RESEARCH REPORT

Sound and Fire Performance of Fire Stops in Multi-Family Dwellings: Flanking Transmission at Joints in Multi-Family Dwellings. Phase 1, Transmission via Fire Stops

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Sound and Fire Performance of Fire Stops in Multi-Family Dwellings

Flanking Transmission at Joints in Multi-Family Dwellings

Phase 1: Transmission Via Fire Stops

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EXECUTIVE SUMMARY

Fire stops can introduce a physical connection between the two sides of a double-stud wall, hence providing structural flanking paths for transmission of vibration which worsens the sound insulation.

This study primarily addressed the specific case of a load-bearing party wall with double wood studs, supporting a floor with wood joists perpendicular to the party wall and a floor deck or sub-floor of 15.9 mm OSB.

Even without structural transmission of vibration through a fire stop, the sound insulation in a real building is normally affected by flanking transmission.

Addition of a fire stop provides yet another path for vibration transmission between the rooms, and hence tends to worsen the sound insulation further. This study examines how a fire stop at the floor/wall junction can degrade the apparent sound insulation of the party wall (the nominal separation) by increasing structural transmission of vibration around that wall via the connected floor system (the flanking path).

Group 0 Constructions have no physical fire stop. Adding batt insulation to fill the wall's inter-stud cavities leaving a gap of 25 mm or less (Case 2) improves sound insulation provided by the party wall itself while adding negligible structural transmission. Strictly speaking, this is not a fire stop, but it does provide the necessary fire resistance (as shown in the companion study of fire spread) and meets the prescriptive requirements for fire separations in the National Building Code.

Group 1 Constructions do not transmit significant vibration either through bending moments or in-plane forces. These involve bridging the space between the joist headers at the floor/wall junction with relatively "soft" materials, which compress in response to vibration, so they transfer negligible vibrational energy to the other side of the junction.

Group 2 Constructions transmit appreciable vibration through in-plane forces, but not through bending moments.

Group 3 Constructions transmit structural vibration primarily by bending moments, and tend to give the strongest flanking effect.

The fire stops studied in this project have been rank ordered in terms of their acoustical performance. They are listed in the table which follows.

Material	Group	Installation	Application
Batt absorption almost filling wall stud cavity	0	Fill wall cavity with insulation	Row and Apartment
No fire stop*	0	N/A	N/A
Semi-rigid fibrous insulation board	1	5 lb/ft^3 density, 25 mm thick, between headers	Row and Apartment
Gypsum Board	2	25 mm thick between headers	Row and Apartment
Sheet Steel	2	0.38 mm thick under wall plates, over floor deck	Row
Continuous OSB or plywood	3	Continuous sheets under wall plates	Row

* While the case with no fire stop is not an acceptable fire control technique, it is included here as a point of reference.

1. None of the investigated fire stop constructions seriously worsened vertical sound insulation (i.e. - the apparent sound insulation of the floor/ceiling system).

2. Some fire stop constructions noticeably worsened the horizontal and diagonal sound transmission. The degradation of horizontal sound insulation (i.e. - the apparent sound insulation of the party wall between adjacent rooms) depends both on material properties and installation of the fire stop, and on the floor construction.

3. Many of the fire stop constructions studied did not reduce the apparent sound insulation below FSTC 50, but they did significantly degrade the performance of a superior party wall which would achieve STC 67 in the absence of any flanking.

4. This study has not evaluated all the variables that are likely to affect the apparent sound insulation. Although it has looked at joist orientation and to some degree the type of decking, these limited measurements suggest that flanking transmission is more severe in the case where the party wall is non-load-bearing and floor joists are oriented parallel to the party wall. The results reported here (for floor joists perpendicular to the party wall) should be clearly identified in any further publications as pertaining only to this specific case. It would be judicious to verify performance with other floor systems before wide dissemination of the results from this work.

SOMMAIRE

Les matériaux coupe-feu peuvent introduire une connexion physique entre les deux côtés d'un mur à poteaux jumelés, favorisant ainsi la transmission indirecte des vibrations et réduisant l'isolation acoustique.

L'étude portait surtout sur le cas déterminé d'un mur mitoyen porteur avec poteaux de bois jumelés, soutenant un plancher avec solives de bois perpendiculaires au mur mitoyen et un platelage ou faux-plancher de 15,9 mm en PPO.

Même sans transmission structurale des vibrations à travers un matériau coupe-feu, l'isolation acoustique dans un véritable bâtiment est normalement modifiée par la transmission indirecte du bruit.

L'addition d'un matériau coupe-feu présente un autre cheminement pour la transmission des vibrations entre les pièces, et tend donc à diminuer davantage l'isolation acoustique. La présente étude examine comment un matériau coupe-feu, placé à la jonction plancher-murs, peut diminuer l'apparente isolation acoustique du mur mitoyen (la séparation nominale) en augmentant la transmission structurale des vibrations autour de ce mur, à travers le plancher (moyen de transmission indirecte).

Les constructions du groupe 0 n'ont aucun matériau coupe-feu. L'addition de nattes isolantes pour remplir les cavités murales entre les poteaux, en laissant un espace de 25 mm ou moins (cas n° 2), augmente l'isolation sonore fournie par le mur mitoyen proprement dit, tout en ajoutant une transmission structurale négligeable. À vrai dire, ce n'est pas un coupe-feu, mais il présente la résistance au feu nécessaire (comme l'indique l'étude connexe sur la propagation des flammes) et correspond aux exigences prescrites pour les séparations coupe-feu, dans le Code national du bâtiment.

Les constructions du groupe 1 ne transmettent pas d'importantes vibrations, que ce soit à travers les moments de flexion ou les forces dans le plan. Pour ce faire, il faut que l'espace entre les chevêtres à la jonction plancher-murs soit rempli de matériaux relativement « mous », qui se compriment en réponse aux vibrations, afin de ne transférer qu'une énergie négligeable à l'autre côté de la jonction.

Les constructions du groupe 2 transmettent une vibration appréciable à travers les forces dans le plan, mais pas à travers les moments de flexion.

Les constructions du groupe 3 transmettent les vibrations structurales essentiellement à travers les moments de flexion, et ont tendance à produire l'effet de transmission indirecte le plus prononcé.

Les coupe-feu étudiés au cours de ce projet ont été classés selon leur performance acoustique. Ils sont énumérés dans le tableau suivant.

Matériau	Groupe	Installation	Application
Absorption par nattes remplissant presque toute la cavité murale entre les poteaux	0	Remplir la cavité murale d'isolant	Maisons en rangée et appartements
Aucun coupe-feu*	0	S.O.	S.O.
Panneaux d'isolation en fibres semi-rigides	1	Densité de 5 lb au pi^3, épaisseur de 25 mm, entre les rives	Maisons en rangée et appartements
Panneaux en placoplâtre	2	Épaisseur de 25 mm entre les rives	Maisons en rangée et appartements
Tôle d'acier	2	Épaisseur de 0,38 mm sous les sablières, au-dessus du platelage	Maisons en rangée
PPO ou contreplaqué en continu	3	Feuilles continues sous les sablières	Maisons en rangée

* Bien que l'absence de coupe-feu ne soit pas une technique acceptable de protection contre le feu, nous l'avons incluse ici comme point de référence.

1. Aucune des constructions à coupe-feu examinées n'aggravait fortement l'isolation acoustique verticale (c.-à-d. l'insonorisation apparente constituée par l'ensemble plancher-plafond).
2. Certaines constructions à coupe-feu empiraient sensiblement la transmission sonore horizontale et en diagonale. La dégradation de l'isolation acoustique (c.-à-d. l'insonorisation apparente constituée par le mur mitoyen entre des pièces adjacentes) dépend à la fois des propriétés matérielles et de l'installation du coupe-feu, ainsi que de la construction du plancher.
3. Bon nombre des constructions à coupe-feu étudiées ne réduisaient pas l'insonorisation apparente en dessous d'un indice de qualité d'isolement mesuré sur place de 50, mais elles dégradaient nettement la performance d'un mur mitoyen supérieur qui aurait atteint un coefficient de transmission acoustique de 67 en l'absence de toute voie de transmission indirecte.
4. La présente étude n'a pas évalué toutes les variables susceptibles de modifier l'insonorisation apparente. Bien qu'elles aient porté sur l'orientation des solives et, dans une certaine mesure, sur le type de platelage, ces mesures limitées suggéraient que la transmission indirecte est plus grave dans les cas où le mur mitoyen est non porteur et où les solives de plancher sont orientées parallèlement au mur mitoyen. Les résultats signalés ici (pour des solives de plancher perpendiculaires au mur mitoyen) doivent être clairement indiqués dans toutes les publications futures comme reliés uniquement à ce cas déterminé. Il serait judicieux de vérifier la performance avec d'autres planchers avant de diffuser largement les résultats de ces travaux.

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INTRODUCTION

This report presents results of the sound transmission part of a research project to examine the sound and fire resistance of wall/floor junctions intended for multi-family residential buildings. These constructions must satisfy National Building Code (NBCC) requirements for both noise control and fire resistance. Some junction designs control fire, but significantly increase the transmission of noise. The objective of this project was to identify details that simultaneously provide good sound and fire resistance.

This part of the project, titled "*Flanking Transmission at Joints in Multi-Family Dwellings Phase I: Transmission Via Fire Stops*", was supported by a consortium that included Canada Mortgage and Housing Corporation, Forintek Canada, Gypsum Manufacturers of Canada, Institute for Research in Construction of the National Research Council Canada, New Home Warranty programs of Ontario, Alberta, British Columbia and the Yukon, Ontario Ministry of Housing, Owens Corning Fiberglas Canada Inc., Roxul Inc., and the Canadian Home Builders' Association.

These partners both supported the project financially and sent representatives to meet periodically as a Steering Committee, to evaluate results and select specimens for subsequent study. The measurements and analysis were performed in the Acoustics Laboratory of the Institute for Research in Construction at the National Research Council Canada.

The study focused on wood-framed construction, specifically the junction between a wood joist floor and a separating wall with two rows of 38 x 89 mm wood studs. These were examined for construction details typical of both row-housing and small apartment buildings. The floor joists were supported on the party wall for all but one of the specimens selected. While it is recognized that other constructions may have similar or worse problems from a noise-control perspective, this combination was identified by the steering committee as the first priority when including fire safety.

The associated study of fire resistance of fire stop materials and wall/floor junction details has been conducted, and is reported separately[1].

This report investigates how five commonly used fire control solutions for the floor/wall junction change (and in some cases seriously worsen) the sound insulation between the rooms separated by the wall and floor. It also tests two retro-fit approaches to remedy, or at least reduce, the effect of noise transmission via fire stop constructions.

For all of these constructions, the report presents basic construction descriptions and the results of "standard" acoustical measurements of the sound insulation between the rooms in the test setup. Appendix A presents more detailed analyses of the sound transmission for selected cases where flanking was significant.

This report also provides:

- acoustical rank ordering of the fire stop techniques;
- limiting sound insulation for the fire stop techniques in the measured assemblies;
- identification of dominant flanking paths for supported floor ceiling assemblies;
- discussion of additional factors that are likely to control flanking transmission.

Flanking Transmission: Definition and Significance

Flanking transmission is transmission of sound energy from one room to another by any path other than directly through the nominally separating wall or floor.

Flanking paths exist in all constructions regardless of type and design. It will be shown, however, that the amount of flanking transmission can be controlled, at least to some extent, by the use of suitable construction details.

Flanking transmission is part of the reason why walls or floors tested in buildings usually exhibit significantly worse performance than the nominally identical wall or floor assembly measured under the "no flanking" laboratory conditions of ASTM E90.

ASTM standards, which provide the technical basis for noise control provisions in the building codes of Canada and the USA, focus on two aspects of sound insulation.

- <u>*Sound transmission through a specific construction*</u>, such as the wall or floor separating two rooms, is the focus of ASTM E90[2] (laboratory tests); ASTM E336[3] is the field equivalent. Instructions focus on avoiding flanking transmission. Single number ratings are obtained by fitting a contour (following ASTM E413[4]) to the sound transmission loss measured in standard frequency bands. This yields the sound transmission class (STC) for laboratory data, or FSTC for field data. Basically, this tells what fraction of the sound energy is transmitted through a given wall or floor construction.

- Sound insulation between two rooms is a second focus of ASTM E336. By fitting the STC contour to the measured noise reduction between two spaces, one obtains the *noise isolation class* (NIC). The normalized version of this (adjusted to a standardized sound decay rate, typical of furnished rooms) is the NNIC. For a performance-oriented building code, it is arguable that objectives should be expressed in terms of NIC or NNIC. Occupants do not care what noise reduction is provided by the nominally separating floor or wall – they care about overall noise reduction, no matter how noise gets from one dwelling to another.

ASTM does not provide a term to describe performance of constructions explicitly including flanking transmission around the nominal separation.

Since this study focuses on sound insulation changes due to flanking transmission at floor/wall junctions, we use a minor extension of ASTM terminology. We followed the lead of international standard ISO 140[5], which defines *apparent* sound reduction index for this purpose.

Definition of Apparent Sound Insulation

Apparent field transmission loss, and *apparent* FSTC, describe ASTM E336 results where flanking is included. To emphasize that flanking is the focus, "*apparent*" is also added to describe impact transmission. Technical details about determination of these ratings are given in Appendix A, with the detailed analysis of results.

It is the *apparent* sound insulation (including the direct path plus all the flanking paths) that determines the perceived degree of sound insulation between rooms - not just the STC of the wall or floor nominally separating the rooms.

The Table 1 shows four flanking scenarios to illustrate how flanking transmission influences the apparent STC and must be considered when selecting a wall or floor assembly to meet a design goal.

When sound insulation via flanking paths is 5 dB better (i.e. - STC is 5 higher) than the direct path via the wall, the apparent STC including flanking is only slightly below that for the wall. However, where equal sound energy is transmitted by the direct and flanking paths, the apparent STC will be 3 lower than the separating wall's STC.

In this illustration, improving the separating wall to STC 60 or STC 65 has little impact on the apparent sound insulation. Unless the flanking path transmits less sound power (higher transmission loss or STC), the apparent STC cannot exceed 55. If the flanking transmission were worse (as it may be in typical buildings), the apparent STC would be limited to even lower values. Very simply, the apparent sound insulation is determined by the weakest link, be it the flanking path or the nominal separating element.

Table 1:
Illustration where flanking paths transmit the same sound power as a wall of STC 55. The effects of flanking reduce apparent insulation more as the sound insulation of the separating wall improves.

Apparent STC due to flanking	Separating Wall	Apparent STC including all paths	Importance of Flanking
STC 55	STC 50	49	Minor
STC 55	STC 55	52	Significant
STC 55	STC 60	54	near-dominant
STC 55	STC 65	55	Dominant

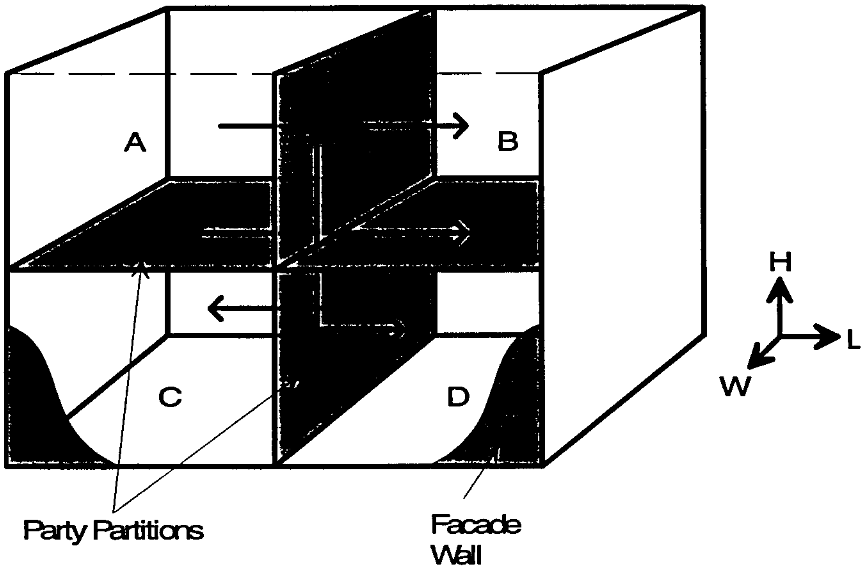
Note that if the flanking path transmitted more sound power, the apparent STC would be even lower in each case.

Generalizing, it is possible for flanking paths to completely control the apparent sound insulation, regardless of the performance of the nominally separating wall or floor. This impact of flanking transmission becomes more significant when high sound insulation is required.

Measurement & Facility Details

Figure 1 shows a sketch of the facility that was designed and constructed in 1992 for the measurement of flanking transmission in lightweight framed multi-family constructions.

Figure 1: Schematic drawing of the flanking facility showing wall and floor specimens in gray. Some possible flanking paths are shown by arrows.



The wall and floor specimens divide the space into four rooms (labeled A, B, C, D in the drawing). Dimensions of the four rooms are given in the table below.

Room	Volume (m^3)	Length (m)	Width (m)	Height (m)
A	50.7	4.60	4.54	2.43
B	45.3	4.11	4.54	2.43
C	40.0	4.66	4.38	2.07
D	35.3	3.96	4.38	2.07

The permanent part of the facility (roof, end walls, foundation floor, and back wall) are constructed of heavy materials and are resiliently isolated from each other and from structural support members, with vibration breaks in the permanent surfaces where the specimens are installed. There is also an experimental facade wall covering the front face of the facility, but this was deliberately isolated from the specimens for this study.

In such a facility, specific construction changes can be systematically introduced so that resulting changes in the sound insulation performance of the experimental surfaces can be accurately determined.

SPECIMEN SERIES

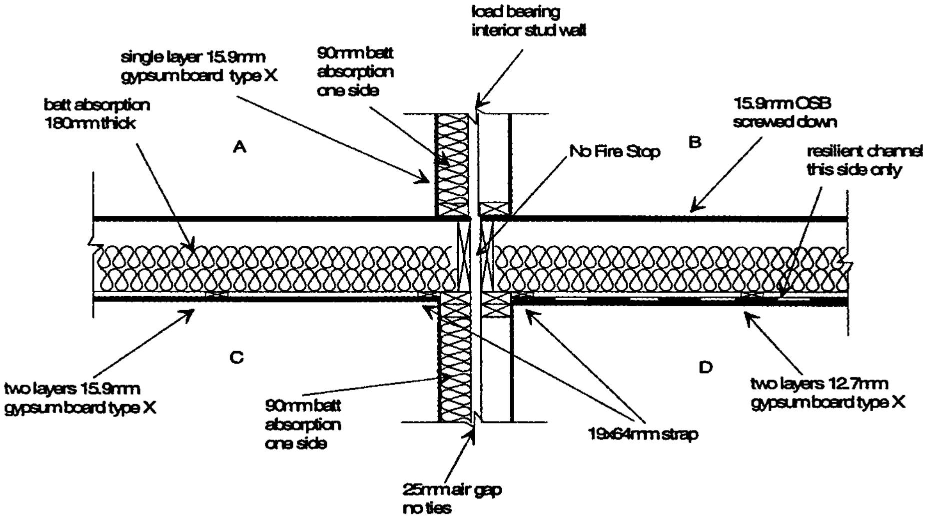
Measurements were made between each pair of rooms, including the diagonals, to determine the effect of the different fire stops and retro-fit constructions implemented in a series of specimens.

The project was structured using reference specimens which did not have fire stopping (and hence did not meet the intent of the 1990 or 1995 NBCC). These specimens provided a point of reference to determine the change in sound transmission due to the various fire stop constructions.

For reasons discussed below, two such reference specimens were used. These were the first and last specimens of the study, and designated as Reference A and Reference B, respectively.

Figure 2 shows the vertical section through the floor and party wall of Reference A. Construction details of the floor and wall framing are discussed more fully later in the report. Note that both floors are fire-rated, but only the floor between rooms B and D has resilient metal channels (which are necessary to provide the sound insulation required between apartments).

Figure 2: Vertical section through the floor and party wall of Reference Case A.



Acoustical performance of this first case was evaluated in considerable detail, to provide the baseline for subsequent specimens.

Reference Case A was then modified by addition of the following fire stop constructions:

Case 2: Additional cavity absorption in the wall space such that *the width of the concealed wall space does not exceed 25 mm (1995 NBCC 9.10.15.2.2.a)*[6]. With this condition met, an explicit fire stop is not required.

Case 3: Gypsum board 25 mm thick installed vertically in the nominal 25 mm space between joist headers at the wall/floor joint. In Case 3, the floor/ceiling assembly is fire rated. This detail satisfies the criteria for location (9.10.15.2.1) and material (9.10.15.3.1.c) for fire stops.

At this stage, two significant changes were made in the approach to evaluating the fire stop constructions:

It was decided to include measurements using a substantially better party wall. Figure 3(a) and (b) show construction details of the basic and superior party wall. Both of these wall constructions were used with most of the later cases.

Figure 3(a): Construction details of the "basic" party wall, which in laboratory testing in the absence of flanking is rated at STC 55.

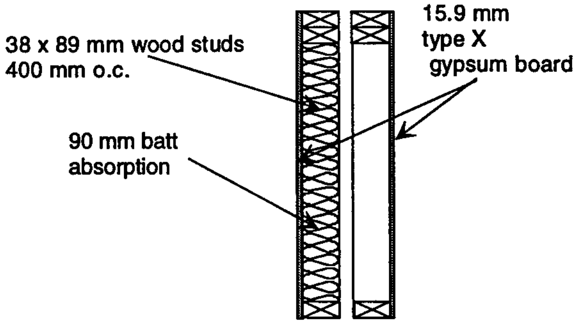
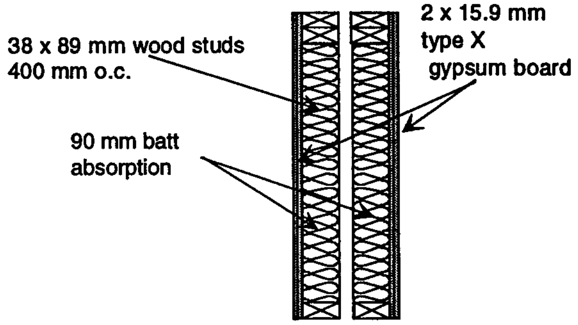


Figure 3(b): The "superior" party wall, which in laboratory testing in the absence of flanking is rated at STC 67.



At the same time, the Steering Committee recommended changing the floor construction between rooms A and C, to provide data more relevant to row housing. Floor B-D would suit apartment style constructions. This meant that Reference A was not a fully valid reference for subsequent measurements. To provide a baseline reference to which subsequent measurements could be legitimately compared, another baseline case without a fire stop (Reference B) was measured at the end of the series. It is described in detail later.

Other fire stop cases were then tested:

Case 4: Gypsum board 25 mm thick installed vertically in the nominal 25 mm space between joist headers at the wall/floor joint. The A-C floor/ceiling assembly is not fire rated. This detail satisfies the criteria for location (9.10.15.2.1) and material (9.10.15.3.1.c) for fire stops. Tested with basic and superior party wall. Use Reference B as baseline case.

Case 5: Semi-rigid batt material installed vertically in the nominal 25 mm space between joist headers at the wall/floor joint. The A-C floor/ceiling assembly is not fire rated. This detail satisfies the criterion for location (9.10.15.2.1) for fire stops, but semi-rigid batt material is not listed (9.10.15.3.1) as an acceptable material. However, semi-rigid materials were tested in the fire component of this project and found to comply with 9.10.15.3.g as interpreted by the Steering Committee of this consortium. Use Reference B as baseline case.

Case 6: 0.38 mm sheet steel (without profile) installed horizontally under the sole plates of the party wall. The A-C floor/ceiling assembly is not fire rated. This detail satisfies the criteria for location (9.10.15.2.1) and material (9.10.15.3.1.a) for fire stops. Tested with basic and superior party wall. Use Reference B as baseline case.

Case 7: 15.9 mm thick OSB continuous under the sole plates of the party wall. The A-C floor/ceiling assembly is not fire rated. This detail satisfies the criteria for location (9.10.15.2.1) and material (9.10.15.3.1.d) for fire stops. Tested with basic and superior party wall. Use Reference B as baseline case.

Case 11: 15.9 mm thick Plywood continuous under the sole plates of the party wall. The A-C floor/ceiling assembly is not fire rated. This detail satisfies the criteria for location (9.10.15.2.1) and material (9.10.15.3.1.d) for fire stops. Tested with the superior party wall. Use Reference B as baseline case.

Case 12: 15.9 mm thick OSB continuous under the sole plates of the party wall. In this case the party wall is non-load bearing and the joists are laid parallel to the party wall. The A-C floor/ceiling assembly is not fire rated. This detail satisfies the criteria for location (9.10.15.2.1) and material (9.10.15.3.1.d) for fire stops. Tested with the superior party wall. Neither Reference A nor Reference B is appropriate as a baseline case for this configuration.

Retro-fit Cases

Two constructions suitable for improving sound insulation of existing constructions, to compensate for obvious flanking, were also investigated. These are called retro-fits (though similar measures could be used in new construction) and were applied to Case 7, the continuous OSB sub-floor which will be shown to be one of the most serious cases of flanking by a fire stop:

> Case 8: Underlay, 15.9 mm thick OSB placed on top of the existing 15.9 mm thick OSB sub-floor which is continuous under the party wall (i.e., Case 7). Tested with basic and superior party walls. Use Reference B as a baseline case.
>
> Case 9: Floating Floor System placed on top of the existing 15.9 mm thick OSB sub-floor which is continuous under the party wall (i.e., Case 7). Tested with superior party wall. Use Reference B as a baseline case.

Reference B

Reference B was similar to Reference A in that it had no fire stop, but the floor between rooms A and C was constructed to match all the specimens after Case 3. This change of floor/ceiling construction was made to obtain data relevant to row housing, in addition to apartment style constructions represented by floor B-D.

The changes involved removing the batt insulation from between the joists, and changing the gypsum board on the ceiling of room C from two layers of 15.9 mm Type X gypsum board to one layer of 12.7 mm regular gypsum board. With these changes, floor A-C was considered representative of row housing (where the floor between levels within a dwelling does not require either STC 50 (minimum) or a fire rating). By contrast, floor B-D satisfies both the sound and fire resistance requirements of the Building Code for a separation between adjacent dwellings, as would be expected in an apartment building.

The floor modifications were not expected to significantly change the horizontal transmission between A and B (as was later confirmed by the results). However, they should highlight any difference in the effect of fire stops on vertical or diagonal transmission in row housing (A-C and B-C) versus apartments (B-D and A-D).

Unfortunately, for horizontal transmission between the lower rooms (C-D), the construction is a mix of apartment and row housing details. For this reason, the C-D data were omitted from the tables in the summary of data in the main report. In practice, it was found that there was very little variation in the apparent airborne sound insulation between rooms C and D due to changes in the fire stop, the ceiling of room C, or the party wall between rooms A and B.

Common Details

The specimens described in the preceding pages have many details in common. Some of those, such as the two constructions for the party wall between rooms A and B, have been described above. Two other key features - the framing of the floor systems and the junction between the party wall and the facade wall are detailed here.

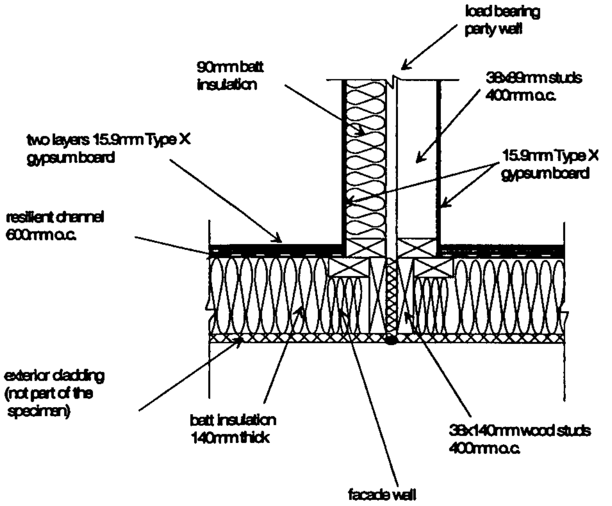


Figure 4

Figure 4 (at left) shows the plan section at the intersection of the party and facade walls. This detail is common to all rooms. Because these tests were designed to establish the effect of individual fire stops at the wall/floor joint, the facade wall joint was chosen to minimize its effect as a flanking path between rooms, and the finish surface of the facade wall (on the side toward the test rooms) was purposely made massive and was resiliently mounted. The facade wall was unchanged throughout the series.

The basic framing of the floors was unchanged throughout the series, and differed between rooms only in the span. The gypsum board ceiling in Room D was attached with resilient metal channels, but that in Room C was screwed directly to the furring strips. The type and number of layers of gypsum board changed (as detailed in the following descriptions of each sample).

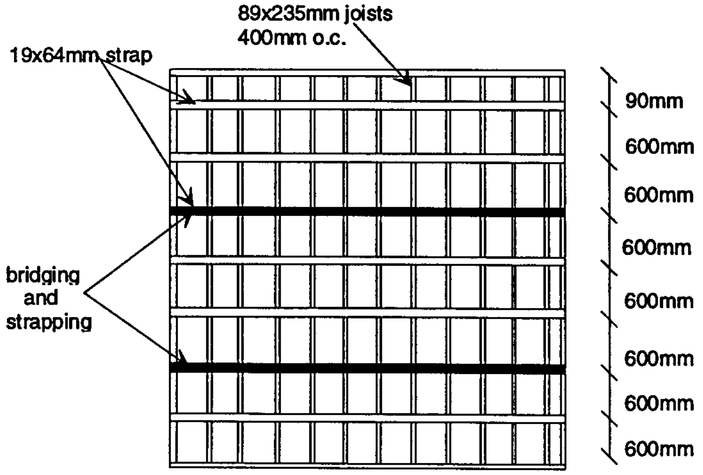


Figure 5

Figure 5 (at left) shows the reflected plan view of the floor framing typical of rooms A and B for all specimens. At one end, the joists were supported on the party wall, and at the other end on isolated supports at the end wall of the facility. Where resilient channels were used in Room D, they were at right angles to the strapping.

SPECIMEN DETAILS AND RESULTS

A description of the construction details is provided for each specimen tested, along with the apparent FSTC and apparent FIIC ratings. The ratings given are determined from the average of the forward and reverse measurements between each room pair.

The results for each specimen are divided into two tables reflecting the division into results appropriate to row housing and results appropriate to apartments.

Unfortunately the hybrid floor construction, designed to allow the study of both row housing and apartment style constructions at the same time, is a compromise. The result is that the A-D diagonal case is not quite as good as would be expected for an apartment construction, the floor of room A is too light and lacks batt insulation. On the other hand, the B-C diagonal case is better than would be expected for a row housing construction, the floor of room B is too heavy and has batt insulation. In the context of this report, the impact of this compromise is likely to be small because the diagonal measurements are used only in qualitative assessments of flanking paths. In practical terms this is a minor concern since in all cases the diagonal provided an apparent FSTC over 60.

Detailed discussions of the results, including determination of flanking paths and inter-specimen comparisons, have been included as appendices to the main report.

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Case 1: **Reference A, No fire stop**
Basic A-B party wall

Purpose:

To establish a reference case to which specimens having a fire stop at the joint can be compared. If there is no difference between the reference case and the cases with the fire stop, then the presence of the fire stop has no effect acoustically.

The floor between rooms A and C was similar to the floor between B and D with the primary difference being the absence of resilient channels. This provides information regarding the effects of resilient channels on the flanking transmission paths.

Party Wall:

Double wood stud load-bearing wall having separate head and sole plates (nominal 25 mm separation between frames), double head plate, 90 mm batt insulation material filling one side of the wall cavity, finished with a single layer of 15.9 mm Type X gypsum board either side. Gypsum board installed vertically and fastened with 36 mm or longer screws placed 400 mm o.c.

Floor:

15.9 mm OSB floor decking fastened with 51 mm or longer #10 straight shank wood screws placed 150 mm o.c. at edges and 300 mm o.c. in the field, 38x235 mm wood joists 400 mm o.c., 180 mm of batt insulation material (2 layers of 90 mm batt material were used), bridging and strapping; 19x64 mm strapping 600 mm o.c. used as furring strips, 19x64 mm bracing no more than 2100 mm o.c. located at strapping points (see Figure 5).

Room C: two layers of 15.9 mm Type X gypsum board placed directly on the wood furring. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Room D: generic resilient channels 600 mm o.c., placed perpendicular to the strapping, two layers of 12.7 mm Type X gypsum board. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor/Wall Intersection:

Load bearing party wall with the joists perpendicular to the party wall, single joist header, no batt insulation in the nominal 25x365 mm cavity formed by the joist headers and the wall plates.

Facade Wall:

See Common Details, page 11.

Case 1: Reference A, No fire stop
Basic A-B party wall

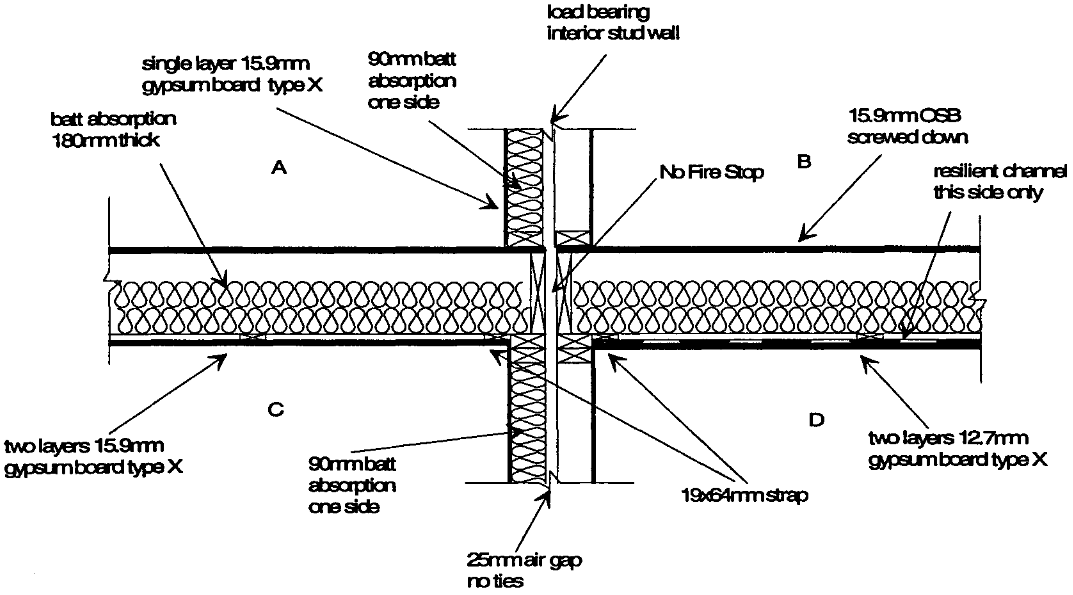

Figure 6

Apparent airborne sound insulation		Room Pairs	Reference A (FSTC)
Apartment	Horizontal	A-B	51
	Vertical	B-D	56
	Diagonal	A-D	71
Direct applied ceiling	Vertical	A-C	45
	Diagonal	B-C	69

Apparent impact sound insulation		Room Pairs	Reference A (FIIC)
Apartment	Horizontal	A-B	61
	Vertical	B-D	51
	Diagonal	A-D	61
Direct applied ceiling	Vertical	A-C	39
	Diagonal	B-C	62

Case 2: Reference A with additional cavity absorption
Basic A-B party wall

Purpose:

This assembly satisfies the intent of the NBCC (1995: 9.10.15.2.2.a) since the cavity is 25 mm or less in width. This technique is applicable to both row and apartment type constructions.

The floor between rooms A and C was similar to the floor between B and D, with the primary difference being the absence of resilient channels. This provides information regarding the effects of resilient channels on the flanking transmission paths.

Note: That if the nominal 25 mm separation between frame work was completely filled with absorption there would be no appreciable difference in the sound insulation and it would satisfy the intent of NBCC (1995: 9.10.15.1.2.2.d).

Party Wall:

Double wood stud load-bearing wall having separate head and sole plates (nominal 25 mm separation between frames), double head plate, 90 mm batt insulation material filling both sides of the wall cavity, finished with a single layer of 15.9 mm Type X gypsum board either side. Gypsum board installed vertically and fastened with 36 mm or longer screws placed 400 mm o.c.

Floor:

15.9 mm OSB floor decking fastened with 51 mm or longer #10 straight shank wood screws placed 150 mm o.c. at edges and 300 mm o.c. in the field, 38x235 mm wood joists 400 mm o.c., 180 mm of batt insulation material (2 layers of 90 mm batt material were used), bridging and strapping; 19x64 mm strapping 600 mm o.c. used as furring strips, 19x64 mm bracing no more than 2100 mm o.c. located at strapping points (see Figure 5).

Room C: two layers of 15.9 mm Type X gypsum board placed directly on the wood furring. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm (2 ¼") or longer screws placed 300 mm o.c. at the edges and in the field.

Room D: generic resilient channels 600 mm o.c., placed perpendicular to the strapping, two layers of 12.7 mm Type X gypsum board. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor/Wall Intersection:

Load bearing party wall with the joists perpendicular to the party wall, single joist header, no batt insulation in the nominal 25x365 mm cavity formed by the joist headers and the wall plates.

Facade Wall:

See Common Details, page 11.

Case 2: Reference A with additional cavity absorption Basic A-B party wall

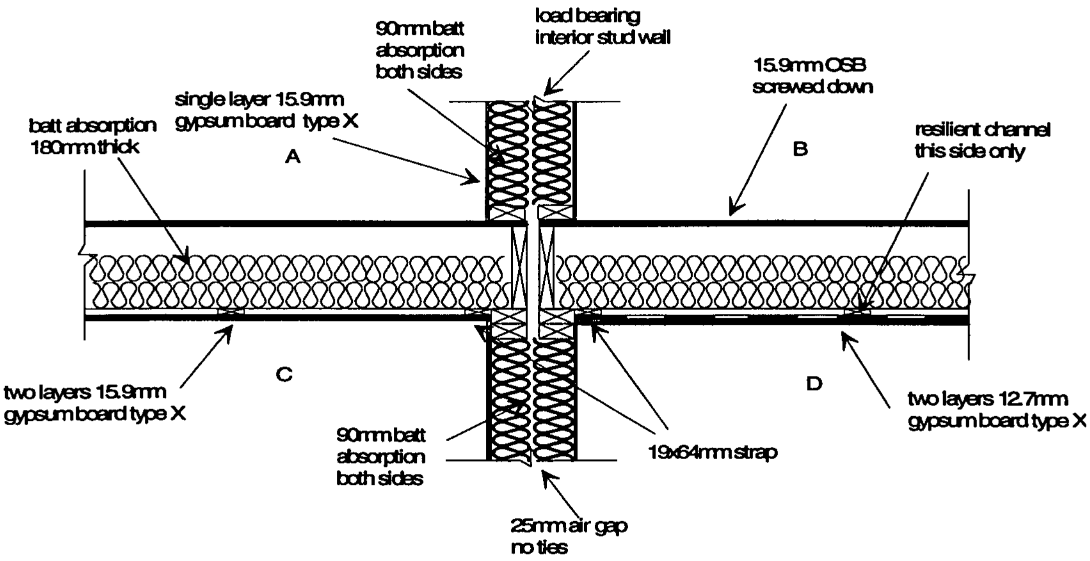

Figure 7

Apparent airborne sound insulation

		Room Pairs	Case: 2 with basic wall (FSTC)	Change re Reference A
Apartment	Horizontal	A-B	56	+5
	Vertical	B-D	56	0
	Diagonal	A-D	75	+1

Direct applied ceiling	Vertical	A-C	46	+1
	Diagonal	B-C	73	+4

Apparent impact sound insulation

		Room Pairs	Case: 2 with basic wall (FIIC)	Change re Reference A
Apartment	Horizontal	A-B	64	+ 3
	Vertical	B-D	50	-1
	Diagonal	A-D	71	+10

Direct applied ceiling	Vertical	A-C	39	0
	Diagonal	B-C	70	+8

Case 3: **Reference A with 25 mm thick gypsum board at joint**
Basic A-B party wall

Purpose:

To establish the effect of introducing a 25 mm gypsum board fire stop in apartment type constructions.

The floor between rooms A and C was similar to the floor between B and D with the primary difference being the absence of resilient channels. This provides information regarding the effects of resilient channels on the flanking transmission paths.

Party Wall:

Double wood stud load-bearing wall having separate head and sole plates (nominal 25 mm separation between frames), double head plate, 90 mm batt insulation material filling one side of the wall cavity, finished with a single layer of 15.9 mm Type X gypsum board either side. Gypsum board installed vertically and fastened with 36 mm or longer screws placed 400 mm o.c.

Floor:

15.9 mm OSB floor decking fastened with 51 mm or longer #10 straight shank wood screws placed 150 mm o.c. at edges and 300 mm o.c. in the field, 38x235 mm wood joists 400 mm o.c., 180 mm of batt insulation material (2 layers of 90 mm batt material were used), bridging and strapping; 19x64 mm strapping 600 mm o.c. used as furring strips, 19x64 mm bracing no more than 2100 mm o.c. located at strapping points (see Figure 5).

Room C: two layers of 15.9 mm Type X gypsum board placed directly on the wood furring. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Room D: generic resilient channels 600 mm o.c., placed perpendicular to the strapping, two layers of 12.7 mm Type X gypsum board. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor/Wall Intersection:

Load bearing party wall with the joists perpendicular to the party wall, single joist header, two layers of 12.7 mm Type X gypsum board (nominal width 600 mm) placed in compression between the joist headers and the wall plates. A single drywall screw in the top corners of each sheet held the material in place.

Facade Wall:

See Common Details, page 11.

Case 3: Reference A with 25 mm thick gypsum board at joint Basic A-B party wall

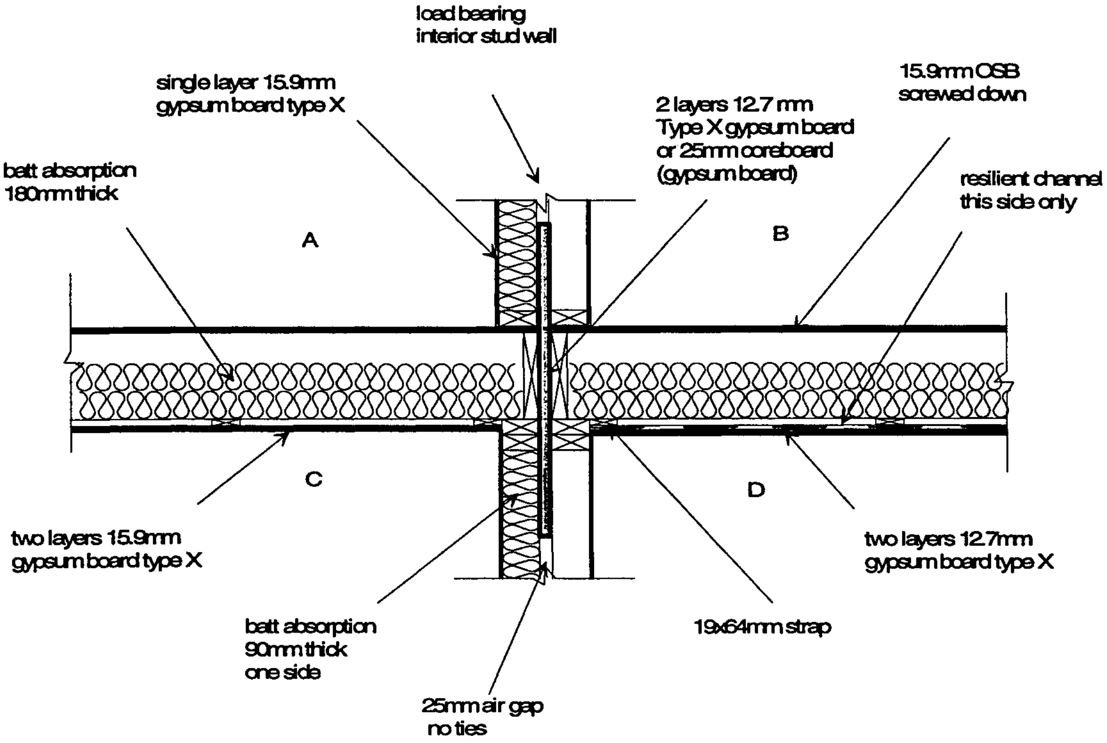

Figure 8

Apparent airborne sound insulation		Room Pairs	Case: 3 with basic wall (FSTC)	Change re Reference A
Apartment	Horizontal	A-B	51	0
	Vertical	B-D	57	+1
	Diagonal	A-D	66	-5

Direct applied ceiling	Vertical	A-C	45	0
	Diagonal	B-C	64	-5

Apparent impact sound insulation		Room Pairs	Case: 3 with basic wall (FIIC)	Change re Reference A
Apartment	Horizontal	A-B	55	-6
	Vertical	B-D	52	+1
	Diagonal	A-D	63	+2

Direct applied ceiling	Vertical	A-C	38	-1
	Diagonal	B-C	59	-3

Case 4: **Reference B with 25 mm gypsum board at joint**
Basic A-B party wall

Purpose:

To establish the effect of introducing a 25 mm gypsum board fire stop.
The floor between rooms A and C is characteristic of row housing type constructions, while the floor between rooms B and D is characteristic of apartment type constructions. The construction is similar to what might be found in stacked constructions where the apartments are offset by one floor. This construction permits study of the different flanking transmission paths which are present in the two types of construction.

Party Wall:

Double wood stud load-bearing wall having separate head and sole plates (nominal 25 mm separation between frames), double head plate, 90 mm batt insulation material filling one side of the wall cavity, finished with a single layer of 15.9 mm Type X gypsum board either side. Gypsum board installed vertically and fastened with 36 mm or longer screws placed 400 mm o.c.

Floor:

15.9 mm OSB floor decking fastened with 51 mm or longer #10 straight shank wood screws placed 150 mm o.c. at edges and 300 mm o.c. in the field, 38x235 mm wood joists 400 mm o.c., bridging and strapping; 19x64 mm strapping 600 mm o.c. used as furring strips, 19x64 mm bracing no more than 2100 mm o.c. located at strapping points (see Figure 5).

Room C: single layer of 12.7 mm regular gypsum board placed directly on the wood furring, (no cavity absorption). The gypsum board was installed with 36 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Room D: 180 mm of batt insulation material (2 layers of 90 mm batt material were used), generic resilient channels 600 mm o.c., placed perpendicular to the strapping, two layers of 12.7 mm Type X gypsum board. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor/Wall Intersection:

Load bearing party wall with the joists perpendicular to the party wall, single joist header, two layers of 12.7 mm Type X gypsum board (nominal width 600 mm) placed in compression between the joist headers. A single drywall screw in the top corners of each sheet held the material in place.

Facade Wall:

See Common Details, page 11.

Case 4: Reference B with 25 mm thick gypsum board at joint
Basic A-B party wall
Row construction in floor A-C

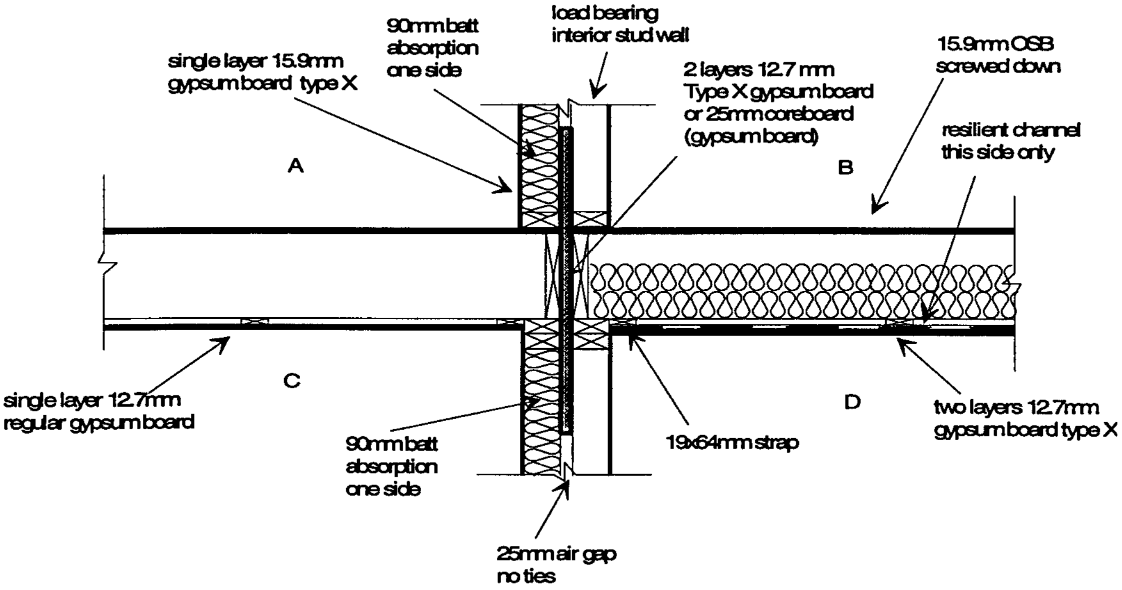

Figure 9

Apparent airborne sound insulation		Room Pairs	Case: 4 with basic wall (FSTC)	Change re Reference B with basic wall	Change re Reference A
Apartment	Horizontal	A-B	50	0	-1
	Vertical	B-D	57	+2	+1
	Diagonal	A-D	65	-5	-6
Row	Vertical	A-C	n/a	n/a	n/a
	Diagonal	B-C	61	-5	-8

Apparent impact sound insulation		Room Pairs	Case: 4 with basic wall (FIIC)	Change re Reference B with basic wall	Change re Reference A
Apartment	Horizontal	A-B	52	-9	-9
	Vertical	B-D	51	+1	0
	Diagonal	A-D	57	n/a	-4
Row	Vertical	A-C	n/a	n/a	n/a
	Diagonal	B-C	60	n/a	-2

Case 4: Reference B with 25 mm thick gypsum board at joint
Superior A-B party wall

Purpose:

To establish the effect of introducing a 25 mm gypsum board fire stop.
The floor between rooms A and C is characteristic of row housing type constructions, while the floor between rooms B and D is characteristic of apartment type constructions. The construction is similar to what might be found in stacked constructions where the apartments are offset by one floor. This construction permits study of the different flanking transmission paths which are present in the two types of construction. The superior A-B wall will establish the limiting sound insulation for the construction with this type of fire stop.

Superior Party Wall:

Double wood stud load-bearing wall having separate head and sole plates (nominal 25 mm separation between frames), double head plate, 90 mm batt insulation material filling both sides of the wall cavity, finished with two layers of 15.9 mm Type X gypsum board installed vertically on either side with staggered joints. The base layer was attached with 36 mm or longer screws placed 400 mm o.c. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor:

15.9 mm OSB floor decking fastened with 51 mm or longer #10 straight shank wood screws placed 150 mm o.c. at edges and 300 mm o.c. in the field, 38x235 mm wood joists 400 mm o.c., bridging and strapping; 19x64 mm strapping 600 mm o.c. used as furring strips, 19x64 mm bracing no more than 2100 mm o.c. located at strapping points (see Figure 5).

Room C: single layer of 12.7 mm regular gypsum board placed directly on the wood furring (no cavity absorption). The gypsum board was installed with 36 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Room D: 180 mm of batt insulation material (2 layers of 90 mm batt material were used), generic resilient channels 600 mm o.c., placed perpendicular to the strapping, two layers of 12.7 mm Type X gypsum board. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor/Wall Intersection:

Load bearing party wall with the joists perpendicular to the party wall, single joist header, two layers of 12.7 mm Type X gypsum board (nominal width 600 mm) placed in compression between the joist headers. A single drywall screw in the top corners of each sheet held the material in place.

Facade Wall:

See Common Details, page 11.

Case 4: Reference B with 25 mm thick gypsum board at joint Superior A-B party wall

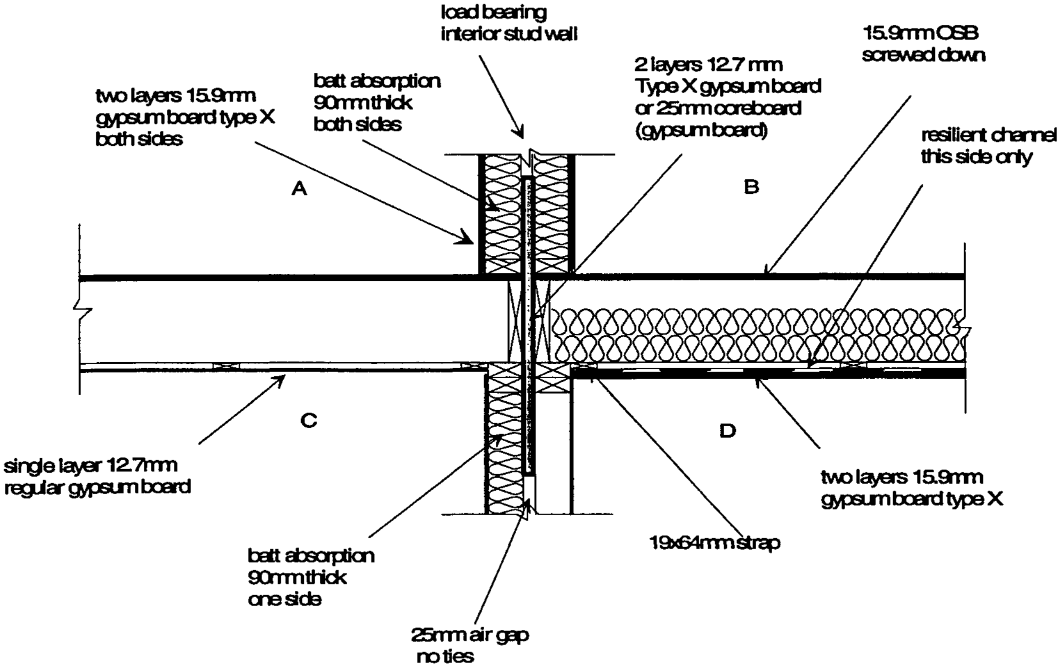

Figure 10

Apparent airborne sound insulation		Room Pairs	Case: 4 with superior wall (FSTC)	Change re Reference B with superior wall
Apartment	Horizontal	A-B	57	-9
	Vertical	B-D	n/a	n/a
	Diagonal	A-D	n/a	n/a

Row	Vertical	A-C	n/a	n/a
	Diagonal	B-C	64	-6

Apparent impact sound insulation		Room Pairs	Case: 4 with superior wall (FIIC)	Change re Reference B with superior wall
Apartment	Horizontal	A-B	57	-9
	Vertical	B-D	n/a	n/a
	Diagonal	A-D	n/a	n/a

Row	Vertical	A-C	n/a	n/a
	Diagonal	B-C	n/a	n/a

Case 5: **Reference B with 25 mm semi-rigid insulation**
Basic A-B party wall

Purpose:

To establish the effect of introducing a 25 mm semi-rigid batt (glass or rock fibre) fire stop. The semi-rigid material had a nominal thickness of 25 mm and a nominal surface density of 5 lbs per cubic foot or 80 kg per cubic meter.

The floor between rooms A and C is characteristic of row housing type constructions, while the floor between rooms B and D is characteristic of apartment type constructions. The construction is similar to what might be found in stacked constructions where the apartments are offset by one floor. This construction permits study of the different flanking transmission paths which are present in the two types of construction.

Party Wall:

Double wood stud load-bearing wall having separate head and sole plates (nominal 25 mm separation between frames), double head plate, 90 mm batt insulation material filling one side of the wall cavity, finished with a single layer of 15.9 mm Type X gypsum board either side. Gypsum board installed vertically and fastened with 36 mm or longer screws placed 400 mm o.c.

Floor:

15.9 mm OSB floor decking fastened with 51 mm or longer #10 straight shank wood screws placed 150 mm o.c. at edges and 300 mm o.c. in the field, 38x235 mm wood joists 400 mm o.c., bridging and strapping; 19x64 mm strapping 600 mm o.c. used as furring strips, 19x64 mm bracing no more than 2100 mm o.c. located at strapping points (see Figure 5).

Room C: single layer of 12.7 mm regular gypsum board placed directly on the wood furring (no cavity absorption). The gypsum board was installed with 36 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Room D: 180 mm of batt insulation material (2 layers of 90 mm batt material were used), generic resilient channels 600 mm o.c., placed perpendicular to the strapping, two layers of 12.7 mm Type X gypsum board. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor/Wall Intersection:

Load bearing party wall with the joists perpendicular to the party wall, single joist header, single layer of 25 mm thick semi-rigid batt material (nominal width 600 mm) placed in compression between the joist headers and the wall plates. A single drywall screw in the top corners of each batt held the material in place.

Facade Wall:

See Common Details, page 11.

Case 5: Reference B with 25 mm semi-rigid batt Basic A-B party wall

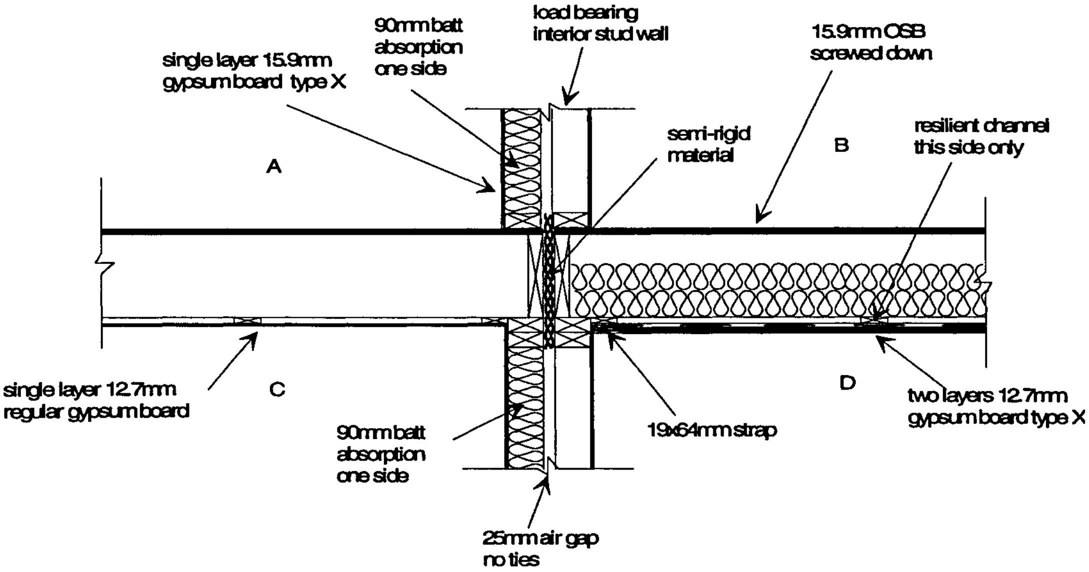

Figure 11

Apparent airborne sound insulation		Room Pairs	Case: 5 with basic wall (FSTC)	Change re Reference B with basic wall	Change re Reference A
Apartment	Horizontal	A-B	52	+2	+1
	Vertical	B-D	57	+2	+1
	Diagonal	A-D	70	0	-1
Row	Vertical	A-C	40	0	n/a
	Diagonal	B-C	66	0	n/a

Apparent impact sound insulation		Room Pairs	Case: 5 with basic wall (FIIC)	Change re Reference B with basic wall	Change re Reference A
Apartment	Horizontal	A-B	59	-2	-2
	Vertical	B-D	51	+1	0
	Diagonal	A-D	59	n/a	-2
Row	Vertical	A-C	35	+2	n/a
	Diagonal	B-C	n/a	n/a	n/a

Case 6: **Reference B with 0.38 mm sheet steel (30 Ga.)**
Basic A-B party wall

Purpose:

To establish the effect of introducing a 0.38 mm sheet steel fire stop.
The floor between rooms A and C is characteristic of row housing type constructions, while the floor between rooms B and D is characteristic of apartment type constructions. The construction is similar to what might be found in stacked constructions where the apartments are offset by one floor. This construction permits study of the different flanking transmission paths which are present in the two types of construction.

Party Wall:

Double wood stud load-bearing wall having separate head and sole plates (nominal 25 mm separation between frames), double head plate, 90 mm batt insulation material filling one side of the wall cavity, finished with a single layer of 15.9 mm Type X gypsum board either side. Gypsum board installed vertically and fastened with 36 mm or longer screws placed 400 mm o.c.

Floor:

15.9 mm OSB floor decking fastened with 51 mm or longer #10 straight shank wood screws placed 150 mm o.c. at edges and 300 mm o.c. in the field, 38x235 mm wood joists 400 mm o.c., bridging and strapping; 19x64 mm strapping 600 mm o.c. used as furring strips, 19x64 mm bracing no more than 2100 mm o.c. located at strapping points (see Figure 5).
Room C: single layer of 12.7 mm regular gypsum board placed directly on the wood furring (no cavity absorption). The gypsum board was installed with 36 mm or longer screws placed 300 mm o.c. at the edges and in the field.
Room D: 180 mm of batt insulation material (2 layers of 90 mm batt material were used), generic resilient channels 600 mm o.c., placed perpendicular to the strapping, two layers of 12.7 mm Type X gypsum board. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor/Wall Intersection:

Load bearing party wall with the joists perpendicular to the party wall, single joist header, single layer of 30 gauge (0.38 mm thick) sheet steel (nominal width 200 mm) was placed under the sole plates of the upper party wall. The sheet steel was installed flat without a profile or crease. (See Figure A17 of Appendix A for fastening diagram.)

Facade Wall:

See Common Details, page 11.

Case 6: Reference B with 0.38 mm sheet steel (30 Ga.) Basic A-B party wall

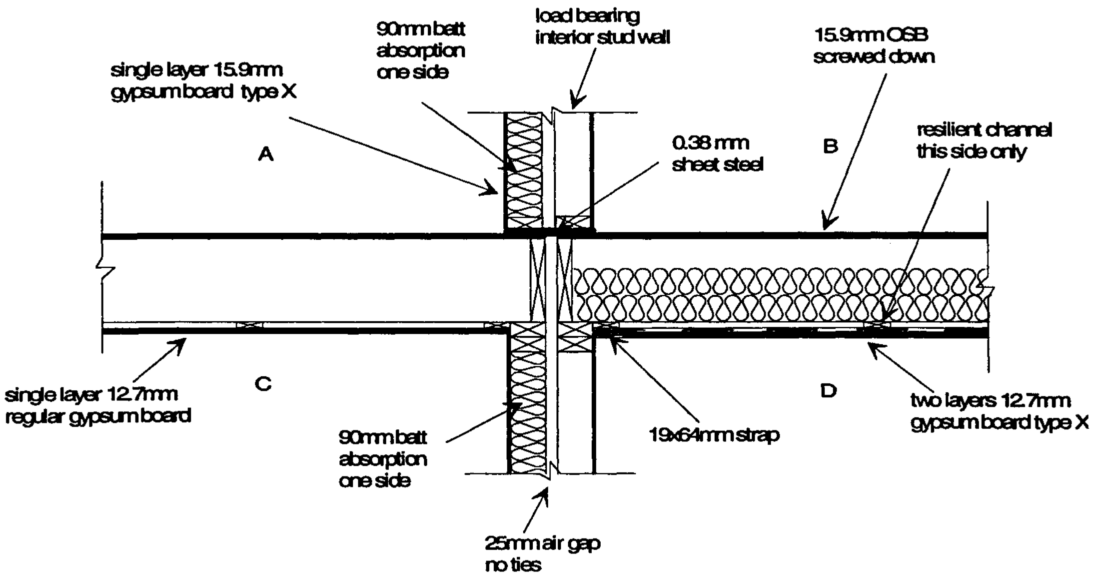

Figure 12

Apparent airborne sound insulation		Room Pairs	Case: 6 with basic wall (FSTC)	Change re Reference B with basic wall	Change re Reference A
Apartment	Horizontal	A-B	51	+1	0
	Vertical	B-D	56	+1	0
	Diagonal	A-D	69	-1	-2

Row	Vertical	A-C	41	+1	-4
	Diagonal	B-C	64	-2	-5

Apparent impact sound insulation		Room Pairs	Case: 6 with basic wall (FIIC)	Change re Reference B with basic wall	Change re Reference A
Apartment	Horizontal	A-B	54	-7	-7
	Vertical	B-D	51	+1	0
	Diagonal	A-D	n/a	n/a	n/a

Row	Vertical	A-C	n/a	n/a	n/a
	Diagonal	B-C	n/a	n/a	n/a

Case 6: Reference B with 0.38 mm sheet steel (30 Ga.)
Superior A-B party wall

Purpose:

To establish the effect of introducing a 0.38 mm sheet steel fire stop.
The floor between rooms A and C is characteristic of row housing type constructions, while the floor between rooms B and D is characteristic of apartment type constructions. The construction is similar to what might be found in stacked constructions where the apartments are offset by one floor. This construction permits study of the different flanking transmission paths which are present in the two types of construction. The superior A-B wall will establish the limiting sound insulation for the construction with this type of fire stop.

Superior Party Wall:

Double wood stud load-bearing wall having separate head and sole plates (nominal 25 mm separation between frames), double head plate, 90 mm batt insulation material filling both sides of the wall cavity, finished with two layers of 15.9 mm Type X gypsum board installed vertically on either side with staggered joints. The base layer was attached with 36 mm or longer screws placed 400 mm o.c. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor:

15.9 mm OSB floor decking fastened with 51 mm or longer #10 straight shank wood screws placed 150 mm o.c. at edges and 300 mm o.c. in the field, 38x235 mm wood joists 400 mm o.c., bridging and strapping; 19x64 mm strapping 600 mm o.c. used as furring strips, 19x64 mm bracing no more than 2100 mm o.c. located at strapping points (see Figure 5).

Room C: single layer of 12.7 mm regular gypsum board placed directly on the wood furring (no cavity absorption). The gypsum board was installed with 36 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Room D: 180 mm of batt insulation material (2 layers of 90 mm batt material were used), generic resilient channels 600 mm o.c., placed perpendicular to the strapping, two layers of 12.7 mm Type X gypsum board. The base layer was attached with 36 mm (or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor/Wall Intersection:

Load bearing party wall with the joists perpendicular to the party wall, single joist header, single layer of 30 gauge (0.38 mm thick) sheet steel (nominal width 200 mm) was placed under the sole plates of the upper party wall. The sheet steel was installed flat without a profile or crease. (See Figure A17 of Appendix A for fastening diagram.)

Facade Wall:

See Common Details, page 11.

Case 6: Reference B with 0.38 mm sheet steel (30 Ga.) Superior A-B party wall

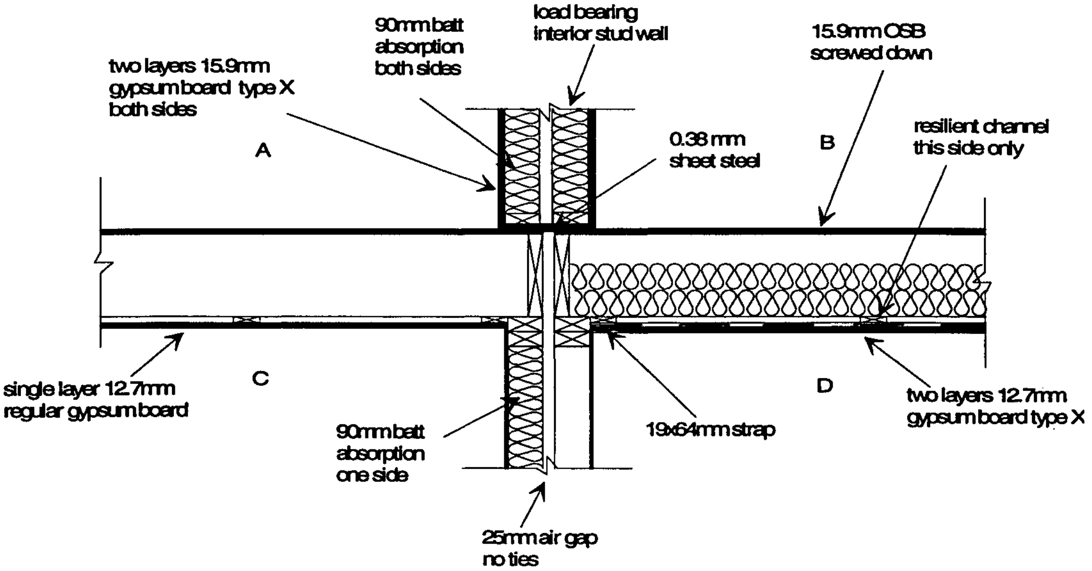

Figure 13

Apparent airborne sound insulation		Room Pairs	Case: 6 with superior wall (FSTC)	Change re Reference B with superior wall
Apartment	Horizontal	A-B	57	-9
	Vertical	B-D	57	+2
	Diagonal	A-D	n/a	n/a

Row	Vertical	A-C	n/a	n/a
	Diagonal	B-C	65	-5

Apparent impact sound insulation		Room Pairs	Case: 6 with superior wall (FIIC)	Change re Reference B with superior wall
Apartment	Horizontal	A-B	55	-9
	Vertical	B-D	n/a	n/a
	Diagonal	A-D	n/a	n/a

Row	Vertical	A-C	38	+5
	Diagonal	B-C	n/a	n/a

Case 7: **Reference B with continuous 15.9 mm OSB sub-floor**
Basic A-B party wall

Purpose:

To establish the effect of introducing a 15.9 mm OSB fire stop by running the sub-floor under the upper party wall.
The floor between rooms A and C is characteristic of row housing type constructions, while the floor between rooms B and D is characteristic of apartment type constructions. The construction is similar to what might be found in stacked constructions where the apartments are offset by one floor. This construction permits study of the different flanking transmission paths which are present in the two types of construction.

Party Wall:

Double wood stud load-bearing wall having separate head and sole plates (nominal 25 mm separation between frames), double head plate, 90 mm batt insulation material filling one side of the wall cavity, finished with a single layer of 15.9 mm Type X gypsum board either side. Gypsum board installed vertically and fastened with 36 mm or longer screws placed 400 mm o.c.

Floor:

15.9 mm OSB floor decking fastened with 51 mm or longer #10 straight shank wood screws placed 150 mm o.c. at edges and 300 mm o.c. in the field, 38x235 mm wood joists 400 mm o.c., bridging and strapping; 9x64 mm strapping 600 mm o.c. used as furring strips, 19x64 mm bracing no more than 2100 mm o.c. located at strapping points (see Figure 5).
Room C: single layer of 12.7 mm regular gypsum board placed directly on the wood furring (no cavity absorption). The gypsum board was installed with 36 mm or longer screws placed 300 mm o.c. at the edges and in the field.
Room D: 180 mm of batt insulation material (2 layers of 90 mm batt material were used), generic resilient channels 600 mm o.c., placed perpendicular to the strapping, two layers of 12.7 mm Type X gypsum board. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor/Wall Intersection:

Load bearing party wall with the joists perpendicular to the party wall, single joist header. The 15.9 mm thick OSB sub-floor was run under the party wall.

Facade Wall:

See Common Details, page 11.

Case 7: Reference B with continuous 15.9 mm OSB sub-floor Basic A-B party wall

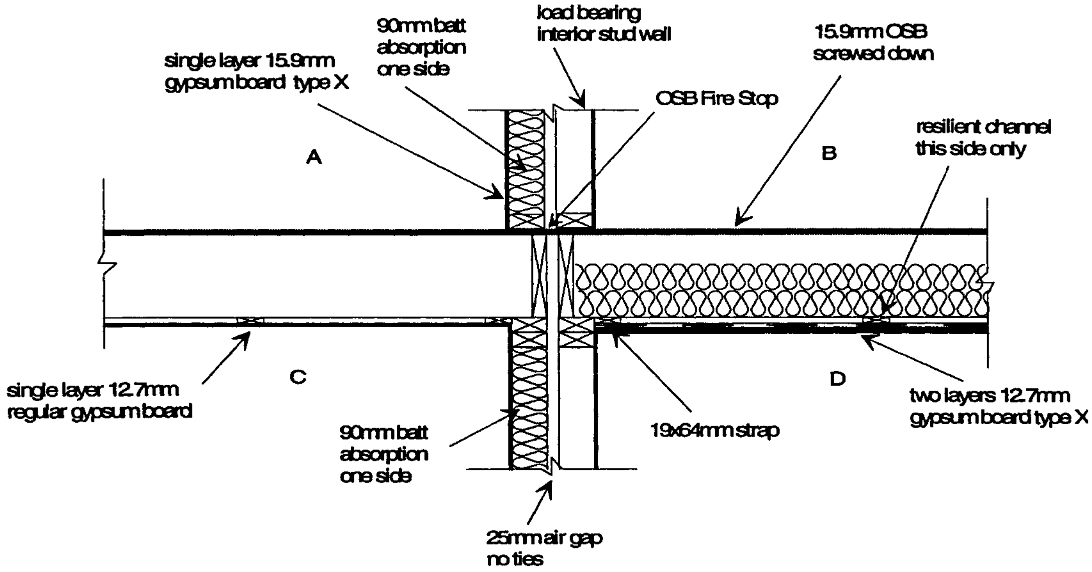

Figure 14

Apparent airborne sound insulation		Room Pairs	Case: 7 with basic wall (FSTC)	Change re Reference B with basic wall	Change re Reference A
Apartment	Horizontal	A-B	50	0	-1
	Vertical	B-D	56	+1	0
	Diagonal	A-D	66	-4	-5

Row	Vertical	A-C	41	+1	n/a
	Diagonal	B-C	61	-5	n/a

Apparent impact sound insulation		Room Pairs	Case: 7 with basic wall (FIIC)	Change re Reference B with basic wall	Change re Reference A
Apartment	Horizontal	A-B	51	-10	-10
	Vertical	B-D	51	+1	0
	Diagonal	A-D	55	n/a	-6

Row	Vertical	A-C	n/a	n/a	n/a
	Diagonal	B-C	58	n/a	-3

Case 7: **Reference B with continuous 15.9 mm OSB sub-floor**
Superior A-B party wall

Purpose:

To establish the effect of introducing a 15.9 OSB fire stop by running the sub-floor under the upper party wall.
The floor between rooms A and C is characteristic of row housing type constructions, while the floor between rooms B and D is characteristic of apartment type constructions. The construction is similar to what might be found in stacked constructions where the apartments are offset by one floor. This construction permits study of the different flanking transmission paths which are present in the two types of construction. The superior A-B wall will establish the limiting sound insulation for the construction with this type of fire stop.

Superior Party Wall:

Double wood stud load-bearing wall having separate head and sole plates (nominal 25 mm separation between frames), double head plate, 90 mm batt insulation material filling both sides of the wall cavity, finished with two layers of 15.9 mm Type X gypsum board installed vertically on either side with staggered joints. The base layer was attached with 36 mm or longer screws placed 400 mm o.c. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor:

15.9 mm OSB floor decking fastened with 51 mm or longer #10 straight shank wood screws placed 150 mm o.c. at edges and 300 mm o.c. in the field, 38x235 mm wood joists 400 mm o.c., bridging and strapping; 19x64 mm strapping 600 mm o.c. used as furring strips, 19x64 mm bracing no more than 2100 mm o.c. located at strapping points (see Figure 5).
Room C: single layer of 12.7 mm regular gypsum board placed directly on the wood furring (no cavity absorption). The gypsum board was installed with 36 mm or longer screws placed 300 mm o.c. at the edges and in the field.
Room D: 180 mm of batt insulation material (2 layers of 90 mm batt material were used), generic resilient channels 600 mm o.c., placed perpendicular to the strapping, two layers of 12.7 mm Type X gypsum board. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor/Wall Intersection:

Load bearing party wall with the joists perpendicular to the party wall, single joist header. The 15.9 mm thick OSB sub-floor was run under the party wall.

Facade Wall:

See Common Details, page 11.

Case 7: Reference B with continuous 15.9 mm OSB sub-floor Superior A-B party wall

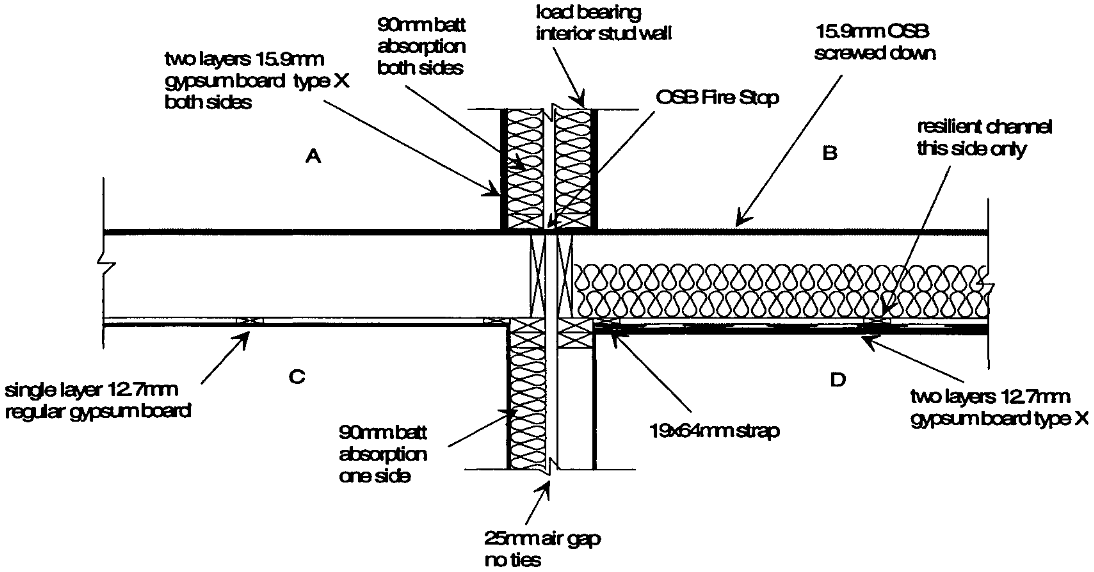

Figure 15

Apparent airborne sound insulation		Room Pairs	Case: 7 with superior wall (FSTC)	Change re Reference B with superior wall
Apartment	Horizontal	A-B	52	-14
	Vertical	B-D	56	+1
	Diagonal	A-D	67	-3
Row	Vertical	A-C	40	0
	Diagonal	B-C	61	-9

Apparent impact sound insulation		Room Pairs	Case: 7 with superior wall (FIIC)	Change re: Reference B with superior wall
Apartment	Horizontal	A-B	51	-15
	Vertical	B-D	n/a	n/a
	Diagonal	A-D	n/a	n/a
Row	Vertical	A-C	n/a	n/a
	Diagonal	B-C	n/a	n/a

Case 8: **(Retro-fit for Case 7) 15.9 mm thick OSB underlay**
Basic A-B party wall

Purpose:

To establish the effectiveness of a 15.9 mm thick OSB underlay applied to an existing continuous sub-floor.

(Throughout this document, the term "underlay" is used to describe the additional layer of floor sheathing applied to the sub-floor.)

The floor between rooms A and C is characteristic of row housing type constructions, while the floor between rooms B and D is characteristic of apartment type constructions. The construction is similar to what might be found in stacked constructions where the apartments are offset by one floor. This construction permits study of the different flanking transmission paths which are present in the two types of construction.

Party Wall:

Double wood stud load-bearing wall having separate head and sole plates (nominal 25 mm separation between frames), double head plate, 90 mm batt insulation material filling one side of the wall cavity, finished with a single layer of 15.9 mm Type X gypsum board either side. Gypsum board installed vertically and fastened with 36 mm or longer screws placed 400 mm o.c.

Base Floor:

15.9 mm OSB floor decking fastened with 51 mm or longer #10 straight shank wood screws placed 150 mm o.c. at edges and 300 mm o.c. in the field, 38x235 mm wood joists 400 mm o.c., bridging and strapping; 19x64 mm strapping 600 mm o.c. used as furring strips, 19x64 mm bracing no more than 2100 mm o.c. located at strapping points (see Figure 5).

Room C: single layer of 12.7 mm regular gypsum board placed directly on the wood furring (no cavity absorption). The gypsum board was installed with 36 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Room D: 180 mm of batt insulation material (2 layers of 90 mm batt material were used), generic resilient channels 600 mm o.c., placed perpendicular to the strapping, two layers of 12.7 mm Type X gypsum board. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor Underlay:

15.9 mm OSB (tongue and groove) underlay applied at right angles to the existing sub-floor. Underlay secured to sub-floor using staples (length, 30 mm (1-3/16"), crown 4 mm (5/32"), chisel point) 38 mm (1-1/2") o.c. around edges and 101 mm (4") o.c. in the field. Joints in the two layers were staggered by at least 200 mm (8").

Floor/Wall Intersection:

Load bearing party wall with the joists perpendicular to the party wall, single joist header. The 15.9 mm thick OSB sub-floor was run under the party wall.

Facade Wall:

See Common Details, page 11.

Case 8: (Retro-fit for Case 7) 15.9 mm thick OSB underlay Basic A-B party wall

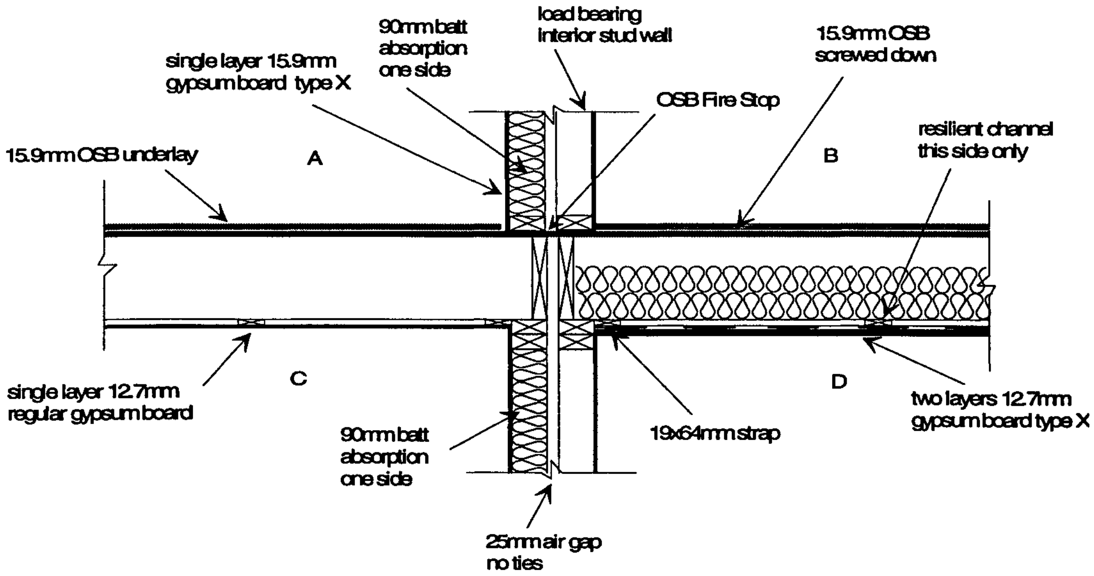

Figure 16

Apparent airborne sound insulation		Room Pairs	Case: 8 with basic wall (FSTC)	Change re Case 7 with basic wall	Change re Reference B with basic wall	Change re Reference A
Apartment	Horizontal	A-B	51	+1	+1	0
	Vertical	B-D	59	+3	+4	+3
	Diagonal	A-D	68	+2	-2	-3

Row	Vertical	A-C	43	+2	+3	n/a
	Diagonal	B-C	63	+2	-3	n/a

Apparent impact sound insulation		Room Pairs	Case: 8 with basic wall (FIIC)	Change re Case 7 with basic wall	Change re Reference B with basic wall	Change re Reference A
Apartment	Horizontal	A-B	55	+4	-6	-6
	Vertical	B-D	52	+1	+2	+1
	Diagonal	A-D	57	+2	n/a	-4

Row	Vertical	A-C	n/a	n/a	n/a	n/a
	Diagonal	B-C	60	+2	n/a	-2

Case 8: **(Retro-fit for Case 7) 15.9 mm thick OSB underlay**
Superior A-B party wall

Purpose:

To establish the effectiveness of a 15.9 mm thick OSB underlay applied to an existing continuous sub-floor.

The floor between rooms A and C is characteristic of row housing type constructions, while the floor between rooms B and D is characteristic of apartment type constructions. The construction is similar to what might be found in stacked constructions where the apartments are offset by one floor. This construction permits study of the different flanking transmission paths which are present in the two types of construction. The superior A-B wall will establish the limiting sound insulation for the construction with this type of fire stop.

Superior Party Wall:

Double wood stud load-bearing wall having separate head and sole plates (nominal 25 mm separation between frames), double head plate, 90 mm batt insulation material filling both sides of the wall cavity, finished with two layers of 15.9 mm Type X gypsum board installed vertically on either side with staggered joints. The base layer was attached with 36 mm or longer screws placed 400 mm o.c. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Base Floor:

15.9 mm OSB floor decking fastened with 51 mm or longer #10 straight shank wood screws placed 150 mm o.c. at edges and 300 mm o.c. in the field, 38x235 mm wood joists 400 mm o.c., bridging and strapping; 19x64 mm strapping 600 mm o.c. used as furring strips, 19x64 mm bracing no more than 2100 mm o.c. located at strapping points (see Figure 5).

Room C: single layer of 12.7 mm regular gypsum board placed directly on the wood furring (no cavity absorption). The gypsum board was installed with 36 mm (or longer screws placed 300 mm o.c. at the edges and in the field.

Room D: 180 mm of batt insulation material (2 layers of 90 mm batt material were used), generic resilient channels 600 mm o.c., placed perpendicular to the strapping, two layers of 12.7 mm Type X gypsum board. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor Underlay:

15.9 mm OSB (tongue and groove) underlay applied at right angles to the existing sub-floor. Underlay secured to sub-floor using staples (length, 30 mm (1-3/16"), crown 4 mm (5/32"), chisel point) 38 mm (1-1/2") o.c. around edges and 101 mm (4") o.c. in the field. Joints in the two layers were staggered by at least 200 mm (8").

Floor/Wall Intersection:

Load bearing party wall with the joists perpendicular to the party wall, single joist header. The 15.9 mm thick OSB sub-floor was run under the party wall.

Facade Wall:

See Common Details, page 11.

Case 8: (Retro-fit for Case 7) 15.9 mm thick OSB underlay Superior A-B party wall

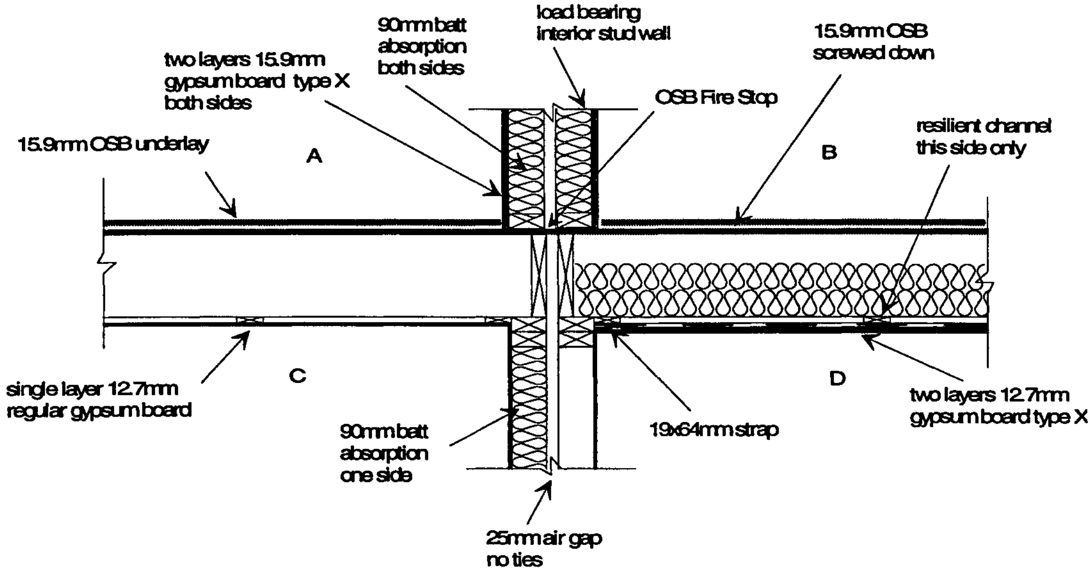

Figure 17

Apparent airborne sound insulation		Room Pairs	Case: 8 with superior wall (FSTC)	Change re Case 7 with superior wall	Change re Reference B with superior wall
Apartment	Horizontal	A-B	60	+8	-6
	Vertical	B-D	59	+3	+4
	Diagonal	A-D	69	+2	-1

Row	Vertical	A-C	43	+3	+3
	Diagonal	B-C	64	+3	-6

Apparent impact sound insulation		Room Pairs	Case: 8 with superior wall (FIIC)	Change re Case 7 with superior wall	Change re: Reference B with superior wall
Apartment	Horizontal	A-B	58	+7	-8
	Vertical	B-D	52	n/a	+2
	Diagonal	A-D	57	n/a	n/a

Row	Vertical	A-C	34	n/a	+1
	Diagonal	B-C	61	n/a	n/a

Case 9: (Retro-fit for Case 7) floating floor system
Superior A-B party wall

Purpose:

To establish the effectiveness of an engineered floating floor applied to an existing continuous sub-floor.

The floor between rooms A and C is characteristic of row housing type constructions, while the floor between rooms B and D is characteristic of apartment type constructions. The construction is similar to what might be found in stacked constructions where the apartments are offset by one floor. This construction permits study of the different flanking transmission paths which are present in the two types of construction. The superior A-B wall will establish the limiting sound insulation for the construction with this type of fire stop.

Superior Party Wall:

Double wood stud load-bearing wall having separate head and sole plates (nominal 25 mm separation between frames), double head plate, 90 mm batt insulation material filling both sides of the wall cavity, finished with two layers of 15.9 mm Type X gypsum board installed vertically on either side with staggered joints. The base layer was attached with 36 mm or longer screws placed 400 mm o.c. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Base Floor:

15.9 mm OSB floor decking fastened with 51 mm or longer #10 straight shank wood screws placed 150 mm o.c. at edges and 300 mm o.c. in the field, 38x235 mm wood joists 400 mm o.c., bridging and strapping; 19x64 mm strapping 600 mm o.c. used as furring strips, 19x64 mm bracing no more than 2100 mm o.c. located at strapping points (see Figure 5).

Room C: single layer of 12.7 mm regular gypsum board placed directly on the wood furring (no cavity absorption). The gypsum board was installed with 36 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Room D: 180 mm of batt insulation material (2 layers of 90 mm batt material were used), generic resilient channels 600 mm o.c., placed perpendicular to the strapping, two layers of 12.7 mm Type X gypsum board. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor Underlay:

58 mm Lamella floating floor system from Roxul Inc. was applied over to the existing sub-floor. The floating floor consists of 18 mm chipboard bonded to 40 mm mineral wool and supplied in 2440x600 mm tongue and groove panels. The panels were laid parallel to the party wall with the joints staggered. A 5 mm gap is left between the panels and the perimeter walls; this gap was filled with mineral wool and then taped.

Floor/Wall Intersection:

Load bearing party wall with the joists perpendicular to the party wall, single joist header. The 15.9 mm thick OSB sub-floor was run under the party wall.

Facade Wall:

See Common Details, page 11.

Case 9: (Retro-fit for Case 7) floating floor system Superior A-B party wall

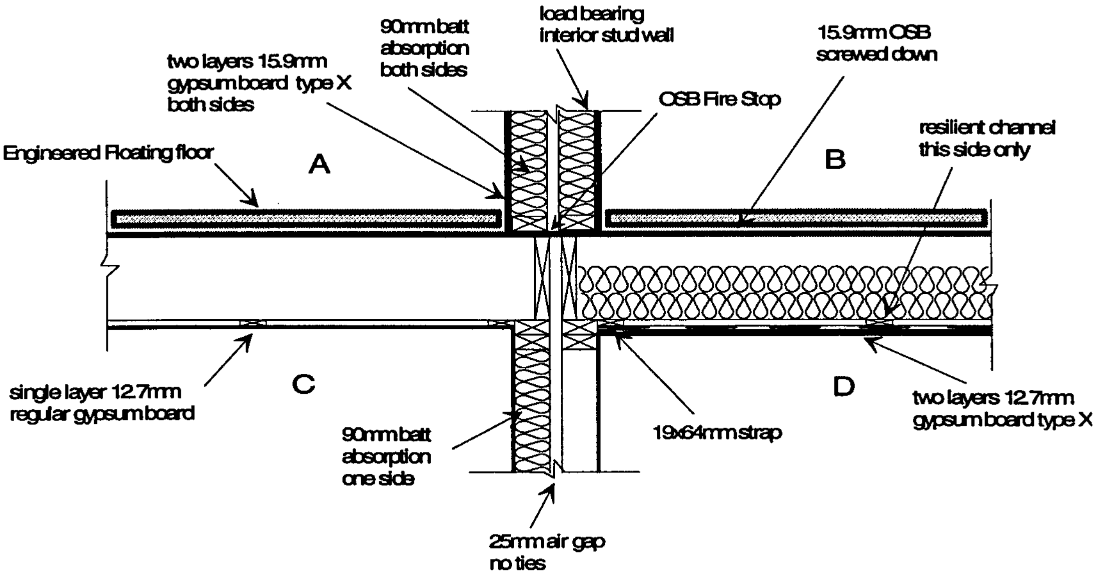

Figure 18

Apparent airborne sound insulation		Room Pairs	Case: 9 with superior wall (FSTC)	Change re Case 7 with superior wall	Change re Reference B with superior wall
Apartment	Horizontal	A-B	67	+15	+1
	Vertical	B-D	65	+9	+10
	Diagonal	A-D	73	+6	+3

Row	Vertical	A-C	51	+11	+11
	Diagonal	B-C	69	+8	-1

Apparent impact sound insulation		Room Pairs	Case: 9 with superior wall (FIIC)	Change re Case 7 with superior wall	Change re: Reference B with superior wall
Apartment	Horizontal	A-B	69	+18	+3
	Vertical	B-D	58	n/a	+8
	Diagonal	A-D	n/a	n/a	n/a

Row	Vertical	A-C	39	n/a	+6
	Diagonal	B-C	n/a	n/a	n/a

Case 10: **Reference B, No fire stop**
Like Reference A but degraded A-C ceiling
Basic A-B party wall

Purpose:

To provide a base case to which specimens having a fire stop at the joint, but not having a fire rated A-C floor assembly (Cases 4 through 9), can be compared. This case may be compared to Reference A (Case 1), to estimate the difference in A-B sound insulation for row and apartment type constructions.

The floor between rooms A and C is characteristic of row housing type constructions, while the floor between rooms B and D is characteristic of apartment type constructions. The construction is similar to what might be found in stacked constructions where the apartments are offset by one floor. This construction permits study of the different flanking transmission paths which are present in the two types of construction.

Party Wall:

Double wood stud load-bearing wall having separate head and sole plates (nominal 25 mm separation between frames), double head plate, 90 mm batt insulation material filling one side of the wall cavity, finished with a single layer of 15.9 mm Type X gypsum board either side. Gypsum board installed vertically and fastened with 36 mm or longer screws placed 400 mm o.c.

Base Floor:

15.9 mm OSB floor decking fastened with 51 mm or longer #10 straight shank wood screws placed 150 mm o.c. at edges and 300 mm o.c. in the field, 38x235 mm wood joists 400 mm o.c., bridging and strapping; 19x64 mm strapping 600 mm o.c. used as furring strips, 19x64 mm bracing no more than 2100 mm o.c. located at strapping points (see Figure 5).

Room C: single layer of 12.7 mm regular gypsum board placed directly on the wood furring (no cavity absorption). The gypsum board was installed with 36 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Room D: 180 mm of batt insulation material (2 layers of 90 mm batt material were used), generic resilient channels 600 mm o.c., placed perpendicular to the strapping, two layers of 12.7 mm Type X gypsum board. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor/Wall Intersection:

Load bearing party wall with the joists perpendicular to the party wall, single joist header, no batt insulation in the nominal 25x365 mm cavity formed by the joist headers and the wall plates.

Facade Wall:

See Common Details, page 11.

Case 10: Reference B, no fire stop
Like Reference A but degraded A-C ceiling
Basic A-B party wall

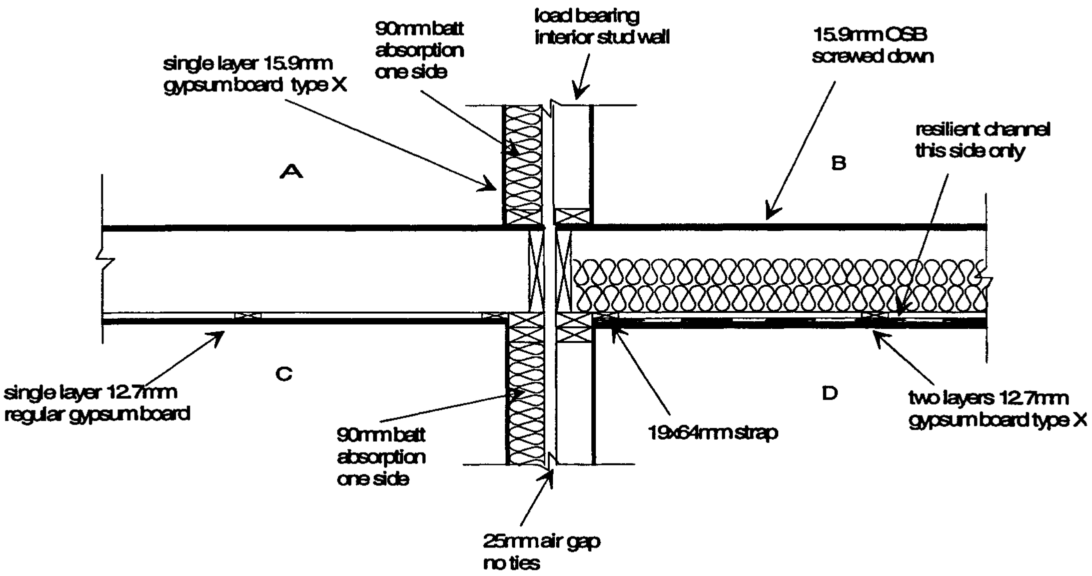

Figure 19

Apparent airborne sound insulation		Room Pairs	Reference B with basic wall (FSTC)	Change re Reference A
Apartment	Horizontal	A-B	50	-1
	Vertical	B-D	55	-1
	Diagonal	A-D	70	-1

Row	Vertical	A-C	40	-5
	Diagonal	B-C	66	-3

Apparent impact sound insulation		Room Pairs	Reference B with basic wall (FIIC)	Change re Reference A
Apartment	Horizontal	A-B	61	0
	Vertical	B-D	50	-1
	Diagonal	A-D	n/a	n/a

Row	Vertical	A-C	33	-6
	Diagonal	B-C	n/a	n/a

Case 10: **Reference B, No fire stop**
Like Reference A but degraded A-C ceiling
Superior A-B party wall

Purpose:

To provide a base case to which specimens having a fire stop at the joint, but not having a fire rated A-C floor assembly (Cases 4 through 9), can be compared. This case may be compared to Reference A (Case1), to estimate the difference in A-B sound insulation for row and apartment type constructions.

The floor between rooms A and C is characteristic of row housing type constructions, while the floor between rooms B and D is characteristic of apartment type constructions. The construction is similar to what might be found in stacked constructions where the apartments are offset by one floor. This construction permits study of the different flanking transmission paths which are present in the two types of construction. The superior A-B wall will establish the limiting sound insulation for the construction with this type of fire stop.

Superior Party Wall:

Double wood stud load-bearing wall having separate head and sole plates (nominal 25 mm separation between frames), double head plate, 90 mm batt insulation material filling both sides of the wall cavity, finished with two layers of 15.9 mm Type X gypsum board installed vertically on either side with staggered joints. The base layer was attached with 36 mm or longer screws placed 400 mm o.c. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Base Floor:

15.9 mm OSB floor decking fastened with 51 mm or longer #10 straight shank wood screws placed 150 mm o.c. at edges and 300 mm o.c. in the field, 38x235 mm wood joists 400 mm o.c., bridging and strapping; 19x64 mm strapping 600 mm o.c. used as furring strips, 19x64 mm bracing no more than 2100 mm o.c. located at strapping points (see Figure 5).

Room C: single layer of 12.7 mm regular gypsum board placed directly on the wood furring (no cavity absorption). The gypsum board was installed with 36 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Room D: 180 mm of batt insulation material (2 layers of 90 mm batt material were used), generic resilient channels 600 mm o.c., placed perpendicular to the strapping, two layers of 12.7 mm Type X gypsum board. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor/Wall Intersection:

Load bearing party wall with the joists perpendicular to the party wall, single joist header, no batt insulation in the nominal 25x365 mm cavity formed by the joist headers and the wall plates.

Facade Wall:

See Common Details, page 11.

Case 10: Reference B, no fire stop
Like Reference A but degraded A-C ceiling
Superior A-B party wall

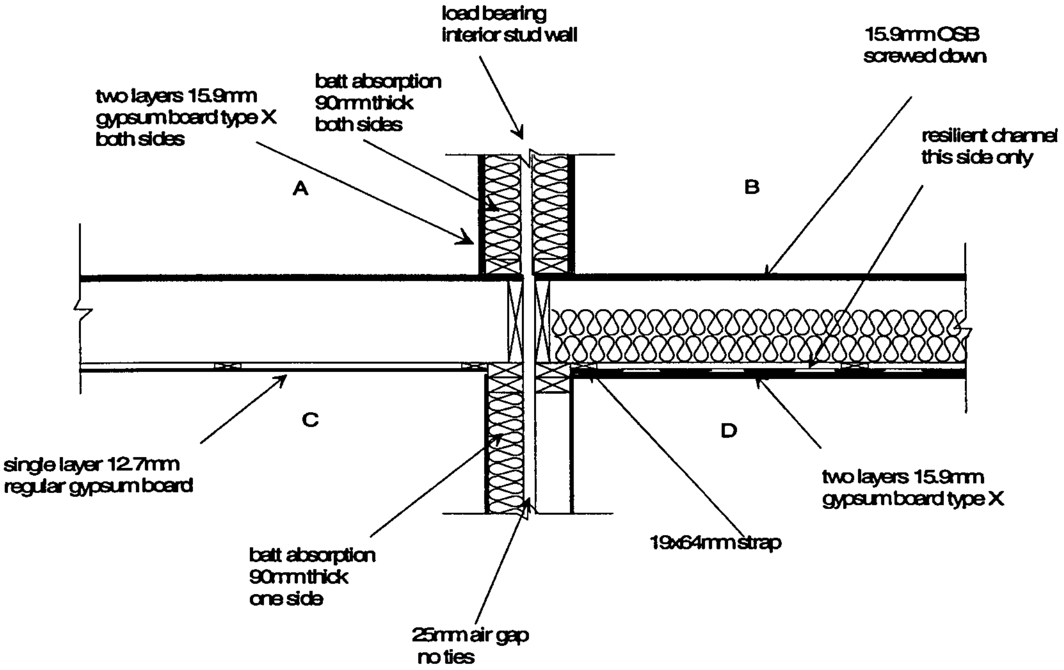

Figure 20

Apparent airborne sound insulation		Room Pairs	Reference B with superior wall (FSTC)	Change re Reference A with basic wall
Apartment	Horizontal	A-B	66	+15
	Vertical	B-D	55	0
	Diagonal	A-D	70	-1

Row	Vertical	A-C	40	-5
	Diagonal	B-C	70	+1

Apparent impact sound insulation		Room Pairs	Reference B with superior wall (FIIC)	Change re Reference A
Apartment	Horizontal	A-B	65	+4
	Vertical	B-D	50	-1
	Diagonal	A-D	n/a	n/a

Row	Vertical	A-C	33	-6
	Diagonal	B-C	n/a	n/a

Case 11: Reference B with continuous 15.9 mm Plywood sub-floor
Superior A-B party wall

Purpose:

To establish the effect of introducing a 15.9 Plywood fire stop by running the sub-floor under the upper party wall.

The floor between rooms A and C is characteristic of row housing type constructions, while the floor between rooms B and D is characteristic of apartment type construction. The construction is similar to what might be found in stacked constructions where the apartments are offset by one floor. This construction permits study of the different flanking transmission paths which are present in the two types of construction. The superior A-B wall will establish the limiting sound insulation for the construction with this type of fire stop.

Superior Party Wall:

Double wood stud load-bearing wall having separate head and sole plates (nominal 25 mm separation between frames), double head plate, 90 mm batt insulation material filling both sides of the wall cavity, finished with two layers of 15.9 mm Type X gypsum board installed vertically on either side with staggered joints. The base layer was attached with 36 mm or longer screws placed 400 mm o.c. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor:

15.9 mm Plywood floor decking fastened with 51 mm or longer #10 straight shank wood screws placed 150 mm o.c. at edges and 300 mm o.c. in the field, 38x235 mm wood joists 400 mm o.c., bridging and strapping; 19x64 mm strapping 600 mm o.c. used as furring strips, 19x64 mm bracing no more than 2100 mm o.c. located at strapping points (see Figure 5).

Room C: single layer of 12.7 mm regular gypsum board placed directly on the wood furring (no cavity absorption). The gypsum board was installed with 36 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Room D: 180 mm of batt insulation material (2 layers of 90 mm batt material were used), generic resilient channels 600 mm o.c., placed perpendicular to the strapping, two layers of 12.7 mm Type X gypsum board. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Floor/Wall Intersection:

Load bearing party wall with the joists perpendicular to the party wall, single joist header. The 15.9 mm thick Plywood sub-floor was run under the party wall.

Facade Wall:

See Common Details, page 11.

Case 11: Reference B with continuous 15.9 mm Plywood sub-floor
Superior A-B party wall

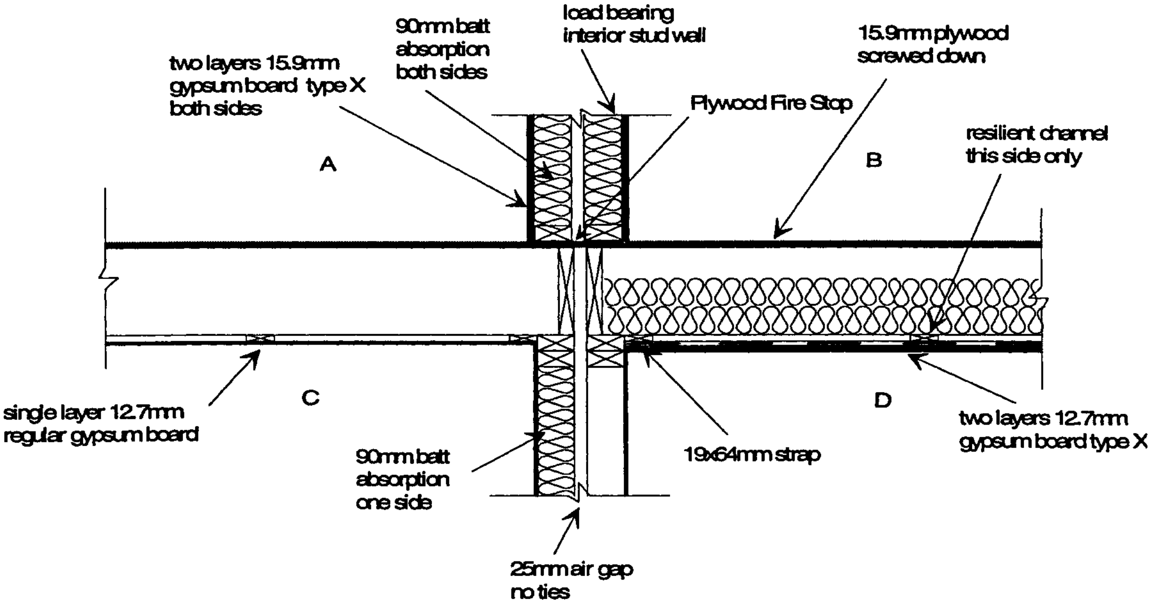

Figure 21

Apparent airborne sound insulation		Room Pairs	Case: 11 with superior wall (FSTC)	Change re Case 7 with superior wall	Change re Reference B with superior wall
Apartment	Horizontal	A-B	51	-1	-15
	Vertical	B-D	55	-1	+0
	Diagonal	A-D	66	-1	-4
Row	Vertical	A-C	38	-2	-2
	Diagonal	B-C	62	+1	-8

Apparent impact sound insulation		Room Pairs	Case: 11 with superior wall (FIIC)	Change re Case 7 with superior wall	Change re: Reference B with superior wall
Apartment	Horizontal	A-B	51	0	-14
	Vertical	B-D	50	n/a	0
	Diagonal	A-D	56	n/a	n/a
Row	Vertical	A-C	33	n/a	0
	Diagonal	B-C	59	n/a	n/a

Case 12: **Case 7 (continuous 15.9 mm OSB) with non-load bearing party wall**
Superior A-B party wall

Purpose:

To establish the effect of joist orientation when a 15.9 OSB fire stop is formed by running the sub-floor under the upper party wall. This case is identical to Case 7 with the exception that the floor assembly has been rotated so that the party wall no longer bears the floor load (i.e., the floor joists are parallel to the party wall).

The floor between rooms A and C is characteristic of row housing type constructions, while the floor between rooms B and D is characteristic of apartment type constructions. The construction is similar to what might be found in stacked constructions where the apartments are offset by one floor. This construction permits study of the different flanking transmission paths which are present in the two types of construction. The superior A-B wall will establish the limiting sound insulation for the construction with this type of fire stop.

Note: Despite the fact that the joists have been reoriented so that the party wall is non-load bearing, the party wall was constructed as if it were load bearing. This allows for direct comparison to Case 7 to assess the impact of joist orientation.

Superior Party Wall:

Double wood stud non load-bearing wall having separate head and sole plates (nominal 25 mm separation between frames), double head plate, 90 mm batt insulation material filling both sides of the wall cavity, finished with two layers of 15.9 mm Type X gypsum board installed vertically on either side with staggered joints. The base layer was attached with 36 mm or longer screws placed 400 mm o.c. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field. This construction is identical to the superior wall of Case 7.

Floor:

15.9 mm OSB floor decking fastened with 51 mm or longer #10 straight shank wood screws placed 150 mm o.c. at edges and 300 mm o.c. in the field, 38x235 mm wood joists 400 mm o.c., bridging and strapping; 19x64 mm strapping 600 mm o.c. used as furring strips, 19x64 mm bracing no more than 2100 mm o.c. located at strapping points

Room C: single layer of 12.7 mm regular gypsum board placed directly on the wood furring (no cavity absorption). The gypsum board was installed with 36 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Room D: 180 mm of batt insulation material (2 layers of 90 mm batt material were used), generic resilient channels 600 mm o.c., placed perpendicular to the strapping, two layers of 12.7 mm Type X gypsum board. The base layer was attached with 36 mm or longer screws placed 300 mm o.c. at the edges and 600 mm o.c. in the field. The top layer was installed with 52 mm or longer screws placed 300 mm o.c. at the edges and in the field.

Note: Floors are identical to those used in Case 7 with the exception that they have been rotated by 90 degrees so that the joists are parallel to the party wall.

Floor/Wall Intersection:

The 15.9 mm thick OSB sub-floor was run under the party wall. Floor joists were oriented parallel to the party wall and trimmer joists used at the party wall.

Facade Wall:

See Common Details, page 11.

Case 12: Continuous 15.9 mm OSB with non-load bearing party walls
Superior A-B party wall

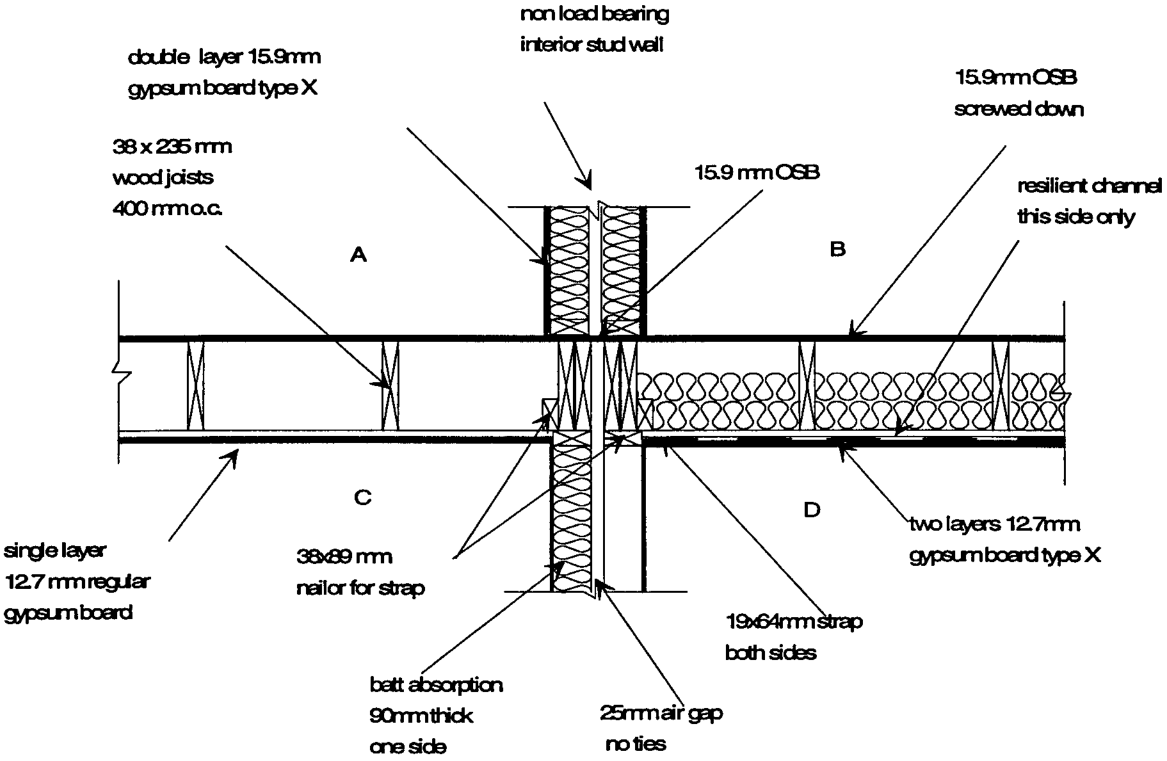

Figure 22

Apparent airborne sound insulation		Room Pairs	Case: 12 with superior wall (FSTC)	Change re Case 7 with superior wall
Apartment	Horizontal	A-B	48	-4
	Vertical	B-D	58	+2
	Diagonal	A-D	67	0
Row	Vertical	A-C	38	-2
	Diagonal	B-C	59	-2

Apparent impact sound insulation		Room Pairs	Case: 12 with superior wall (FIIC)	Change re: Case 7 with superior wall
Apartment	Horizontal	A-B	55	+3
	Vertical	B-D	52	n/a
	Diagonal	A-D	55	n/a
Row	Vertical	A-C	32	n/a
	Diagonal	B-C	62	n/a

DISCUSSION OF RESULTS

Fire stops can introduce a physical connection between the two sides of a double-stud wall, hence providing structural flanking paths for transmission of vibration which worsens sound insulation.

Material properties, installation details, and physical dimensions of the fire stop determine the effect it will have on sound insulation. The reduction in sound insulation due to a given fire stop construction is obviously also dependent on the floor and wall assemblies involved.

The discussion will be broken into two sections. The first illustrates that the impact of a fire stop is highly dependent on the construction of the building elements to which it is connected. The second provides a brief description of the flanking transmission in floor/wall system specific to this study, and then provides a comparison of the relative effect of specific fire stops on the resulting sound transmission.

Effect of Floor/Wall System Construction on Flanking Transmission

This study has examined the sound insulation degradation due to fire stops applied at the intersection of double wood stud wall by a floor/ceiling assembly. To accurately rank order the fire stops in terms of their acoustical desirability, the construction of the floor/ceiling assembly and the supporting party wall remained virtually unchanged. While this ensures an accurate rank ordering of the materials, it does not provide information regarding the performance of the fire stops in a wide range of constructions.

Two cases (11 and 12) were used to show that sound insulation was not only dependent on the fire stop but also on the floor/ceiling construction.

A comparison of horizontal sound insulation between rooms A and B with the continuous OSB sub-floor fire stop of Case 7 and Case 12 indicates that even though the construction of the party walls may be identical, the sound insulation can vary significantly due to details in the floor construction. Case 7 had a load bearing party wall (joists were oriented at right angles to the party wall) and exhibited FSTC 52 while Case 12 had a non-load bearing party wall (the joists were parallel to the party wall) and exhibited FSTC 48.

The 4 point difference can be attributed to the orientation of the floor and its framing members with respect to the party wall since the party wall construction remained unchanged.

Possible differences due to sub-floor type (OSB or plywood) were also investigated when the joists were oriented perpendicular to the party wall. A comparison of Case 7 and 11 data indicates a small but systematic reduction in the sound insulation as a result of using plywood rather than OSB when the sub-floor is continuous under the party wall.

Cases 11 and 12 clearly show that the impact on the sound insulation caused by a rigid fire stop is not only dependent on the type of fire stop but also on the construction details of the floor/ceiling and wall assemblies to which it is connected.

This study has not evaluated the effects of all the variables that determine the apparent sound insulation although it has identified joist orientation and the type of decking as being important factors. Apparent sound insulation results as well as limiting sound insulation projections given in this report are only applicable to the case for which they were measured or estimated. Application of the results to significantly different constructions is inappropriate and may result in significant errors.

The following factors were not considered in the project but may affect the apparent sound insulation of a construction having a structural fire stop: joist depth and spacing, solid blocking or trimmer joists at the joint, bridging and strapping, stud spacing, and method of sole plate attachment to the supporting floor.

Flanking Transmission in this Floor/Wall System

Even without structural transmission of vibration through a fire stop, the sound insulation in a real building is normally affected by flanking transmission.

Sound from an airborne source causes vibration of all surfaces of the room, not just the partition separating the room from an adjoining room, and this increases the vibrational energy flowing into the nominal partition. Similarly, in the receiving room, vibrational energy transferred to the other surfaces of the room causes sound radiation into the room in addition to that from the nominally separating partition.

As discussed in detail in Appendix B, the flanking transmission involving these adjoining surfaces reduces the apparent sound transmission loss for the separating wall or floor, relative to that observed in standard laboratory testing. In the case of the Basic Party Wall in this study, the apparent sound insulation was reduced from a laboratory STC 55 to an apparent FSTC of 51.

Addition of a fire stop provides yet another path for vibration transmission between the rooms, and hence tends to worsen the sound insulation further. This study examines how a fire stop at the floor/wall junction can degrade the apparent sound insulation of the party wall (the nominal separation) by increasing structural transmission of vibration around that wall via the connected floor system (the flanking path).

For the cases studied, both with floor joists perpendicular and parallel to the party wall, it is clear that vibrational intensity is rapidly attenuated across the surface of the floor away from the floor/wall junction. This was demonstrated by mapping the sound energy radiated from the floor of the receiving room, using the acoustic intensity technique.

Figure 23

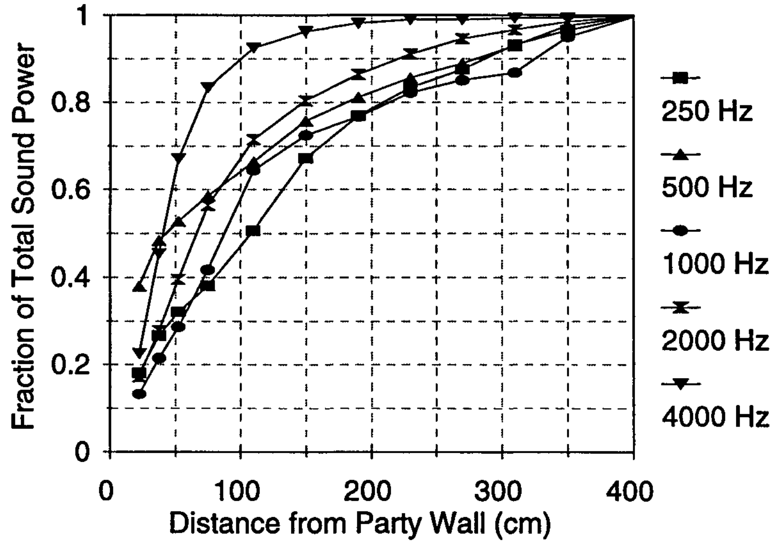

Figure 23 shows the fraction of the total sound power radiated within a given distance from the wall/floor junction, when the OSB sub floor is continuous under the party wall. For all frequency bands, the radiated sound power drops off rapidly; most is radiated from the narrow zone within 200 mm from the wall. A similar trend is exhibited when the joists are oriented parallel to the party (Case 12).

This rapid attenuation of the vibrational energy limits sound radiation from the floor surface, and means that for rooms wider than 200 cm (measured perpendicular to the party wall) the amount of energy radiated from the floor is independent of the width of the room. Similar behaviour was exhibited by the floor when covered by the underlay or when sheet steel or gypsum board was installed at the joint.

It should be pointed out that the results of this study are limited to cases where the receiving room is at least 200 cm wide, with the joists perpendicular to the party wall. The case with floor joists parallel to the party wall was shown to have more serious flanking, 4 FSTC points lower when the fire stop was formed by a continuous sub-floor.

Effect of the Fire Stops on Sound Transmission

Basically, the strength of the flanking transmission depends on how the fire stop transfers vibrational energy, and how effectively that vibrational energy is converted to radiated sound. The fire stop materials or techniques can be placed into groups depending on the method of vibrational energy transmission.

This grouping also forms a good basis for a rank ordering of their effect on sound insulation.

Group 0: No Fire Stop

Adding batt insulation to fill the wall's inter-stud cavities leaving a gap of 25 mm or less (Case 2), improves sound insulation provided by the party wall itself, while adding negligible structural transmission. Strictly speaking, this is not a fire stop, but it does provide the necessary fire resistance (as shown in the companion study of fire spread) and meets the prescriptive requirements for fire separations in the National Building Code.

This would appear to be an ideal solution for constructions having either load bearing or non-load bearing party walls, unless a continuous floor deck is required at the floor/wall junction for structural reasons such as shear bracing.

If the wall cavity space without insulation exceeds 25 mm (as in Reference A (Case 1) with the Basic Party Wall construction), then the fire resistance and direct sound transmission through the party wall are less satisfactory. This does not satisfy the prescriptive requirements of the National Building Code for fire control, but again there is no structural transmission of vibration across the floor/wall junction. Hence, from a noise control perspective, this is the appropriate reference case to gauge the effect of flanking via a fire stop.

Group 1: Transmits Negligible Forces

Group 1 Constructions do not transmit significant vibration either through bending moments or in-plane forces. These involve bridging the floor/wall junction with relatively "soft" materials, which compress in response to vibration, so they transfer negligible vibrational energy to the other side of the junction. One such case was tested:

- semi-rigid fibrous board, 25 mm thick rock fibre, 5 lb/ft^3 density, installed vertically to fill the space between the joist headers, and extending slightly into the inter-stud space above and below the floor (Case 5).

Presumably such fibrous board, rock or glass fibre, would only be used in double stud wall systems where there was insufficient cavity absorption to leave a space of 25 mm or less. The semi-rigid material would not transmit energy efficiently, unless it is excessively compressed. In the limit that the semi-rigid material becomes excessively compressed, the system may approach the performance exhibited when gypsum board was installed vertically at the joint. This extreme can easily be avoided by using material that readily compresses when squeezed, and is only slightly thicker than the gap to be filled.

Compressed batt absorption or over-filling the cavities in the stud party wall should have a similar effect, but was not tested in this series.

Group 2: Transmits only In-Plane Forces

Group 2 Constructions transmit appreciable vibration through in-plane forces, but not through bending moments. Cases tested in this study were:

- Gypsum board 25 mm thick, installed vertically between the joist headers (Cases 3 and 4), and
- Sheet steel 0.38 mm thick, installed horizontally under the sole plates at floor level (Case 6).

In-plane transmission is a second order effect since in-plane motion must be converted to bending motion for sound energy to be radiated. Thus the effect of fire stop constructions in this group tends not to be as severe as those that directly induce significant bending transmission.

The sheet steel and the gypsum board are installed differently, and have significantly different material properties:

- The sheet steel fire stop is fastened under both sets of sole plates, directly on top of the floor decking. It transmits vibrational force between the OSB layers for both compression and extension in the plane of the floor deck.
- The gypsum board panel extends above and below the floor/wall junction, essentially filling the gap between the joist headers and the wall studs. Unlike the sheet steel, this tends to

transmit only on the compressive cycle (since the material is only connected to one side of the wall) and the points of contact tend to be at the joist headers. It is likely that after building settling has occurred there might be considerable compression allowing the propagation of in-plane vibrations in both directions.

Presumably because of these differences, the changes in sound transmission due to these two constructions differed significantly.

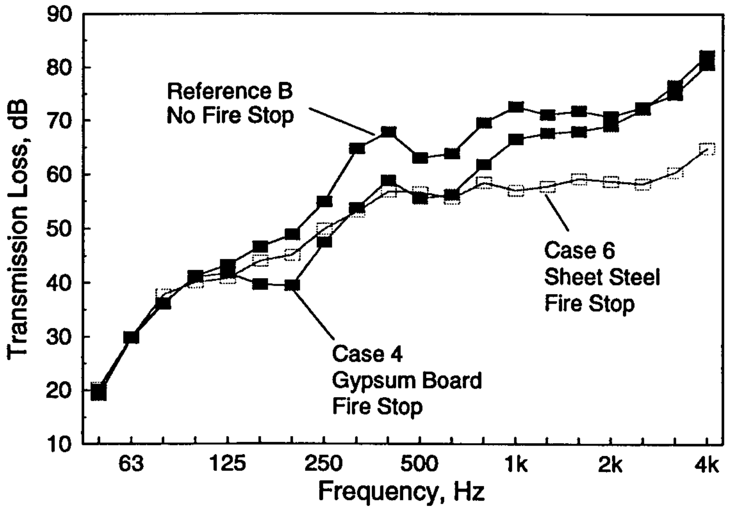

Figure 24

Describing the sound insulation performance with single number ratings rather than the transmission loss data introduces some loss of information. For example, Figure 24 shows the measured apparent airborne sound insulation with the sheet steel and the gypsum board fire stops, when the superior party wall was used. In both cases, the sound insulation was FSTC 57, despite the significantly different transmission loss trends. With the gypsum board, the FSTC rating is controlled by performance in the low-frequency range (125-400 Hz) whereas with the sheet steel installed, the FSTC is limited by higher frequencies (400-4000 Hz). The single number rating simplifies the comparison of elements or systems, but at the expense of informative detail.

Group 3: Transmits In-Plane and Bending Forces

Group 3 Constructions transmit structural vibration primarily by bending moments, and tend to give the strongest flanking effect.

Continuous OSB or plywood floor decking (run under the sole plates of the party wall) falls in this category.

Using a continuous surface as a fire stop is least satisfactory for noise control, because it permits significant transmission of bending waves, which couple efficiently to sound fields on both sides of the party wall.

A mathematical model for this type of joint has been developed and has been shown to predict the change in sound insulation. The model indicates that transmission through the fire stop is determined by the bending stiffness of the fire stop joint relative to bending stiffness of the plates (decking of the floor, and gypsum board of the walls).

Rank Ordering the Fire Stops

This study enabled rank ordering of the various fire stop constructions in terms of their impact on apparent sound insulation, as shown in Table 2:

Table 2: Rank ordering of the fire stop constructions. This is limited in application to the constructions shown in Cases 1—11 (i.e., those having a load bearing party wall).

Material	Group	Installation	Application
Batt absorption almost filling wall stud cavity	0	Fill wall cavity with insulation	Row and Apartment
No fire stop*	0	N/A	N/A
Semi-rigid fibrous insulation board	1	5 lb/ft^3 density, 25 mm thick, between headers	Row and Apartment
Gypsum Board	2	25 mm thick between headers	Row and Apartment
Sheet Steel	2	0.38 mm thick under wall plates, over floor deck	Row
Continuous OSB or plywood	3	Continuous sheets under wall plates	Row

* While the case with no fire stop is not an acceptable fire control technique, it is included here as a point of reference.

Assigning Limits to the Sound Insulation for the Fire Stops Considered

Ideally, the designer, consultant or engineer would predict the apparent sound insulation for the assembly and assess the correct fire stop detailing to use.

Unfortunately, this is not practical. Elements of the very complex system must be simplified and described in terms of readily available sound insulation parameters, such as STC. Calculations were performed to estimate (in terms of STC ratings) the effect of each type of fire stop on the apparent sound insulation, and hence the range of wall sound insulation for which each fire stop will have a negligible, or at least marginally negative, effect.

The projected results are strictly only applicable for the construction tested. There is insufficient data to make limiting sound insulation projections for the various fire stops in an arbitrary construction. However, based on Case 12 it is likely that constructions having a non-load bearing party wall will achieve a lower apparent sound insulation than the same floor and walls arranged such that the party wall is load bearing.

Based on Case 11, where the continuous OSB sub-floor was replaced by continuous plywood of the same nominal thickness, a very small but systematic reduction in apparent sound insulation may be expected. But, since the difference was 1 FSTC point or less (between all room pairs except AC), we shall consider OSB and plywood of the same nominal thickness to be interchangeable in the following discussions.

Group 0 & 1: Cavity Absorption and Semi-Rigid Insulation

For practical purposes, the apparent sound insulation is not limited by the fire stopping technique. Thus, this group of fire stops is suitable for all ranges of design sound insulation. Note that adding additional cavity absorption to the wall so that there is a 25 mm air space or less will be the best method.

Group 2: Sheet Steel or Gypsum Board

For this type of fire stop, flanking transmission was dominated by forces in the plane of the floor. In both cases the flanking paths involving the floor significantly reduce the apparent airborne sound insulation.

Regardless of the party wall construction, the apparent airborne sound insulation will not be better than FSTC 57 with these fire stops and this floor assembly. This group of fire stops was not tested in the construction having the non-load bearing party wall. It is quite possible that lower apparent sound insulation may be achieved if the party wall was non-load bearing (i.e., the joists were oriented parallel to the party wall).

Table 3: Estimated effect on apparent wall FSTC due to Group 2 fire stop (sheet steel or gypsum board installed at the wall/floor joint where the party wall is load bearing).

Fire Stop	Apparent FSTC not reduced	Apparent FSTC reduced by 1	Apparent FSTC reduced by 2	Apparent FSTC Limit
Sheet Steel 0.38 mm thick flat, no profile	< 47	48-53	54-55	57
Gypsum Board 25 mm thick	< 47	48-53	54-55	57
	Values above are apparent wall FSTC in absence of a fire stop. * see note below			

The Table indicates that the impact of fire stops is a function of the apparent sound insulation of the assembly without fire stopping: the greater the insulation, the greater the impact.

For example, if the 0.38 mm sheet steel were used in an assembly that achieved an apparent sound insulation of less than FSTC 47 without a fire stop, there would be no degradation. However, if the apparent sound insulation of the assembly were between 48 and 53 FSTC, then adding the fire stop will reduce the apparent sound insulation by 1 FSTC. And, if the apparent sound insulation of the assembly is 54 or 55 FSTC, then adding the fire stop will reduce the apparent sound insulation by 2 FSTC. Regardless of the party wall construction, the apparent sound insulation will not be better than FSTC 57 due to flanking paths involving the floor decking.

In the limit that bending transmission is low, in-plane transmission cannot be ignored. Although no tests were made to substantiate the concept, the in-plane forces should be reduced if horizontally-oriented 0.38 mm sheet steel were profiled with a 20x20 mm crease running parallel to the joint.

Group 3: Continuous OSB or Plywood Decking

For this type of fire stop, transmission by bending moments controlled the apparent airborne sound insulation.

The frequency range 400-4000 Hz was most affected. With the superior party wall, the limiting sound insulation was found to be FTSC 52, when the floor deck was a single layer of 15.9 mm thick OSB or plywood and the floor was supported by the party wall.

Table 4: Estimated effect on apparent wall FSTC due to Group 3 fire stop (continuous OSB and load bearing party wall).

Fire Stop	Apparent FSTC not reduced	Apparent FSTC reduced by 1	Apparent FSTC reduced by 2	Apparent FSTC Limit
15.9 mm OSB or plywood	< 42	43-48	49-50	52*
15.9 mm OSB with 15.9 mm underlay	< 50	51-56	57-58	60
	Values above are apparent wall FSTC in absence of a fire stop. ** see note below			

* The apparent sound insulation with a non-load bearing party wall may be as much as 4 points lower than that indicated in Table 4 which was for the floor/ceiling assembly supported by a load bearing party wall. There is insufficient data, however, to make projections for the case with a non-load bearing party wall.

** Note: In this study, a degradation of 4 in the STC was observed for the basic wall with the Case 1 floor construction having no fire stop. This is consistent with the generally accepted rule of thumb, that there will be a degradation of 1-5 in the STC for walls built as part of a building system with respect to a laboratory test of the nominally identical wall.

The actual degradation depends upon construction details such as joist orientation, bridging and strapping, floor decking, edge conditions of the wall. etc. This will have an impact on regulations specifying design criteria for assemblies required to meet a performance standard. Further work will be required to provide general design rules for wood frame constructions.

Case 8 (with an additional layer of 15.9 mm OSB added on top, except at the fire stop) reduced the flanking effect considerably. This is ascribed to the increased mass and stiffness of the floor deck. Similar improvements due to enhancing the floor deck would be expected with other fire stops, such as the gypsum board or sheet steel constructions tested as Cases 3, 4, and 6.

Other ways of increasing floor mass and stiffness, such as concrete topping on the floor surface, should provide comparable benefits in limiting the transmission of structural vibration.

CONCLUSIONS RE FLANKING IN GENERAL

The conclusions begin with some observations related to the effect of flanking transmission in general, followed by conclusions pertaining to the effect of fire stops with the wall/floor constructions examined here.

1. When the wall or floor nominally separating two rooms is connected to adjacent surfaces, flanking paths are introduced. These paths will reduce the apparent sound insulation provided by the partition. In this study, a party wall construction exhibited an apparent FSTC of only 52 when installed normally above a wood joist floor, although acoustic intensity measurement showed in situ performance consistent with its laboratory rating of STC 55. This reduction of apparent sound insulation is consistent with consultants' rule-of-thumb that performance in completed buildings is typically 3 to 5 dB worse than laboratory ratings.

2. The dominant flanking path around a supported floor assembly was from the floor decking to the surface of the wall below. The path from the wall above to the wall below the floor assembly was less important. Note that mounting the ceiling on resilient channels does not eliminate this path; this is apt to limit vertical sound insulation in wood-framed apartment buildings.

3. Suitable treatments for flanking between horizontally adjacent rooms around a party wall via a floor/ceiling assembly include improving the floor decking (with a heavy topping, floating floor or thick underlay). For rooms diagonally adjacent, installing the gypsum board ceiling of the lower room on resilient channels will reduce flanking transmission.

CONCLUSIONS RE FIRE STOPS

Fire stops installed at the intersection of walls and floors introduce structure-borne flanking paths, which further degrade the apparent sound insulation. A number of conclusions can be drawn regarding the effect of the fire stop constructions studied here:

1. The best choice seems to be adding batt insulation to the inter-stud cavities of the party wall so that *the width of the concealed wall space is less than 25 mm (NBCC 1995, 9.10.15.2.a) or the wall space is filled with insulation (NBCC 1990, 9.10.15.2.3).* Not only has this been shown to provide adequate fire control (as discussed in companion report of fire resistance), but also it provides improved noise control by lessening direct transmission through the party wall without introducing a path for structural transmission of vibration.

2. None of the fire stop constructions investigated seriously worsened vertical sound insulation (i.e.- the apparent sound insulation of the floor/ceiling system).

3. Filling the gap between joist headers with slightly compressed semi-rigid fibrous insulation was shown in the companion fire resistance study to meet the intent of the Code's fire control requirements, and should have negligible effect on sound transmission if the material is not excessively compressed during installation or through uneven building settling. The amount of compression can be minimized by ensuring the material completely covers the joist header, plus adjacent sole plate(s), and head plates(s). The density of the batt should be minimized.

4. Other fire stop constructions noticeably worsened the horizontal and diagonal sound transmission. The degradation of horizontal sound insulation (i.e. - the apparent sound insulation of the party wall between adjacent rooms) depends both on material properties and installation of the fire stop, and on the floor construction.

5. Unfortunately, this study has not evaluated the effects of all the variables that are likely to affect the apparent sound insulation. Mathematical modeling suggests and this study confirms that flanking transmission is more severe in the case where the party wall is non-load-bearing, and floor joists are oriented parallel to the party wall. The results reported here (for floor joists perpendicular to the party wall) should be clearly identified in any further publications as pertaining to this specific case. It should be noted that factors such as joist depth and spacing, as well as bridging and strapping, solid blocking or trimmer joists at the joint, are likely to be factors and therefore it would be judicious to verify performance with other floor systems before wide dissemination of the results from this work.

6. Many of the fire stop constructions studied did not reduce the apparent sound insulation below FSTC 50, but they did significantly degrade performance with a superior party wall. (Also note conclusion 5 above.)

7. The compressive stiffness of vertically oriented materials (filling the gap between floor headers) should be minimized. For example, semi-rigid batt materials would be preferable to gypsum board, or other materials having high compressive stiffness.

8. The fire stops studied in this project have been rank ordered in terms of their acoustical performance or suitability. They are listed in Table 2 in the Discussion above.

9. Continuous floor decking as a fire stop introduced the most serious vibration transmission between the two sides of the party wall. Flanking paths involving the floor surface controlled the apparent sound insulation. With a load bearing party wall (i.e., joists oriented perpendicular to the party wall), the limiting sound insulation was found to be FSTC 52. However, when the party wall is non-load bearing (i.e., joists oriented parallel to the party wall) the limiting sound insulation was found to be FSTC 48. Lower values can be expected with marginal party walls. For acoustical reasons, this type of fire stop should be avoided unless other requirements dictate its use.

   The mechanism for flanking transmission through a structural connection in the form of a fire stop is very complex and not fully understood. The degradation to the sound insulation has been shown to be a function of both the fire stop material and the building elements which it connects.

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Appendix A

Detailed Analysis

of

Cases 1 - 12

INTRODUCTION

This Appendix provides a detailed discussion of the possible flanking paths in a double leaf construction. Some of these paths are inherent in the supporting structure, others are only introduced with the insertion of a fire stop. Included is a discussion of repeatability and reproducibility to provide a basis for determining whether any observed changes may be considered significant.

A detailed analysis for each case is provided, with comparisons to the appropriate reference case. The magnitude of the impact for the various fire stop techniques are examined and related to physical properties of the fire stop. The flanking paths involved are identified, and in some cases it is possible to show that different paths are important at different frequencies.

POSSIBLE FLANKING PATHS

For double leaf constructions used in this study, Figure A1 identifies components potentially transmitting vibrational energy. The Figure also shows, as an example, the horizontal transmission paths between the upper two rooms A and B.

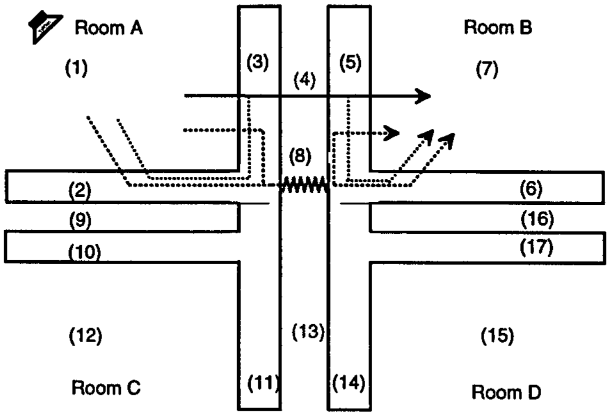


Figure A1: Direct transmission and flanking paths in the horizontal direction. The direct path is shown by the solid line while flanking paths are shown by the dashed lines.

Sub-system Numbers

1. Source Room A
2. Floor decking (15.9 mm OSB)
3. Party wall leaf (15.9 mm Type X gypsum board)
4. Party wall cavity (nominal depth 205 mm, having one or two layers of batt insulation)
5. Party wall leaf (15.9 mm Type X gypsum board)
6. Floor decking (15.9 mm OSB)
7. Receiving Room B
8. Fire Stop
9. Floor cavity (nominal depth 254 mm having two layers of 89 mm batt insulation)
10. Ceiling Room C: (two layers 15.9 mm Type X gypsum board on wood furring)
11. Party wall leaf (15.9 mm Type X gypsum board)
12. Receiving Room C

13. Party wall cavity (nominal depth 205 mm, having one or two layers of batt insulation
14. Party wall leaf (15.9 mm Type X gypsum board)
15. Receiving Room D
16. Floor cavity (nominal depth 254 mm having two layers of 89 mm batt insulation)
17. Ceiling Room D: (two layers 12.7 mm Type X gypsum on wood furring and resilient channels).

Transmission Paths Rooms A to B

It can be seen that a series of flanking paths exist. Besides the direct path, three flanking paths are present solely because the leaves are supported by a floor system. When there is a structural connection, in the form of a fire stop that bridges the wall and floor elements on both sides of the nominal space between the joist headers, a further four flanking paths are introduced:

Direct

- 1-3-4-5-7

Flanking Due to the Floor

- 1-2-3-4-5-7
- 1-2-3-4-5-6-7
- 1-3-4-5-6-7

Flanking Due to the Fire Stop

- 1-2-8-6-7
- 1-2-8-5-7
- 1-3-8-5-7
- 1-3-8-6-7

Vertical Transmission Paths Rooms A to C & B to D

In the case of vertical transmission between rooms A and C, it can be seen that in addition to the direct path there are four flanking paths affecting the airborne sound insulation and two paths affecting the impact sound insulation.

Direct

- 1-2-9-10-12

Flanking Due to Supporting Structure

- 1-3-11-12
- 1-2-11-12
- 1-3-10-12 (path not important for B-D as resilient channels remove this path)

- 1-2-10-12 (path not important for B-D as resilient channels remove this path)
- Others of less importance involving the cavity (e.g., 1-3-2-9-10-12, etc.)

Transmission Paths Room C to D

There are fewer horizontal transmission paths between the lower rooms C and D. Besides the direct path, there is one other path, because the ceiling is connected directly to the joists in room C. Resilient channels connecting the ceiling to the joists in room D provide a vibration break thus any paths involving the ceiling of room D are of lesser importance and are ignored for the purpose of this study. When a structural connection is made, in the form of a fire stop bridging the space between the joist headers, then two additional flanking paths are introduced.

Direct

- 12-11-13-14-15

Flanking due to the Ceiling

- 12-10-11-13-14-15

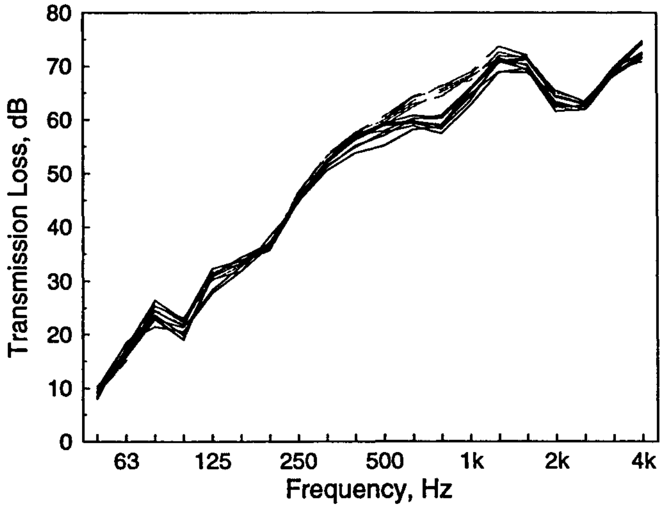
Flanking Due to the Fire Stop

- 12-10-8-14-15
- 12-11-8-14-15

These flanking paths, due to the rather indirect path through the joists to the fire stop and then back through the joists, do not transmit much energy and hence do not contribute substantially to the transmission loss between rooms C and D. For this reason, the data between rooms C and D are not included in this report. This is borne out by Figure A2 which shows the range of apparent airborne sound transmission loss found for all measurement configurations used in this study. The dashed curves are for a set of measurements with the party wall connected to the side walls with metal straps. This connection increased the damping of the party wall and resulted in an increased transmission loss around 1000 Hz, but did not result in any change in the FSTC.

Once the nominally separating assembly is connected to an element that is contained in either of the rooms being separated, there will be at least one flanking path introduced.

Figure A2: Apparent airborne sound transmission loss between rooms C and D for all measurement configurations.



DETAILS OF TEST METHODS

In this report, the system performance is assessed by using the two standard test methods that are referenced by the National Building Code. The method of acoustic intensity is also used as it enables the measurement of the sound power of each surface and can be related to the single number ratings used by the Code. The test methods are now discussed.

* Airborne Sound Insulation (ASTM E336[1]): This test method provides airborne sound transmission loss information for the individual third octave frequencies. In accordance with ASTM E336 and E413, the Field Sound Transmission Class, FSTC, descriptor is obtained to rate the airborne sound insulation. E336 states that without flanking surfaces masked-off, the reported FSTC represents the Minimum Field Sound Transmission Class for the nominal separation. The E336 test differs from the "laboratory" E90 test in that the E90 test does not allow there to be any significant flanking transmission. Thus, in the limit that there is no flanking transmission in a field construction, the FSTC obtained using E336 should equal the STC obtained using E90 for the nominally identical floor or wall. The National Building Code of Canada (NBCC 9.11.1 and .2) and all provincial codes require a minimum airborne sound insulation of STC 50 for a party wall or party floor. Since in this report we wish to characterize the performance of the complete system rather than that of the individual elements, surfaces involving flanking paths have not been covered or masked-off unless otherwise stated. Following ASTM E90 and E336, the

results are normalized to the area of the partition under study (party wall or floor) to provide a convenient means of comparison and called apparent airborne sound insulation to emphasize the point that they include all flanking paths in the structure. The transmission loss between diagonally placed rooms is normalized to 10m^2 since the partition area is not defined.

* Impact Sound Insulation (ASTM E1007[2]): In accordance with ASTM E1007 and E989, the Field Impact Insulation Class, FIIC, descriptor is obtained to rate the impact insulation of the floor and its supporting structure. E1007 recognizes that the supporting structure of the floor will constitute a flanking path. In the limit that there is no flanking transmission, the FIIC obtained using E1007 should equal the IIC obtained under the laboratory conditions of E492 for the identical floor. Currently, the National Building Code does not require a minimum impact sound insulation. However, the Commentary on Part 9 of the 1990 NBCC[3] recommends that the bare floor assembly (without carpet) achieve an IIC 55 or better. The FIIC is defined for floor systems, however measurements are reported here for horizontally adjacent and diagonally adjacent rooms, normalized to the area of the separating partition, or 10 m^2 in the case of diagonal measurements. To indicate that these are not standard measurements they are referred to as apparent impact sound insulation.

* Acoustic Intensity: This test method (ANSI S12.12)[4], unlike the previous two, allows for measurement of sound power radiated from each individual surface in situ. The acoustic intensity is measured over a specific surface, usually in third octaves. From the data it is possible to compare the sound energy radiated from each room surface in situ. For the separating wall or floor, transmission loss data obtained from the intensity technique can be compared directly to results from the standard airborne test (E336) and can also be reduced to an FSTC rating using ASTM E413. Unfortunately, the intensity method has not been standardized for application in rating the sound insulation of building elements. The ISO organization has formed a committee for such a purpose.

MEASUREMENT DETAILS

Using custom hardware and software developed at NRC, the measurements are performed completely under computer control, from calibration and microphone probe positioning to report generation. This provides a high degree of precision and repeatability.

For conventional tests with airborne or impact sources, the sound pressure levels are sampled at a minimum of 6 positions in each room. The robot systems in each room position the microphones (B&K 4134 Type 12.5 mm precision condenser microphones with random incidence response), and signals are measured using a Norsonics 830 precision real-time analyser. For airborne source, the computer directs noise signals to the loudspeakers in each room in turn to measure noise reduction between each pair of rooms and the rate of sound decay in each room. A sequence of 12 complete measurements (horizontal, vertical and diagonal pairs of rooms, each for 6 microphone positions in each room) was performed. Data presented in the report for a given room pair (e.g. - A-B) are the average of two measurements, one with each room as the source. Impact measurements were made using a standard tapping machine (conforming to ASTM E1007 and ISO-140-VII) in either room A or B, and measuring the resulting sound pressure levels at all microphone positions in each of the other three rooms.

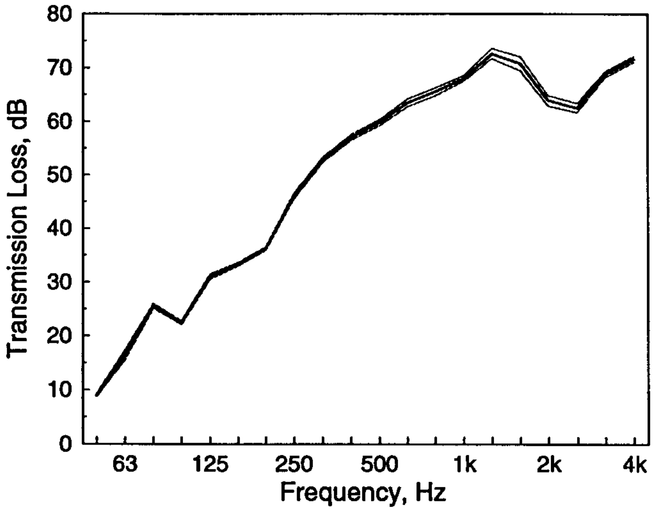
Intensity measurements were made using a B&K 3519 intensity probe fitted with 12.5 mm B&K Type 4181 precision matched condenser microphones. With a 12 mm microphone separation, this probe was able to make measurements from 20 Hz to 5000 Hz with less than 1 dB error. The output of the probe was measured using a Norsonics 830 precision real-time analyser. Measurements were made 150 mm from the surface using the robot system in each room to position the microphones. Walls were measured at 130 locations equally spaced on 10 equally spaced vertical columns. Floors were measured at 132 locations arranged on 11 equally spaced lines perpendicular to the party wall. The distance between measurement locations increased from 150 mm for the first 600 mm from the party wall to 400 mm so that the sampling density was highest close to the wall/floor junction where the structural flanking was expected to occur.

MEASUREMENT REPEATABILITY AND SIGNIFICANT DIFFERENCE

Acoustical measurement in rooms involves sampling non-uniform sound fields and as such has associated with it a degree of uncertainty. By correctly performing a number of measurements to determine a spatial average, the uncertainties can be reduced. Also, by taking the mean of the two directions in the case of airborne transmission, such uncertainties can be further reduced. Upper and lower limits can then be assigned to the probable error in the measurement. These precision limits can be described in terms of the concepts of *repeatability* and *reproducibility.*

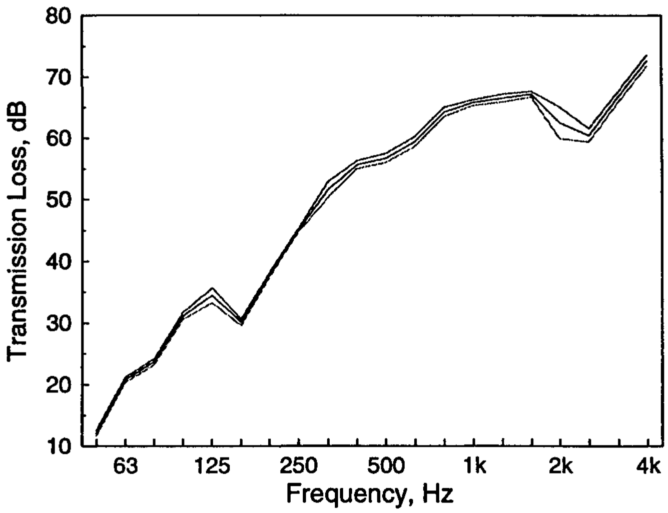
Repeatability is defined as the 95% confidence levels for repeated measurements obtained for the same specimen. Figure A3 shows the mean and 95% confidence limits for measurements on the same specimen repeated over several months. The range in values is typically less than 1 dB in most of the third octave bands. The single number rating, FSTC, did not change more than 1 point.

Figure A3: Repeated apparent airborne sound insulation measurements for the same specimen showing the high degree of repeatability associated with the measurement system and procedure.



Reproducibility is defined as the closeness of agreement between sets of measured data obtained for the nominally identical specimen that has been constructed at different times. The measurement reproducibility naturally has two components. The first is the measurement repeatability and the second the uncertainty due to construction practice and materials, etc. Figure A4 shows the mean and 95% confidence limits for nominally the same specimen constructed three times. The deviation from the mean is less than 2 dB in most of the third octave bands and the single number rating, FSTC, had a range of 2 points.

Figure A4: Mean and 95% confidence limits for the measured apparent airborne sound insulation of nominally identical party wall specimens having been removed and then reconstructed.



Variability expected among measured results for nominally equivalent specimens in this study should be between the extremes of reproducibility and repeatability, because all measurements were made with a consistent test method using the same facility and equipment.

Both the FSTC and FIIC results were particularly sensitive to sound transmission in the 125 and 160 Hz bands, and small changes in transmission for these bands frequently altered the single number rating.

Allowing for these factors, a difference of 1 between FSTC (or FIIC) ratings for two specimens should not be considered significant. A change of 2 indicates a possible difference, while 3 or more indicates an unquestioned real difference. In the case of a 2 FSTC (or FIIC) change, the third octave band data were examined in order to make a determination.

This interpretation is similar to the criteria used in the report of the project *Sound Transmission Through Gypsum Board Walls*[5].

MEASURED DATA

In this section, the measures of apparent airborne and apparent impact sound insulation are presented in terms of the single number ratings FSTC and FIIC for the assembly subject to the various fire stopping details.

Case 1

Reference A, No Fire Stopping

The Reference A was constructed without any fire stop present as shown in Figure A5. The measured apparent airborne and apparent impact sound insulation data are summarized in Table A1 and Table A2. The airborne and impact data for the Reference A become the point of reference to which other specimens will be compared to assess the impact of the fire stop technique.

Figure A5: Vertical section through the Reference A floor and party wall.

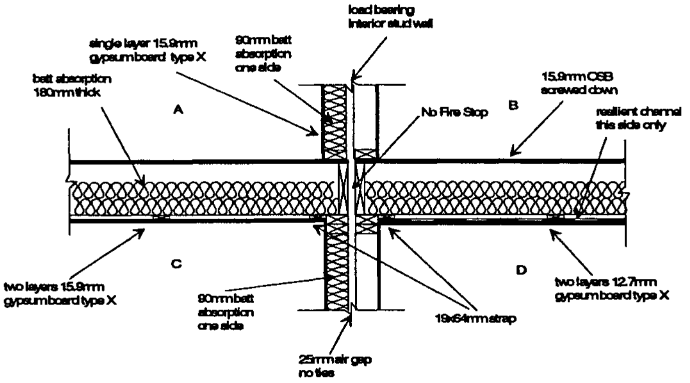


Table A1: Measured apparent airborne sound insulation measured in accordance with ASTM E336 and expressed in terms of the single number rating FSTC.

Apparent airborne sound insulation		Room Pairs	Case 1 (FSTC)
Apartment	Horizontal	A-B	51
	Vertical	B-D	56
	Diagonal	A-D	71
Row	Vertical	A-C	45
	Diagonal	B-C	69

Table A2: Measured apparent impact sound insulation measured in accordance with ASTM E1007 and expressed in terms of the single number rating FIIC.

Apparent impact sound insulation		Room Pairs	Case 1 (FIIC)
Apartment	Horizontal	A-B	61
	Vertical	B-D	51
	Diagonal	A-D	61
Row	Vertical	A-C	39
	Diagonal	B-C	62

Comparing the sound insulation for room pairs AC and BD, it is evident that there can be a significant benefit to resiliently mounting the finished gypsum board surface of the ceiling when structure-borne paths control the sound insulation.

Under the "no-flanking" conditions of the ASTM E90 test method, the party wall between rooms A and B should achieve STC 55. However, when the wall is connected to other elements (i.e., the floor), flanking paths will be introduced and the apparent sound insulation can be degraded. The magnitude of the degradation is a complex function involving the mass, type of connection, spacing of framing, etc.

Technical Discussion

Appendix B, "Reference A-B Sound Insulation with Basic Party Wall Construction", discusses the measured sound insulation between rooms A and B for the Reference A wall and compares it to that measured for the nominally identical wall under the ASTM E90 conditions of "no-flanking".

Appendix C, "Analysis of Flanking Transmission Between Rooms B and D", discusses the sound insulation between rooms B and D and examines the dominant flanking paths and the effect of beams (joist headers, and sole plates) on the structure-borne flanking transmission.

Appendix D, "Determination of Flanking Paths for Case 7 A-B Sound Insulation with Basic Party Wall Construction", discusses the measurement procedures and analysis used to determine the flanking paths for the case of a continuous OSB shear membrane used as a fire stop.

Summary

The Reference A has shown that flanking paths associated with the supporting structure(s) can impair the sound insulation of the nominally separating element. The party wall experienced a 2 FSTC point degradation relative to the laboratory test case. This is thought to be due to the interaction with the floor system.

Case 2

Filled Wall Cavity

Figure A6 shows the specimen construction where another layer of 90 mm thick cavity absorption was added so that the width of the concealed wall space is less than 25 mm (NBCC 1995, 9.10.15.2.a) and an explicit fire stop is not required.

Figure A6: Vertical section through the Case 2 floor and party wall showing the additional layer of 90 mm batt cavity absorption in the party wall.

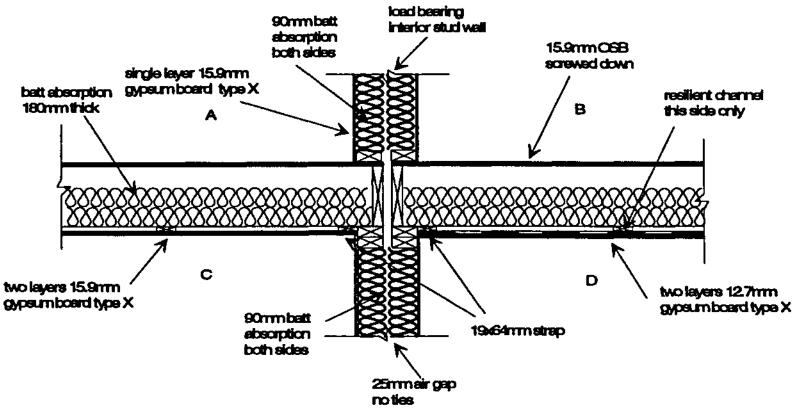


Table A3: Case 2 Apparent airborne sound insulation measured in accordance with ASTM E336 and expressed in terms of the single number rating FSTC.

Apparent airborne sound insulation		Room Pairs	Case: 2 with basic wall (FSTC)	Change re Reference A
Apartment	Horiz.	A-B	56	+5
	Vert.	B-D	56	0
	Diag.	A-D	75	+1

Row	Vert.	A-C	46	+1
	Diag.	B-C	73	+4

Table A4: Case 2 Apparent impact sound insulation measured in accordance with ASTM E1007 and expressed in terms of the single number rating FIIC.

Apparent impact sound insulation		Room Pairs	Case: 2 with basic wall (FIIC)	Change re Reference A
Apartment	Horiz.	A-B	64	+ 3
	Vert.	B-D	50	-1
	Diag.	A-D	71	+10

Row	Vert.	A-C	39	0
	Diag.	B-C	70	+8

The additional layer of absorption increased the apparent airborne sound insulation between the horizontally adjacent rooms as shown in Table A3. The sound insulation between rooms A and B increased 5 FSTC points to give FSTC 56. The nominally identical party wall under the laboratory conditions of an ASTM E90 test would give STC 57. The measured apparent impact and apparent airborne sound insulation data are shown in Table A4.

Discussion

The additional absorption in the party wall cavities did not appreciably change the sound insulation performance in the vertical directions. This was expected as the flanking paths between B-D are structural ones whose path is primarily in the gypsum board cladding of the load bearing party wall (see Appendix C). The sound insulation between rooms A and C is determined solely by the floor/ceiling assembly and is not affected by the additional wall cavity absorption.

However, the additional cavity absorption in the party wall did improve the sound insulation between room pairs A-B, and those on the diagonal. The apparent airborne sound insulation between A and B increased by 5 FSTC points. Examining Figure A1 which shows the propagation paths between rooms A and B, it can be seen that since there are is no fire stop, all the flanking paths and the direct path must pass through the wall cavity. So any treatment involving the cavity will improve the sound insulation for all paths. It is for this reason that the additional cavity absorption is so effective.

The physical methods of energy transport through such a system are complex with several methods of energy transport — resonant, non-resonant and combinations of the two. In this case the improvement appears to be due to the increased cavity damping offered by the additional absorption[6]. This increased cavity damping has the effect of reducing the amount of energy that can be transported across the wall assembly.

Summary

The data suggest that, acoustically, adding additional cavity absorption so that the width of the concealed wall space is less than 25 mm (NBCC 1995, 9.10.15.2.a) or the wall space is completely filled with insulation (NBCC 1990, 9.10.15.2.(3)) is an excellent method to satisfy the intent of the Code for fire stopping. The method will, at worst, be neutral to the sound insulation (given that the material is not in compression between the gypsum board surfaces).

It should be noted that the difference in sound insulation performance for a double wood stud wall having a completely filled cavity (nominally 205 mm of material) and the same wall having 180 mm (two layers of 90 mm) batt material and a nominal 25 mm air space should be minimal. For practical purposes the two should be considered to be equal.

Case 3

25 mm Gypsum Board in Compression at the Joint (Apartment Construction)

Figure A7 shows the specimen construction. The gypsum board fire stop at the joint was formed from two sheets of 12.7 mm thick Type X gypsum board, nominally 600 mm wide, placed in the nominal 25 mm space between the joist headers.

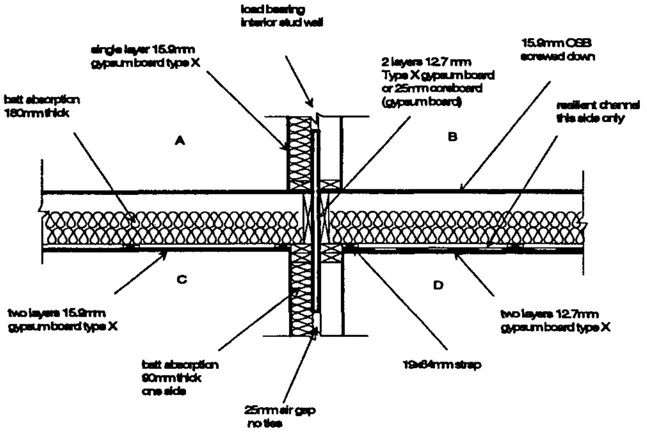


Figure A7: Section through the floor and party wall of the Case 3 assembly showing the vertically installed gypsum board fire stop.

Table A5 and Table A6 show the measured apparent airborne and apparent impact sound insulation. In terms of single number ratings, the physical coupling caused by the fire stop, has caused no change in the apparent airborne sound insulation between the room pair A-B. There is a significant degradation (5 FSTC points) in the apparent airborne sound insulation between the diagonal room pairs A-D and B-C.

Table A5: Case 3 apparent airborne sound insulation measured in accordance with ASTM E336 and expressed in terms of the single number rating FSTC.

Apparent airborne sound insulation		Room Pairs	Case: 3 with basic wall (FSTC)	Change re Reference A
Apartment	Horizontal	A-B	51	0
	Vertical	B-D	57	+1
	Diagonal	A-D	66	-5
Row	Vertical	A-C	45	0
	Diagonal	B-C	64	-5

Table A6: Case 3 Apparent impact sound insulation measured in accordance with ASTM E1007 and expressed in terms of the single number rating FIIC.

Apparent impact sound insulation		Room Pairs	Case: 3 with basic wall (FIIC)	Change re Reference A
Apartment	Horizontal	A-B	55	-6
	Vertical	B-D	52	+1
	Diagonal	A-D	63	+2
Row	Vertical	A-C	38	-1
	Diagonal	B-C	59	-3

Discussion

The vertical sound insulation between room pairs A-C and B-D was virtually unaffected by the presence of this type of fire stop. This is to be expected as the flanking paths between the vertical room pairs is structure-borne in the gypsum board cladding of the party wall via the floor joists.

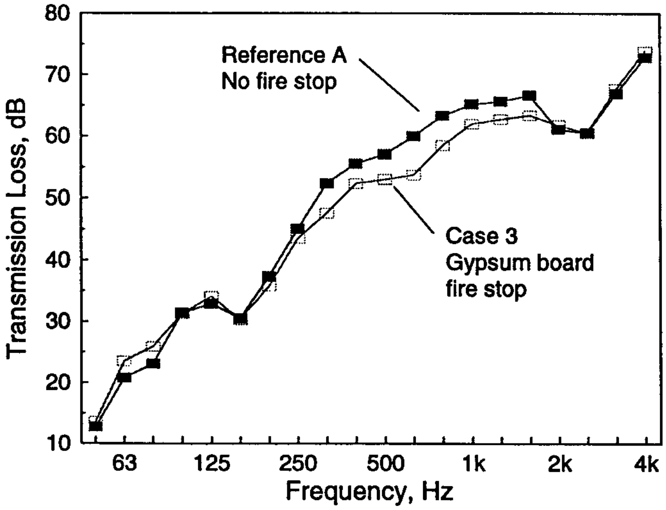
The diagonal sound insulation was affected by the increased physical coupling. Whereas before the only path was airborne through the wall cavities, there is now a structure-borne path via the fire stop. This path has caused a 5 FSTC reduction in the apparent airborne sound insulation for rooms on the diagonal. Despite this reduction the sound insulation is still well in excess of FSTC 60.

The change in apparent impact sound insulation between rooms A and B demonstrates that the gypsum board fire stop between the joist headers introduces a strong structural connection allowing increased energy flow between the upper two rooms.

Technical Discussion

The gypsum board fire stop forms a physical connection between dwellings on either side of the party wall. Figure A1 shows the paths that the sound energy may take when traveling between the rooms A and B. It can be seen that the gypsum board fire stop introduces four additional flanking paths (1-2-8-6-7, 1-2-8-5-7, 1-3-8-5-7, 1-3-8-6-7), all of which are structure-borne and do not involve the party wall cavity.

Figure A8: Comparison of the apparent airborne sound insulation for room pairs A-B with and without the gypsum board fire stop, Case 3 and Reference A, Case 1, respectively.



Although the apparent airborne sound insulation between rooms A and B has not changed, Figure A8 shows that there was significant degradation to the apparent airborne sound insulation in the frequency range 200-1600 Hz due to the structural connection. However, this did not result in an FSTC reduction.

A detailed discussion of the flanking paths will be given in the technical discussion of Case 4.

Summary

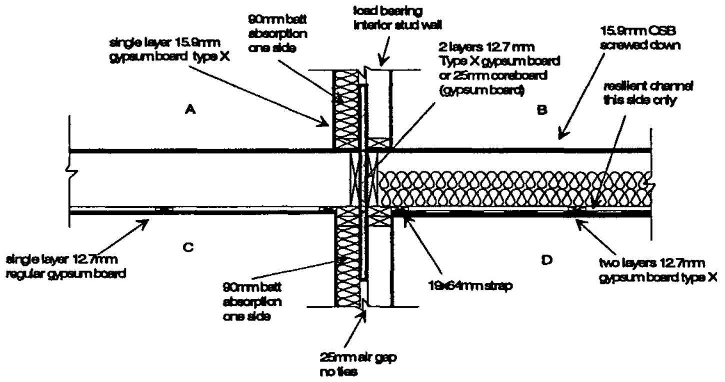
Solid fire stops filling the nominal 25 mm space between the joist headers create a structural connection that introduces four flanking paths. Three of which involve wall surfaces and one is completely independent of the wall. For the basic wall, the impact on the apparent sound insulation was minimal.

Case 4:

25 mm Gypsum Board in Compression at the Joint (Row Construction)

Figure A9 shows the specimen construction. The fire stop was the same as Case 3 and was formed from two sheets of 12.7 mm thick type X gypsum board, nominally 600 mm wide, placed in the nominal 25 mm space between the joist headers.

Figure A9: Section through the floor and party wall of the Case 4 assembly showing the vertically installed gypsum board fire stop.



This construction was intended to illustrate the effect, if any, caused by changing the type of floor/ceiling construction. The floor/ceiling assembly separating rooms A and C has been changed to one that might be representative of row-type housing. The cavity absorption has been removed from floor/ceiling assembly and the gypsum board of the ceiling has also been changed to a single layer of 12.7 mm regular. The construction of the floor/ceiling assembly separating rooms B and D remains unchanged (i.e., that of apartment or stacked construction).

Basic Wall Construction

Table A7 and Table A8 show the measured sound insulation for this construction.

Table A7: Case 4 apparent airborne sound insulation measured in accordance with ASTM E336 and expressed in terms of the single number rating FSTC.

Apparent airborne sound insulation		Room Pairs	Case: 4 with basic wall (FSTC)	Change re Reference B with basic wall	Change re Case 3 with basic wall
Apartment	Horiz.	A-B	50	0	-1
	Vert.	B-D	57	+2	0
	Diag.	A-D	65	-5	-1
Row	Vert.	A-C	n/a	n/a	n/a
	Diag.	B-C	61	-4	-3

Table A8: Case 4 Apparent impact sound insulation measured in accordance with ASTM E1007 and expressed in terms of the single number rating FIIC.

Apparent impact sound insulation		Room Pairs	Case: 4 with basic wall (FIIC)	Change re Reference B with basic wall	Change re Case 3 with basic wall
Apartment	Horiz.	A-B	52	-9	-3
	Vert.	B-D	51	+1	-1
	Diag.	A-D	57	n/a	-6
Row	Vert.	A-C	n/a	n/a	n/a
	Diag.	B-C	60	n/a	+1

Comparing the measured sound insulation with those of Case 3, it can be seen that changing (degrading) the floor/ceiling assembly between rooms A-C caused, in general, only a slight degradation of the apparent sound insulation for all room combinations.

The sound insulation between rooms B-D was virtually unaffected by the change to the floor ceiling assembly between rooms A-C. This is to be expected as the flanking paths between rooms B-D are structure-borne in the gypsum board cladding of the party wall. The largest change, between rooms B-C, is caused by replacing the two layers of gypsum board with one lighter layer.

It is also interesting to note that the horizontal impact sound insulation between rooms A and B has dropped from FIIC 61 for the Reference B to FIIC 52. While the supplement to the Code only suggests that a floor separation have an IIC 55 or better, it seems that in cases of strong horizontal connections there may be merit to applying this criterion to horizontally separated rooms. If this were done, then the assembly would not meet the criterion of IIC 55.

Superior Wall Construction

Table A9 and Table A10 show the measured sound insulation for this construction when the basic party wall separating rooms A and B was removed and replaced with the superior party wall to determine the flanking limit for this fire stop detail.

Table A9: Case 4 with superior wall, apparent airborne sound insulation measured in accordance with ASTM E336 and expressed in terms of the single number rating FSTC.

Apparent airborne sound insulation		Room Pairs	Case: 4 with superior wall (FSTC)	Change re Reference B with superior wall
Apartment	Horiz.	A-B	57	-9
	Vert.	B-D	n/a	n/a
	Diag.	A-D	n/a	n/a
Row	Vert.	A-C	n/a	n/a
	Diag.	B-C	64	-6

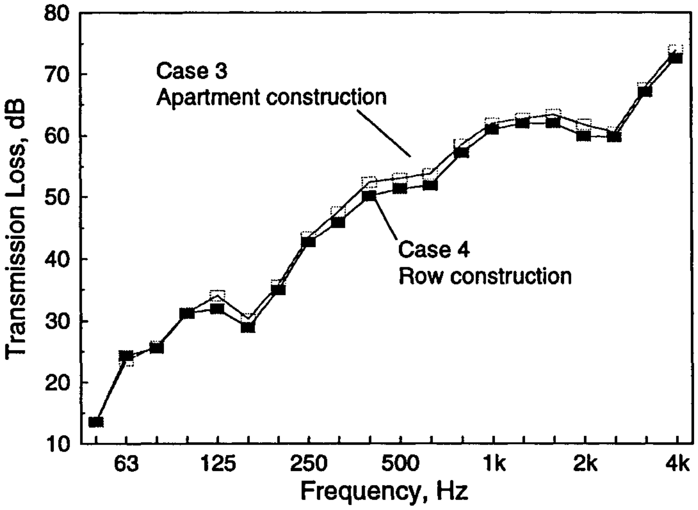
Table A10: Case 4 with superior wall, apparent impact sound insulation measured in accordance with ASTM E1007 and expressed in terms of the single number rating FIIC.

Apparent impact sound insulation		Room Pairs	Case: 4 with superior wall (FIIC)	Change re Reference B with superior wall
Apartment	Horiz.	A-B	57	-9
	Vert.	B-D	n/a	n/a
	Diag.	A-D	n/a	n/a

Row	Vert.	A-C	n/a	n/a
	Diag.	B-C	n/a	n/a

With the superior party wall the apparent sound insulation between rooms A-B was FSTC 57 which is a significant improvement over the FSTC 50 with the basic wall, but is significantly less than the potential for this wall construction. The change in sound insulation suggests that the direct path and/or flanking paths involving the party wall were limiting the sound insulation when the basic wall was installed.

Figure A10: Comparison between measured A-B apparent airborne sound insulation for the gypsum board fire stopping installed in apartment (Case 3, FSTC 51) and row (Case 4, FSTC 50) construction.



Technical Discussion

Figure A10 shows that there was a small, but appreciable, drop in the sound insulation between upper room pair, A-B, as a result of the construction change to the floor/ceiling assembly in room A. The apparent airborne sound insulation was degraded by 1 FSTC point giving an apparent airborne sound insulation of FSTC 50 between rooms A-B. Without further investigation it can not be determined if the change in the A-B sound insulation was due to removing the cavity absorption, or using a lighter gypsum board on the ceiling, or both. Removing the cavity absorption will make sound transmission across the floor slightly more efficient as the joist cavities will act to channel energy away from the floor/party wall joint without appreciable attenuation with distance. Also, reducing the mass of the ceiling will make the floor more mobile and the floor assembly will have a greater displacement for the same applied force at the joint.

The consequence of removing the cavity absorption and replacing the two layers of gypsum board with a single layer of a lighter variety is that previously unimportant flanking paths become important and a degradation has occurred.

Measurements of the sound intensity radiated from the receiving room floor while masking the receiving room wall provide a measure of the sound insulation provided by all paths involving the receiving room floor. Figure A11 compares the sound insulation offered by all the paths involving the receiving room floor (1-2-3-4-5-6-7, 1-3-4-5-6-7, 1-2-8-6-7, and 1-3-8-6-7) when the basic and superior party walls were installed. From the Figure, it is evident that flanking paths involving the floor were not significantly affected by the quite substantial change in the wall. Of the four flanking paths, the only path which does not involve a party wall leaf (element 3 or 5) is the path 1-2-8-6-7. Since there is little improvement due to the superior wall, the dominant flanking path cannot involve either one of the party wall leaves. The dominant flanking path for the receiving room floor surface must then be 1-2-8-6-7.

Figure A11: Sound insulation for flanking paths involving the receiving room floor for Case 4 (gypsum board installed vertically at the joint, row construction) with the basic and superior party walls.

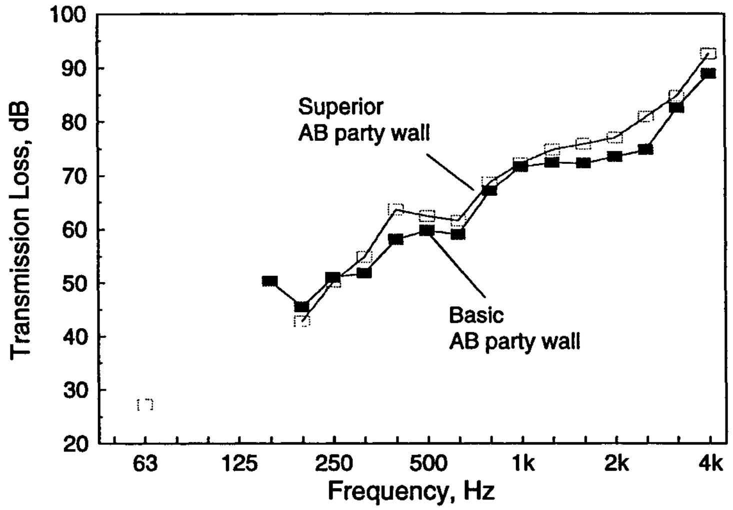
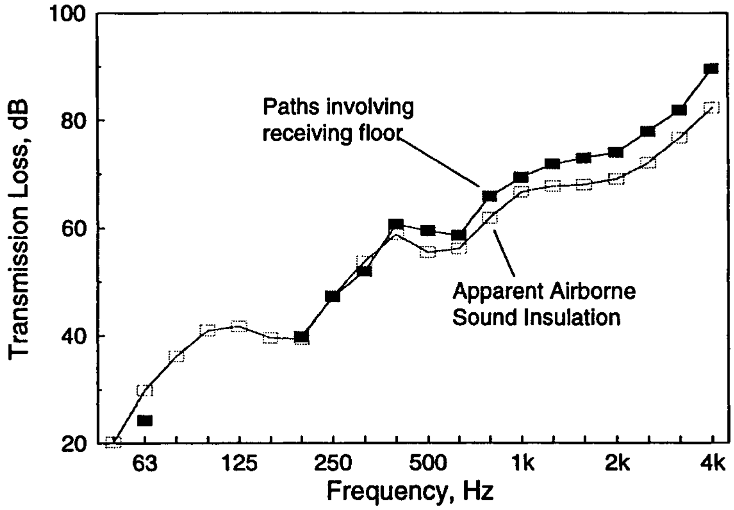


Figure A12 shows that the apparent airborne sound insulation is very close to the sound insulation offered by the flanking paths involving the receiving room floor, when the superior wall is installed.

Figure A12: Comparison of the apparent sound insulation and the sound insulation of flanking paths involving the receiving room floor when the superior party wall construction was used.



Consequently, it is unreasonable to expect that the sound insulation of this assembly to be much better than FSTC 57 due to the flanking path involving the floor decking (1-2-8-6-7). An improved floor surface in the form of a concrete topping, floating floor, or even an underlay should improve both the apparent sound insulation and the apparent impact sound insulation of this assembly.

Fire stops formed from gypsum board in compression at the joint provide significant physical coupling and may cause lightweight wall and floor assemblies to be degraded.

Summary

Data from Cases 3 and 4 would suggest that the impact of structural fire stops will be more severe in row housing as a result of the lighter weight and uninsulated floor/ceiling assemblies. A one or two FSTC point difference may be experienced for assemblies having floors at the same level.

Cases 3 and 4 have considered the case where the floors on either side of the party wall are at the same height, however, in terraced row housing there may be split-level floors where the gypsum board is in compression between the joist header on one side and the stud work of the other. The worst location for the fire stop is at the mid-point of the party wall on the other side. The maximum displacement of a plate or beam for a given force is achieved when the force is applied at the mid-point.

Thus, the impact of vertically oriented fire stops is likely to be much greater when the floors are at different levels. In light of this, consideration should be given to a technique that does not form a strong physical bridge.

Case 5

Semi-Rigid Batt Material in Compression at the Joint

Figure A13 shows the specimen construction. The 25 mm thick semi-rigid batt material (5 lb/ft^3 rock fibre) was installed in the nominal 25 mm space between the joist headers. The material was oriented such that the nominal 600 mm dimension was placed vertically; the same as the gypsum board of Cases 3 and 4.

Figure A13: Section through the floor and party wall of the Case 5 assembly showing the 25 mm semi-rigid batt material installed vertically at the joint.

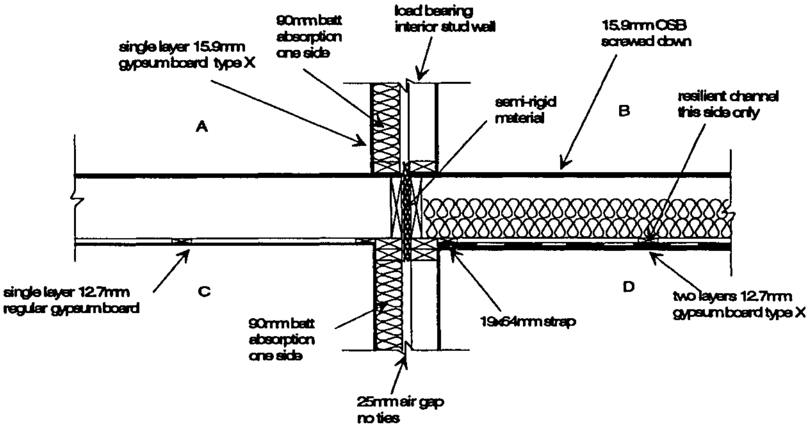


Table A11: Case 5 Apparent airborne sound insulation measured in accordance with ASTM E336 and expressed in terms of the single number rating FSTC.

Apparent airborne sound insulation		Room Pairs	Case: 5 with basic wall (FSTC)	Change re Reference B with basic wall
Apartment	Horiz.	A-B	52	+2
	Vert.	B-D	57	+2
	Diag.	A-D	70	0

Row	Vert.	A-C	40	0
	Diag.	B-C	66	0

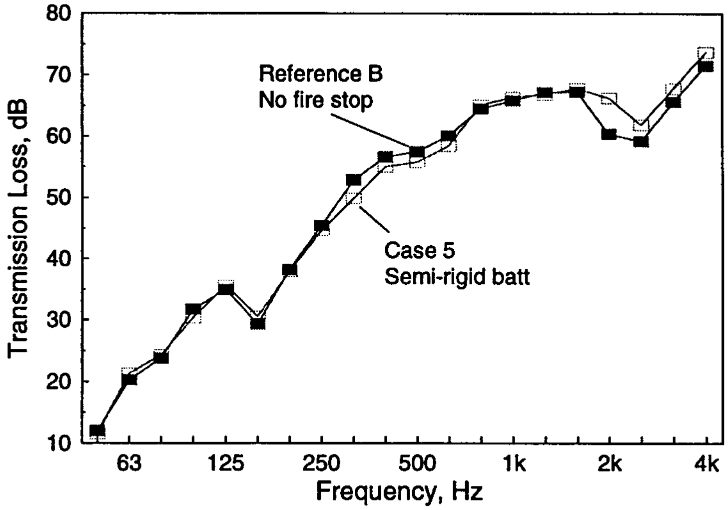
Table A12: Case 5 Apparent impact sound insulation measured in accordance with ASTM E1007 and expressed in terms of the single number rating FIIC.

Apparent impact sound insulation		Room Pairs	Case: 5 with basic wall (FIIC)	Change re Reference B with basic wall
Apartment	Horiz.	A-B	59	-2
	Vert.	B-D	51	+1
	Diag.	A-D	59	n/a

Row	Vert.	A-C	35	+2
	Diag.	B-C	n/a	n/a

The presence of the 5 lb/ft^3 (80 kg/m^3) semi-rigid material installed vertically at the joint had no appreciable impact on the sound insulation between rooms A and B as shown in Figure A14. The small differences in the sound insulation may be attributed to reproducibility uncertainty.

Figure A14: Comparison of the apparent airborne sound insulation with the semi-rigid fire stop for the basic party wall construction and Reference B, without any fire stop. The very close agreement indicates that there is no appreciable degradation due to the 5 lb/ft³ semi-rigid batt material at the joint. The FSTC rating was unchanged at 52.



This type of fire stop is suitable for applications where the wall/floor systems have been designed for a high degree of sound insulation.

Technical Discussion

For materials installed vertically at the joint and held in place through slight compression, it is the compressive stiffness of the material that will determine the amount of vibratory energy transmitted from one side of the joint to the other. The lower the compressive stiffness the better.

Figure A15: Dynamic stiffness of 3 lb/ft³ glass fiber and 5 lb/ft³ semi-rigid mineral fiber batt materials subject to various compressive loadings.

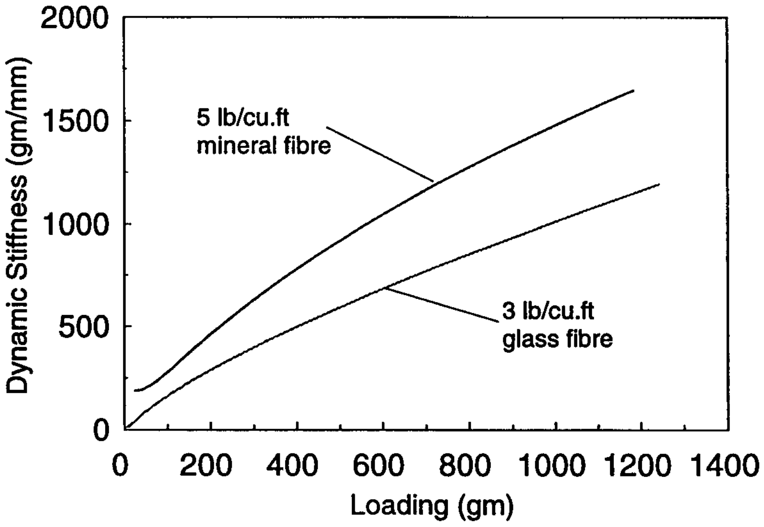


Figure A15 shows the dynamic stiffness of both the 3 lb/ft³ (48 kg/m³) and 5 lb/ft³ material subject to various loading. It is important to note that the dynamic stiffness of the material changes with loading. That is the more loading the more stiff the material becomes. With this in mind, care must then be taken during the installation process not to overly compress the material between the joist headers. The amount of compression can be minimized by ensuring that the material completely covers the sole plate(s), joist header, and head plates(s). For this reason it is suggested that the nominal 600x1200 mm sheets be installed uncut with the 600 mm dimension providing the vertical coverage in the joint space.

For fibrous materials in general, a lower density means a lower compressive stiffness and improved acoustical performance at the joint. Thus, for the same amount of compression, it can be expected that semi-rigid batt materials having a density of 5 lb/ft^3 or less will exhibit similar or better performance to the material measured.

Summary

Installing semi-rigid batt material (glass or rock fibre) in the space between the joist headers will be acoustically neutral as long as the material is not excessively compressed either during installation or through uneven building settling. The amount of compression can be minimized by ensuring that the material completely covers the sole plate(s), joist header, and head plates(s). A 5 lb/ft^3 batt should have no adverse effect for walls that are likely to be used in multi-family dwellings.

Case 6

0.38 mm Sheet Steel

Figure A16 shows the specimen construction. The fire stop was nominal 30 gauge galvanized sheet steel (measured thickness 0.38 mm, or 0.015 inches) installed at the floor level under the sole plates of the party wall. The flat and unprofiled sheet steel was nominally 200 mm (8 inches) wide (so as not to protrude past the gypsum board surfaces of the wall). The sheet steel stock is readily available as flashing from roofing material suppliers.

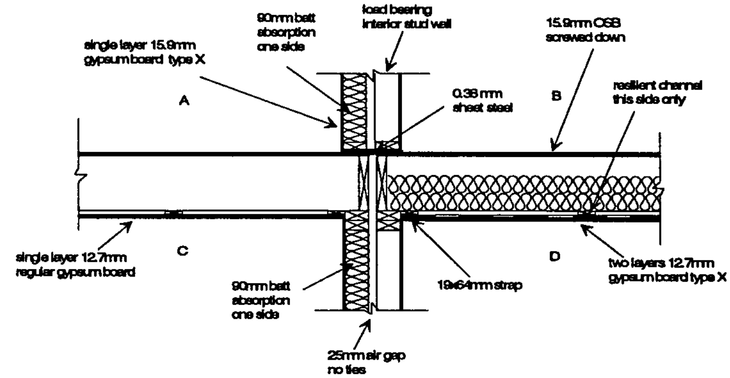


Figure A16: Section through the floor and party wall of the Case 6 assembly showing the flat 0.38 mm sheet steel fire stop installed at the floor level.

Figure A17 shows the fastener spacing used to secure the sheet steel to the OSB decking. The close fastener spacing used was designed to eliminate any slip between the sheet steel and decking. This would simulate the real-life condition of very high friction between the steel and the decking that would occur when the party wall was fully loaded.

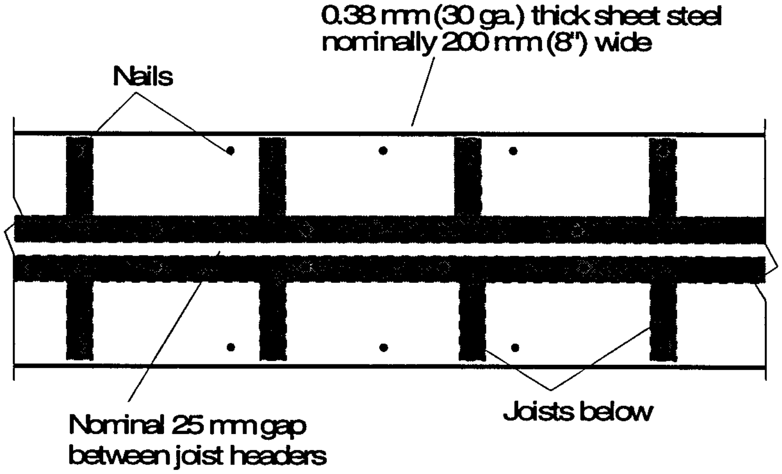


Figure A17: Location of fasteners (44 mm long roofing nails 3.2 mm diameter with 11.1 mm diameter head) placed every 150 mm to secure the sheet steel to the sub-floor.

Basic Party Wall Construction

Table A13 and Table A14 show that there was some degradation to the sound insulation between the upper two rooms, A and B. The apparent airborne sound insulation was not degraded while the apparent impact sound insulation was degraded by 7 points. The change in the apparent impact sound insulation clearly illustrates the strong physical coupling that exists between the two sides of the wall.

Table A13: Case 6 apparent airborne sound insulation measured in accordance with ASTM E336 and expressed in terms of the single number rating FSTC.

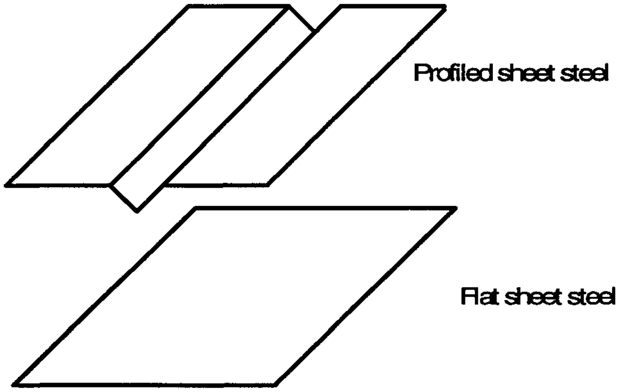
Apparent airborne sound insulation		Room Pairs	Case: 6 with basic wall (FSTC)	Change re Reference B with basic wall
Apartment	Horiz.	A-B	51	+1
	Vert.	B-D	56	+1
	Diag.	A-D	69	-1
Row	Vert.	A-C	41	+1
	Diag.	B-C	64	-2

Table A14: Case 6 apparent impact sound insulation measured in accordance with ASTM E1007 and expressed in terms of the single number rating FIIC.

Apparent impact sound insulation		Room Pairs	Case: 6 with basic wall (FIIC)	Change re Reference B with basic wall
Apartment	Horiz.	A-B	54	-7
	Vert.	B-D	51	+1
	Diag.	A-D	n/a	n/a
Row	Vert.	A-C	n/a	n/a
	Diag.	B-C	n/a	n/a

Since for horizontally oriented fire stops the amount of transmission by bending moments is proportional to the bending stiffness of the fire stop[7], the thickness should be minimized where possible (i.e., use 0.38 mm material NBCC 9.10.15.3.1.a and no thicker).

Figure A18: Sketch of the profiled and flat sheet steel fire stops.



The impact may be further minimized by placing a profile in the material that runs parallel to the joint as shown in Figure A18. The sheet steel fire stop with the profile was not tested as part of this project but the use of a profile is strongly recommended. The profile might be 19 mm (3/4 inch) wide and 19 mm (3/4 inch) deep. The cost of the material with the crease would be only marginally more per linear foot assuming a 200 mm (8 inch) width.

A profiled sheet steel fire stop should reduce transmission by forces in the plane of the floor decking and should also further reduce transmission due to bending moments. Appendix E discusses methods of energy transmission through the joint in further detail.

Superior Party Wall Construction

The basic party wall separating rooms A and B was removed and replaced with the superior party wall to determine the flanking limit for this fire stop detail. Table A15 and Table A16 show the measured sound insulation for this construction.

Table A15: Case 6 with superior wall apparent airborne sound insulation measured in accordance with ASTM E336 and expressed in terms of the single number rating FSTC.

Apparent airborne sound insulation		Room Pairs	Case: 6 with superior wall (FSTC)	Change re Reference B with superior wall
Apartment	Horiz.	A-B	57	-9
	Vert.	B-D	57	+2
	Diag.	A-D	n/a	n/a
Row	Vert.	A-C	n/a	n/a
	Diag.	B-C	65	-5

Table A16: Case 6 with superior wall apparent impact sound insulation measured in accordance with ASTM E1007 and expressed in terms of the single number rating FIIC.

Apparent impact sound insulation		Room Pairs	Case: 6 with superior wall (FIIC)	Change re Reference B with superior wall
Apartment	Horiz.	A-B	55	-9
	Vert.	B-D	n/a	n/a
	Diag.	A-D	n/a	n/a
Row	Vert.	A-C	38	+5
	Diag.	B-C	n/a	n/a

With the superior party wall, the apparent airborne sound insulation between rooms A and B was FSTC 57 which is a significant improvement over the FSTC 51 with the basic wall. The change in sound insulation suggests that the direct path and/or flanking paths involving the party wall were limiting the sound insulation when the basic wall was installed. However, the FSTC 57 with the sheet steel fire stop installed is considerably lower than the STC 67 potential of the wall.

Technical Discussion

Figure A19 shows that the apparent airborne sound insulation between rooms A and B with the basic wall construction was severely degraded in the frequency range 315-4000 Hz. The degradation was in excess of 10 dB for many of the frequencies. This did not translate into a reduction in the FSTC rating because direct transmission through the basic wall in the frequency range 125-250 Hz was controlling the single number rating.

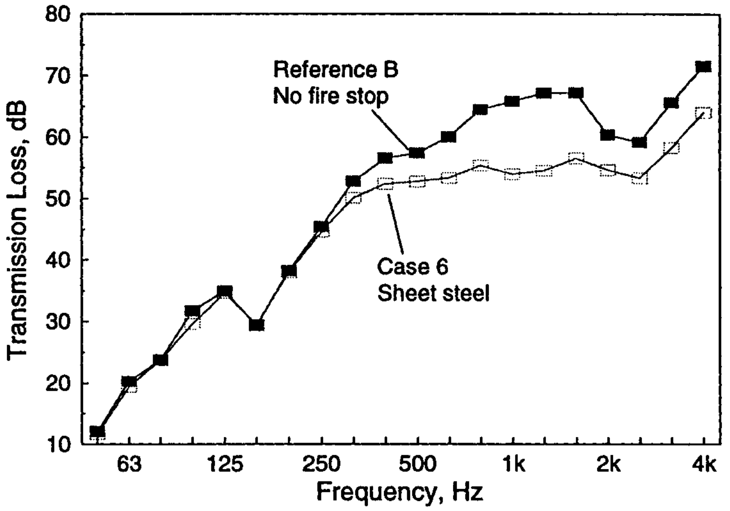


Figure A19: Comparison of the apparent airborne sound insulation between the Reference B and Case 6 (0.38 mm sheet steel installed flat under the sole plates of the upper party wall). Despite the degradation in the high frequencies, the sheet steel fire stop did not reduce the FSTC.

Figure A20 shows the measured apparent airborne sound insulation along with the sound insulation for flanking paths involving floor and party wall. The flanking path sound insulation is determined by measuring the sound intensity radiating from the surface in question while the other radiating surfaces are masked. Normalizing this to the area of the party wall gives the apparent airborne sound insulation of the flanking paths. The Figure shows that in the frequency range 315-4000 Hz the energy radiated by the floor is comparable or higher than that radiated by the party wall. This suggests that if the floor in the receiving room were treated so that flanking paths involving the floor were no longer significant there would be at least a 3 dB improvement in the range 315-4000 Hz.

Figure A20: Case 6 (0.38 mm sheet steel fire stopping) apparent airborne sound insulation (FSTC 51), flanking paths involving the receiving room floor and the sound insulation for all paths involving the receiving room party wall (FSTC 52).

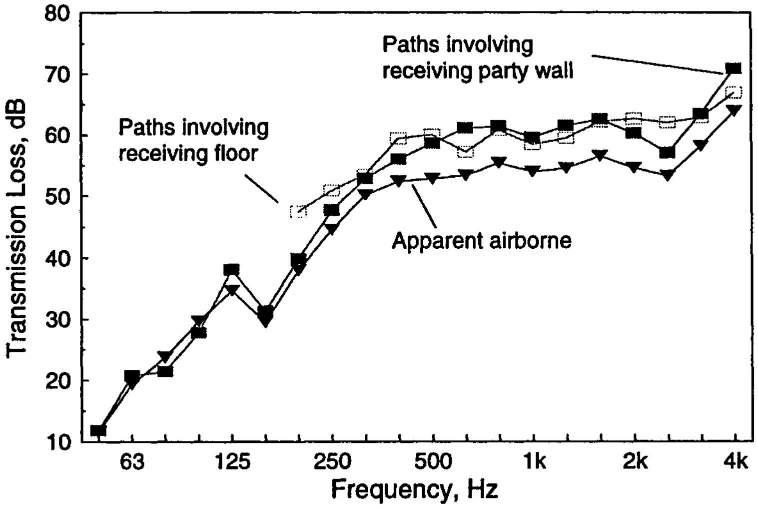
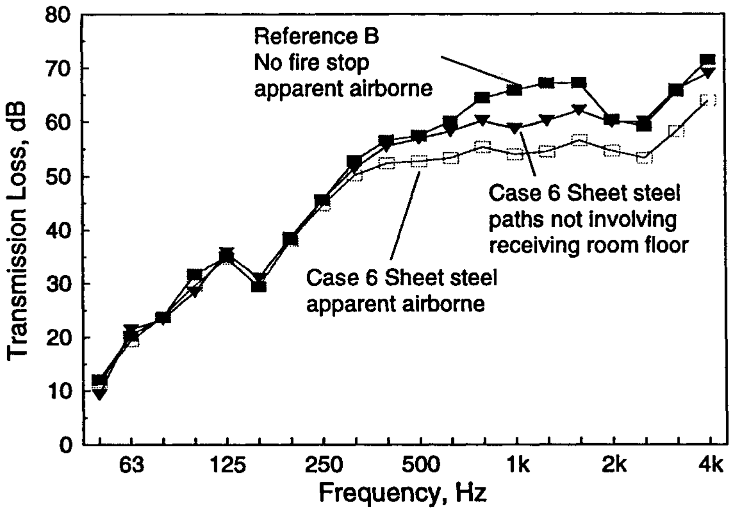


Figure A21 shows that in actuality more than 3 dB is achieved when the sound insulation is measured with the receiving room floor masked off and that the apparent airborne sound insulation approached that of the Reference B without any flanking paths involving the fire stop.

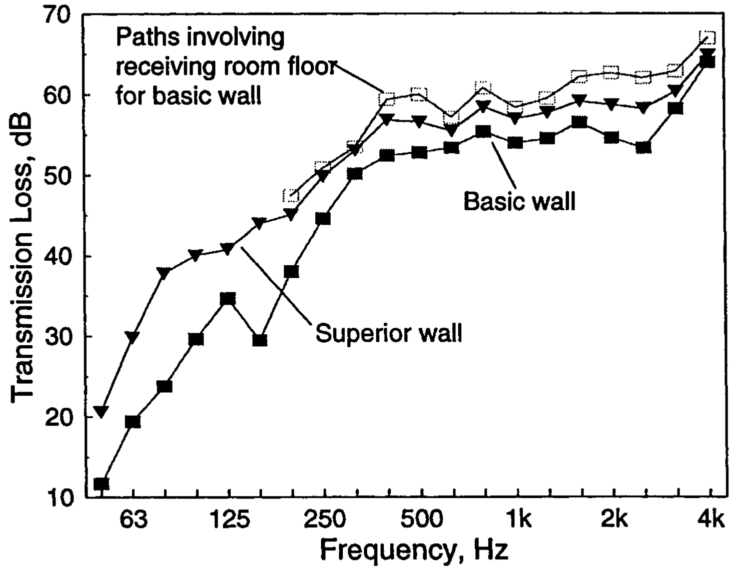
Figure A21: Case 6 measured apparent airborne sound insulation for the system and for paths not involving the receiving room floor. Also shown for comparison is the Reference B apparent airborne sound insulation.



By symmetry, if the floor were also treated in the source room then a further 3 dB improvement could be realized. With both floors treated there should only be the direct path plus the flanking path through the fire stop linking the leaves of the party wall, (1-3-8-5-7) and Figure A21 would suggest that the assembly might come very close to achieving the sound insulation potential of the Reference B.

Figure A22 compares the apparent airborne sound insulation for the basic party wall and the superior party wall. From the Figure it is evident that the significant improvement exhibited in the low frequencies as a result of using the superior wall was not realized in the frequency range 315-4000 Hz. This is thought to be the result of flanking paths involving the floor. Also shown in the Figure is the apparent airborne sound insulation for paths involving the receiving room floor (1-2-3-4-5-6-7, 1-3-4-5-6-7, 1-2-8-6-7, and 1-3-8-6-7) when the basic wall construction was installed. The similarity in sound insulation offered by the floor with the basic wall and the apparent sound insulation offered for the complete assembly with the superior wall suggest that the dominant flanking paths involve the floor. In particular, the path 1-2-8-6-7 (in the source room floor, under the party wall via the fire stop, and out into the receiving room by the receiving room floor decking) which does not involve the party wall.

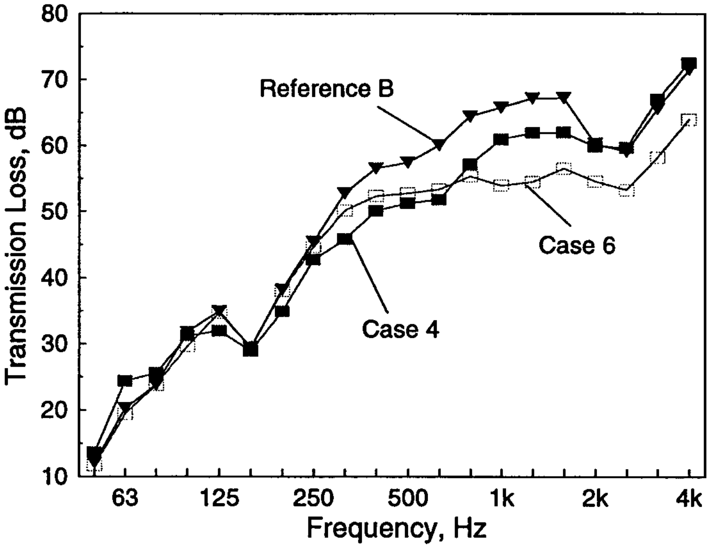
Figure A22: Case 6 measured apparent airborne sound insulation for the basic and superior party wall constructions. Also included is the sound insulation for all paths involving the receiving room floor with the basic party wall installed.



Consequently, it is unreasonable to expect that the sound insulation of this assembly to be better than FSTC 57 due to the flanking path involving the floor decking (1-2-8-6-7). An improved floor surface in the form of a concrete topping, floating floor, or even an underlay would improve the sound insulation of this assembly.

Simple prediction models suggest that the impact of the sheet steel fire stop would be minimal and probably less than the gypsum board at the joint. The measured data, shown in Figure A23, show that the impact is greater. This may be due to the fact that while the flat sheet steel will not support the transmission of vibration by bending moments (because it can easily bend along the axis parallel to the joint), the sheet steel will support the transmission by in-plane forces. This is similar to the method of transmission for the gypsum board at the joint.

Figure A23: Measured A-B apparent airborne sound insulation for the Reference B (no fire stop), Case 6 (flat sheet steel fire stop), and case 4 (gypsum board fire stop) all with the basic party wall construction.



Since the sheet steel is connected to both sides of the wall, force transmission will occur for displacements that give rise to both compression and extension of the sheet steel.

In-plane motion can normally be ignored because the transmission is usually dominated by moment transmission which lends itself to more effective radiation of sound energy. However, when there is only weak transmission via bending moments, the in-plane contribution no longer becomes negligible.

Summary

Fire stops formed through rigid structural connections bridging the elements on either side of a double leaf construction will degrade the performance of the complete assembly. Despite the low bending stiffness offered by the sheet steel, the apparent A-B sound insulation was impacted. The impact is thought to be due to the transmission of forces in the plane of the floor decking and sheet steel fire stop. In this axis the fire stop is very stiff.

The impact on the sound insulation can be minimized by selecting the thinnest acceptable material (0.38 mm) and may be helped by placing a profile (such as shown in Figure A18) in the material to reduce in-plane stiffness.

Case 7

Continuous 15.9 mm OSB Floor Decking

Figure A24 shows the 15.9 mm thick OSB sub-floor continued under the sole plates of the double wood stud party wall.

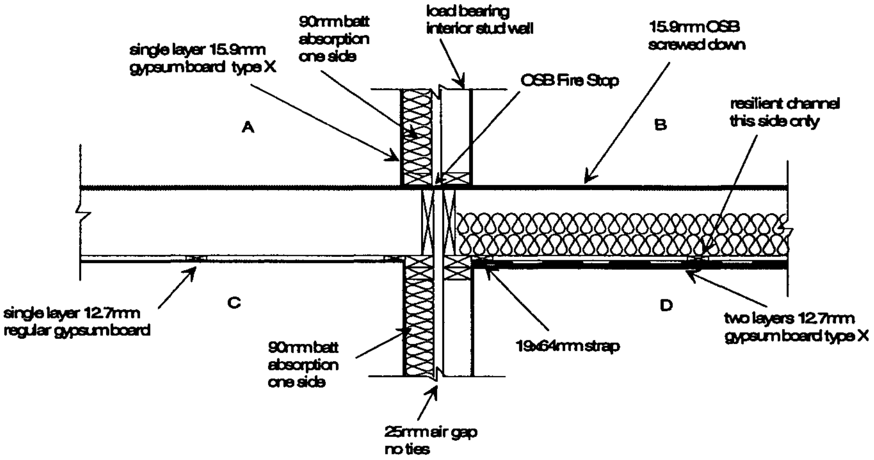


Figure A24: Section through the floor and party wall of the Case 7 assembly showing the continuous 15.9 mm OSB sub-floor under the party wall.

Basic Party Wall Construction

Table A17 shows that continuing the sub-floor under the party wall does not have a serious impact on the apparent airborne sound insulation, except for the diagonal cases. The horizontal apparent airborne sound insulation between rooms A and B which share the continuous sub-floor remained at FSTC 50; just in compliance with the intent of the Code.

The effect on the apparent impact sound insulation, shown in Table A18, is much more serious, with a drop of 10 points from FIIC 61 to FIIC 51 between rooms A and B. If the suggested impact insulation criterion of IIC 55 given the Commentary to the Code were applied to the A-B apparent impact sound insulation, then the assembly would not comply.

Table A17: Case 7 apparent airborne sound insulation measured in accordance with ASTM E336 and expressed in terms of the single number rating FSTC.

Apparent airborne sound insulation		Room Pairs	Case: 7 with basic wall (FSTC)	Change re Reference B with basic wall
Apartment	Horiz.	A-B	50	0
	Vert.	B-D	56	+1
	Diag.	A-D	66	-4
Row	Vert.	A-C	41	+1
	Diag.	B-C	61	-5

Table A18: Case 7 apparent impact sound insulation measured in accordance with ASTM E1007 and expressed in terms of the single number rating FIIC.

Apparent impact sound insulation		Room Pairs	Case: 7 with basic wall (FIIC)	Change re Reference B with basic wall
Apartment	Horiz.	A-B	51	-10
	Vert.	B-D	51	+1
	Diag.	A-D	55	n/a
Row	Vert.	A-C	n/a	n/a
	Diag.	B-C	58	n/a

Using a continuous surface that runs past a demising partition is probably the least desirable method of providing fire stopping and should be avoided. There may be instances where structural requirements for a continuous shear diaphragm in the floor decking demand this type of construction. Cases 8 and 9 investigate techniques for improving the sound insulation in constructions that have significant flanking at the joint.

Superior Party Wall Construction

The basic party wall separating rooms A and B was removed and replaced with the superior party wall to determine the flanking limit for this fire stop detail.

Table A19: Case 7 with superior wall apparent airborne sound insulation measured in accordance with ASTM E336 and expressed in terms of the single number rating FSTC.

Apparent airborne sound insulation		Room Pairs	Case: 7 with superior wall (FSTC)	Change re Reference B with superior wall
Apartment	Horiz.	A-B	52	-14
	Vert.	B-D	56	+1
	Diag.	A-D	67	-3
Row	Vert.	A-C	40	0
	Diag.	B-C	61	-9

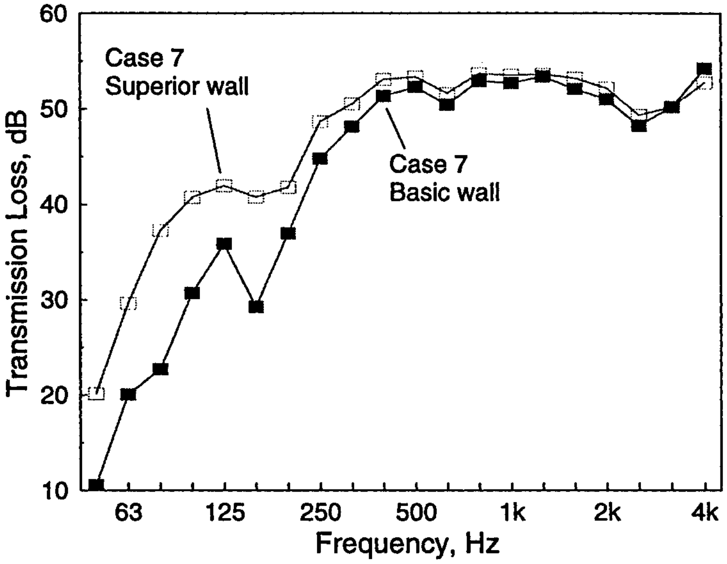
Table A20: Case 7 with superior wall apparent impact sound insulation measured in accordance with ASTM E1007 and expressed in terms of the single number rating FIIC.

Apparent impact sound insulation		Room Pairs	Case: 7 with superior wall (FIIC)	Change re: Reference B with superior wall
Apartment	Horiz.	A-B	51	-15
	Vert.	B-D	n/a	n/a
	Diag.	A-D	n/a	n/a
Row	Vert.	A-C	n/a	n/a
	Diag.	B-C	n/a	n/a

It is clear from Table A19 and Table A20 that there has been a serious degradation of both the apparent airborne sound insulation and the apparent impact sound insulation between rooms A and B.

Figure A25 shows that with the superior party wall the apparent airborne sound insulation between rooms A and B was FSTC 52 which is only a marginal improvement over the FSTC 50 with the basic wall.

Figure A25: Comparison of the apparent airborne sound insulation for Case 7 (continuous OSB sub floor) when the basic and superior party walls are installed.

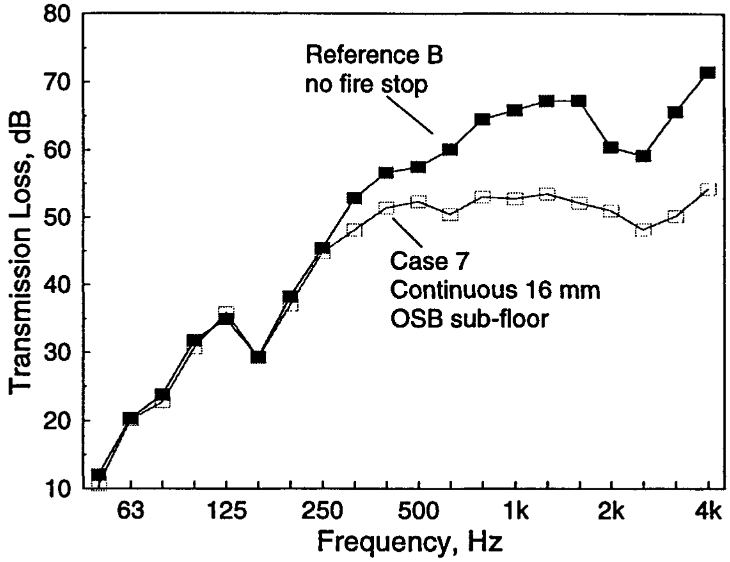


The slight change in the single number rating and the marginal improvement in sound insulation in the frequency range 400-3150 Hz show that the sound insulation is not being controlled by direct sound transmission through the party wall. Rather, the flanking paths involving the floor were controlling the apparent sound insulation.

Technical Discussion

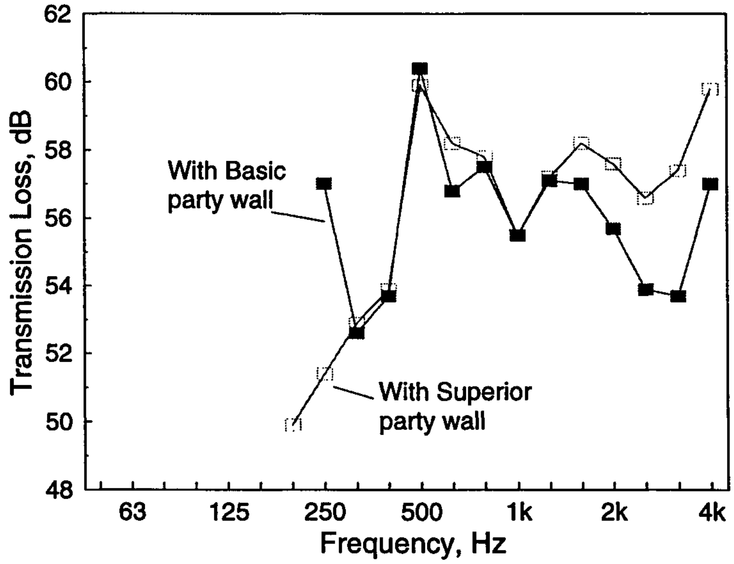
Figure A26 compares the apparent airborne sound insulation for both the Reference B and Case 7 with the continuous 15.9 mm OSB sub-floor. From the Figure it is evident that there was a significant degradation due to the continuous sub-floor. Similar to the sheet steel of Case 6, the degradation occurred in the frequency range 315-4000 Hz, although with the continuous sub-floor the degradation is more severe. In both cases, the degradation did not affect the single number FSTC rating since it was being controlled in the frequency range 160-250 Hz.

Figure A26: Comparison of the apparent airborne sound insulation for the Reference B construction and Case 7 having the continuous 15.9 mm OSB sub-floor.



In Appendix D it is shown that for the basic party wall construction the sound insulation was controlled by flanking paths involving the floor. Figure A27 compares the sound insulation for flanking paths involving the floor for both the basic and superior party walls. From the Figure it is evident that there was only a marginal improvement in the sound insulation of paths involving the floor. It is the 2-3 dB improvement in the sound insulation in the 2500 Hz third octave band, shown in the Figure, that caused the 2 FSTC improvement.

Figure A27: Measured sound insulation for paths involving the receiving room floor for the cases when the A-B party wall is of basic construction and superior construction.



Consequently, it is unreasonable to expect that the sound insulation of this assembly to be better than FSTC 52 due to the flanking path involving the sub floor (1-2-8-6-7). An improved floor surface in the form of a concrete topping, floating floor, or even an underlay would improve the sound insulation of this assembly.

Summary

The continuous sub-floor under the party wall introduced a strong physical connection between the two sides of the party wall. The structural connection introduced significant flanking paths that limited the apparent sound insulation. It would be unrealistic to expect a similar construction (floor construction) to achieve an apparent airborne sound insulation better than FSTC 52 regardless of the construction of the framed party wall. For acoustical reasons this type of fire stop should be avoided unless other requirements dictate its use.

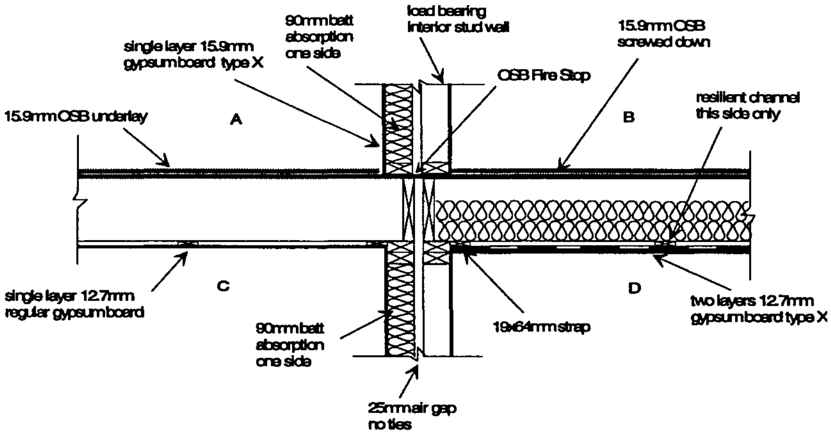
RETRO-FITS

Two retro-fits are examined as methods to improve the sound insulation of existing or new constructions. The first method examined is the application of a 15.9 mm underlay, while the second is a floating floor system. Both of which will be applied on top of the continuous sub-floor of Case 7. The data are now presented and the effectiveness of each treatment discussed.

Case 8: 15.9 mm OSB Underlay

Figure A28 shows the 15.9 mm thick OSB underlay applied to the exposed portions of the continuous sub-floor of Case 7.

Figure A28: Section through the floor and party wall of the Case 8 assembly showing the retro-fit using 15.9 mm OSB underlay applied to the exposed part of the continuous sub-floor.



Basic Party Wall Construction

Table A21 and Table A22 show that adding the underlay to the continuous sub-floor under the party wall can improve the horizontal sound insulation. The underlay improved the horizontal apparent airborne sound insulation between rooms A and B by a single FSTC point. There was a more significant improvement in the apparent impact sound insulation between rooms A and B, with a 4 FIIC point improvement being realized.

Table A21: Case 8 apparent airborne sound insulation measured in accordance with ASTM E336 and expressed in terms of the single number rating FSTC.

Apparent airborne sound insulation		Room Pairs	Case: 8	Change re	
			with basic wall (FSTC)	Case 7 with basic wall	Reference B with basic wall
Apartment	Horiz.	A-B	51	+1	+1
	Vert.	B-D	59	+3	+4
	Diag.	A-D	68	+2	-2
Row	Vert.	A-C	43	+2	+3
	Diag.	B-C	63	+2	-3

Table A22: Case 8 apparent impact sound insulation measured in accordance with ASTM E1007 and expressed in terms of the single number rating FIIC.

Apparent impact sound insulation		Room Pairs	Case: 8	Change re	
			with basic wall (FIIC)	Case 7 with basic wall	Reference B with basic wall
Apartment	Horiz.	A-B	55	+4	-6
	Vert.	B-D	52	+1	+2
	Diag.	A-D	57	+2	n/a
Row	Vert.	A-C	n/a	n/a	n/a
	Diag.	B-C	60	+2	n/a

The largest improvement in apparent airborne sound insulation was between rooms B and D (3 FSTC points) since the underlay improved the sound insulation of both the direct and dominant flanking path as shown in Appendix C. In the case of all other rooms, the underlay will only improve flanking paths.

Superior Party Wall Construction

The basic party wall separating rooms A and B was removed and replaced with the superior party wall to determine the flanking limit for this fire stop detail.

Table A23: Case 8 with superior wall apparent airborne sound insulation measured in accordance with ASTM E336 and expressed in terms of the single number rating FSTC.

Apparent airborne sound insulation		Room Pairs	Case: 8 with superior wall (FSTC)	Change re Case 7 with superior wall	Change re Reference B with superior wall
Apartment	Horiz.	A-B	60	+8	-6
	Vert.	B-D	59	+3	+4
	Diag.	A-D	69	+2	-1
Row	Vert.	A-C	43	+3	+3
	Diag.	B-C	64	+3	-6

Table A24: Case 8 with superior wall apparent impact sound insulation measured in accordance with ASTM E1007 and expressed in terms of the single number rating FIIC.

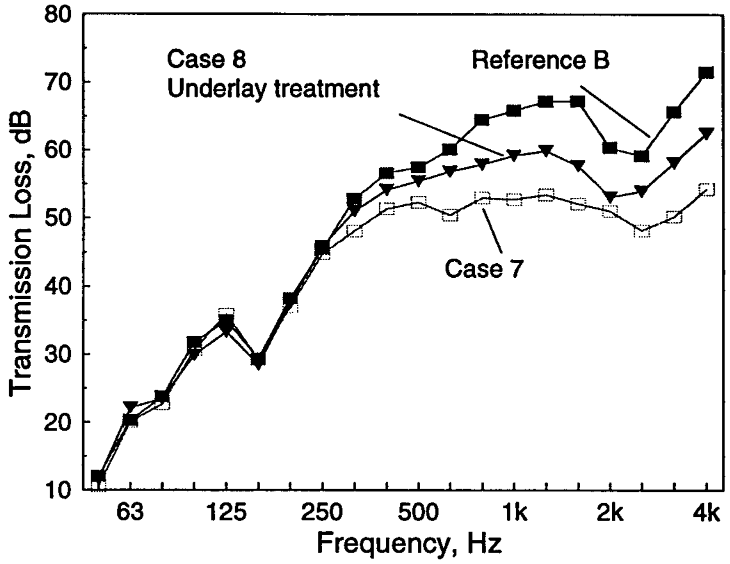
Apparent impact sound insulation		Room Pairs	Case: 8 with superior wall (FIIC)	Change re Case 7 with superior wall	Change re: Reference B with superior wall
Apartment	Horiz.	A-B	58	+7	-8
	Vert.	B-D	52	n/a	+2
	Diag.	A-D	57	n/a	n/a
Row	Vert.	A-C	34	n/a	+1
	Diag.	B-C	61	n/a	n/a

With the superior party wall, the apparent airborne sound insulation between rooms A and B increased by 8 FSTC points to FSTC 60.

Technical Discussion

The retro-fit, in the form of a thicker than normal underlay, provided significant improvement in sound insulation between rooms A and B in the frequency range 315-4000 Hz as shown in Figure A29. However, due to the fact that the single number FSTC rating is being controlled by frequencies less than 315 Hz, a significant increase in the single number sound insulation was not realized for the basic wall.

Figure A29: Examination of the effectiveness of the 15.9 mm thick OSB underlay as a retro-fit by comparing the apparent airborne sound insulation to the Reference B and Case 8 when the basic party wall construction is used.



However when the basic party wall is replaced by the superior wall, Figure A30 shows that the underlay significantly increased the apparent sound insulation for all frequencies greater than 80 Hz. The single number rating is controlled by the coincidence dip at 2000 Hz and it is the significant improvement at the high frequencies that has caused an 8 FSTC point change in the single number rating.

Figure A30: Examination of the improvement in apparent airborne sound insulation as a result of using the 15.9 mm OSB underlay as a retro-fit when the superior party wall is used.

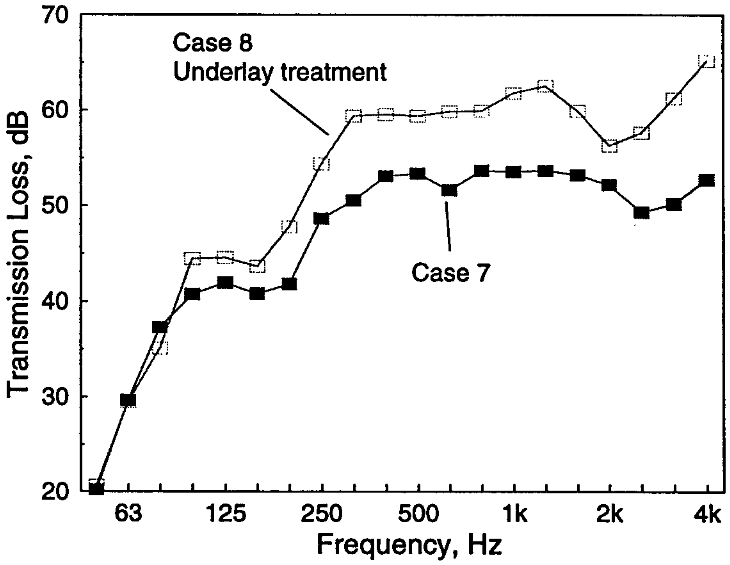
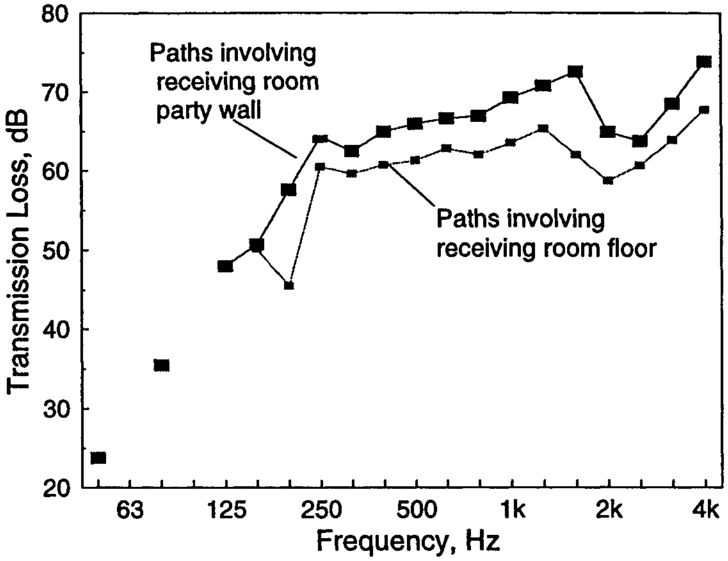


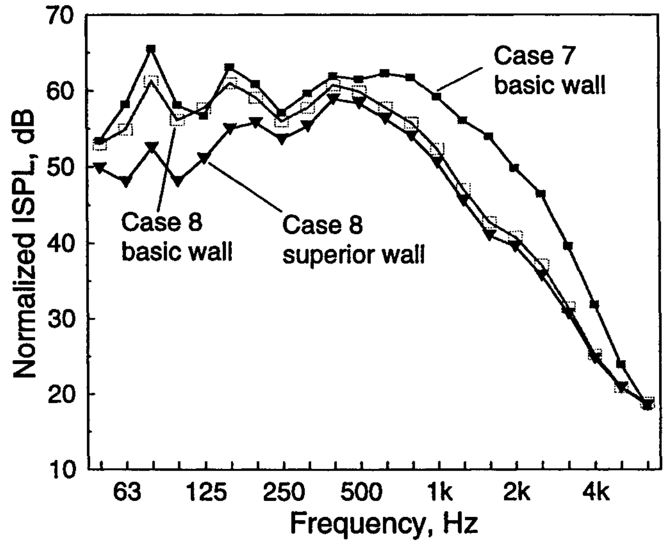
Figure A31 shows that despite the underlay, the sound insulation is still being controlled by flanking paths involving the receiving room floor and that an even more effective floor treatment would yield better results.

Figure A31: Comparison of the relative importance of transmission paths involving the floor and the party wall.



Not only the airborne but the impact sound insulation is also dependent on the type of party wall. Figure A32 shows the measured normalized apparent impact sound insulation measured in the receiving room with and without the underlay treatment. It is clear that the underlay greatly improves the sound insulation in the frequency range 315-4000 Hz with the basic party wall separating rooms A and B. There is a small but measurable improvement in the frequency range 63-250 Hz. The underlay improved the field impact insulation class from FSTC 51 to FSTC 55. If, with the underlay present, the basic wall is replaced by the superior wall, then there is very significant improvement in the frequency range 63-250 Hz, but no appreciable improvement for frequencies above 400 Hz.

Figure A32: Examination of the effectiveness of the underlay treatment on the apparent impact sound insulation between rooms A and B for the basic and superior wall constructions.



These trends suggest that there are two distinctly different paths for the energy to propagate from the source room floor to the receiving room; one path involves only the floor and transmits mid- and high-frequency energy, while the second involves the floor feeding energy into the party wall and is responsible for low-frequency transmission.

The results suggest that the apparent sound insulation between rooms A and B is determined by a complex interaction between the wall and floor. Thus, the effectiveness of a retro-fit applied to either the floor or wall surface will depend on the other.

Summary

The effectiveness of the over-sized underlay was dependent on the construction of the party wall. Very significant improvements, 8 FSTC points, were realized when the treatment was used with the superior wall. The results would suggest that underlay by itself may not be sufficient to counteract the impact of the continuous sub-floor. But, if used in conjunction with an adequate party wall (either nominally or through retro-fit), the underlay can be a very effective tool.

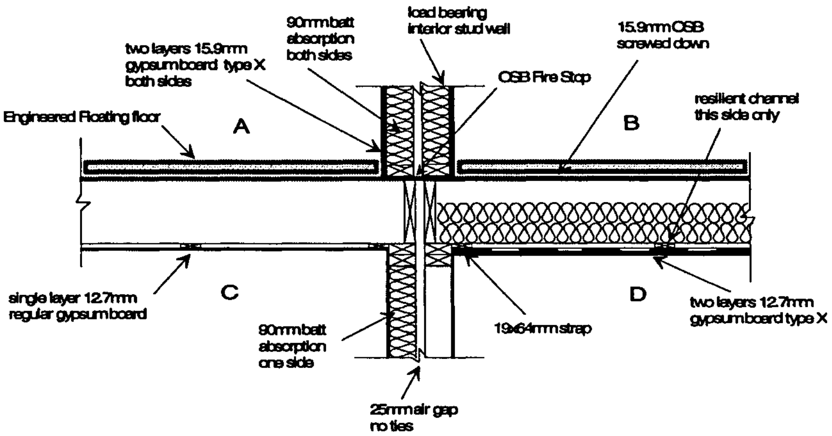
The underlay, in addition to helping improve the A-B sound insulation, also improved the vertical sound insulation by about 3 FSTC points.

Case 9

Floating Floor System

Figure A33 shows the floating floor system installed on the exposed portions of the continuous sub-floor of Case 7. The floating floor was a commercially available "Lamella" system obtained from Roxul Inc.

Figure A33: Section through the floor and party wall of the Case 9 assembly showing the retro-fit using an engineered floating floor.



Superior Party Wall Construction

Table A25 and Table A26 show that adding the floating floor system can improve the horizontal sound insulation. In fact the apparent airborne sound insulation between rooms A and B is actually slightly better than for the Reference B in the 125 to 250 Hz range, resulting in an increase of 1 FSTC point.

Table A25: Case 9 with superior wall apparent airborne sound insulation measured in accordance with ASTM E336 and expressed in terms of the single number rating FSTC.

Apparent airborne sound insulation		Room Pairs	Case: 9 with superior wall (FSTC)	Change re Case 7 with superior wall	Change re Reference B with superior wall
Apartment	Horiz.	A-B	67	+15	+1
	Vert.	B-D	65	+9	+10
	Diag.	A-D	73	+6	+3
Row	Vert.	A-C	51	+11	+11
	Diag.	B-C	69	+8	-1

Table A26: Case 9 with superior wall apparent impact sound insulation measured in accordance with ASTM E1007 and expressed in terms of the single number rating FIIC.

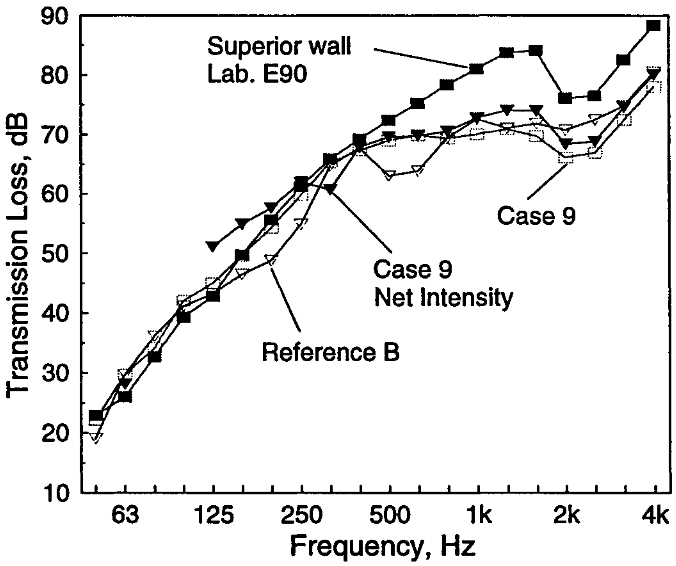
Apparent impact sound insulation		Room Pairs	Case: 9 with superior wall (FIIC)	Change re Case 7 with superior wall	Change re: Reference B with superior wall
Apartment	Horiz.	A-B	69	+18	+3
	Vert.	B-D	58	n/a	+8
	Diag.	A-D	n/a	n/a	n/a
Row	Vert.	A-C	39	n/a	+6
	Diag.	B-C	n/a	n/a	n/a

The apparent impact sound insulation between rooms A and B shows a substantial improvement of 18 points which makes it 4 points higher than the Reference B.

Technical Discussion

The addition of the floating floor as a retro-fit produced a system which is substantially better than the original construction without the fire stop. Figure A34 shows the apparent airborne sound insulation between rooms A and B for the floating floor and the Reference B construction with the same superior party wall. The floating floor effectively eliminates any flanking paths involving the receiving room floor. The sum of the sound intensity through the floor and party wall, also shown in Figure A34, exhibits consistently higher transmission loss above 800 Hz than does the measured apparent airborne sound insulation, indicating that there are other flanking paths contributing. This difference, which is of the order of 3 dB, suggests that these paths are of the same importance as flanking paths involving the party wall. The laboratory E90 measurement for this wall is shown for comparison, a detailed discussion of the differences is given in Appendix B.

Figure A34: Comparison of apparent airborne sound insulation with the Reference B and the laboratory test of the same wall. Also shown is the sum of the sound intensity through the party wall and receiving room floor.

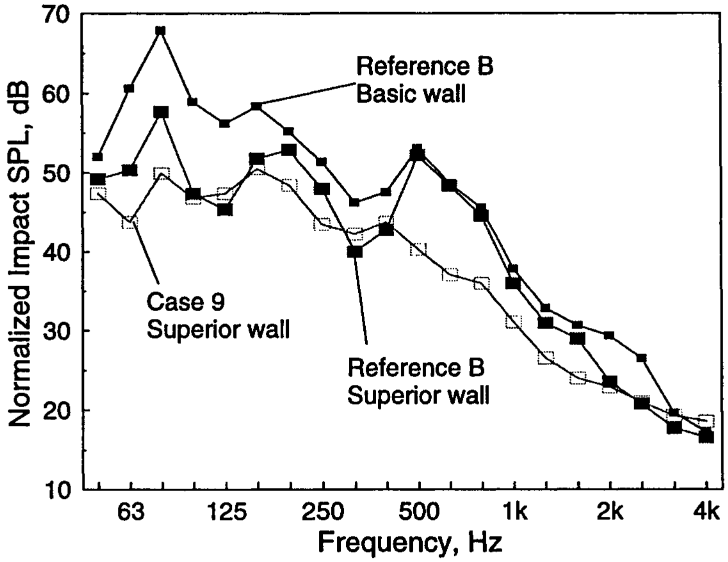


The substantial improvements in the FSTC between rooms B and D and rooms A and C are consistent with what would be expected for a floor of this type since the fire stop is not a consideration for these paths.

The apparent airborne sound insulation between the diagonal rooms B and C does not change significantly, indicating that the two paths involving direct coupling of the party wall through the fire stop to the ceiling and wall of room C are the controlling paths. The addition of the floating floor leaves only one structural flanking path between rooms A and D, from party wall through fire stop to party wall, and produces a 3 point improvement in the FSTC. One inference that can be drawn from this is that radiation from the ceiling in room C is probably controlling the FSTC for transmission between rooms B and C.

Figure A35 shows the apparent impact sound insulation between rooms A and B. In this case the flanking involving the source and receiving room floors has been effectively eliminated, leaving only the path 1-3-8-5-7. The result is an 18 point improvement over Case 7.

Figure A35: Comparison of apparent impact sound insulation between rooms A-B for Case 9 and the Reference B.



A comparison of the impact sound insulation for the Reference B with both basic and superior walls shows that like Case 8 the mid- and high-frequency energy is transmitted via paths involving only the floor despite the absence of any direct connection such as a fire stop. The floating floor effectively removes this path and results in an improvement of 4 FIIC points in the horizontal apparent impact sound insulation. The improvement at low-frequencies when the basic wall was replaced with the superior wall indicates, as with Case 8, that energy is transmitted by paths involving the receiving room floor feeding the party wall. This floating floor is quite stiff and does not perform as well at low-frequencies as it does in the mid- and high-frequencies.

Summary

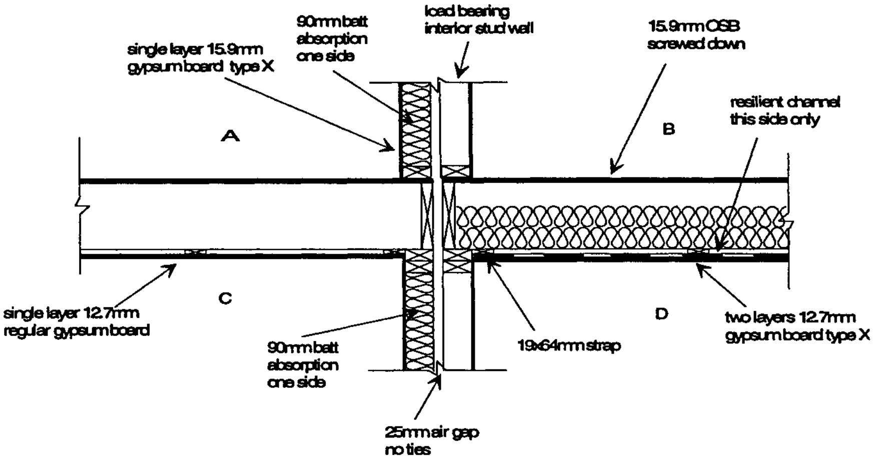
The installation of the floating floor resulted in a wall/floor system for which the apparent airborne sound insulation is as good as that of the basic system without a fire stop. The removal of all flanking paths involving the source and receiving room floors provided enhanced airborne sound. The apparent impact sound insulation was substantially improved for all room combinations. It is expected that other commercially available floating floor systems that are properly designed and installed will provide comparable improvement. The exact improvement will be a function of the dynamic stiffness and mass. Consequently results may vary for different products.

Case 10

Reference B, No Fire Stop

The Reference B was constructed without any fire stop and is shown in Figure A36 and differs from the Reference A only in the details of the floor between rooms A and C. The measured apparent airborne sound insulation and apparent impact sound insulation are shown in Table A27 and Table A28. The data for the Reference B are the reference case to which Case 4 through Case 9 can be compared to assess the impact of the fire stop or retro fit technique.

Figure A36: Section through the floor and party wall of the Case 10 assembly.



Basic Party Wall Construction

The apparent airborne sound insulation is essentially unchanged for all room combinations not involving room C.

Table A27: Case 10 apparent airborne sound insulation measured in accordance with ASTM E336 and expressed in terms of the single number rating FSTC.

Apparent airborne sound insulation		Room Pairs	Reference B with basic wall (FSTC)	Change re Reference A
Apartment	Horiz.	A-B	50	-1
	Vert.	B-D	55	-1
	Diag.	A-D	70	-1

Row	Vert.	A-C	40	-5
	Diag.	B-C	66	-3

Table A28: Case 10 apparent impact sound insulation measured in accordance with ASTM E1007 and expressed in terms of the single number rating FIIC.

Apparent impact sound insulation		Room Pairs	Reference B with basic wall (FIIC)	Change re Reference A
Apartment	Horiz.	A-B	61	0
	Vert.	B-D	50	-1
	Diag.	A-D	n/a	n/a

Row	Vert.	A-C	33	-6
	Diag.	B-C	n/a	n/a

The apparent impact sound insulation between rooms A and B and rooms B and D are also unchanged from the Reference A.

Superior Party Wall Construction

In order to establish the flanking limits for Cases 4 through 9 measurements were also made with the party wall between rooms A and B replaced with a superior wall. To provide a reference case to which these could be compared the Reference B was also measured with the superior party wall.

Table A29: Case 10 with superior wall apparent airborne sound insulation measured in accordance with ASTM E336 and expressed in terms of the single number rating FSTC.

Apparent airborne sound insulation		Room Pairs	Reference B with superior wall (FSTC)
Apartment	Horiz.	A-B	66
	Vert.	B-D	55
	Diag.	A-D	70
Row	Vert.	A-C	40
	Diag.	B-C	70

Table A30: Case 10 with superior wall apparent impact sound insulation measured in accordance with ASTM E1007 and expressed in terms of the single number rating FIIC.

Apparent impact sound insulation		Room Pairs	Reference B with superior wall (FIIC)
Apartment	Horiz.	A-B	65
	Vert.	B-D	50
	Diag.	A-D	n/a
Row	Vert.	A-C	33
	Diag.	B-C	n/a

Technical discussion

Figure A37 provides a comparison of the apparent airborne sound insulation between rooms A and B for the Reference A and the Reference B. There is no discernible difference, indicating that the degradation of the A-C floor has virtually no impact on the A-B sound insulation. It is interesting to note that there is a small but measurable change in the apparent airborne sound insulation between rooms B and C. The fact that there is a change is not surprising, since the ceiling of room C was reduced in weight and the cavity insulation removed, but its small size indicates that the paths involving the party wall are more important than those involving the ceiling of room C.

Figure A37: Comparison of the Reference A and Reference B apparent airborne sound insulation for horizontal A-B and diagonal B-C transmission with basic party wall construction.

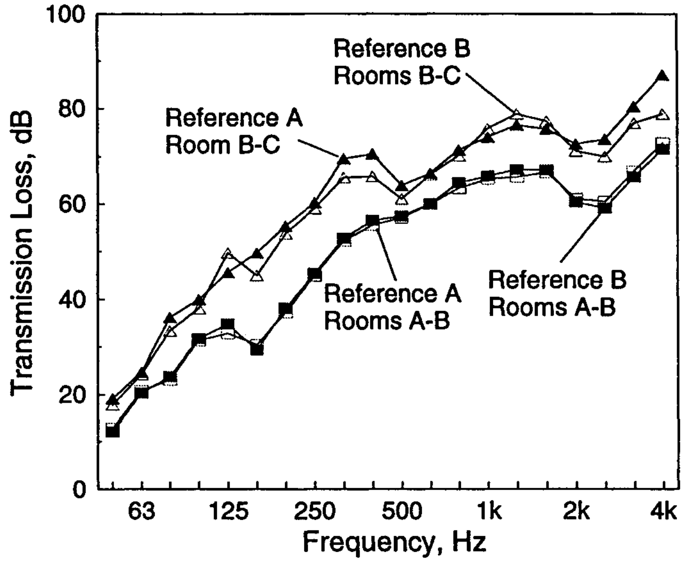
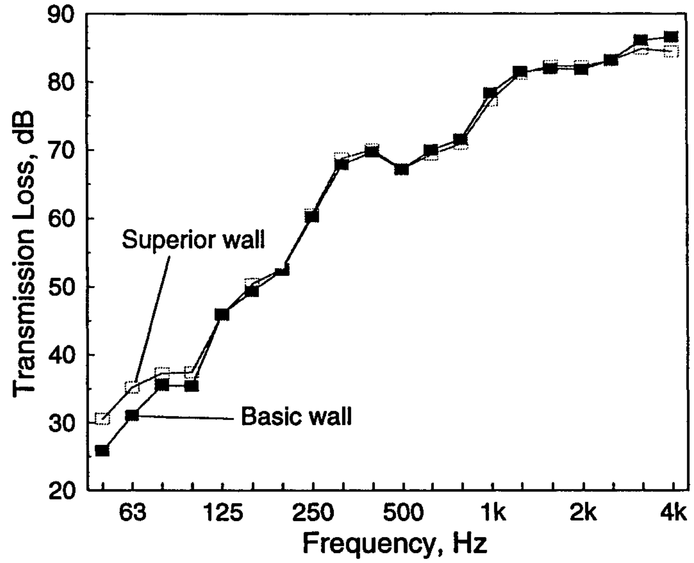


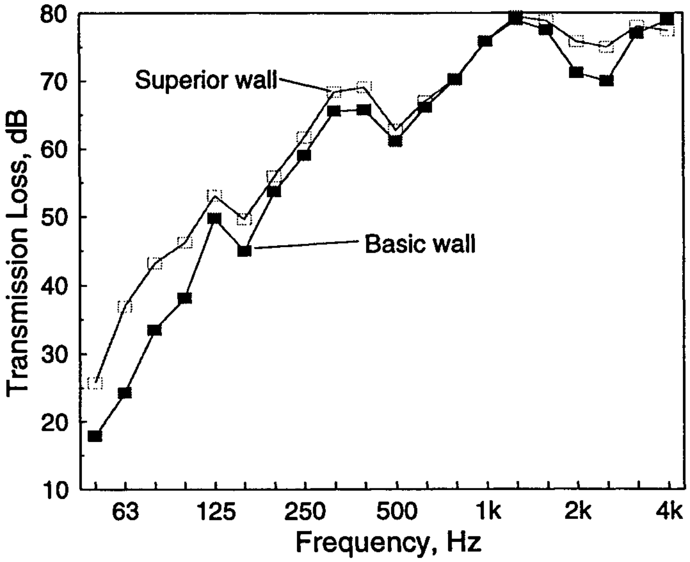
Figure A38 shows the apparent airborne sound insulation between rooms A and D for the basic and the superior walls. Over most of the frequency range there is no difference between the two indicating that the transmission is controlled by paths that do not involve the upper party wall.

Figure A38: Comparison of the Reference B apparent airborne sound insulation between rooms A and D for the basic and superior walls.



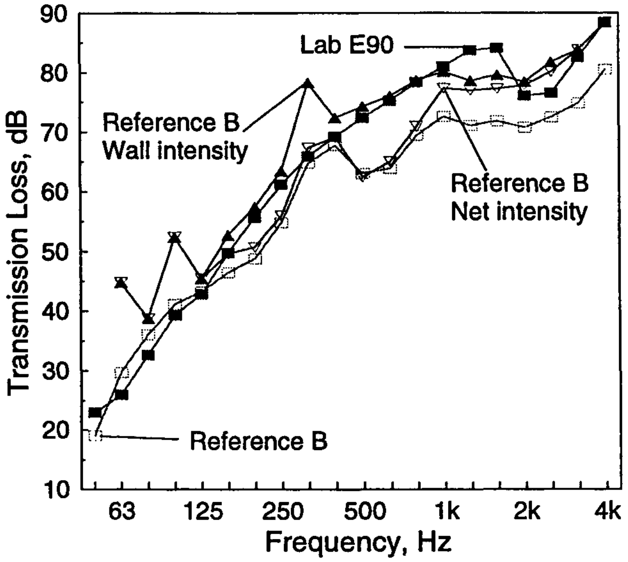
The situation is different between rooms B and C as shown in Figure A39. In this case transmission is controlled by paths involving both the party wall and the floor. This shows up as increased transmission loss at frequencies below 500 Hz and above 1000 Hz.

Figure A39: Comparison of the apparent airborne sound insulation between rooms B and C for the basic and superior walls.



The sum of the sound intensity through the party wall and the receiving room floor with the superior party wall installed are shown in Figure A40 and indicate that the apparent airborne sound insulation is controlled by transmission through the receiving room floor for frequencies below 1 kHz. The FSTC as measured with intensity through the party wall alone provides good agreement with the laboratory E90 measurement and appears to be the limiting case for frequencies above 1 kHz. It is clear though that above 800 Hz there is still substantial energy being transmitted via paths that do not include either the receiving room party wall surface or the receiving room floor. This is quite different from the basic wall case as discussed in Appendix B.

Figure A40: Comparison of the superior wall apparent airborne sound insulation for the Reference B with the Lab E90 for the same wall and the sum of the sound intensity through the party wall and receiving room floor.



Summary

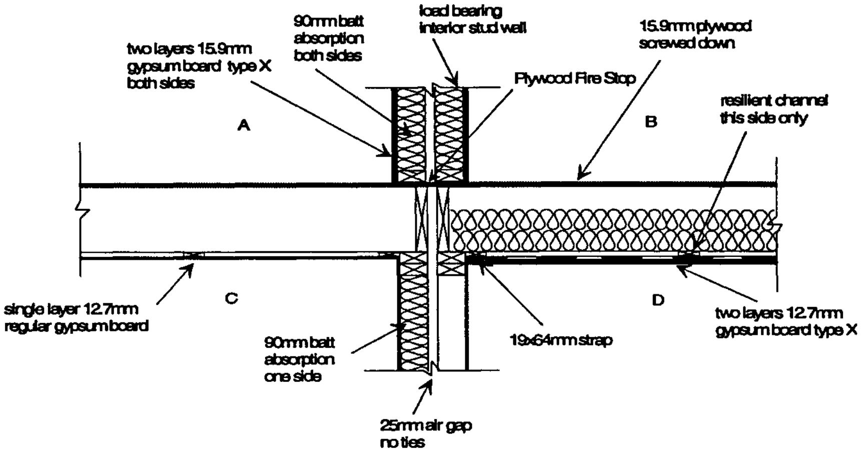
The Reference B measurements with the superior wall show that there are flanking paths associated with the supporting structure. This degradation of the wall occurs at high frequencies and only results in a 1 FSTC point degradation.

Case 11

Continuous 15.9mm Plywood Floor Decking

Case 11 may be compared directly to Case 7 to assess the effect of decking type, OSB or plywood, when the fire stop is formed by a continuous plywood sub-floor run under the party wall. Figure A41 shows that the Case 11 construction differs only from Case 7 in the type of sub-floor material. The measured apparent airborne sound insulation and apparent impact sound insulation are shown in Table A31 and Table A32. Also included for comparison are the Case 7 data.

Figure A41: Section through the floor and party wall of the Case 11 assembly.



Superior Party Wall Construction

In order to establish the flanking limits for this type of construction measurements were made with a superior party wall separating rooms A and B. To provide a reference case to which these could be compared, Case 7 data for the superior party wall are also given.

Table A31: Case 11 with superior wall apparent airborne sound insulation measured in accordance with ASTM E336 and expressed in terms of the single number rating FSTC.

Apparent airborne sound insulation		Room Pairs	Case: 11 with superior wall (FSTC)	Change re Case 7 with superior wall	Change re Reference B with superior wall
Apartment	Horizontal	A-B	51	-1	-15
	Vertical	B-D	55	-1	+0
	Diagonal	A-D	66	-1	-4
Row	Vertical	A-C	38	-2	-2
	Diagonal	B-C	62	+1	-8

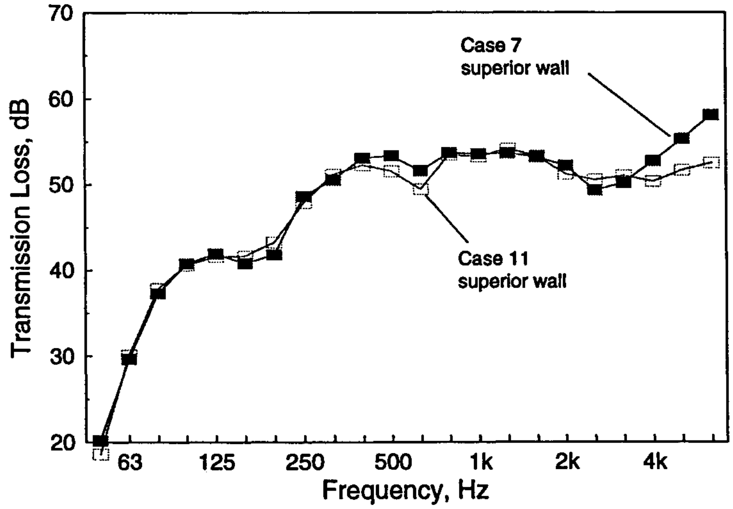
Table A32: Case 11 with superior wall apparent impact sound insulation measured in accordance with ASTM E1007 and expressed in terms of the single number rating FIIC.

Apparent impact sound insulation		Room Pairs	Case: 11 with superior wall (FIIC)	Change re Case 7 with superior wall	Change re: Reference B with superior wall
Apartment	Horizontal	A-B	51	0	-14
	Vertical	B-D	50	n/a	0
	Diagonal	A-D	56	n/a	n/a
Row	Vertical	A-C	33	n/a	0
	Diagonal	B-C	59	n/a	n/a

Technical discussion

Figure A42 provides a comparison of the apparent airborne sound insulation between rooms A and B for Cases 7 and 11. With the exception of a more pronounced dip in the transmission loss at 630 Hz, there is no appreciable difference in the sound insulation for frequencies below 1600 Hz. Frequencies 2000 Hz and above, the plywood exhibits lower sound insulation. This is due to the broad critical frequency range which is typical of constructions having plywood sheathing. The system with the plywood offered an apparent sound insulation of FSTC 51 between rooms A and B which was one point lower than the nominally identical construction with the continuous OSB.

Figure A42: Comparison of the A-B sound insulation for Case 7 (continuous OSB) and Case 11 (continuous plywood).

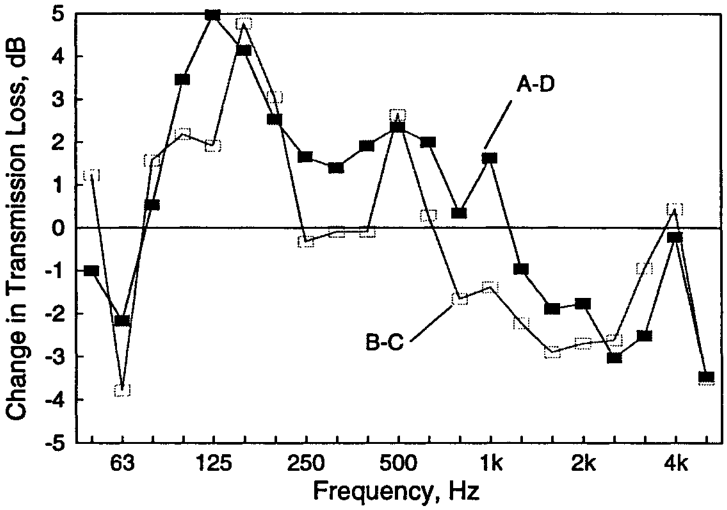


In terms of a single number rating the apparent sound insulation between room pairs on the diagonal where not appreciably affected by the change in floor decking type. The airborne sound insulation between A-D dropped by one point to FSTC 66, while B-C increased by one point to FSTC 62. Figure A43 shows that there was a distinct trend associated with the change in floor decking.

With the OSB sub-floor, both sets of rooms on the diagonal A-D and B-C, experienced greater low frequency sound insulation but reduced high frequency insulation.

The B-D sound insulation experienced a slight degradation as a result of replacing the OSB sub-floor with plywood; a one FSTC point drop was experienced.

Figure A43: Change in the apparent airborne sound insulation (Case 7 minus Case 11) for diagonal room pairs (A-D and B-C) as a result of replacing the continuous OSB sub-floor with continuous plywood.



Summary

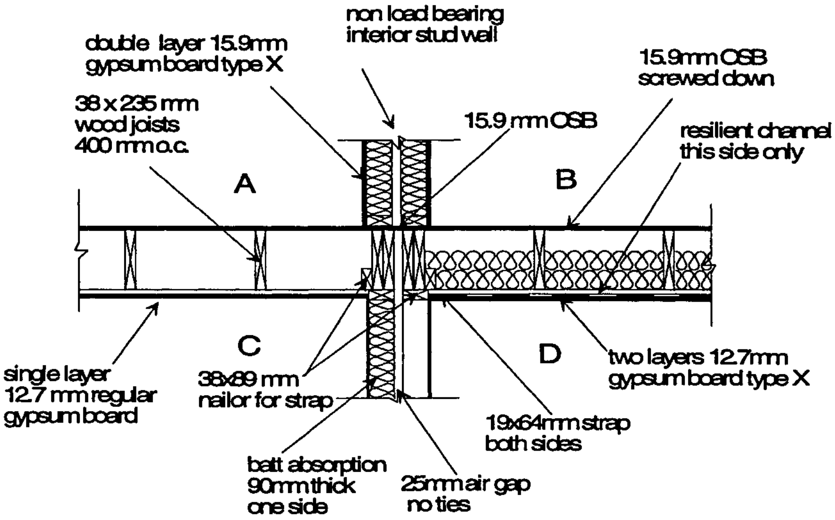
Case 7 and 11 data indicate that there was a slight but consistent degradation of the apparent airborne sound insulation as a result of replacing the continuous OSB floor decking with continuous plywood of the same thickness. Typically there was 1 FSTC point degradation. For practical purposes, in this report the apparent sound insulation of Cases 7 and 11 may be considered to be equal.

Case 12

Continuous 15.9mm OSB Floor Decking with Non-Load Bearing Party Walls

Case 12 may be compared directly to Case 7 to assess the effect of the floor framing orientation with respect to the party wall. In Case 7 the floor/ceiling assemblies were supported by a load bearing party wall which defines that the joists will be oriented at right angles to the party wall. Figure A44 shows that the Case 12 construction differed from the Case 7 construction only in that the floor/ceiling assembly was oriented so the joists were parallel to the party wall (i.e., the floor had been rotated through 90 degrees and the party wall construction was unchanged).

Figure A44: Section through the floor and party wall of the Case 12 assembly.



Superior Party Wall Construction

In order to establish the flanking limits for this type of construction measurements were made with a superior party wall separating rooms A and B. The measured apparent airborne sound insulation and apparent impact sound insulation are shown in Table A33 and Table A34. To provide a reference case to which these could be compared Case 7 data for the superior party wall are also given.

Table A33: Case 12 with superior wall apparent airborne sound insulation measured in accordance with ASTM E336 and expressed in terms of the single number rating FSTC.

Apparent airborne sound insulation		Room Pairs	Case: 12 with superior wall (FSTC)	Change re Case 7 with superior wall
Apartment	Horizontal	A-B	48	-4
	Vertical	B-D	58	+2
	Diagonal	A-D	67	0

Row	Vertical	A-C	38	-2
	Diagonal	B-C	59	-2

Table A34: Case 12 with superior wall apparent impact sound insulation measured in accordance with ASTM E1007 and expressed in terms of the single number rating FIIC.

Apparent impact sound insulation		Room Pairs	Case: 12 with superior wall (FIIC)	Change re: Case 7 with superior wall
Apartment	Horizontal	A-B	55	+3
	Vertical	B-D	52	n/a
	Diagonal	A-D	55	n/a
Row	Vertical	A-C	32	n/a
	Diagonal	B-C	62	n/a

Technical discussion

Table A33 shows that the orientation of the floor framing members can have a very significant impact on the airborne sound insulation. The A-B sound insulation was degraded by 4 FSTC points as a result of changing the joist orientation from perpendicular to parallel to the party wall (which is equivalent to changing the party wall from load bearing to non-load bearing).

Figure A45: Comparison of the A-B airborne sound insulation for Case 12 (non-load bearing party wall) and Case 7 (load bearing party wall). Structurally, the difference between the two constructions is that the floor/ceiling assembly has been rotated through 90 degrees so that the joists are parallel to the party wall in Case 12.

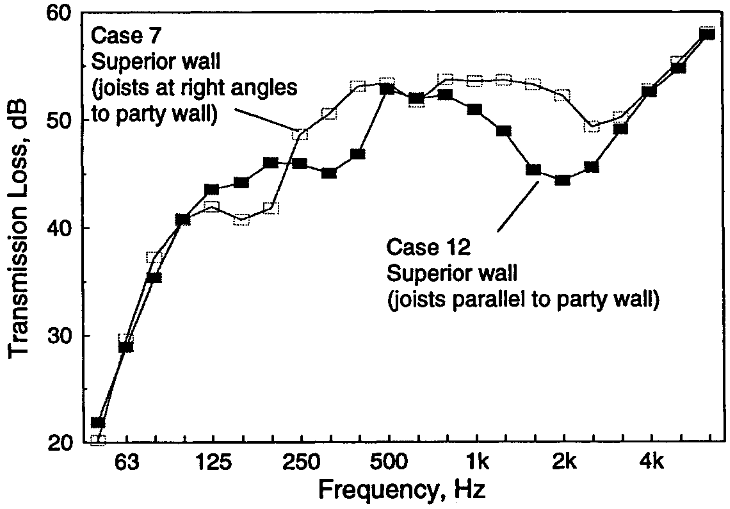
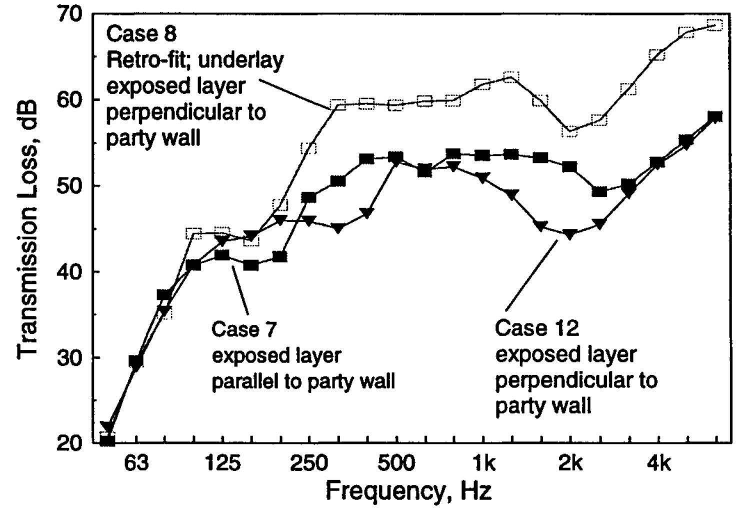


Figure A45 shows that in the frequency range 125 – 3150 Hz the measured A-B sound insulation is significantly different. The characteristic dip in the transmission loss at 160 Hz that was present in Case 7, and all other cases, appears to have shifted in frequency to 315 Hz. There also appears to be a shift in the critical frequency. In Case 7 (with the joists at right angles to the party wall), the critical frequency occurred at about 2500 Hz and resulted in a shallow dip in the TL response. However, in Case 12 the critical frequency occurred at about 2000 Hz and resulted in a strong and broad dip in the transmission loss performance.

Figure A46 indicates that when the underlay retro-fit (of Case 8) was applied to Case 7 a similar shift in the critical frequency occurred. The OSB underlay sheet of Case 8 was applied at right angles to the base layer so the exposed layer was perpendicular to the party wall; the same orientation as in Case 12. This suggests that that orientation of the exposed decking may be an important factor in determining the apparent sound insulation in the mid to high frequencies. It is interesting to note that the dip at 160 Hz was unaffected by the change in the orientation of the exposed OSB material. This further suggests that the 160 Hz dip (load bearing party walls) and 315 Hz (non-load bearing party wall) may be associated with the orientation of the joists.

Figure A46: Comparison of the A-B critical frequency as a function of the orientation of the exposed OSB floor surface. In Cases 8 and 12 the OSB sheets are oriented perpendicular to the party wall, while for Case 7 they are parallel to the party wall.



The apparent impact sound insulation was also affected by the change in floor orientation. However, unlike the airborne sound insulation, the impact sound insulation increased as a result of orienting the framing members parallel to the party wall. A 4 FIIC point increase was experienced.

If an analysis of the flanking paths between rooms A and B were conducted for both airborne and impact excitation, it would suggest that the change in A-B sound insulation might be explained if the path 1-3-8-5-7 (wall -to- fire stop -to- wall as shown in Figure A1) had become considerably more important as a result of the floor orientation. Path 1-3-8-5-7 is the only one not involved in the impact transmission for the two directions.

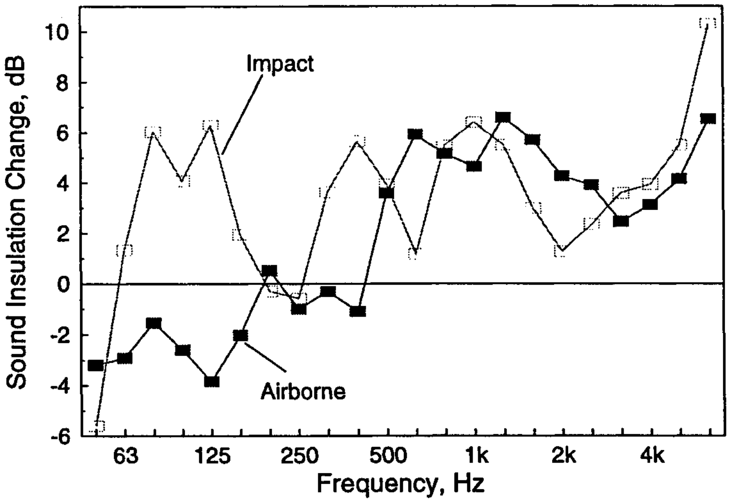
However, such a simplistic path analysis assumes that vibration energy propagating in the floor decking parallel to the joists experiences the same losses as energy propagating across the joists.

Data from a previous study has shown that vibratory energy propagating in the floor decking of a framed floor/ceiling assembly experiences much greater attenuation when traveling in a direction perpendicular to the joists. This may partially explain the improvement in the Case 12 A-B impact sound insulation where energy must propagate at right angles to the joists in order to reach the joint at the party wall. Further work is needed to determine the exact cause of the change in sound insulation.

Both the B-D airborne and impact sound insulation improved as a result of the change in floor orientation. With the floor joists parallel to the party wall (Case 12; non-load bearing party wall) the airborne sound insulation increased by 2 points to FSTC 58, while the impact sound insulation increased by 1 point to FSTC 52.

Figure A47 shows that in the frequency range 630—3150 Hz both the airborne and impact sound insulation increased by about 4 dB as a result of changing the orientation of the floor framing members from perpendicular to parallel to the supporting party wall. Below 630 Hz the trends are very different. The airborne sound insulation decreased while the impact sound insulation increased.

Figure A47: Change in A-B sound insulation (Case 12 minus Case 7) that resulted from reorienting the floor so that the party wall is non-load bearing.



If there is a significantly different rate of attenuation for vibratory energy propagating parallel or perpendicular to the floor framing members then a change in the orientation of the floor would significantly affect the importance of flanking paths involving the floor decking. In Case 12, flanking paths involving the floor decking of room B (which controlled the Case 7 sound insulation in the mid to high frequencies) will be highly attenuated because vibratory energy incident on the floor/wall joint must propagate at right angles to the joists.

Summary

A comparison of the Case 7 and 12 data indicate that the orientation of the floor framing members (i.e., whether the party wall is load bearing or non-load bearing) has a significant impact on the apparent sound insulation (both airborne and impact) between rooms for which there exist flanking paths involving the floor decking.

The effect of the floor framing members is complex and effects the airborne and impact sound insulation differently. Between rooms A and B the airborne sound insulation was degraded by 4 FSTC points while between rooms B and D there was an increase of 3 FSTC. Thus, if the A-B sound insulation were to be maximized then a load bearing party wall would be used (so that the floor joists would be perpendicular to the party wall), while if B-D sound insulation were to be maximized then a non-load bearing party wall would be used (so that the floor joists would be parallel to the party wall).

Further work is needed to understand how vibratory energy propagates across a framed floor and to determine the construction details that will increase the sound insulation without increasing construction cost.

REFERENCES

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[4] ANSI S12.12-1992

[5] Quirt, J.D., Warnock, A.C.C., Birta, J.A., "Summary report for the consortium on gypsum board walls: Sound transmission results," NRC Internal Report IRC-IR-693, October 1995.

[6] Craik, R.J.M., Nightingale, T.R.T., Steel, J.A., "Sound transmission through a double leaf partition with edge flanking," J. Acous. Soc. Am., Vol. 101, No. 2, pp. 964-969, 1997.

[7] Craik, R.J.M., Nightingale, T.R.T., Steel, J.A., "Sound transmission through a double leaf partition with edge flanking," J. Acous. Soc. Am., Vol. 101, No. 2, pp. 964-969, 1997.

Appendix B

Reference A-B Sound Insulation

with

Basic Party Wall Construction

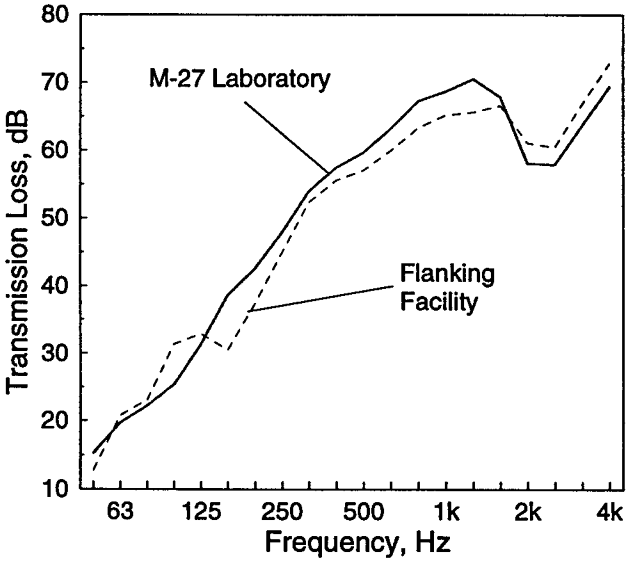
INTRODUCTION

This Appendix will compare the apparent airborne sound insulation for the Reference A party wall between rooms A and B to the nominally identical wall tested under the "no-flanking" conditions of ASTM E90. Differences between the sets of measured sound insulation data will be discussed as well as the practical implications to the sound insulation than can be expected for complete constructions in the field.

MEASURED SOUND INSULATION DATA

Figure B1 compares the sound insulation of the Reference A party wall (15.9 mm Type X gypsum board, wood studs, 90 mm mineral fibre batt, 25 mm air space, wood studs, 15.9 mm Type X gypsum board) as measured in the Flanking Facility with the nominally identical wall measured in the M-27 Laboratory. It is clear that the two sets of measured sound insulation data are not identical despite having nominally identical wall construction. The differences in the measured transmission loss data are reflected in the single number ratings. In the laboratory, the party wall achieved an STC 55 while the same wall installed in Base Case specimen (without structural flanking at the joint) only achieved an FSTC 51.

Figure B1: Measured transmission loss data for the Reference A party wall in the Flanking Facility and the nominally identical wall in the M-27 Laboratory.



The differences between the two sets of data can be explained by examining differences in the facilities.

DISCUSSION OF THE MEASURED DATA

It is clear from the measured transmission loss data of Figure B1 that in the very low frequencies, 63-125 Hz, the measured sound insulation of the wall assembly is greater when measured in the flanking facility than when measured in the M-27 Laboratory. This measured difference in the low frequency sound insulation may be attributed to the difference in room sizes for the two tests facilities. The receiving room of the flanking facility is too small to support many modes of vibration in the frequency range 63-125 Hz. The M 27 receiving room is sufficiently large to support modes in the lowest part of this frequency range. Very simply, the receiving rooms are behaving differently due to their different volumes.

It is generally recognized that tests conducted with small receiving rooms tend to overestimate low-frequency sound insulation when compared to tests conducted with a much larger receiving room. Since the room volumes of the flanking facility more closely match the volumes of rooms in multi-family dwellings, measured data of the flanking facility correctly reflect the effect of room size that would be experienced in real constructions.

Test chambers used to conduct the ASTM E90 test method tend to be very large (maybe 6-8 times the volume of the flanking facility room) in order to remove any errors associated with room size. It is very important for the receiving room to have a large volume to avoid introducing a measurement bias in the low-frequency sound insulation.

In the very high frequencies, 1250-5000 Hz, the measured transmission loss is also higher in the flanking facility than in the M-27 Laboratory. This is typical of laboratories that were designed to conduct ASTM E90 transmission loss tests on a wide range of wall or floor specimens. Many authors[1] and the International Standards Organization in ISO 140 Part 3[2] (ISO equivalent of ASTM E 90) recognize that a difference in specimen mounting can significantly affect the measured sound insulation in the high frequencies (i.e., above the critical frequency of the specimen). In the flanking facility, the specimens are mounted to walls or floors of similar mass which enables the specimen to easily transmit energy to other parts of the structure which reduces the amount of energy radiated into the receiving room. In E90 laboratory facilities, the mounting is usually very heavy relative to the specimen. In such cases, transmission into the mount is not very efficient so more energy is radiated into the receiving room, which means the specimen in the E90 facility will exhibit a lower sound insulation.

In the range 160-1000 Hz, the transmission loss is lower in the Flanking Facility than in the M-27 Laboratory. This can best be attributed to flanking paths involving the floor, side walls and ceiling of the source and receiving room.

In the 160 Hz frequency band, the measured data obtained in the flanking facility shows a significant drop in transmission loss relative to the M-27 Laboratory. It is thought that this is due to the interaction of the wall/floor system. This dip at 160 Hz is unfortunate because transmission loss in this band determines the single number STC rating. Several tests have been conducted to investigate the reduction in sound insulation at 160 Hz. The results are now presented and discussed.

In order not to introduce flanking paths in the E90 test measurement, the facility surfaces are extremely thick and massive, typically about 8” thick high density concrete. This is quite different than the very lightweight floor assembly on which the upper party wall is mounted. It was shown in Appendix A (see Figure A1) that mounting the party wall on a lightweight floor assembly caused there to be three flanking paths. It is thought that one or more of these three flanking paths involving the floor is contributing to the degradation in the sound insulation at 160 Hz.

Figure B2: Measured sound insulation for the Reference A party wall in the Flanking Facility with the floor of both the source and receiving rooms masked. Given for comparison is measured sound insulation of the nominally identical wall in the M-27 Laboratory.

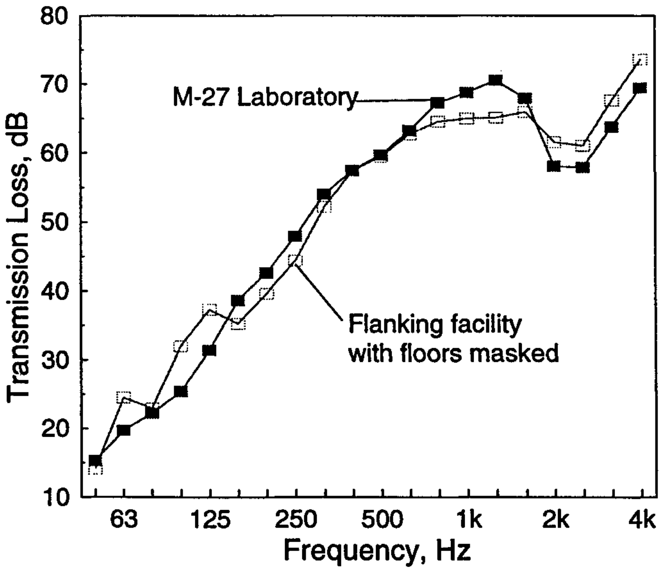


Figure B2 shows the measured sound insulation for the Reference A party wall in the flanking facility when the floors in both the source and receiving rooms are masked (covered with 50 mm thick sound absorbing material and a layer of 13 mm thick gypsum board). It can be seen that there is some improvement in the sound insulation in the frequency bands 160-1000 Hz. This suggests that if all flanking paths involving the floor, side walls and ceiling were completely suppressed then the sound insulation in this frequency range would approach that of the same wall under E90 conditions. With the floors masked the apparent airborne sound insulation between rooms A and B was FSTC 56 which is one STC point higher than the identical wall measured under E90 conditions. As stated earlier, a one STC point difference in measures should not be considered significant. Differences in the high frequencies (1250 Hz and above) are still present since the floor masking does not affect the ability of the wall to dissipate energy at its edges.

Further supporting this premise, Figure B3 shows the measured sound insulation of the wall assembly when the ANSI S12.12 intensity test method is used to obtain the radiated sound power. There are two differences to notice. First, the agreement is better in the very low frequencies (50-125 Hz). This is because the intensity technique is independent of the volume of the receiving room quite unlike the ASTM E90 and E336 test methods. Second, the 160-1000 Hz degradation is very much diminished relative to the case when both the source and receiving room floors were exposed. This is because the intensity technique enables the sound insulation of transmission paths for the individual surfaces to be determined. When the intensity technique is applied to the receiving room party wall only the direct path and flanking path involving that wall are measured (1-3-4-5-7 and 1-2-3-4-5-7) omitting the two paths involving the receiving room floor (1-3-4-5-6-7, 1-2-3-4-5-6-7). (Figure A1 of Appendix A shows the paths.) The sound insulation for the two paths involving the receiving room wall was FSTC 56 the same as when both the source and receiving room floors were masked.

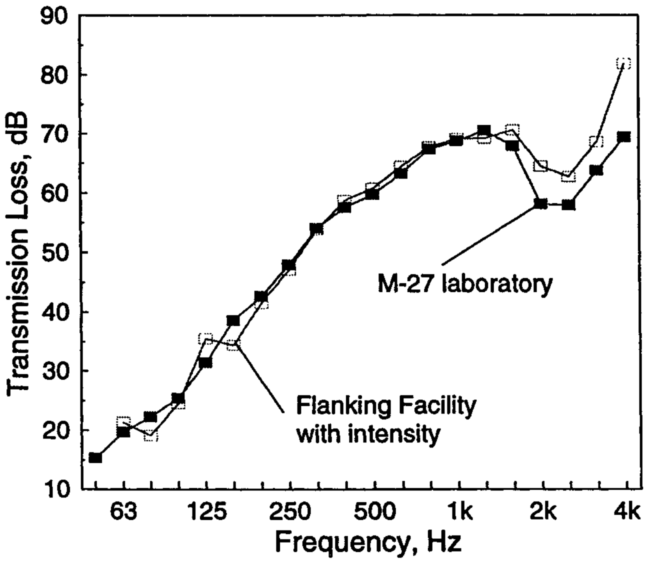


Figure B3: Measured sound insulation for the Reference A party wall in the Flanking Facility using the sound intensity technique. Given for comparison is measured sound insulation of the nominally identical wall in the M-27 Laboratory.

If the floor of the source room were masked the only flanking path contained in the measured intensity data (1-2-3-4-5-7) would be removed and the measured sound insulation for the party wall as installed in the flanking facility would agree with the same wall measured under E90 conditions. As before, the mounting of the specimen determines the sound insulation in the frequency range 1600 Hz and above.

This argument ignores the fact that there are also flanking paths involving the side walls and ceilings of the source and receiving rooms analogous to those involving the floor. In general, these paths would be expected to have much higher transmission loss since these surfaces are much heavier than the floor. When the Reference B case was measured with the superior party wall, it was found the performance was badly degraded at all frequencies above 500 Hz, suggesting that for this wall these other flanking paths were beginning to become important.

CONCLUSIONS

Room size was found to effect the measured low frequency insulation (50-125 Hz); a very small receiving room tended to bias the results toward higher transmission loss values. The mounting of the specimen was shown to effect the sound insulation performance of the specimen at high frequencies (1250-4000 Hz). The specimen exhibited the greater measured sound insulation when mounted to a construction of like mass.

The Reference A basic wall demonstrated that as much as a 2 to 3 STC point degradation in the wall sound insulation can be experienced relative to laboratory tests even without structural flanking bridging the two leaves of a double stud wall. The degradation is thought to be due to the interaction of the wall and the supporting floor and as such will be a function of the floor construction (decking type, thickness, joist orientation, floor bridging/strapping and cavity absorption). Further work needs to be conducted to determine the precise cause of the degradation and methods to minimize it.

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1 R. J. M. Craik, "The Influence of the Laboratory on Measurements of Wall Performance", Applied Acoustics, Vol. 35, pp. 25-46, 1992.

2 ISO 140 Acoustics – Measurement of sound insulation in buildings and of building elements Part 3: Laboratory measurement of airborne sound insulation of building elements International Organization for Standardization.

Appendix C

Analysis of Flanking Transmission

Between Rooms B and D

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STATISTICAL ENERGY ANALYSIS APPLIED TO LIGHTWEIGHT CONSTRUCTIONS PART 1: SOUND TRANSMISSION THROUGH FLOORS

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This is the first of three papers on the application of statistical energy analysis (SEA) to a lightweight wood frame construction. In this paper the basic theory behind SEA will be presented by examining a simple model for sound propagation through the floor/ceiling assembly shown in Figure 1.

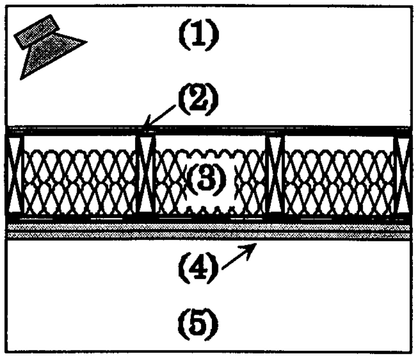

Figure 1: Sketch of the floor/ceiling assembly. (1): source room, (2): 15.9 mm OSB decking, (3): 235 mm deep cavity with two layers of 89 mm batt insulation, (4): 2 layers 12.7 mm type X gypsum board mounted on resilient channels, (5): receive room.

SEA enables the prediction of energy contained in individual elements (or sub-systems) of a complete system when power is input in one or more of the sub-systems. The basic principle of SEA requires that the power, W, into a sub-system is equal to the power lost either through transmission, radiation, or internal losses.

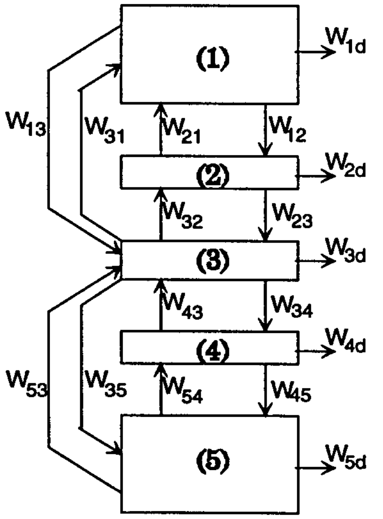

Figure 2: Sub-system diagram for the SEA model of the modelled floor/ceiling assembly.

Figure 2 shows a sub-system diagram with the paths of power flow illustrated by the arrows. It has been assumed that the resilient channels remove any coupling between the floor decking and the gypsum board ceiling via the joists. There are arrows showing power flow directly from room to cavity or via versa apparently without involving the floor decking or the gypsum board ceiling. These represent the non-resonant paths of energy transport that are essentially independent of the damping of the element through which energy passes.

The following set of equations can be written describing the partition of energy between the sub-systems,

$$\begin{bmatrix} -\eta_1 & \eta_{21} & \eta_{31} & 0 & 0 \\ \eta_{12} & -\eta_2 & \eta_{32} & 0 & 0 \\ \eta_{13} & \eta_{23} & -\eta_3 & \eta_{43} & \eta_{53} \\ 0 & 0 & \eta_{34} & -\eta_4 & \eta_{54} \\ 0 & 0 & \eta_{35} & \eta_{45} & -\eta_5 \end{bmatrix} \bullet \begin{bmatrix} E_1 \\ E_2 \\ E_3 \\ E_4 \\ E_5 \end{bmatrix} = \begin{bmatrix} -W_1/\omega \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \qquad [1]$$

where the power flow between sub-systems i and j is given by

$$W_{ij} = E_i \omega \eta_{ij}, \qquad [2]$$

E_i is the energy stored in i, ω is the angular frequency, and η_{ij} is the coupling loss factor (CLF) between i and j. The CLF is defined as the fraction of energy transmitted in one radian cycle. Also, the concept of a total loss factor (TLF) was introduced to simplify the set of equations,

$$\eta_i = \eta_{id} + \sum_j \eta_{ij}, \qquad [3]$$

where j indicates the sub-systems to which i is connected and η_{id} is the internal loss factor. The TLF is the faction of energy transmitted, lost due heat and radiation. The TLF is easily measured as it is a simple function of the reverberation time, T, and frequency, f,

$$\eta_i = \frac{2.2}{fT_i} \qquad [4]$$

Thus the energy in any one of the sub-systems can be found by solving a set of equations involving CLF's and TLF's.

CLF's

The CLF will depend on i and j and how they are coupled. It is beyond the scope of this paper to derive the individual CLF equations but rather they will just be presented to indicate their dependencies. Craik has previously provided a detailed examination[1].

Resonant transmission from a room volume to a plate (i.e., (1) to (2) and (5) to (4)) is given by,

$$\eta_{12} = \frac{5556 S_2 f_{c2} \sigma_2}{V_1 \rho_{s2} f^3}, \qquad [5]$$

where S_2 is the surface area of the decking, f_{c2} is its critical frequency, ρ_{s2} is its surface density, and f is the frequency. The radiation factor, σ, can be calculated from various equations[2] depending on the accuracy required.

Resonant transmission from a plate to a room (i.e., (2) to (3), and (4) to (5)) is given by,

$$\eta_{45} = \frac{66\sigma_4}{\rho_{s4} f}. \qquad [6]$$

If the method of energy transport between rooms/cavities is non-resonant transmission then the coupling loss factor can be determined from the non-resonant transmission coefficient, τ_{ij}, for the element separating the rooms or cavities. For example, the CLF between the source room (1) and the floor cavity (3) for non-resonant transmission is,

$$\eta_{13} = \frac{13.7 S_3 \tau_{13}}{f V_1}, \qquad [7]$$

where τ_{13} is the transmission coefficient of the floor decking.

CLF's associated with joints occur commonly when modelling complete building assemblies,

$$\eta_{ij} = 0.1365 \left(\frac{h C_{Li}}{f} \right)^{\frac{1}{2}} \frac{L}{S_i} \tau_{ij} \qquad [8]$$

where C_{Li} is longitudinal wave speed for sub-system i, L is the length of the joint, S_i is the surface area of the sub-system i, and τ_{ij} is the power transmission coefficient between i and j.

The CLF between two sub-systems can be measured using the consistency relation,

$$\eta_{12} = \frac{E_2 \eta_2}{E_1}, \qquad [9]$$

where η is the modal density. In writing this equation it has been assumed that the power input into sub-system 2 from all other subsystems other than 1 can be ignored. The estimates of the energy contained in a plate can be obtained from the measured space-time averaged surface velocity $<v^2>$ given,

$$E_{plate} = \langle v^2 \rangle \rho_s S, \qquad [10]$$

where ρ_s is the surface density, and S is surface area. Alternately, if the sub-system is a room or cavity then the energy can be estimated from the space-time average sound pressure $<p^2>$ given,

$$E_{room/cavity} = \frac{\langle p^2 \rangle V}{\rho_o c_o^2}, \qquad [11]$$

where V is the room volume, ρ_o is the density of air, and c_o is the speed of sound in air.

Transmission through the floor cavity

The model of Price and Crocker[3] was used to predict the transmission through cavity. It assumes that transmission from a room into the cavity of a partition wall or floor is the same as transmission into a small room from a much larger room. Both resonant and non-resonant transmission are possible. Transmission out of the partition cavity into the receive room then follows from the consistency relationship,

$$n_{room} \eta_{room,cavity} = n_{cavity} \eta_{cavity,room} \qquad [12]$$

where n is the modal density.

Measured and Predicted Results

Often it is easier, and even more accurate, to use the measured TLF for a similar or nominally identical sub-system in a similar construction than it is to assume that the TLF is the sum of the CLF's. Given in Table 1 are the measured regression fit equations for the total loss factors of some common lightweight building elements,

Sub-system	Density (kg/m^3)	Total loss factor
Gypsum board of a wood stud wall	751	$0.5f^{-0.37}$
16 mm OSB floor decking	451	$0.4f^{-0.37}$
Wood joist floor cavity 1/2 to 3/4 full of absorption	n/a	$3.0f^{-0.34}$

Table 1: Computed TLF's from measured data for some common building elements. Values will vary depending on specific factors such as joint types amount and type of cavity absorption, etc.

The five sub-system model shown in Figure 1 represents a very simplified model for the floor ceiling assembly. The effect of the joists have been ignored, and it is assumed that the resilient channel prevents structure borne transmission from the decking to the gypsum board ceiling. The measured TLF's listed in Table 1 were used in the model. All CLF's were calculated according the equations given. Figure 3 shows that despite the very simple model the measured and predicted results are in good agreement.

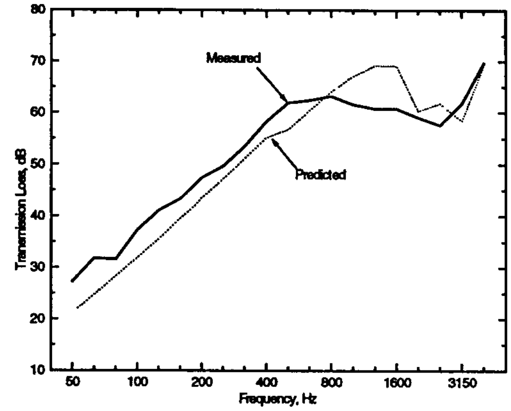

Figure 3: Measured and predicted transmission loss.

The SEA prediction tends to overestimate the efficiency of the coupling between the room/cavities and the wall surfaces, thus underestimating the transmission loss. This is especially true at the critical frequencies (2000 and 3000 Hz). More accurate models of the radiation efficiency which controls the degree of coupling can be used but with significantly more computation time.

Conclusions

The predicted transmission loss of the simplified model agrees well with measured results despite the many assumptions (the resilient channels remove any physical coupling from floor decking to the gypsum board ceiling via the joists, and the joists have no effect). The model showed that transmission through a cavity can be modelled using the method of Price and Crocker.

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STATISTICAL ENERGY ANALYSIS APPLIED TO LIGHTWEIGHT CONSTRUCTIONS PART 2: JOINTS BETWEEN FLOORS AND PARTY WALLS

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This is the second of three papers on the application of statistical energy analysis (SEA) to a lightweight wood frame construction. This paper considers methods of modelling the joint that is formed when a load bearing party wall is added to the floor/ceiling assembly considered in Part 1[1] of this series. As in Part 1, the SEA model will use assumptions to keep the model as simple as possible. They are: there is no significant coupling between the floor decking and the gypsum board ceiling, the studs of the walls can be ignored, and the joists of the floor/ceiling assembly can be ignored. The simplified assembly and the sub-systems are shown in Figure 1.

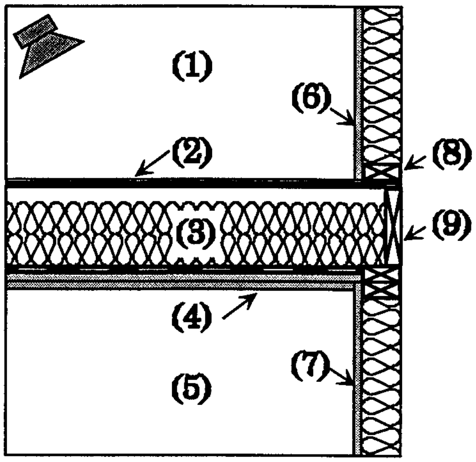

Figure 1: Section through the floor and load-bearing party walls. (1): source room, (2): 15.9 mm OSB decking, (3): 235 mm deep cavity with two layers of 89 mm batt insulation, (4): 2 layers 12.7 mm type X gypsum board mounted on resilient channels, (5): receive room, (6) and (7): 15.9 mm type X gypsum board, (8): 38x89 mm sole plate, (9): 38x235 mm joist header.

The material properties of sub-systems are given in Table 1.

Sub-system	length (m)	width (m)	height (m)	density (kg/m^3)	f_c (Hz)
2	4.5	4.6	n/a	451	2000
4	4.5	4.6	n/a	751	3000
6	4.5	n/a	2.4	751	2500
7	4.5	n/a	2.0	751	2500
8	4.5	0.089	0.038	451	n/a
9	4.5	0.038	0.235	451	n/a

Table 1: Material properties of the sub-systems.

From Figure 1, which shows the sub-systems of the simplified model SEA model, it can be seen that the load bearing party wall introduces a series of flanking paths: 1-6-7-5, 1-2-7-5, 1-2-6-7-5, etc. It is assumed that the gypsum board ceiling (sub-system (4)) is not involved in any of the flanking paths since it is mounted on resilient channels and is only very weakly connected to the head of the lower party wall.

In order to model the flanking paths, the joint between the walls and the floor/ceiling assembly must be modelled. A series of different models for the joint are now presented and their accuracy discussed.

Simple Tee Joint

A tee formed by the intersection of the gypsum board party wall (sub-systems (6) and (7)) by the OSB floor decking (sub-system (2)) is the simplest representation of the joint. It is assumed that the plates are rigidly connected and that the beams (sub-systems (8) and (9)) at the joint can be ignored. In Figures 2, 3 and 4 the predicted velocity level differences (VLD's) are shown and labeled as 'Simple "Tee"'. Measured data is also shown for comparison. The simple tee joint model completely fails to predict the VLD's (as calculated from Equation 10[1]) for the paths 2-7 shown in Figure 3 and 6-7 shown in Figure 4. The prediction for path 2-6 is perhaps the best of the three predictions; showing the general trend for frequencies greater than 400 Hz. It is clear from the measured data that the type of coupling between the floor decking (2) and the upper party wall (6) is different than that to the lower party wall (7). A more complex model is required which does not have the symmetry suggested by the simple tee joint.

Tee Joint with a Beam

The upper and lower party walls are of nominally identical construction so it is likely that the differences in the measured VLD's between the two paths 3-5 and 3-6 will be due to different coupling mechanisms for each path. Figure 1 suggests that the joist header might be involved in the coupling between the floor decking and the lower party wall. Similarly, the upper party wall might be viewed as also being connected to the joist header. In this representation the head plates of the lower party wall are taken to be an extension of the joist header thereby making an equivalent beam of dimension 38x311 mm. The model of Steel[2] was used to calculate the joint transmission coefficients and using Equation 10[1] the VLD's were computed. In Figures 2, 3 and 4 the predictions are labeled '"Tee" with Beam' and show that including a joist header did not improve the accuracy of the predictions for any of the paths. This suggests that the joint may not behave as a "Tee".

Examining the measured data, it can be seen that the VLD for the path 6-7 is close to the sum of the VLD's for the paths 2-6 and 2-7. This might suggest that the joint should be modelled as two corner joints sharing a common plate; the floor decking (sub-system (2)).

Two corner joints sharing a common plate

In this representation, the joint is modelled as being two corner joints sharing a common plate, the floor decking. The first corner joint will be between the floor decking (2) and the gypsum board of the upper party wall (6). The 38x89 mm sole plate (8) common to both (2) and (6) is included. The second corner joint will be between the floor decking (2) and the lower party wall (7). The 38x235 mm joist header (9) common to both is included. The predicted VLD's for the three paths are labeled "2 Corner Joints" and are shown in Figures 2, 3 and 4. For all three paths there is reasonably good agreement between measured and predicted results for the frequency range 400-4000 Hz. However, below 400 Hz the predictions are quite poor. The VLD's are underestimated and in all cases the wrong trend is indicated.

Discussion

For most ribbed panels there is a transition between behaving as a single plate and a series of independent sub-panels defined by the ribs. The 400 Hz third octave marks the cut-on of cross modes in the sub-panels and a corresponding increase in modal density as shown in Table 2.

1/3 Octave Band (Hz)	Number of Modes	Angular range (degrees)
Less than 100	0	n/a
100	5	$5 \le \theta \le 23$
125	3	$27 \le \theta \le 35$
160	3	$38 \le \theta \le 44$
200	2	$46 \le \theta \le 49$
250	3	$51 \le \theta \le 54$
315	3	$56 \le \theta \le 59$
400	13	$5 \le \theta \le 62$

Table 2: Number of modes and angular range for the OSB floor decking sub-panels (0.4x4.6 m dimension).

Below about 400 Hz the floor may behave as a single plate or a series of independent sub-panels. As sub-panels, there are only a very small number of modes in any one of the third octaves below 400 Hz. The angular range of the modes within each third octave band is quite narrow. This does not satisfy the requirent of SEA that there be a diffuse field.

To investigate the behaviour of the sub-panels, all the modes were computed along with their angle of incidence on the joint. The joint transmission coefficients for each mode were computed using the "two corner joints sharing a common plate" model and band averaged to compute the VLD's in the usual way. The results are shown in the Figures and labeled as "2 Corner Joints + Modes". Improvement in the predictions for all paths are shown for frequencies above about 315 Hz. This suggests that the sub-panel model is the most accurate once the cross modes have cut-on. For paths 2-6 and 2-7 the sub-panel model apparently improved results for frequencies below 315 Hz. However, this was not the case for 6-7.

Conclusions

Measured and predicted results for sound transmission along flanking paths have been shown. Best agreement is found with predictions which allow for separate joints. The first is between floor deck and upper party wall with the sole plate included. The second is between the floor deck and lower party wall with the joist header included. Modelling the system using two joints assumes that there is no direct coupling mechanism between the sole plate and the joist header. In measured specimen, the sole plate was nailed to the floor decking and not the joist header.

The model gives very good agreement with measured results at frequencies above 400 Hz with measured and predicted transmission reducing with increasing frequency. It is in this range of very good agreement where flanking paths involving the joint may become significant. At lower frequencies where flanking via the joints will not be important, the measured transmission is much weaker than predicted.

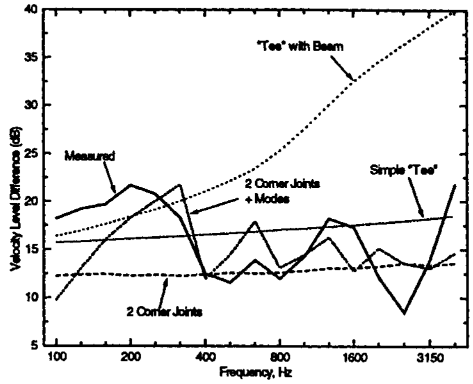

Figure 2: Measured and predicted velocity level differences for transmission from floor decking (2) to upper party wall (6).

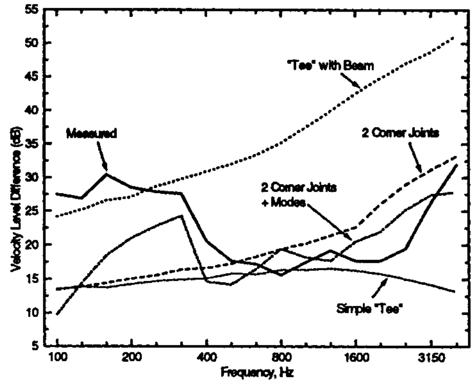

Figure 3: Measured and predicted velocity level differences for transmission from floor decking (2) to lower party wall (7).

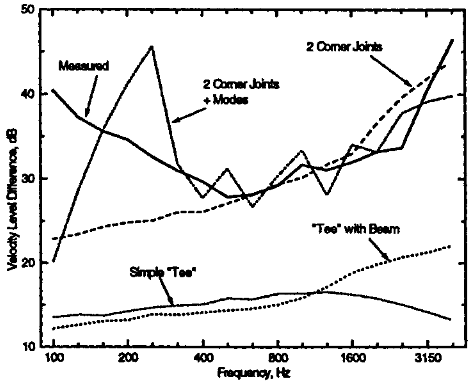

Figure 4: Measured and predicted velocity level differences for transmission from the upper party wall (6) to the lower party wall (7).

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[1] Nightingale, Craik, Steel, "Statistical energy analysis applied to lightweight constructions Part 1: sound transmission through floors," Canadian Acoustics, Vol 23, No. 3, pp 41-42, 1995.

[2] Steel, John, A., "Sound transmission between plates in framed structures," Journal of Sound and Vibration, Vol 178, No 3, pp. 379-394, 1994.

STATISTICAL ENERGY ANALYSIS APPLIED TO LIGHTWEIGHT CONSTRUCTIONS PART 3: MEASUREMENTS AND PREDICTIONS OF FLANKING TRANSMISSION

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This is the third of three papers on the application of statistical energy analysis (SEA) to a lightweight wood frame construction. This paper takes the basic model for direct transmission presented in Part 1[1] and uses the 'two corner joints sharing a common plate' model developed in Part 2[2] to describe the coupling to the load bearing party walls. The model will be used to reveal the dominant flanking paths and to investigate the potential effectiveness of two retrofits.

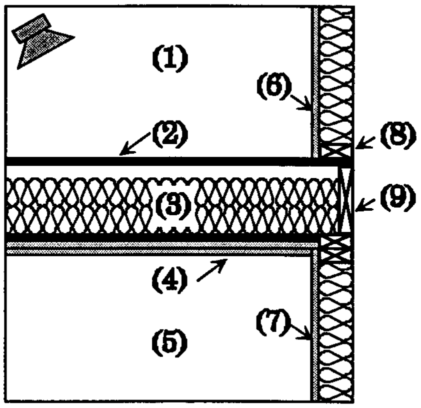

Figure 1: Sketch the floor/ceiling assembly and the load bearing party walls that are modelled. The sub-systems are (1): source room, (2): 15.9 mm OSB decking, (3): 235 mm deep cavity with two layers of 89 mm batt insulation, (4): 2 layers 12.7 mm type X gypsum board mounted on resilient channels, (5): receive room, (6) and (7): 15.9 mm type X gypsum board.

As in Part 1, the SEA model will use assumptions to keep the model as simple as possible. They are: there is no significant coupling between the floor decking and the gypsum board ceiling, the studs of the walls can be ignored, and the joists of the floor/ceiling assembly can be ignored. The SEA sub-system diagram for the complete model is shown in Figure 2.

Measured and predicted net transmission loss

Figure 3 shows the measured and predicted net transmission loss (TL) for the assembly shown in Figure 1. The predicted results indicate the correct trends in the measured transmission loss, but the SEA model tends to underestimate the transmission loss. This underestimation of the TL was also present in the SEA prediction for the floor/ceiling assembly without any flanking paths given in Part 1. This suggests that the basic model for the transmission through the floor/ceiling assembly is biased toward underestimating the transmission loss (i.e., overestimating the coupling between sub-systems).

In the low frequencies 50-200 Hz, differences may be due to incorrectly estimating the total loss factor of the floor cavity, and/or incorrectly estimating the coupling between the surfaces forming the cavity (i.e., the OSB floor decking and the gypsum board ceiling). It should also be realized that the low modal density of the small source and receive rooms (volumes, source: 50 m^3 and receive: 40 m^3) will tend to increase uncertainty in the transmission loss measurements in the low frequencies.

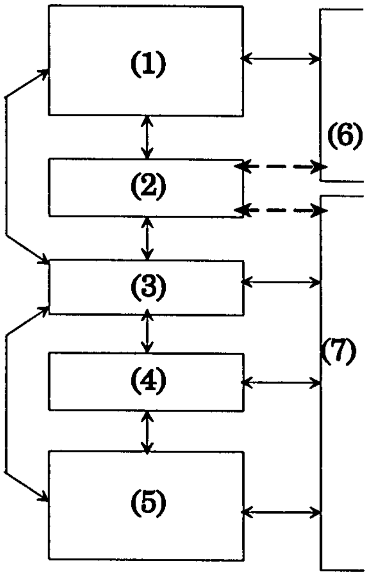

Figure 2: SEA sub-system model used to describe the direct and flanking paths for the floor/ceiling assembly. Paths via the joints are indicated by the wide dashed lines.

In the mid-frequencies, 250-1600 Hz the model has good agreement with measured results. A significant portion of this range, above 315 Hz, is controlled by flanking transmission, indicating that when both the transmission through the joint and the coupling between the room and its surfaces can be modelled accurately, there is good agreement with measured results.

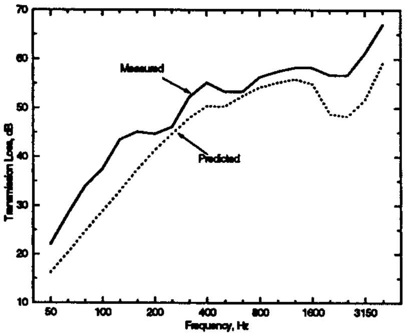

Figure 3: Measured and predicted net transmission loss (including flanking paths) for the floor ceiling assembly.

In the high frequencies 2000-4000 Hz flanking transmission completely controls the sound isolation and the SEA model underestimates the transmission loss. The underestimation is most likely due to the fact that the coupling between the flanking surfaces and the room volume is overestimated at the critical frequencies of the flanking surfaces (floor decking: 2000 Hz, party walls: 2500 Hz, and ceiling: 3000 Hz). A more exact method for computing the radiation efficiency could have been used.

Noise reduction as a function of flanking path

SEA lends itself to the prediction of noise reduction for a particular flanking path. The noise reduction for room to room transmission is given in terms of the computed counpling and total loss factors for the sub-systems in the path and, V, the volumes of the source and receive rooms,

$$NR_{1-2-3-4\ldots n} = 10\log\left[\frac{\eta_{12}\eta_{23}\eta_{34}\cdots\eta_{n-1,n}V_n}{\eta_2\eta_3\eta_4\cdots\eta_n V_1}\right] \qquad [1]$$

Figure 4 shows the predicted noise reduction for the three most important flanking paths 1-2-7-5, 1-6-2-7-5 and 1-6-2-3-4-5.

It is clear that the path 1-2-7-5 is the dominant flanking path, controlling the net sound reduction for all frequencies greater than 315 Hz. The path 1-6-2-7-5 is the next important, but has typically 10 dB greater noise reduction than path 1-2-7-5. Of almost negligible importance is the path 1-6-2-3-4-5. From the path analysis it can be seen that the two flanking paths offering the least noise reduction are those involving the party wall (sub-system (7)) in the lower room. In both cases, because of the joint model chosen, the energy must travel through the floor decking (sub-system (2)) and the joist header (sub-system (9)) to get to the party wall of the receive room.

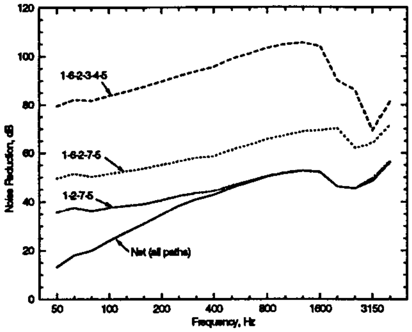

Figure 4: Predicted noise reduction (or sound pressure level difference) between the source room (sub-system (9)) and the receive room (sub-system (10)) as a function of the flanking path.

Treatments to improve the sound isolation

The path analysis indicates that the most important path is 1-2-7-5. Sound transmission along this path can only be reduced by treating sub-systems 2, 7 or redesigning the joint that connects them. If sub-system 2 is treated then, sound isolation of both the direct and flanking paths can be improved, and there is the greatest potential for improvement to the sound isolation.

A possible treatment for new or existing constructions might be to add a concrete topping to the floor decking. Figure 5 shows the predicted transmission loss for the assembly with and without a 38 mm thick concrete topping (91 kg/m^2). (In the prediction it was assumed that the bending stiffness of the topping and the OSB would be about that of the concrete topping alone.) The predictions indicate that there should be a significant increase in the sound isolation in the low frequencies where the mass of the topping helps to control the direct transmission through the floor/ceiling assembly. Differences between the bending stiffness of the concrete topping and the gypsum board of the walls tends to reduce transmission through the joints for high frequencies. With the topping, the predicted sound isolation is STC 64, a 12 point improvement from the STC 53 without the treatment.

Alternately, one could place the gypsum board of the upper and lower party walls on resilient channels. This should effectively remove the structural coupling between the finish gypsum board surfaces and the frame work. This will remove all the flanking paths. Figure 5 shows that a significant improvement only ocurrs for frequencies above about 400 Hz. In terms of a single number rating, the sound isolation would be STC 58 with the treatment, a five point improvement.

Redesigning the joint is an option for new constructions. Further work needs to be done in this area. It was shown in Part 2 that including the joist header in the model reduced joint transmission in the high frequencies. Thus, using a double joist header may help to reduce transmission through the joint.

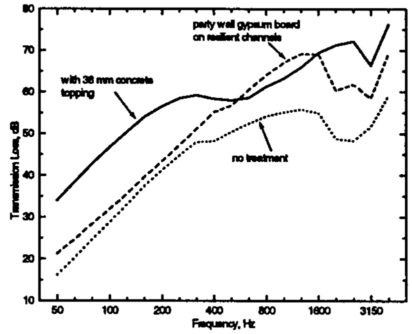

Figure 5: Predicted transmission loss for various treatments to improve the sound isolation between the two rooms. It has been assumed that the joint model developed in part 2 is still valid for the case when the OSB is covered with a concrete topping.

General conclusions Parts 1, 2, and 3

Part 1 in the series showed that the direct sound transmission through a floor/ceiling assembly can be modelled with good accuracy using the method of Price and Crocker. This method requires that the total loss factor of the cavity be accurately known. The assumption that the joists could be ignored and that resilient channel in the ceiling removed any structural paths from the decking to the ceiling was reasonable for direct transmission.

Part 2 showed that the joint between the floor/ceiling assembly and the load bearing party wall was complex, having to be treated as two corner joints sharing a common plate. Including the sole plate and joist header in the model were necessary if the joint transmission was to be accurately predicted in the high frequencies. The results suggest that greater accuracy can be attained by computing the joint transmission coefficients at each modal frequency of the sub-panels. This had the largest effect for frequencies below the first cross mode of the sub-panels.

Part 3 showed that flanking paths controlled the net transmission loss for frequencies greater than about 400 Hz. The most dominant flanking path was from the floor decking through the joist header and into the party wall below. Predictions also showed that adding a concrete topping to the floor decking would be an effective way of increasing the net sound isolation.

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[1] Nightingale, T.R.T., Craik, Robert J.M , Steel, John .A., "Statistical energy analysis applied to lightweight constructions Part 1: sound transmission through floors," Canadian Acoustics, Vol. 23, No. 3, pp. 41-42, 1995.

[2] Nightingale, T.R.T., Steel, John A., "Statistical energy analysis applied to lightweight constructions:Part 2: joints between floors and party walls," Canadian Acoustics, Vol. 23, No. 3, pp 43-44, 1995.

Appendix D

Determination of Flanking Paths

for

Case 7 AB Sound Insulation

with

Basic Party Wall Construction

INTRODUCTION

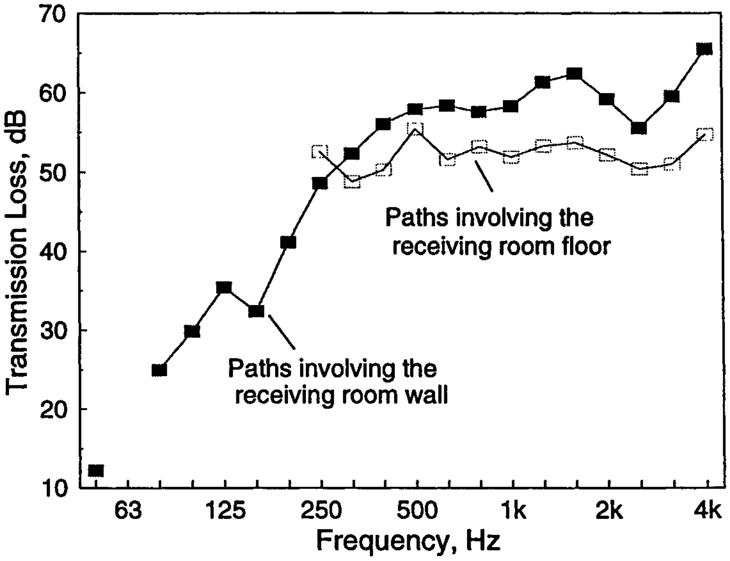
The continuous OSB sub-floor represents the most serious case of flanking between rooms A and B considered in this study. This Appendix examines this case in some detail to show how the flanking path can be determined.

The sound intensity technique was used to obtain a measure of the sound insulation of flanking paths involving the receiving room party wall and floor. The data are presented and compared to show that paths involving the receiving room floor control the apparent airborne sound insulation. The presented data indicates that treatments to the party wall will be largely ineffective.

SOUND INSULATION FOR PATHS INVOLVING THE FLOOR AND PARTY WALL

The sound insulation for paths involving the floor and the party wall of the Case 7 construction with the basic party wall is shown in Figure D1. The paths involving the receiving room floor are determined by masking the receiving room party wall and performing an intensity measurement over the receiving room floor. Similarly, the paths involving the receiving room wall are determined by masking the receiving room floor and performing an intensity measurement over the receiving room wall. In both cases the result is normalized to the area of the party wall to permit a direct comparison of the results. It is clear that in the frequency range 315-4000 Hz, flanking paths involving the floor offer much less sound insulation than the direct and flanking paths involving the party wall. Thus, in the range 315-4000 Hz, flanking paths involving the floor are controlling the apparent sound insulation.

Figure D1: Comparison of the sound insulation for all paths involving the floor and party wall when the basic wall construction is used.



DETERMINATION OF THE SOUND INSULATION FOR FLANKING PATHS INVOLVING THE PARTY WALL

The sound insulation offered by all paths involving the party wall are shown in Figure D2 for Reference B and for Case 7. From the Figure it is evident that the presence of the fire stop introduced a significant degradation to the sound insulation in the frequency range 630-4000 Hz.

Figure D2: Measured sound insulation for paths involving the receiving room party wall for Reference B (no fire stop) and Case 7 (continuous OSB sub-floor).

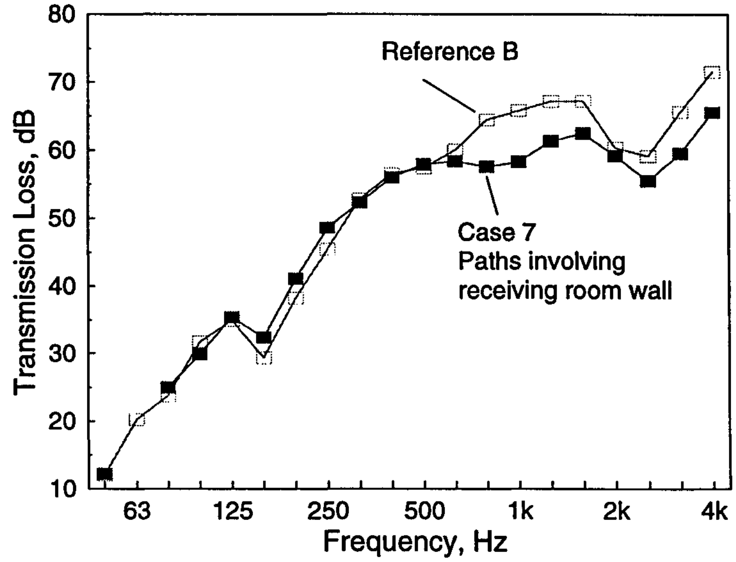


Table D1 shows the flanking paths involving the receiving room party wall for the two cases; it can be seen that paths 1-2-8-5-7 and 1-3-8-5-7 were introduced as a result of the continuous sub-floor (Figure A1 of Appendix A provides an illustration of the flanking paths and defines the naming convention). It is these paths that are responsible for the degradation. Figure D4 shows the calculated sound insulation for these paths.

Table D1: Flanking paths for Reference B and Case 7 involving the receiving room party wall.

Reference B (no fire stop)	Case 7 (continuous sub-floor)	Flanking paths due to continuous sub-floor
1-3-4-5-7, Direct path 1-2-3-4-5-7	1-3-4-5-7, Direct path 1-2-3-4-5-7 1-2-8-5-7 1-3-8-5-7	1-2-8-5-7 1-3-8-5-7

DETERMINATION OF THE SOUND INSULATION FOR FLANKING PATHS INVOLVING THE FLOOR

The sound insulation offered by all paths involving the receiving room floor for Reference B and for Case 7 are shown in Figure D3. From the Figure it is evident that the presence of the fire stop introduced a significant degradation to the sound insulation in the frequency range 315-4000 Hz. From Table D2, which shows all the paths involving the receiving room floor for the two cases, it can be seen that paths 1-2-8-6-7 and 1-3-8-6-7 were not present in Reference B. It is these paths that are responsible for the degradation. Figure D4 shows the calculated sound insulation for these paths.

Figure D3: Measured sound insulation for paths involving the receiving room floor Reference B (no fire stop) and Case 7 (continuous OSB sub-floor).

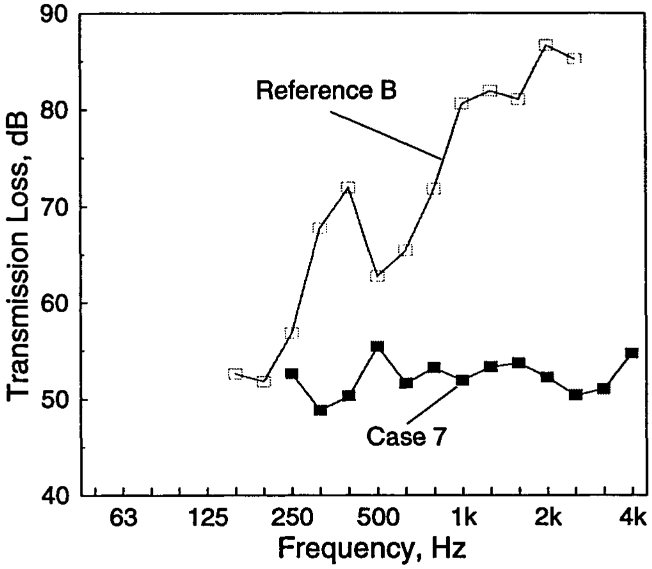


Table D2: Flanking paths for Reference B and Case 7 involving the receiving room floor.

Reference B (no fire stop)	Case 7 (continuous sub-floor)	Flanking paths due to continuous sub-floor
1-3-4-5-7, Direct path	1-3-4-5-7, Direct path	
1-3-4-5-6-7	1-3-4-5-6-7	
1-2-3-4-5-6-7	1-2-3-4-5-6-7	
	1-2-8-6-7	1-2-8-6-7
	1-3-8-6-7	1-3-8-6-7

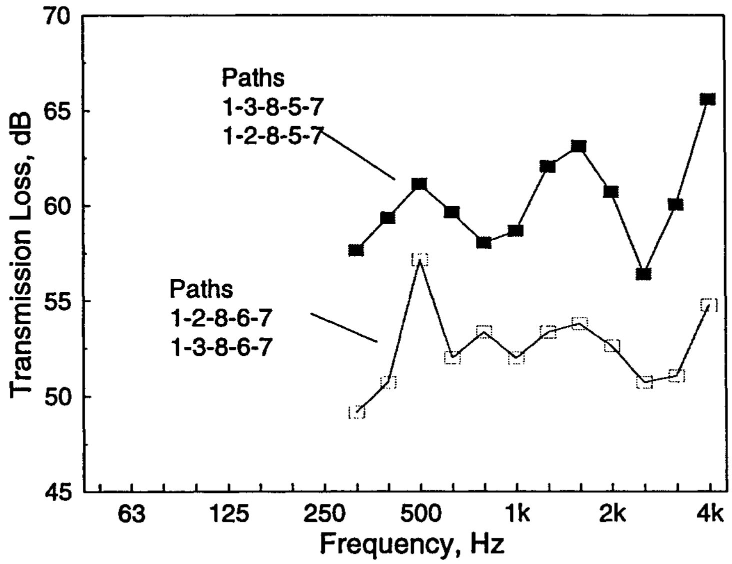
DETERMINATION OF THE DOMINANT FLANKING PATH OF CASE 7

The data given in Figure D2 and Figure D3 were used to calculate the sound insulation for flanking paths caused by the fire stop for both the floor and party wall of the receiving room. Figure D4 shows that paths involving the receiving room floor (1-2-8-6-7, 1-3-8-6-7) offer much less insulation, typically only offering only about 52 dB, whereas paths involving the party wall (1-3-8-5-7, 1-2-8-5-7) are typically about 61 dB.

With this knowledge, the most effective retro-fit treatment(s) would then be applied to paths involving the receiving room floor

(1-2-8-6-7 or 1-2-8-6-7). However, if one of the two floor paths had considerably less sound insulation, then only one transmission path need be treated.

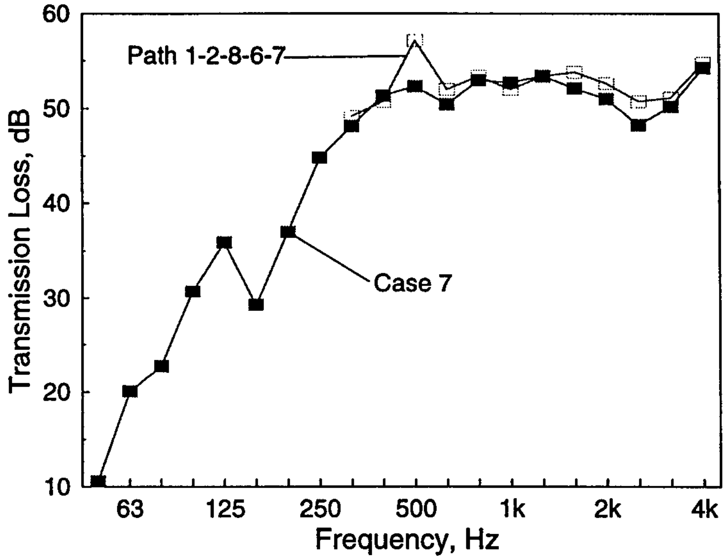
Figure D4: Calculated sound insulation for structure-borne flanking paths involving the fire stop joint and the party wall surface (1-2-8-5-7 and 1-3-8-5-7). Also shown is the calculated sound insulation for the structure-borne flanking paths involving the receiving room floor (1-3-8-6-7 and 1-2-8-6-7).



Path 1-2-8-5-7 is simply the mirror image of 1-3-8-6-7 when the receiving room becomes the source room and visa versa. Since the sound insulation of a system is independent of direction, reciprocity dictates that the two flanking paths must have the same insulation.

From Figure D4 it can be seen that path 1-2-8-5-7 (hence 1-3-8-6-7 by reciprocity) has at least 60 dB of sound insulation; about 10 dB more that for the sum of paths involving the floor (1-2-8-6-7, 1-3-8-6-7). Thus, path 1-3-8-6-7 does not contribute significantly to the sum and the path 1-2-8-6-7 must have a sound insulation that is 10 dB lower than 1-3-8-6-7. Path 1-2-8-6-7 is therefore the dominant transmission path. The sound insulation for path 1-2-8-6-7 is compared to the apparent airborne sound insulation for Case 7 in Figure D5.

Figure D5: Measured apparent airborne sound insulation for Case 7 and the calculated sound insulation for the structure-borne flanking path 1-2-8-6-7 involving the continuous sub-floor at the fire stop joint.



From the Figure D5 it is evident that the flanking path 1-2-8-6-7 completely controls the apparent sound insulation over the frequency range 315-4000 Hz. This path does not involve any party wall element so attempts to increase the apparent sound insulation by improving the party wall will be ineffective.

Figure D6: Calculated sound insulation for flanking path 1-2-8-6-7 and the fitted STC 52 contour.

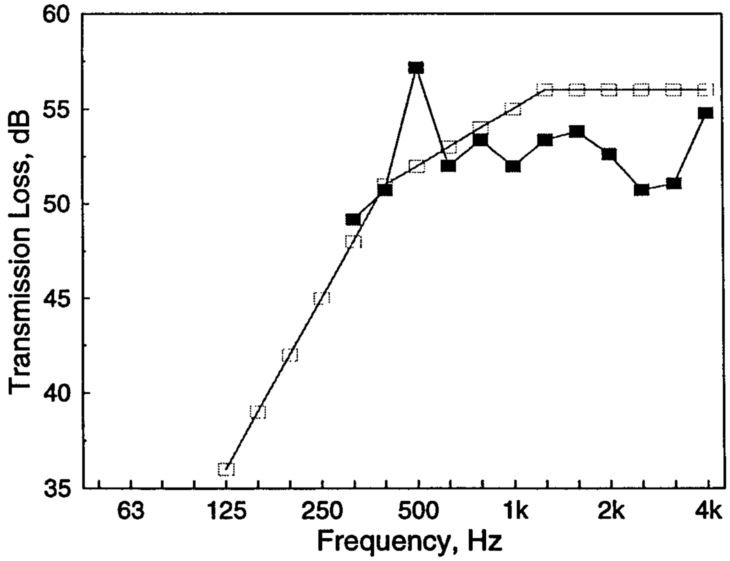


Figure D6 shows that the maximum sound insulation for flanking path 1-2-8-6-7 is STC 52. Since, this flanking path does not include the party wall, the apparent sound insulation between rooms A and B with the continuous sub-floor will never be greater than FSTC 52.

This limiting sound insulation was verified when the measured apparent airborne sound insulation increased by 2 STC points to FSTC 52 as a result of replacing the basic party wall (STC 55) with a wall capable of STC 67 under laboratory conditions.

CONCLUSIONS

Flanking paths formed by a continuous sub-floor surface that was common to both the source and receiving rooms caused a serious degradation to the apparent airborne sound insulation. Path analysis using intensity data revealed that flanking paths involving the party wall were insignificant when compared to flanking paths involving the sub-floor.

It was also shown that the dominant flanking path (1-2-8-6-7; sub-floor to sub-floor via fire stop joint) did not involve any element of the party wall. Consequently, with the continuous sub-floor, the apparent airborne sound insulation between rooms A and B would never exceed FSTC 52 regardless of the type of party wall. This was verified when the apparent airborne sound insulation improved by only 2 STC points to FSTC 52 as a result of replacing the STC 55 party wall with an STC 67 party wall.

Continuous surfaces which are common to both the source and receiving rooms should be avoided, unless required for structural integrity.

Appendix E

Flanking Transmission
Between Leaves of a Double Wall

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Liverpool, England

pp. 719-724

FLANKING TRANSMISSION BETWEEN LEAVES OF A DOUBLE WALL

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INTRODUCTION

Lightweight double leaf walls are widely used to provide a high degree of sound isolation. For optimal effectiveness each side of the double leaf wall has its own set of framing members with no structural connection between the two sides. This type of construction creates a continuous cavity that may provide unimpeded transmission of smoke and fire. To prevent the propagation of smoke and fire, fire stops are placed in party walls where the wall is intersected by floors.

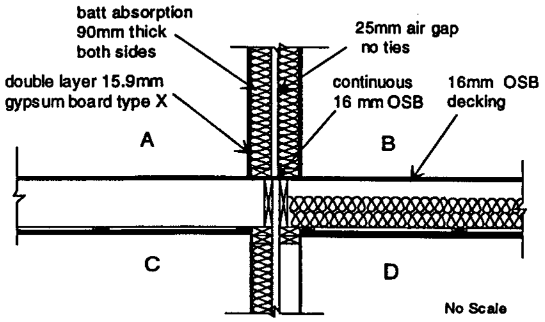
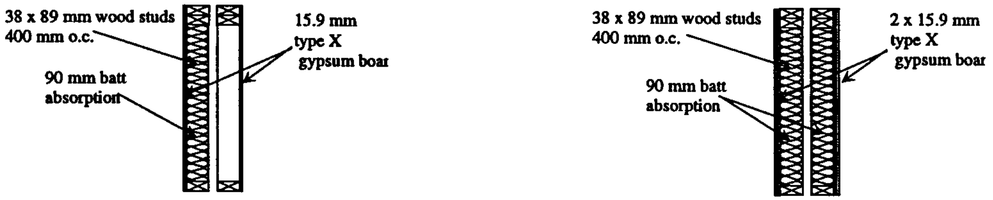


Figure 1: Vertical section through the construction specimen showing the fire stop formed by the continuous floor decking and the superior A-B party wall.

This paper will present a model to predict vibration transmission by bending moments due to horizontally oriented fire stops bridging the nominal 25 mm space at the wall/floor intersection. The model will be used to predict the degradation to the net sound isolation due to using a 16 mm thick oriented strand board (OSB) fire stop formed by continuing the floor decking under the party wall. Figure 1 shows the base construction that was modelled. In the study two different party walls were used to separate the upper two rooms A and B. Figure 2 shows the construction details for the two assemblies.



Base Party Wall

Superior Party wall

Figure 2: Construction of the Base and Superior wall constructions separating rooms A and B.

JOINT MODEL

The construction shown in Figure 1 can be visualized as being two tee joints formed by the intersection of the floor by the upper and lower party walls and that these two tee joints are coupled by the fire stop at the floor level. However, for this type of wood frame construction, it has been shown that transmission in either tee assembly should be modelled as two corner joints sharing a common plate - the floor decking. This means that when modelling the transmission between the upper two rooms A and B the fire stop joint can be considered to be two corner joints connected by the fire stop as shown in Figure 3.

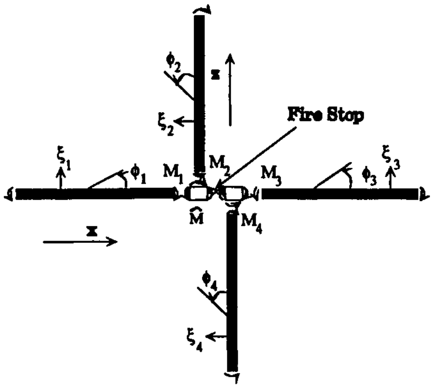


Figure 3: Mechanical representation of the fire stop joint as applied to transmission between the upper two rooms.

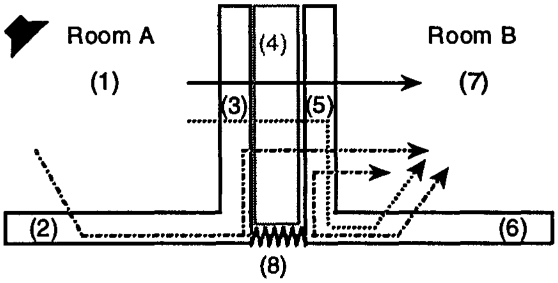


Figure 4: Schematic representation of the sub-systems considered in the model; 1, 3: floor decking; 2, 4: wall leaves; 5: wall cavity; 6: source room; 7: fire stop; 8: receive room.

In forming the model it is assumed that the only method of transmission will be by bending moments of the fire stop and that transmission by inplane forces can be ignored. It will also be assumed that the high frequency attenuation introduced by the polar rotation inertia and shear moment of the 38x89 mm wall sole plates can be ignored[1]. A series of continuity and boundary conditions are now defined to describe the motion and behaviour of the plates and fire stop:

1. At the joint the displacements of all plates are zero;
2. The right angle between plates 1 and 2 is preserved;
3. The right angle between plates 3 and 4 is preserved;
4. The sum of the moments about the left hand pin is zero;
5. The sum of the moments about the right hand pin is zero;
6. The angular deformation of the fire stop is determined by the bending stiffness and the moment.

These conditions give the following governing equations

- $T_{n1} = -1 - T_1,\ T_{n2} = -T_2,\ T_{n3} = -T_3$, and $T_{n4} = -T_4$ (1)
- $\phi_1 = \phi_2$ and $\phi_3 = \phi_4$ (2, 3)
- $M_1 - M_2 + M_f = 0$ and $M_4 - M_3 - M_f = 0$ (4, 5)

- $$M_f = (\phi_3 - \phi_1) B_f \qquad (6)$$

where the numeric subscript indicates the plate, T is the amplitude of the travelling component and the subscript *'n'* refers to the near field or evanescent component, M is the moment of inertia, ϕ is slope, and B_f is the bending stiffness of the fire stop.

If a pure bending wave on plate 1 is incident at angle, θ, then the transverse displacements on the four plates are given by,

$$\xi_1 = (e^{-ik_1\cos\theta_1 x} + T_1 e^{ik_1\cos\theta_1 x} + T_{n1} e^{k_{n1}x})(e^{-ik_1\sin\theta_1 y} e^{i\omega t}), \qquad (7)$$

$$\xi_2 = T_2 e^{-ik_2\cos\theta_2 z} + T_{n2} e^{-k_{n2}z} \qquad (8)$$

$$\xi_3 = T_3 e^{-ik_3\cos\theta_3 x} + T_{n3} e^{-k_{n3}x} \qquad (9)$$

$$\xi_4 = T_4 e^{ik_4\cos\theta_4 z} + T_{n4} e^{k_{n4}z} \qquad (10)$$

where k is the wave number and the last term of equation 7 is common to all displacement equations and is not given in subsequent equations. The term k_{n1} is the near field wave number and is given by $k_n^2 = k^2(1 + \sin^2\theta)$ for any plate. The angle at which the waves leave the joint can be found from Snell's law which requires that $k_1 \sin\theta_1 = k_m \sin\theta_m$. The slopes, ϕ, and moments, M, used in the governing equations are related to the transverse displacement by, ξ, by

$$\phi = \frac{\partial \xi}{\partial x} \text{ and } M = -B\left(\frac{\partial^2 \xi}{\partial x^2} + \mu \frac{\partial^2 \xi}{\partial y^2}\right) \qquad (11,12)$$

where μ is Poisson's ratio and B is the bending stiffness of the plate.

Equations 7-10 are now substituted into equations 1-6 to give four simultaneous equations having the transverse displacements of the four plates as the unknown variables,

$$T_1[-k_{n1} + ik_1\cos\theta_1] + T_2[-k_{n2} + ik_2\cos\theta_2] = k_{n1} + ik_1\cos\theta_1 \qquad (13)$$

$$T_3[k_{n3} - ik_3\cos\theta_3] + T_4[k_{n4} - k_4\cos\theta_4] = 0 \qquad (14)$$

$$\begin{aligned} &T_1[2B_1k_1^2 + B_f k_{n1} - iB_f k_1\cos\theta_1] + T_2[-2B_2k_2^2] \\ &+ T_3[B_f k_{n3} - iB_f k_3\cos\theta_3] = -2B_1k_1^2 - B_f k_{n1} - iB_f k_1\cos\theta_1 \end{aligned} \qquad (15)$$

$$\begin{aligned} &T_1[-B_f k_{n1} - iB_f k_1\cos\theta_1] + T_3[-2B_3k_3^2 - B_f k_{n3} + iB_f k_3\cos\theta_3] \\ &+ T_4[2B_4k_4^2] = B_f k_{n1} + iB_f k_1\cos\theta_1 \end{aligned} \qquad (16)$$

The stiffness of the fire stop can be found by considering a small element of beam and using fundamental mechanics

$$B_f = \frac{Yh^3}{12(1-\mu^2)L} \qquad (17)$$

where L is the span of the fire stop (typically 25 mm), h is the thickness of the fire stop (such as 16 mm for the OSB decking) and Y is Young's Modulus of the fire stop material.

The transmission coefficient can then be found from

$$\tau_{12}(\theta) = \frac{\rho_{s2} k_1 \cos\theta_2}{\rho_{s1} k_2 \cos\theta_1} |T_2|^2 \qquad (18)$$

The angular average transmission coefficient is then given by

$$\tau_{av} = \int_0^{\pi/2} \tau(\theta)\cos(\theta)d\theta \qquad (19)$$

In the special case that there is normal incidence at the joint and all the plates have the same bending stiffness the equations can be solved analytically. The transmission from plate 1 to 3 or 1 to 4 is given by,

$$R_{13} = R_{14} = 10\log 8\left(\frac{2}{c^2} + \frac{2}{c} + 1\right) \qquad (20)$$

where

$$C = \frac{B_f}{Bk} \qquad (21)$$

When C tends to zero, as occurs at very high frequencies or for very soft fire stops, then the transmission loss tends to infinity. When C tends to infinity, then the transmission loss tends to 9 dB. The joint transmission loss for normal incidence is about 1.8 to 1.9 dB lower that for random incidence.

MEASURED AND PREDICTED RESULTS

The eight sub-system SEA model shown in Figure 4 was used to represent the key elements in the transmission between rooms A and B. The purpose of this paper is not to define the theory for modelling sound transmission through double leaf constructions as this is available elsewhere[2,3], but rather issues surrounding the joint are discussed. Table 1 shows the material properties used in the joint calculation.

Material or Structural Element	Joint Stiffness (L = 25 mm) (Nm)	Young's Modulus (N/m^2)	Poisson's Ratio	Density (kg/m^3)	Decay Time (s)
16 mm OSB	54700	4.04×10^9	0.2	600	$9.9f^{-0.78}$
16 mm Gypsum Board	n/a	1.9×10^9	0.2	720	$9.9f^{-0.78}$
Wall Cavity	n/a	n/a	n/a	n/a	Base: $3f^{-0.58}$ Superior: $5.7f^{-0.63}$

Table 1: Material properties of the fire stop and elements in the SEA model.

Continuous Floor Decking: The fire stop is formed by continuing the OSB floor decking across the nominal 25 mm air space between the joist headers. There is reasonable agreement between the measured and predicted results as shown in Figure 5A.

Differences in the very low frequencies may be explained by the mass-air-mass resonance of the wall cavity which has been calculated to occur at about 40 Hz. The prediction underestimates the transmission loss near the critical frequency of the floor and wall (2000 and 2500 Hz, respectively). This is due to an overestimation in the strength of coupling between the room and wall and vice versa and is a result of assuming that the surfaces were isotropic. Both gypsum board and OSB are highly orthotropic.

Figure 5B shows the measured and predicted transmission loss results for all flanking paths involving the receive room floor. There is reasonable agreement between measured and predicted results through most of the range. The exception occurs at the critical frequency where there is much stronger transmission than was measured.

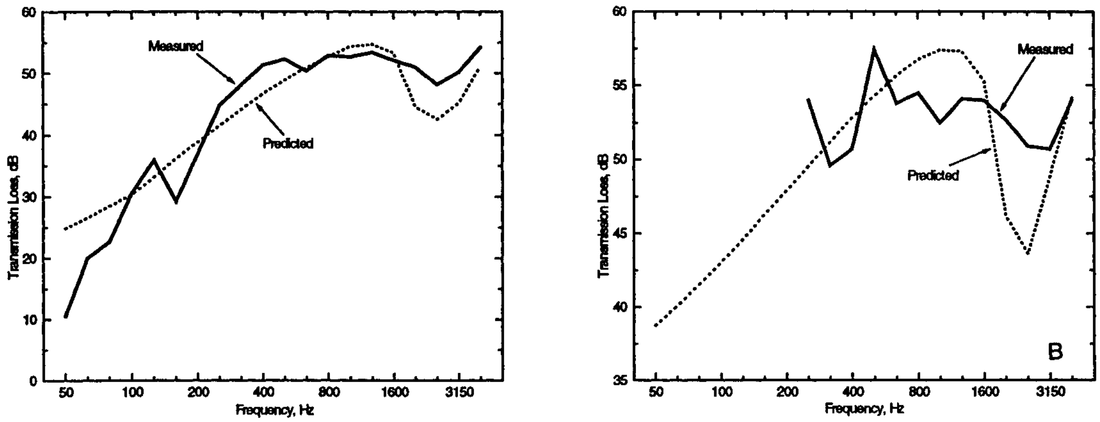


Figure 5: Measured and predicted net transmission loss between rooms A and B with base case party wall construction and the 16 mm thick OSB fire stop formed by continuing the floor decking; A: Net transmission loss, B: Transmission loss for flanking paths involving the receive floor.

Figure 6 shows the transmission loss for the four most important flanking paths involving the fire stop joint. From the figure it can be seen that the dominant flanking path is *floor-to-floor* directly under the party wall and does not involve any of the party wall elements. Paths involving the party wall leaves are about 5 dB less important relative to the path only involving the floor decking.

The base party wall was replaced with a the wall of *superior* construction and the measured and predicted net transmission loss are shown in Figure 7. From the figure it can be seen that there is good agreement over the most of the frequency range. There is an overestimation of the transmission loss in the frequency range 500 to 1600 Hz.

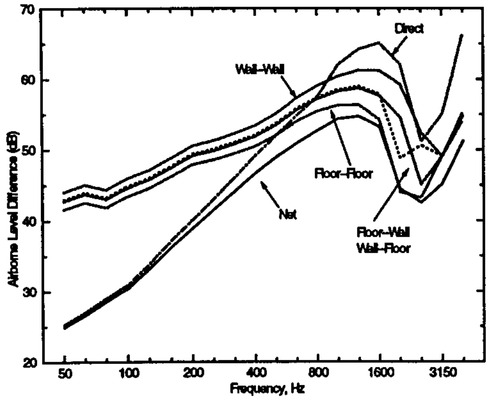


Figure 6: Predicted airborne level difference for the most important flanking paths with the base party wall construction and the 16 mm thick OSB fire stop formed by the continuous floor decking

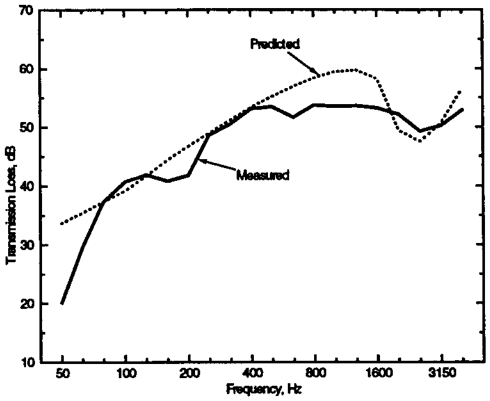


Figure 7: Measured and predicted net transmission loss with the superior party wall construction and the 16 mm thick OSB fire stop formed by the continuous floor decking.

Simple Retro-Fit: Since the dominant flanking path is *floor-to-floor* via the fire stop, improving the performance of the floor decking through a retro-fit may be useful. An additional layer of 16 mm OSB was placed over the exposed surfaces. Doubling the effective thickness of the deck will reduce the efficiency of the floor to accept and/or radiate sound energy. It will also reduce the amount of energy transmitted across the joint since there will be a 2 to 8 fold increase in bending stiffness of plates 1 and 3 while the bending stiffness of the joint remains constant. A factor of four was used in the prediction model as complete composite action was not achieved by the 100 mm nailing grid.

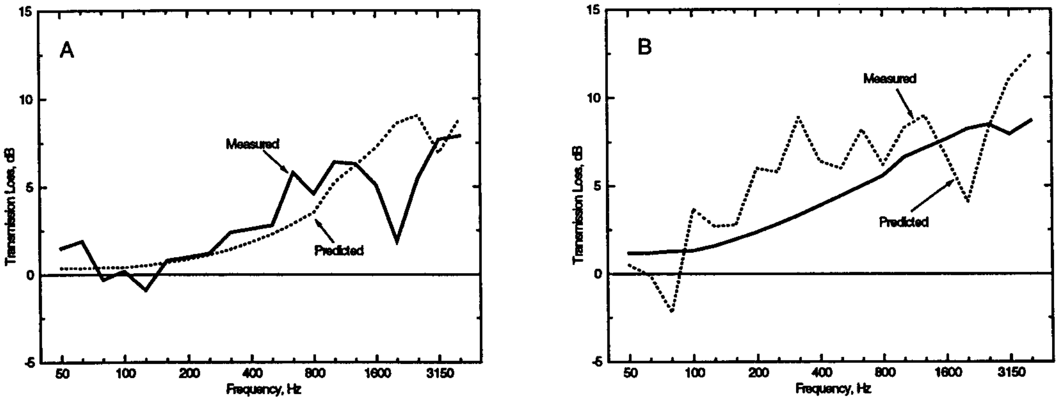


Figure 8: Measured and predicted change in the net sound isolation due to the placement of a 16 mm thick OSB underlay to the existing floor decking. A: Base wall construction, B: Superior wall construction.

Figures 8A and 8B show that there is a significant change in the net transmission loss when the additional layer of floor decking is used. There is a slightly greater benefit when used with the superior party wall since all wall paths have been reduced. Trends are correctly shown with the exception of 2000 Hz where the additional layer of OSB was placed at right angles to the first caused a shift in the critical frequency which was not reflected in the model. This could be solved by changing the implementation in the model.

CONCLUSIONS

A mathematical model has been presented to describe the transmission through a joint formed by a thin horizontally oriented material bridging either side of a party wall. The model assumes that transmission will occur only by bending moments. This was shown to be an acceptable approximation for a very stiff fire stop material (e.g., 16 mm OSB). The model accurately predicted the net sound isolation and that for flanking paths involving the receive room floor. The model was able to accurately predict the improvement due to the underlay treatment of the floor decking.

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[1] Nightingale, T.R.T., Steel, John, A., "Statistical energy analysis applied to lightweight constructions Part 2: Joints between floors and party walls, Canadian Acoustics Vol. 23, No. 3, pp. 43-44, 1995.

[2] Craik, Robert J.M., " ", Proceedings Issue INTERNOISE 96 Liverpool, 1996.

[3] Craik, Robert J.M., Steel, John A., Nightingale, Trevor, R.T., "Sound transmission through framed buildings," IRC-IR-672, Institute for Research in Construction, National Research Council Canada, May 1995.