Horizontal Impact Sound Insulation: Field Observations

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ABSTRACT

This paper presents horizontal impact noise test results collected over the last five years during the Auckland 'Apartment boom' and aims to improve the industry's 'information base' when considering horizontal impact noise transmission in multi-storey apartment buildings. This topic is particularly relevant to the New Zealand building industry today in light of the likelihood that the revised Building Code that is under consideration will include objective horizontal criterion. Horizontal impact insulation test results on various types of concrete floor systems (precast, post-tensioned, etc) are presented. Results observed with commonly utilised impact treatments below tiled floor systems have been included and compared. Based on the field results presented possible horizontal impact noise criteria are considered.

INTRODUCTION

This paper presents some of the observations collected by Norman Disney & Young over the past 5 years with respect to horizontal impact noise transmission. The observations are limited to ceramic tiles on various impact protection systems with continuous concrete floor systems between apartments as commonly encountered within New Zealand.

Historically, the noise from impact sources has been assessed vertically to address a major source of complaints in multi-storey apartment situations. The New Zealand Building Code adopted the use of the Impact Insulation Class (IIC) method of assessment as part of Clause G6 published in 1992. IIC ratings measured outside a laboratory situation are referred to as Field Impact Insulation Class ratings (FIIC). More recently, concerns have been raised within the New Zealand construction industry that the objective assessment of FIIC ratings only in the vertical with a minimum on-site objective of FIIC 50 may result in substandard levels of amenity for residents adjacent to the area in question.

This paper is intended to provide some feedback on the level of horizontal impact insulation currently provided with industry standard practices to assist in the setting of any criteria on this matter.

METHODOLOGY

The three impact protection systems used in these case studies are generically described below:

System 1: 8mm bituminous pad with 2mm felt substrate.

System 2: 6mm Cork

System 3: 5mm thick polyurethane with thickener to provide 'body' and prevent slump to polyurethane.

These are three of the more efficient systems utilised in the industry with all the systems continually being observed in the 'field' to provide improvements over the bare slab condition, when assessed in the vertical, of approximately 15 FIIC points or more.

The majority of the impact isolation systems utilised in New Zealand do not involve screeds and these are arranged with associated waterproof membranes in close proximity to the hard floor surface system.

The performance of these impact isolation systems when installed below ceramic tiles has been observed on various concrete floor systems. The floor systems included:

- 170mm thick post-tensioned concrete floor system
- Hi-Bond (profiled steel tray) utilised as formwork with maximum concrete thicknesses in the range 110-120mm supported by a steel framed structure
- 75-90mm of concrete topping on pre-stressed ribs with 25-30mm timber infill between ribs as formwork
- 75mm concrete topping to precast Double Tee units

The field test results for each floor system are presented in the sections which follow and have been illustrated graphically with Normalized impact sound pressure levels, L'_n being obtained in one-third octave bands in general accordance with ISO 140-7 "Acoustics – Measurement of sound insulation in buildings and of building elements, Part 7: Field measurements of impact sound insulation of floors".

In addition, the various single number quantities utilised to describe the impact sound insulation of building elements have been established and presented in tabular form for each of the field tests.

The table for each floor system gives the nominal Field Impact Insulation Class (FIIC), Weighted normalized impact sound pressure level ($L'_{n,w}$), Weighted normalized impact sound pressure level plus spectrum adaptation term ($L'_{n,w} + C_I$), Weighted standardized impact sound pressure level ($L'_{nT,w}$) and any relevant comments with respect to the receiving room spatial conditions.

Although the standard classification for determination of Impact Insulation Class (*ASTM E989-89* 1999*)* suggests that the single figure rating IIC should be restricted to comparing floor-ceiling assemblies, its use is included in this study to include building elements for horizontal assessment as well. This has been included as the single figure IIC rating system is the most widely understood and utilised method of impact noise rating utilised within the New Zealand construction industry.

CASE STUDY 1 POST-TENSIONED FLOOR

Floor System

The floor consisted of a 170mm thick post-tensioned floor system. The resilient media utilised below the tiles was system 1. Bathrooms on the project were vertically stacked. The tapping machine was positioned on the bathroom floor and the observations were made in the living space or bedroom space in the adjacent apartment diagonally across. Both the source and receiving spaces occurred adjacent the dividing apartment wall.

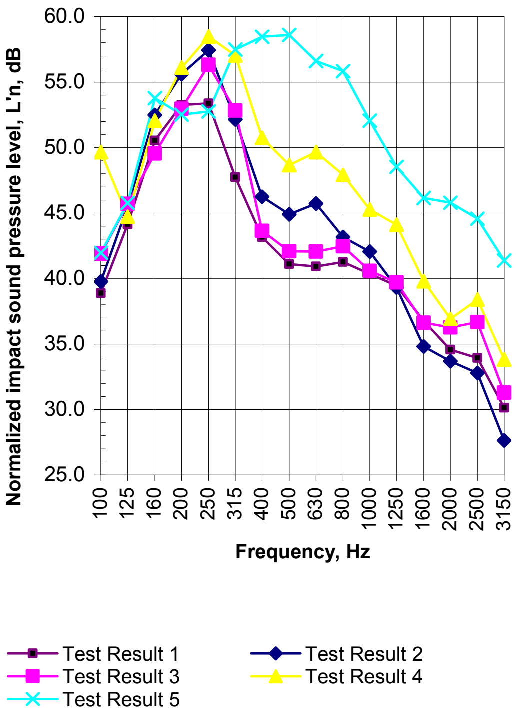

Figure 1. Post-Tensioned Floor System

The higher impact noise levels observed in Test 5 are not fully understood.

The higher levels of impact noise observed in the lower frequency bands ranging between 160 and 315 Hz are a characteristic of System 1.

CASE STUDY 2 HI-BOND FLOOR

Floor System

Table 1. Post-tensioned Floor and System 1

Test	FIIC	$L'_{n,w}$	$L'_{n,w} + C_I$	$L'_{nT,w}$	Rec. Space
1	65	45	44	46	Finished
2	63	46	47	47	Finished
3	64	46	45	48	Finished
4	61	49	49	48	Finished
5	55	55	51	56	Finished

The Hi-Bond floor system consists of a profiled galvanised steel tray as formwork. The troughs are 55mm deep. The maximum thickness of the concrete floor specimens tested ranged between 110mm and 120mm. This implies minimum thicknesses of concrete of only 55mm to 65mm. The resilient media utilised below the tiles was system 2. A large majority of the apartments on this project were built to a 'studio' type plan. The tapping machine was positioned on the kitchen tiles and measurements made in the immediately adjacent living space or bedroom. The only exception was test 4 where observations were made in the adjacent apartment diagonally across. The floor system was oriented structurally so that the 'ribs' and 'troughs' in the floor occurred parallel to the dividing inter-tenancy wall. Supporting steel beams occurred at right angles to the inter-tenancy wall. These beams are interrupted along the dividing wall line via a SHS post.

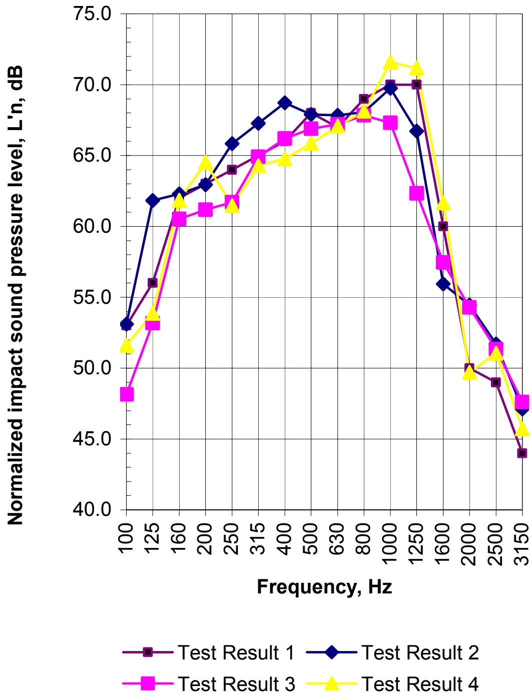

Figure 2. Hi-Bond Floor System

The higher levels of impact noise observed in some frequency bands for test 4 would fall in line with our expectations.

Table 2. Hi-Bond and System 2

Test	FIIC	$L'_{n,w}$	$L'_{n,w} + C_I$	$L'_{nT,w}$	Rec. Space
1	42	66	62	63	Bare
2	44	66	62	64	Bare
3	46	64	61	62	Bare
4	41	66	63	64	Bare

CASE STUDY 3 PRESTRESSED RIBS

Floor System

The floor consisted of 150mm deep prestressed ribs at approximately 900mm centres with 25mm thick timber infill panels between ribs. The concrete topping was 75mm thick.

Kitchens were open to livings spaces on this project. The tapping machine was placed on kitchen tiles and impact noise levels were observed in the living space of the adjacent apartment. The resilient media utilised below the tiles was system 2. The prestressed ribs were orientated so as to run parallel with the dividing inter-tenancy wall.

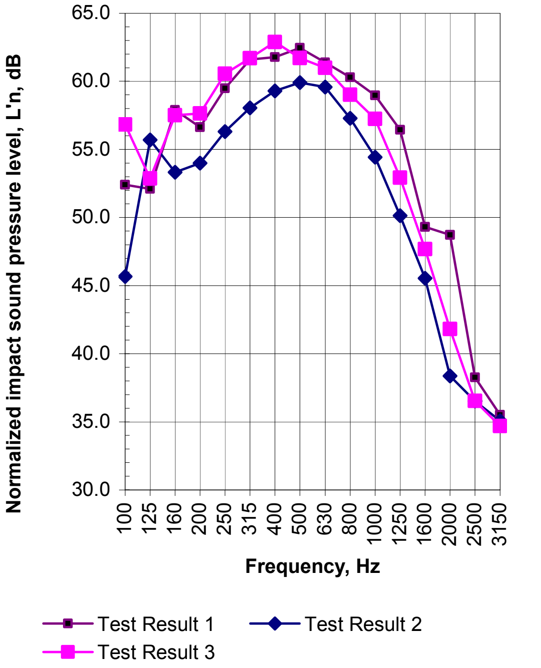

Figure 3. Pre-Stressed Ribs plus Timber Infill Floor System

This group of tests shows a small relative difference between test results. This case study did not exhibit the same level of variance encountered in other case studies. Mid and high frequency variations between test results is evidently small for this group of field tests, particularly when compared to the other data sets collected.

Table 3. Prestressed Ribs and System 2

Test	FIIC	$L'_{n,w}$	$L'_{n,w} + C_I$	$L'_{nT,w}$	Rec. Space
1	52	58	55	57	Bare
2	56	52	53	56	Bare
3	53	57	55	56	Bare

CASE STUDY 3B PRESTRESSED RIBS

Floor System

The floor consisted of 150mm deep prestressed ribs at 900-1100mm centres with 30mm thick timber infill panels between ribs. The concrete topping was 90mm thick.

All bedrooms had ensuites on this project. The tapping machine was placed on ensuite tiles and impact noise levels were observed in the bedroom space of the adjacent apartment. The resilient media utilised below the tiles was system 2.

For Tests 1 and 2 the ribs were orientated so as to be straddling the dividing inter-tenancy wall. The nearest edge of the tiled section tested was also positioned 2m from the dividing apartment wall.

For test 3 the ribs were orientated as to run parallel to the dividing inter-tenancy wall. The tiled section tested was positioned adjacent the dividing apartment wall.

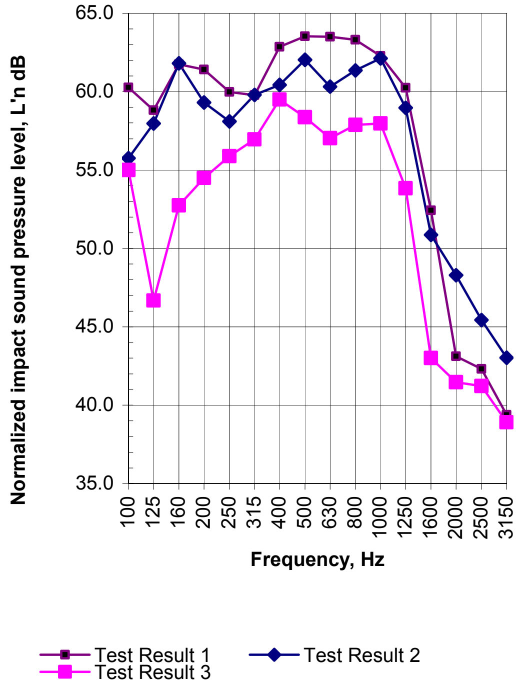

Figure 4. Pre-Stressed Ribs plus Timber Infill Floor System

The results indicate the importance of the rib orientation on the degree of impact insulation provided regardless of the resilient media utilised below the tiles.

CASE STUDY 4 DOUBLE TEE'S

Floor System

The floor consisted 250 Double Tee precast units with a 75mm thick concrete topping. The Double Tee legs were orientated structurally so as to be perpendicular to the dividing apartment walls. The Double Tee units were continuous between apartments. The resilient media utilised below the tiles was system 3.

For test 1 the tapping machine was placed on the kitchen tiles of one apartment and impact noise levels were observed in the living space of the adjacent apartment. The kitchen and living spaces were both positioned adjacent the dividing apartment wall.

For test 2 and 3 the tapping machine was placed on the tiled surface system of one-apartment and impact noise levels were observed in the nearest bedroom space of the adjacent apartment. The receiving bedroom space was located 1.2m from the dividing inter-tenancy wall with a corridor acting as a 'buffer' space. The tiled areas were positioned adjacent the apartment wall.

Table 4. Prestressed Ribs and System 2

Test	FIIC	$L'_{n,w}$	$L'_{n,w} + C_I$	$L'_{nT,w}$	Rec. Space
1	50	60	58	58	Bare
2	51	59	56	58	Bare
3	55	55	52	54	Bare

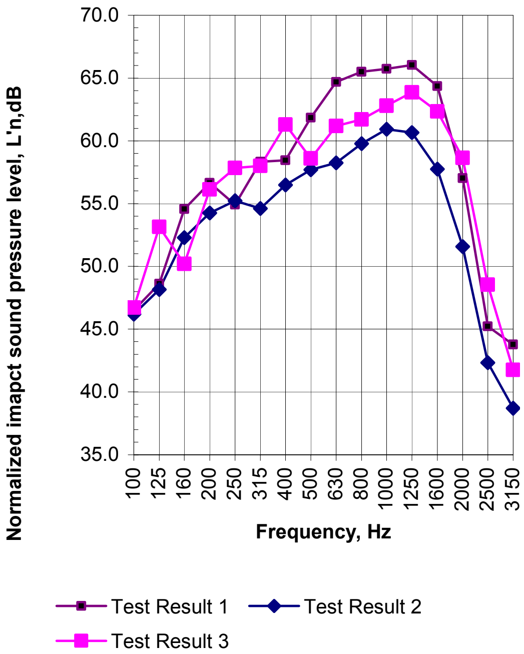

Figure 5. Double Tee Floor System

Not surprisingly the single number ratings indicate impact insulation levels to be lowest where receiver locations are closer proximity to the hard floor surface system tested.

CASE STUDY 4B DOUBLE TEE'S

Floor System

The floor consisted of 200 Double Tee precast units with a 75mm thick concrete topping. The Double Tee legs were orientated structurally so as to be perpendicular to the dividing apartment walls. The Double Tee units terminated along the inter-tenancy wall line at a 530 UB steel beam running along the centre line of the dividing inter-tenancy wall. The structural concrete topping was continuous between apartments. The resilient media below the tiles was system 1.

For both tests 1 and 2 the tapping machine was placed on the bathroom tiles of one apartment and impact noise levels were measured in the living space of the adjacent apartment. The bathroom and living spaces were both positioned adjacent the dividing apartment wall.

Table 5. TT Floor and System 3

Test	FIIC	$L'_{n,w}$	$L'_{n,w} + C_I$	$L'_{nT,w}$	Rec. Space
1	46	64	58	67	Finished
2	51	59	53	62	Finished
3	47	63	57	65	Finished

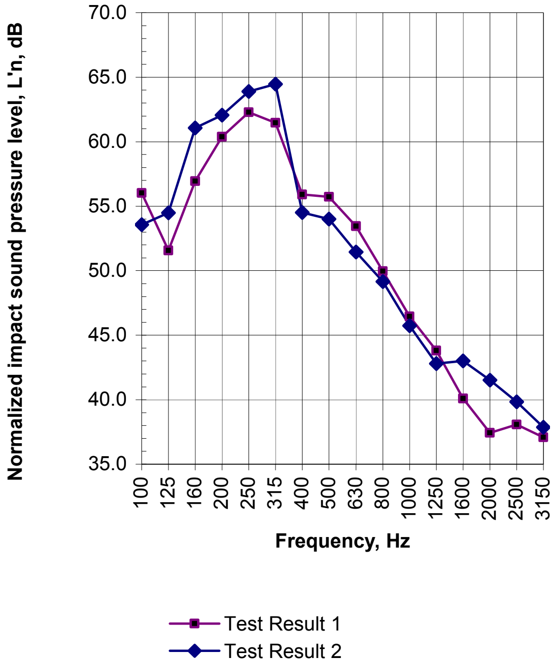

Figure 6. Double Tee Floor System

The higher levels of impact noise observed in the lower frequency bands ranging between 160 and 400 Hz are a characteristic of System 1. This performance is also repeated in the similar frequency range in Case Study 1. The low levels of impact noise received in the mid and high frequency bands witnessed here is also apparent in Case Study 1.

Table 6. TT Floor and System 1

Test	FIIC	$L'_{n,w}$	$L'_{n,w} + C_I$	$L'_{nT,w}$	Rec. Space
1	57	53	53	47	Finished
2	56	54	55	48	Finished

CLARIFICATIONS

Airborne noise was suitably controlled so as not to be an influencing factor.

CONCLUSIONS

Based on the sets of data gathered to date, there are some general conclusions that can be drawn with respect to the physical mechanisms that control the level of horizontal impact sound insulation. Many of these mechanisms are not surprising but remain unquantified in terms of New Zealand building practices.

- The high levels of impact noise witnessed in Case Study 4 highlight the need for a cautious approach with respect to introducing horizontal criteria.
- The very high levels of impact noise witnessed in Case Study 2 would appear to be near the worst-case practical limitation of horizontal impact noise insulation with current industry practices. Of further interest however are the negative effects that are expected with unfavourable tray orientation and continuous beaming between apartments.
- The orientation of ribs, beams, etc. in anisotropic floor systems is important. Where ribs or Double Tee elements run parallel to the wall, comparatively higher levels of horizontal impact sound insulation are continually observed.

- The transmission of horizontal impact noise appears to be significantly variable even with very similar test scenarios. The reasons for this are not yet understood. The surprising level of variability in insulation levels associated with similar scenarios gives cause for concern when considering the introduction of objective criteria in a nationally legislated document.

SUGGESTED AREAS FOR FURTHER RESEARCH

The authors of this paper recognise the limitations associated with drawing conclusions on any topic with a relatively small population sample. This is particularly true in this study where there are a significant number of contributing factors to performance. Given the limited data presented in this paper, the authors do not recommend relying on the conclusions for design purposes. The authors would like to encourage other acoustic designers to contribute to the limited database so that a better understanding of the issues can involved can be gained.

Notwithstanding amenity effects, the authors consider that it is important to understand any practical limitations associated with horizontal impact insulation prior to its introduction in legislation. Accordingly, the authors recommend that any further investigations into horizontal impact noise focus on establishing a rigorous understanding of;

- Any implications of horizontal impact criteria as they relate to steel framed buildings.
- Any limitation in performance associated structural elements running continuously between apartments
- Quantifying the extent of any benefits that stand to be gained by introducing blocking masses between apartments

REFERENCES

ASTM International 1999, *Standard Classification for Determination of Impact Insulation Class (IIC)*, E 989 – 89 (Reapproved 1999). Retrieved from ASTM International online database.

ASTM International 2004, Standard Test Method for Field Measurement of Tapping Machine Impact Sound Transmission Through Floor-Ceiling Assemblies and Associated Support Structures, E 1007 – 04. Retrieved January 23, 2005, from ASTM International online database.

International Organization for Standardization 1996, *Acoustics – Rating of sound insulation in buildings and of buildings elements – Part 2: Impact sound insulation*, ISO 717-2:1996(E). Retrieved June 16, 2003, from ISO Store online database.

International Organization for Standardization 1998, Acoustics – Measurement of sound insulation in buildings and of building elements – Part 6: Laboratory measurements of impact sound insulation of floors, ISO 140-6:1998(E). Retrieved June 16, 2003, from ISO Store online database.

International Organization for Standardization 1998, Acoustics – Measurement of sound insulation in buildings and of building elements – Part 7: Field measurements of impact sound insulation of floors, ISO 140-7:1998(E). Retrieved June 16, 2003, from ISO Store online database.