Measurement of the vibration reduction index between concrete masonry walls and precast hollow core floors

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Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/23001872
Client Report (National Research Council of Canada. Construction), 2017-05-01

NRC·CNRC CONSTRUCTION

Measurement of the Vibration Reduction Index between Concrete Masonry Walls and Precast Hollow Core Floors

Canadian Concrete Masonry Producers Association

Report A1-008727.1

1 May, 2017

National Research Council Canada
Conseil national de recherches Canada

Canada

Table of Contents

List of Figures

Executive Summary

Measurements of the vibration reduction index (K_{ij}) were made in full accordance with the standard, ISO 108048 on junctions constructed from 190 mm thick hollow concrete block masonry walls connected to 203 mm (8”) thick precast prestressed hollow core slabs, with the objective to collect the data required to determine the Apparent Sound Transmission Class (ASTC) rating of building constructions which use these elements.

The vibration reduction index measured in the laboratory was equal to or higher than that predicted using the theory outlined in Annex E of the standard, ISO 15712-1 over the frequency range of interest. Based on the distribution of the velocity levels measured on the concrete masonry walls and the precast hollow core floors, it was determined that these elements behave as homogeneous elements for the purpose of calculating the ASTC rating of this construction. Therefore, the results of this study suggest that theoretical calculations of the vibration reduction indices found in Annex E of ISO 15712 can be used to predict the vibration reduction index of other junctions between concrete masonry walls and precast hollow core floors with a mass per area greater than or equal to 323 kg/m^2.

Based on the findings from this study, it is expected that constructions of hollow concrete block masonry walls with a mass per unit area greater than 238 kg/m^2 connected to precast hollow core floors with a mass per unit area greater than 323 kg/m^2 will achieve ASTC ratings which are equal to or greater than 47.

This report includes examples of calculations of the ASTC ratings for constructions consisting of bare concrete masonry walls connected to bare precast hollow core floors. The examples using the simplified and detailed methods show that constructions of bare (no liners, unpainted) normal weight 190 mm thick hollow concrete block masonry walls connected to bare 203 mm (8”) thick precast prestressed hollow core slabs can achieve an ASTC rating of 48 for side-by-side rooms (horizontal transmission) and an ASTC rating of 55 for one-above-the-other rooms (vertical transmission). The installation of linings on the floor, ceiling or walls would increase the ASTC ratings.

Although the values of the vibration reduction index which were measured for this study were for junctions with the continuous voids of the hollow core planks oriented perpendicular to the concrete masonry walls, the results may also be used for the case where the voids are oriented parallel to the walls. The vibration reduction indices are expected to be higher for the case where the continuous voids are oriented parallel to the concrete masonry walls and so using vibration reduction index values for the case of voids oriented perpendicular to the concrete masonry walls may yield more conservative values than may be found in practice. The benefit of using the same results for both cases is that it eliminates the risk of using the wrong set of data for the calculation of the ASTC rating.

1. Motivation and Objective

The 2015 edition of the National Building Code of Canada (NBCC) includes significant changes to the acoustic requirements for residential constructions. Earlier editions of the NBCC described the acoustic requirements in terms of the Sound Transmission Class (STC) rating of the assemblies that separate dwelling units in a building. In the 2015 edition, for constructions that separate dwelling units, the requirements based on a STC rating were replaced with new requirements based on the Apparent Sound Transmission Class (ASTC) rating. The requirements for constructions that separate dwelling units from elevator shafts or refuse chutes remained unchanged in the 2015 NBCC.

It is important to note that the STC rating is not interchangeable with the ASTC rating. While the STC rating only considers the sound transmitted through the common wall or floor between rooms the ASTC rating includes contributions from other transmission paths between the rooms (referred to as flanking paths as shown in Figure 1) and is therefore a better metric of the sound transmission that occupants in buildings will experience in practice. Since the ASTC rating includes transmission paths other than the direct transmission path, it is typically lower in numerical value than the STC rating of the common wall or floor.

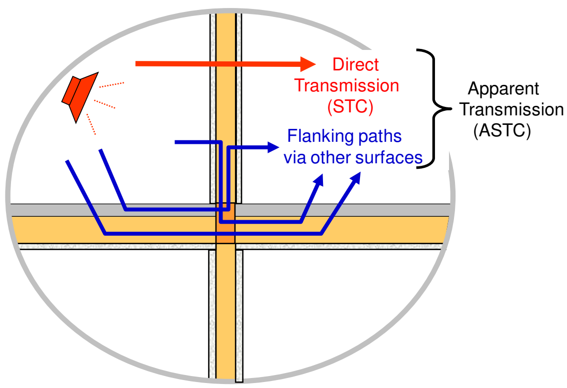


Figure 1: Comparison between STC and ASTC.

The 2015 NBCC allows for three methods of demonstrating compliance with the acoustic requirements. The methods include post completion field testing, constructing buildings using the prescribed acceptable solutions found in Part 9 of the NBCC or the prediction of the ASTC rating using the prediction methods based on the standards, ISO 15712 [1] and ISO 10848 [2] and using theoretically calculated or measured data. This study focuses on the method of showing compliance by the prediction of the ASTC rating.

Note that the ISO standards are written in terms of ISO metrics. For use in North America, the ISO metrics must be converted into ASTM metrics. The calculation method and the conversion of the ISO metrics to ASTM metrics are described in detail in the NRC Research Report RR-331 *Guide to Calculating Airborne Sound Transmission in Buildings* [3]. The Report, RR-331 and the ISO standards outline a method of predicting the ASTC rating based on laboratory measurements of the structure-borne sound through the junctions between building elements and laboratory measurements of the transmission loss directly through the separating building element (the assembly that separates the adjacent living spaces). For example, as shown in Figure 2, one of the flanking paths between two rooms is between the floor in room 1 (element i in the figure) and the common wall between room 1 and room 2 (element j in the figure).

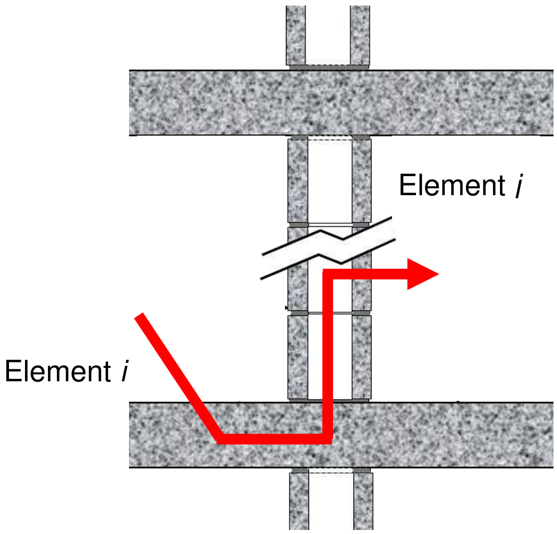


Figure 2: Example of a flanking transmission path between elements *i* and *j*.

According to the ISO 15712 standard, the first order approximation of the flanking transmission for the path between elements i and j can be predicted from the transmission loss of elements i and j and the vibration reduction index through the junction as shown in Equation 1 and graphically in Figure 3 such that:

$$FlankingTL = \frac{TL_i + TL_j}{2} + K_{ij} + 10\log\left[\frac{S_s}{l_o l_{ij}}\right] \qquad (1)$$

where:

- TL_i is the resonant transmission loss of element i in 1/3 octave bands if using the detailed method or the STC rating if using the simplified method
- TL_j is the resonant transmission loss of element j in 1/3 octave bands if using the detailed method or the STC rating if using the simplified method
- S_s is the area of the separating element in square meters
- l_o = 1 m
- l_{ij} is the length in meters of the common junction between elements i and j.

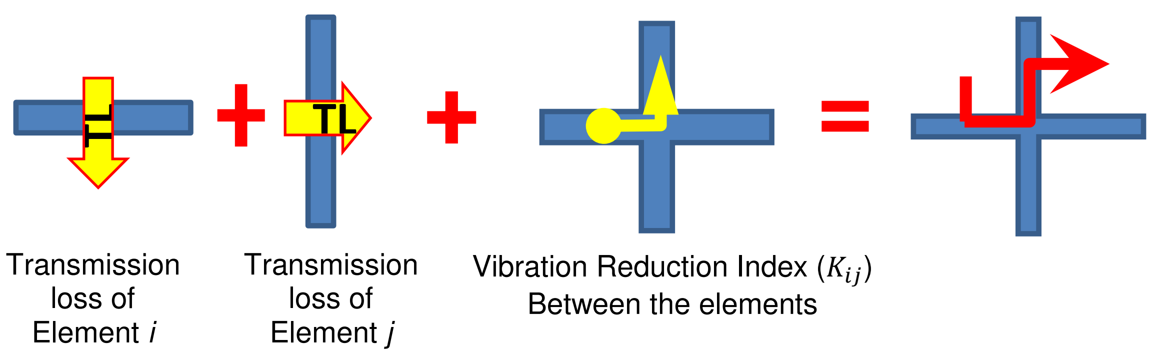


Figure 3: Steps to calculate the flanking transmission along the path. The calculation also includes a normalization based on the element properties.

Therefore, to predict the flanking transmission loss for the path between elements i and j, the resonant transmission loss values of element *i* and element *j* are needed along with the vibration reduction index K_{ij} between the elements. Note that concrete elements typically have critical frequencies at the bottom of the frequency range of interest which allows the transmission loss measured in the laboratory to be used as the resonant transmission loss in Equation 1 without correction.

For isotropic and homogeneous elements, the vibration reduction index may be calculated theoretically using the examples found in Annex E of ISO 15712. However, for elements that are not both isotropic and homogeneous, the vibration reduction index must be measured for use in the calculation of the ASTC rating.

A common construction method which utilizes concrete block walls is to structurally connect the walls to precast hollow core floors. This structural system is often used in multi-storey buildings. A precast hollow core floor refers to an adjoining series of flat, rectangular-section slabs of prestressed concrete having tubular voids which extend the full length of each slab. Builders and architects will need to be able to predict the ASTC rating of constructions of concrete block walls joined with precast hollow core slabs. However, while concrete block walls have been shown in prior studies [4] conducted at the NRC to behave like isotropic homogeneous elements in terms of sound transmission, a separate study at the NRC [5] on individual unconnected precast hollow core concrete slabs showed that the planks are neither homogeneous nor isotropic due to the hollow voids in the slabs. The implication of this finding is that it may not be possible to apply the theoretical predictions of the vibration reduction index from ISO 15712-1 to calculate the ASTC rating of constructions which use precast hollow core concrete floors. Therefore, measurement data is expected to be required for the prediction of the ASTC rating of any construction that incorporated hollow core slabs.

However, there was the possibility that the hollow core floors could be considered as “solid” floors in terms of sound insulation if experimental measurements of the velocity measured on the precast hollow core slabs *in situ* was uniformly distributed and the experimental measurement of the vibration reduction index of constructions utilizing the slabs resulted in data that agreed with theoretical predictions.

The main objective of this study was to collect the data required for the prediction of the ASTC rating between dwellings in buildings constructed of concrete masonry walls and precast hollow core floors. A further objective of the study was to determine if the measured vibration reduction index values measured for the construction agreed with the values predicted theoretically using Annex E of ISO 15712-1. If the measured and predicted values were similar or if the measured values were higher than the predicted values, then the theoretical predictions of the vibration reduction index as described in Annex E of ISO 15712-1 could be applied to constructions of concrete masonry walls connected to precast hollow core floors.

2. Testing Procedure

2.1 The Construction of the Mock-Up Junction

The vibration reduction index (K_{ij}) between concrete masonry walls and precast hollow core floors was determined from measurements made on a full scale mock-up junction which was designed in full compliance with the standard, ISO 10848 which specifies the procedure for measuring the vibration reduction index. A sketch of the mock-up junction used for the investigation is shown in Figure 4 and the actual cross-junction is shown in Figure 5.

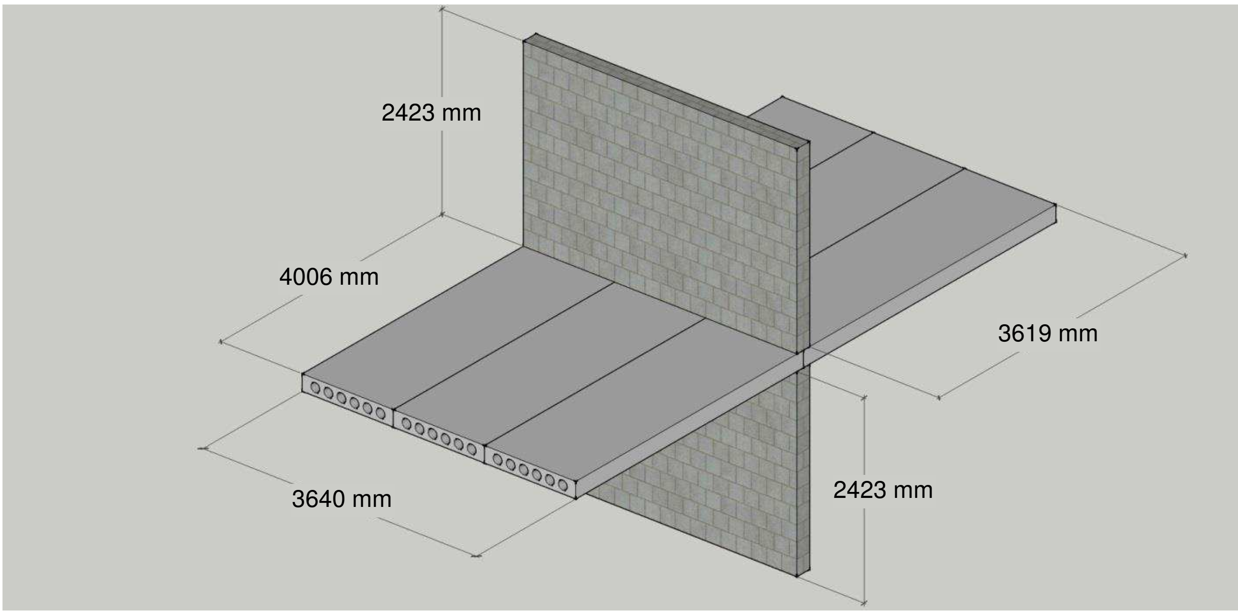


Figure 4: The full-scale mock-up junction between the concrete masonry walls and the hollow core floors with dimensions shown as built. All of the dimensions shown were measured from the surfaces of the elements.

Note that the floors on each side of the junction were different lengths (3.619m and 4.006m) in accordance with the requirements of ISO 10848.

Figure 5: The mock-up junction between the concrete masonry walls and the hollow core floors. Note that the Alumina beams shown below the floor and along the wall did not contact the structure during the testing and were only present to support the structure during the construction phases.

The concrete masonry walls were constructed by a qualified and reputable masonry contractor using 190 mm thick hollow concrete block masonry units with a mass per unit area of 238 kg/m^2. The 203 mm (8 inch) thick hollow core slabs shown in Figure 6 were purchased from a local precast manufacturer and had an average mass per unit area of 323 kg/m^2. All of the slabs were cut to the desired lengths at the precast manufacturing facility.

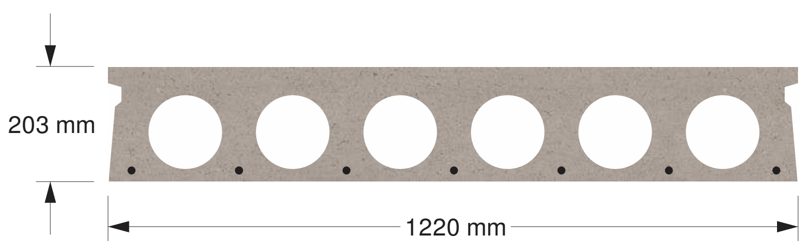


Figure 6: Cross-section of the 203 mm (8 inch) precast hollow core slab with nominal dimensions.

Slabs with a thickness of 203 mm were chosen for this study rather than thicker slabs (254 or 305 mm, 10” or 12”, respectively) because the 203 mm slabs were less likely to respond according to theory than the 305 mm slabs. If the 203 mm thick slabs were found to result in vibration reduction indices that agreed with theory, then it could be assumed that thicker slabs would agree with theory as well.

The mock-up junction was designed so that the slabs and therefore the continuous hollow voids were oriented perpendicular to the masonry walls. This orientation of the hollow voids was chosen for this study to result in conservative values (lower values) of the vibration reduction indices than if the hollow voids were oriented parallel to the wall. Alternatively, a junction with the hollow voids oriented parallel to the wall is expected to have a higher vibration reduction index because structure-borne sound transmitted perpendicular to the wall would be expected to be attenuated by the voids. Furthermore, the use of the vibration reduction index values with the hollow voids oriented perpendicular to the wall would result in only one set of values which could be used regardless of the orientation of the voids relative to the walls. Additional precast hollow core slabs were also ordered from the manufacturer in case the results of the study showed that the measured vibration reduction index did not agree with theoretical predictions so that measurements could also be made on junctions with the voids oriented parallel to the concrete masonry walls.

The details for the junction between the floors and the walls are shown in Figure 7.

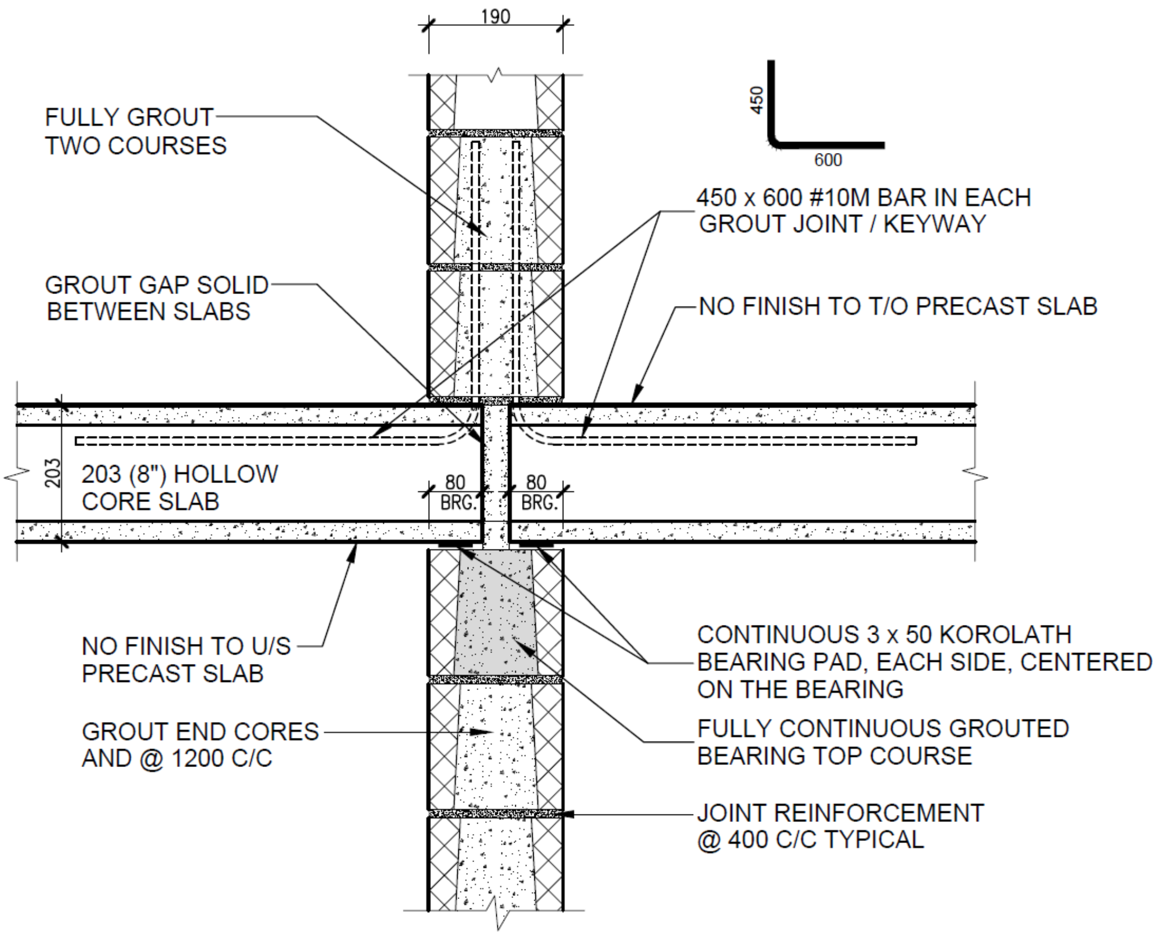


Figure 7: Construction details of the mock-up junction. The only reinforcing bars used in the construction were positioned between the hollow core slabs and the upper wall.

Note that Korolath multi-polymer plastic bearing strips (compressive strength of 55 to 62 MPa) were installed the full length of the junction between the lower wall and the hollow core slabs as shown in Figure 8. In building construction, this is a common form of bearing for precast hollow core floor planks on concrete block masonry.

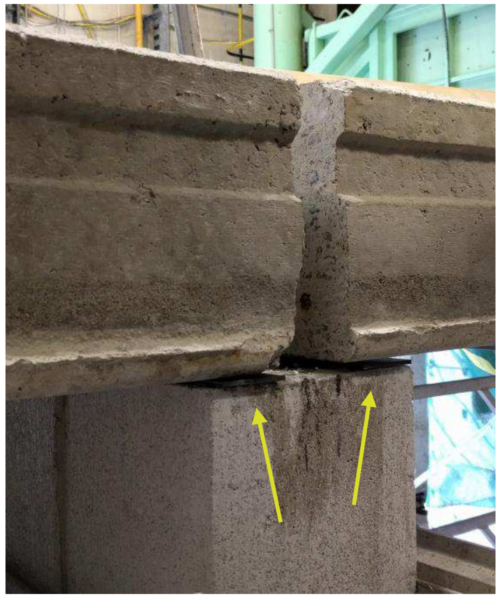


Figure 8: The 3 mm x 50 mm Korolath bearing strips installed between the concrete masonry wall and the precast hollow core slabs.

As shown in Figure 9, all of the keyways between the slabs as well as the head joint between the slabs at the slab/wall junction were filled with grout using materials and procedures commonly used on-site and following the instructions provided by the CCMPA as detailed in Appendix B.

Figure 9: Grout was used to fill the keyways between the precast hollow core slabs and the head joint between adjacent slabs within the masonry wall.

The grout between the precast hollow core slabs was allowed to cure for twenty-four hours before the upper concrete masonry wall was constructed. Once the upper wall was completed, the construction was allowed to cure for five weeks before the testing began

The free ends of the hollow core slabs were supported using scaffolding as shown in Figure 10.

Figure 10: View of the scaffolding used to support the free ends of the hollow core slabs. Although the scaffolding is shown in the figure to contact the wall and slabs in several positions, these Alumina beams were removed prior to testing and only the Alumina beams at the ends of the floors remained in contact with the floors during the testing.

Handrails were installed along the perimeter of the floors prior to the start of the testing. The handrails only contacted the floor elements and did not affect the measurements.

The standard ASTC examples used in the NRC Research Reports RR-331 and RR-334 require vibration reduction index values for a T-junction between one floor and the walls in addition to the values for the cross-junction. To make these measurements, after the completion of the testing of the cross-junction, the floor on one side of the mock-up junction was removed by cutting it as shown in Figure 11.

Figure 11: View of the T-junction with one of the floors removed.

The velocity level difference and the reverberation time measurements were repeated for the T-junction.

2.2 Measurement Overview

The measurements to determine the surface velocity of each element and the vibration reduction index (K_{ij}) between the concrete masonry walls and precast hollow core floors were made in full compliance with ISO 10848.

The measurement procedure calls for exciting each wall or floor element in three different positions and measuring the velocity distribution across all of the elements. The excitation was done using a 400 N electromagnetic shaker which was attached to three randomly distributed positions on each element. The shaker was connected to the elements using a thin metal rod as shown in Figure 12.

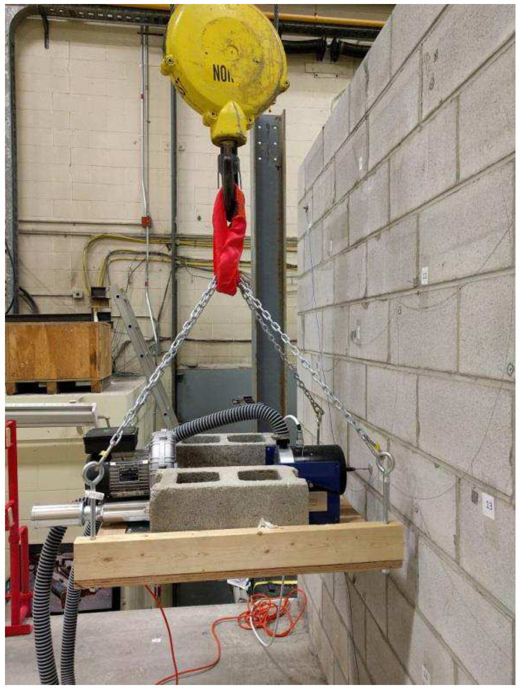


Figure 12: The electromagnetic shaker attached to the wall via a thin metal rod called a stinger. The contact between the stinger and the wall was achieved using a square piece of aluminum with a threaded hole which was glued to the wall. The stinger was then screwed into the hole in the aluminum square.

The shaker was suspended as shown in Figure 12 or supported by a stand as shown in Figure 13 so that the shaker never came in contact with the elements other than via the stinger.

Figure 13: The electromagnetic shaker attached to the floor element. The shaker was supported by a stand to avoid contact with any of the elements.

The surface velocity of the elements was measured using accelerometers which were randomly distributed across the test element within the boundaries set by ISO 10848 as shown in Figure 14.

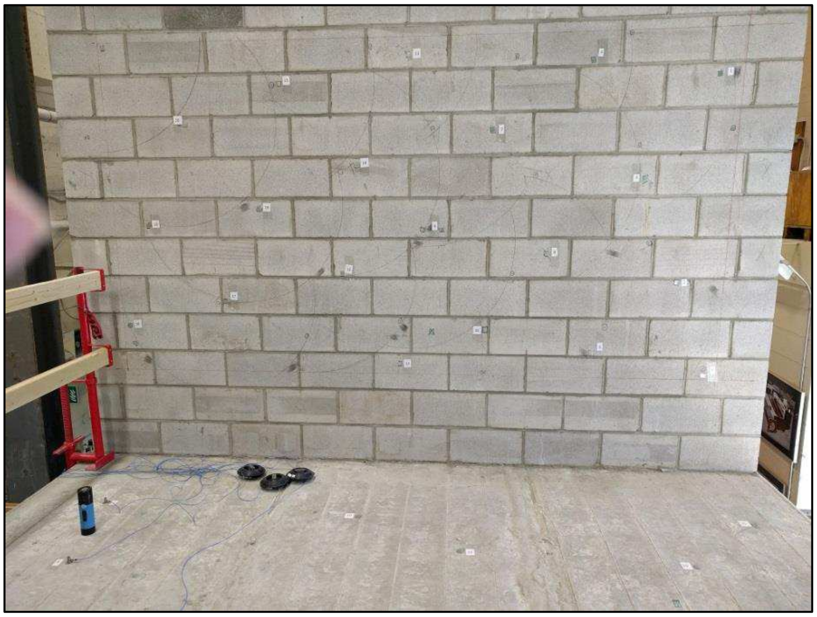


Figure 14: An example of the accelerometer positions on one of the walls and floors. Thin steel tabs were glued to the concrete and the accelerometers were attached to the tabs using magnets. The white markings beside the tabs showed the accelerometer position number.

The standard requires that the accelerometers are positioned such that there is:

- 0.5 m between the accelerometer positions,
- 0.25 m between the accelerometer positions and the edges of the element,
- 1 m between the excitation position and the accelerometer positions.

This last requirement was achieved by disregarding any accelerometer positions on an element which were within 1 m of an excitation position on the same element.

Although the standard requires only nine accelerometer positions to be randomly distributed across each element, twenty accelerometer positions were used on each side of each element for this study both to achieve a high level of confidence in the results and to study the velocity distribution across the elements.

For each measurement, the shaker generated a signal of white noise for thirty seconds during which the velocity level was measured by the accelerometers. Next, the background noise was measured for thirty seconds. The quality of the data was then checked before moving the accelerometers to the next positions and repeating the measurements of the background noise and the velocity level. This procedure was repeated until the velocity in all of the accelerometer positions was measured for that shaker position.

In addition, the structural reverberation time was measured using the shaker as a source generating a swept sine. The reverberation time was measured in several accelerometer positions for each excitation point.

More details about the calculations used to determine the vibration reduction index in accordance with ISO10848 are shown in Appendix B.

2.3 Calculation of the Single Number Rating of the Vibration Reduction Index

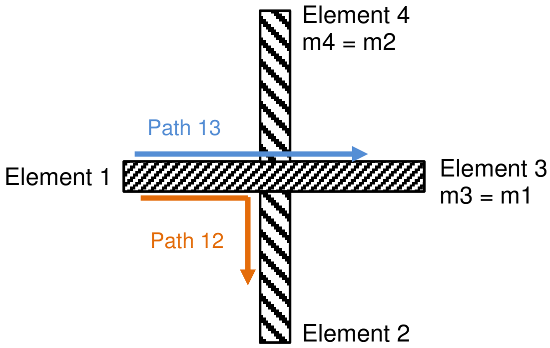
The procedure used for this study to calculate the single number rating of the vibration reduction differs from the procedure outlined in ISO 15712-1:2005. The standard states that: "If the values for the vibration reduction index depend on frequency, the value at 500 Hz may be taken as a good approximation, but the result can then be less accurate." Rather than follow this procedure, the single number ratings for the vibration reduction indices presented in RR-331 and the accompanying technical reports determine the single number rating as the average value of the nine 1/3 octave bands between 200 Hz and 1250 Hz, inclusive. This calculation method will also be adopted in the next revision of the ISO 15712-1 standard.

3. Vibration Reduction Index Values

3.1 Measurement Results

3.1.1 Cross-Junction

The measured vibration reduction indices for the cross-junction are shown in Figure 15 and are listed in tabular form in Appendix C. The higher the value of the vibration reduction index for path ij, the greater the attenuation of structure-borne sound through that transmission path.



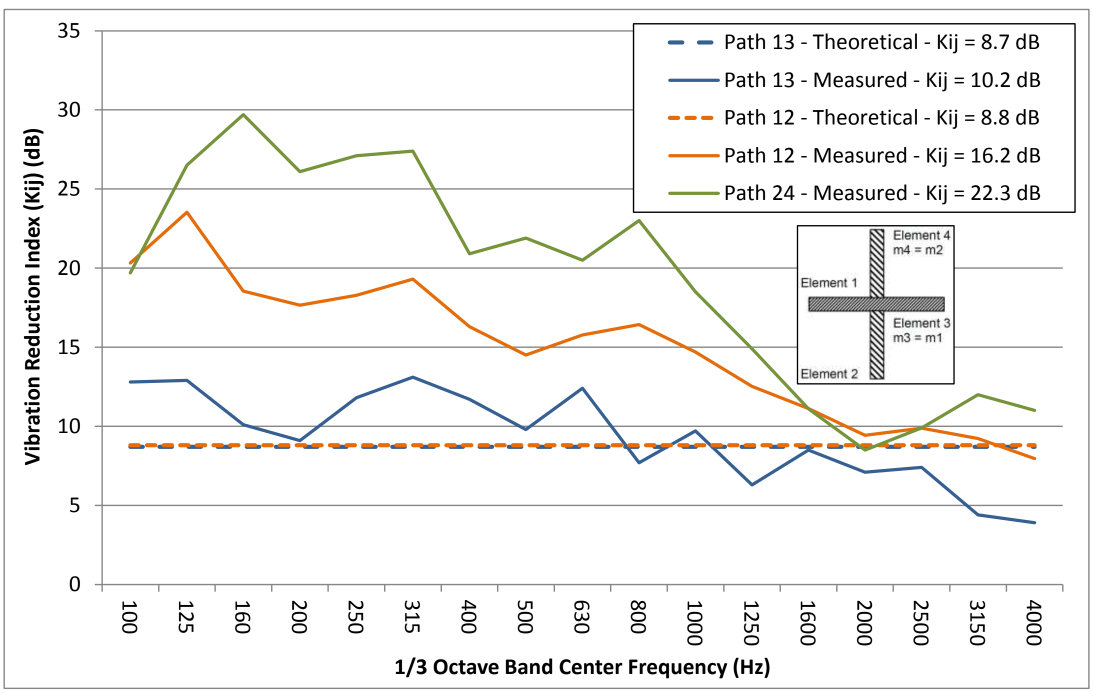


Figure 15: Measured values for the vibration reduction index of the cross-section. Also shown in the figure are the theoretical values as calculated according to ISO 15712-1:2005.

Also shown in the figure are the theoretical values for the vibration reduction indices as calculated according to Annex E of ISO 15712-1:2005. The standard describes the theoretical calculation of the single number K_{ij} value for constructions which include heavy, homogeneous, isotropic elements. The theoretical calculations are limited in that they are only valid for rigid junctions where the elements on each side have the same mass per unit areas and the theoretical calculations are frequency independent whereas the measured vibration reduction index values tend to fluctuate with frequency.

The data in the figure show that the vibration reduction indices for the different transmission paths (12, 24 and 13) are different from each other as would be expected. The lowest values are for the transmission path from floor to floor (path 13) which is expected since the only discontinuity between floors 1 and 3 is the grout filled junction between the slabs. The wall-wall path (path 24) has the highest vibration reduction index value since the junction is discontinuous due to the placement of the precast hollow core floors between the walls and the continuous Korolath bearing strips located between the floors and the lower wall.

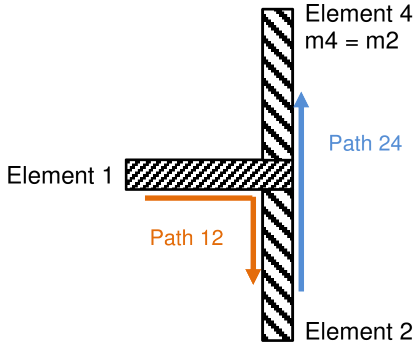
A comparison between the theoretical values and the measured values shows that the floor-floor path (path 13) agrees with theory over most of the frequency range and the single number values differ by only 1.5 dB. This result indicates that in terms of the acoustic properties, the hollow core floors behave according to theory. As precast hollow core floors are not the homogeneous isotropic elements to which the theory applies, this result was unexpected and shows that the theory is nevertheless applicable. The measured vibration reduction indices for paths 12 and 13 are shown to be higher than the theoretical values below the 2000 Hz 1/3 octave band. These results may be due to the use of the bearing strips between the floors and the lower wall and due to the fact that the construction does not adhere to the assumptions used for the calculation of the theoretical values (rigid junctions and homogeneous and isotropic elements).

It is expected that if the hollow voids and therefore the slabs were oriented parallel to the wall, the attenuation of the structure-borne sound travelling between the floors would be greater resulting in higher vibration reduction index values for paths 12 and 13.

The reverberation times measured on each of the elements of the cross-junction are shown in Appendix D.

3.1.2 T-junction

The measured vibration reduction indices for the T-junction are shown in Figure 16 and are listed in tabular form in Appendix C. Also shown in the figure are the theoretical values for the vibration reduction indices as calculated according to Annex E of ISO 15712-1:2005.



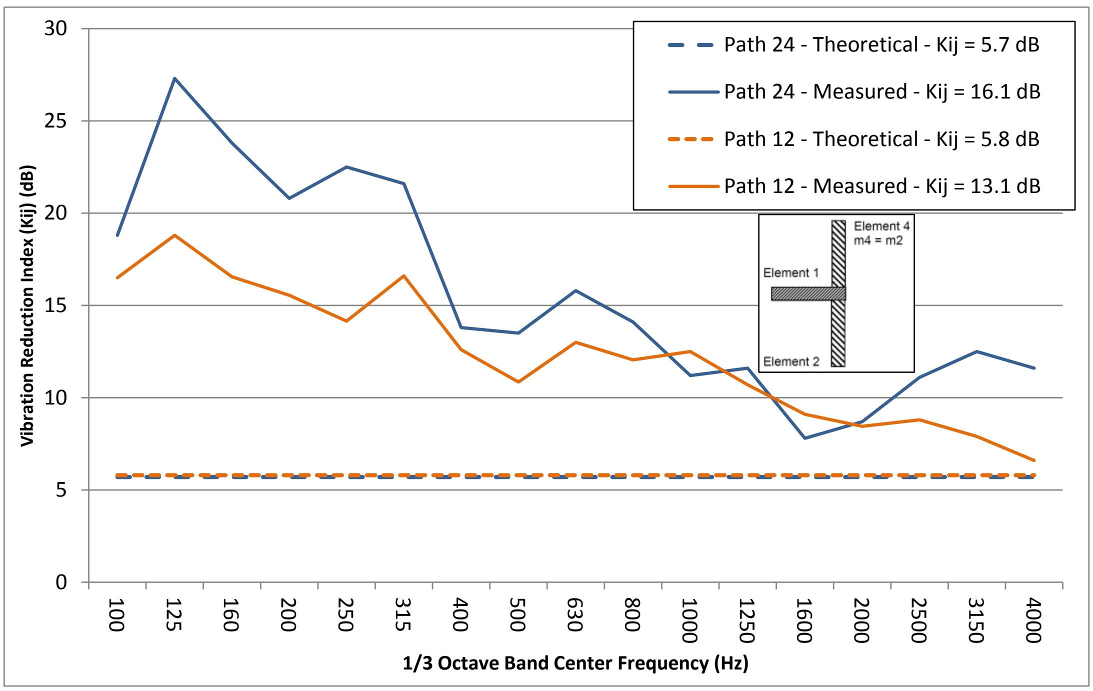


Figure 16: Measured values for the vibration reduction index of the T-junction. Also shown in the figure are the theoretical values as calculated according to ISO 15712-1:2005.

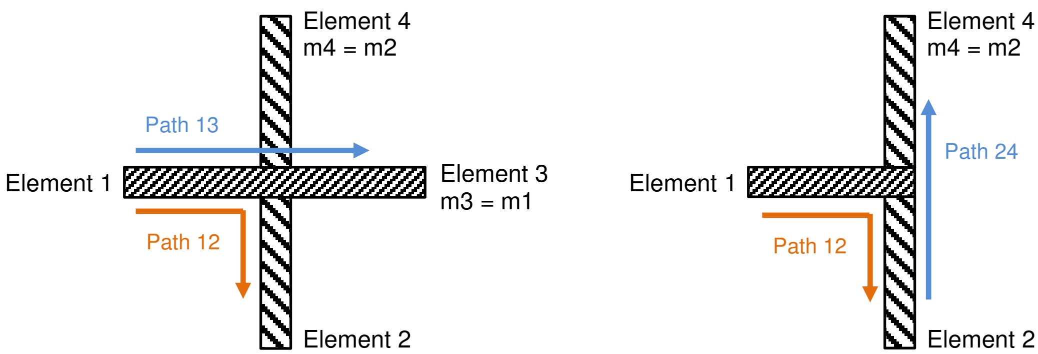
The T-junction values shown in the figure are lower than the values measured for the same paths for the cross-junction. This is to be expected since energy is no longer being dissipated in element 3 (the floor element which was removed). A comparison between the measured and theoretical vibration reduction index values shows that, as with the case of the cross-junction, whereas theory is not intended for this type of construction, the measurement results demonstrate that the theory is nevertheless applicable.

The reverberation times measured on each of the elements of the T-junction are shown in Appendix D.

3.2 Prediction of the Vibration Reduction Index Values

Based on the comparison between the measured and the predicted values for the vibration reduction index, it was concluded that the values for the vibration reduction index for constructions of hollow concrete block masonry walls connected to 203 mm thick precast concrete hollow core slabs may be predicted using the equations presented in Annex E of the standard, ISO 15712-1. The predicted values will be lower than the measured values presented in the prior section and will therefore offer more conservative estimates than the measurement results.

The values for the vibration reduction indices for paths 12 and 13 for the cross-junction are shown in Figure 17 and path 12 for the T-junction is shown in Figure 18 for a range of values of the mass per unit area of the precast concrete hollow core slabs (300 kg/m^2 to 400 kg/m^2) when connected to hollow concrete block masonry walls with a mass per unit area of 238 kg/m^2. Note that the vibration reduction index for path 24 for the junctions is dependent only on the mass per unit area of the hollow concrete block masonry walls and therefore remains the same regardless of the value of the mass per unit area of the floors.



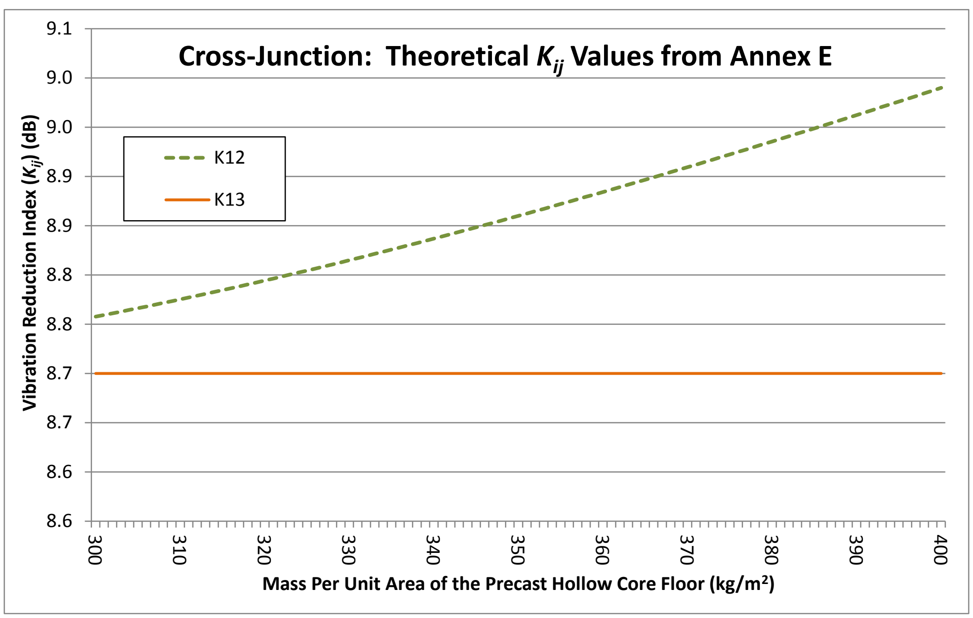


Figure 17: Predicted values of the vibration reduction index (K_{ij}) of paths 12 and 13 for the cross-junction for increasing values of the mass per unit area of the precast concrete hollow core floors connected to concrete masonry walls with a mass per unit area of 238 kg/m^2.

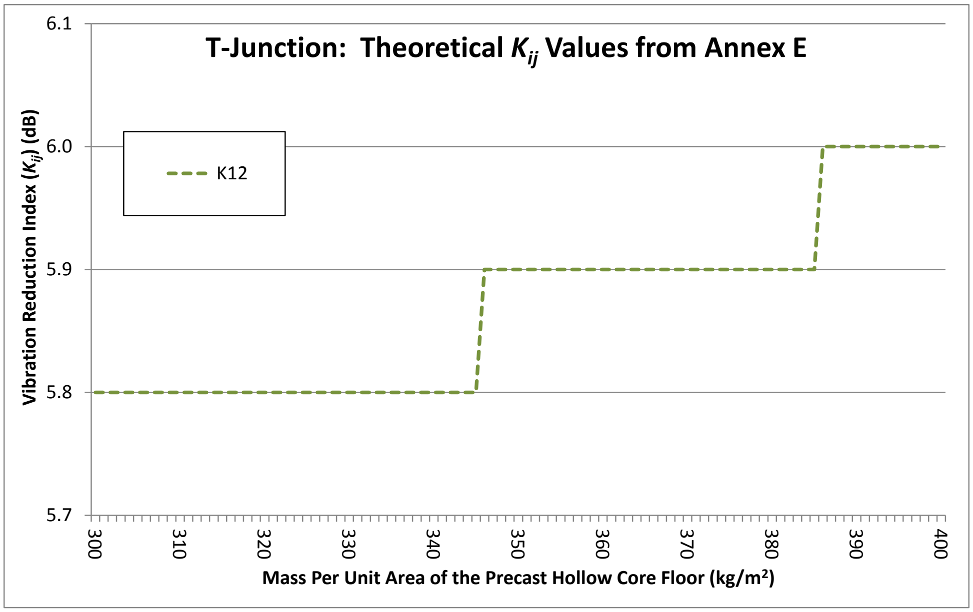


Figure 18: Predicted values of the vibration reduction index (K_{ij}) of path 12 for the T-junction for increasing values of the mass per unit area of the precast concrete hollow core floors connected to concrete masonry walls with a mass per unit area of 238 kg/m^2.

The figures show that the theoretical values of the vibration reduction index for path 12 of both the cross-junction and the T-junction change by no more than 0.2 dB as the mass per unit area of the precast concrete hollow core floor is increased from 300 kg/m^2 to 400 kg/m^2.

The predictions found in Annex E of ISO 17712-1 only give a single number rating for the vibration reduction indices. These single number ratings can be used to calculate the ASTC ratings using either the simplified or detailed methods. For example, the predicted ASTC ratings using the predicted values for the vibration reduction indices for precast concrete hollow core floors with a mass per unit area of 323 kg/m^2 are shown in Section 5.3. The examples are identical to that shown in Section 5.2 except that the theoretical values for the vibration reduction index are being used instead of the measured values.

The example shows that the use of the theoretical values for the vibration reduction indices results in a lower ASTC rating than the use of the measured values (47 using the theoretical values instead of 48 using the measured values). However, the predicted ASTC rating still meets the acoustic requirements of the National Building Code of Canada.

Hollow concrete block masonry walls with a mass per unit area greater than 238 kg/m^2 are expected to have transmission loss values that are equal to or greater than the values reported for the hollow concrete block masonry walls evaluated for this study. Likewise, precast hollow core floors with a mass per unit area greater than 323 kg/m^2 are expected to have transmission loss values that are equal to or greater than the values reported for the precast hollow core floors evaluated in this study. Therefore, based on the findings from this study, it is expected that constructions of hollow concrete block masonry walls with a mass per unit area equal to or greater than 238 kg/m^2 connected to precast hollow core floors with a mass per unit area equal to or greater than 323 kg/m^2 will achieve ASTC ratings which are equal to or greater than 47.

4. Analysis of the Measured Data

4.1.1 Effect of the Korolath bearing strips

The junction between the upper concrete masonry wall and the precast hollow core floor included steel bar reinforcement between the floor and the wall. The junction between the lower concrete masonry wall and the precast hollow core floor did not include these bars, but it did include continuous Korolath bearing strips between the top of the masonry wall and the underside of the hollow core plank (see Figure 7). Since these two junctions were different in design, the velocity level difference between the upper wall and the floor and the velocity level difference between the lower wall and the floor are compared in Figure 19 to determine the effect of the bearing strips.

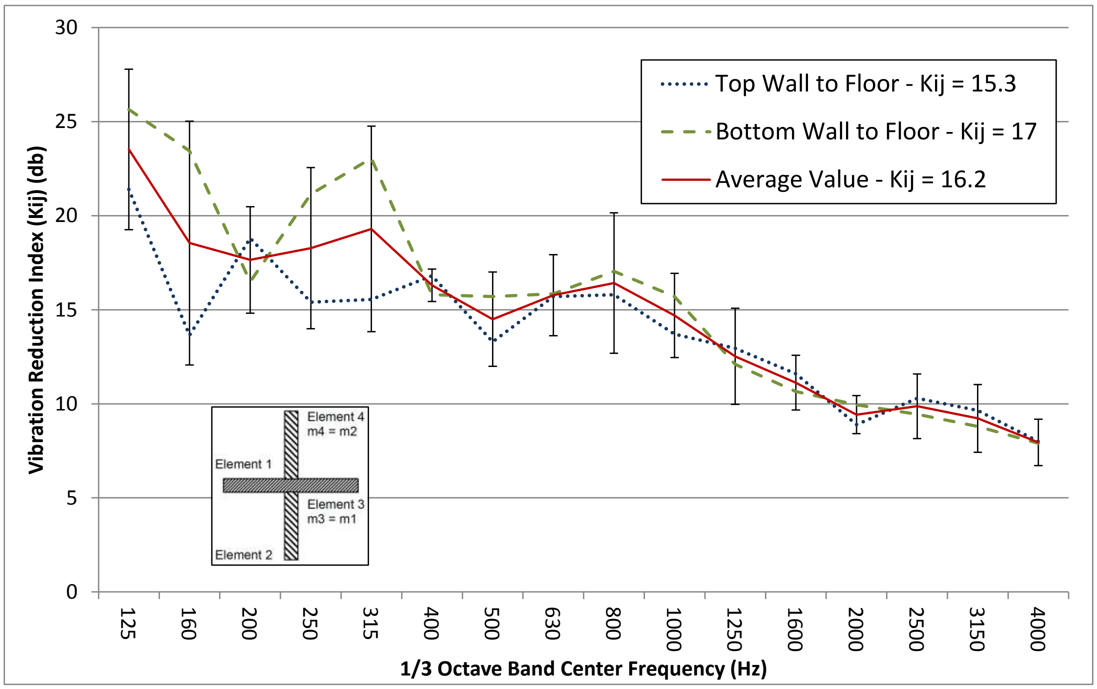


Figure 19: Comparison between the vibration reduction indices between the upper wall (element 4) and the floors (elements 1 and 3) and the lower wall (element 2) and the floors. Also shown is the average value. The error bars are the 95 % confidence intervals for the average value which are only based on the variance between the average vibration reduction index values.

The figure shows that the vibration reduction indices for the two paths are similar above the 315 Hz 1/3 octave band. In the 315 Hz 1/3 octave band and below, the vibration reduction index of the junction with the bearing strip is higher with the exception of the 200 Hz 1/3 octave band. The difference in the values may be due to the influence of the bearing strip and the absence of steel bar reinforcement in the connection between elements 1 and 2. However, looking at the confidence intervals shows that the vibration reduction index between the upper wall and the floor and the vibration reduction index between the lower wall and the floor are statistically part of the same distribution. Therefore, the average value which includes both the effect of the steel bar reinforcements and the continuous bearing strip is the best estimate of the vibration reduction index between the floors and the walls.

4.1.2 Velocity Distribution on the Concrete Masonry Walls

The standards, ISO 15712 and ISO 10848 assume the vibratory response is the same on both sides of solid concrete elements since the solid concrete elements are homogeneous and isotropic. The opposite is true for lightweight elements with studs or joists where the velocity levels are different on each side of the elements. Therefore, if the average velocity levels measured on each side of the concrete masonry walls were similar and reasonably uniform, then it could be concluded that the concrete masonry wall was responding as a homogeneous element for purposes of the calculation of the flanking transmission.

The velocity levels for a concrete masonry wall (element 1) are compared when a shaker was attached to side A of the wall in Figure 20.

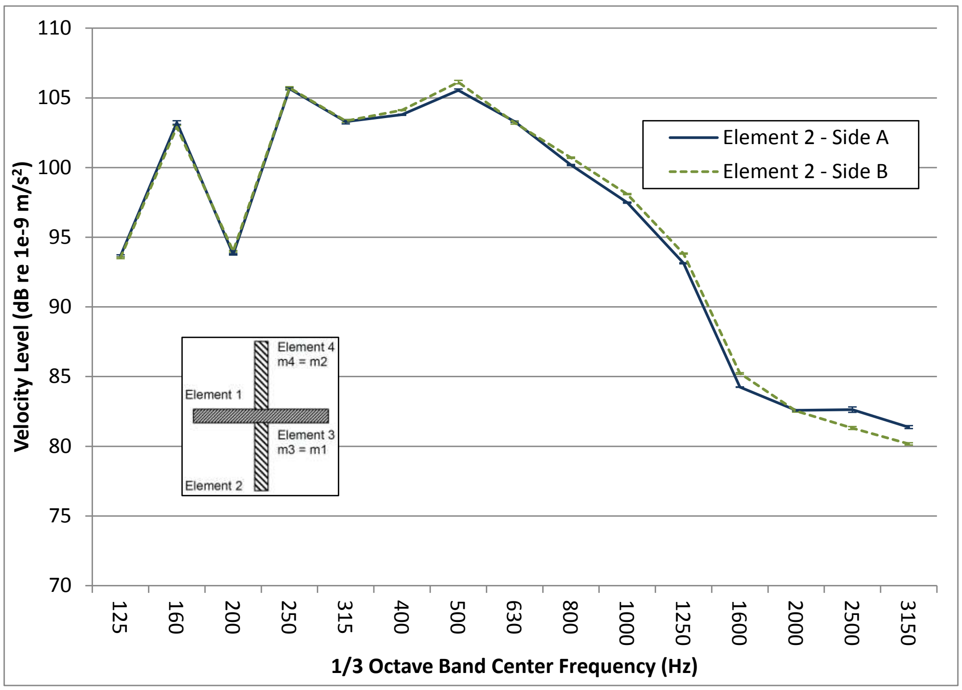


Figure 20: The time and spatially averaged velocity level measured on each side of the lower concrete masonry wall. The error bars are the 95% confidence based on the standard deviation of the velocity levels measured at the accelerometer positions.

The figure shows a difference of 1.3 dB or less in all of the 1/3 octave bands. A comparison of the velocity levels on both sides of the element when other elements were excited showed equally good agreement. The 95% confidence interval for the velocity level distribution on each measurement side was no greater than 0.2 dB. The results reaffirm that concrete block masonry walls can be treated as homogeneous elements for the purposes of calculating flanking sound transmission.

4.1.3 Velocity Distribution on the Precast Hollow Core Floors

The spatially averaged velocity level was measured on each side of the precast hollow core floor for each of the excitation points on the junction. The velocity levels were compared to determine if the floor was responding as a homogeneous element. The velocity levels for a precast hollow core floor (element 1) are compared in Figure 21 for the case when a shaker was attached to side A of the floor.

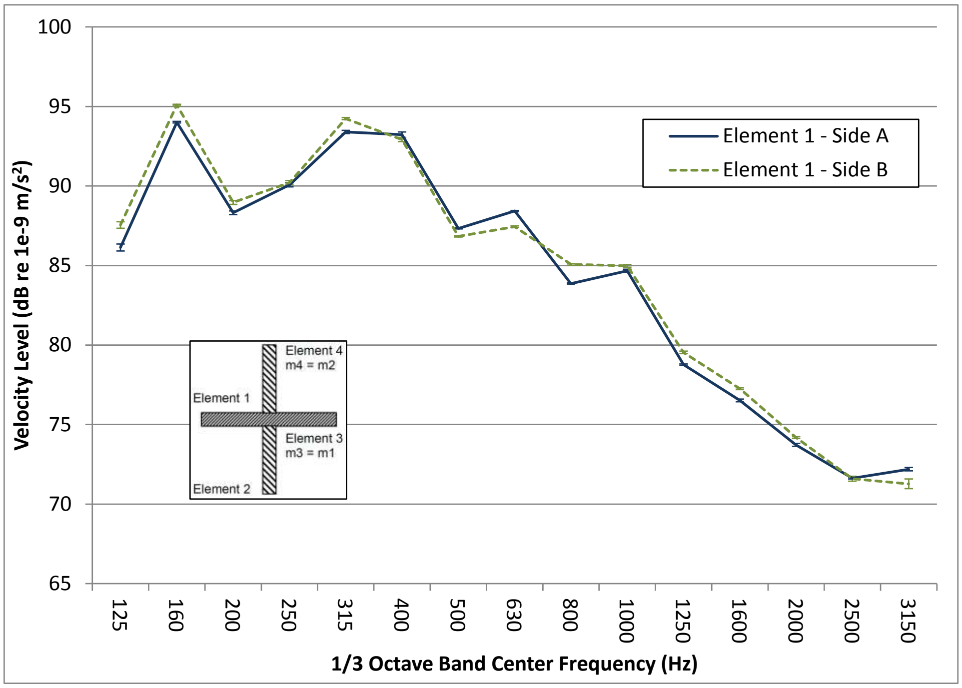


Figure 21: The time and spatially averaged velocity level measured on each side of the hollow core plank. The error bars are the 95% confidence intervals based on the standard deviation of the velocity levels measured at the accelerometer positions.

The figure shows a difference of 1.4 dB or less across all of the 1/3 octave bands. While the similarity between the velocity levels is not as good as for the concrete masonry wall, the agreement is still very good. The 95% confidence interval for the velocity level distribution on each measurement side was no greater than 0.2 dB.

The average velocity levels measured on each of the three floor slabs which were positioned side-by-side to create element 1 are compared in Figure 22, Figure 23 and Figure 24 when each slab was excited in turn by the electromagnetic shaker. The comparison is made to examine the effect of the continuous grout filled keyways between the floor slabs on the overall velocity distribution of the floor. A homogeneous isotropic element would be expected to show a fairly uniform velocity distribution across the element. Therefore, large differences between the velocity levels measured on each slab would indicate that the floor was not behaving as a homogeneous element.

The results for excitation on slabs 1 and 3 (the slabs on the outside of element 1) show that the average velocity level of the excited slab tended to be higher than for the other slabs as would be expected. However, since the 95% confidence intervals overlap, it is likely that measurement uncertainty contributed to cases where the velocity level on the excited slab was lower than on the other slabs. The figures indicate that despite the hollow cores and the grout filled gaps between the slabs, the overall velocity levels on the slabs were similar enough for the floor to be considered homogeneous for the purposes of the calculation of the vibration reduction index. The 4 cm thick layers of concrete on each side of the voids of the slabs most likely behave as a solid concrete slab in terms of the transmission of vibration and properly grouted floors will show a fairly uniform velocity distribution at distances greater than 1m from the point of excitation.

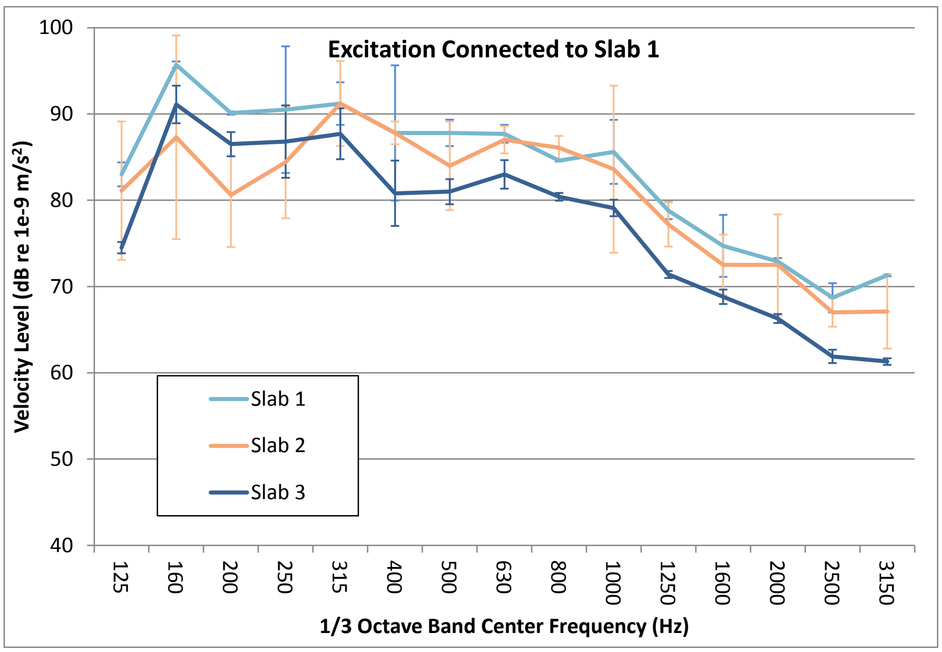


Figure 22: The average velocity level measured on each of the slabs that made up element 1 when the electromagnetic shaker was attached to slab 1. The error bars are the 95% confidence interval based on the standard deviation between the measurement points.

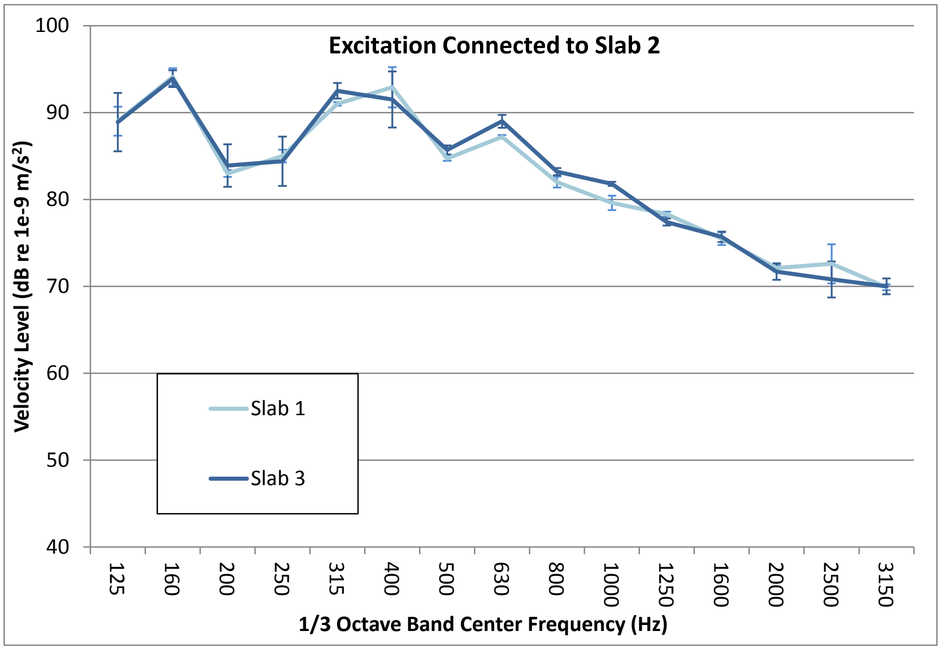


Figure 23: The average velocity level measured on each slab when the electromagnetic shaker was attached to slab 2 (the center slab of element 1). The error bars are the 95% confidence interval based on the standard deviation between the measurement points. There weren't enough measurement points on slab 2 for the comparison since data from any position within 1 m of the excitation was disregarded per ISO 10848-1.

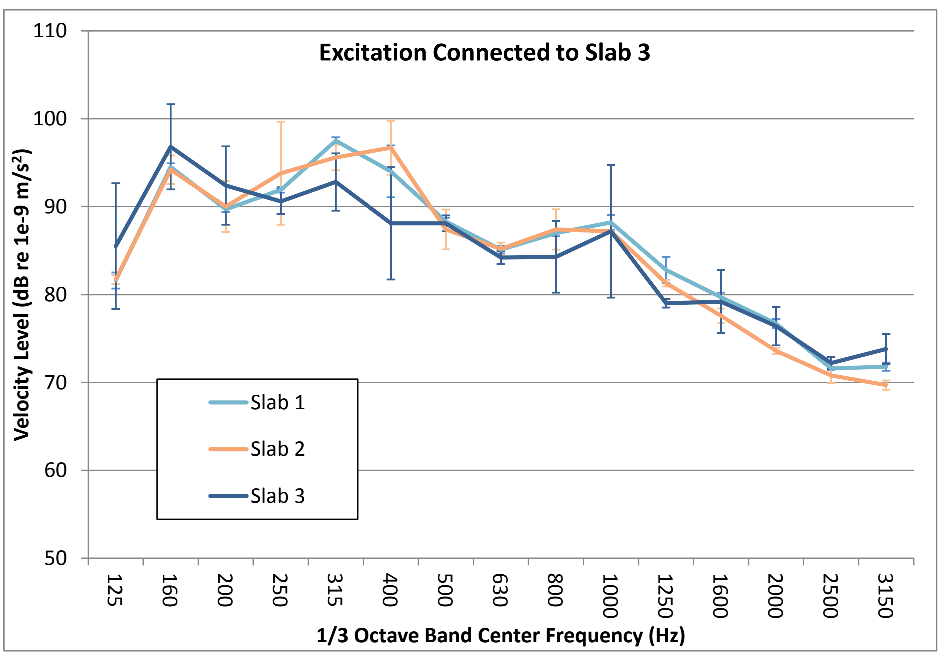


Figure 24: The average velocity level measured on each slab when the electromagnetic shaker was attached to slab 3. The error bars are the 95% confidence interval based on the standard deviation between the measurement points.

Figure 25 shows the average velocity level measured on the three slabs when the concrete masonry wall below the floor was excited with the shaker. The excitation position was located on the wall below Slab 1.

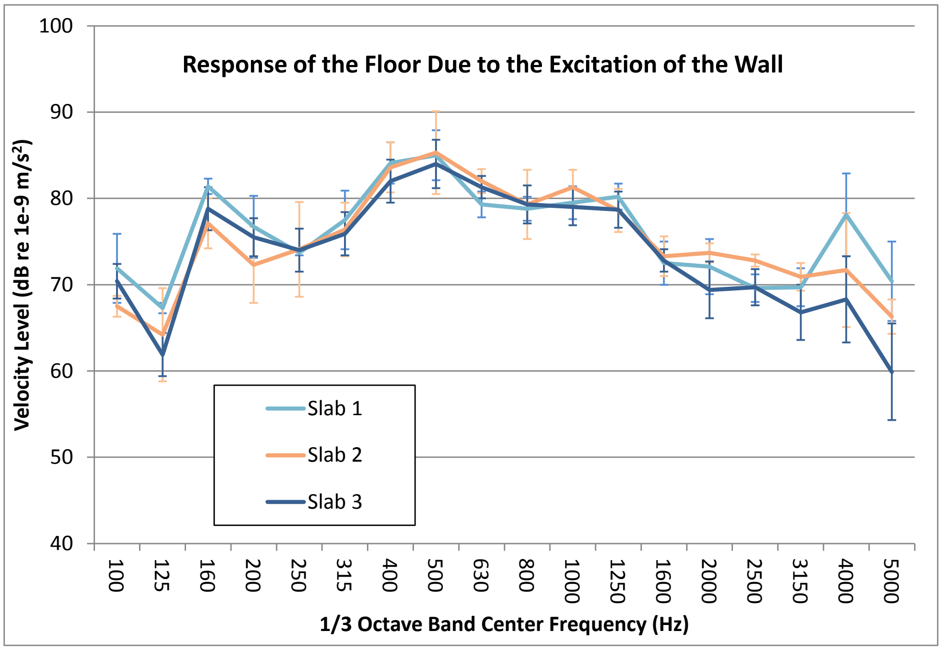


Figure 25: The average velocity level measured on each slab when the electromagnetic shaker was attached to the concrete masonry wall located below the floor. The error bars are the 95% confidence interval based on the standard deviation between measurement points.

The figure shows that the average velocity level measured on the three slabs was similar over most of the frequency range and the differences between the levels on the slabs were less than the cases when the slabs were excited as would be expected. The results give further evidence that properly grouted precast hollow core floors will show a reasonable velocity distribution across the element.

5. Example ASTC Rating Calculations

The examples of the calculation of the ASTC ratings in this report include calculations using both the simplified and the detailed methods. For the majority of the examples, the ASTC ratings using the simplified and the detailed method are the same or differ by one ASTC point.

However, the difference between the calculation methods would be expected to be more significant if linings (floor toppings, gypsum board on the walls or ceiling, etc) were to be applied to the constructions. Research [7] at the NRC has shown that when a lining is applied on one side of the wall, the simplified method tends to result in flanking STC values that are the same or up to 4 points lower than the detailed method. When the lining is applied to both sides of the wall, the simplified method can result in values that are up to 6 points lower than the detailed method for some linings, but can also over predict the flanking STC rating for other linings. Therefore, when linings are applied to the concrete masonry walls or the precast hollow core floors or ceilings, the use of the detailed method to calculate the ASTC rating can result in higher ASTC ratings in some cases than the use of the simplified method.

5.1 Standard Scenarios for the Examples

For the purposes of this report, the ASTC ratings of building constructions that include concrete masonry walls connected to precast hollow core floors are calculated using the Standard Scenarios for side-by-side and one-above-the-other rooms which are used in RR-331. The Standard Scenario rooms are shown in Figure 26 and Figure 27.

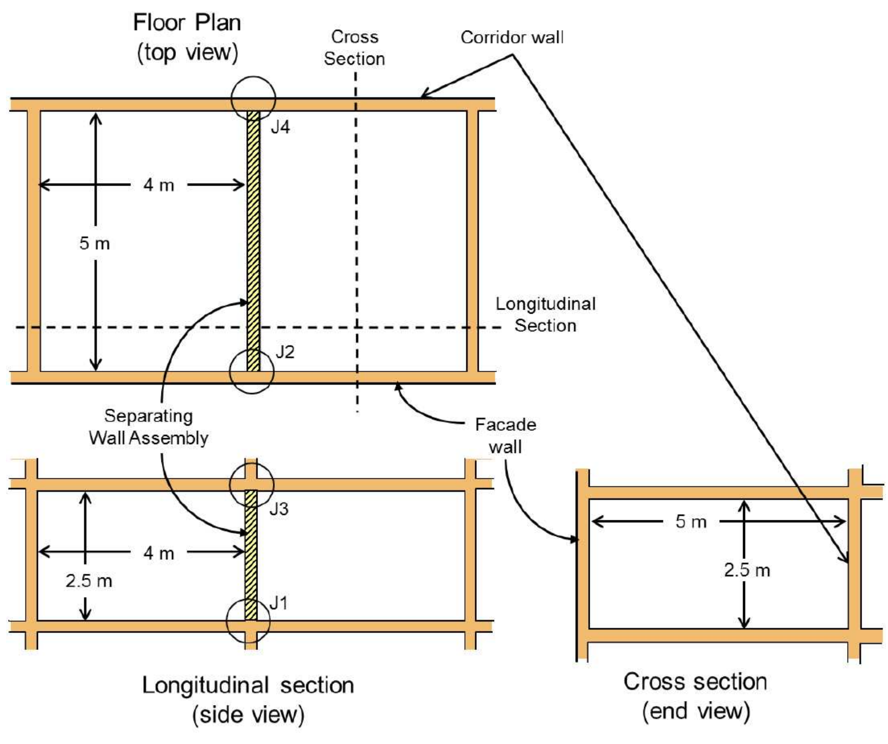


Figure 26: Standard Scenario from the NRC Research Report RR-331 for "horizontal room pair" case where the pair of rooms are side-by-side with a separating wall assembly between the two rooms.

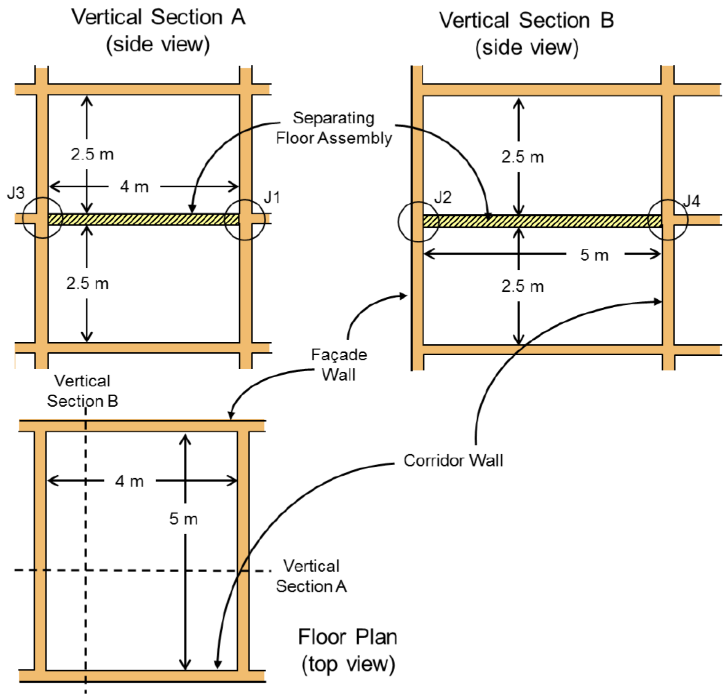


Figure 27: Standard Scenario from the NRC Research Report RR-331 for "vertical room pair" case where one of the pair of rooms is above the other with a floor/ceiling assembly between the two rooms.

The pertinent dimensions and junction details of the Standard Scenario rooms are:

- For horizontal room pairs (rooms are side-by-side) the separating wall is 2.5 m high by 5 m wide and the flanking floors and ceilings are 4 m by 5 m and the flanking walls are 2.5 m by 4 m.
- For vertical room pairs (one room is above the other) the separating floor/ceiling is 4 m by 5 m 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 a 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 a 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 this Standard Scenario, such as room pairs where one of the rooms is an end unit, resulting in a T-junction can change the ASTC ratings.

5.2 ASTC Examples - 203 mm Precast Hollow Core Floors - Measured K_{ij} Values

The following examples using both the simplified and the detailed calculation methods are for constructions of 190 mm thick hollow concrete block masonry units with a mass per unit area of 238 kg/m^2 connected to 203 mm (8 inch) thick hollow core slabs with a mass per unit area of 323 kg/m^2. The transmission loss values for the concrete block masonry wall are laboratory measured values from the NRC Report RR-334 [6]. The transmission loss values for the precast hollow core slabs are laboratory measured values from the NRC Client Report A1-004972.1.

Note that examples in this section differ from those in Section 5.3 for the same constructions. The examples in this section use the experimentally measured vibration reduction index values for the junctions between the concrete block masonry walls and the hollow core floors whereas the examples in Section 5.3 use theoretical values for the vibration reduction index. The two sets of examples are presented to demonstrate the effect of using the theoretical values of the vibration reduction index instead of the measured values.

5.2.1 ASTC Examples - Simplified Method

The following two examples use the simplified method of the calculations as detailed in the National Research Council Report RR-331. The experimentally measured vibration reduction index values are used for the examples. The transmission loss values for the concrete block masonry wall are laboratory measured values from the NRC Report RR-334 [6]. The transmission loss values for the precast hollow core slabs are laboratory measured values from the NRC Client Report A1-004972.1. The simplified method uses the single number ratings for the transmission loss and the vibration reduction index for the calculations. Examples using the detailed method which uses data in 1/3 octave bands are presented in Section 5.2.2.

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5.2.1.1 Horizontal Room Pair - 203 mm Precast Hollow Core Floor - Measured K_{ij} Values - Simplified Method

EXAMPLE 1: **(SIMPLIFIED METHOD)**

- **Rooms side-by-side**
- **Loadbearing normal weight concrete block walls and precast concrete hollow core floors with rigid junctions**

Separating wall assembly (loadbearing) with:
- One wythe of concrete blocks[1] with mass 238 kg/m² (e.g. 190 mm hollow blocks with normal weight aggregate) with no lining

Junction 1: Bottom Junction (separating wall / floor) with:
- 203 mm (8") precast hollow core slab[2] with mass 323 kg/m² with no added topping or flooring
- Rigid mortared/grouted cross junction with the concrete block wall assembly

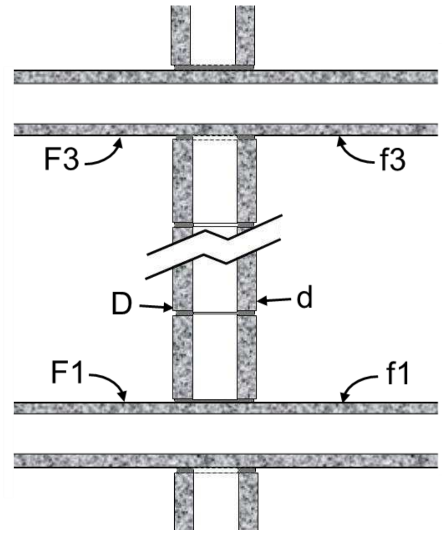
Junction 2 or 4: Each Side (separating wall / abutting side wall) with:
- Abutting side wall and separating wall of concrete blocks[1] with mass 238 kg/m² (e.g. 190 mm hollow blocks with normal weight aggregate), with no lining
- rigid mortared T-junctions

Junction 3: Top Junction (separating wall / ceiling) with:
- 203 mm (8") precast hollow core slab[2] with mass 323 kg/m² with no added ceiling lining
- Rigid mortared/grouted cross-junction with a concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.

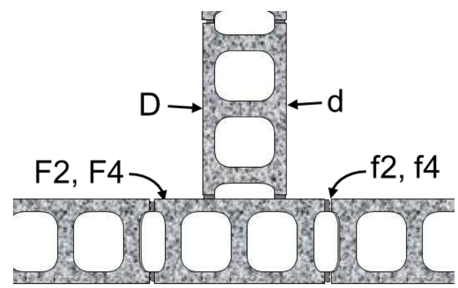
Acoustical Parameters:

For 190 mm concrete block walls:		
Mass/unit area (kg/m²) =	238	(Separating wall)
	238	(Flanking wall)
For 203 mm precast hollow core floor		
Mass/unit area (kg/m²) =	323	
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 190 mm concrete block separating wall with 203 mm thick precast concrete hollow core floor. (Side view of Junctions 1 and 3)



Junction of the separating wall with a side wall, both of 190 mm concrete block. (Plan view of Junctions 2 and 4).

Junction		Kij (in dB)			Reference
Number	Type	Path Ff	Path Fd	Path Df	
1	Rigid-Cross junction	10.2	16.2	16.2	ISO 15712-1, Eq. E.3
2	Rigid T-junction	5.7	5.8	5.8	ISO 15712-1, Eq. E.4
3	Rigid-Cross junction	10.2	16.2	16.2	ISO 15712-1, Eq. E.3
4	Rigid T-junction	5.7	5.8	5.8	ISO 15712-1, Eq. E.4

	ISO Symbol	Reference		SNR
Separating Partition (190 mm concrete block)				
Laboratory STC for Dd	R_s,w	RR-334, NRC-Mean BLK190(NW)		49
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	ISO 15712-1, Eq. 24 and 30	49+ MAX(0,0) + MIN(0,0)/2 =	49
Junction 1 (Rigid Cross junction, 190 mm block separating wall / 203 mm precast hollow core floor)				
Flanking Element F1:				
Laboratory STC for F1	R_F1,w	Report A1-004972.1		56
ΔSTC change by Lining	ΔR_F1,w	No Lining		0
Flanking Element f1:				
Laboratory STC for f1	R_f1,w	Report A1-004972.1		56
ΔSTC change by Lining	ΔR_f1,w	No Lining		0
Flanking STC for path Ff	R_ Ff,w	ISO 15712-1, Eq. 28a & 31	56/2 + 56/2 + MAX(0,0) + MIN(0,0)/2 + 10.2 + 4 =	70
Flanking STC for path Fd	R_ Fd,w	ISO 15712-1, Eq. 28a & 31	56/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 16.2 + 4 =	73
Flanking STC for path Df	R_ Df,w	ISO 15712-1, Eq. 28a & 31	49/2 + 56/2 + MAX(0,0) + MIN(0,0)/2 + 16.2 + 4 =	73
Junction 1: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-7 + 10^- 7.3 + 10^- 7.3) =	67
Junction 2 (Rigid T-Junction, 190 mm block separating wall / 190 mm block flanking wall)				
Flanking Element F2:				
Laboratory STC for F2	R_F2,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_F2,w	No Lining		0
Flanking Element f2:				
Laboratory STC for f2	R_f2,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_f2,w	No Lining		0
Flanking STC for path Ff	R_ Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =	62
Flanking STC for path Fd	R_ Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 5.8 + 7 =	62
Flanking STC for path Df	R_ Df,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 5.8 + 7 =	62
Junction 2: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-6.2 + 10^- 6.2 + 10^- 6.2) =	57
Junction 3 (Rigid Cross junction, 190 mm block separating wall / 203 mm precast hollow core ceiling slab)				
Flanking Element F3:				
Laboratory STC for F3	R_F3,w	Report A1-004972.1		56
ΔSTC change by Lining	ΔR_F3,w	No Lining		0
Flanking Element f3:				
Laboratory STC for f3	R_f3,w	Report A1-004972.1		56
ΔSTC change by Lining	ΔR_f3,w	No Lining		0
Flanking STC for path Ff	R_ Ff,w	ISO 15712-1, Eq. 28a & 31	56/2 + 56/2 + MAX(0,0) + MIN(0,0)/2 + 10.2 + 4 =	70
Flanking STC for path Fd	R_ Fd,w	ISO 15712-1, Eq. 28a & 31	56/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 16.2 + 4 =	73
Flanking STC for path Df	R_ Df,w	ISO 15712-1, Eq. 28a & 31	49/2 + 56/2 + MAX(0,0) + MIN(0,0)/2 + 16.2 + 4 =	73
Junction 3: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-7 + 10^- 7.3 + 10^- 7.3) =	67
Junction 4 (Rigid T-junction, 190 mm block separating wall / 190 mm block flanking wall)				
Flanking Element F4:				
Laboratory STC for F4	R_F4,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_F4,w	No Lining		0
Flanking Element f4:				
Laboratory STC for f4	R_f4,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_f4,w	No Lining		0
Flanking STC for path Ff	R_ Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =	62
Flanking STC for path Fd	R_ Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 5.8 + 7 =	62
Flanking STC for path Df	R_ Df,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 5.8 + 7 =	62
Junction 4: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-6.2 + 10^- 6.2 + 10^- 6.2) =	57
Total Flanking STC (4 Junctions)		Subset of Eq. 1.1	Combining 12 Flanking STC values	54
ASTC due to Direct plus All Flanking Paths		Equation 1.1	Combining Direct STC with 12 Flanking STC values	**48**

5.2.1.2 Vertical Room Pair - 203 mm Precast Hollow Core Floor - Measured K_{ij} Values - Simplified Method

EXAMPLE 2: (SIMPLIFIED METHOD)

- **Rooms one-above-the-other**
- **Loadbearing normal weight concrete block walls and precast concrete hollow core floors with rigid junctions**

Separating floor/ceiling assembly with:
- 203 mm (8") precast hollow core slab[2] with mass 323 kg/m^2 with no flooring on top, or ceiling lining below

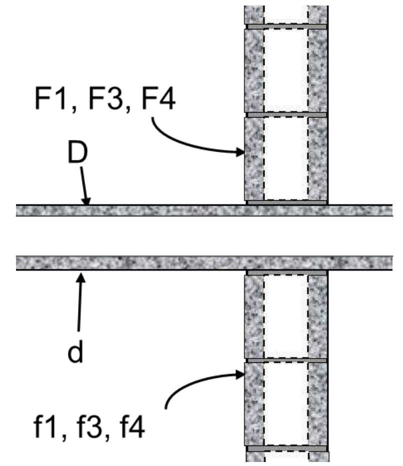
Junction 1, 3, 4: Cross Junction of separating floor / flanking wall with:
- Rigid mortared/grouted cross-junction with concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.
- Wall above and below floor of one wythe of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate[1]) with no lining of walls

Junction 2: T-Junction of separating floor / flanking wall with:
- Rigid mortared/grouted cross-junction with a concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.
- Wall above and below floor of one wythe of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate) with no lining of walls

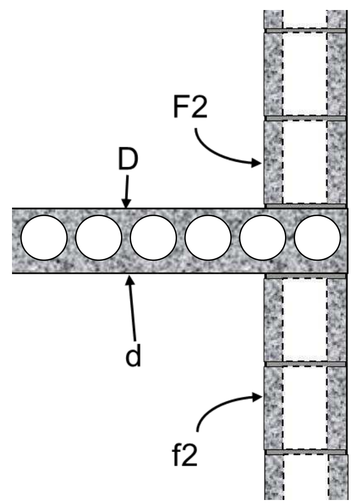
Acoustical Parameters:

For 190 mm concrete block walls:		
Mass/unit area (kg/m^2) =	238	(Wall at junctions 1&3)
	238	(Wall at junctions 2&4)
For 203 mm hollow core concrete floor:		
Mass/unit area (kg/m^2) =	323	
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 precast concrete hollow core floor with 190 mm concrete block wall. (Side view of Junctions 1, 3, 4)



T-Junction of separating floor of 203 mm thick precast concrete hollow core floor with 190 mm concrete block wall. (Side view of Junction 2).

Junction		Kij (in dB)			Reference
Number	Type	Path Ff	Path Fd	Path Df	
1	Rigid-Cross junction	22.3	16.2	16.2	ISO 15712-1, Eq. E.3
2	Rigid T-junction	16.1	13.1	13.1	ISO 15712-1, Eq. E.4
3	Rigid-Cross junction	22.3	16.2	16.2	ISO 15712-1, Eq. E.3
4	Rigid-Cross junction	22.3	16.2	16.2	ISO 15712-1, Eq. E.4

	ISO Symbol	Reference		SNR
Separating Partition (203 mm precast hollow core floor)				
Laboratory STC for Dd	R_s,w	Report A1-004972.1		56
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	ISO 15712-1, Eq. 24 and 30	56+ MAX(0,0) + MIN(0,0)/2 =	56
Junction 1 (Rigid-Cross junction between a seperating element of 203 mm precast hollow core floor and a flanking wall of 190 mm block)				
Flanking Element F1:				
Laboratory STC for F1	R_F1,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_F1,w	No Lining		0
Flanking Element f1:				
Laboratory STC for f1	R_f1,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_f1,w	No Lining		0
Flanking STC for path Ff	R_Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 22.3 + 6 =	77
Flanking STC for path Fd	R_Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 56/2 + MAX(0,0) + MIN(0,0)/2 + 16.2 + 6 =	75
Flanking STC for path Df	R_Df,w	ISO 15712-1, Eq. 28a & 31	56/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 16.2 + 6 =	75
Junction 1: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-7.7 + 10^- 7.5 + 10^- 7.5) =	71
Junction 2 (Rigid-T junction between a seperating element of 203 mm precast hollow core floor and a flanking wall of 190 mm block)				
Flanking Element F2:				
Laboratory STC for F2	R_F2,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_F2,w	No Lining		0
Flanking Element f2:				
Laboratory STC for f2	R_f2,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_f2,w	No Lining		0
Flanking STC for path Ff	R_Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 16.1 + 7 =	72
Flanking STC for path Fd	R_Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 56/2 + MAX(0,0) + MIN(0,0)/2 + 13.1 + 7 =	73
Flanking STC for path Df	R_Df,w	ISO 15712-1, Eq. 28a & 31	56/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 13.1 + 7 =	73
Junction 2: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-7.2 + 10^- 7.3 + 10^- 7.3) =	68
Junction 3 (Rigid-Cross junction between a seperating element of 203 mm precast hollow core floor and a flanking wall of 190 mm block)				
Flanking Element F3:				
Laboratory STC for F3	R_F3,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_F3,w	No Lining		0
Flanking Element f3:				
Laboratory STC for f3	R_f3,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_f3,w	No Lining		0
Flanking STC for path Ff	R_Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 22.3 + 6 =	77
Flanking STC for path Fd	R_Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 56/2 + MAX(0,0) + MIN(0,0)/2 + 16.2 + 6 =	75
Flanking STC for path Df	R_Df,w	ISO 15712-1, Eq. 28a & 31	56/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 16.2 + 6 =	75
Junction 3: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-7.7 + 10^- 7.5 + 10^- 7.5) =	71
Junction 4 (Rigid-Cross junction between a seperating element of 203 mm precast hollow core floor and a flanking wall of 190 mm block)				
Flanking Element F4:				
Laboratory STC for F4	R_F4,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_F4,w	No Lining		0
Flanking Element f4:				
Laboratory STC for f4	R_f4,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_f4,w	No Lining		0
Flanking STC for path Ff	R_Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 22.3 + 7 =	78
Flanking STC for path Fd	R_Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 56/2 + MAX(0,0) + MIN(0,0)/2 + 16.2 + 7 =	76
Flanking STC for path Df	R_Df,w	ISO 15712-1, Eq. 28a & 31	56/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 16.2 + 7 =	76
Junction 4: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-7.8 + 10^- 7.6 + 10^- 7.6) =	72
Total Flanking STC (4 Junctions)		Subset of Eq. 1.1	Combining 12 Flanking STC values	64
ASTC due to Direct plus All Flanking Paths		Equation 1.1	Combining Direct STC with 12 Flanking STC values	**55**

5.2.2 ASTC Examples - Detailed Method

The examples presented in this section use the detailed method of the calculations as described in the National Research Council Report RR-331. The detailed method differs from the simplified method because the calculations are based on data in 1/3 octave bands instead of the single number ratings.

The experimentally measured vibration reduction index values are used for the examples in this section. The transmission loss values for the concrete block masonry wall are laboratory measured values from the NRC Report RR-334 [6]. The transmission loss values for the precast hollow core slabs are laboratory measured values from the NRC Client Report A1-004972.1.

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5.2.2.1 Horizontal Room Pair - 203 mm Precast Hollow Core Floor - Measured K_{ij} Values - Detailed Method

EXAMPLE 3: (DETAILED METHOD)

- **Rooms side-by-side**
- **Loadbearing normal weight concrete block walls and precast concrete hollow core floors with rigid junctions**

Separating wall assembly (loadbearing) with:
- One wythe of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate) with no lining

Junction 1: Bottom Junction (separating wall / floor) with:
- 203 mm (8") precast hollow core slab[2] with mass 323 kg/m^2 with no added topping or flooring
- Rigid mortared/grouted cross junction with the concrete block[1] wall assembly

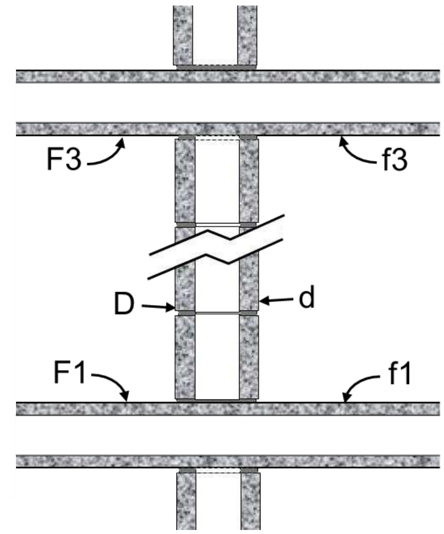
Junction 2 or 4: Each Side (separating wall / abutting side wall) with:
- Abutting side wall and separating wall of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate), with no lining
- rigid mortared T-junctions

Junction 3: Top Junction (separating wall / ceiling) with:
- 203 mm (8") precast hollow core slab[2] with mass 323 kg/m^2 with no added ceiling lining
- Rigid mortared/grouted cross-junction with a concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.

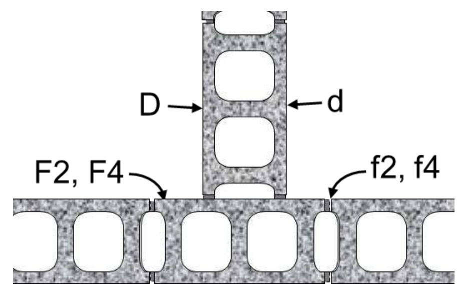
Acoustical Parameters:

For 190 mm concrete block walls:		
Mass/unit area (kg/m^2) =	238	(Separating wall)
	238	(Flanking wall)
For 203 mm precast hollow core floor		
Mass/unit area (kg/m^2) =	323	
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 190 mm concrete block separating wall with 203 mm thick precast concrete hollow core floor. (Side view of Junctions 1 and 3)



Junction of the separating wall with a side wall, both of 190 mm concrete block. (Plan view of Junctions 2 and 4).

	ISO Symbol	Reference	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	SNR
Direct STC Rating of Path Dd									
Sound Transmission Loss	$R_{D,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Correction, Resonant Transmission		N/A	0	0	0	0	0	0	
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	
Effect of Airborne Flanking and Leakage		N/A	0	0	0	0	0	0	
Direct TL in-situ	$R_{D,situ}$	ISO 15712-1, Eq. 24	35	38	44	50	58	62	49
Junction 1 (Rigid Cross junction, 190 mm block separating wall / 203 mm precast hollow core floor)									
Flanking Path Ff_1									
Transmission Loss Element F1	$R_{F1,lab}$	Report A1-004972.1	38	46	52	60	65	72	56
Transmission Loss Element f1	$R_{f1,lab}$	Report A1-004972.1	38	46	52	60	65	72	56
Correction, Resonant Transmission F1		N/A	0	0	0	0	0	0	
Correction, Resonant Transmission f1		N/A	0	0	0	0	0	0	
TL in-situ for Element F1	$R_{F1,situ}$	Eq. 19, T_s,situ = T_s,lab	38	46	52	60	65	72	56
TL in-situ for Element f1	$R_{f1,situ}$	Eq. 19, T_s,situ = T_s,lab	38	46	52	60	65	72	56
Change by Lining on the Source Side	ΔR_{F1}	N/A	0	0	0	0	0	0	
Change by Lining on the Receiving Side	ΔR_{f1}	N/A	0	0	0	0	0	0	
Junction 1 - Coupling									
Vibration Reduction Index for Ff	$K_{F1,f}$	Measured	12.9	11.8	9.8	9.7	7.1	3.9	10.2
Vibration Reduction Index for Fd	$K_{F1,d}$	Measured	23.5	18.3	14.5	14.7	9.4	8.0	16.2
Vibration Reduction Index for Df	$K_{D,f1}$	Measured	23.5	18.3	14.5	14.7	9.4	8.0	16.2
Flanking Transmssion Loss - Path Values									
Flanking TL for Path Ff1	R_{F1f1}	ISO 15712-1 Eq 25b	55	62	66	74	76	80	71
Flanking TL for Path Fd1	R_{F1d}	ISO 15712-1 Eq 25b	64	64	66	74	75	79	72
Flanking TL for Path Df1	R_{Df1}	ISO 15712-1 Eq 25b	64	64	66	74	75	79	72
Flanking STC for Junction 1		**0**	54	59	62	69	71	75	67
Junction 2 (Rigid T-Junction, 190 mm block separating wall / 190 mm block flanking wall)									
Flanking Path Ff_2									
Transmission Loss Element F2	$R_{F2,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Transmission Loss Element f2	$R_{f2,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Correction, Resonant Transmission F2		N/A	0	0	0	0	0	0	
Correction, Resonant Transmission f2		N/A	0	0	0	0	0	0	
TL in-situ for Element F2	$R_{F2,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	
TL in-situ for Element f2	$R_{f2,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	
Change by Lining on the Source Side	ΔR_{F2}	N/A	0	0	0	0	0	0	
Change by Lining on the Receiving Side	ΔR_{f2}	N/A	0	0	0	0	0	0	
Junction 2 - Coupling									
Vibration Reduction Index for Ff	$K_{F2,f}$	ISO 15712-1 Annex E	5.7	5.7	5.7	5.7	5.7	5.7	5.7
Vibration Reduction Index for Fd	$K_{F2,d}$	ISO 15712-1 Annex E	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Vibration Reduction Index for Df	$K_{D,f2}$	ISO 15712-1 Annex E	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Flanking Transmssion Loss - Path Values									
Flanking TL for Path Ff2	R_{F2f2}	ISO 15712-1 Eq 25b	55	62	66	74	76	80	62
Flanking TL for Path Fd2	R_{F2d}	ISO 15712-1 Eq 25b	64	64	66	74	75	79	62
Flanking TL for Path Df2	R_{Df2}	ISO 15712-1 Eq 25b	64	64	66	74	75	79	62
Flanking STC for Junction 2			43	46	52	58	66	70	57
Junction 3 (Rigid Cross junction, 190 mm block separating wall / 203 mm precast hollow core ceiling slab)									
All values are the same as for Junction 1									
Flanking TL for Path Ff3	R_{F3f3}	ISO 15712-1 Eq 25b	55	62	66	74	76	80	71
Flanking TL for Path Fd3	R_{F3d}	ISO 15712-1 Eq 25b	64	64	66	74	75	79	72
Flanking TL for Path Df3	R_{Df3}	ISO 15712-1 Eq 25b	64	64	66	74	75	79	72
Flanking STC for Junction 3			54	58	61	69	70	74	67
Junction 4 (Rigid T-junction, 190 mm block separating wall / 190 mm block flanking wall)									
All values are the same as for Junction 2									
Flanking TL for Path Ff4	R_{F4f4}	ISO 15712-1 Eq 25b	48	51	57	63	71	75	62
Flanking TL for Path Fd4	R_{F4d}	ISO 15712-1 Eq 25b	48	51	57	63	71	75	62
Flanking TL for Path Df4	R_{Df4}	ISO 15712-1 Eq 25b	48	51	57	63	71	75	62
Flanking STC for Junction 4			43	46	52	58	66	70	57
Total Flanking STC (combined transmssion for all of the flanking paths)			40	43	49	55	62	66	54
ASTC due to Direct plus Flanking Transmission		RR-335, Eq. 1.1	34	37	43	49	56	60	**48**

5.2.2.2 Vertical Room Pair - 203 mm Precast Hollow Core Floor - Measured K_{ij} Values - Detailed Method

EXAMPLE 4: (DETAILED METHOD)

- **Rooms one-above-the-other**
- **Loadbearing normal weight concrete block walls and precast concrete hollow core floors with rigid junctions**

Separating floor/ceiling assembly with:

- 203 mm (8") precast hollow core slab[2] with mass 323 kg/m^2 with no flooring on top, or ceiling lining below

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

- Rigid mortared/grouted cross-junction with concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.
- Wall above and below floor of one wythe of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate[1]) with no lining of walls

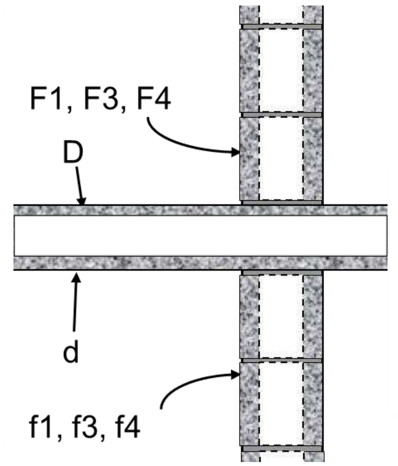
Junction 2: T-Junction of separating floor / flanking wall with:

- Rigid mortared/grouted cross-junction with concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.
- Wall above and below floor of one wythe of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate) with no lining of walls

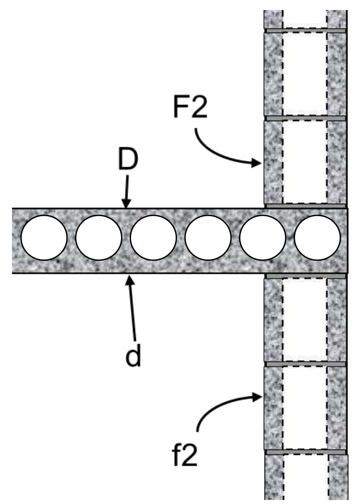
Acoustical Parameters:

For 190 mm concrete block walls:		
Mass/unit area (kg/m^2) =	238	(Separating wall)
	238	(Flanking wall)
For 203 mm precast hollow core floor		
Mass/unit area (kg/m^2) =	323	
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



Cross junction of separating floor of 203 mm thick precast concrete hollow core floor with 190 mm concrete block wall. (Side view of Junctions 1, 3, 4)



T-Junction of separating floor of 203 mm thick precast concrete hollow core floor with 190 mm concrete block wall. (Side view of Junction 2).

	ISO Symbol	Reference	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	SNR
Direct STC Rating of Path Dd									
Sound Transmission Loss	$R_{D,lab}$	Report A1-004972.1	38	46	52	60	65	72	56
Correction, Resonant Transmission		N/A	0	0	0	0	0	0	
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	
Effect of Airborne Flanking and Leakage		N/A	0	0	0	0	0	0	
Direct TL in-situ	$R_{D,situ}$	ISO 15712-1, Eq. 24	38	46	52	60	65	72	56
Junction 1 (Rigid-Cross junction between a seperating element of 203 mm precast hollow core floor and a flanking wall of 190 mm block)									
Flanking Path Ff_1									
Transmission Loss Element F1	$R_{F1,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Transmission Loss Element f1	$R_{f1,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Correction, Resonant Transmission F1		N/A	0	0	0	0	0	0	
Correction, Resonant Transmission f1		N/A	0	0	0	0	0	0	
TL in-situ for Element F1	$R_{F1,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	49
TL in-situ for Element f1	$R_{f1,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	49
Change by Lining on the Source Side	ΔR_{F1}	N/A	0	0	0	0	0	0	
Change by Lining on the Receiving Side	ΔR_{f1}	N/A	0	0	0	0	0	0	
Junction 1 - Coupling									
Vibration Reduction Index for Ff	$K_{F1,f}$	Measured	26.5	27.1	21.9	18.5	8.5	11.0	22.3
Vibration Reduction Index for Fd	$K_{F1,d}$	Measured	23.5	18.3	14.5	14.7	9.4	8.0	16.2
Vibration Reduction Index for Df	$K_{D,f1}$	Measured	23.5	18.3	14.5	14.7	9.4	8.0	16.2
Flanking Transmssion Loss - Path Values									
Flanking TL for Path Ff1	R_{F1f1}	ISO 15712-1 Eq 25b	68	71	72	75	73	79	74
Flanking TL for Path Fd1	R_{F1d}	ISO 15712-1 Eq 25b	66	66	69	76	77	81	74
Flanking TL for Path Df1	R_{Df1}	ISO 15712-1 Eq 25b	66	66	69	76	77	81	74
Flanking STC for Junction 1			62	63	65	71	70	75	70
Junction 2 (Rigid-T junction between a seperating element of 203 mm precast hollow core floor and a flanking wall of 190 mm block)									
Flanking Path Ff_2									
Transmission Loss Element F2	$R_{F2,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Transmission Loss Element f2	$R_{f2,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Correction, Resonant Transmission F2		N/A	0	0	0	0	0	0	
Correction, Resonant Transmission f2		N/A	0	0	0	0	0	0	
TL in-situ for Element F2	$R_{F2,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	
TL in-situ for Element f2	$R_{f2,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	
Change by Lining on the Source Side	ΔR_{F2}	N/A	0	0	0	0	0	0	
Change by Lining on the Receiving Side	ΔR_{f2}	N/A	0	0	0	0	0	0	
Junction 2 - Coupling									
Vibration Reduction Index for Ff	$K_{F2,f}$	Measured	27.3	22.5	13.5	11.2	8.7	11.6	16.1
Vibration Reduction Index for Fd	$K_{F2,d}$	Measured	18.8	14.2	10.9	12.5	8.5	6.6	13.1
Vibration Reduction Index for Df	$K_{D,f2}$	Measured	18.8	14.2	10.9	12.5	8.5	6.6	13.1
Flanking Transmssion Loss - Path Values									
Flanking TL for Path Ff2	R_{F2f2}	ISO 15712-1 Eq 25b	68	71	72	75	73	79	70
Flanking TL for Path Fd2	R_{F2d}	ISO 15712-1 Eq 25b	66	66	69	76	77	81	73
Flanking TL for Path Df2	R_{Df2}	ISO 15712-1 Eq 25b	66	66	69	76	77	81	73
Flanking STC for Junction 2			59	59	61	67	71	76	67
Junction 3 (Rigid-Cross junction between a seperating element of 203 mm precast hollow core floor and a flanking wall of 190 mm block)									
All values are the same as for Junction 1									
Flanking TL for Path Ff3	R_{F3f3}	ISO 15712-1 Eq 25b	68	71	72	75	73	79	74
Flanking TL for Path Fd3	R_{F3d}	ISO 15712-1 Eq 25b	66	66	69	76	77	81	74
Flanking TL for Path Df3	R_{Df3}	ISO 15712-1 Eq 25b	66	66	69	76	77	81	74
Flanking STC for Junction 3			62	63	65	71	70	75	70
Junction 4 (Rigid-Cross junction between a seperating element of 203 mm precast hollow core floor and a flanking wall of 190 mm block)									
All values are the same as for Junction 2									
Flanking TL for Path Ff4	R_{F4f4}	ISO 15712-1 Eq 25b	68	72	73	75	73	80	75
Flanking TL for Path Fd4	R_{F4d}	ISO 15712-1 Eq 25b	67	67	69	77	78	82	75
Flanking TL for Path Df4	R_{Df4}	ISO 15712-1 Eq 25b	67	67	69	77	78	82	75
Flanking STC for Junction 4			63	64	66	71	71	76	71
Total Flanking STC (combined transmssion for all of the flanking paths)			55	56	57	63	65	70	63
ASTC due to Direct plus Flanking Transmission		RR-335, Eq. 1.1	38	46	51	58	62	68	55

5.3 ASTC Examples - 203 mm Precast Hollow Core Floors - Theoretical K_{ij} Values

The following examples using both the simplified and the detailed calculation methods are for constructions of 190 mm thick hollow concrete block masonry units with a mass per unit area of 238 kg/m^2 connected to 203 mm (8 inch) thick hollow core slabs with a mass per unit area of 323 kg/m^2. The transmission loss values for the concrete block masonry wall are laboratory measured values from the NRC Report RR-334 [6]. The transmission loss values for the precast hollow core slabs are laboratory measured values from the NRC Client Report A1-004972.1.

The examples in this section differ from those in section 5.2 because theoretical vibration reduction index values are used for the junctions which include the precast hollow core floors instead of the experimentally measured values. The calculation of the theoretical vibration reduction index values is explained in Sections 3.1 and 3.2 of this report.

5.3.1 ASTC Examples - Simplified Method

The following two examples use the simplified method of the calculations as detailed in the National Research Council Report RR-331.

The theoretically calculated vibration reduction index values are used for the examples in this section. The transmission loss values for the concrete block masonry wall are laboratory measured values from the NRC Report RR-334 [6]. The transmission loss values for the precast hollow core slabs are laboratory measured values from the NRC Client Report A1-004972.1.

5.3.1.1 Horizontal Room Pair - 203 mm Precast Hollow Core Floor - Theoretical K_{ij} Values - Simplified Method

EXAMPLE 1: (SIMPLIFIED METHOD)

- **Rooms side-by-side**
- **Loadbearing normal weight concrete block walls and precast concrete hollow core floors with rigid junctions**

Separating wall assembly (loadbearing) with:

- One wythe of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate) with no lining

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

- 203 mm (8") precast hollow core slab[2] with mass 323 kg/m^2 with no added topping or flooring
- Rigid mortared/grouted cross junction with the concrete block[1] wall assembly

Junction 2 or 4: Each Side (separating wall / abutting side wall) with:

- Abutting side wall and separating wall of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate), with no lining
- rigid mortared T-junctions

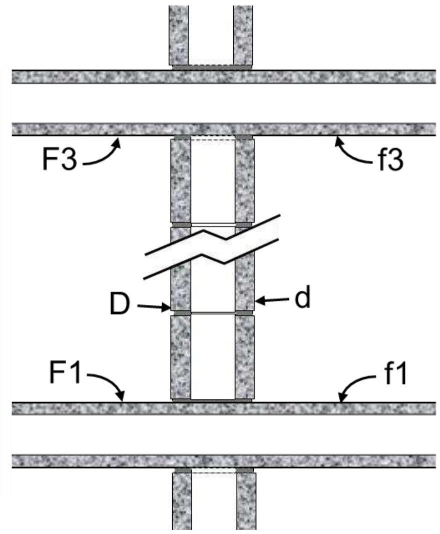
Junction 3: Top Junction (separating wall / ceiling) with:

- 203 mm (8") precast hollow core slab[2] with mass 323 kg/m^2 with no added ceiling lining
- Rigid mortared/grouted cross-junction with concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.

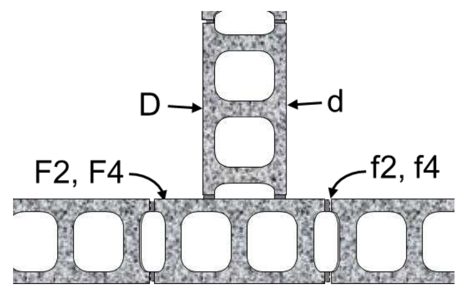
Acoustical Parameters:

For 190 mm concrete block walls:		
Mass/unit area (kg/m^2) =	238	(Separating wall)
	238	(Flanking wall)
For 203 mm precast hollow core floor		
Mass/unit area (kg/m^2) =	323	
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 190 mm concrete block separating wall with 203 mm thick precast concrete hollow core floor. (Side view of Junctions 1 and 3)



Junction of the separating wall with a side wall, both of 190 mm concrete block. (Plan view of Junctions 2 and 4).

Junction		Kij (in dB)			Reference
Number	Type	Path Ff	Path Fd	Path Df	
1	Rigid-Cross junction	8.7	8.8	8.8	ISO 15712-1, Eq. E.3
2	Rigid T-junction	5.7	5.7	5.7	ISO 15712-1, Eq. E.4
3	Rigid-Cross junction	8.7	8.8	8.8	ISO 15712-1, Eq. E.3
4	Rigid T-junction	5.7	5.7	5.7	ISO 15712-1, Eq. E.4

	ISO Symbol	Reference		SNR
Separating Partition (190 mm concrete block)				
Laboratory STC for Dd	R_s,w	RR-334, NRC-Mean BLK190(NW)		49
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	ISO 15712-1, Eq. 24 and 30	49+ MAX(0,0) + MIN(0,0)/2 =	49
Junction 1 (Rigid Cross junction, 190 mm block separating wall / 203 mm precast hollow core floor)				
Flanking Element F1:				
Laboratory STC for F1	R_F1,w	Report A1-004972.1		56
ΔSTC change by Lining	ΔR_F1,w	No Lining		0
Flanking Element f1:				
Laboratory STC for f1	R_f1,w	Report A1-004972.1		56
ΔSTC change by Lining	ΔR_f1,w	No Lining		0
Flanking STC for path Ff	R_Ff,w	ISO 15712-1, Eq. 28a & 31	56/2 + 56/2 + MAX(0,0) + MIN(0,0)/2 + 8.7 + 4 =	69
Flanking STC for path Fd	R_Fd,w	ISO 15712-1, Eq. 28a & 31	56/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 8.8 + 4 =	65
Flanking STC for path Df	R_Df,w	ISO 15712-1, Eq. 28a & 31	49/2 + 56/2 + MAX(0,0) + MIN(0,0)/2 + 8.8 + 4 =	65
Junction 1: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-6.9 + 10^- 6.5 + 10^- 6.5) =	61
Junction 2 (Rigid T-Junction, 190 mm block separating wall / 190 mm block flanking wall)				
Flanking Element F2:				
Laboratory STC for F2	R_F2,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_F2,w	No Lining		0
Flanking Element f2:				
Laboratory STC for f2	R_f2,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_f2,w	No Lining		0
Flanking STC for path Ff	R_Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =	62
Flanking STC for path Fd	R_Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 5.8 + 7 =	62
Flanking STC for path Df	R_Df,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 5.8 + 7 =	62
Junction 2: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-6.2 + 10^- 6.2 + 10^- 6.2) =	57
Junction 3 (Rigid Cross junction, 190 mm block separating wall / 203 mm precast hollow core ceiling slab)				
Flanking Element F3:				
Laboratory STC for F3	R_F3,w	Report A1-004972.1		56
ΔSTC change by Lining	ΔR_F3,w	No Lining		0
Flanking Element f3:				
Laboratory STC for f3	R_f3,w	Report A1-004972.1		56
ΔSTC change by Lining	ΔR_f3,w	No Lining		0
Flanking STC for path Ff	R_Ff,w	ISO 15712-1, Eq. 28a & 31	56/2 + 56/2 + MAX(0,0) + MIN(0,0)/2 + 8.7 + 4 =	69
Flanking STC for path Fd	R_Fd,w	ISO 15712-1, Eq. 28a & 31	56/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 8.8 + 4 =	65
Flanking STC for path Df	R_Df,w	ISO 15712-1, Eq. 28a & 31	49/2 + 56/2 + MAX(0,0) + MIN(0,0)/2 + 8.8 + 4 =	65
Junction 3: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-6.9 + 10^- 6.5 + 10^- 6.5) =	61
Junction 4 (Rigid T-junction, 190 mm block separating wall / 190 mm block flanking wall)				
Flanking Element F4:				
Laboratory STC for F4	R_F4,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_F4,w	No Lining		0
Flanking Element f4:				
Laboratory STC for f4	R_f4,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_f4,w	No Lining		0
Flanking STC for path Ff	R_Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =	62
Flanking STC for path Fd	R_Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 5.8 + 7 =	62
Flanking STC for path Df	R_Df,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 5.8 + 7 =	62
Junction 4: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-6.2 + 10^- 6.2 + 10^- 6.2) =	57
Total Flanking STC (4 Junctions)		Subset of Eq. 1.1	Combining 12 Flanking STC values	53
ASTC due to Direct plus All Flanking Paths		Equation 1.1	Combining Direct STC with 12 Flanking STC values	**47**

5.3.1.2 Vertical Room Pair - 203 mm Precast Hollow Core Floor - Theoretical K_{ij} Values - Simplified Method

EXAMPLE 2: (SIMPLIFIED METHOD)

- **Rooms one-above-the-other**
- **Loadbearing normal weight concrete block walls and precast concrete hollow core floors with rigid junctions**

Separating floor/ceiling assembly with:
- 203 mm (8") precast hollow core slab[2] with mass 323 kg/m^2 with no flooring on top, or ceiling lining below

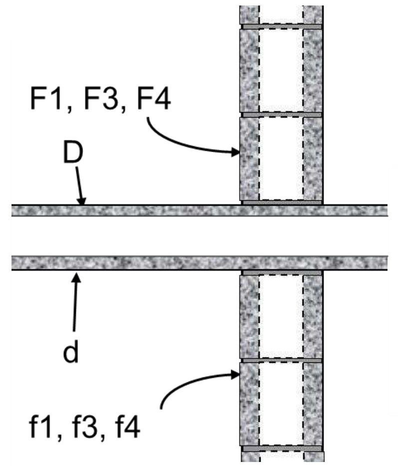
Junction 1, 3, 4: Cross Junction of separating floor / flanking wall with:
- Rigid mortared/grouted cross-junction with concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.
- Wall above and below floor of one wythe of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate[1]) with no lining of walls

Junction 2: T-Junction of separating floor / flanking wall with:
- Rigid mortared/grouted cross-junction with a concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.
- Wall above and below floor of one wythe of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate) with no lining of walls

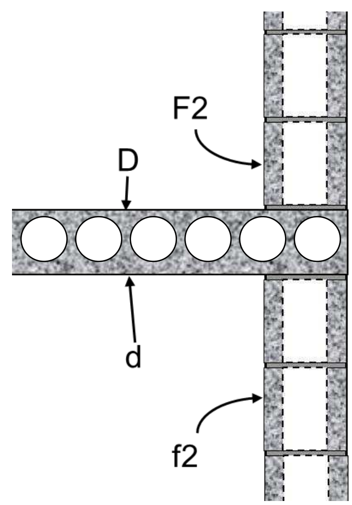
Acoustical Parameters:

For 190 mm concrete block walls:		
Mass/unit area (kg/m^2) =	238	(Separating wall)
	238	(Flanking wall)
For 203 mm precast hollow core floor		
Mass/unit area (kg/m^2) =	323	
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



Cross junction of separating floor of 203 mm thick precast concrete hollow core floor with 190 mm concrete block wall. (Side view of Junctions 1, 3, 4)



T-Junction of separating floor of 203 mm thick precast concrete hollow core floor with 190 mm concrete block wall. (Side view of Junction 2).

Junction		Kij (in dB)			Reference
Number	Type	Path Ff	Path Fd	Path Df	
1	Rigid-Cross junction	22.3	8.8	8.8	ISO 15712-1, Eq. E.3
2	Rigid T-junction	16.1	5.8	5.8	ISO 15712-1, Eq. E.4
3	Rigid-Cross junction	22.3	8.8	8.8	ISO 15712-1, Eq. E.3
4	Rigid T-junction	22.3	5.8	5.8	ISO 15712-1, Eq. E.4

	ISO Symbol	Reference		SNR
Separating Partition (203 mm precast hollow core floor)				
Laboratory STC for Dd	R_s,w	Report A1-004972.1		56
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	ISO 15712-1, Eq. 24 and 30	56+ MAX(0,0) + MIN(0,0)/2 =	56
Junction 1 (Rigid-Cross junction between a seperating element of 203 mm precast hollow core floor and a flanking wall of 190 mm block)				
Flanking Element F1:				
Laboratory STC for F1	R_F1,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_F1,w	No Lining		0
Flanking Element f1:				
Laboratory STC for f1	R_f1,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_f1,w	No Lining		0
Flanking STC for path Ff	R_Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 22.3 + 6 =	77
Flanking STC for path Fd	R_Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 56/2 + MAX(0,0) + MIN(0,0)/2 + 8.8 + 6 =	67
Flanking STC for path Df	R_Df,w	ISO 15712-1, Eq. 28a & 31	56/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 8.8 + 6 =	67
Junction 1: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-7.7 + 10^- 6.7 + 10^- 6.7) =	64
Junction 2 (Rigid-T junction between a seperating element of 203 mm precast hollow core floor and a flanking wall of 190 mm block)				
Flanking Element F2:				
Laboratory STC for F2	R_F2,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_F2,w	No Lining		0
Flanking Element f2:				
Laboratory STC for f2	R_f2,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_f2,w	No Lining		0
Flanking STC for path Ff	R_Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 16.1 + 7 =	72
Flanking STC for path Fd	R_Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 56/2 + MAX(0,0) + MIN(0,0)/2 + 5.8 + 7 =	65
Flanking STC for path Df	R_Df,w	ISO 15712-1, Eq. 28a & 31	56/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 5.8 + 7 =	65
Junction 2: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-7.2 + 10^- 6.5 + 10^- 6.5) =	62
Junction 3 (Rigid-Cross junction between a seperating element of 203 mm precast hollow core floor and a flanking wall of 190 mm block)				
Flanking Element F3:				
Laboratory STC for F3	R_F3,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_F3,w	No Lining		0
Flanking Element f3:				
Laboratory STC for f3	R_f3,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_f3,w	No Lining		0
Flanking STC for path Ff	R_Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 22.3 + 6 =	77
Flanking STC for path Fd	R_Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 56/2 + MAX(0,0) + MIN(0,0)/2 + 8.8 + 6 =	67
Flanking STC for path Df	R_Df,w	ISO 15712-1, Eq. 28a & 31	56/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 8.8 + 6 =	67
Junction 3: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-7.7 + 10^- 6.7 + 10^- 6.7) =	64
Junction 4 (Rigid-Cross junction between a seperating element of 203 mm precast hollow core floor and a flanking wall of 190 mm block)				
Flanking Element F4:				
Laboratory STC for F4	R_F4,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_F4,w	No Lining		0
Flanking Element f4:				
Laboratory STC for f4	R_f4,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_f4,w	No Lining		0
Flanking STC for path Ff	R_Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 22.3 + 7 =	78
Flanking STC for path Fd	R_Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 56/2 + MAX(0,0) + MIN(0,0)/2 + 5.8 + 7 =	65
Flanking STC for path Df	R_Df,w	ISO 15712-1, Eq. 28a & 31	56/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 5.8 + 7 =	65
Junction 4: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-7.8 + 10^- 6.5 + 10^- 6.5) =	62
Total Flanking STC (4 Junctions)		Subset of Eq. 1.1	Combining 12 Flanking STC values	57
ASTC due to Direct plus All Flanking Paths		Equation 1.1	Combining Direct STC with 12 Flanking STC values	**53**

5.3.2 ASTC Examples - Detailed Method

The examples presented in this section use the detailed method of the calculations as described in the National Research Council Report RR-331. The detailed method differs from the simplified method because the calculations are based on data in 1/3 octave bands instead of the single number ratings.

The examples in this section use the theoretical vibration reduction index values for the junctions between the concrete block masonry walls and the hollow core floors. The transmission loss values for the concrete block masonry wall are laboratory measured values from the NRC Report RR-334 [6]. The transmission loss values for the precast hollow core slabs are laboratory measured values from the NRC Client Report A1-004972.1.

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5.3.2.1 Horizontal Room Pair - 203 mm Precast Hollow Core Floor - Theoretical K_{ij} Values - Detailed Method

EXAMPLE 3: (DETAILED METHOD)

- **Rooms side-by-side**
- **Loadbearing normal weight concrete block walls and precast concrete hollow core floors with rigid junctions**

Separating wall assembly (loadbearing) with:

- One wythe of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate) with no lining

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

- 203 mm (8”) precast hollow core slab[2] with mass 323 kg/m^2 with no added topping or flooring
- Rigid mortared/grouted cross junction with the concrete block[1] wall assembly

Junction 2 or 4: Each Side (separating wall / abutting side wall) with:

- Abutting side wall and separating wall of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate), with no lining
- rigid mortared T-junctions

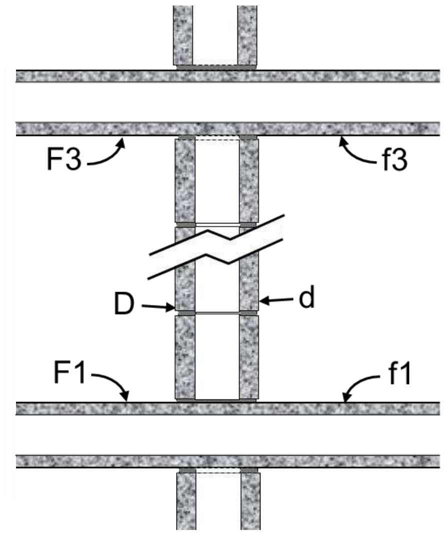
Junction 3: Top Junction (separating wall / ceiling) with:

- 203 mm (8”) precast hollow core slab[2] with mass 323 kg/m^2 with no added ceiling lining
- Rigid mortared/grouted cross-junction with concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.

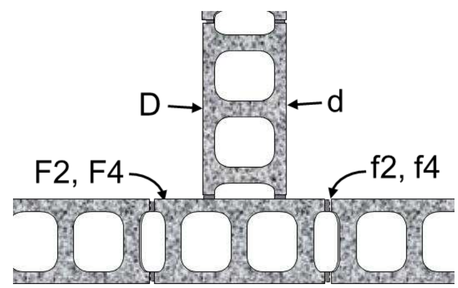
Acoustical Parameters:

For 190 mm concrete block walls:		
Mass/unit area (kg/m^2) =	238	(Separating wall)
	238	(Flanking wall)
For 203 mm precast hollow core floor		
Mass/unit area (kg/m^2) =	323	
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 190 mm concrete block separating wall with 203 mm thick precast concrete hollow core floor. (Side view of Junctions 1 and 3)



Junction of the separating wall with a side wall, both of 190 mm concrete block. (Plan view of Junction 2 or 4).

	ISO Symbol	Reference	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	SNR
Direct STC Rating of Path Dd									
Sound Transmission Loss	$R_{D,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Correction, Resonant Transmission		N/A	0	0	0	0	0	0	
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	
Effect of Airborne Flanking and Leakage		N/A	0	0	0	0	0	0	
Direct TL in-situ	$R_{D,situ}$	ISO 15712-1, Eq. 24	35	38	44	50	58	62	49
Junction 1 (Rigid Cross junction, 190 mm block separating wall / 203 mm precast hollow core floor)									
Flanking Path Ff_1									
Transmission Loss Element F1	$R_{F1,lab}$	Report A1-004972.1	38	46	52	60	65	72	56
Transmission Loss Element f1	$R_{f1,lab}$	Report A1-004972.1	38	46	52	60	65	72	56
Correction, Resonant Transmission F1		N/A	0	0	0	0	0	0	
Correction, Resonant Transmission f1		N/A	0	0	0	0	0	0	
TL in-situ for Element F1	$R_{F1,situ}$	Eq. 19, T_s,situ = T_s,lab	38	46	52	60	65	72	56
TL in-situ for Element f1	$R_{f1,situ}$	Eq. 19, T_s,situ = T_s,lab	38	46	52	60	65	72	56
Change by Lining on the Source Side	ΔR_{F1}	N/A	0	0	0	0	0	0	
Change by Lining on the Receiving Side	ΔR_{f1}	N/A	0	0	0	0	0	0	
Junction 1 - Coupling									
Vibration Reduction Index for Ff	$K_{F1,f}$	ISO 15712-1 Annex E	8.7	8.7	8.7	8.7	8.7	8.7	8.7
Vibration Reduction Index for Fd	$K_{F1,d}$	ISO 15712-1 Annex E	8.8	8.8	8.8	8.8	8.8	8.8	8.8
Vibration Reduction Index for Df	$K_{D,f1}$	ISO 15712-1 Annex E	8.8	8.8	8.8	8.8	8.8	8.8	8.8
Flanking Transmssion Loss - Path Values									
Flanking TL for Path Ff1	R_{F1f1}	ISO 15712-1 Eq 25b	51	59	65	73	78	85	69
Flanking TL for Path Fd1	R_{F1d}	ISO 15712-1 Eq 25b	49	55	61	68	74	80	65
Flanking TL for Path Df1	R_{Df1}	ISO 15712-1 Eq 25b	49	55	61	68	74	80	65
Flanking STC for Junction 1			45	51	57	64	70	76	61
Junction 2 (Rigid T-Junction, 190 mm block separating wall / 190 mm block flanking wall)									
Flanking Path Ff_2									
Transmission Loss Element F2	$R_{F2,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Transmission Loss Element f2	$R_{f2,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Correction, Resonant Transmission F2		N/A	0	0	0	0	0	0	
Correction, Resonant Transmission f2		N/A	0	0	0	0	0	0	
TL in-situ for Element F2	$R_{F2,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	
TL in-situ for Element f2	$R_{f2,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	
Change by Lining on the Source Side	ΔR_{F2}	N/A	0	0	0	0	0	0	
Change by Lining on the Receiving Side	ΔR_{f2}	N/A	0	0	0	0	0	0	
Junction 2 - Coupling									
Vibration Reduction Index for Ff	$K_{F2,f}$	ISO 15712-1 Annex E	5.7	5.7	5.7	5.7	5.7	5.7	5.7
Vibration Reduction Index for Fd	$K_{F2,d}$	ISO 15712-1 Annex E	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Vibration Reduction Index for Df	$K_{D,f2}$	ISO 15712-1 Annex E	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Flanking Transmssion Loss - Path Values									
Flanking TL for Path Ff2	R_{F2f2}	ISO 15712-1 Eq 25b	51	59	65	73	78	85	62
Flanking TL for Path Fd2	R_{F2d}	ISO 15712-1 Eq 25b	49	55	61	68	74	80	62
Flanking TL for Path Df2	R_{Df2}	ISO 15712-1 Eq 25b	49	55	61	68	74	80	62
Flanking STC for Junction 2			43	46	52	58	66	70	57
Junction 3 (Rigid Cross junction, 190 mm block separating wall / 203 mm precast hollow core ceiling slab)									
All values are the same as for Junction 1									
Flanking TL for Path Ff3	R_{F3f3}	ISO 15712-1 Eq 25b	51	59	65	73	78	85	69
Flanking TL for Path Fd3	R_{F3d}	ISO 15712-1 Eq 25b	49	55	61	68	74	80	65
Flanking TL for Path Df3	R_{Df3}	ISO 15712-1 Eq 25b	49	55	61	68	74	80	65
Flanking STC for Junction 3			45	51	57	64	70	76	61
Junction 4 (Rigid T-junction, 190 mm block separating wall / 190 mm block flanking wall)									
All values are the same as for Junction 2									
Flanking TL for Path Ff4	R_{F4f4}	ISO 15712-1 Eq 25b	48	51	57	63	71	75	62
Flanking TL for Path Fd4	R_{F4d}	ISO 15712-1 Eq 25b	48	51	57	63	71	75	62
Flanking TL for Path Df4	R_{Df4}	ISO 15712-1 Eq 25b	48	51	57	63	71	75	62
Flanking STC for Junction 4			43	46	52	58	66	70	57
Total Flanking STC (combined transmssion for all of the flanking paths)			38	42	48	54	62	66	53
ASTC due to Direct plus Flanking Transmission		RR-335, Eq. 1.1	33	36	42	49	56	61	**47**

5.3.2.2 Vertical Room Pair - 203 mm Precast Hollow Core Floor - Theoretical K_{ij} Values - Detailed Method

EXAMPLE 4: (DETAILED METHOD)

- **Rooms one-above-the-other**
- **Loadbearing normal weight concrete block walls and precast concrete hollow core floors with rigid junctions**

Separating floor/ceiling assembly with:

- 203 mm (8") precast hollow core slab[2] with mass 323 kg/m² with no flooring on top, or ceiling lining below

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

- Rigid mortared/grouted cross-junction with concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.
- Wall above and below floor of one wythe of concrete blocks[1] with mass 238 kg/m² (e.g. 190 mm hollow blocks with normal weight aggregate[1]) with no lining of walls

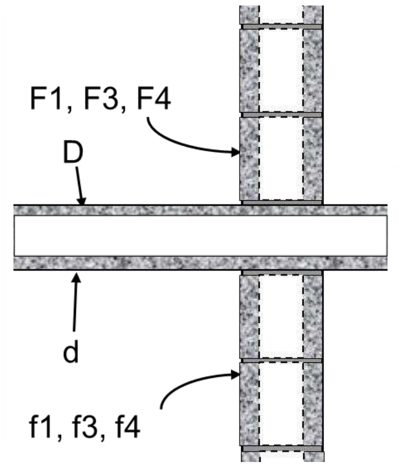
Junction 2: T-Junction of separating floor / flanking wall with:

- Rigid mortared/grouted cross-junction with a concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.
- Wall above and below floor of one wythe of concrete blocks[1] with mass 238 kg/m² (e.g. 190 mm hollow blocks with normal weight aggregate) with no lining of walls

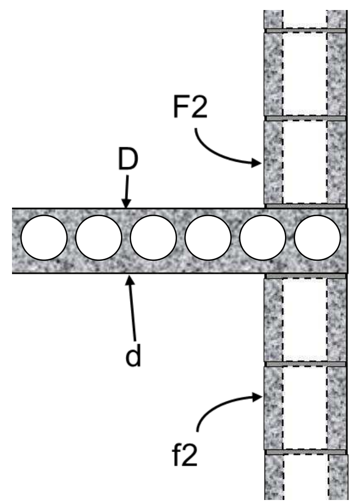
Acoustical Parameters:

For 190 mm concrete block walls:		
Mass/unit area (kg/m^2) =	238	(Separating wall)
	238	(Flanking wall)
For 203 mm precast hollow core floor		
Mass/unit area (kg/m^2) =	323	
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



Cross junction of separating floor of 203 mm thick precast concrete hollow core floor with 190 mm concrete block wall. (Side view of Junctions 1, 3, 4)



T-Junction of separating floor of 203 mm thick precast concrete hollow core floor with 190 mm concrete block wall. (Side view of Junction 2).

	ISO Symbol	Reference	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	SNR
Direct STC Rating of Path Dd									
Sound Transmission Loss	$R_{D,lab}$	Report A1-004972.1	38	46	52	60	65	72	56
Correction, Resonant Transmission		N/A	0	0	0	0	0	0	
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	
Effect of Airborne Flanking and Leakage		N/A	0	0	0	0	0	0	
Direct TL in-situ	$R_{D,situ}$	ISO 15712-1, Eq. 24	38	46	52	60	65	72	56
Junction 1 (Rigid-Cross junction between a seperating element of 203 mm precast hollow core floor and a flanking wall of 190 mm block)									
Flanking Path Ff_1									
Transmission Loss Element F1	$R_{F1,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Transmission Loss Element f1	$R_{f1,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Correction, Resonant Transmission F1		N/A	0	0	0	0	0	0	
Correction, Resonant Transmission f1		N/A	0	0	0	0	0	0	
TL in-situ for Element F1	$R_{F1,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	49
TL in-situ for Element f1	$R_{f1,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	49
Change by Lining on the Source Side	ΔR_{F1}	N/A	0	0	0	0	0	0	
Change by Lining on the Receiving Side	ΔR_{f1}	N/A	0	0	0	0	0	0	
Junction 1 - Coupling									
Vibration Reduction Index for Ff	$K_{F1,f}$	Measured	26.5	27.1	21.9	18.5	8.5	11.0	22.3
Vibration Reduction Index for Fd	$K_{F1,d}$	ISO 15712-1 Annex E	8.8	8.8	8.8	8.8	8.8	8.8	8.8
Vibration Reduction Index for Df	$K_{D,f1}$	ISO 15712-1 Annex E	8.8	8.8	8.8	8.8	8.8	8.8	8.8
Flanking Transmssion Loss - Path Values									
Flanking TL for Path Ff1	R_{F1f1}	ISO 15712-1 Eq 25b	68	71	72	75	73	79	74
Flanking TL for Path Fd1	R_{F1d}	ISO 15712-1 Eq 25b	51	57	63	70	76	82	67
Flanking TL for Path Df1	R_{Df1}	ISO 15712-1 Eq 25b	51	57	63	70	76	82	67
Flanking STC for Junction 1			48	54	60	66	70	76	64
Junction 2 (Rigid-T junction between a seperating element of 203 mm precast hollow core floor and a flanking wall of 190 mm block)									
Flanking Path Ff_2									
Transmission Loss Element F2	$R_{F2,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Transmission Loss Element f2	$R_{f2,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Correction, Resonant Transmission F2		N/A	0	0	0	0	0	0	
Correction, Resonant Transmission f2		N/A	0	0	0	0	0	0	
TL in-situ for Element F2	$R_{F2,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	
TL in-situ for Element f2	$R_{f2,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	
Change by Lining on the Source Side	ΔR_{F2}	N/A	0	0	0	0	0	0	
Change by Lining on the Receiving Side	ΔR_{f2}	N/A	0	0	0	0	0	0	
Junction 2 - Coupling									
Vibration Reduction Index for Ff	$K_{F2,f}$	Measured	27.3	22.5	13.5	11.2	8.7	11.6	16.1
Vibration Reduction Index for Fd	$K_{F2,d}$	ISO 15712-1 Annex E	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Vibration Reduction Index for Df	$K_{D,f2}$	ISO 15712-1 Annex E	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Flanking Transmssion Loss - Path Values									
Flanking TL for Path Ff2	R_{F2f2}	ISO 15712-1 Eq 25b	68	71	72	75	73	79	70
Flanking TL for Path Fd2	R_{F2d}	ISO 15712-1 Eq 25b	51	57	63	70	76	82	65
Flanking TL for Path Df2	R_{Df2}	ISO 15712-1 Eq 25b	51	57	63	70	76	82	65
Flanking STC for Junction 2			46	52	57	63	69	75	62
Junction 3 (Rigid-Cross junction between a seperating element of 203 mm precast hollow core floor and a flanking wall of 190 mm block)									
All values are the same as for Junction 1									
Flanking TL for Path Ff3	R_{F3f3}	ISO 15712-1 Eq 25b	68	71	72	75	73	79	74
Flanking TL for Path Fd3	R_{F3d}	ISO 15712-1 Eq 25b	51	57	63	70	76	82	67
Flanking TL for Path Df3	R_{Df3}	ISO 15712-1 Eq 25b	51	57	63	70	76	82	67
Flanking STC for Junction 3			48	54	60	66	70	76	64
Junction 4 (Rigid-Cross junction between a seperating element of 203 mm precast hollow core floor and a flanking wall of 190 mm block)									
All values are the same as for Junction 2									
Flanking TL for Path Ff4	R_{F4f4}	ISO 15712-1 Eq 25b	68	72	73	75	73	80	75
Flanking TL for Path Fd4	R_{F4d}	ISO 15712-1 Eq 25b	49	55	61	68	74	80	65
Flanking TL for Path Df4	R_{Df4}	ISO 15712-1 Eq 25b	49	55	61	68	74	80	65
Flanking STC for Junction 4			46	52	58	64	69	75	62
Total Flanking STC (combined transmssion for all of the flanking paths)			41	47	52	59	64	70	57
ASTC due to Direct plus Flanking Transmission		RR-335, Eq. 1.1	36	43	49	56	61	68	**53**

5.4 ASTC Examples - 305 mm Precast Hollow Core Floors - Theoretical K_{ij} Values

The examples in this section use theoretical vibration reduction index values to calculate the ASTC ratings of constructions of 190 mm thick hollow concrete block masonry units with a mass per unit area of 238 kg/m^2 connected to 305 mm (12 inch) thick hollow core slabs with a mass per unit area of 415 kg/m^2. The calculation of the theoretical values is explained in Sections 3.1 and 3.2 of this report.

The transmission loss values for the concrete block masonry wall are laboratory measured values from the NRC Report RR-334 [6]. The transmission loss values for the precast hollow core slabs are laboratory measured values from the NRC Client Report A1-004972.2.

5.4.1 ASTC Examples - Simplified Method

The following two examples use the simplified method of the calculations as detailed in the National Research Council Report RR-331. The examples in this section use the theoretical vibration reduction index values for the junctions between the concrete block masonry walls and the hollow core floors. The transmission loss values for the concrete block masonry wall are laboratory measured values from the NRC Report RR-334 [6]. The transmission loss values for the precast hollow core slabs are laboratory measured values from the NRC Client Report A1-004972.2.

5.4.1.1 Horizontal Room Pair - 305 mm Precast Hollow Core Floor - Theoretical K_{ij} Values - Simplified Method

EXAMPLE 1: (SIMPLIFIED METHOD)

- **Rooms side-by-side**
- **Loadbearing normal weight concrete block walls and precast concrete hollow core floors with rigid junctions**

Separating wall assembly (loadbearing) with:

- One wythe of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate) with no lining

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

- 305 mm (12") precast hollow core slab[2] with mass 415 kg/m^2 with no added topping or flooring
- Rigid mortared/grouted cross junction with the concrete block[1] wall assembly

Junction 2 or 4: Each Side (separating wall / abutting side wall) with:

- Abutting side wall and separating wall of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate), with no lining
- rigid mortared T-junctions

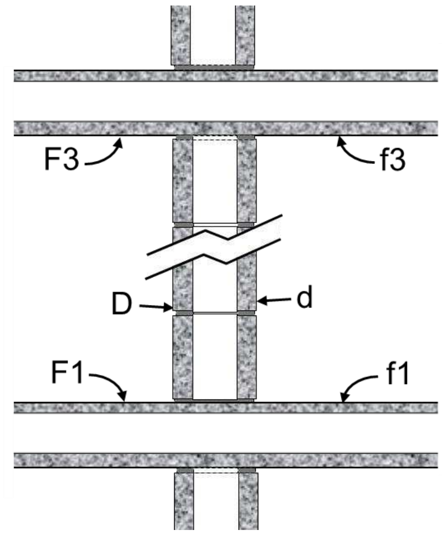
Junction 3: Top Junction (separating wall / ceiling) with:

- 305 mm (12") precast hollow core slab[2] with mass 415 kg/m^2 with no added ceiling lining
- Rigid mortared/grouted cross-junction with concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.

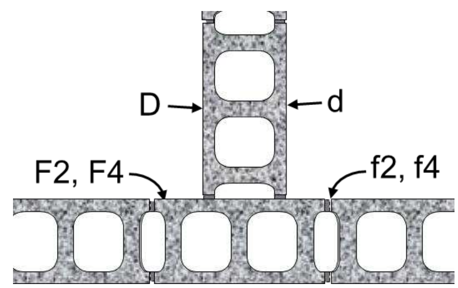
Acoustical Parameters:

For 190 mm concrete block walls:		
Mass/unit area (kg/m^2) =	238	(Separating wall)
	238	(Flanking wall)
For 305 mm precast hollow core floor		
Mass/unit area (kg/m^2) =	415	
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 190 mm concrete block separating wall with 305 mm thick precast concrete hollow core floor. (Side view of Junctions 1 and 3)



Junction of the separating wall with a side wall, both of 190 mm concrete block. (Plan view of Junctions 2 and 4).

Junction		Kij (in dB)			Reference
Number	Type	Path Ff	Path Fd	Path Df	
1	Rigid-Cross junction	8.7	9.0	9.0	ISO 15712-1, Eq. E.3
2	Rigid T-junction	5.7	6.0	6.0	ISO 15712-1, Eq. E.4
3	Rigid-Cross junction	8.7	9.0	9.0	ISO 15712-1, Eq. E.3
4	Rigid T-junction	5.7	6.0	6.0	ISO 15712-1, Eq. E.4

	ISO Symbol	Reference		SNR
Separating Partition (190 mm concrete block)				
Laboratory STC for Dd	R_s,w	RR-334, NRC-Mean BLK190(NW)		49
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	ISO 15712-1, Eq. 24 and 30	49+ MAX(0,0) + MIN(0,0)/2 =	49
Junction 1 (Rigid Cross junction, 190 mm block separating wall / 305 mm precast hollow core floor)				
Flanking Element F1:				
Laboratory STC for F1	R_F1,w	Report A1-004972.2		57
ΔSTC change by Lining	ΔR_F1,w	No Lining		0
Flanking Element f1:				
Laboratory STC for f1	R_f1,w	Report A1-004972.2		57
ΔSTC change by Lining	ΔR_f1,w	No Lining		0
Flanking STC for path Ff	R_ Ff,w	ISO 15712-1, Eq. 28a & 31	57/2 + 57/2 + MAX(0,0) + MIN(0,0)/2 + 8.7 + 4 =	70
Flanking STC for path Fd	R_ Fd,w	ISO 15712-1, Eq. 28a & 31	57/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 9 + 4 =	66
Flanking STC for path Df	R_ Df,w	ISO 15712-1, Eq. 28a & 31	49/2 + 57/2 + MAX(0,0) + MIN(0,0)/2 + 9 + 4 =	66
Junction 1: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-7 + 10^- 6.6 + 10^- 6.6) =	62
Junction 2 (Rigid T-Junction, 190 mm block separating wall / 190 mm block flanking wall)				
Flanking Element F2:				
Laboratory STC for F2	R_F2,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_F2,w	No Lining		0
Flanking Element f2:				
Laboratory STC for f2	R_f2,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_f2,w	No Lining		0
Flanking STC for path Ff	R_ Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =	62
Flanking STC for path Fd	R_ Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 6 + 7 =	62
Flanking STC for path Df	R_ Df,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 6 + 7 =	62
Junction 2: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-6.2 + 10^- 6.2 + 10^- 6.2) =	57
Junction 3 (Rigid Cross junction, 190 mm block separating wall / 305 mm precast hollow core ceiling slab)				
Flanking Element F3:				
Laboratory STC for F3	R_F3,w	Report A1-004972.2		57
ΔSTC change by Lining	ΔR_F3,w	No Lining		0
Flanking Element f3:				
Laboratory STC for f3	R_f3,w	Report A1-004972.2		57
ΔSTC change by Lining	ΔR_f3,w	No Lining		0
Flanking STC for path Ff	R_ Ff,w	ISO 15712-1, Eq. 28a & 31	57/2 + 57/2 + MAX(0,0) + MIN(0,0)/2 + 8.7 + 4 =	70
Flanking STC for path Fd	R_ Fd,w	ISO 15712-1, Eq. 28a & 31	57/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 9 + 4 =	66
Flanking STC for path Df	R_ Df,w	ISO 15712-1, Eq. 28a & 31	49/2 + 57/2 + MAX(0,0) + MIN(0,0)/2 + 9 + 4 =	66
Junction 3: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-7 + 10^- 6.6 + 10^- 6.6) =	62
Junction 4 (Rigid T-junction, 190 mm block separating wall / 190 mm block flanking wall)				
Flanking Element F4:				
Laboratory STC for F4	R_F4,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_F4,w	No Lining		0
Flanking Element f4:				
Laboratory STC for f4	R_f4,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_f4,w	No Lining		0
Flanking STC for path Ff	R_ Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 5.7 + 7 =	62
Flanking STC for path Fd	R_ Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 6 + 7 =	62
Flanking STC for path Df	R_ Df,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 6 + 7 =	62
Junction 4: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-6.2 + 10^- 6.2 + 10^- 6.2) =	57
Total Flanking STC (4 Junctions)		Subset of Eq. 1.1	Combining 12 Flanking STC values	53
ASTC due to Direct plus All Flanking Paths		Equation 1.1	Combining Direct STC with 12 Flanking STC values	**48**

5.4.1.2 Vertical Room Pair - 305 mm Precast Hollow Core Floor - Theoretical K_{ij} Values - Simplified Method

EXAMPLE 2: (SIMPLIFIED METHOD)

- **Rooms one-above-the-other**
- **Loadbearing normal weight concrete block walls and precast concrete hollow core floors with rigid junctions**

Separating floor/ceiling assembly with:
- 305 mm (12") precast hollow core slab[2] with mass 415 kg/m^2 with no flooring on top, or ceiling lining below

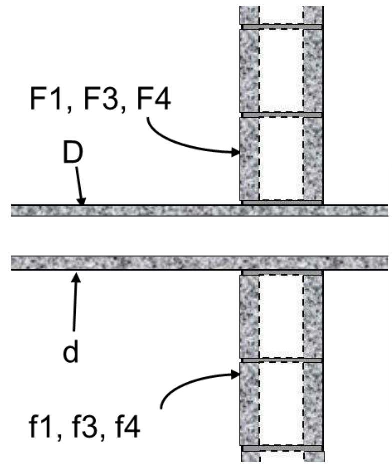
Junction 1, 3, 4: Cross Junction of separating floor / flanking wall with:
- Rigid mortared/grouted cross-junction with concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.
- Wall above and below floor of one wythe of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate[1]) with no lining of walls

Junction 2: T-Junction of separating floor / flanking wall with:
- Rigid mortared/grouted cross-junction with a concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.
- Wall above and below floor of one wythe of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate) with no lining of walls

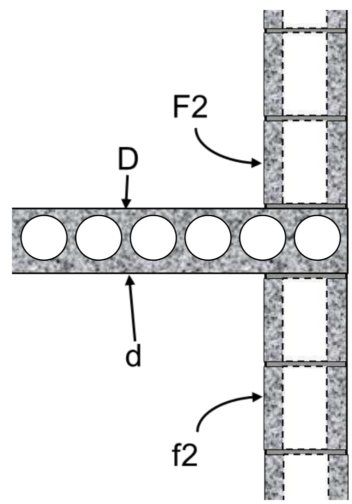
Acoustical Parameters:

For 190 mm concrete block walls:		
Mass/unit area (kg/m^2) =	238	(Separating wall)
	238	(Flanking wall)
For 305 mm precast hollow core floor		
Mass/unit area (kg/m^2) =	415	
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



Cross junction of separating floor of 305 mm thick precast concrete hollow core floor with 190 mm concrete block wall. (Side view of Junctions 1, 3, 4)



T-Junction of separating floor of 305 mm thick precast concrete hollow core floor with 190 mm concrete block wall. (Side view of Junction 2).

Junction		Kij (in dB)			Reference
Number	Type	Path Ff	Path Fd	Path Df	
1	Rigid-Cross junction	22.3	9.0	9.0	ISO 15712-1, Eq. E.3
2	Rigid T-junction	16.1	6.0	6.0	ISO 15712-1, Eq. E.4
3	Rigid-Cross junction	22.3	9.0	9.0	ISO 15712-1, Eq. E.3
4	Rigid T-junction	22.3	6.0	6.0	ISO 15712-1, Eq. E.4

	ISO Symbol	Reference		SNR
Separating Partition (305 mm precast hollow core floor)				
Laboratory STC for Dd	R_s,w	Report A1-004972.2		57
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	ISO 15712-1, Eq. 24 and 30	57+ MAX(0,0) + MIN(0,0)/2 =	57
Junction 1 (Rigid-Cross junction between a seperating element of 305 mm precast hollow core floor and a flanking wall of 190 mm block)				
Flanking Element F1:				
Laboratory STC for F1	R_F1,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_F1,w	No Lining		0
Flanking Element f1:				
Laboratory STC for f1	R_f1,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_f1,w	No Lining		0
Flanking STC for path Ff	R_Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 22.3 + 6 =	77
Flanking STC for path Fd	R_Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 57/2 + MAX(0,0) + MIN(0,0)/2 + 9 + 6 =	68
Flanking STC for path Df	R_Df,w	ISO 15712-1, Eq. 28a & 31	57/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 9 + 6 =	68
Junction 1: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-7.7 + 10^- 6.8 + 10^- 6.8) =	65
Junction 2 (Rigid-T junction between a seperating element of 305 mm precast hollow core floor and a flanking wall of 190 mm block)				
Flanking Element F2:				
Laboratory STC for F2	R_F2,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_F2,w	No Lining		0
Flanking Element f2:				
Laboratory STC for f2	R_f2,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_f2,w	No Lining		0
Flanking STC for path Ff	R_Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 16.1 + 7 =	72
Flanking STC for path Fd	R_Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 57/2 + MAX(0,0) + MIN(0,0)/2 + 6 + 7 =	66
Flanking STC for path Df	R_Df,w	ISO 15712-1, Eq. 28a & 31	57/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 6 + 7 =	66
Junction 2: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-7.2 + 10^- 6.6 + 10^- 6.6) =	62
Junction 3 (Rigid-Cross junction between a seperating element of 305 mm precast hollow core floor and a flanking wall of 190 mm block)				
Flanking Element F3:				
Laboratory STC for F3	R_F3,w	Report A1-004972.2		49
ΔSTC change by Lining	ΔR_F3,w	No Lining		0
Flanking Element f3:				
Laboratory STC for f3	R_f3,w	Report A1-004972.2		49
ΔSTC change by Lining	ΔR_f3,w	No Lining		0
Flanking STC for path Ff	R_Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 22.3 + 6 =	77
Flanking STC for path Fd	R_Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 57/2 + MAX(0,0) + MIN(0,0)/2 + 9 + 6 =	68
Flanking STC for path Df	R_Df,w	ISO 15712-1, Eq. 28a & 31	57/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 9 + 6 =	68
Junction 3: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-7.7 + 10^- 6.8 + 10^- 6.8) =	65
Junction 4 (Rigid-Cross junction between a seperating element of 305 mm precast hollow core floor and a flanking wall of 190 mm block)				
Flanking Element F4:				
Laboratory STC for F4	R_F4,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_F4,w	No Lining		0
Flanking Element f4:				
Laboratory STC for f4	R_f4,w	RR-334, NRC-Mean BLK190(NW)		49
ΔSTC change by Lining	ΔR_f4,w	No Lining		0
Flanking STC for path Ff	R_Ff,w	ISO 15712-1, Eq. 28a & 31	49/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 22.3 + 7 =	78
Flanking STC for path Fd	R_Fd,w	ISO 15712-1, Eq. 28a & 31	49/2 + 57/2 + MAX(0,0) + MIN(0,0)/2 + 6 + 7 =	66
Flanking STC for path Df	R_Df,w	ISO 15712-1, Eq. 28a & 31	57/2 + 49/2 + MAX(0,0) + MIN(0,0)/2 + 6 + 7 =	66
Junction 4: Flanking STC for all paths		Subset of Eq. 1.1	- 10*LOG10(10^-7.8 + 10^- 6.6 + 10^- 6.6) =	63
Total Flanking STC (4 Junctions)		Subset of Eq. 1.1	Combining 12 Flanking STC values	58
ASTC due to Direct plus All Flanking Paths		Equation 1.1	Combining Direct STC with 12 Flanking STC values	**54**

5.4.2 ASTC Examples - Detailed Method

The examples presented in this section use the detailed method of the calculations as detailed in the National Research Council Report RR-331. The detailed method differs from the simplified method because the calculations are based on data in 1/3 octave bands instead of the single number ratings.

The examples use the theoretical vibration reduction index values for the junctions between the concrete block masonry walls and the hollow core floors. The transmission loss values for the concrete block masonry wall are laboratory measured values from the NRC Report RR-334 [6]. The transmission loss values for the precast hollow core slabs are laboratory measured values from the NRC Client Report A1-004972.2.

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5.4.2.1 Horizontal Room Pair - 305 mm Precast Hollow Core Floor - Theoretical K_{ij} Values - Detailed Method

EXAMPLE 3: (DETAILED METHOD)

- **Rooms side-by-side**
- **Loadbearing normal weight concrete block walls and precast concrete hollow core floors with rigid junctions**

Separating wall assembly (loadbearing) with:

- One wythe of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate) with no lining

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

- 305 mm (12”) precast hollow core slab[2] with mass 415 kg/m^2 with no added topping or flooring
- Rigid mortared/grouted cross junction with the concrete block[1] wall assembly

Junction 2 or 4: Each Side (separating wall / abutting side wall) with:

- Abutting side wall and separating wall of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate), with no lining
- rigid mortared T-junctions

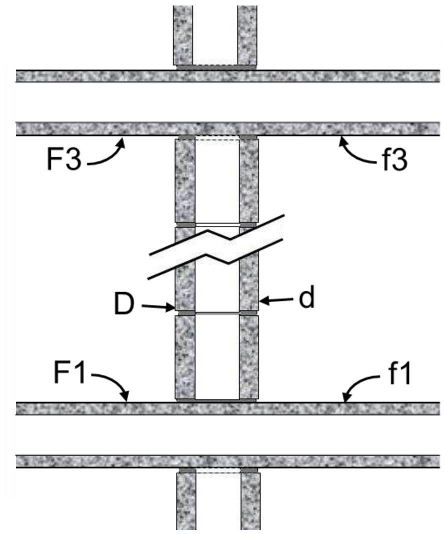
Junction 3: Top Junction (separating wall / ceiling) with:

- 305 mm (12”) precast hollow core slab[2] with mass 415 kg/m^2 with no added ceiling lining
- Rigid mortared/grouted cross-junction with concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.

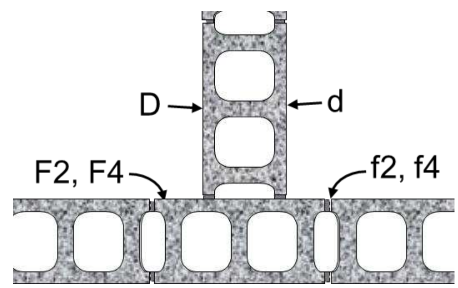
Acoustical Parameters:

For 190 mm concrete block walls:		
Mass/unit area (kg/m^2) =	238	(Separating wall)
	238	(Flanking wall)
For 305 mm precast hollow core floor		
Mass/unit area (kg/m^2) =	415	
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 190 mm concrete block separating wall with 305 mm thick precast concrete hollow core floor. (Side view of Junctions 1 and 3)



Junction of the separating wall with a side wall, both of 190 mm concrete block. (Plan view of Junction 2 or 4).

	ISO Symbol	Reference	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	SNR
Direct STC Rating of Path Dd									
Sound Transmission Loss	$R_{D,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Correction, Resonant Transmission		N/A	0	0	0	0	0	0	
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	
Effect of Airborne Flanking and Leakage		N/A	0	0	0	0	0	0	
Direct TL in-situ	$R_{D,situ}$	ISO 15712-1, Eq. 24	35	38	44	50	58	62	49
Junction 1 (Rigid Cross junction, 190 mm block separating wall / 305 mm precast hollow core floor)									
Flanking Path Ff_1									
Transmission Loss Element F1	$R_{F1,lab}$	Report A1-004972.2	40	49	53	59	65	67	57
Transmission Loss Element f1	$R_{f1,lab}$	Report A1-004972.2	40	49	53	59	65	67	57
Correction, Resonant Transmission F1		N/A	0	0	0	0	0	0	
Correction, Resonant Transmission f1		N/A	0	0	0	0	0	0	
TL in-situ for Element F1	$R_{F1,situ}$	Eq. 19, T_s,situ = T_s,lab	40	49	53	59	65	67	57
TL in-situ for Element f1	$R_{f1,situ}$	Eq. 19, T_s,situ = T_s,lab	40	49	53	59	65	67	57
Change by Lining on the Source Side	ΔR_{F1}	N/A	0	0	0	0	0	0	
Change by Lining on the Receiving Side	ΔR_{f1}	N/A	0	0	0	0	0	0	
Junction 1 - Coupling									
Vibration Reduction Index for Ff	$K_{F1,f}$	ISO 15712-1 Annex E	8.7	8.7	8.7	8.7	8.7	8.7	8.7
Vibration Reduction Index for Fd	$K_{F1,d}$	ISO 15712-1 Annex E	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Vibration Reduction Index for Df	$K_{D,f1}$	ISO 15712-1 Annex E	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Flanking Transmssion Loss - Path Values									
Flanking TL for Path Ff1	R_{F1f1}	ISO 15712-1 Eq 25b	53	62	66	72	78	80	70
Flanking TL for Path Fd1	R_{F1d}	ISO 15712-1 Eq 25b	51	57	62	68	75	78	67
Flanking TL for Path Df1	R_{Df1}	ISO 15712-1 Eq 25b	51	57	62	68	75	78	67
Flanking STC for Junction 1		**0**	46	53	58	64	71	73	62
Junction 2 (Rigid T-Junction, 190 mm block separating wall / 190 mm block flanking wall)									
Flanking Path Ff_2									
Transmission Loss Element F2	$R_{F2,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Transmission Loss Element f2	$R_{f2,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Correction, Resonant Transmission F2		N/A	0	0	0	0	0	0	
Correction, Resonant Transmission f2		N/A	0	0	0	0	0	0	
TL in-situ for Element F2	$R_{F2,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	
TL in-situ for Element f2	$R_{f2,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	
Change by Lining on the Source Side	ΔR_{F2}	N/A	0	0	0	0	0	0	
Change by Lining on the Receiving Side	ΔR_{f2}	N/A	0	0	0	0	0	0	
Junction 2 - Coupling									
Vibration Reduction Index for Ff	$K_{F2,f}$	ISO 15712-1 Annex E	5.7	5.7	5.7	5.7	5.7	5.7	5.7
Vibration Reduction Index for Fd	$K_{F2,d}$	ISO 15712-1 Annex E	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Vibration Reduction Index for Df	$K_{D,f2}$	ISO 15712-1 Annex E	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Flanking Transmssion Loss - Path Values									
Flanking TL for Path Ff2	R_{F2f2}	ISO 15712-1 Eq 25b	53	62	66	72	78	80	62
Flanking TL for Path Fd2	R_{F2d}	ISO 15712-1 Eq 25b	51	57	62	68	75	78	62
Flanking TL for Path Df2	R_{Df2}	ISO 15712-1 Eq 25b	51	57	62	68	75	78	62
Flanking STC for Junction 2			43	46	52	58	66	70	57
Junction 3 (Rigid Cross junction, 190 mm block separating wall / 305 mm precast hollow core ceiling slab)									
All values are the same as for Junction 1									
Flanking TL for Path Ff3	R_{F3f3}	ISO 15712-1 Eq 25b	53	62	66	72	78	80	70
Flanking TL for Path Fd3	R_{F3d}	ISO 15712-1 Eq 25b	51	57	62	68	75	78	67
Flanking TL for Path Df3	R_{Df3}	ISO 15712-1 Eq 25b	51	57	62	68	75	78	67
Flanking STC for Junction 3			46	53	58	64	71	73	62
Junction 4 (Rigid T-junction, 190 mm block separating wall / 190 mm block flanking wall)									
All values are the same as for Junction 2									
Flanking TL for Path Ff4	R_{F4f4}	ISO 15712-1 Eq 25b	48	51	57	63	71	75	62
Flanking TL for Path Fd4	R_{F4d}	ISO 15712-1 Eq 25b	48	51	57	63	71	75	62
Flanking TL for Path Df4	R_{Df4}	ISO 15712-1 Eq 25b	48	51	57	63	71	75	62
Flanking STC for Junction 4			43	46	52	58	66	70	57
Total Flanking STC (combined transmssion for all of the flanking paths)			38	42	48	54	62	65	53
ASTC due to Direct plus Flanking Transmission		RR-335, Eq. 1.1	33	37	43	49	56	60	**48**

5.4.2.2 Vertical Room Pair - 305 mm Precast Hollow Core Floor - Theoretical K_{ij} Values - Detailed Method

EXAMPLE 4: (DETAILED METHOD)

- **Rooms one-above-the-other**
- **Loadbearing normal weight concrete block walls and precast concrete hollow core floors with rigid junctions**

Separating floor/ceiling assembly with:
- 305 mm (12") precast hollow core slab[2] with mass 415 kg/m^2 with no flooring on top, or ceiling lining below

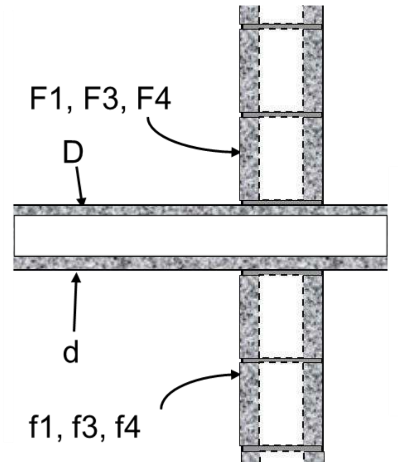
Junction 1, 3, 4: Cross Junction of separating floor / flanking wall with:
- Rigid mortared/grouted cross-junction with concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.
- Wall above and below floor of one wythe of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate[1]) with no lining of walls

Junction 2: T-Junction of separating floor / flanking wall with:
- Rigid mortared/grouted cross-junction with a concrete block[1] wall assembly with a 3 mm continuous bearing strips between the underside of the floor and the top of the block wall.
- Wall above and below floor of one wythe of concrete blocks[1] with mass 238 kg/m^2 (e.g. 190 mm hollow blocks with normal weight aggregate) with no lining of walls

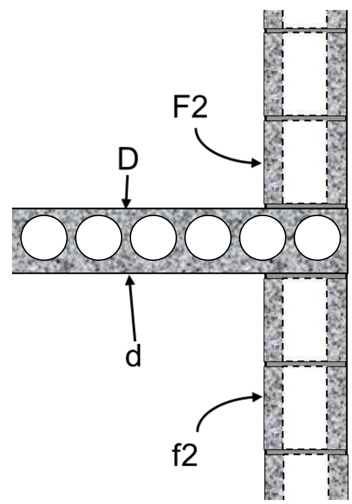
Acoustical Parameters:

For 190 mm concrete block walls:		
Mass/unit area (kg/m^2) =	238	(Separating wall)
	238	(Flanking wall)
For 305 mm precast hollow core floor		
Mass/unit area (kg/m^2) =	415	
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



Cross junction of separating floor of 305 mm thick precast concrete hollow core floor with 190 mm concrete block wall. (Side view of Junctions 1, 3, 4)



T-Junction of separating floor of 305 mm thick precast concrete hollow core floor with 190 mm concrete block wall. (Side view of Junction 2).

	ISO Symbol	Reference	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	SNR
Direct STC Rating of Path Dd									
Sound Transmission Loss	$R_{D,lab}$	Report A1-004972.2	40	49	53	59	65	67	57
Correction, Resonant Transmission		N/A	0	0	0	0	0	0	
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	
Effect of Airborne Flanking and Leakage		N/A	0	0	0	0	0	0	
Direct TL in-situ	$R_{D,situ}$	ISO 15712-1, Eq. 24	40	49	53	59	65	67	57
Junction 1 (Rigid-Cross junction between a seperating element of 305 mm precast hollow core floor and a flanking wall of 190 mm block)									
Flanking Path Ff_1									
Transmission Loss Element F1	$R_{F1,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Transmission Loss Element f1	$R_{f1,lab}$	RR-334, NRC-Mean BLK190(NW)	35	38	44	50	58	62	49
Correction, Resonant Transmission F1		N/A	0	0	0	0	0	0	
Correction, Resonant Transmission f1		N/A	0	0	0	0	0	0	
TL in-situ for Element F1	$R_{F1,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	49
TL in-situ for Element f1	$R_{f1,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	49
Change by Lining on the Source Side	ΔR_{F1}	N/A	0	0	0	0	0	0	
Change by Lining on the Receiving Side	ΔR_{f1}	N/A	0	0	0	0	0	0	
Junction 1 - Coupling									
Vibration Reduction Index for Ff	$K_{F1,f}$	Measured	26.5	27.1	21.9	18.5	8.5	11.0	22.3
Vibration Reduction Index for Fd	$K_{F1,d}$	ISO 15712-1 Annex E	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Vibration Reduction Index for Df	$K_{D,f1}$	ISO 15712-1 Annex E	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Flanking Transmssion Loss - Path Values									
Flanking TL for Path Ff1	R_{F1f1}	ISO 15712-1 Eq 25b	68	71	72	75	73	79	74
Flanking TL for Path Fd1	R_{F1d}	ISO 15712-1 Eq 25b	53	59	64	70	77	80	69
Flanking TL for Path Df1	R_{Df1}	ISO 15712-1 Eq 25b	53	59	64	70	77	80	69
Flanking STC for Junction 1			50	55	60	66	70	75	65
Junction 2 (Rigid-T junction between a seperating element of 305 mm precast hollow core floor and a flanking wall of 190 mm block)									
Flanking Path Ff_2									
Transmission Loss Element F2	$R_{F2,lab}$	Report A1-004972.2	35	38	44	50	58	62	49
Transmission Loss Element f2	$R_{f2,lab}$	Report A1-004972.2	35	38	44	50	58	62	49
Correction, Resonant Transmission F2		N/A	0	0	0	0	0	0	
Correction, Resonant Transmission f2		N/A	0	0	0	0	0	0	
TL in-situ for Element F2	$R_{F2,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	
TL in-situ for Element f2	$R_{f2,situ}$	Eq. 19, T_s,situ = T_s,lab	35	38	44	50	58	62	
Change by Lining on the Source Side	ΔR_{F2}	N/A	0	0	0	0	0	0	
Change by Lining on the Receiving Side	ΔR_{f2}	N/A	0	0	0	0	0	0	
Junction 2 - Coupling									
Vibration Reduction Index for Ff	$K_{F2,f}$	Measured	27.3	22.5	13.5	11.2	8.7	11.6	16.1
Vibration Reduction Index for Fd	$K_{F2,d}$	ISO 15712-1 Annex E	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Vibration Reduction Index for Df	$K_{D,f2}$	ISO 15712-1 Annex E	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Flanking Transmssion Loss - Path Values									
Flanking TL for Path Ff2	R_{F2f2}	ISO 15712-1 Eq 25b	68	71	72	75	73	79	70
Flanking TL for Path Fd2	R_{F2d}	ISO 15712-1 Eq 25b	53	59	64	70	77	80	66
Flanking TL for Path Df2	R_{Df2}	ISO 15712-1 Eq 25b	53	59	64	70	77	80	66
Flanking STC for Junction 2			47	53	58	63	69	74	62
Junction 3 (Rigid-Cross junction between a seperating element of 305 mm precast hollow core floor and a flanking wall of 190 mm block)									
All values are the same as for Junction 1									
Flanking TL for Path Ff3	R_{F3f3}	ISO 15712-1 Eq 25b	68	71	72	75	73	79	74
Flanking TL for Path Fd3	R_{F3d}	ISO 15712-1 Eq 25b	53	59	64	70	77	80	69
Flanking TL for Path Df3	R_{Df3}	ISO 15712-1 Eq 25b	53	59	64	70	77	80	69
Flanking STC for Junction 3			49	55	60	66	70	75	65
Junction 4 (Rigid-Cross junction between a seperating element of 305 mm precast hollow core floor and a flanking wall of 190 mm block)									
All values are the same as for Junction 2									
Flanking TL for Path Ff4	R_{F4f4}	ISO 15712-1 Eq 25b	68	72	73	75	73	80	75
Flanking TL for Path Fd4	R_{F4d}	ISO 15712-1 Eq 25b	50	56	61	67	74	77	66
Flanking TL for Path Df4	R_{Df4}	ISO 15712-1 Eq 25b	50	56	61	67	74	77	66
Flanking STC for Junction 4			47	53	58	64	69	73	63
Total Flanking STC (combined transmssion for all of the flanking paths)			42	48	53	59	64	68	57
ASTC due to Direct plus Flanking Transmission		RR-335, Eq. 1.1	38	46	50	56	61	64	**55**

5.5 Footnotes for the Examples

1. For the 190 mm thick concrete block walls in these examples, the value of 238 kg/m^2 is the measured mass per unit area for the tested wall specimen including mortar. Normal weight (NW) 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 NW hollow core units are not less than 53% solid, and 140 mm NW hollow core units are not less than 73% solid, each giving a minimum wall mass per area over 238 kg/m^2.

2. The continuous hollow voids of the hollow core slabs can be oriented either parallel or perpendicular to the concrete block wall.

6. Summary and Conclusions

The measurements conducted for this project describe the transmission of structure-borne sound through junctions between concrete masonry walls and precast hollow core floors. The data allow for the prediction of the ASTC rating of buildings constructed with these materials.

The velocity distribution measured on both sides of the concrete masonry walls and on both sides of the precast hollow core floors were within 1 dB and 1.4 dB, respectively. The velocity distribution across the concrete masonry walls and the precast hollow core floors were also fairly uniform. These results indicate that both the concrete masonry walls and the precast hollow core floors behave as homogeneous elements in terms of their vibratory response. Therefore, although the theory for the prediction of the velocity reduction index found in Annex E of ISO 15712-1 is not intended for this type of construction, the theory is nevertheless applicable.

The precast hollow core floors used for this project were 203 mm (8 inch) thick and had a mass per unit are of 323 kg/m^2. The theory for the prediction of the velocity reduction index found in Annex E of ISO 15712-1 is also expected to be applicable to thicker floors.

Hollow concrete block masonry walls with a mass per unit area greater than 238 kg/m^2 are expected to have transmission loss values that are equal to or greater than the values reported for the hollow concrete block masonry walls evaluated for this study. Likewise, precast hollow core floors with a mass per unit area greater than 323 kg/m^2 are expected to have transmission loss values that are equal to or greater than the values reported for the precast hollow core floors evaluated in this study. Therefore, based on the findings from this study, it is expected that constructions of hollow concrete block masonry walls with a mass per unit area of or greater to 238 kg/m^2 connected to precast hollow core floors with a mass per unit area equal to or greater than 323 kg/m^2 will achieve ASTC ratings which are equal to or greater than 47.

Although the values of the vibration reduction index were evaluated for the case where the continuous voids of the hollow core planks were oriented perpendicular to the concrete masonry walls, the results may also be used for the case were the voids are oriented parallel to the walls. The vibration reduction indices are expected to be higher for the case where the continuous voids are oriented parallel to the concrete masonry walls and so using vibration reduction index values for the case of voids oriented perpendicular to the concrete masonry walls may yield more conservative values than may be found in practice. The benefit of using the same results for both cases is that it eliminates the risk the wrong set of data used for the calculation of the ASTC rating. Therefore, only the one set of values will be used to calculate the ASTC ratings for any construction using hollow concrete block masonry walls connected to precast prestressed hollow core slabs, regardless of the orientation of the slabs and the hollow voids.

References

[1] ISO 15712-1:2005 -- Building acoustics -- Estimation of acoustic performance of buildings from the performance of elements -- Part 1: Airborne sound insulation between rooms. Geneva, Switzerland: International Standards Organization; 2005.

[2] ISO 10848-1:2006 -- Acoustics -- Laboratory measurement of the flanking transmission of airborne and impact sound between adjoining rooms -- Part 1: Frame document. Geneva, Switzerland: International Standards Organization; 2006.

[3] Zeitler B, Quirt D, Hoeller C, Mahn J, Schoenwald S, Sabourin I. NRC Research Report RR-331: Guide to Calculating Airborne Sound Transmission in Buildings: 2nd Edition. Ottawa, Canada: National Research Council Canada; 2016.

[4] Zeitler B, Quirt D, Schoenwald S, Mahn J. NRC Research Report RR-334: Apparent Sound Insulation in Concrete Block Buildings. Ottawa, Canada: National Research Council Canada; 2015.

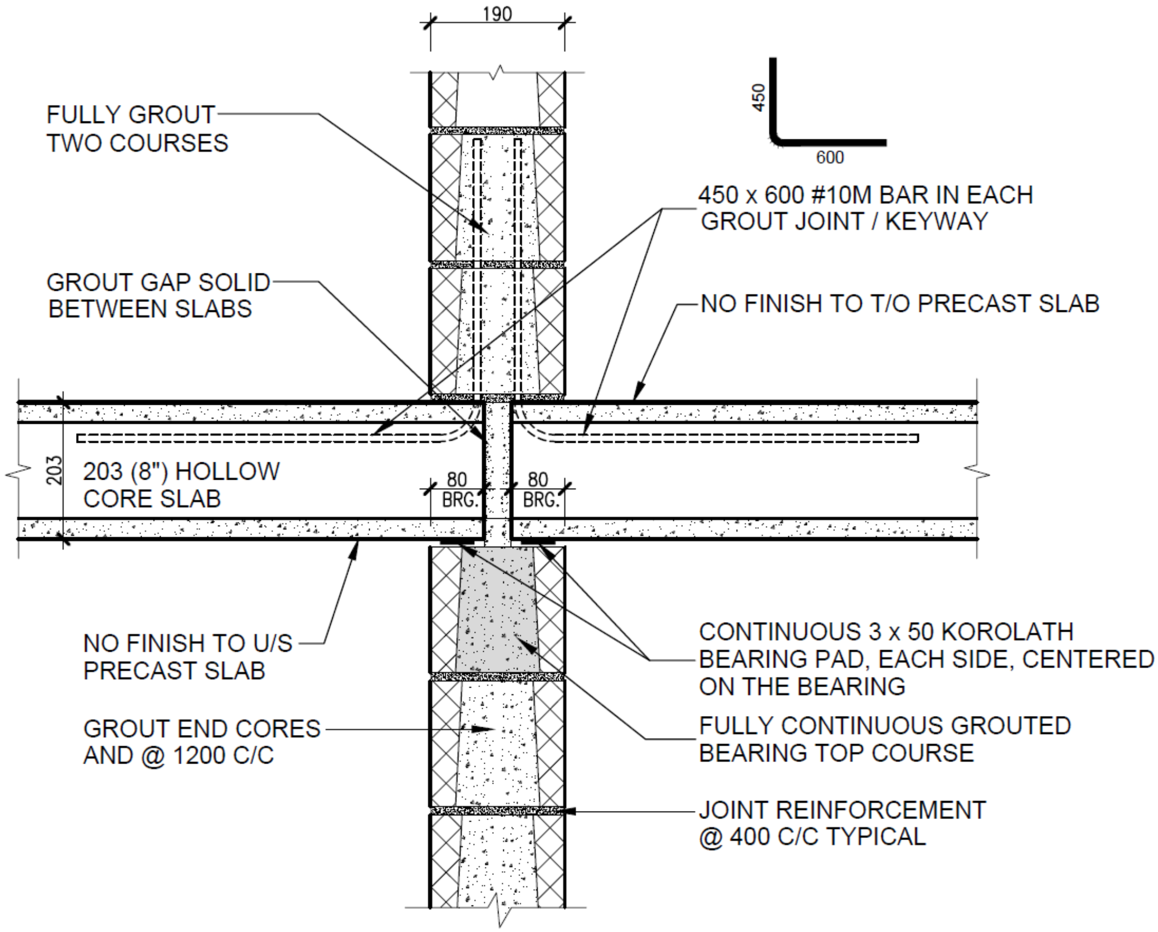
[5] Sabourin I, Mahn J. A1-004972.3: Analysis of Vibration Data of Hollow Core Concrete Floors to Assess the Applicability of ISO 15712. Ottawa, Canada: National Research Council Canada; 2014.

[6] Zeitler B, Quirt D, Schoenwald S, Mahn J. RR-334: Apparent Sound Insulation in Concrete Block Buildings. Ottawa, Canada: National Research Council Canada; 2015.

[7] Mahn J, Hoeller C, Quirt D. *The simplified method versus the detailed method of calculating flanking sound transmission through walls with linings*, Proceedings of the 22nd International Congress on Acoustics, Buenos Aires, Argentina, 2016.

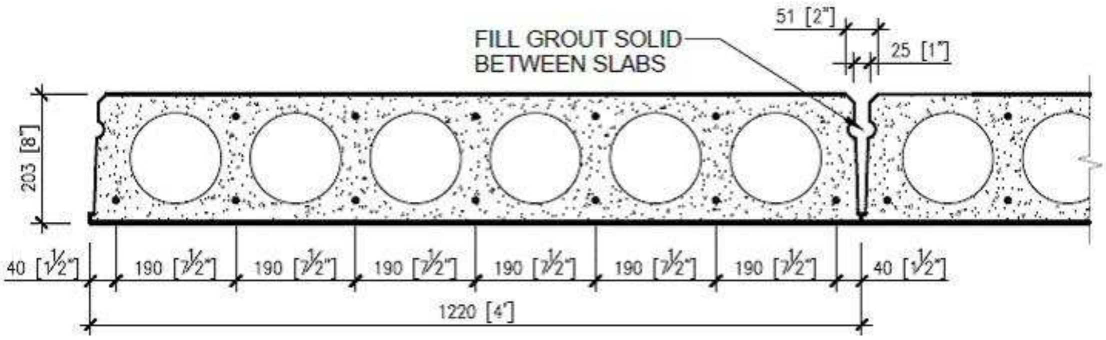
Appendix A - Construction Details for the Hollow Core Planks

The masons and precast installers constructed the junction in accordance with the following details provided by CCMPA and CPCI:



The mason and precast installer placed bar reinforcement and grouted the joints/keyways of the precast hollow core floors following the instructions provided by the CCMPA and CPCI.

- Suitably position slabs to allow for the placement of one #10M reinforcing L-bar between adjacent slabs. Clear keyways of any debris.
- Position one #10M reinforcing L-bar in each grout keyway between the slabs with the vertical leg of the L-bar positioned roughly along the centreline of the concrete masonry wall. Block the outer ends of the keyway to prevent grout loss.
- Place no grout in the cores of the slabs. Place grout only in the keyways between the slabs along their entire length as shown in the figure below. Grout the keyway solid. Compact the grout around the steel reinforcement. When grouting is completed, clean excess grout from the floor either by scraping or sweeping. Cure the grout for not less than (12) hours before introducing a load or commencing work on top of the installed units.



- Use fine grout, prescribed in accordance with CSA A179 as shown in the table below. Do not use lime. Grout should be sufficiently fluid to allow it to flow into the keyway and assure complete filling of the keyway.

	Parts by volume			
			Aggregate measured in damp, loose state	
Grout type	**Cement***	**Lime†**	**Fine aggregate (sand)**	**Coarse aggregate**
Fine	1	0 to 1/10	2-1/4 to 3 times the sum of the cementitious materials	0

Appendix B - Calculation of the Vibration Reduction Index

The standard, ISO 10848 details the calculation of the Vibration Reduction Index K_{ij} based on measurement data. The calculations are made in several steps.

1. Measure the time averaged mean squared velocity on each element due to the excitation of element *i* in each of three excitation positions. The velocity level was measured simultaneous on all of the elements and the velocity level difference $D_{v,ij}$ was determined in 1/3 octave bands from Equation 9 of ISO 10848 such that:

$$D_{v,ij} = \frac{1}{MN}\sum_{m=1}^{M}\sum_{n=1}^{N}\left(D_{v,ij}\right)_{mn}$$

   where M is the number of excitation positions on element i, N is the number of accelerometer positions on the elements and $\left(D_{v,ij}\right)_{mn}$ is the velocity level difference for one excitation point and one pair of transducer positions only such that:

$$\left(D_{v,ij}\right)_{mn} = 10\log_{10}\frac{\int_0^{Tm} v_i^2 dt}{\int_0^{Tm} v_j^2 dt}$$

   where v_i^2 and v_j^2 are the velocities normal to the surface at points on elements i and j, respectively and Tm is the integration time (45 seconds).

2. The velocity level differences between elements i and j and elements j and i are direction averaged such that:

$$\overline{D_{v,ij}} = \frac{1}{2}\left(D_{v,ij} + D_{v,ji}\right)$$

3. The equivalent absorption length a_i of element i is calculated in 1/3 octave bands from the surface area of the element and the structural reverberation time such that:

$$a_i = \frac{2.2\pi^2 S_i}{T_{s,i} c_o \sqrt{\frac{f}{f_o}}}$$

   where S_i is the surface area of element i in m^2, $T_{s,i}$ is the structural reverberation time in seconds, c_o is the speed of sound in air in meters per second, f is the center frequency of the 1/3 octave band in hertz and f_o is 1000 Hz.

4. The vibration reduction index K_{ij} between elements i and j is calculated such that:

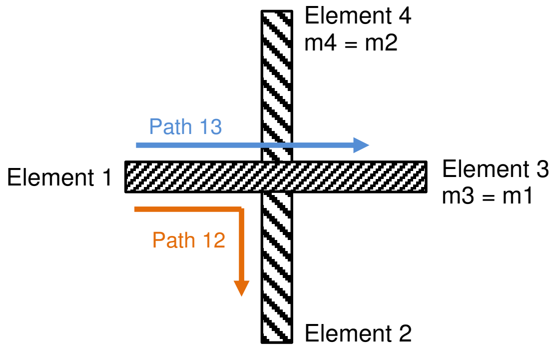
$$K_{ij} = \overline{D_{v,ij}} + 10\log_{10}\left(\frac{l_{ij}}{\sqrt{a_i a_j}}\right)$$

   where l_{ij} is the length in meters of the junction between elements i and j.

Appendix C - Vibration Reduction Index Data

The vibration reduction indices are presented in 1/3 octave bands.

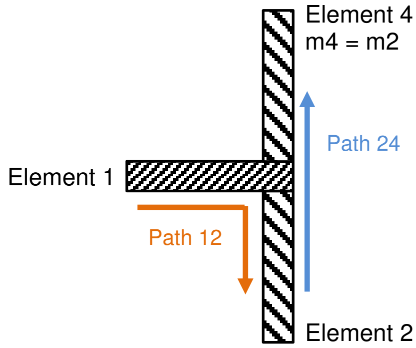
Cross-Junctions



1/3 Octave Band Center Frequency (Hz)	Path		
	13	12	24
125	12.9	23.5	26.5
160	10.1	18.6	29.7
200	9.1	17.7	26.1
250	11.8	18.3	27.1
315	13.1	19.3	27.4
400	11.7	16.3	20.9
500	9.8	14.5	21.9
630	12.4	15.8	20.5
800	7.7	16.4	23.0
1000	9.7	14.7	18.5
1250	6.3	12.5	14.9
1600	8.5	11.1	11.1
2000	7.1	9.4	8.5
2500	7.4	9.9	9.9
3150	4.4	9.2	12.0
4000	3.9	8.0	11.0
Single Number	10.2	16.2	22.3

The single number value is calculated from the meant of the 1/3 octave bands from 200 Hz to 1250 Hz, inclusive.

T-Junctions



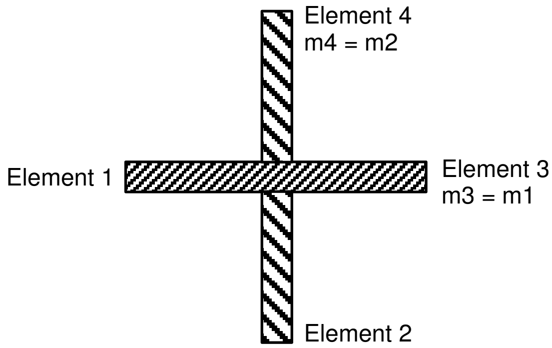
1/3 Octave Band Center Frequency (Hz)	Path	
	24	12
125	27.3	18.8
160	23.8	16.55
200	20.8	15.55
250	22.5	14.15
315	21.6	16.6
400	13.8	12.6
500	13.5	10.85
630	15.8	13
800	14.1	12.05
1000	11.2	12.5
1250	11.6	10.7
1600	7.8	9.1
2000	8.7	8.45
2500	11.1	8.8
3150	12.5	7.9
4000	11.6	6.6
Single Number	16.1	13.1

The single number value is calculated from the meant of the 1/3 octave bands from 200 Hz to 1250 Hz, inclusive.

Appendix D - Reverberation Time Data

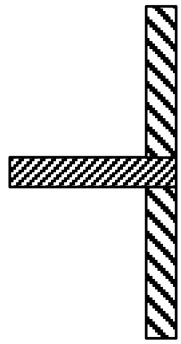
The reverberation times are presented in 1/3 octave bands.

Cross-Junction



1/3 Octave Band Center Frequency (Hz)	Path			
	1	2	3	4
125	1.04	0.93	1.72	1.74
160	0.78	0.86	1.11	0.95
200	0.87	0.54	0.74	0.86
250	0.53	0.51	0.80	0.79
315	0.44	0.57	0.36	0.52
400	0.45	0.33	0.43	0.53
500	0.31	0.30	0.32	0.43
630	0.22	0.30	0.34	0.36
800	0.19	0.26	0.26	0.35
1000	0.22	0.19	0.21	0.23
1250	0.14	0.15	0.17	0.20
1600	0.13	0.11	0.13	0.14
2000	0.10	0.08	0.11	0.10
2500	0.09	0.06	0.09	0.09
3150	0.08	0.06	0.07	0.08
4000	0.07	0.05	0.05	0.07

T-Junction



1/3 Octave Band Center Frequency (Hz)	Element		
	1	2	4
125	1.01	0.79	1.41
160	0.99	0.72	0.69
200	0.77	0.46	0.57
250	0.47	0.48	0.55
315	0.54	0.50	0.50
400	0.56	0.26	0.33
500	0.53	0.29	0.21
630	0.38	0.32	0.19
800	0.23	0.24	0.15
1000	0.21	0.18	0.16
1250	0.15	0.13	0.15
1600	0.13	0.08	0.12
2000	0.09	0.07	0.09
2500	0.08	0.06	0.07
3150	0.08	0.06	0.07
4000	0.06	0.04	0.06