RESEARCH REPORT

CASE STUDY : RETROFIT ACOUSTIC TREATMENTS IN A HERITAGE APARTMENT BUILDING

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CASE STUDY:

RETROFIT ACOUSTIC TREATMENTS IN A HERITAGE APARTMENT BUILDING

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Executive Summary

Several units in a five-story 1927 apartment building in Ottawa were recently renovated. The original walls and ceilings were finished with lath and plaster and some walls were balloon framed, in which the vertical framing is continuous for several floors. The owner tested the noise reduction of the floor between two apartments of identical floor plans, one above the other, and wanted to improve the sound isolation between the apartments. Test data on STC and IIC ratings for new materials and construction can be found in the National Building Code. However, little data is available on the sound transmission characteristics of earlier construction with lath and plaster. A retrofit project was undertaken with advice from an acoustic specialist and support by CMHC.

The acoustical effectiveness of several retrofit techniques for the floor/ceilings in the apartment were tested and documented on the basis of technical merit, cost, and airborne sound and impact isolation. Two retrofit strategies were undertaken; the first involving the removal of the existing lath and plaster ceiling and its replacement with drywall on resilient channel supports; the second involving the application of drywall on resilient channel supports over the lath and plaster ceiling, which had been perforated with holes to reduce the potential of acoustic coupling. The ceiling cavities were filled with sound insulation in all cases.

All retrofit treatments improved the acoustic isolation of the floor assembly. However, the most expensive strategy that involved removal of the existing ceiling improved the acoustic performance of the floor assembly less than the cheaper strategy. The reasons for the inferior performance of the more expensive repair are not identified in this study; however, it is believed that the balloon framing might have caused some sound leaks in the vicinity of the first retrofit strategy, which contributed to a decrease in the apparent sound performance of the floor.

Résumé

Plusieurs logements situés dans un immeuble de cinq étages, datant de 1927, ont été récemment rénovés à Ottawa. Les murs et les plafonds originaux étaient composés de lattes et d'enduit de plâtre, et certains murs avaient une ossature à claire-voie, c'est-à-dire que et les poteaux traversaient plusieurs étages d'une seule venue. Le propriétaire a mis à l'essai la capacité du plancher à réduire les bruits entre deux appartements identiques, situés l'un par-dessus l'autre, pour améliorer l'isolement acoustique entre les deux. Des données d'essai relatives aux indices ITS et IIC concernant les constructions et les matériaux neufs peuvent être consultées dans le Code national du bâtiment du Canada. Toutefois, peu de données sont disponibles en ce qui a trait aux caractéristiques de la transmission du son dans les vieilles constructions composées de lattes et d'enduit de plâtre. Des travaux de rattrapage ont été entrepris selon les conseils d'un spécialiste en acoustique et avec l'aide de la SCHL.

L'efficacité acoustique des plusieurs techniques de rattrapage pour les planchers et les plafonds de l'appartement a été mise à l'essai et documentée en fonction du mérite technique, du coût, de la transmission des bruits aériens et de l'isolement aux bruits d'impact. Deux stratégies de rattrapage ont été entreprises. En ce qui a trait à la première, les plafonds de lattes et d'enduit de plâtre ont été retirés et remplacés par des plaques de plâtre sur des fourrures souples. La seconde stratégie consistait à poser des plaques de plâtre sur des fourrures souples par-dessus les lattes et l'enduit de plâtre qu'on a d'abord perforés afin de réduire les échanges acoustiques. Les cavités du plafond ont été remplies avec de l'isolant acoustique dans tous les cas.

Tous les travaux de rattrapage ont amélioré l'isolation acoustique du plancher. Par contre, la stratégie la plus coûteuse des deux, c'est-à-dire celle qui consistait à retirer le plafond existant, a été la moins efficace. L'étude n'établit pas les raisons du rendement inférieur. Toutefois, l'ossature à claire-voie a possiblement causé des fuites à proximité des travaux de la première stratégie de rattrapage, qui auraient contribué à l'apparente diminution du rendement acoustique du plancher.

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Case Study: Retrofit Acoustic Treatments in a Heritage Apartment Building

1. Introduction

When renovating older buildings there is frequently a desire to improve sound isolation between rooms or apartments. However, the renovator is faced with a dilemma: little acoustical guidance or data exists to assist in the selection of retrofit techniques for older types of construction such as lath and plaster, balloon framing and older types of solid masonry construction. In this case study, sponsored by Canada Mortgage and Housing Corporation, CMHC, a series of retrofit treatments have been applied to the floor/ceilings separating two apartment units in a heritage apartment building. The study provides field data on the improvements in sound isolation (FSTC) and impact isolation (FIIC) achieved through the retrofit treatments. The costs of the retrofit treatments are also discussed.

Extensive test data are available, for example in the National Building Code of Canada[1], on the sound transmission properties of walls and floor/ceilings for construction using modern materials and construction techniques, such as gypsum board on wood or steel framing. Hence for new construction, or for the retrofitting of relatively new buildings, it is relatively straightforward to specify materials and construction methods for walls or floor/ceilings which have known sound isolation properties. In contrast, little if any data is available on the sound transmission characteristics of walls or floor/ceilings made with earlier construction materials and techniques such as lath and plaster.

The sound transmission between two rooms consists of direct sound transmission through the separating partition and sound transferred via flanking paths. Flanking paths are indirect sound transmission paths involving structural members or other solid material by which sound passes in to the receiving room. For rooms above each other, an example of a flanking path is sound traveling along the walls between the two rooms. As discussed below, the effectiveness of retrofit treatments applied to the separating partition will often be limited by the presence of significant flanking.

The Strathcona, shown in Figure 1, is a five story apartment building in Ottawa built in 1927. In keeping with construction techniques of the period, walls and ceilings are of lath and plaster construction and some of the walls are framed using balloon framing techniques, i.e. the vertical framing is continuous over several floors. The current owner of the Strathcona, Andrex Holdings Ltd., was in the process of renovating two apartments of identical floor plans, one above the other, and was keen to improve the sound isolation between the apartments. A project, with sponsorship from CMHC, was undertaken on the following basis.

- The aim of the project was to test and document the acoustical effectiveness of several retrofit techniques for the floor/ceilings in the apartment building. Effectiveness was to be evaluated both in technical terms, sound isolation (FSTC) and impact isolation (FIIC), and in terms of the cost of the retrofit.

- The selection and implementation of retrofit measures, and the before and after testing, had to be done in a relatively short time frame between rentals of the two units. Andrex Holdings wanted to know what could be done practically and economically to the ceilings of the lower apartment to improve sound transmission. Changes to the walls, floors or building framing, which could affect flanking transmission, were not to be considered due to cost and time constraints.

- Hugh Williamson Associates provided acoustical advice on the selection of retrofit methods, provided before and after sound and impact testing and took the lead role in the evaluation and documentation of the case study.

- The generous assistance of Sandy Smallwood and his staff at Andrex Holdings is gratefully acknowledged for making the building available, providing cost information and making many useful suggestions and contributions to the project.

- CMHC staff also contributed useful input to the selection of retrofit techniques and evaluation of the results.

- Don Buchan of Buchan Lawton Parent also participated in the project by performing inter-suite air leakage testing.

Figure 1 The Strathcona

2. Selection of Retrofit Details

The floor plans of the two apartments, one above the other, are identical to that shown in Figure 2. Internal apartment walls all contained balloon framing, that is, the wall studs were continuous between floors. During renovation, the size of bedroom three was reduced to allow the addition of a small laundry as shown in Figure 2. The floor/ceiling construction prior to renovation is shown in Figure 3 and consists of the following.

- 6 mm (¼”) hardwood tongue and groove flooring.
- 25 mm by 150 mm (1” by 6”) planking sub-floor, with approximately 3 mm (1/8”) gaps between the planks.
- 240 mm by 45 mm (9.5” by 1.75”) wood joists on 406 mm (16”) centers.
- ‘pugging’: 12 mm (1/2”) boards covered in approximately 30 mm (1.25”) of light weight concrete set approximately 75 mm (3”) below the top of the joists, see Figure 2. Note that the ‘pugging’ was not a solid continuous layer, i.e. holes and gaps were common.
- Lath and plaster ceiling.

Figure 4 is a photo of the floor joists and of the living/dining room viewed from below after removal of the lath and plaster ceiling.

It was considered to be impractical from a cost perspective to replace the floor. Hence, in keeping with modern construction techniques, it was decided that the best approach would be to replace the existing lath and plaster ceiling with two layers of 12.7 mm (1/2”) gypsum board suspended from the joists on resilient channels, and to provide acoustic insulation in the cavity space above the gypsum board. (The ‘pugging’ was left in place because there was no obvious benefit to remove it. The extra mass of the ‘pugging’, approximately 20 kg/m^2, could be of some benefit acoustically.) Having four rooms available for testing, the living/dining room plus three bedrooms, allowed for four variants of the above approach to be tested as summarized in Table 1.

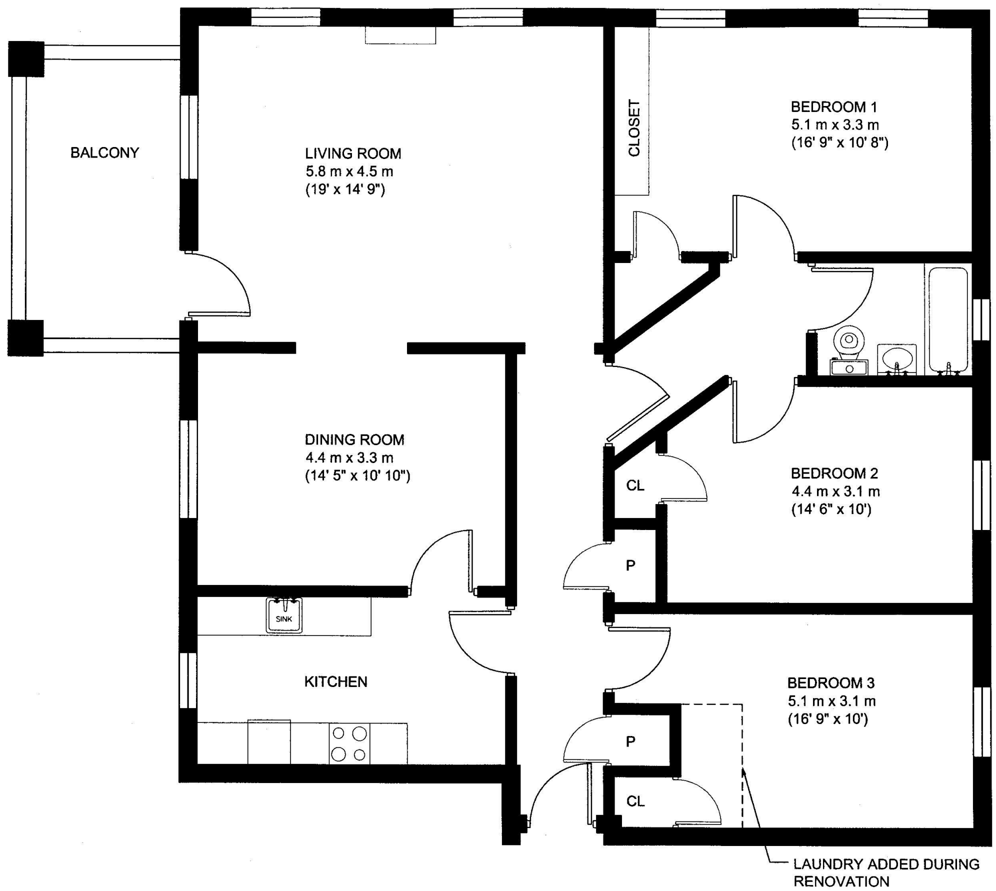

Figure 2 Floor Plan of Test Apartments – Both Identical

(Note: Laundry added to bedroom 3 during renovation)

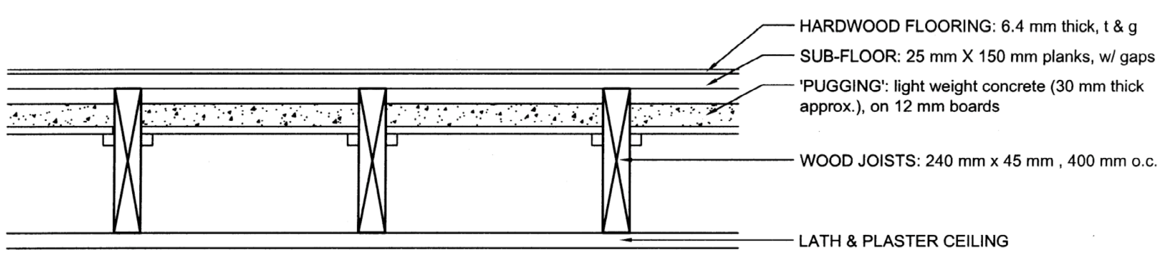

Figure 3 Original Floor/Ceiling Construction

Figure 4 Photo of Floor Joists in the Living/Dining Room with the Lath and Plaster Ceiling Removed

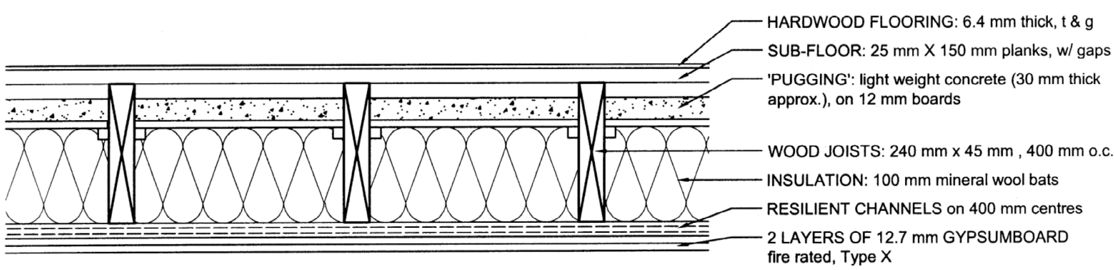

Figure 5 Retrofit Floor/Ceiling Construction in the Living/Dining Room

It is well known[2] that leaving an exiting ceiling in place, then adding one or two layers of gypsum board on resilient channels, leads to relatively poor acoustical results in terms of STC (Sound Transmission Class) or IIC (Impact Insulation Class). The small air space between the old ceiling and the new gypsum board leads to a close acoustical coupling and poor sound isolation, especially at low frequencies. It was considered that the optimal treatment would be the complete removal of the lath and plaster ceiling prior to installing batt insulation, then installing the resilient channels and two layers of gypsum board. This was the retrofit which was applied to the living/dining room ceiling as shown in Figure 5.

The complete removal of a lath and plaster ceiling creates large amounts of debris and dust, and increases the cost of the retrofit. Making sufficient holes in the lath and plaster ceiling prior to fitting the resilient channels and gypsum board should also be an effective way of substantially eliminating the acoustic coupling and hence achieving the desired high level of acoustic isolation. What was unknown, however, was how many holes and of what size would be required to effectively eliminate the acoustic coupling.

On the above basis, varying patterns of holes were made in the lath and plaster ceilings of bedrooms 1, 2 and 3 as indicated in Table 1. Figure 6 illustrates generically the retrofit construction in the bedrooms. In bedroom 1, the intent was to place 100 mm (4") diameter holes at approximately 400 mm (16") centres on a grid pattern in the lath and plaster ceiling. Holes were made using a hammer to break into the ceiling. However, because of the crude technique, i.e. using a hammer, the holes mostly extended further in the directions of the lath as shown in Figure 7.

In bedroom 2, the hammer technique for forming holes was again used, but nominally 100 mm (4") diameter holes were spaced approximately on an 800 mm (32") grid pattern.

In bedroom 3, a 25 mm (1") diameter drill was used to drill a regular pattern of holes in the lath and plaster ceiling spaced on a 100 mm (16") grid pattern.

In all three bedrooms, blown-in cellulose insulation was used to provide cavity insulation. In the case of bedrooms 1 and 2, a sheet of polythene was stapled to the ceiling prior to blowing in the insulation. This prevented the insulation from falling through the large holes during the installation of the resilient channels and gypsum board layers.

Test data for modern cavity wall construction suggests that the type of cavity insulation, fibreglass batts vs. mineral wool batts vs. blown-in cellulose, is of relatively little importance in determining acoustic insulation properties of a wall or ceiling[3]. On this basis it was felt that the use of mineral wool batts in the living/dining room ceiling and blown-in cellulose insulation in the three bedrooms would not be a significant source of variation in the acoustic performances of the floor/ceilings.

Care was taken to ensure that there were no direct air paths between the apartments. An air-seal test was performed and any leaks which were identified were sealed with flexible caulking.

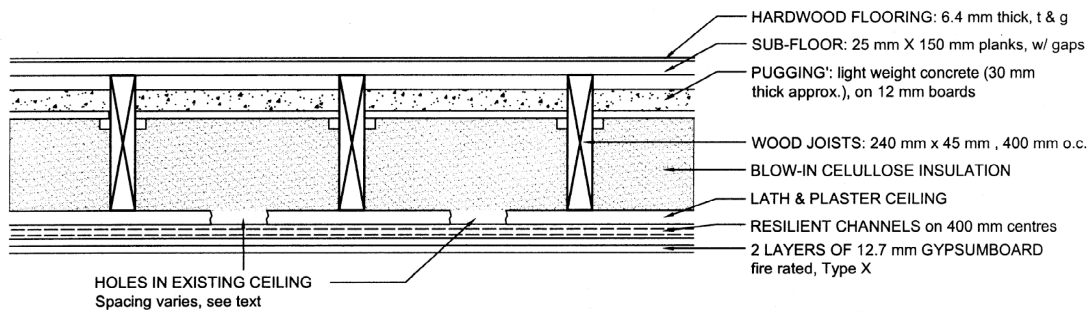

Figure 6 Retrofit Floor/Ceiling Construction in Bedrooms

Figure 7 Hammer Holes Made in the Lath and Plaster Ceiling of Bedroom 1

Original Construction	**Retrofitted Construction**			
All rooms	**Living/ dining room**	**Bedroom 1**	**Bedroom 2**	**Bedroom 3**
6 mm hardwood flooring	as original	as original	as original	as original
25 mm planking sub-floor, with gaps	as original	as original	as original	as original
240 mm by 45 mm wood joists	as original	as original	as original	as original
'pugging': light weight concrete on boards	as original	as original	as original	as original
no insulation	100 mm mineral wool batts	blown-in cellulose, approx.100 mm thick	blown-in cellulose, approx.100 mm thick	blown-in cellulose, approx.100 mm thick
lath and plaster ceiling	lath and plaster <u>ceiling removed</u> (approx. free area: 100%)	<u>hammer holes</u> in lath and plaster ceiling, approx. 100 mm dia., on 400 mm grid (approx. free area: 15%)	<u>hammer holes</u> in lath and plaster ceiling, approx. 100 mm dia., on 800 mm grid (approx. free area: 8%)	<u>drilled holes</u> in lath and plaster ceiling, 25 mm dia., on 400 mm grid (approx. free area: 0.3%)
	no sheeting	polythene sheet to hold blown-in insulation	polythene sheet to hold blown-in insulation	polythene sheet to hold blown-in insulation
	resilient channels on 400 mm centres	resilient channels on 400 mm centres	resilient channels on 400 mm centres	resilient channels on 400 mm centres
	two layers of gypsum board 12.7 mm, Type X, fire rated	two layers of gypsum board 12.7 mm, Type X, fire rated	two layers of gypsum board 12.7 mm, Type X, fire rated	two layers of gypsum board 12.7 mm, Type X, fire rated

Table 1 Ceiling Construction, Before and After Retrofit

3. Test Methodology and Results

Testing Standards

Sound insulation tests were conducted between upper and lower rooms using the appropriate American Society of Testing Materials, ASTM, standard[4] for determining Field Sound Transmission Class, FSTC. The essence of this test is that a sound source is placed in one of the rooms, then sound level differences between the source room and the receiving room are measured in various frequency bands. After applying corrections for the size of the rooms, the area of the common wall or floor/ceiling and the amount of acoustic absorption in the receiving room, an FSTC rating is determined. FSTC is a measure of both direct (through the common wall or floor/ceiling) and flanking sound transmission.

Note that the term Sound Transmission Class, STC, which is commonly quoted in standards for wall or ceiling construction, refers to the sound transmission rating as determined under laboratory conditions[5] where flanking effects are essentially eliminated. Field measurements, FSTC, measure the sound transmission between two rooms and not just the separating partition. The result of a FSTC test will often be less than the laboratory determined STC rating for the separating wall or floor/ceiling of the same construction because a field test includes sound transferred between the rooms via flanking paths as well as by direct airborne sound transmission through the wall or floor/ceiling being tested. An example of a flanking path in a floor/ceiling test would be sound which passes along a wall from the source room into the receive room. If flanking is significant, i.e. if a significant amount of sound transfer occurs through paths other than the test wall or floor/ceiling, then the FSTC result may be significantly below the laboratory determined STC for the same wall or floor/ceiling construction. In effect, flanking transmission can put a limit on the amount of improvement in sound isolation which can be achieved by upgrading the separating partition.

Impact insulation tests were also conducted between upper and lower rooms using the appropriate ASTM standard procedure[6] for determining Field Impact Insulation Class, FIIC. The essence of this test is that a standard tapping machine, Figure 8, creates impacts on the floor of the upper room while sound levels are measured in the lower room over a range of frequency bands. After correcting the measured sound levels for acoustic absorption in the lower room, an FIIC rating is determined. FIIC is essentially a measure of the structure borne sound being transmitted from the tapping machine to the receiving room below.

As with sound transmission, FIIC is the field testing equivalent of Impact Insulation Class, IIC, which is commonly quoted in construction standards. IIC is determined using a laboratory testing procedure[7] where flanking paths are essentially eliminated. FIIC is often less than the laboratory determined IIC for a floor/ceiling of the same construction due to the presence of flanking paths, An example of a flanking path is sound from the tapping machine entering the room below via a path which involves the walls.

Testing Procedures

As far as was practical, before and after sound transmission and impact tests were conducted each of the four sets of rooms are set out in Table 2.

It was not possible to conduct the before tests on the living/dining room because the lath and plaster ceiling had been removed prior to the commencement of the case study. The before results are in fact the results of test conducted on the living/dining rooms of a separate set of nominally identical apartments within the same building.

Because construction work for the new laundry had already commenced in bedroom 3 prior to the start of the case study, the before tests for this bedroom could not be done.

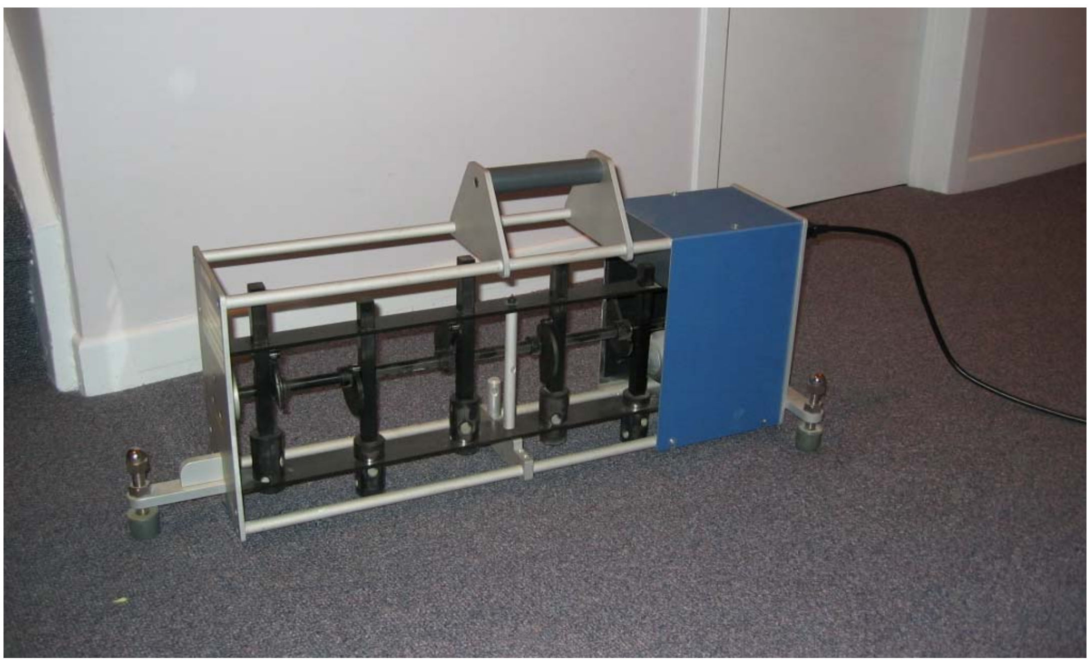

Figure 8 The Tapping Machine

Room	State	FSTC	FIIC
Bedroom 1	Before – lath & plaster ceiling	42	41
Bedroom 1	After - large holes on 400 mm centers in old lath & plaster ceiling, blown-in insulation, resilient channels, 2 layers of 12.7 mm gypsum board	52 (improvement +10)	48 (improvement +7)
Bedroom 2	Before – lath & plaster ceiling	42	43
Bedroom 2	After - large holes on 800 mm centers in old lath & plaster ceiling, blown-in insulation, resilient channels, 2 layers of 12.7 mm gypsum board	50 (improvement +8)	47 (improvement +4)
Bedroom 3	Before - not available for testing	-	-
Bedroom 3	After – drilled 25 mm holes on 400 mm centers in old lath & plaster ceiling, blown-in insulation, resilient channels, 2 layers of 12.7 mm gypsum board	46 (estimated improvement +4)	46 (estimated improvement +3 - 5)
Living/Dining Room	Before* – lath & plaster ceiling	39	39
Living/Dining Room	After - old lath & plaster ceiling removed, 100 mm mineral wool insulation batts, resilient channels, 2 layers of 12.7 mm gypsum board	46 (improvement +7)	45 (improvement +6)

* Measured in another set of apartments of identical floor plan in the same building.

Table 2 Sound Transmission (STC) and Impact Isolation Test Results

Cost Considerations

The costs of undertaking these retrofit measures are set out in Table 3. Costs were monitored during the renovations and the values set out in Table 3 are based on the costs which normally occur during such a renovation: labour, materials and supervision. Any additional costs purely associated with the case study, for example the cost of acoustic testing, have not been included. (As unsatisfactory results were obtained when 25 mm (1") holes were drilled in the original ceiling, the cost of this treatment is not included in Table 3.)

Retrofit	Estimated Cost
Full removal of former ceiling: • Removal and disposal of lath and plaster ceiling • Install 100 mm (4") mineral wool insulation batts • Install resilient channels, on 400 mm (16") centers • Install two layers of gypsum board 12.7 mm, Type X, fire rated	\$108 – 118 per m^2 (\$10 - 11 per ft^2)
Large holes in former ceiling: • Make holes, approximately 100 mm (4") diameter, in former lath and plaster ceiling on a 400 or 800 mm grid pattern. Dispose of waste. • Blown-in cellulose insulation (includes cost of applying a polythene sheet to hold insulation in place during installation. • Install resilient channels, on 400 mm (16") centers • Install two layers of gypsum board 12.7 mm, Type X, fire rated	\$65 per m^2 (\$6 per ft^2)

Table 3 Cost of Retrofit Treatments

4. Discussion

As set out in Table 2, the improvements in FSTC due to the retrofit measures vary from 4 to 10 points and the improvements in FIIC vary from 3 to 7 points. (Note that an improvement of only 3 points in these measures would be considered just noticeable, but, improvements of 6 or more points would be considered significant and useful.)

In the rooms where either the old lath and plaster ceiling was removed, or breeched with large holes, approximately 100 mm (4") diameter, the improvements achieved are very significant in FSTC terms (7 to 10 point improvement) and moderately significant in FIIC terms (4 to 7 point improvement). It may not be surprising that impact properties are less affected by the retrofit treatments than airborne sound transmission properties because impact transmission is more strongly affected by the structure of the floor which was not changed.

The least improvement was obtained in bedroom 3 where only small holes were drilled in the old lath and plaster ceiling. This suggests that the numbers and sizes of holes placed in the old ceiling may not have been adequate to remove the acoustic coupling. The percentage of open area for the drilled holes in bedroom 3 is much lower than that produced by the larger hammer holes in bedrooms 1 and 2, see Table 2. Alternatively, there could be a flanking path which is limiting the improvements in bedroom 3. There is some uncertainty here which could not be resolved within the scope of this project.

In absolute terms, see Table 2, best results were achieved in bedrooms 1 and 2 while poorer results were obtained in the living/dining room and in bedroom 3.

Laboratory test results[8] are available for the following modern construction which is approximately equivalent to the retrofitted floor/ceiling construction in the apartment.

- Floor: 15 mm thick oriented strand board
- Wood joists: 235 mm depth, on 406 mm centers
- 153 mm glass fibre cavity insulation
- resilient channels on 406 mm centers
- two layers of gypsum board 12.7 mm, Type X, fire rated

The laboratory test results for the above floor are STC 56 and IIC 50.

Given that the testing of the apartment floor/ceilings was done under field conditions, the results in bedrooms 1 and 2, FSTC 52 and 50, FIIC 48 and 47, are comparable and satisfactory. The lower values in the field test may be due to minor amounts of flanking (e.g. transmission along walls) and differences between the floor constructions, for example the apartment floor (6 mm (1/4") hardwood plus 25 mm (1") planks with gaps) is probably less of a noise barrier compared to the 15 mm of oriented strand board in the laboratory tests.

On the other hand the results in the living/dining room, FSTC 46 and FIIC 45 are considerably below the laboratory test result, and considerably below the results in bedroom 1 and 2. As the construction details of the retrofit were carefully executed, this suggests that there may be a major flanking path in the living/dining room which is preventing the achievement of higher acoustic insulation values.

Considerable care is advised in generalizing the above results. The results are those of a case study where each construction was evaluated only once and tested under field conditions. While it is anticipated that the case study indicates trends and what could generally be expected in terms of results, actual results in any given application can be expected to vary.

It is hoped that further research and/or case studies of this type will assist in clarifying the effects of these and other retrofit acoustical treatments.

5. Conclusions

A case study has been conducted of several retrofit methods for improving sound transfer in a floor/ceiling construction which includes a lath and plaster ceiling. The results of the case study are as follows.

- Both airborne sound and impact sound insulation have been significantly improved by adding fibrous cavity insulation and replacing the lath and plaster ceiling with two layers of 12.7 mm (1/2") fire rated, Type X gypsum board suspended on resilient channels.

- Results indicate that it is probably not necessary to completely remove the former lath and plaster ceiling. Good results were obtained when a series of large holes equivalent to approximately 10% of the ceiling area was made in the former ceiling prior to applying the resilient channels and gypsum board. Poor results were obtained when only a series of small holes were drilled in the original ceiling, although other factors such as flanking may have contributed to this poor result.

- In two cases, sound and impact transmission values were obtained which are close to laboratory test values for similar modern constructions. In another case, where it appears that sound was being carried between floors by other paths, perhaps flanking down the walls, lesser isolation results were obtained, but the improvement was still significant.

This is a case study and considerable caution should be taken in applying these results to other buildings. Treating the direct path (ceiling in this case) will have variable results because of the possible effects of flanking. Because of flanking, the exact improvement due to treating the direct path will be unique to each construction so it is not possible to generalize results. For a retrofit to be efficient and cost effective, the dominant transmission paths should be measured and the treatment carefully chosen so that all the paths are suppressed by an appropriate amount to meet the design goal. This will typically require the services of a professional trained in noise and vibration control.

With appropriate care, significant improvements in sound isolation can be achieved through retrofit techniques. Cost data for the retrofit techniques applied in this case study are provided to assist in evaluating cost/benefits for other projects.

References

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