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Noise Attenuation by Roof Cladding Systems

Laboratory Testing Part 1 Results: Cladding Only

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Summary

Based on the results of the laboratory evaluation of the claddings only, the number of claddings to be included in the laboratory evaluation of complete roof systems will be reduced to four:

Metal Tile: Chip
Profiled Metal: Corrugate 0.4
Concrete Tile without Underlay
Concrete Tile with Underlay

The evaluation of the claddings alone resulted in several findings including:

- The addition of underlay under both metal and concrete tiles increased the weighted intensity sound reduction indices of the claddings.
- Concrete tiles with underlay had a weighted intensity sound reduction index which was 5 dB higher than concrete tiles without underlay. Therefore, there is a significant difference between concrete tiles with and without underlay.
- The profiled metal claddings had higher intensity sound reduction indices than the tiles without underlay due to the gaps between the tiles which act as sound leaks

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1. Introduction

This report documents the results of part 1 of the laboratory tests for the study commissioned by the New Zealand Metal Roofing Manufacturers Association Inc. The purpose of the part 1 measurements was to evaluate the sound reduction index of both metal and concrete claddings to determine if the number of claddings used for subsequent parts of the laboratory evaluation could be reduced. The claddings included in the evaluation are shown in Table 1.

Type	Cladding
Metal Tiles	Paint
	Chip
	Chip with Underlay
Profiled Metal	Longrun 0.4
	Longrun 0.55
	Corrugate 0.4
	Corrugate 0.4 with 17.5 mm Plywood Sarking
Concrete Tiles	Concrete Tile
	Concrete Tile with Underlay
Plywood	17.5 mm Plywood

Table 1: Claddings included in Part 1 of the laboratory evaluation.

The table includes additional claddings which were not part of the original scope of the evaluation but were added during the course of the testing. The additions to the evaluation included the Corrugate 0.4 with plywood sarking, the metal chip tile with underlay and the plywood alone.

The noise attenuation of each of the claddings was evaluated at the University of Canterbury. The materials were supplied by the Metal Roofing Manufacturers Association and the claddings were installed into the opening by professional roofers. The measurements and analysis were conducted by the Acoustics Group at the University of Canterbury.

The evaluation of the sound reduction indices of the claddings evaluated in this study is an important part of understanding the transmission of noise through roof systems. The results of the evaluation allowed for the reduction in the number of claddings to be used for subsequent parts of the laboratory testing. Furthermore, knowledge of the sound reduction indices of the claddings may be helpful to predict the noise through roof systems (inclusive of the cladding, the trusses and the ceiling) in the future. However, claddings are never applied to buildings in isolation. The ability of noise to transmitted from the exterior of a building to the rooms inside through the cladding is influenced not only by the sound reduction index of the cladding, but by the ability of the trusses to transmit structure-borne noise, the air in the plenum, the insulation above the ceiling, and the acoustic properties of the ceiling. It was noted in the Phase 1 report that these other factors have been found in prior studies [1-3] to have a much larger influence on the transmission of noise through the roof system than the sound reduction index of the cladding. Therefore, the results and discussions presented in this part 1 of the laboratory evaluation should be considered to only apply to the claddings in isolation and not to the transmission of noise into buildings through the roof system.

2. Test Method

2.1. Acoustic Measurements

The sound reduction index of each of the claddings was measured using the sound intensity method in full accordance with ISO 15186-1:2000 [4]. The claddings were each installed into a 11.52 m^2 opening between a reverberant chamber and a semi-anechoic chamber. A diffuse sound field was generated in the reverberation chamber using a Brüel and Kjær dodecahedral sound source with a pink noise signal generated by a Brüel & Kjær PULSE analyzer. The sound pressure level in the reverberant chamber was measured using an array of five Brüel & Kjær Type 4189 1/2 inch, free field microphones which were also connected to the PULSE analyzer. The microphones were calibrated with a Brüel & Kjær acoustic calibrator, Type 4231.

The transmitted sound intensity was measured using a Brüel and Kjær 2260 sound analyzer with Brüel and Kjær BZ7205 sound intensity software and a Brüel and Kjær Type 3595 sound intensity probe kit. The sound intensity probe kit was calibrated using a Brüel & Kjær acoustic calibrator, Type 4231 and a Brüel & Kjær adaptor, Type DP0888.

The average transmitted sound intensity was calculated by averaging the results of six to ten scans of the measurement surface. Each scan included sweeping the intensity probe over the measurements surface twice, once in a horizontal direction and once in a vertical direction.

The intensity sound reduction index was calculated according to the equation:

$$R = L_{ps} - L_{it} - 6 \text{ (dB)}$$

where L_{ps} is the sound pressure measured in the reverberation room (dB re 2 x 10^{-5} Pa) and L_{it} is the sound intensity level measured in the semi anechoic chamber (dB re 1 x 10^{-12} W/m^2). The sound pressure level in the reverberant chamber was determined from an average of five measurements in five positions in the reverberant chamber. The intensity sound reduction index was calculated in the 1/3 octave bands between 100 and 5000 Hz. Measurements in the 1/3 octave bands below 100 Hz and above 5000 Hz were also included, but for reference only since measurements in these 1/3 octave bands were outside of the scope of ISO15186-1:2000.

2.2. Sample Installation

The claddings were installed into the 11.52 m^2 opening between the reverberation room and the semi-anechoic receiving room at the University of Canterbury. The source and receiving rooms were complaint with the requirements of ISO 15186-1:2000 *Acoustics -- Measurement of sound insulation in buildings and of building elements using sound intensity -- Part 1: Laboratory measurements* [4]. The claddings were installed by professional roofers onto a wooden frame which was built into the concrete opening between the source and the receiver rooms as required by ISO 15186-1. The wooden frame was built *in-situ* and was not fastened to the concrete opening with the exception of the testing of the concrete tiles in which case it was anchored to the concrete by two fasteners. The wooden frame included wood studs which were located at 900 mm centres as shown in Figure 2. The edges of the cladding were sealed against noise leaks using a sealing compound applied to the reverberation room side of the cladding as shown in Figure 1.

Figure 1: Sealing compound around the edges of the cladding to prevent sound leakage around the edges of the cladding.

The sealing compound was used around the entire perimeter of the cladding, except in the case of the metal tiles where a resilient material was inserted under the bottom row of tiles.

2.2.1. Profiled Metal Cladding

The profiled metal claddings were screwed to battens which were nailed to the trusses as shown in Figure 2.

Figure 2: Corrugate 0.4 installed in the test opening as viewed from the semi-anechoic room.

All of the profiled metal claddings were screwed to the battens with the exception of the cladding with the plywood sarking as shown in Figure 3.

Figure 3: Corrugate 0.4 with plywood sarking as viewed from the semi-anechoic room.

When plywood sarking was used, the cladding was screwed directly to the plywood without the use of battens. The seams between the sheets of plywood were sealed with masking tape which was applied from the semi-anechoic room side.

2.2.2. Metal Tiles

The metal tiles were nailed to battens located at 370 mm centres as shown in Figure 4.

Figure 4: Battens used for the metal tiles as viewed from the semi-anechoic room.

When the chip tile and the painted tile were tested without underlay, the top row of the metal tiles were bent along the top, inside face of the concrete opening as shown in Figure 5.

Figure 5: Metal tiles with the top row of tiles bent at the top of the concrete opening.

When the chip tile was tested with underlay, the top row of tiles were not bent at the top as shown in Figure 6.

Figure 6: Metal tiles with underlay which were tested with the top row of tiles ending at the top of the concrete opening instead of being bent over.

All of the metal tiles were tested with a layer of resilient material located between the bottom row of tiles and the floor of the chamber as shown in Figure 7.

Figure 7: Resilient material located between the bottom row of tiles and the concrete floor.

The purpose of the resilient material was to seal the large gaps between the metal tiles and the concrete.

2.2.3. Concrete Tiles

The concrete tiles were nailed to battens as shown in Figure 8 and Figure 9.

Figure 8: Concrete tiles nailed to battens as viewed from the semi-anechoic room side of the test opening.

Figure 9: Concrete tiles nailed to battens as viewed from the reverberation room side of the test opening.

Each row of the concrete tiles was nailed to the battens. Resilient material was not used under the bottom row of tiles as shown in Figure 10.

Figure 10: Bottom row of the concrete tiles showing the sealing compound.

The gap at the bottom of the concrete tiles was small enough to be sealed with the sealing compound.

2.2.4. Claddings with Underlay

Both the metal chip tile and the concrete tile were tested with underlay. The underlay was installed under the battens as shown in Figure 11 and Figure 12.

Figure 11: Tiles with underlay as viewed from the reverberation room side.

Figure 12: Underlay as viewed from the semi-anechoic room side.

The decision to install the underlay under the battens rather than under the tiles was believed to affect the intensity sound reduction index of the claddings as discussed in Section 4.2.

2.3. Measurement Uncertainty

The standard, ISO 15186-1:2000 does not include an estimate of the uncertainty of the measurements it describes. However it may be expected that the standard deviation of reproducibility of the measurements will not be greater than the standard deviation of reproducibility using two adjacent reverberation rooms as described in Annex A of ISO 140-2 [5] and listed in Appendix B of this report.

2.4. Calculation of Single Number Ratings

Single number ratings are commonly used to quickly evaluate the noise attenuation of claddings. New Zealand currently uses the STC rating which is determined from the intensity sound reduction index in the 125 Hz to the 4000 Hz 1/3 octave bands according to ASTM E 413 - 04 [6].

Revisions to the Building Code in New Zealand are currently out for comment [7]. The proposed changes to the code include the replacement of the STC rating by the weighted sound reduction index R_w which is calculated according to AS/NZS ISO 717-1:2004 [8]. Therefore, the calculation of the weighted intensity sound reduction index will also be included in the results presented in this report. The weighted intensity sound reduction index differs from the STC rating in that it is calculated using sound reduction index data in the 1/3 octave bands between 100 Hz and 3150 Hz 1/3 octave bands.

The proposed revisions to the Building Code also includes the level difference in the evaluation of the noise attenuation of claddings. The weighted intensity normalized level difference $D_{I,n,w}$ calculated according to ISO 15186-1:2000 and AS/NZS ISO 717-1:2004 is also included in the results.

ISO 717-1:2004 includes spectrum adaptation terms to take into account the different spectra of noise sources such as road traffic noise. The spectrum adaption term for traffic C_{tr} was intended to optimize sound insulation against traffic, propeller driven aircraft and jet aircraft at a distance [9]. C_{tr} is based on an average traffic noise spectrum and has a strong weight at the low frequencies, but keeps 100 Hz as the lower frequency limit for measurements in accordance with ISO15186-1. The spectrum adaptation terms are derived from 1/3 octave values. The weighted sound reduction index and the spectrum adaptation terms are stated with the spectrum adaptation term in parenthesis after the single-number quantity, for example, $R_{I,w}(C_{tr})$ = 41 (-4) dB [8]. Requirements for facades may be written as a sum of the weighted sound reduction index and the spectrum adaptation term such that: $R_{I,w}$ + C_{tr} = 36 dB where C_{tr} has been used to adjust the value of $R_{I,w}$ to account for the low frequency traffic noise.

A summary of the single number ratings calculated in this study is shown in Table 2.

Calculation	Symbol	Reference Standard
STC Rating	STC	ASTM E 413 - 04
Weighted Intensity Sound Reduction Index	$R_{I,w}$	AS/NZS ISO 717-1:2004
Weighted Intensity Sound Reduction Index plus the Spectrum Adaptation Term for Traffic	$R_{I,w}$ (C_{tr})	AS/NZS ISO 717-1:2004
Weighted Intensity Normalized Level Difference	$D_{I,n,w}$	AS/NZS ISO 717-1:2004
Weighted Intensity Normalized Level Difference plus the Spectrum Adaptation Term for Traffic	$D_{I,n,w}$ (C_{tr})	AS/NZS ISO 717-1:2004

Table 2: Single number ratings evaluated in this study.

3. Results

The single number ratings of all of the claddings are compared in Table 3.

Type	Cladding	Single Number Ratings				
		STC	$R_{I,w}$	$D_{I,n,w}$	$R_{I,w}$ (C_{tr})	$D_{I,n,w}$ (C_{tr})
Metal Tile	Paint	16	16	15	16 (-1)	15 (-1)
	Chip	16	16	16	16 (-1)	16 (-1)
	Chip with Underlay	18	18	17	18 (-3)	17 (-2)
Profiled Metal	Longrun 0.4	17	17	17	17 (-2)	17 (-3)
	Longrun 0.55	18	18	17	18 (-2)	17 (-1)
	Corrugate 0.4	19	19	19	19 (-3)	19 (-4)
	Corrugate 0.4 with 17.5 mm Plywood	25	25	24	25 (-3)	24 (-2)
Concrete Tile	Concrete Tile	15	16	16	16 (-1)	16 (-1)
	Concrete Tile with Underlay	21	21	20	21 (-3)	20 (-3)
Plywood	17.5 mm Plywood	23	23	22	23 (-2)	22 (-2)

Table 3: Comparison of single number ratings of the claddings.

The values of the single number ratings can differ for each cladding due to the differences in how the single number values are calculated.

The STC rating and the weighted intensity sound reduction index of each of the claddings are ranked from highest to lowest in Table 4.

Cladding	STC	$R_{I,w}$ (dB)
Corrugate 0.4 with 17.5 mm Plywood Sarking	25	25
Concrete Tile with Underlay	21	21
Profiled Metal - Corrugate 0.4	19	19
Metal Tile - Chip with Underlay	18	18
Profiled Metal - Longrun 0.55	18	18
Profiled Metal - Longrun 0.4	17	17
Metal Tile - Paint	16	16
Metal Tile - Chip	16	16
Concrete Tile	15	16

Table 4: Ranking of the claddings according to both the STC rating and the weighted intensity sound reduction index.

The data in the table indicates that the metal and concrete tiles without underlay had the lowest single number ratings of the claddings tested, most likely due to the gaps between the tiles. The size of the gaps between the concrete tiles was greater than that of the gaps between the metal tiles. The effect of the gaps between the tiles was reduced by the addition of underlay under the battens. The addition of the underlay was shown to increase the value of the weighted intensity sound reduction index by 2 dB in the case of the metal chip tile and by 5 dB in the case of the concrete tile. Therefore, the addition of underlay had a significant effect on the sound reduction index of the cladding as discussed in Section 4.2.

The profiled metal claddings performed better than the metal tiles due to the absence of air gaps. The Corrugate 0.4 performed better than the Longrun claddings which were tested as discussed in Section 4.3.

The addition of the 17.5 mm plywood under the Corrugate 0.4 was shown to increase the value of $R_{I,w}$ by 6 dB and resulted in the highest value of $R_{I,w}$ of all of the claddings.

The weighted intensity sound reduction indices adjusted using the C_{tr} spectrum adaptation term are ranked in Table 5. The C_{tr} spectrum adaptation term is not currently used in New Zealand. Nor is C_{tr} being considered as part of the revisions to the building code. However, the use of the spectrum adaptation term provides an estimate of the sound insulation of the claddings specifically due to traffic and aircraft noise.

Cladding	$R_{I,w} + C_{tr}$ (dB)
Profiled Metal - Longrun 0.4	21
Concrete Tile	21
Metal Tile - Chip	18
Metal Tile - Chip with Underlay	16
Profiled Metal - Longrun 0.55	16
Corrugate 0.4 with 17.5 mm Plywood Sarking	15
Concrete Tile with Underlay	15
Profiled Metal - Corrugate 0.4	15
Metal Tile - Paint	15

Table 5: Ranking of the claddings according to $R_{I,w} + C_{tr}$.

The ranking of the claddings in Table 5 is significantly different to that in Table 4. If the C_{tr} spectrum adaptation term is taken into account, the use of the underlay and the plywood sarking decreases the magnitude of the sound insulation the claddings provide against traffic noise. The concrete and chip metal tiles are shown to perform much better without underlay. The profiled metal Longrun 0.4 was tied with the concrete tile as the best performing cladding when the C_{tr} spectrum adaptation term was taken into account.

4. Discussion

4.1. Metal Tile

The intensity sound reduction indices of the metal tiles are compared in Figure 13.

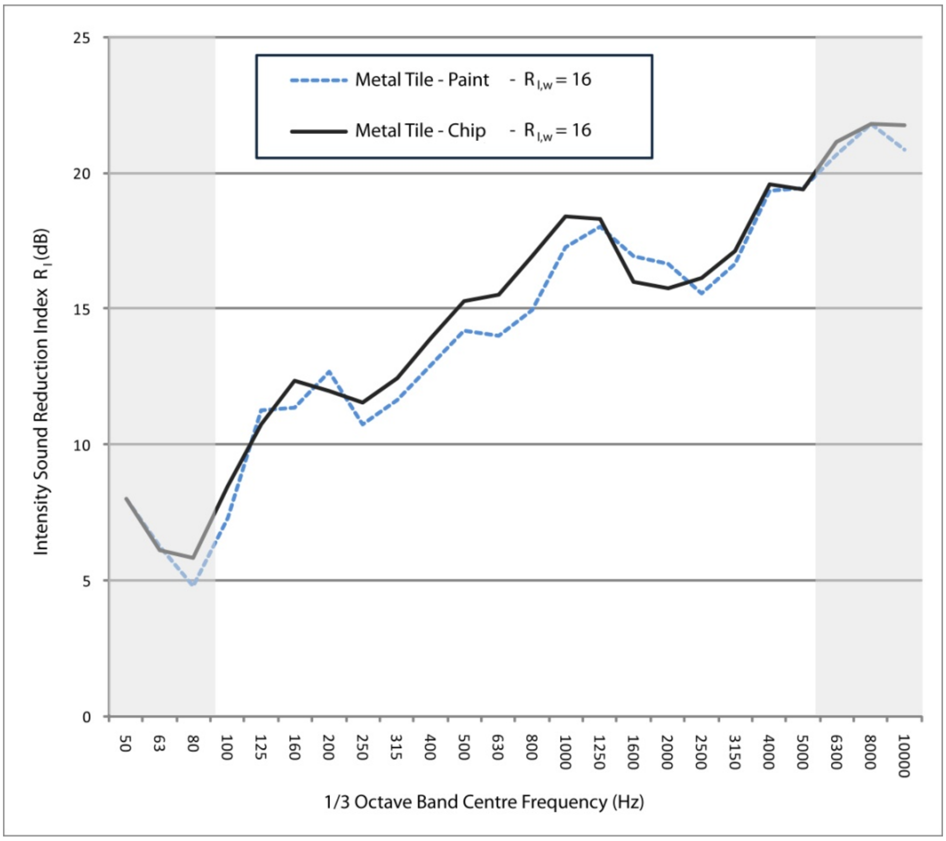

Figure 13: Comparison of the intensity sound reduction indices of the metal tiles. The data in the 1/3 octave bands less than 100 Hz and greater than 5000 Hz (shown in grey in the figure) are outside the scope of ISO 15186-1 and are presented for reference only.

The intensity sound reduction indices of the paint and chip tiles are within 2 dB of each other over the entire frequency range of interest with the largest difference being between the 630 Hz and 1000 Hz 1/3 octave bands. The similarity of the sound reduction index curves suggests that the subsequent parts of this study can be conducted using only one of the metal tiles.

4.2. Underlay

The sound reduction indices of the metal chip tile and the concrete tile with and without underlay are compared in Figure 14.

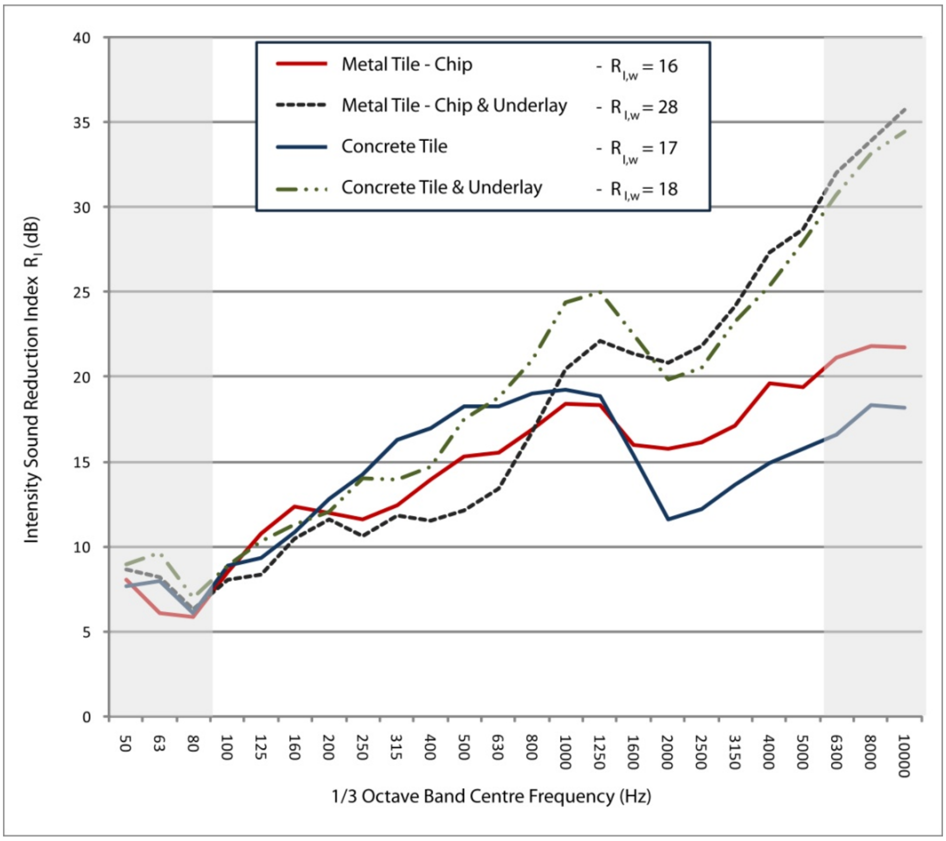

Figure 14: Comparison of the intensity sound reduction index of the concrete and metal chip tiles with and without underlay. The data in the 1/3 octave bands less than 100 Hz and greater than 5000 Hz (shown in grey in the figure) are outside the scope of ISO 15186-1 and are presented for reference only.

The figure shows that the addition of the underlay under the battens increased the intensity sound reduction index of the claddings in the 1/3 octave bands above approximately 630 Hz. The effect of the underlay indicates that the sound leaks between the tiles were responsible for the lower sound reduction index of the tiles as opposed to that of the profiled metal claddings. The concrete tiles had larger gaps between the tiles than the metal tiles and therefore the increase in the intensity sound reduction index for the tiles with underlay was larger for the concrete tiles than the metal tiles.

Although the sound reduction index of the underlay was not expected to be high, the addition of the underlay under the battens was effective at reducing the effect of the sound leaks between the tiles. The sound leaks through the gaps in the tiles had the strongest effect on the total sound reduction index of the tiles for two reasons. The first reason was that at the low frequencies, the intensity sound reduction index of the claddings was low and therefore the magnitude of the noise through the sound leaks was negligible compared to the sound transmission through the tiles. At the higher frequencies, the sound transmission through the tiles was lower and therefore even the smallest sound leak could decrease the total sound reduction index significantly [10]. The second reason was that the transmission of sound through slits has been found to be higher at the higher frequencies due to slit resonances [11].

Also noticeable in Figure 14 are dips in the magnitude of the intensity sound reduction index of both tiles around the 315 Hz to the 500 Hz 1/3 octave band. For these measurements, the underlay was installed under the battens which left a cavity between the underlay and the cladding (see Figure 11). These dips are thought to be caused by the mass-air-mass resonance due to the cavity between the underlay and the cladding. Had the underlay been installed directly under the tiles, the magnitude of the dips would most likely be reduced and the weighted intensity sound reduction indices of the tiles with underlay could have been higher.

4.3. Profiled Metal

The intensity sound reduction indices of the profiled metal claddings are compared in Figure 15.

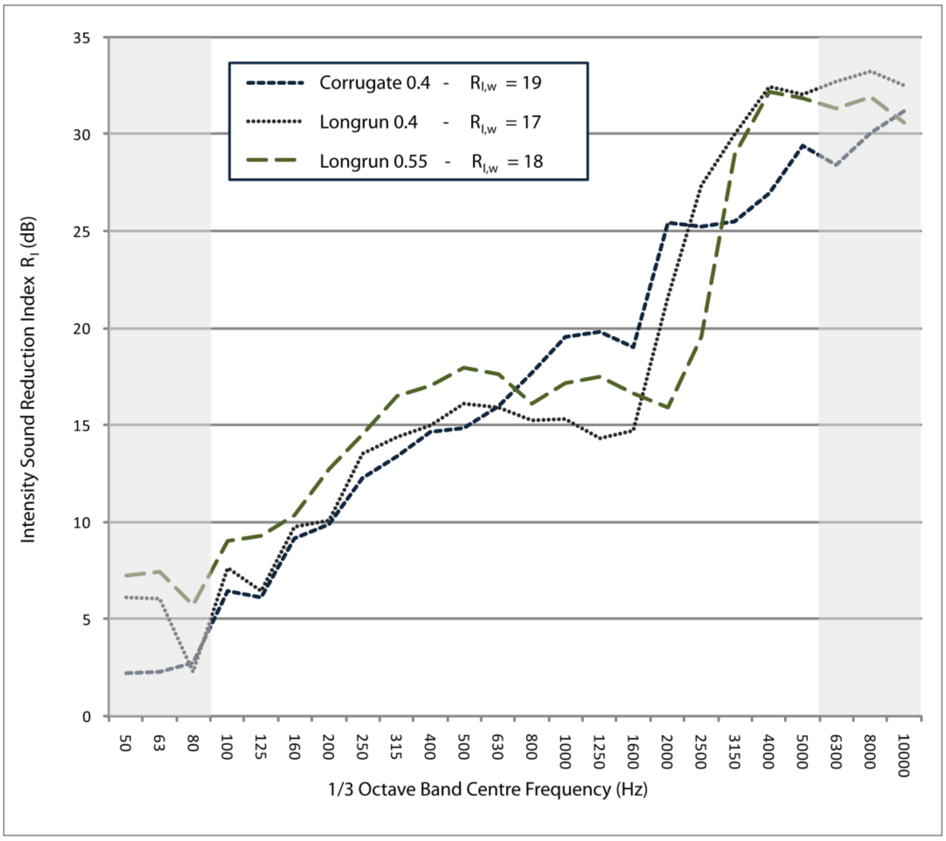

Figure 15: Comparison of the intensity sound reduction indices of the profiled metal claddings. The data in the 1/3 octave bands less than 100 Hz and greater than 5000 Hz (shown in grey in the figure) are outside the scope of ISO 15186-1 and are presented for reference only.

The three profiled metal claddings included in the evaluation showed similar trends in the sound reduction index curves. Between the 100 Hz and the 800 Hz 1/3 octave bands, the sound reduction indices differed between the claddings by a maximum of 3 dB. The thicker, Longrun 0.55 performed better than the Longrun 0.4 or the Corrugate 0.4 in this frequency range most likely due to the additional mass of the thicker material. In the frequency range between the 1000 Hz and the 2500 Hz 1/3 octave bands, the difference between the intensity sound reduction indices were greater than the rest of the frequency range due to dips in the spectrum. These dips are commonly seen in corrugated panels between the 2000 Hz and 4000 Hz 1/3 octave bands and correspond to an air resonance between the corrugations or a mechanical resonance of the flat panel between the ribs [12].

The Corrugate 0.4, the profile of which is shown in Figure 16 did not exhibit as significant a dip as the other profiled metal claddings.

Figure 16: Corrugate 0.4 profile.

The lack of a significant dip could be due to the two patterns of anti-symmetric corrugations. The resonances of the two patterns of corrugations would be different which could have effectively reduced the effect of each resonance.

4.4. Profiled Metal with Plywood Sarking

The effect of adding 17.5 mm plywood sarking under the Corrugate 0.4 is shown in Figure 17.

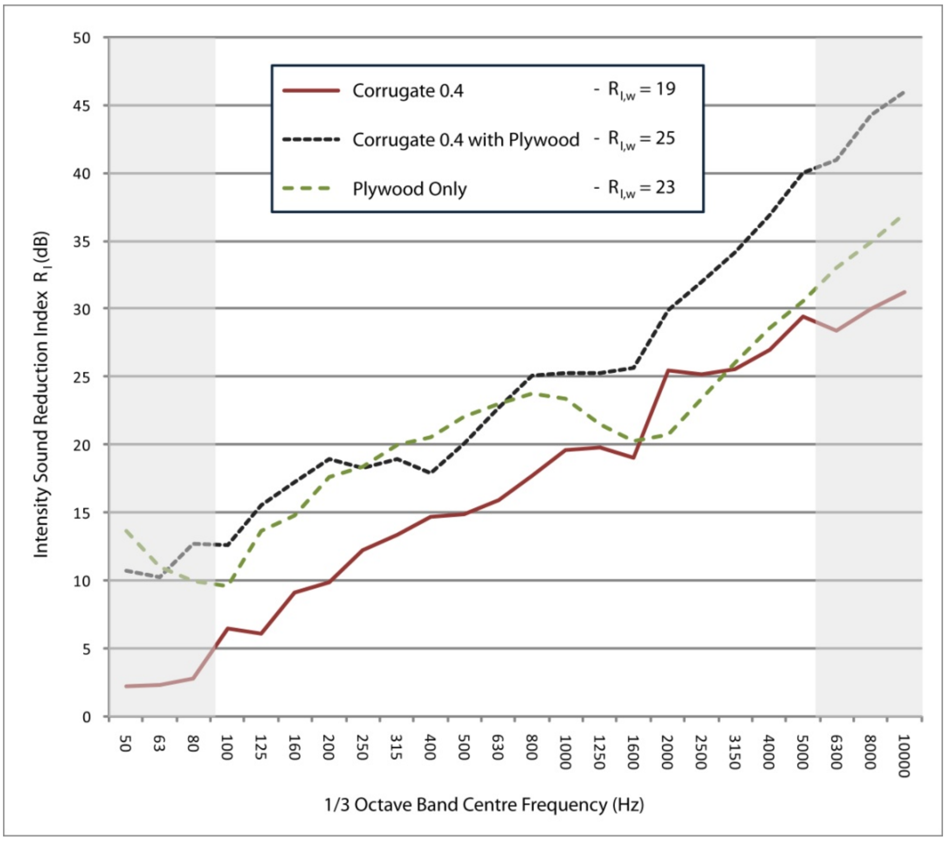

Figure 17: Comparison of the intensity sound reduction index of the Corrugate 0.4 with and without plywood sarking. Also shown in the figure is the intensity sound reduction index of the plywood only. The data in the 1/3 octave bands less than 100 Hz and greater than 5000 Hz (shown in grey in the figure) are outside the scope of ISO 15186-1 and are presented for reference only.

The figure shows that the addition of the plywood under the cladding increased the magnitude of the intensity sound reduction index across the entire frequency range by an average of 7 dB. A comparison between the curves shows that the increase in the intensity sound reduction index of the Corrugate 0.4 with the plywood in the 1000 Hz 1/3 octave band and below is predominantly due to the plywood. Above the 1000 Hz 1/3 octave band, the combination of the plywood and the Corrugate 0.4 resulted in the higher values of the intensity sound reduction index. The dip at the critical frequency of the plywood in the 1600 Hz 1/3 octave band is essentially eliminated by the addition of the Corrugate 0.4 cladding.

5. Conclusions

Based on the results of just the claddings, the number of claddings to be considered for the remainder of the laboratory testing will be reduced to the four show in Table 6.

Metal Tile: Chip
Profiled Metal: Corrugate 0.4
Concrete Tile without Underlay
Concrete Tile with Underlay

Table 6: List of claddings to be considered for the remainder of the laboratory study.

The profiled metal claddings had higher weighted intensity sound reduction indices than the metal or concrete tiles due to the effect of sound leaks between the tiles.

The concrete tiles without underlay had the lowest STC rating of all of the claddings tested. However, concrete tiles with underlay had one of the highest weighted sound reduction indices of the claddings tested. Therefore, concrete tiles with and without underlay will be included in the subsequent parts of the laboratory testing.

The installation of underlay under metal and concrete tiles increases the intensity sound reduction index of the tiles at the higher frequencies by reducing the effect of the sound leaks between the tiles. The increase in the weighted intensity sound reduction index may be higher if the underlay is installed directly beneath the tiles rather than under the battens.

The installation of 17.5 mm plywood under the Corrugate 0.4 increased the weighted intensity sound reduction index of the cladding by 6 dB and resulted in the highest value of all of the claddings tested. However, if the descriptor C_{tr} was taken into account, the Corrugate 0.4 without sarking had the highest value of $R_{I,w} + C_{tr}$.

Appendix A: List of Equipment

Description	Manufacturer	Model	Serial Number
Analyzer	Brüel & Kjær	PULSE C Frame with 7539 5 Chanel Module	2483932
Acoustic Calibrator	Brüel & Kjær	4231	1934296
Dodecahedron Loudspeaker	Brüel & Kjær	OmniPower 4296	2071500
Dodecahedron Amplifier	Brüel & Kjær	2716	2301358
Analyzer	Brüel & Kjær	2260	1894145
Sound Intensity Probe	Brüel & Kjær	4197	2225922
Microphones	Brüel & Kjær	4189-L	2573559
			2573560
			2573561
			2573562
			2573563

Appendix B: Standard Deviation of Reproducibility

The standard, ISO 15186-1 does not make note of the expected standard deviation of reproducibility of the measurement method the standard describes. However, it may be reasonable to expect that the standard deviation of reproducibility would not be great than that using the method described in the ISO 140 series of standards. ISO 140-2 lists the standard deviation of reproducibility as determined from round robin testing and is reproduced in Table 7.

1/3 Octave Band Centre Frequency (Hz)	Standard Deviation of Reproducibility from ISO 140-2 (dB)
100	9.0
125	8.5
160	6.0
200	5.5
250	5.5
315	4.5
400	4.5
500	4.0
630	3.5
800	3.0
1000	2.5
1250	3.0
1600	3.5
2000	3.5
2500	3.5
3150	3.5
4000	3.5
5000	3.5

Table 7: Standard deviation of reproducibility from ISO 140-2.

Appendix C: Sound Reduction Index Data

The intensity sound reduction indices of each of the claddings in 1/3 octave bands are presented in the following tables.

1/3 Octave Band Centre Frequency (Hz)	R_I of Profiled Metal Claddings (dB)			
	Longrun 0.4	Longrun 0.55	Corrugate 0.4	Corrugate 0.4 with 17.5 mm Plywood
100	7.6	9.0	6.5	12.6
125	6.5	9.3	6.1	15.5
160	9.8	10.4	9.1	17.3
200	10.1	12.8	9.9	19.0
250	13.5	14.5	12.3	18.3
315	14.4	16.5	13.4	18.9
400	15.0	17.0	14.7	17.9
500	16.1	18.0	14.8	20.1
630	15.9	17.6	16.0	22.7
800	15.2	16.1	17.7	25.1
1000	15.3	17.2	19.6	25.3
1250	14.3	17.5	19.8	25.3
1600	14.7	16.6	19.0	25.6
2000	21.6	15.9	25.5	29.9
2500	27.4	19.5	25.2	32.0
3150	30.0	28.9	25.5	34.2
4000	32.4	32.2	26.9	36.9
5000	32.0	31.8	29.4	40.0

Table 8: Intensity sound reduction index of the profiled metal claddings in 1/3 octave bands.

1/3 Octave Band Centre Frequency (Hz)	R_I of Metal Tiles (dB)		
	Paint	Chip	Chip with Underlay
100	7.3	8.5	8.1
125	11.2	10.7	8.3
160	11.3	12.4	10.5
200	12.7	12.0	11.6
250	10.8	11.6	10.6
315	11.6	12.5	11.8
400	12.9	13.9	11.5
500	14.2	15.3	12.1
630	14.0	15.5	13.4
800	15.0	16.9	16.7
1000	17.3	18.4	20.4
1250	18.0	18.3	22.1
1600	16.9	16.0	21.3
2000	16.7	15.8	20.8
2500	15.6	16.1	21.8
3150	16.6	17.1	24.2
4000	19.4	19.6	27.3
5000	19.5	19.4	28.7

Table 9: Intensity sound reduction index of the metal tiles in 1/3 octave bands.

1/3 Octave Band Centre Frequency (Hz)	R_I of Concrete Tiles (dB)	
	Concrete Tile	Concrete Tile with Underlay
100	8.9	8.9
125	9.3	10.3
160	10.8	11.3
200	12.8	12.1
250	14.3	14.0
315	16.3	13.9
400	17.0	14.7
500	18.3	17.5
630	18.3	18.8
800	19.0	21.0
1000	19.2	24.4
1250	18.8	25.0
1600	15.4	22.5
2000	11.6	19.8
2500	12.2	20.5
3150	13.6	23.3
4000	14.9	25.3
5000	15.8	27.9

Table 10: Intensity sound reduction index of the concrete tiles in 1/3 octave bands.

1/3 Octave Band Centre Frequency (Hz)	R_I of 17.5mm Plywood (dB)
100	9.5
125	13.7
160	14.8
200	17.6
250	18.4
315	20.0
400	20.6
500	22.0
630	23.0
800	23.7
1000	23.4
1250	21.5
1600	20.2
2000	20.8
2500	23.3
3150	26.0
4000	28.6
5000	30.6

Table 11: Intensity sound reduction index of the 17.5 mm plywood in 1/3 octave bands.

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