F4,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_F4,w	No Lining ,		0	
Flanking Element f4:					
Laboratory STC for f4	R_f4,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_f4,w	No Lining ,		0	
Flanking STC for path Ff	R_ Ff,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Flanking STC for path Fd	R_ Fd,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Flanking STC for path Df	R_ Df,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Junction 4: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.2 + 10^- 7.2 + 10^- 7.2) =		**67**
Total Flanking STC (4 Junctions)		Subset of Eq. 4.1.1	Combining 12 Flanking STC values		**60**
ASTC due to Direct plus All Flanking Path		Equation 4.1.1	Combining Direct STC with 12 Flanking STC values		**57**

EXAMPLE 4.1-H2: (SIMPLIFIED METHOD)

- **Rooms side-by-side**
- **Loadbearing solid precast concrete walls and hollowcore precast concrete floors with rigid junctions**

(Same as Example 4.1-H1 plus floor topping)

Separating wall assembly (loadbearing) with:
- solid reinforced precast concrete wall (i.e.- normal weight concrete, wall thickness 200 mm and mass/area 460 kg/m² including grout at joints) with no linings

Junction 1: Bottom Junction (separating wall / floor) with:
- floor of hollowcore precast concrete slabs (i.e.- normal weight concrete, 203 mm thick, mass/area 300 kg/m² including grout at joints) with lining of 25 mm thick gypsum concrete topping without finish flooring on top
- rigid grouted cross junction with precast concrete wall

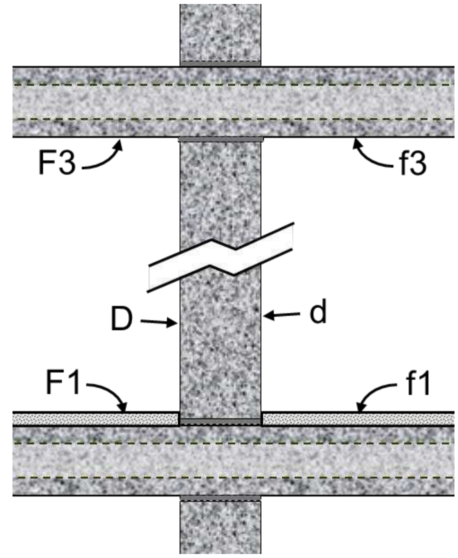
Junction 2 or 4: T-junction of separating wall / abutting side wall:
- side wall and separating wall of solid reinforced precast concrete (i.e.- normal weight concrete, 200 mm thick, mass/area 460 kg/m² including grout at joints) with no linings
- rigid grouted T-junctions

Junction 3: Top Junction (separating wall / ceiling) with:
- floor of hollowcore precast slabs (i.e.- normal weight concrete, 203 mm thick, mass/area 300 kg/m² including grout at joints) with no ceiling lining below
- rigid grouted cross junction with solid precast concrete wall

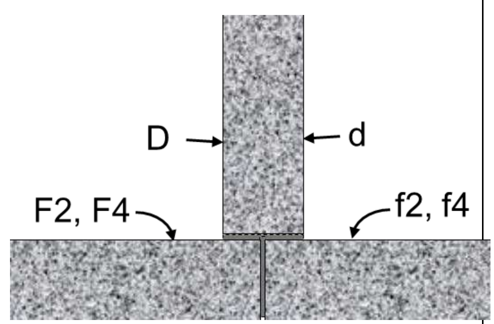
Acoustical Parameters:

For 200 mm solid precast concrete walls:		
Mass/unit area (kg/m²) =	460	(Separating wall)
	460	(Flanking wall)
For 203mm hollowcore precast concrete floor:		
Mass/unit area (kg/m²) =	300	
Separating partition area (m²) =	12.5	
Floor/wall junction length (m) =	5.0	
Separating partition height (m) =	2.5	
10*log(S_Partition/l_junction 1&3) =	4.0	
10*log(S_Partition/l_junction 2&4) =	7.0	

Illustration for this case



Junction of separating wall of 200 mm-thick solid reinforced precast concrete with floor and ceiling of 203 mm thick hollowcore precast concrete.
(Side view of Junctions 1 and 3)



Junction of separating wall with side wall, both of 200 mm solid reinforced precast concrete. (Plan view of Junction 2 or 4).

Junction		Mass ratio	Path Ff Kij (in dB) =	Path Fd	Path Df	Reference
1	Rigid-Cross junction	1.53	12.1	8.9	8.9	ISO 15712-1, Eq. E.3
2	Rigid T-junction	1.00	5.7	5.7	5.7	ISO 15712-1, Eq. E.4
3	Rigid-Cross junction	1.53	12.1	8.9	8.9	ISO 15712-1, Eq. E.3
4	Rigid T-junction	1.00	5.7	5.7	5.7	ISO 15712-1, Eq. E.4

	ISO Symbol	Reference		STC or Δ STC	STC or ASTC
Separating Partition					
Laboratory STC for Dd	R_s,w	RR-334, CON200		59	
ΔSTC change by Lining on D	ΔR_D,w	No Lining ,		0	
ΔSTC change by Lining on d	ΔR_d,w	No Lining ,		0	
Direct STC in situ	R_Dd,w	RR-333, Eq. 4.1.2	59 + MAX(0,0) + MIN(0,0)/2 =		**59**
Junction 1 (Separating Wall/Floor)					
Flanking Element F1:					
Laboratory STC for F1	R_F1,w	RR-333, HCON203(Mean)		55	
ΔSTC change by Lining	ΔR_F1,w	RR-333, ΔSTC-HCON203-F01		1	
Flanking Element f1:					
Laboratory STC for f1	R_f1,w	RR-333, HCON203(Mean)		55	
ΔSTC change by Lining	ΔR_f1,w	RR-333, ΔSTC-HCON203-F01		1	
Flanking STC for path Ff	R_ Ff,w	RR-333, Eq. 4.1.3	55/2 + 55/2 + MAX(1,1) + MIN(1,1)/2 + 12.1 + 4 =		**73**
Flanking STC for path Fd	R_ Fd,w	RR-333, Eq. 4.1.3	55/2 + 59/2 + MAX(1,0) + MIN(1,0)/2 + 8.9 + 4 =		**71**
Flanking STC for path Df	R_ Df,w	RR-333, Eq. 4.1.3	59/2 + 55/2 + MAX(0,1) + MIN(0,1)/2 + 8.9 + 4 =		**71**
Junction 1: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.3 + 10^- 7.1 + 10^- 7.1) =		**67**
Junction 2 (Separating Wall/Wall)					
Flanking Element F2:					
Laboratory STC for F2	R_F2,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_F2,w	No Lining ,		0	
Flanking Element f2:					
Laboratory STC for f2	R_f2,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_f2,w	No Lining ,		0	
Flanking STC for path Ff	R_ Ff,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Flanking STC for path Fd	R_ Fd,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Flanking STC for path Df	R_ Df,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Junction 2: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.2 + 10^- 7.2 + 10^- 7.2) =		**67**
Junction 3 (Separating Wall/Ceiling)					
Flanking Element F3:					
Laboratory STC for F3	R_F3,w	RR-333, HCON203(Mean)		55	
ΔSTC change by Lining	ΔR_F3,w	No Lining ,		0	
Flanking Element f3:					
Laboratory STC for f3	R_f3,w	RR-333, HCON203(Mean)		55	
ΔSTC change by Lining	ΔR_f3,w	No Lining ,		0	
Flanking STC for path Ff	R_ Ff,w	RR-333, Eq. 4.1.3	55/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 12.1 + 4 =		**71**
Flanking STC for path Fd	R_ Fd,w	RR-333, Eq. 4.1.3	55/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 4 =		**70**
Flanking STC for path Df	R_ Df,w	RR-333, Eq. 4.1.3	59/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 4 =		**70**
Junction 3: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.1 + 10^- 7 + 10^- 7) =		**66**
Junction 4 (Separating Wall/Wall)					
Flanking Element F4:					
Laboratory STC for F4	R_F4,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_F4,w	No Lining ,		0	
Flanking Element f4:					
Laboratory STC for f4	R_f4,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_f4,w	No Lining ,		0	
Flanking STC for path Ff	R_ Ff,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Flanking STC for path Fd	R_ Fd,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Flanking STC for path Df	R_ Df,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Junction 4: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.2 + 10^- 7.2 + 10^- 7.2) =		**67**
Total Flanking STC (4 Junctions)		Subset of Eq. 4.1.1	Combining 12 Flanking STC values		**61**
ASTC due to Direct plus All Flanking Paths		Equation 4.1.1	Combining Direct STC with 12 Flanking STC values		**57**

EXAMPLE 4.1-V1: (SIMPLIFIED METHOD)

- **Rooms one-above-the-other**
- **Loadbearing solid precast concrete walls and hollowcore precast concrete floors with rigid junctions**

Separating floor/ceiling assembly with:

- hollowcore precast slabs (i.e.- normal weight concrete, floor 203 mm thick, mass/area 300 kg/m² including grout at joints)
- no topping or finish flooring, and no ceiling lining below

Junction 1, 3, 4:
Cross Junction of separating floor / flanking wall with:

- rigid grouted cross junction with precast concrete walls above and below the floor
- walls of solid reinforced precast concrete (i.e.- normal weight concrete, wall 200 mm thick, mass/area 460 kg/m² including grout at joints) with no lining of walls

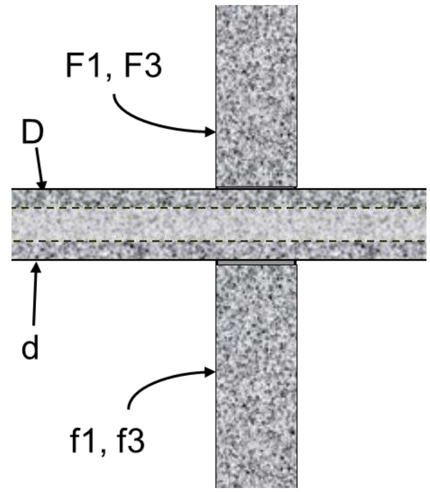
Junction 2: T-Junction of separating floor / flanking wall with:

- rigid grouted T-junctions with precast concrete walls above and below floor
- walls of solid reinforced precast concrete (i.e.- normal weight concrete, 200 mm thick, and mass/area 460 kg/m² including grout at joints) with no lining of walls

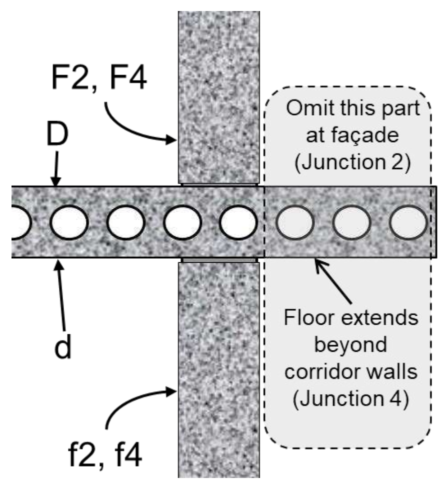
Acoustical Parameters:

For 200 mm solid precast concrete walls:			
Mass/unit area (kg/m^2) =	460	(Wall at junctions 1&3)	
	460	(Wall at junctions 2&4)	
For 203mm hollowcore precast concrete floor:			
Mass/unit area (kg/m^2) =	300		
Separating partition area (m^2) =		20	
Junction 1 & 3 length (m) =		5.0	
Junction 2 & 4 length (m) =		4.0	
10*log(S_Partition/l_junction 1&3) =		6.0	
10*log(S_Partition/l_junction 2&4) =		7.0	

Illustration for this case



Cross junction of separating floor of 203 mm thick hollowcore precast concrete with precast concrete wall. (Side view of Junctions 1, 3)



Junction of separating floor of 203 mm thick hollowcore precast concrete floor with precast concrete flanking wall. (Side view of Junction 2 or 4).

Junction		Mass ratio for Ff	Path Ff Kij (in dB) =	Path Fd	Path Df	Reference
1	Rigid-Cross junction	0.65	5.7	8.9	8.9	ISO 15712-1, Eq. E.3
2	Rigid-T junction	0.65	3.3	5.9	5.9	ISO 15712-1, Eq. E.4
3	Rigid-Cross junction	0.65	5.7	8.9	8.9	ISO 15712-1, Eq. E.3
4	Rigid-Cross junction	0.65	5.7	8.9	8.9	ISO 15712-1, Eq. E.3

	ISO Symbol	Reference	Calculation	STC or Δ STC	STC or ASTC
Separating Partition					
Laboratory STC for Dd	R_s,w	RR-333, HCON203(Mean)		55	
ΔSTC change by Lining on D	ΔR_D,w	No Lining ,		0	
ΔSTC change by Lining on d	ΔR_d,w	No Lining ,		0	
Direct STC in situ	R_Dd,w	RR-333, Eq. 4.1.2	55 + MAX(0,0) + MIN(0,0)/2 =		**55**
Junction 1 (Separating Floor/Wall)					
Flanking Element F1:					
Laboratory STC for F1	R_F1,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_F1,w	No Lining ,		0	
Flanking Element f1:					
Laboratory STC for f1	R_f1,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_f1,w	No Lining ,		0	
Flanking STC for path Ff	R_ Ff,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 6 =		**71**
Flanking STC for path Fd	R_ Fd,w	RR-333, Eq. 4.1.3	59/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 6 =		**72**
Flanking STC for path Df	R_ Df,w	RR-333, Eq. 4.1.3	55/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 6 =		**72**
Junction 1: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.1 + 10^- 7.2 + 10^- 7.2) =		**67**
Junction 2 (Separating Floor/Wall)					
Flanking Element F2:					
Laboratory STC for F2	R_F2,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_F2,w	No Lining ,		0	
Flanking Element f2:					
Laboratory STC for f2	R_f2,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_f2,w	No Lining ,		0	
Flanking STC for path Ff	R_ Ff,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 3.3 + 7 =		**69**
Flanking STC for path Fd	R_ Fd,w	RR-333, Eq. 4.1.3	59/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 5.9 + 7 =		**70**
Flanking STC for path Df	R_ Df,w	RR-333, Eq. 4.1.3	55/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.9 + 7 =		**70**
Junction 2: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-6.9 + 10^- 7 + 10^- 7) =		**65**
Junction 3 (Separating Floor/Wall)					
Flanking Element F3:					
Laboratory STC for F3	R_F3,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_F3,w	No Lining ,		0	
Flanking Element f3:					
Laboratory STC for f3	R_f3,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_f3,w	No Lining ,		0	
Flanking STC for path Ff	R_ Ff,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 6 =		**71**
Flanking STC for path Fd	R_ Fd,w	RR-333, Eq. 4.1.3	59/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 6 =		**72**
Flanking STC for path Df	R_ Df,w	RR-333, Eq. 4.1.3	55/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 6 =		**72**
Junction 3: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.1 + 10^- 7.2 + 10^- 7.2) =		**67**
Junction 4 (Separating Floor/Wall)					
Flanking Element F4:					
Laboratory STC for F4	R_F4,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_F4,w	No Lining ,		0	
Flanking Element f4:					
Laboratory STC for f4	R_f4,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_f4,w	No Lining ,		0	
Flanking STC for path Ff	R_ Ff,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Flanking STC for path Fd	R_ Fd,w	RR-333, Eq. 4.1.3	59/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 7 =		**73**
Flanking STC for path Df	R_ Df,w	RR-333, Eq. 4.1.3	55/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 7 =		**73**
Junction 4: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.2 + 10^- 7.3 + 10^- 7.3) =		**68**
Total Flanking STC (4 Junctions)		Subset of Eq. 4.1.1	Combining 12 Flanking STC values		**60**
ASTC due to Direct plus All Flanking Paths		Equation 4.1.1	Combining Direct STC with 12 Flanking STC values		**54**

EXAMPLE 4.1-V2: (SIMPLIFIED METHOD)

- **Rooms one-above-the-other**
- **Loadbearing solid precast concrete walls and hollowcore precast concrete floors with rigid junctions**

(Same as Example 4.1-V1 plus floor topping)

Separating floor/ceiling assembly with:

- hollowcore precast slabs (i.e.- normal weight concrete, 203 mm thick, mass/area 300 kg/m² including grout at joints)
- lining of 25 mm thick gypsum concrete topping without finish flooring on top of floor, and no ceiling lining below

Junction 1, 3, 4:
Cross Junction of separating floor / flanking wall with:

- rigid grouted cross junction with precast concrete walls above and below the floor
- walls of solid reinforced precast concrete (i.e.- normal weight concrete, 200 mm thick, mass/area 460 kg/m² including grout at joints) with no lining of walls

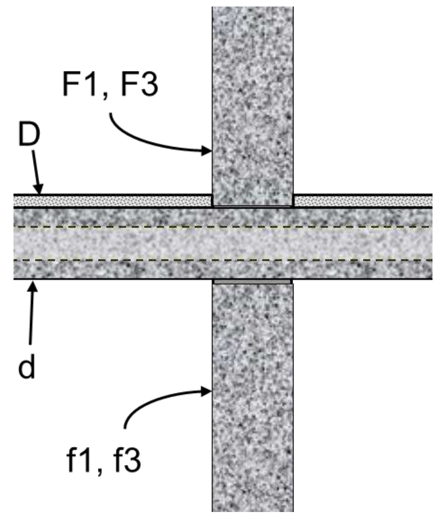
Junction 2: T-Junction of separating floor / flanking wall with:

- rigid grouted T-junctions with precast concrete walls above and below floor
- walls of solid reinforced precast concrete (i.e.- normal weight concrete, 200 mm thick, mass/area 460 kg/m² including grout at joints) with no lining of walls

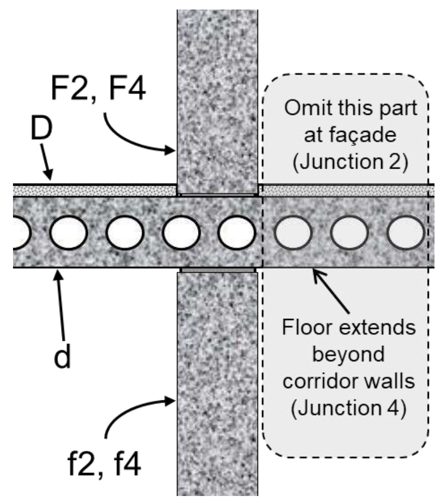
Acoustical Parameters:

For 200 mm solid precast concrete walls:		
Mass/unit area (kg/m^2) =	460	(Wall at junctions 1&3)
	460	(Wall at junctions 2&4)
For 203mm hollowcore precast concrete floor:		
Mass/unit area (kg/m^2) =	300	
Separating partition area (m^2) =	20	
Junction 1 & 3 length (m) =	5.0	
Junction 2 & 4 length (m) =	4.0	
10*log(S_Partition/l_junction 1&3) =	6.0	
10*log(S_Partition/l_junction 2&4) =	7.0	

Illustration for this case



Cross junction of separating floor of 203 mm thick hollowcore precast concrete with precast concrete wall. (Side view of Junctions 1, 3)



Junction of separating floor of 203 mm thick hollowcore precast concrete floor with precast concrete flanking wall. (Side view of Junction 2 or 4).

Junction		Mass ratio for Ff	Path Ff Kij (in dB) =	Path Fd	Path Df	Reference
1	Rigid-Cross junction	0.65	5.7	8.9	8.9	ISO 15712-1, Eq. E.3
2	Rigid-T junction	0.65	3.3	5.9	5.9	ISO 15712-1, Eq. E.4
3	Rigid-Cross junction	0.65	5.7	8.9	8.9	ISO 15712-1, Eq. E.3
4	Rigid-Cross junction	0.65	5.7	8.9	8.9	ISO 15712-1, Eq. E.3

	ISO Symbol	Reference		STC or Δ STC	STC or ASTC
Separating Partition					
Laboratory STC for Dd	R_s,w	RR-333, HCON203(Mean)		55	
ΔSTC change by Lining on D	ΔR_D,w	RR-333, ΔSTC-HCON203-F01		1	
ΔSTC change by Lining on d	ΔR_d,w	No Lining ,		0	
Direct STC in situ	R_Dd,w	RR-333, Eq. 4.1.2	55 + MAX(1,0) + MIN(1,0)/2 =		**56**
Junction 1 (Separating Floor/Wall)					
Flanking Element F1:					
Laboratory STC for F1	R_F1,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_F1,w	No Lining ,		0	
Flanking Element f1:					
Laboratory STC for f1	R_f1,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_f1,w	No Lining ,		0	
Flanking STC for path Ff	R_ Ff,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 6 =		**71**
Flanking STC for path Fd	R_ Fd,w	RR-333, Eq. 4.1.3	59/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 6 =		**72**
Flanking STC for path Df	R_ Df,w	RR-333, Eq. 4.1.3	55/2 + 59/2 + MAX(1,0) + MIN(1,0)/2 + 8.9 + 6 =		**73**
Junction 1: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.1 + 10^- 7.2 + 10^- 7.3) =		**67**
Junction 2 (Separating Floor/Wall)					
Flanking Element F2:					
Laboratory STC for F2	R_F2,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_F2,w	No Lining ,		0	
Flanking Element f2:					
Laboratory STC for f2	R_f2,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_f2,w	No Lining ,		0	
Flanking STC for path Ff	R_ Ff,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 3.3 + 7 =		**69**
Flanking STC for path Fd	R_ Fd,w	RR-333, Eq. 4.1.3	59/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 5.9 + 7 =		**70**
Flanking STC for path Df	R_ Df,w	RR-333, Eq. 4.1.3	55/2 + 59/2 + MAX(1,0) + MIN(1,0)/2 + 5.9 + 7 =		**71**
Junction 2: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-6.9 + 10^- 7 + 10^- 7.1) =		**65**
Junction 3 (Separating Floor/Wall)					
Flanking Element F3:					
Laboratory STC for F3	R_F3,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_F3,w	No Lining ,		0	
Flanking Element f3:					
Laboratory STC for f3	R_f3,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_f3,w	No Lining ,		0	
Flanking STC for path Ff	R_ Ff,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 6 =		**71**
Flanking STC for path Fd	R_ Fd,w	RR-333, Eq. 4.1.3	59/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 6 =		**72**
Flanking STC for path Df	R_ Df,w	RR-333, Eq. 4.1.3	55/2 + 59/2 + MAX(1,0) + MIN(1,0)/2 + 8.9 + 6 =		**73**
Junction 3: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.1 + 10^- 7.2 + 10^- 7.3) =		**67**
Junction 4 (Separating Floor/Wall)					
Flanking Element F4:					
Laboratory STC for F4	R_F4,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_F4,w	No Lining ,		0	
Flanking Element f4:					
Laboratory STC for f4	R_f4,w	RR-334, CON200		59	
ΔSTC change by Lining	ΔR_f4,w	No Lining ,		0	
Flanking STC for path Ff	R_ Ff,w	RR-333, Eq. 4.1.3	59/2 + 59/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =		**72**
Flanking STC for path Fd	R_ Fd,w	RR-333, Eq. 4.1.3	59/2 + 55/2 + MAX(0,0) + MIN(0,0)/2 + 8.9 + 7 =		**73**
Flanking STC for path Df	R_ Df,w	RR-333, Eq. 4.1.3	55/2 + 59/2 + MAX(1,0) + MIN(1,0)/2 + 8.9 + 7 =		**74**
Junction 4: Flanking STC for all paths		Subset of Eq. 4.1.1	- 10*LOG10(10^-7.2 + 10^- 7.3 + 10^- 7.4) =		**68**
Total Flanking STC (4 Junctions)		Subset of Eq. 4.1.1	Combining 12 Flanking STC values		**61**
ASTC due to Direct plus All Flanking Paths		Equation 4.1.1	Combining Direct STC with 12 Flanking STC values		**55**

Summary for Section 4.1. Simplified Method for Precast Concrete Walls and Floors

The worked examples 4.1-H1 to 4.1-V2 illustrate the use of the Simplified Method for calculating the sound transmission between rooms in a building with solid precast concrete walls and hollowcore precast concrete floor assemblies, with or without linings added to some of the floors.

The worked examples 4.1-H1 and 4.1-V1 illustrate the basic process for calculating the sound transmission between rooms in a building with bare precast concrete walls and floors (i.e. without added gypsum board finish on the walls or ceiling, or flooring over the concrete slab). The ASTC rating for these examples is lower than the STC rating of the separating assembly. The relative contributions of direct transmission and flanking transmission are very similar when the rooms are side-by-side, but the flanking is much less important when one room is above the other.

The worked examples 4.1-H2 and 4.1-V2 with a lining on the floor demonstrate how to include linings in the calculation of the ASTC ratings. The lining is shown to increase the flanking transmission for the floor-floor path for the horizontal room pair, but to have a negligible effect on the ASTC rating. The addition of the lining did increase the ASTC rating of the vertical room pair.

For the side-by-side pair of rooms

The effect of adding a lining of gypsum concrete on top of the hollowcore precast concrete floors is shown in Example 4.1-H2. It is clear that this lining has only a very small effect:

- Adding a lining with ΔSTC=1 to the floor surfaces in Example 4.1-H2 does not change the predicted ASTC rating, though it does raise the Flanking STC for Junction 1 and for total flanking by 1 point.
- A larger benefit from linings could be gained with suitable gypsum board linings on the walls and ceilings, but no data for such linings on precast concrete assemblies is currently available.

For one room above the other

The effect of adding a lining of gypsum concrete on top of the hollowcore precast concrete floors is shown in Example 4.1-V2. It is clear that this lining has only a small effect:

- Adding a lining with ΔSTC=1 to the floor surfaces in Example 4.1-V2 increases the predicted ASTC rating from 54 to 55, and similar changes are evident in the Direct STC rating for transmission though the floor and in the Total Flanking STC rating.
- A larger benefit from linings could be gained by adding suitable gypsum board linings on the walls and ceilings, but no data for such linings on precast concrete assemblies is currently available.

4.2 Detailed ASTC Rating Calculation for Precast Concrete Walls and Floors

The standard, ISO 15712-1 presents a Detailed Method for calculating structure-borne transmission. The calculation process of the Detailed Method is designed for constructions involving heavy, homogeneous surfaces which support reverberant vibration fields such as concrete floors or hollow concrete block masonry walls. Some considerations which are specific to these assemblies are:

- The internal loss factors for concrete wall and floor assemblies range from 0.006 for solid concrete to 0.015 for typical concrete masonry. Losses due to the transfer of energy to the attached assemblies are generally larger than the corresponding losses for laboratory specimens, especially at the lower frequencies. Therefore, the in-situ sound transmission loss for each bare concrete or masonry flanking surface will tend to be higher than the corresponding laboratory sound transmission loss determined according to ASTM E90. It is therefore appropriate to apply a correction to obtain the in-situ sound transmission loss from the laboratory sound transmission loss using Equation 19 of ISO 15712-1.
- For flanking surfaces, Section 4.2.2 in ISO 15712-1 notes that only the resonant sound transmission loss should be included in the calculations. This requires a correction of the sound transmission loss measured in the laboratory below the critical frequency. For bare precast concrete wall or floor assemblies, the critical frequency is below 125 Hz, so no correction to remove the non-resonant sound transmission loss from the measured sound transmission loss is needed.
- The mortar/grouted bonded junctions of precast concrete floors and walls are consistent with the symmetric rigid junction assumptions of Annex E of ISO 15712-1. Therefore, the junction attenuation for a range of cases can be treated using the expressions to calculate Kij according to Annex E of ISO 15712-1.

The input data required for the calculations include both laboratory sound transmission loss data measured according to ASTM E90 (for the base precast concrete wall or floor assemblies and for the change in sound transmission loss due to linings applied to these assemblies) and the junction attenuation values calculated using the expressions from Annex E of ISO 15712-1. .

The calculation process using the Detailed Method follows the steps illustrated in Figure 4.2.1, and explained in detail below.

Direct Transmission through the Separating Assembly

Figure 4.2.1 shows the steps required to transform the laboratory sound transmission loss data through a bare separating assembly of precast concrete into the direct in-situ transmission loss. The transformation requires a correction to adjust for the differences between losses in a laboratory test specimen and the losses when the assembly is connected to adjoining structures in-situ in the building. Note that all of the calculations are made in one-third octave bands.

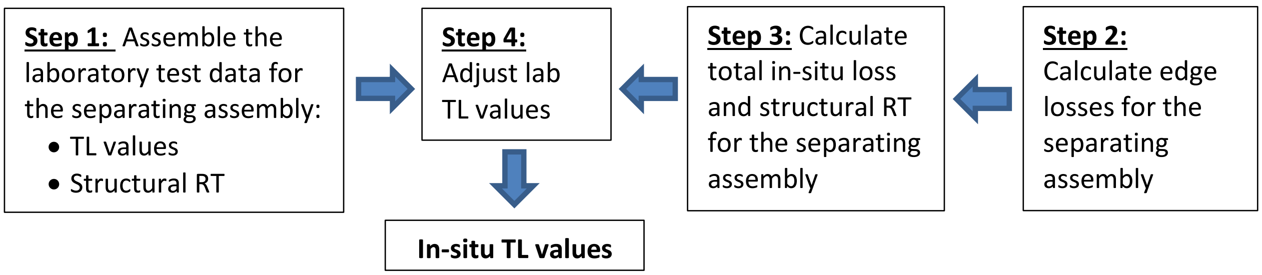


Figure 4.2.1: Steps to calculate the in-situ transmission loss for the bare separating assembly.

Step 1: Assemble the required laboratory test data:

- Laboratory sound transmission loss (TL) values measured in one-third octave bands according to ASTM E90 for the floor or wall assembly of bare concrete without added linings. The treatment of linings in the calculation is explained later in the calculation procedure.
- Structural reverberation time (T_S) measured in one-third octave bands according to ISO 10848-1 in the laboratory at the time the transmission loss of the floor or wall was measured, if available. Alternatively, if measured data is not available, a conservative estimate of the total loss factor for a laboratory specimen can be calculated from Eq. C.5 of Annex C of ISO 15712-1.
- Mass per unit area for the unlined wall and floor assemblies for the walls and floors involved in the flanking paths.
- Dimensions of the walls and floors involved in the flanking paths.
- The coincidence frequency for each of the walls and floors involved in the flanking paths.

Step 2: Calculate the edge losses for the separating assembly in-situ:

- For each edge of the separating assembly, calculate the vibration reduction index (K_{ij}) between the separating assembly and each of the attached assemblies (walls and/or floors) using the appropriate case from Annex E of ISO 15712-1. These values depend on the junction geometries and on the ratio of the mass per areas for the assemblies.
- For each edge, calculate the resulting absorption coefficient using the calculated values of K_{ij} and the coincidence frequency (frequency at which the wavelength on the element and in surrounding air coincide) for the attached assemblies in Eq. C.2 of ISO 15712-1.

Step 3: Calculate total loss for the separating assembly and its in-situ structural reverberation time:

- Use the 2nd equation of Eq. C.1 of ISO 15712-1 to calculate the combination of internal losses, radiation losses and edge losses. A comparison between the values calculated for a common surface for a vertical pair of rooms and a horizontal pair of rooms gives a check on the loss calculations. The total loss is frequency-dependent for most junction types. Note the worked examples only give the value in the 500 Hz one-third octave band as a benchmark value.
- Use the 1st equation of Eq. C.1 of ISO 15712-1 to calculate the resulting structural reverberation time of the assembly.

Step 4: Calculate the in-situ transmission loss values for the separating assembly using the ratio of the structural reverberation times according to Eq. 19 in Section 4.2.2 of ISO 15712-1.

Transmission via Flanking Elements

A similar procedure is required to adjust the flaking transmission loss of each flanking path for in-situ losses associated with the connecting junction and the two wall or floor surfaces that comprise the flanking path. The calculation process is presented in Figure 4.2.2, and each step is subsequently explained.

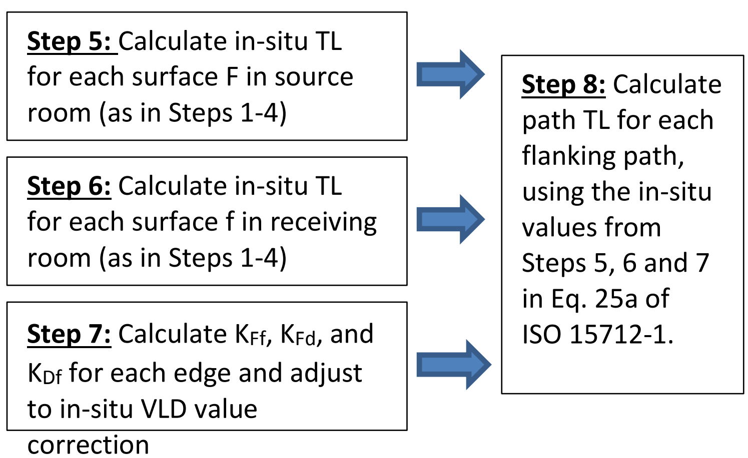


Figure 4.2.2: Steps to calculate the flanking transmission loss for each flanking path.

Note that because of the symmetry in the Standard Scenario used for the examples in this Report and because the preceding calculation for direct transmission provides in-situ values for surfaces D and d, the examples in this Report require Steps 5 and 6 for only four of the room surfaces: a floor/ceiling assembly, a separating wall, a corridor wall, and a façade wall. Applying the Detailed Method to rooms other than those in the Standard Scenario may require further calculations.

Step 5: Calculate the in-situ transmission loss values for each flanking assembly F in the source room by repeating the procedure of Steps 1 – 4 for these assemblies. Note that for an assembly of concrete (cast-in-place concrete or precast concrete slabs or hollow concrete block masonry) the coincidence frequency is below 125 Hz. Therefore, the radiation efficiency is equal to unity in the frequency range of interest and the resonant sound transmission loss (required for these calculations) is equal to the sound transmission loss measured in the standard ASTM E90 laboratory test without correction.

Step 6: Calculate the in-situ transmission loss values for each flanking assembly f in the receiving room by repeating the procedure of Steps 1 – 4 for these assemblies.

Step 7: Calculate the in-situ velocity level difference (VLD) values for the junction attenuation for each flanking path according to the following:

- Calculate the vibration reduction index (K_{ij}) between the pair of assemblies using the appropriate case from Annex E of ISO 15712-1.
- Calculate the VLD for the junction of each flanking path using Eq. 21 and 22 of ISO 15712-1 which normalizes the Kij values for each flanking path based on the properties of the elements of the flanking path such as the structural reverberation times, the dimensions and the critical frequencies.

Step 8: Calculate the flanking transmission loss values for each flanking path for the unlined assemblies:

- Use the in-situ transmission loss values calculated in Steps 5 and 6, the VLD values calculated in Step 7 and the areas of the elements to determine the flanking transmission loss values for each flanking path using Eq. 25a of ISO 15712-1.

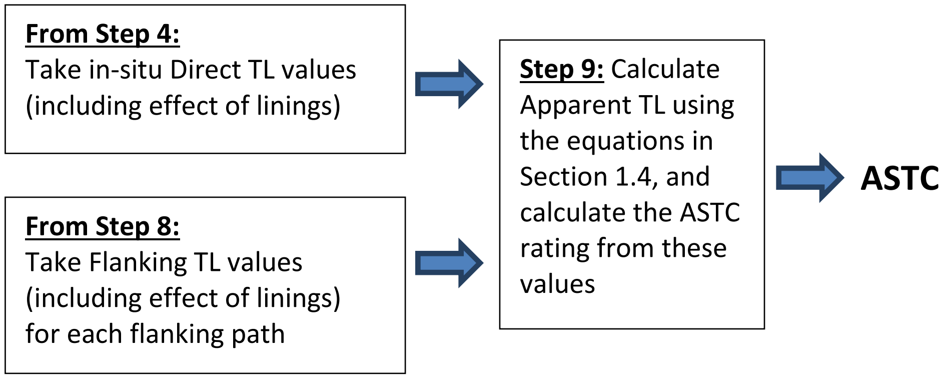
Including Linings in the Calculation Process

Including the effect of changes in the sound transmission loss due to the addition of linings requires only minor additions to the preceding eight steps:

At Step 4: To calculate the in-situ direct sound transmission loss through the separating assembly, add the laboratory data for the change in the transmission loss (ΔTL) due to a lining added to the source side and the laboratory data for the change in the transmission loss (ΔTL) due to an added lining on the receiving side using Eq. 24 of ISO 15712-1. The changes are identified in Eq. 24 of ISO 15712-1 as $\Delta R_{D,situ}$ and $\Delta R_{d,situ}$, respectively.

At Step 8: To calculate the flanking sound transmission via each flanking path, add the laboratory data for the change in the transmission loss (ΔTL) due to a lining added to element i in the source room and the laboratory data for the change in the transmission loss (ΔTL) due to an added lining on element j in the receiving room, using Eq. 25a of ISO 15712-1. The changes are identified in the equation as $\Delta R_{i,situ}$ and $\Delta R_{j,situ}$, respectively.

Combining the Direct and the Flanking Sound Transmission



Step 9: Combine the sound power transmitted via the direct path through the separating assembly and the 12 flanking paths (3 at each edge of the separating assembly).

- Use Equations 1.4 in Section 1.4 of this Report (equivalent to Section 4.1 of ISO 15712-1) to calculate the apparent transmission loss (ATL).
- Use the resulting values of the apparent transmission loss in the procedure of ASTM E413 to calculate the ASTC rating.

EXAMPLE 4.2-H1: (DETAILED METHOD)

- **Rooms side-by-side**
- **Loadbearing solid precast concrete walls and hollowcore precast concrete floors with rigid junctions**

Separating wall assembly (loadbearing) with:

- solid reinforced precast concrete wall (i.e.- normal weight concrete, wall thickness 200 mm and mass/area 460 kg/m² including grout at joints) with no linings

Junction 1: Bottom Junction (separating wall / floor) with:

- floor of hollowcore precast concrete slabs (i.e.- normal weight concrete, floor thickness 203 mm and mass/area 300 kg/m² including grout at joints) with no lining on top
- rigid grouted cross junction with precast concrete wall

Junction 2 or 4: T-junction of separating wall / abutting side wall:

- side wall and separating wall of solid reinforced precast concrete (i.e.- normal weight concrete, 200 mm thick, mass/area 460 kg/m² including grout at joints) with no linings
- rigid grouted T-junctions

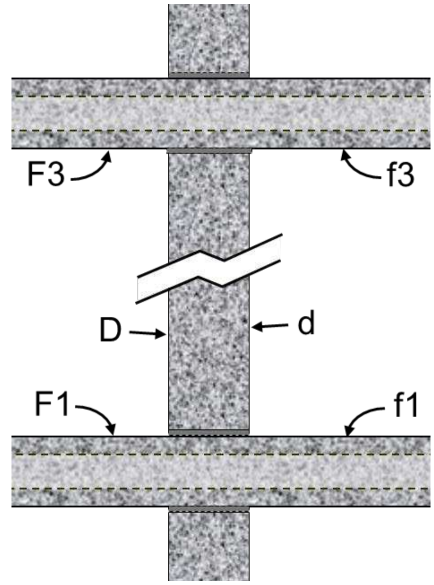
Junction 3: Top Junction (separating wall / ceiling) with:

- floor of hollowcore precast slabs (i.e.- normal weight concrete, 203 mm thick, mass/area 300 kg/m² including grout at joints) with no ceiling lining below
- rigid grouted cross junction with solid precast concrete wall

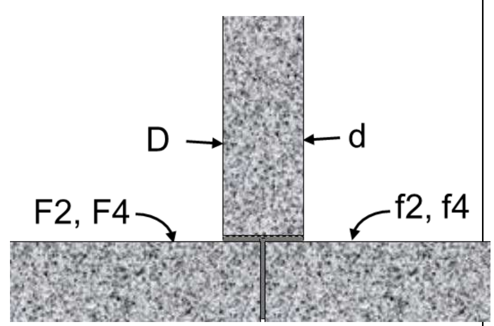
Acoustical Parameters:

	For separating assembly:					
internal loss, η_i =	0.006		c_L =	3500		
mass (kg/m²) =	460		f_c =	93		(Eq. C.2)
	Reference	K_Ff	K_Dd'	K_Fd	K_Df	Σ l_k . α_k
X-Junction 1 or 3	ISO 15712-1, Eq. E.3	12.1	5.7	8.9	8.9	0.799
T-Junction 2 or 4	ISO 15712-1, Eq. E.4	5.7		5.7	5.7	0.410
Total loss, η_tot	ISO 15712-1, Eq. C.1			0.037	(at 500 Hz)	
	Similarly, for flanking elements F and f at Junction 1 & 3,					
internal loss, η_i =	0.015		c_L =	3500		
mass (kg/m²) =	300		f_c =	91		
Total loss, η_tot	ISO 15712-1, Eq. C.1			0.032	(at 500 Hz)	
	Similarly, for flanking elements F and f at Junction 2 & 4,					
internal loss, η_i =	0.006		c_L =	3500		
mass (kg/m²) =	460		f_c =	93		
Total loss, η_tot,2	ISO 15712-1, Eq. C.1			0.036	(at 500 Hz)	
Total loss, η_tot,4	ISO 15712-1, Eq. C.1			0.032	(at 500 Hz)	

Illustration for this case



Junction of separating wall of 200 mm-thick solid reinforced precast concrete with floor and ceiling of 203 mm thick hollowcore precast concrete.
(Side view of Junctions 1 and 3)



Junction of separating wall with side wall, both of 200 mm solid reinforced precast concrete. (Plan view of Junction 2 or 4).

	ISO Symbol	Reference	125	250	500	1000	2000	4000	STC or ASTC
Separating Partition									
Sound Transmission Loss (TL)	R_D,lab	RR-334, CON200	41	49	55	62	69	75	59
Structural Reverberation Time	T_s,lab	RR-334, RT-CON200	0.324	0.250	0.240	0.170	0.093	0.060	
Change by Lining on source side	ΔR_D	No Lining ,	0	0	0	0	0	0	
Change by Lining on receive side	ΔR_d	No Lining ,	0	0	0	0	0	0	
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.249	0.172	0.116	0.078	0.051	0.032	
Leakage or Airborne Flanking		Sealed & Blocked	0.0	0.0	0.0	0.0	0.0	0.0	
Direct TL in-situ	**R_D,situ**	**ISO 15712-1, Eq. 19, 24**	**42**	**51**	**58**	**65**	**72**	**78**	**61**

	ISO Symbol	Reference		125	250	500	1000	2000	4000	STC or ASTC
Junction 1 (Separating Wall/Floor)										
Sound Transmission Loss, F1 or f1	R_F1,lab	RR-333, HCON203(Mean)		38	44	52	58	63	71	55
Structural Reverberation Time	T_s,lab	RR-333, RT-HCON203(Mean)		0.314	0.204	0.130	0.109	0.084	0.050	
Change by Lining on source side	ΔR_F1	No Lining ,		0	0	0	0	0	0	
Change by Lining on receive side	ΔR_f1	No Lining ,		0	0	0	0	0	0	
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3		0.347	0.222	0.137	0.082	0.047	0.026	
TL in-situ for F1	R_F1,situ	ISO 15712-1, Eq. 19		37.6	43.6	51.8	59.2	65.5	73.8	55
TL in-situ for f1	R_f1,situ	ISO 15712-1, Eq. 19		37.6	43.6	51.8	59.2	65.5	73.8	55
Junction J1 - Coupling										
Velocity Level Difference for Ff	D_v,Ff_1,situ	ISO 15712-1, Eq. 21, 22		15.3	15.7	16.3	17.0	17.9	18.9	
Velocity Level Difference for Fd	D_v,Fd_1,situ	ISO 15712-1, Eq. 21, 22		11.8	12.0	12.4	12.9	13.5	14.3	
Velocity Level Difference for Df	D_v,Df_1,situ	ISO 15712-1, Eq. 21, 22		11.8	12.0	12.4	12.9	13.5	14.3	
Flanking Transmission Loss - Path data										
Flanking TL for Path Ff_1	R_Ff	ISO 15712-1, Eq. 25a		**51**	**57**	**66**	**74**	**81**	**91**	**69**
Flanking TL for Path Fd_1	R_Fd	ISO 15712-1, Eq. 25a		**51**	**58**	**66**	**74**	**81**	**89**	**69**
Flanking TL for Path Df_1	R_Df	ISO 15712-1, Eq. 25a		**51**	**58**	**66**	**74**	**81**	**89**	**69**
Junction 1: Flanking STC for all paths		Subset of RR-333, Eq. 1.2	- 10*LOG10(10^-6.9 + 10^- 6.9 + 10^- 6.9) =							64
Junction 2 (Separating Wall/Wall)										
Sound Transmission Loss, F2 or f2	R_F2,lab	RR-334, CON200		41	49	55	62	69	75	59
Structural Reverberation Time	T_s,lab	RR-334, RT-CON200		0.324	0.250	0.240	0.170	0.093	0.060	
Change by Lining on source side	ΔR_F2	No Lining ,		0	0	0	0	0	0	
Change by Lining on receive side	ΔR_f2	No Lining ,		0	0	0	0	0	0	
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3		0.192	0.133	0.091	0.061	0.041	0.026	
TL in-situ for F2	R_F2,situ	ISO 15712-1, Eq. 19		43.3	51.7	59.2	66.4	72.6	78.6	62
TL in-situ for f2	R_f2,situ	ISO 15712-1, Eq. 19		43.3	51.7	59.2	66.4	72.6	78.6	62
Junction J2 - Coupling										
Velocity Level Difference for Ff	D_v,Ff_2,situ	ISO 15712-1, Eq. 21, 22		11.4	11.5	11.6	11.9	12.1	12.5	
Velocity Level Difference for Fd	D_v,Fd_2,situ	ISO 15712-1, Eq. 21, 22		11.3	11.4	11.6	11.8	12.1	12.6	
Velocity Level Difference for Df	D_v,Df_2,situ	ISO 15712-1, Eq. 21, 22		11.3	11.4	11.6	11.8	12.1	12.6	
Flanking Transmission Loss - Path data										
Flanking TL for Path Ff_2	R_Ff	ISO 15712-1, Eq. 25a		**56**	**64**	**72**	**79**	**86**	**92**	**75**
Flanking TL for Path Fd_2	R_Fd	ISO 15712-1, Eq. 25a		**54**	**63**	**71**	**78**	**85**	**91**	**73**
Flanking TL for Path Df_2	R_Df	ISO 15712-1, Eq. 25a		**54**	**63**	**71**	**78**	**85**	**91**	**73**
Junction 2: Flanking STC for all paths		Subset of RR-333, Eq. 1.2	- 10*LOG10(10^-7.5 + 10^- 7.3 + 10^- 7.3) =							69
Junction 3 (Separating Wall/Ceiling)										
All input values the same as for Junction 1										
Junction 3: Flanking STC for all paths		Subset of RR-333, Eq. 1.2								64
Junction 4 (Separating Wall/Wall)										
All input data the same as for Junction 2, but different junctions at ceiling and floor change loss factors from Junction 2										
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3		0.232	0.160	0.109	0.073	0.048	0.026	
TL in-situ for F4	R_F4,situ	ISO 15712-1, Eq. 19		42.5	50.9	58.4	65.7	71.9	77.9	61
TL in-situ for f4	R_f4,situ	ISO 15712-1, Eq. 19		42.5	50.9	58.4	65.7	71.9	77.9	61
Junction J4 - Coupling										
Velocity Level Difference for Ff	D_v,Ff_4,situ	ISO 15712-1, Eq. 21, 22		10.6	10.7	10.9	11.1	11.4	11.9	
Velocity Level Difference for Fd	D_v,Fd_4,situ	ISO 15712-1, Eq. 21, 22		10.9	11.0	11.2	11.5	11.8	12.3	
Velocity Level Difference for Df	D_v,Df_4,situ	ISO 15712-1, Eq. 21, 22		10.9	11.0	11.2	11.5	11.8	12.3	
Flanking Transmission Loss - Path data										
Flanking TL for Path Ff_4	R_Ff	ISO 15712-1, Eq. 25a		**54**	**63**	**70**	**78**	**84**	**91**	**73**
Flanking TL for Path Fd_4	R_Fd	ISO 15712-1, Eq. 25a		**54**	**62**	**70**	**77**	**84**	**91**	**73**
Flanking TL for Path Df_4	R_Df	ISO 15712-1, Eq. 25a		**54**	**62**	**70**	**77**	**84**	**91**	**73**
Junction 4: Flanking STC for all paths		Subset of RR-333, Eq. 1.2	- 10*LOG10(10^-7.3 + 10^- 7.3 + 10^- 7.3) =							68
Total Flanking (for all 4 junctions)		Subset of RR-333, Eq. 1.1		42	49	57	65	72	79	60
ASTC due to Direct plus Flanking Paths		RR-333, Eq. 1.1		**39**	**47**	**54**	**62**	**69**	**76**	**57**

EXAMPLE 4.2-H2: (DETAILED METHOD)

- **Rooms side-by-side**
- **Loadbearing solid precast concrete walls and hollowcore precast concrete floors with rigid junctions**

(Same as Example 4.2-H1 plus floor topping)

Separating wall assembly (loadbearing) with:
- solid reinforced precast concrete wall (i.e.- normal weight concrete, wall thickness 200 mm and mass/area 460 kg/m² including grout at joints) with no linings

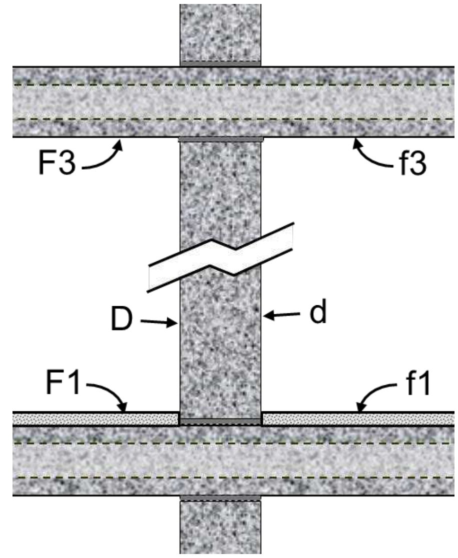
Junction 1: Bottom Junction (separating wall / floor) with:
- floor of hollowcore precast concrete slabs (i.e.- normal weight concrete, 203 mm thick, mass/area 300 kg/m² including grout at joints) with lining of 25 mm thick gypsum concrete topping without finish flooring on top
- rigid grouted cross junction with precast concrete wall

Junction 2 or 4: T-junction of separating wall / abutting side wall:
- side wall and separating wall of solid reinforced precast concrete (i.e.- normal weight concrete, 200 mm thick, mass/area 460 kg/m² including grout at joints) with no linings
- rigid grouted T-junctions

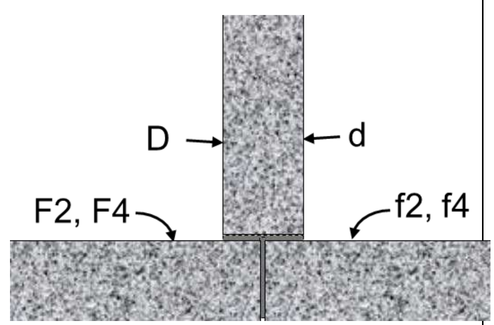
Junction 3: Top Junction (separating wall / ceiling) with:
- floor of hollowcore precast slabs (i.e.- normal weight concrete, 203 mm thick, mass/area 300 kg/m² including grout at joints) with no ceiling lining below
- rigid grouted cross junction with solid precast concrete wall

For separating assembly:						
internal loss, η_i =	0.006		c_L =	3500		
mass (kg/m²) =	460		f_c =	93		(Eq. C.2)
	Reference	K_Ff	K_Dd'	K_Fd	K_Df	Σ l_k . α_k
X-Junction 1 or 3	ISO 15712-1, Eq. E.3	12.1	5.7	8.9	8.9	0.799
T-Junction 2 or 4	ISO 15712-1, Eq. E.4	5.7		5.7	5.7	0.410
Total loss, η_tot	ISO 15712-1, Eq. C.1			0.037	(at 500 Hz)	
Similarly, for flanking elements F and f at Junction 1 & 3,						
internal loss, η_i =	0.015		c_L =	3500		
mass (kg/m²) =	300		f_c =	91		
Total loss, η_tot	ISO 15712-1, Eq. C.1			0.032	(at 500 Hz)	
Similarly, for flanking elements F and f at Junction 2 & 4,						
internal loss, η_i =	0.006		c_L =	3500		
mass (kg/m²) =	460		f_c =	93		
Total loss, η_tot,2	ISO 15712-1, Eq. C.1			0.036	(at 500 Hz)	
Total loss, η_tot,4	ISO 15712-1, Eq. C.1			0.032	(at 500 Hz)	

Illustration for this case



Junction of separating wall of 200 mm-thick solid reinforced precast concrete with floor and ceiling of 203 mm thick hollowcore precast concrete.
(Side view of Junctions 1 and 3)



Junction of separating wall with side wall, both of 200 mm solid reinforced precast concrete. (Plan view of Junction 2 or 4).

	ISO Symbol	Reference	125	250	500	1000	2000	4000	STC or ASTC
Separating Partition									
Sound Transmission Loss (TL)	R_D,lab	RR-334, CON200	41	49	55	62	69	75	59
Structural Reverberation Time	T_s,lab	RR-334, RT-CON200	0.324	0.250	0.240	0.170	0.093	0.060	
Change by Lining on source side	ΔR_D	No Lining ,	0	0	0	0	0	0	
Change by Lining on receive side	ΔR_d	No Lining ,	0	0	0	0	0	0	
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.249	0.172	0.116	0.078	0.051	0.032	
Leakage or Airborne Flanking		Sealed & Blocked	0.0	0.0	0.0	0.0	0.0	0.0	
Direct TL in-situ	R_D,situ	ISO 15712-1, Eq. 19, 24	**42**	**51**	**58**	**65**	**72**	**78**	**61**

	ISO Symbol	Reference	125	250	500	1000	2000	4000	STC or ASTC
Junction 1 (Separating Wall/Floor)									
Sound Transmission Loss, F1 or f1	R_F1,lab	RR-333, HCON203(Mean)	38	44	52	58	63	71	55
Structural Reverberation Time	T_s,lab	RR-333, RT-HCON203(Mean)	0.314	0.204	0.130	0.109	0.084	0.050	
Change by Lining on source side	ΔR_F1	ΔTL-HCON203-F01 ,	2	0	1	4	4	3	
Change by Lining on receive side	ΔR_f1	ΔTL-HCON203-F01 ,	2	0	1	4	4	3	
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.347	0.222	0.137	0.082	0.047	0.026	
TL in-situ for F1	R_F1,situ	ISO 15712-1, Eq. 19	37.6	43.6	51.8	59.2	65.5	73.8	55
TL in-situ for f1	R_f1,situ	ISO 15712-1, Eq. 19	37.6	43.6	51.8	59.2	65.5	73.8	55
<u>Junction J1 - Coupling</u>									
Velocity Level Difference for Ff	D_v,Ff_1,situ	ISO 15712-1, Eq. 21, 22	15.3	15.7	16.3	17.0	17.9	18.9	
Velocity Level Difference for Fd	D_v,Fd_1,situ	ISO 15712-1, Eq. 21, 22	11.8	12.0	12.4	12.9	13.5	14.3	
Velocity Level Difference for Df	D_v,Df_1,situ	ISO 15712-1, Eq. 21, 22	11.8	12.0	12.4	12.9	13.5	14.3	
<u>Flanking Transmission Loss - Path data</u>									
Flanking TL for Path Ff_1	R_Ff	ISO 15712-1, Eq. 25a	**55**	**57**	**68**	**82**	**89**	**97**	**70**
Flanking TL for Path Fd_1	R_Fd	ISO 15712-1, Eq. 25a	**53**	**58**	**67**	**78**	**85**	**92**	**70**
Flanking TL for Path Df_1	R_Df	ISO 15712-1, Eq. 25a	**53**	**58**	**67**	**78**	**85**	**92**	**70**
Junction 1: Flanking STC for all paths		Subset of RR-333, Eq. 1.2	- 10*LOG10(10^-7 + 10^- 7 + 10^- 7) =						65
Junction 2 (Separating Wall/Wall)									
Sound Transmission Loss, F2 or f2	R_F2,lab	RR-334, CON200	41	49	55	62	69	75	59
Structural Reverberation Time	T_s,lab	RR-334, RT-CON200	0.324	0.250	0.240	0.170	0.093	0.060	
Change by Lining on source side	ΔR_F2	No Lining ,	0	0	0	0	0	0	
Change by Lining on receive side	ΔR_f2	No Lining ,	0	0	0	0	0	0	
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.192	0.133	0.091	0.061	0.041	0.026	
TL in-situ for F2	R_F2,situ	ISO 15712-1, Eq. 19	43.3	51.7	59.2	66.4	72.6	78.6	62
TL in-situ for f2	R_f2,situ	ISO 15712-1, Eq. 19	43.3	51.7	59.2	66.4	72.6	78.6	62
<u>Junction J2 - Coupling</u>									
Velocity Level Difference for Ff	D_v,Ff_2,situ	ISO 15712-1, Eq. 21, 22	11.4	11.5	11.6	11.9	12.1	12.5	
Velocity Level Difference for Fd	D_v,Fd_2,situ	ISO 15712-1, Eq. 21, 22	11.3	11.4	11.6	11.8	12.1	12.6	
Velocity Level Difference for Df	D_v,Df_2,situ	ISO 15712-1, Eq. 21, 22	11.3	11.4	11.6	11.8	12.1	12.6	
<u>Flanking Transmission Loss - Path data</u>									
Flanking TL for Path Ff_2	R_Ff	ISO 15712-1, Eq. 25a	**56**	**64**	**72**	**79**	**86**	**92**	**75**
Flanking TL for Path Fd_2	R_Fd	ISO 15712-1, Eq. 25a	**54**	**63**	**71**	**78**	**85**	**91**	**73**
Flanking TL for Path Df_2	R_Df	ISO 15712-1, Eq. 25a	**54**	**63**	**71**	**78**	**85**	**91**	**73**
Junction 2: Flanking STC for all paths		Subset of RR-333, Eq. 1.2	- 10*LOG10(10^-7.5 + 10^- 7.3 + 10^- 7.3) =						69
Junction 3 (Separating Wall/Ceiling)									
All input values the same as for Junction 1									
Junction 3: Flanking STC for all paths		Subset of RR-333, Eq. 1.2							65
Junction 4 (Separating Wall/Wall)									
All input data the same as for Junction 2, but different junctions at ceiling and floor change loss factors from Junction 2									
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.232	0.160	0.109	0.073	0.048	0.026	
TL in-situ for F4	R_F4,situ	ISO 15712-1, Eq. 19	42.5	50.9	58.4	65.7	71.9	77.9	61
TL in-situ for f4	R_f4,situ	ISO 15712-1, Eq. 19	42.5	50.9	58.4	65.7	71.9	77.9	61
<u>Junction J4 - Coupling</u>									
Velocity Level Difference for Ff	D_v,Ff_4,situ	ISO 15712-1, Eq. 21, 22	10.6	10.7	10.9	11.1	11.4	11.9	
Velocity Level Difference for Fd	D_v,Fd_4,situ	ISO 15712-1, Eq. 21, 22	10.9	11.0	11.2	11.5	11.8	12.3	
Velocity Level Difference for Df	D_v,Df_4,situ	ISO 15712-1, Eq. 21, 22	10.9	11.0	11.2	11.5	11.8	12.3	
<u>Flanking Transmission Loss - Path data</u>									
Flanking TL for Path Ff_4	R_Ff	ISO 15712-1, Eq. 25a	**54**	**63**	**70**	**78**	**84**	**91**	**73**
Flanking TL for Path Fd_4	R_Fd	ISO 15712-1, Eq. 25a	**54**	**62**	**70**	**77**	**84**	**91**	**73**
Flanking TL for Path Df_4	R_Df	ISO 15712-1, Eq. 25a	**54**	**62**	**70**	**77**	**84**	**91**	**73**
Junction 4: Flanking STC for all paths		Subset of RR-333, Eq. 1.2	- 10*LOG10(10^-7.3 + 10^- 7.3 + 10^- 7.3) =						68
Total Flanking (for all 4 junctions)		Subset of RR-333, Eq. 1.1	42	49	57	66	73	80	60
ASTC due to Direct plus Flanking Paths		RR-333, Eq. 1.1	**39**	**47**	**55**	**62**	**69**	**76**	**58**

EXAMPLE 4.2-V1: (DETAILED METHOD)

- **Rooms one-above-the-other**
- **Loadbearing solid precast concrete walls and hollowcore precast concrete floors with rigid junctions**

Separating floor/ceiling assembly with:

- hollowcore precast slabs (i.e.- normal weight concrete, floor 203 mm thick, mass/area 300 kg/m² including grout at joints)
- no topping or finish flooring, and no ceiling lining below

Junction 1, 3, 4:
Cross Junction of separating floor / flanking wall with:

- rigid grouted cross junction with precast concrete walls above and below the floor
- walls of solid reinforced precast concrete (i.e.- normal weight concrete, wall 200 mm thick, mass/area 460 kg/m² including grout at joints) with no lining of walls

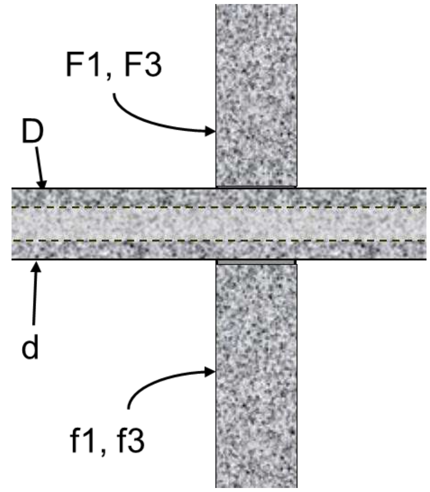
Junction 2: T-Junction of separating floor / flanking wall with:

- rigid grouted T-junctions with precast concrete walls above and below floor
- walls of solid reinforced precast concrete (i.e.- normal weight concrete, 200 mm thick, and mass/area 460 kg/m² including grout at joints) with no lining of walls

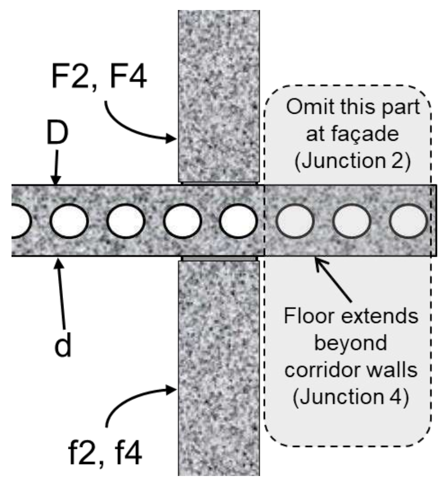
Acoustical parameters:

For separating assembly:						
internal loss, η_i =	0.015		c_L =	3500		
mass (kg/m²) =	300		f_c =	91		(Eq. C.2)
	Reference	K_Ff	K_Dd'	K_Fd	K_Df	Σ l_k . α_k
X-Junction 1, 3, 4	ISO 15712-1, Eq. E.3	5.7	12.1	8.9	8.9	0.485
T-Junction 2	ISO 15712-1, Eq. E.4	3.3		5.9	5.9	0.626
Total loss, η_tot	ISO 15712-1, Eq. C.1			0.033	(at 500 Hz)	
Similarly, for flanking elements F and f at Junction 1 & 3,						
internal loss, η_i =	0.006		c_L =	3500		
mass (kg/m²) =	460		f_c =	93		
Total loss, η_tot	ISO 15712-1, Eq. C.1			0.037	(at 500 Hz)	
Similarly, for flanking elements F and f at Junction 2 & 4,						
internal loss, η_i =	0.006		c_L =	3500		
mass (kg/m²) =	460		f_c =	93		
Total loss, η_tot,2	ISO 15712-1, Eq. C.1			0.048	(at 500 Hz)	
Total loss, η_tot,4	ISO 15712-1, Eq. C.1			0.034	(at 500 Hz)	

Illustration for this case



Cross junction of separating floor of 203 mm thick hollowcore precast concrete with precast concrete wall. (Side view of Junctions 1, 3)



Junction of separating floor of 203 mm thick hollowcore precast concrete floor with precast concrete flanking wall. (Side view of Junction 2 or 4).

	ISO Symbol	Reference	125	250	500	1000	2000	4000	STC or ASTC
Separating Floor									
Sound Transmission Loss (TL)	R_D,lab	RR-333, HCON203(Mean)	38	44	52	58	63	71	55
Structural Reverberation Time	T_s,lab	Measured T_s	0.31	0.20	0.13	0.11	0.08	0.05	
Change by Lining on source side	ΔR_D	No lining ,	0	0	0	0	0	0	
Change by Lining on receive side	ΔR_d	No lining ,	0	0	0	0	0	0	
Transferred Data In-situ									
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.347	0.222	0.137	0.082	0.047	0.026	
Effect of Airborne Flanking		No leakage	0.0	0.0	0.0	0.0	0.0	0.0	
Direct TL in-situ	**R_D,situ**	**ISO 15712-1, Eq. 24**	**38**	**44**	**52**	**59**	**66**	**74**	**55**

	ISO Symbol	Reference	125	250	500	1000	2000	4000	STC or ASTC
Junction 1 (Separating Floor/Wall)									
Sound Transmission Loss, F1 or f1	R_F1,lab	RR-334, CON200	41	49	55	62	69	75	59
Structural Reverberation Time	T_s,lab	RR-334, RT-CON200	0.324	0.250	0.240	0.170	0.093	0.060	
Change by Lining on source side	ΔR_F1	No lining ,	0	0	0	0	0	0	
Change by Lining on receive side	ΔR_f1	No lining ,	0	0	0	0	0	0	
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.249	0.172	0.117	0.078	0.051	0.032	
TL in-situ for F1	R_F1,situ	ISO 15712-1, Eq. 19	42.1	50.6	58.1	65.4	71.6	77.7	61
TL in-situ for f1	R_f1,situ	ISO 15712-1, Eq. 19	42.1	50.6	58.1	65.4	71.6	77.7	61
Junction J1 - Coupling									
Velocity Level Difference for Ff	D_v,Ff_1,situ	ISO 15712-1, Eq. 21, 22	8.2	8.4	8.5	8.8	9.1	9.6	
Velocity Level Difference for Fd	D_v,Fd_1,situ	ISO 15712-1, Eq. 21, 22	11.7	12.0	12.4	12.9	13.5	14.3	
Velocity Level Difference for Df	D_v,Df_1,situ	ISO 15712-1, Eq. 21, 22	11.7	12.0	12.4	12.9	13.5	14.3	
Flanking Transmission Loss - Path data									
Flanking TL for Path Ff_1	R_Ff	ISO 15712-1, Eq. 25a	**52**	**61**	**69**	**76**	**83**	**89**	**71**
Flanking TL for Path Fd_1	R_Fd	ISO 15712-1, Eq. 25a	**53**	**60**	**68**	**76**	**83**	**91**	**71**
Flanking TL for Path Df_1	R_Df	ISO 15712-1, Eq. 25a	**53**	**60**	**68**	**76**	**83**	**91**	**71**
Junction 1: Flanking STC for all paths		Subset of RR-333, Eq. 1.2	- 10*LOG10(10^-7.1 + 10^- 7.1 + 10^- 7.1) =						66
Junction 2 (Separating Floor/Wall)									
Sound Transmission Loss, F2 or f2	R_F2,lab	RR-334, CON200	41	49	55	62	69	75	59
Structural Reverberation Time	T_s,lab	RR-334, RT-CON200	0.324	0.250	0.240	0.170	0.093	0.060	
Change by Lining on source side	ΔR_F2	No lining ,	0	0	0	0	0	0	
Change by Lining on receive side	ΔR_f2	No lining ,	0	0	0	0	0	0	
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.192	0.133	0.091	0.061	0.041	0.026	
TL in-situ for F2	R_F2,situ	ISO 15712-1, Eq. 19	43.3	51.7	59.2	66.4	72.6	78.6	62
TL in-situ for f2	R_f2,situ	ISO 15712-1, Eq. 19	43.3	51.7	59.2	66.4	72.6	78.6	62
Junction J2 - Coupling									
Velocity Level Difference for Ff	D_v,Ff_2,situ	ISO 15712-1, Eq. 21, 22	7.0	7.1	7.2	7.4	7.7	8.1	
Velocity Level Difference for Fd	D_v,Fd_2,situ	ISO 15712-1, Eq. 21, 22	9.8	10.1	10.4	10.9	11.5	12.2	
Velocity Level Difference for Df	D_v,Df_2,situ	ISO 15712-1, Eq. 21, 22	9.8	10.1	10.4	10.9	11.5	12.2	
Flanking Transmission Loss - Path data									
Flanking TL for Path Ff_2	R_Ff	ISO 15712-1, Eq. 25a	**53**	**62**	**69**	**77**	**83**	**90**	**72**
Flanking TL for Path Fd_2	R_Fd	ISO 15712-1, Eq. 25a	**52**	**59**	**68**	**75**	**82**	**90**	**70**
Flanking TL for Path Df_2	R_Df	ISO 15712-1, Eq. 25a	**52**	**59**	**68**	**75**	**82**	**90**	**70**
Junction 2: Flanking STC for all paths		Subset of RR-333, Eq. 1.2	- 10*LOG10(10^-7.2 + 10^- 7 + 10^- 7) =						66
Junction 3 (Separating Floor/Wall)									
All input values the same as for Junction 1									
Junction 3: Flanking STC for all paths		Subset of RR-333, Eq. 1.2							66
Junction 4 (Separating Floor/Wall)									
All input data the same as for Junction 2, but different junctions at ceiling and floor change loss factors and junction attenuation									
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.232	0.160	0.109	0.073	0.048	0.026	
TL in-situ for F4	R_F4,situ	ISO 15712-1, Eq. 19	42.5	50.9	58.4	65.7	71.9	77.9	61
TL in-situ for f4	R_f4,situ	ISO 15712-1, Eq. 19	42.5	50.9	58.4	65.7	71.9	77.9	61
Junction J4 - Coupling									
Velocity Level Difference for Ff	D_v,Ff_4,situ	ISO 15712-1, Eq. 21, 22	8.6	8.7	8.8	9.1	9.4	9.8	
Velocity Level Difference for Fd	D_v,Fd_4,situ	ISO 15712-1, Eq. 21, 22	12.4	12.7	13.0	13.5	14.1	14.9	
Velocity Level Difference for Df	D_v,Df_4,situ	ISO 15712-1, Eq. 21, 22	12.4	12.7	13.0	13.5	14.1	14.9	
Flanking Transmission Loss - Path data									
Flanking TL for Path Ff_4	R_Ff	ISO 15712-1, Eq. 25a	**54**	**63**	**70**	**78**	**84**	**91**	**73**
Flanking TL for Path Fd_4	R_Fd	ISO 15712-1, Eq. 25a	**54**	**62**	**70**	**77**	**85**	**92**	**72**
Flanking TL for Path Df_4	R_Df	ISO 15712-1, Eq. 25a	**54**	**62**	**70**	**77**	**85**	**92**	**72**
Junction 4: Flanking STC for all paths		Subset of RR-333, Eq. 1.2	- 10*LOG10(10^-7.3 + 10^- 7.2 + 10^- 7.2) =						68
Total Flanking (for all 4 junctions)		Subset of RR-333, Eq. 1.1	42	50	58	65	72	80	61
ASTC due to Direct plus Flanking Paths		RR-333, Eq. 1.1	**37**	**43**	**51**	**58**	**65**	**73**	**54**

EXAMPLE 4.2-V2: (DETAILED METHOD)

- **Rooms one-above-the-other**
- **Loadbearing solid precast concrete walls and hollowcore precast concrete floors with rigid junctions**

(Same as Example 4.2-V1 plus floor topping)

Separating floor/ceiling assembly with:

- hollowcore precast slabs (i.e.- normal weight concrete, 203 mm thick, mass/area 300 kg/m^2 including grout at joints)
- lining of 25 mm thick gypsum concrete topping without finish flooring on top of floor, and no ceiling lining below

Junction 1, 3, 4:
Cross Junction of separating floor / flanking wall with:

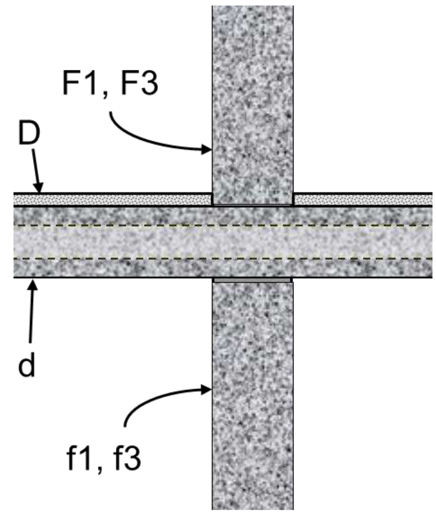
- rigid grouted cross junction with precast concrete walls above and below the floor
- walls of solid reinforced precast concrete (i.e.- normal weight concrete, 200 mm thick, mass/area 460 kg/m^2 including grout at joints) with no lining of walls

Junction 2: T-Junction of separating floor / flanking wall with:

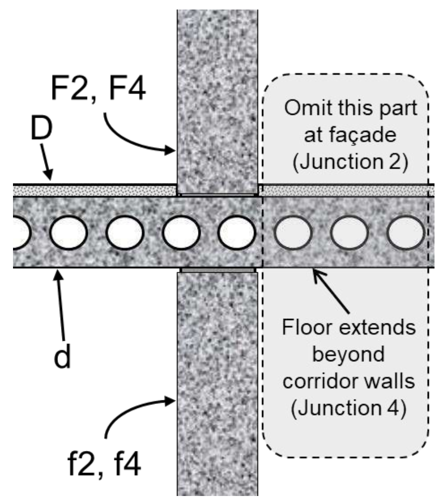
- rigid grouted T-junctions with precast concrete walls above and below floor
- walls of solid reinforced precast concrete (i.e.- normal weight concrete, 200 mm thick, mass/area 460 kg/m^2 including grout at joints) with no lining of walls

For separating assembly:						
internal loss, η_i =	0.015		c_L =	3500		
mass (kg/m^2) =	300		f_c =	91		(Eq. C.2)
	Reference	K_Ff	K_Dd'	K_Fd	K_Df	Σ l_k . α_k
X-Junction 1, 3, 4	ISO 15712-1, Eq. E.3	5.7	12.1	8.9	8.9	0.485
T-Junction 2	ISO 15712-1, Eq. E.4	3.3		5.9	5.9	0.626
Total loss, η_{tot}	ISO 15712-1, Eq. C.1			0.033	(at 500 Hz)	
Similarly, for flanking elements F and f at Junction 1 & 3,						
internal loss, η_i =	0.006		c_L =	3500		
mass (kg/m^2) =	460		f_c =	93		
Total loss, η_{tot}	ISO 15712-1, Eq. C.1			0.037	(at 500 Hz)	
Similarly, for flanking elements F and f at Junction 2 & 4,						
internal loss, η_i =	0.006		c_L =	3500		
mass (kg/m^2) =	460		f_c =	93		
Total loss, $\eta_{tot,2}$	ISO 15712-1, Eq. C.1			0.048	(at 500 Hz)	
Total loss, $\eta_{tot,4}$	ISO 15712-1, Eq. C.1			0.034	(at 500 Hz)	

Illustration for this case



Cross junction of separating floor of 203 mm thick hollowcore precast concrete with precast concrete wall. (Side view of Junctions 1, 3)



Junction of separating floor of 203 mm thick hollowcore precast concrete floor with precast concrete flanking wall. (Side view of Junction 2 or 4).

	ISO Symbol	Reference	125	250	500	1000	2000	4000	STC or ASTC
Separating Floor									
Sound Transmission Loss (TL)	R_D,lab	RR-333, HCON203(Mean)	38	44	52	58	63	71	55
Structural Reverberation Time	T_s,lab	Measured T_s	0.31	0.20	0.13	0.11	0.08	0.05	
Change by Lining on source side	ΔR_D	ΔTL-HCON203-F01 ,	2	0	1	4	4	3	
Change by Lining on receive side	ΔR_d	No lining ,	0	0	0	0	0	0	
Transferred Data In-situ									
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.347	0.222	0.137	0.082	0.047	0.026	
Effect of Airborne Flanking		No leakage	0.0	0.0	0.0	0.0	0.0	0.0	
Direct TL in-situ	R_D,situ	ISO 15712-1, Eq. 24	**40**	**44**	**53**	**63**	**70**	**77**	**56**

	ISO Symbol	Reference	125	250	500	1000	2000	4000	STC or ASTC
Junction 1 (Separating Floor/Wall)									
Sound Transmission Loss, F1 or f1	R_F1,lab	RR-334, CON200	41	49	55	62	69	75	59
Structural Reverberation Time	T_s,lab	RR-334, RT-CON200	0.324	0.250	0.240	0.170	0.093	0.060	
Change by Lining on source side	ΔR_F1	No lining ,	0	0	0	0	0	0	
Change by Lining on receive side	ΔR_f1	No lining ,	0	0	0	0	0	0	
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.249	0.172	0.117	0.078	0.051	0.032	
TL in-situ for F1	R_F1,situ	ISO 15712-1, Eq. 19	42.1	50.6	58.1	65.4	71.6	77.7	61
TL in-situ for f1	R_f1,situ	ISO 15712-1, Eq. 19	42.1	50.6	58.1	65.4	71.6	77.7	61
Junction J1 - Coupling									
Velocity Level Difference for Ff	D_v,Ff_1,situ	ISO 15712-1, Eq. 21, 22	8.2	8.4	8.5	8.8	9.1	9.6	
Velocity Level Difference for Fd	D_v,Fd_1,situ	ISO 15712-1, Eq. 21, 22	11.7	12.0	12.4	12.9	13.5	14.3	
Velocity Level Difference for Df	D_v,Df_1,situ	ISO 15712-1, Eq. 21, 22	11.7	12.0	12.4	12.9	13.5	14.3	
Flanking Transmission Loss - Path data									
Flanking TL for Path Ff_1	R_Ff	ISO 15712-1, Eq. 25a	**52**	**61**	**69**	**76**	**83**	**89**	**71**
Flanking TL for Path Fd_1	R_Fd	ISO 15712-1, Eq. 25a	**53**	**60**	**68**	**76**	**83**	**91**	**71**
Flanking TL for Path Df_1	R_Df	ISO 15712-1, Eq. 25a	**55**	**60**	**69**	**80**	**87**	**94**	**72**
Junction 1: Flanking STC for all paths		Subset of RR-333, Eq. 1.2	- 10*LOG10(10^-7.1 + 10^- 7.1 + 10^- 7.2) =						67
Junction 2 (Separating Floor/Wall)									
Sound Transmission Loss, F2 or f2	R_F2,lab	RR-334, CON200	41	49	55	62	69	75	59
Structural Reverberation Time	T_s,lab	RR-334, RT-CON200	0.324	0.250	0.240	0.170	0.093	0.060	
Change by Lining on source side	ΔR_F2	No lining ,	0	0	0	0	0	0	
Change by Lining on receive side	ΔR_f2	No lining ,	0	0	0	0	0	0	
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.192	0.133	0.091	0.061	0.041	0.026	
TL in-situ for F2	R_F2,situ	ISO 15712-1, Eq. 19	43.3	51.7	59.2	66.4	72.6	78.6	62
TL in-situ for f2	R_f2,situ	ISO 15712-1, Eq. 19	43.3	51.7	59.2	66.4	72.6	78.6	62
Junction J2 - Coupling									
Velocity Level Difference for Ff	D_v,Ff_2,situ	ISO 15712-1, Eq. 21, 22	7.0	7.1	7.2	7.4	7.7	8.1	
Velocity Level Difference for Fd	D_v,Fd_2,situ	ISO 15712-1, Eq. 21, 22	9.8	10.1	10.4	10.9	11.5	12.2	
Velocity Level Difference for Df	D_v,Df_2,situ	ISO 15712-1, Eq. 21, 22	9.8	10.1	10.4	10.9	11.5	12.2	
Flanking Transmission Loss - Path data									
Flanking TL for Path Ff_2	R_Ff	ISO 15712-1, Eq. 25a	**53**	**62**	**69**	**77**	**83**	**90**	**72**
Flanking TL for Path Fd_2	R_Fd	ISO 15712-1, Eq. 25a	**52**	**59**	**68**	**75**	**82**	**90**	**70**
Flanking TL for Path Df_2	R_Df	ISO 15712-1, Eq. 25a	**54**	**59**	**69**	**79**	**86**	**93**	**71**
Junction 2: Flanking STC for all paths		Subset of RR-333, Eq. 1.2	- 10*LOG10(10^-7.2 + 10^- 7 + 10^- 7.1) =						66
Junction 3 (Separating Floor/Wall)									
All input values the same as for Junction 1									
Junction 3: Flanking STC for all paths		Subset of RR-333, Eq. 1.2							67
Junction 4 (Separating Floor/Wall)									
All input data the same as for Junction 2, but different junctions at ceiling and floor change loss factors and junction attenuation									
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.232	0.160	0.109	0.073	0.048	0.026	
TL in-situ for F4	R_F4,situ	ISO 15712-1, Eq. 19	42.5	50.9	58.4	65.7	71.9	77.9	61
TL in-situ for f4	R_f4,situ	ISO 15712-1, Eq. 19	42.5	50.9	58.4	65.7	71.9	77.9	61
Junction J4 - Coupling									
Velocity Level Difference for Ff	D_v,Ff_4,situ	ISO 15712-1, Eq. 21, 22	8.6	8.7	8.8	9.1	9.4	9.8	
Velocity Level Difference for Fd	D_v,Fd_4,situ	ISO 15712-1, Eq. 21, 22	12.4	12.7	13.0	13.5	14.1	14.9	
Velocity Level Difference for Df	D_v,Df_4,situ	ISO 15712-1, Eq. 21, 22	12.4	12.7	13.0	13.5	14.1	14.9	
Flanking Transmission Loss - Path data									
Flanking TL for Path Ff_4	R_Ff	ISO 15712-1, Eq. 25a	**54**	**63**	**70**	**78**	**84**	**91**	**73**
Flanking TL for Path Fd_4	R_Fd	ISO 15712-1, Eq. 25a	**54**	**62**	**70**	**77**	**85**	**92**	**72**
Flanking TL for Path Df_4	R_Df	ISO 15712-1, Eq. 25a	**56**	**62**	**71**	**81**	**89**	**95**	**73**
Junction 4: Flanking STC for all paths		Subset of RR-333, Eq. 1.2	- 10*LOG10(10^-7.3 + 10^- 7.2 + 10^- 7.3) =						68
Total Flanking (for all 4 junctions)		Subset of RR-333, Eq. 1.1	43	50	58	66	73	80	61
ASTC due to Direct plus Flanking Paths		RR-333, Eq. 1.1	**38**	**43**	**52**	**61**	**68**	**75**	**55**

Summary for Section 4.2: Calculation Examples for Detailed Method

The worked examples 4.2-H1 to 4.2-V2 illustrate the use of the Detailed Method for calculating the sound transmission loss between rooms in a building with solid precast concrete walls and hollowcore precast concrete floor assemblies, with or without linings added to some of the floors.

Examples 4.2-H1 and 4.2-V1 show the performance for two cases with "bare" precast concrete assemblies. Examples 4.2-H2 and 4.2-V2 show corresponding cases with improvements in direct and/or flanking transmission loss via specific paths due to the addition of floor linings. Many other lining options are possible, but evaluating the benefit of specific linings is not the focus of this section – rather, it provides a basis for comparing the Detailed Method with the Simplified Method presented in Section 4.1.

Each example has a counterpart in the Simplified Method calculations in Section 4.1. The differences between the results (Detailed Method vs. Simplified Method) are compared in the table below.

Detailed Method		Simplified Method		Subsets (Detailed vs. Simplified)	
Example	ASTC	Example	ASTC	Direct STC	Total Flanking STC
4.2-H1	57	4.1-H1	57	61 vs. 61	59 vs. 60
4.2-H2	57	4.1-H2	58	61 vs. 61	59 vs. 60
4.2-V1	54	4.1-V1	54	55 vs. 55	61 vs. 61
4.2-V2	55	4.1-V4	55	56 vs. 56	61 vs. 61

This limited set of comparisons is consistent with larger validation studies of the ISO procedure, which have shown that the Detailed Method tends to give slightly higher values of R'_w (the counterpart of the ASTC rating) than the Simplified Method, especially if linings are used.

The basic conclusion that can be drawn from these examples is that the Simplified and Detailed Methods predict similar ASTC ratings for precast concrete buildings. For the cases presented here, most of the ASTC ratings were the same for both methods with differences evident in the total Flanking STC. The differences between the methods would tend to increase for designs with better linings on most surfaces with the Simplified Method tending to calculate ASTC ratings that are lower than those calculated using the Detailed Method.

The calculations using both the Simplified and Detailed Methods used the mean value for the transmission loss and the mean structural reverberation time for the 203 mm thick hollowcore prestressed concrete floor. The determination of the mean value included one floor which had a mass per unit area of 273 kg/m^2 (with grout). Based on the calculations, it is expected that 190 mm normal weight hollow concrete block units, nominally 53% solid (assembly surface weight of at least 238 kg/m^2) or 200 mm thick walls of solid reinforced precast concrete (mass per unit area 460 kg/m^2 including grout at the joints) connected to a hollowcore prestressed concrete floor with a mass per unit area of 273 kg/m^2 (with grout) will achieve an ASTC rating which is greater than or equal to 47.

5 Appendices

Appendix A1 presents data in one-third octave bands. Details of the test facilities and the measurement procedures are given in Chapter 2 and Chapter 3. The data includes:

- The airborne sound transmission loss data for the precast concrete wall assemblies and the hollowcore precast concrete floor assemblies (without added linings) which was measured according to ASTM standard E90.
- The change in the transmission loss ΔTL data linings applied to the hollowcore precast concrete floor assemblies.

The process for determining the ΔTL values is described in Chapter 2. The one-third octave band ΔTL data given in this Appendix may be used for calculations according to the Detailed Method of ISO 15712-1, as described in Section 4.2. The single number STC and ΔSTC data given in this Appendix may be used for calculations according to the Simplified Method of ISO 15712-1, as described in Section 4.1.

Appendix A2 presents the procedure for calculating the ΔSTC rating. It is a subset of a more general set of procedures presented in NRC Research Report RR-331, "Guide to Calculating Airborne Sound Transmission in Buildings" [14].

Appendix A3 presents references for ASTC examples for buildings constructed of hollowcore precast concrete floor assemblies connected to hollow concrete block masonry walls.

Appendix A4 presents an ASTC example of a buildings constructed of hollowcore precast concrete floor assemblies connected to outer walls of hollow concrete block masonry walls and non-load bearing steel stud walls between rooms.

5.1 Appendix A1: Sound Transmission Loss for Precast Concrete Assemblies

Table A1.1: Sound transmission loss for hollowcore precast concrete floor assemblies

Floor Code	Description	STC	63 Hz			125 Hz			250 Hz		
HCON305	Hollowcore prestressed concrete slabs 305 mm thick, with joints fully grouted, mass/area of 435 kg/m^2	57	40	43	42	39	40	42	43	49	49
HCON203(344)	Hollowcore prestressed concrete slabs 203 mm thick, with joints fully grouted, mass/area of 344 kg/m^2	56	40	40	39	35	38	41	41	46	48
HCON203(Mean)	Hollowcore prestressed concrete slabs 203 mm thick, with joints fully grouted, Mean of tests for specimens with mass/areas of 273 kg/m^2, 305 kg/m^2 and 344 kg/m^2	55	32	42	40	37	38	40	41	44	46

Note: Corresponding data for solid reinforced concrete assembly CON200 is given in Report RR-334.

Table A1.2: Change in sound transmission loss due to lining on precast concrete floor assemblies

Lining Code	Description	ΔSTC	125 Hz			250 Hz		
DTL-HCON203-F01	25 mm thick gypsum concrete topping applied over floor assembly of hollowcore prestressed concrete slabs 203 mm thick	1	1	2	-1	1	0	1
DTL-HCON203-F02	6mm carpet and underlay on 25 mm thick gypsum concrete topping applied over floor assembly of hollowcore prestressed concrete slabs 203 mm thick	1	-1	1	-2	1	0	0

(Continuation of Table A1.1 from opposite page):

500 Hz			1000 Hz			2000 Hz			4000 Hz			Reference
53	52	56	57	59	60	62	65	68	66	67	70	TLF-14-038
49	52	55	57	60	62	64	65	67	68	72	75	TLF-14-034
49	52	54	56	58	60	62	63	65	67	71	72	TLF-14-034, TLF-17-081, TLF-18-008

(Continuation of Table A1.2 from opposite page):

500 Hz			1000 Hz			2000 Hz			4000 Hz			Reference
0	1	2	3	4	4	4	4	4	3	3	1	TLF-18-001, TLF-17-081
0	1	2	3	5	7	8	10	12	13	14	15	TLF-18-002, TLF-17-081

Table A1.3: Structural reverberation time data for hollowcore precast concrete floor specimens

Specimen Code	Specimen Description	63 Hz			125 Hz			250 Hz		
RT-HCON305	Hollowcore prestressed concrete slabs 203 mm thick, with joints fully grouted, mass/area of 435 kg/m^2	1.2	.67	.77	.54	.60	.50	.54	.42	.34
RT- HCON203(344)	Hollowcore prestressed precast concrete slabs 203 mm thick, with joints fully grouted, mass/area of 344 kg/m^2	1.1	.73	.67	.59	.46	.44	.41	.33	.34
RT-HCON203(Mean)	Hollowcore prestressed precast concrete slabs 203 mm thick, with joints fully grouted, Mean of tests for specimens with mass/area of 273, 344 kg/m^2	.81	.52	.48	.41	.31	.29	.25	.20	.20

Note: Corresponding data for solid reinforced concrete assembly CON200 is given in Report RR-334.

(Continuation of Table A1.3 from opposite page):

500 Hz			1000 Hz			2000 Hz			4000 Hz			Reference
.28	.24	.21	.21	.15	.15	.14	.13	.10	.09	.07	.06	TLF-14-038
.22	.20	.18	.17	.17	.11	.10	.11	.09	.07	.06	.04	TLF-14-034
.14	.13	.11	.11	.11	.08	.08	.08	.07	.06	.05	.04	TLF-14-034, TLF-18-008

5.2 Appendix A2: Calculating ΔSTC for Linings on Precast Concrete Floors

It is common practice, especially in residential buildings, to add finishing surfaces to the basic structural floor or wall assemblies to conceal both the bare structure surfaces as well as the building services such as electrical wiring, water pipes and ventilation ducts. The finishing on walls or ceilings is commonly comprised of gypsum board panels, framing used to support the gypsum board panels and sound absorptive material in the inter-framing cavities between the gypsum board and the face of the basic structural floor or wall assemblies. On floors, the finish may include toppings such as concrete or a floating floor as well as flooring such as hardwood or tiles. These elements are described in ISO 15712-1 as "linings" or "liners" or "layers" or "coverings". The term "linings" is used in this Report. To characterize the change in sound transmission loss due to adding a specific lining to a heavy base wall or floor, a single number rating called ΔSTC is introduced.

Key issues concerning ΔSTC include:

- ΔSTC is a required input for calculation of the ASTC rating using the Simplified Method of ISO 15712-1 which is presented in Chapter 4.
- Values of ΔSTC calculated from the experimental data in this Report are presented in Table 2.2.1. Readers of this Report can use the tabulated ΔSTC values without the need to perform the ASTC rating calculations detailed in Section 4.1.
- The procedure for calculating the ΔSTC rating is presented here for completeness. It is a subset of a more general set of procedures presented in NRC Research Report RR-331, "Guide to Calculating Airborne Sound Transmission in Buildings".

ASTM does not define a ΔSTC rating, but there is a counterpart in the ISO standards called ΔR_W. The procedure used here is modified from its ISO counterpart in two ways:

1. The STC calculation according to ASTM E413 is substituted for the ISO single number rating R_W, plus additional Steps 4 and 5 are included, as shown in Figure A2.2 and explained in the adjacent text.
2. The procedure to calculate ΔSTC values for the Simplified Method used in Chapter 4 uses a Reference Curve, as explained in general in Appendix A1 of Report RR-331. The set of for reference curves provided in Appendix A1 of RR-331 is largely based on the Reference Curves in Annex B of ISO 140-16. The reference curves in Appendix A1 of RR-331 include a reference curve for heavy concrete floors of solid reinforced concrete and three curves for base wall assemblies.

In selecting the appropriate reference curve for the calculation of the ΔSTC rating of a lining on a hollowcore precast concrete floor, the mass or thickness of the unlined base wall or floor assembly is irrelevant. What matters is the frequency dependence of its sound transmission loss curve, especially around the frequency where the curve transitions from a comparatively flat plateau at low frequencies to a slope rising at about 2 dB per one-third octave band. If the standard reference curves are not a good match to the sound transmission loss curve for the base assembly to which the linings were added, the ISO standard also permits the use of the transmission loss curve for the tested base assembly as a special reference curve, with the restriction that the calculated single number rating applies only when the lining is applied to a base construction that closely matches the tested case.

<u>The most suitable Reference Curve</u> was determined by comparing the most appropriate Reference Curve from RR-331 versus the measured sound transmission loss data for the bare, hollowcore precast concrete floor assemblies presented in Section 2.1 of this Report. To establish the best reference curve for a given base specimen, the reference curve should be fitted to the transmission loss curve for the tested assembly. This permits clear assessment of the fit below and above the frequency where the curve bends up (about 250 Hz for the precast concrete specimens). The reference curve can be shifted up or down (changing the transmission loss at all frequency bands by the same amount) without altering the calculation of ΔSTC because the ΔSTC is the *difference* between the STC for the reference curve versus the STC for the curve obtained by adding the ΔTL curve to the reference curve.

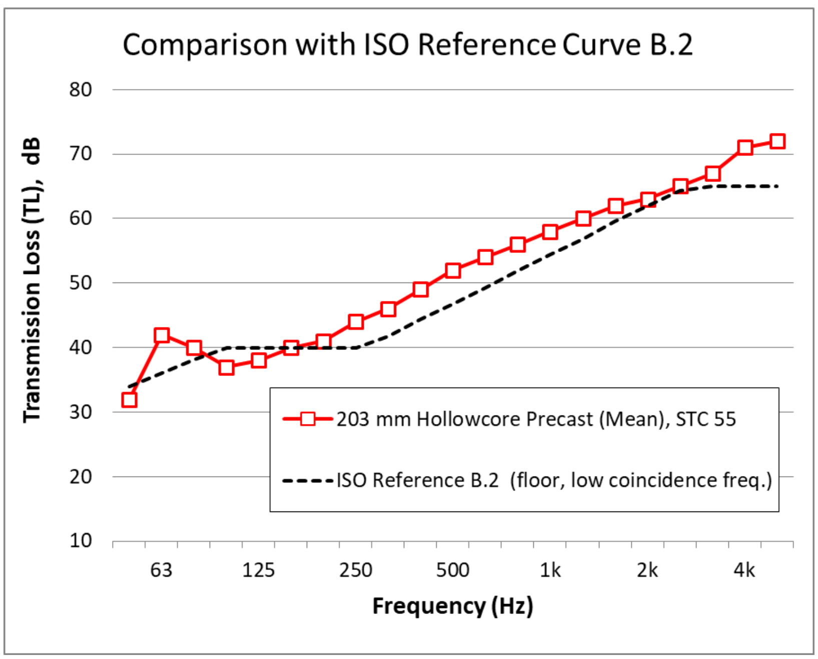
Figure A2.1 compares Reference Curve Floor 1 (ISO ref. Curve B.2) versus the measured sound transmission loss curve for 203 mm thick hollowcore precast concrete, HCON203(Mean). Unfortunately, the systematic difference in the rising section and the characteristic dips of the HCON203 curves in the plateau region below 250 Hz were shown to change the calculated ΔSTC results.

Rather than develop a new reference curve for the two linings evaluated in this Report, the transmission loss curve for* HCON203(Mean) *was used as the reference curve for hollowcore precast concrete floor assemblies

Figure A2.1
Sound transmission loss for the HCON203(Mean) case versus ISO Reference Curve B.2. which is intended for concrete floors.

For this case, the line segments do not match very well:

- In the rising segment (250 Hz to 2 kHz) the measured values lie several dB above the corresponding values of the Reference Curve.
- In the low frequency plateau (100 Hz to 250 Hz) the mean deviation is small, but there are differences that alter the effect of negative ΔTL values.



Procedure for Calculating the ΔSTC Rating

The procedure to establish the change in transmission loss ΔTL due to adding each tested lining was presented in Sections 2.2 and 2.3. The following procedure uses those values for ΔTL (in one-third octave bands) for each lining to calculate the corresponding single number ΔSTC ratings.

The ΔSTC rating is used in the Simplified Method calculation of the ASTC rating, as presented in Section 4.1 of Chapter 4. The steps in the procedure are shown schematically in Figure A2.2 and explained in the text below.

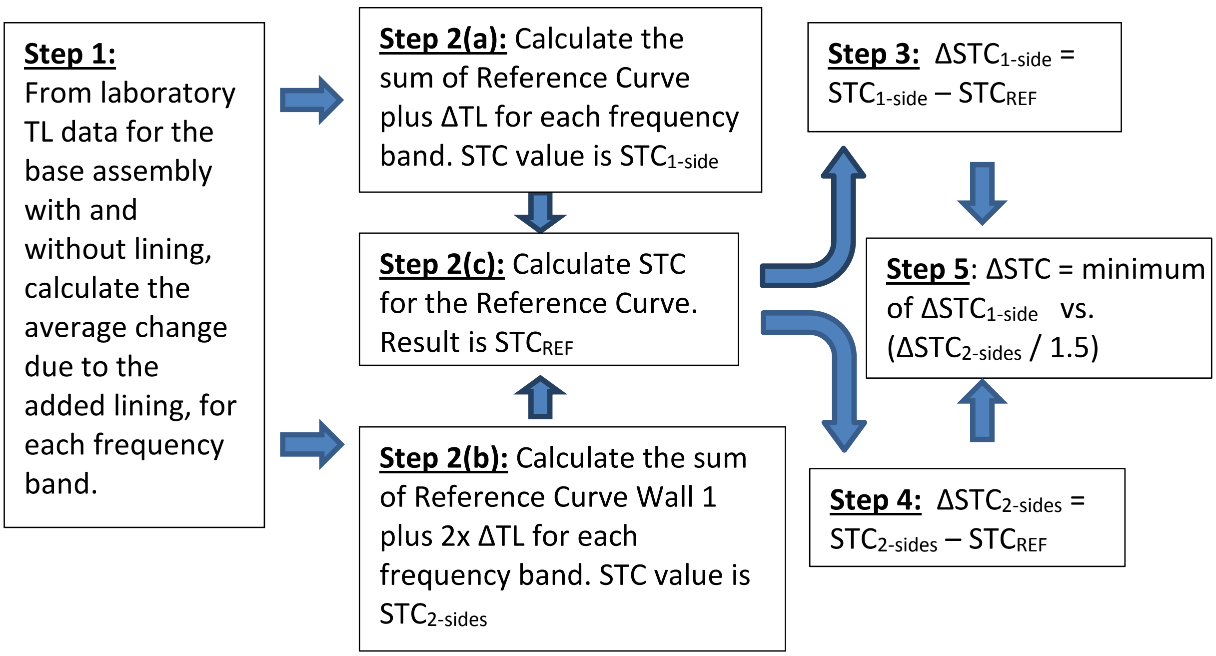


Figure A2.2: Steps to calculate the Single Number Rating ΔSTC for Added Linings (as detailed below)

Step 1. The change in the sound transmission loss (ΔTL) due to the addition of the lining on the Base assembly is calculated from the laboratory test results according to ASTM E90 (for the base assembly without any added lining and for that assembly with lining(s) added) for each frequency band, including at least 125 Hz to 4 kHz. This may involve averaging results from several pairs of assemblies.

Step 2. (a) Calculate the sum of the sound transmission loss for the chosen reference curve (from Table A2.1) plus ΔTL for each frequency band. The STC rating for this case is $STC_{1\text{-Side}}$.
(b) Calculate the sum of the sound transmission loss for the Reference curve (from Table A2.1) plus 2 x ΔTL for each frequency band. The STC rating for this case is $STC_{2\text{-Sides}}$.
(c) Calculate the STC rating for the reference curve (STC_{REF}).

Step 3. Subtract the STC rating of the reference curve (STC_{REF}) from $STC_{1\text{-side}}$ to obtain $\Delta STC_{1\text{-Side}}$.

Step 4. Subtract the STC rating of the reference curve (STC_{REF}) from $STC_{2\text{-sides}}$ to obtain $\Delta STC_{2\text{-Sides}}$.

Step 5. Calculate the ΔSTC value: ΔSTC is the smaller of $\Delta STC_{1\text{-}Side}$ and $\Delta STC_{2\text{-}Sides}$ divided by 1.5, rounded to integers (e.g. 20/1.5 ⇨ 13).

The change in STC when there is a lining on both surfaces of the wall or floor assemblies (Step 4) and where $\Delta STC_{2\text{-}sides}$ is divided by 1.5 in Step 5 can be understood by considering the use of ΔSTC values in Eq. 4.1.2 and 4.1.3 and in the worked examples of Chapter 4. The selection of the more conservative value of $\Delta STC_{1\text{-}Side}$ and $\Delta STC_{2\text{-}Sides}$ at Step 5 is required to avoid an overestimation of the ΔSTC rating in the simplified calculation procedure. The risk of an overestimation is a concern for linings with negative ΔTL values at the low frequencies which can occur for improperly designed linings such as gypsum board wall or ceiling linings with a small separation between the gypsum board lining and the adjacent concrete surface. The results for wall linings in Report RR-334 provide some examples of improperly designed linings.

5.3 Appendix A3: ASTC Examples for Buildings Constructed of Hollowcore Precast Concrete Floor Assemblies Connected to Hollow Concrete Block Masonry Walls

Worked examples for calculating the ASTC rating for buildings constructed of hollowcore precast concrete floor assemblies connected to hollow concrete block masonry walls can be found in RR-334 *Apparent Sound Insulation in Concrete Block Buildings*.

5.4 Appendix A4: ASTC Example for a Building Constructed of Hollowcore Precast Concrete Floor Assemblies Connected to Non-load Bearing Steel Stud Walls between Rooms.

Building constructions of concrete floors combined with lightweight framed interior wall assemblies are identified in ISO 15712-1 as a special concern for which the standard approach may not give accurate results. To ensure a reasonably conservative approach, Research Report RR-331 recommends the approach of Annex C of ISO 15712-1 to the calculation procedure for these systems.

Please reference Chapter 5 of RR-331 Guide to Calculating Airborne Sound Transmission in Buildings for more information about the method and the extended scenario used for the calculation of the ASTC rating for hybrid constructions.

EXAMPLE 5.4.1: DETAILED METHOD

- **Rooms side-by-side, EXTENDED SCENARIO**
- **Hollowcore precast concrete floors and heavy concrete or masonry façade with lightweight steel stud internal walls**

Separating framed wall assembly with:

- One row of loadbearing 152 mm steel studs[5] of 1.37 mm thick steel, spaced 600 mm o.c., with absorptive material[3] filling the cavities between studs
- 2 layers of 16 mm fire-rated gypsum board[4] attached directly to one side and supported on resilient metal channels[7] on the other side

Junction 1: Bottom Junction (separating wall / floor) with:

- Floor of hollowcore precast concrete slabs (i.e.- normal weight concrete, floor thickness 203 mm and mass/area 300 kg/m²) including grout at joints) with no lining on top
- Rigid cross-junction with steel-framed[5] separating wall assembly

Junction 2: Separating wall / abutting perimeter side wall with:

- Abutting side wall of 190 mm hollow concrete block masonry[1] constructed using normal weight units not less than 53% solid, and with mass per area of 238 kg/m² with no lining.
- T-junction with steel stud[5] separating wall assembly

Junction 3: Top Junction (separating wall / ceiling) with:

- Ceiling of hollowcore precast concrete slabs (i.e.- normal weight concrete, floor thickness 203 mm and mass/area 300 kg/m² including grout at joints) with no lining on top
- Cross-junction with steel stud[5] separating wall assembly

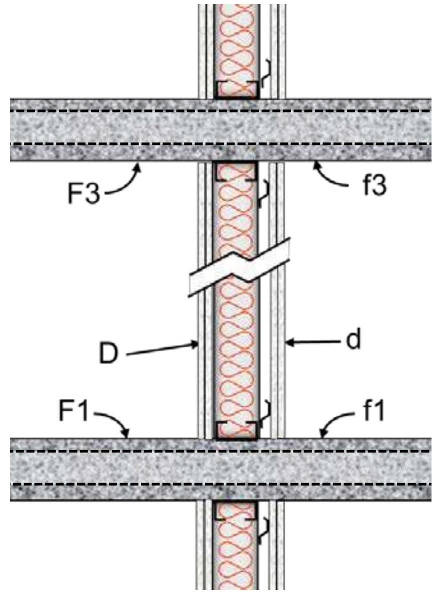
Junction 4: Separating wall / abutting corridor wall with:

- Abutting corridor wall with non-loadbearing 90 mm steel studs[5] of 0.46 mm thick steel, with two layers of fire-rated gypsum board on each side, mounted on resilient metal channels[7] in one room
- T-junction with steel stud[5] separating wall

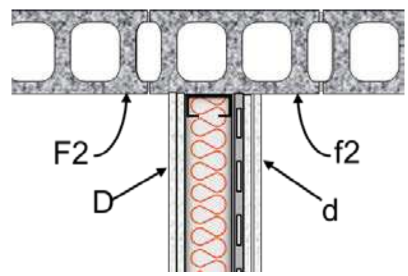
Acoustical Parameters:

For Separating Assembly:					
internal loss, η_i =	dominant (same loss for laboratory and in-situ)				
mass (kg/m²) =	56.8	f_c =	2500		
For Flanking Corridor Wall:	Parameters are the same except mass = 46 kg/m²				
For Flanking Elements F and f at Junction 1 & 3 (Extended hollowcore floor / ceiling)					
internal loss, η_i =	0.015	c_L =	3500		
mass (kg/m²) =	300	f_c =	91		
	Reference	K_Ff	K_Fd	K_dF	Σ l_k . α_k
X-Junction 1 or 3	ISO 15712-1, Eq. 23 & E.7	-3.0	17.2	17.2	(ignore)
T-Junction 2	ISO 15712-1, Eq. 23 & E.4	-3.0	16.2	16.2	6.57
Total loss, η_tot	ISO 15712-1, Eq. C.1-C.3		0.069	(at 500 Hz)	
Similarly, for Flanking Elements F and f at Junction 2 (Extended masonry façade)					
internal loss, η_i =	0.015	c_L =	3500		
mass (kg/m²) =	238	f_c =	98		
	Reference	K_Ff	K_Fd	K_dF	Σ l_k . α_k
T- (above,below)	ISO 15712-1, Eq. 23 & E.4	8.1	5.8		4.5
corner edges	ISO 15712-1, Eq. 23 & E.9		-2.0		
Total loss, η_tot,2	ISO 15712-1, Eq. C.1-C.3		0.087	(at 500 Hz)	

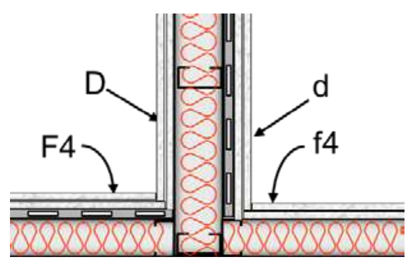
Illustration for this case



Junction of steel stud separating wall floor and ceiling of 203 mm thick hollowcore precast concrete. (Side view of Junctions 1 and 3)



Junction of separating wall with flanking façade wall, of 190 mm concrete block. (Plan view of Junction 2)



Junction of separating wall with flanking corridor wall framed with steel studs. (Plan view of Junction 4)

	ISO Symbol	Reference	125	250	630	1250	2500	5000	STC or ASTC
Separating Partition									
Sound Transmission Loss (TL)	R_D,lab	RR-337, CFS-S152-W33	37	51	56	63	57	64	58
Leakage or Airborne Flanking		Sealed & Blocked	0	0	0	0	0	0	
Direct TL in-situ	R_D,situ	4.2.2: Equal to lab. TL	**37**	**51**	**56**	**63**	**57**	**64**	**58**
Junction 1: Separating Wall/Floor									
Sound Transmission Loss, F1 or f1	R_F1,lab	HCON203(Mean)	38	44	52	58	63	71	55
Structural Reverberation Time	T_s,lab	RT-HCON203(Mean)	0.310	0.200	0.130	0.110	0.080	0.050	
Change by Lining on source side	ΔR_F1	No lining	0	0	0	0	0	0	
Change by Lining on receive side	ΔR_f1	No lining	0	0	0	0	0	0	
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.140	0.095	0.063	0.041	0.026	0.016	
TL in-situ for F1	R_F1,situ	ISO 15712-1, Eq. 19	41.4	47.2	55.1	62.3	67.8	75.9	59
TL in-situ for f1	R_f1,situ	ISO 15712-1, Eq. 19	45.0	47.9	56.0	65.0	73.5	81.8	59
Junction J1 - Coupling									
Velocity Level Difference for Ff	D_v,Ff_1,situ	ISO 15712-1, Eq. 21, 22	4.1	4.3	4.5	4.9	5.3	5.9	
Velocity Level Difference for Fd	D_v,Fd_1,situ	ISO 15712-1, Eq. 21, 22	20.7	21.8	22.9	24.1	25.3	26.6	
Velocity Level Difference for Df	D_v,Df_1,situ	ISO 15712-1, Eq. 21, 22	20.7	21.8	22.9	24.1	25.3	26.6	
Flanking Transmission Loss - Path data									
Flanking TL for Path Ff_1	R_Ff	ISO 15712-1, Eq. 25a	**45**	**50**	**58**	**66**	**74**	**83**	**61**
Flanking TL for Path Fd_1	R_Fd	ISO 15712-1, Eq. 25a	**59**	**70**	**77**	**86**	**87**	**90**	**80**
Flanking TL for Path Df_1	R_Df	ISO 15712-1, Eq. 25a	**61**	**70**	**78**	**87**	**90**	**90**	**80**
Junction 1: Flanking STC for all paths			- 10*LOG10(10^-6.1 + 10^- 8 + 10^- 8) =						61
Junction 2: Separating Wall/Wall									
Sound Transmission Loss, F2 or f2	R_F2,lab	RR-334, Mean-BLK190(NW)	35	38	44	50	58	62	49
Structural Reverberation Time	T_s,lab	RR-334, RT-Mean-BLK190(NW)	0.394	0.255	0.168	0.101	0.056	0.041	
Change by Lining on source side	ΔR_F2	No lining	0	0	0	0	0	0	
Change by Lining on receive side	ΔR_f2	No lining	0	0	0	0	0	0	
Structural Reverb. Time in-situ	T_s,situ	ISO 15712-1, Eq. C.1-C.3	0.109	0.075	0.050	0.033	0.022	0.014	
TL in-situ for F2	R_F2,situ	ISO 15712-1, Eq. 19	40.6	43.3	49.2	54.8	62.1	66.8	54
TL in-situ for f2	R_f2,situ	ISO 15712-1, Eq. 19	40.6	43.3	49.2	54.8	62.1	66.8	54
Junction J2 - Coupling									
Velocity Level Difference for Ff	D_v,Ff_2,situ	ISO 15712-1, Eq. 21, 22	5.2	5.3	5.5	5.8	6.2	6.7	
Velocity Level Difference for Fd	D_v,Fd_2,situ	ISO 15712-1, Eq. 21, 22	21.8	22.9	24.0	25.1	26.3	27.5	
Velocity Level Difference for Df	D_v,Df_2,situ	ISO 15712-1, Eq. 21, 22	21.8	22.9	24.0	25.1	26.3	27.5	
Flanking Transmission Loss - Path data									
Flanking TL for Path Ff_2	R_Ff	ISO 15712-1, Eq. 25a	**47**	**50**	**56**	**62**	**69**	**74**	**60**
Flanking TL for Path Fd_2	R_Fd	ISO 15712-1, Eq. 25a	**61**	**71**	**77**	**84**	**86**	**90**	**81**
Flanking TL for Path Df_2	R_Df	ISO 15712-1, Eq. 25a	**61**	**71**	**77**	**84**	**86**	**90**	**81**
Junction 2: Flanking STC for all paths			- 10*LOG10(10^-6 + 10^- 8.1 + 10^- 8.1) =						60
Junction 3: Separating Wall/Ceiling									
All input values the same as for Junction 1									
Flanking TL for Path Ff_3	R_Ff	ISO 15712-1, Eq. 25a	**45**	**50**	**58**	**66**	**74**	**83**	**61**
Flanking TL for Path Fd_3	R_Fd	ISO 15712-1, Eq. 25a	**59**	**70**	**77**	**86**	**87**	**90**	**80**
Flanking TL for Path Df_3	R_Df	ISO 15712-1, Eq. 25a	**61**	**70**	**78**	**87**	**90**	**90**	**80**
Junction 3: Flanking STC for all paths									61
Junction 4: Separating Wall/Wall									
Flanking Transmission Loss - Measured									
Flanking TL for Path Ff_4	R_Ff	RR-337, CFS-WW-LB152-01	**63**	**90**	**85**	**90**	**78**	**90**	**82**
Flanking TL for Path Fd_4	R_Fd	RR-337, CFS-WW-LB152-01	**67**	**75**	**85**	**90**	**78**	**90**	**82**
Flanking TL for Path Df_4	R_Df	RR-337, CFS-WW-LB152-01	**65**	**68**	**77**	**81**	**72**	**83**	**76**
Junction 4: Flanking STC for all paths			- 10*LOG10(10^-8.2 + 10^- 8.2 + 10^- 7.6) =						74
Total Flanking (for all 4 junctions)									56
ASTC due to Direct plus Flanking Paths		RR-331, Eq. 1.4	**35**	**44**	**51**	**58**	**56**	**63**	**54**

6 References and Endnotes

Technical Standards

1. ASTM E90-09, "Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements", ASTM International, West Conshohocken, PA, USA.
2. ASTM E336-10, "Standard Test Method for Measurement of Airborne Sound Insulation in Buildings", ASTM International, West Conshohocken, PA, USA.
3. Other ASTM standards referenced and used in ASTM E90 and E336 include: ASTM E413-10, "Classification for Rating Sound Insulation" and ASTM E2235-04 "Standard Test Method for Determination of Decay Rates for Use in Sound Insulation Test Methods", ASTM International, West Conshohocken, PA, USA.
4. ISO 717:2013, "Acoustics—Rating of sound insulation in buildings and of building elements—Part 1: Airborne Sound Insulation, Part 2: Impact Sound Insulation" International Organization for Standardization, Geneva.
5. ISO 10140:2011, Parts 1 to 5, "Laboratory measurement of sound insulation of building elements", International Organization for Standardization, Geneva. Note: In 2011 the ISO 10140 series replaced ISO 140 Parts 1, 3, 6, 8, 10, 11 and 16. In 2014, ISO 140-4 was replaced by ISO 16283-1, "Field measurement of sound insulation in buildings and of building elements."
6. ISO 10848:2006, Parts 1 to 4, "Laboratory measurement of flanking transmission of airborne and impact sound between adjoining rooms", International Organization for Standardization, Geneva.
7. ISO 15712:2005, Part 1, "Estimation of acoustic performance of buildings from the performance of elements", International Organization for Standardization, Geneva.

Other Technical References

8. L. Cremer and M. Heckl, "Structure-borne sound", edited by E.E. Ungar, Springer-Verlag, New York (original edition 1973, 2nd edition 1996).
9. E. Gerretsen, "Calculation of the sound transmission between dwellings by partitions and flanking structures", Applied Acoustics, Vol. 12, pp 413-433 (1979), and "Calculation of airborne and impact sound insulation between dwellings", Applied Acoustics, Vol. 19, pp 245-264 (1986).
10. R.J.M. Craik, "Sound transmission through buildings: Using statistical energy analysis", Gower Publishing (1996).
11. D.B. Pedersen, "Evaluation of EN 12354 part 1 and 2 for Nordic Dwelling Houses", Applied Acoustics, Vol. pp 259-268 (2000), (Validation and background studies for the ISO 15712 procedures).

Sources for Sound Transmission Data

Source references for sound transmission loss data (both collections of conventional laboratory test results for wall and floor assemblies according to ASTM E90, and flanking sound transmission tests according to ISO 10848) including many NRC Construction reports in the RR- and IR- series are available from the Publications Archive of the National Research Council Canada at http://nparc.cisti-icist.nrc-cnrc.gc.ca/npsi/ctrl?lang=en.

12. The software application *soundPATHS* is accessible online at the website of the National Research Council Canada. The calculations are based on experimental studies in the laboratories of the NRC: http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/soundpaths/index.html
13. Technical details concerning the measurement protocol (consistent with ISO 10848) and discussion of the findings of the experimental studies are presented in a series of NRC reports:
    - 13.1. Report A1-100035-02.1, "Report to Research Consortium for Wood and Wood-Hybrid Mid-Rise Buildings, Acoustics – Sound Insulation in Mid-Rise Buildings" (2013)
    - 13.2. IR-754, "Flanking Transmission at Joints in Multi-Family Dwellings. Phase 1: Effects of Fire Stops at Floor/Wall Intersections", T.R.T. Nightingale and R.E. Halliwell, (1997)
    - 13.3. RR-103, "Flanking Transmission in Multi-Family Dwellings Phase II: Effects of Continuous Structural Elements at Wall/Floor Junctions", T.R.T. Nightingale, R.E. Halliwell, and J.D. Quirt (2002)
    - 13.4. RR-168, "Flanking Transmission at the Wall/Floor Junction in Multifamily Dwellings - Quantification and Methods of Suppression", T.R.T. Nightingale, R.E. Halliwell, J.D. Quirt and F. King (2005)
    - 13.5. RR-218, "Flanking Transmission in Multi-Family Dwellings Phase IV", T.R.T. Nightingale, J.D. Quirt, F. King and R.E. Halliwell, (2006)
    - 13.6. RR-219, "Guide for Sound Insulation in Wood Frame Construction", J.D. Quirt, T.R.T. Nightingale, and F. King (2006). See also NRC Construction Technology Update 66, "Airborne Sound Insulation in Multi-Family Buildings", J.D. Quirt and T.R.T. Nightingale (2008)
    - 13.7. J. K. Richardson, J. D. Quirt, R. Hlady, "Best Practice Guide on Fire Stops and Fire Blocks and their Impact on Sound Transmission", NRCC #49677 (2007)
    - 13.8. IR-832, "Sound Insulation of Load-Bearing Shear-Resistant Wood and Steel Stud Walls", T.R.T. Nightingale, R.E. Halliwell, J.D. Quirt and J.A. Birta (2002)
    - 13.9. RR-169, "Summary Report for Consortium on Fire Resistance and Sound Insulation of Floors: Sound Transmission and Impact Insulation Data", A.C.C. Warnock (2005)
14. RR-331, "Guide to Calculating Airborne Sound Transmission in Buildings" (4th Edition, 2018) is a companion to this Report, which presents both the "Detailed Method" and the "Simplified Method" of ISO 15712-1 for calculating sound transmission in buildings.
15. The databases of flanking sound transmission data used in Guide RR-331 and in *soundPATHS* will be consolidated in a series of NRC publications presenting data from recent studies:
    - 15.1. RR-333 Apparent Sound Insulation in Precast Concrete Buildings (2019)
    - 15.2. RR-334 Apparent Sound Insulation in Concrete Block Buildings (2019)
    - 15.3. RR-335 Apparent Sound Insulation in Cross-Laminated Timber Buildings (2019)
    - 15.4. RR-336 Apparent Sound Insulation in Wood-Framed Buildings (2017)
    - 15.5. RR-337 Apparent Sound Insulation in Cold-Formed Steel-Framed Buildings (2017)

Endnotes

1 For the concrete block walls in these examples, the value of 238 kg/m^2 is the measured mass per area for the tested wall specimen including grout. Normal weight concrete block masonry units conform to CSA A165.1 and have a concrete mass density of not less than 2000 kg/m^3. 190 mm hollow block units are not less than 53% solid, and 140 mm hollow block units are not less than 73% solid, each giving a minimum wall mass per area over 200 kg/m^2. Higher mass concrete block masonry construction can be achieved by using semi-solid or fully solid units, or more commonly, by grouting the cells of the hollow units. Additional information on the material properties and the sound transmission loss values for other concrete block wall assemblies are given in NRC Research Report RR-334.

3 Sound absorbing material is porous (closed-cell foam is not included) and readily-compressible, and includes fiber processed from rock, slag, glass or cellulose fiber. Such material provides acoustical benefit for direct transmission through lightweight framed wall or floor assemblies, and for flanking transmission when installed in the cavities between lining surfaces and heavy homogeneous structural elements of concrete, concrete block or CLT. Note that overfilling the cavity could diminish the benefit.

4 Gypsum board panels commonly form the exposed surface on lightweight framed wall or floor assemblies and on linings for heavy homogeneous structural wall or floor assemblies of concrete, concrete block or CLT. The gypsum board panels are installed with framing, fasteners, and fastener spacing conforming to installation details required by CSA A82.31-M or ASTM C754. Sound transmission results should only be used where the actual construction details correspond to the details of the test specimens on which ratings are based. “Fire-rated gypsum board” is typically heavier than non-fire-rated gypsum board, which gives improved resistance to sound transmission loss through the assembly. The term “fire-rated” is used in this Guide to denote gypsum board with mass per area of at least 8.7 kg/m^2 for 12.7 mm thickness, or 10.7 kg/m^2 for 15.9 mm thickness.

5 Steel studs and joists are made from sheet steel into standard profiles by roll-forming the steel sheets through a series of dies. The process does not require heat to form the profiles, hence their description as cold-formed steel framing. The studs and joists are formed from sheet steel with a “C-shaped” cross-section profile in accordance with AISI S201, and are joined top and bottom by a rectangular U-shaped runner. “Non-loadbearing steel studs” are formed from sheet steel with a maximum thickness of 0.46 mm (25 gauge). Their profile permits some flexing of the faces to which gypsum board is attached, which limits vibration transmission between the gypsum board layers comprising the two faces of a wall assembly. Loadbearing cold-formed steel (CFS) framing includes floor joists and wall studs that are made from thicker sheet steel. Appropriate fastening details are specified in Section 9.29 of the National Building Code of Canada or in CSA A82.31-M or ASTM C754.

7 Resilient metal channels are formed from sheet steel with maximum thickness 0.46 mm (25 gauge), with profile essentially as shown in Figure 7.2, with slits or holes in the single “leg” between the faces fastened to the framing and to the gypsum board. Installation must conform to ASTM C754. Steel furring channels are also formed from sheet steel but are shaped with a “hat” profile as illustrated in Figure 7.3. Gypsum board is fastened to the channels as required by CSA A82.31 M or ASTM C754.

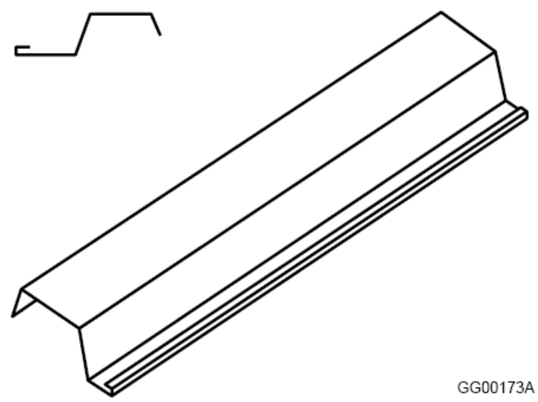


Figure 7.2: Drawing to illustrate the typical profile of resilient metal channels. The approximate dimensions in cross-section are 13 mm x 60 mm.
(Copied from Figure A-9.10.3.1.-D of National Building Code of Canada, with permission)