CONTROL OF ORE TRANSFER STATION NOISE AT A MINING SITE

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Abstract

A large ore transfer station at a mining site in Western Australia caused a noise problem to a large nearby area. The noise was mostly from the impact of the falling ore on the chute of the transfer station, which was random and low frequency in nature. A noise measurement conducted at a residence about 2.5km away from the transfer station indicated that noise level, though dependent upon the wind directions, was about 38 dB(A), which is above the environmental noise limit assigned to the area at night. The impact noise inside the station was as high as 100 dB(A), very likely to cause the noise exposure level of workers working in and around the station to exceed the occupational daily noise exposure limit of 85 dB(A). The impact of the falling ore on the chute was so strong that the vibrations of the chute, as well as of the whole structure of the station, were measured at very high levels. The reduction of low-frequency structure-borne noise from the vibration was one of the major priorities in the noise control project. A noise control system involving various technologies of noise absorption, wave trapping, noise barrier, vibration isolation and reduction has been successfully installed. The noise level on the top floor of the station has been significantly reduced by more than 10 dB(A). The vibration-borne noise has been dramatically decreased, as the vibration levels on the noise panels are now over 10 dB lower. The noise radiated to the environment from the station has been significantly attenuated. At the locations from 3 m to 48 m away from the station, the noise levels have been reduced by about 7 - 12 dB(A).

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Introduction

The transfer station is a three-storey building. The ore from the upper conveyor is transferred to the lower conveyor through a huge chute. The noise is mostly due to the impact of the falling ore on the chute, which consists of following three components.

1. Structure borne noise from the walls of the chute;
2. Air borne noise from the top and opening sides of the chute; and
3. Structure borne noise from other supporting structures of the station (such as beams, panels, etc.).

A detailed noise and vibration measurement was conducted aiming at identifying the noise problem and locating the major noise sources[1]. The measurement included (1) the noise and vibration distribution and the noise intensity within the transfer station; (2) the noise around the transfer station; and (3) the noise at far-field locations. The major noise and vibration sources in the transfer station, and the noise contribution from each major source to the resident area were also analysed and identified. The following conclusions were drawn from the analysis of the measurement.

1. The vibration of the supporting structures was very strong, so was the resulted structure-borne noise;
2. The dimension of the noise source was quite large - extending to three storeys;
3. The major noise source within the transfer station was from the opening of the chute, which was at least more than 2 dB higher than those from other sources;
4. The noisiest part of the transfer station was on its first floor, i.e. where the major noise source of the station was located;
5. The transfer station noise was random and low frequency in nature. Due to the fact that the high-frequency noise decays at a faster rate with distance than low-frequency noise, low-frequency noise attenuation is one of the major concerns in this project;
6. The structural borne noise was mostly from the chute, due to its significantly higher vibration level.
7. There was a noise panel that partly enclosed the first and top floors. The vibration from the existing panel was also at high level, especially for the frequency lower than 400 Hz.

Noise Control System Design

Combined with the control objective and the noise properties, the major design considerations included[2]:

1. The noise should be trapped and absorbed inside the station by using the wave trapping structure.
2. The wave trapping panels should be isolated from the transfer station structure - in order to reduce the low-frequency structure-borne noise.
3. It is expected that the total noise radiation from the transfer station can be significantly reduced if the noise on the first floor of the station can be trapped.

Wave Trapping Design

The objective of this design is to trap the noise in the first floor and ground floor, which decreases the noise radiation from the top floor. By doing so, the total noise radiation to the environment can be reduced and the noise source of the transfer station can be confined to lower floors. As a result, the noise propagation to the far field will be effectively reduced. The noise control structure is shown in Fig 1.

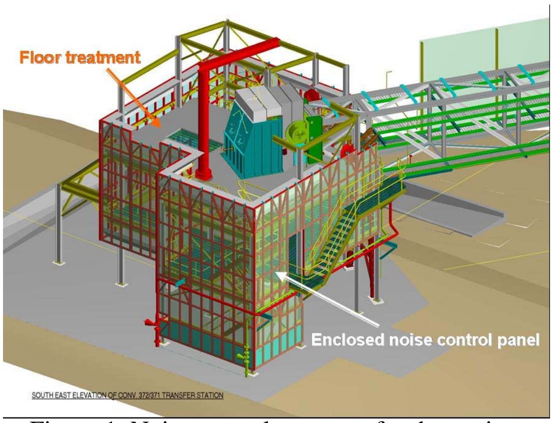


Figure 1. Noise control structure for the station.

To make sure the design objective can be met, the dimensions and arrangement of the enclosed noise control panels, the absorptive materials, and the floor and ceiling treatments were extensively studied and analysed.

Selection of Absorptive Materials

The noise absorptive materials to be used with the noise panels should have very high absorptive coefficient for broad frequency range, especially at frequencies as low as 100 Hz. The selection of the absorptive materials was conducted using a standing-wave tube. Due to the restriction of the panel thickness, the thickness of the absorptive mat was chosen from 50 mm to 120 mm. Four materials - rockwool, heavy glass fibre, light glass fibre, and foam and their combinations - were tested. The results showed that two combinations - 10 cm rockwool and two layers of 5 cm rockwool sandwiched with 2 cm heavy glass fibre - have much higher absorption both at high and low frequencies, as seen in Fig. 2. Although the sandwiched structure has better low-frequency absorption, the 10-cm rockwool was selected due to the cost-effective consideration.

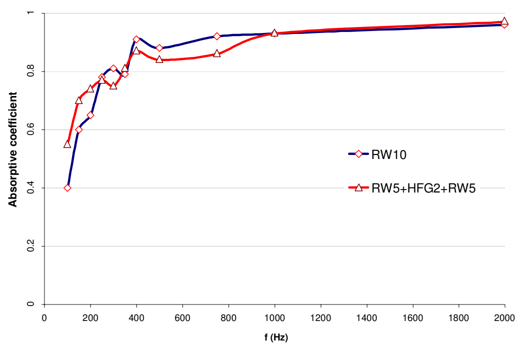


Figure 2. Sound absorptive coefficients of two optimal combinations.

Wave trapping panel design

Both noise control panels on the ground floor and first floor were designed to trap and absorb the noise. They enclosed the station almost down to the ground, except an area on southwest side, where a large opening with a height of 2.5 m was reserved - due to maintenance requirement. A wave-trapping edge was designed for the panels on their bottom end to reduce the noise escape from this opening. The structure of the noise control panels for the first and ground floor and the wave-trapping treatment on the bottom end of the panels of the opening are shown in Fig. 3. The 100 mm rockwool layer attached to the 1mm thick aluminium base panel makes the panels very absorptive for the frequency higher than 200 Hz, as indicated in Fig. 2. The 100 mm rockwool layer also contributes damping to the panel, and reduces the structure-borne noise due to the vibration of the panel.

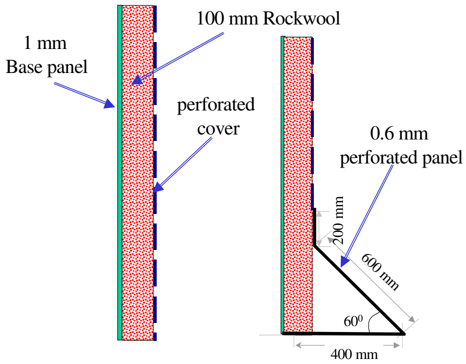


Figure 3. Noise panels for the first and ground floors.

The noise panel for the top floor, however, was to block the direct noise propagation and reduce the noise diffraction over the panel. The structure of these panels is shown in Fig. 4. Again, a wave-trapping cap was also designed for these panels[3].

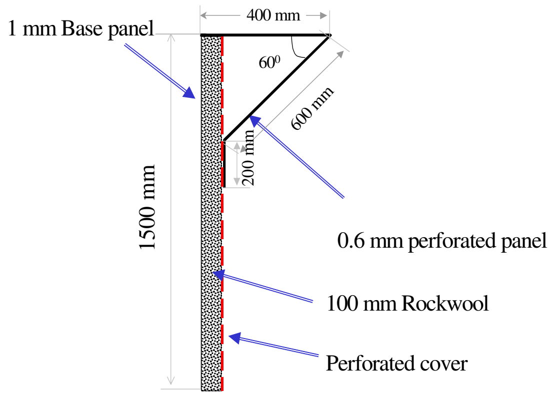


Figure 4. Wave trapping panels for the top floor.

Floor treatment

The wave trapping design was to trap and absorb the noise in the space where it is created, i.e. the first floor of the station. The noise insulation and absorption treatment on the floor of the top floor is very important. After extensive structure feasibility studies, the floor treatment on the top floor was designed as shown in Fig. 5. A 150 mm concrete slab was laid on the floor. Beneath the floor, i.e. the ceiling of the first floor, the noise absorption treatment was designed, which is a 100 mm rockwool.

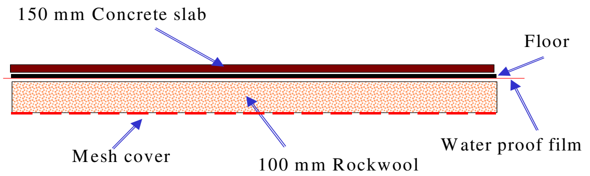


Figure 5. Insulation and absorption treatment on the top floor.

Vibration Isolation Design

To prevent the structure-borne noise from the panel vibration, the vibration isolation of the wave trapping structure from the transfer station structure is critical. The noise control panel was such designed as to be totally separated from the structure of the station using vibration isolators. The vibration insulation method used in this project is shown in Fig. 6.

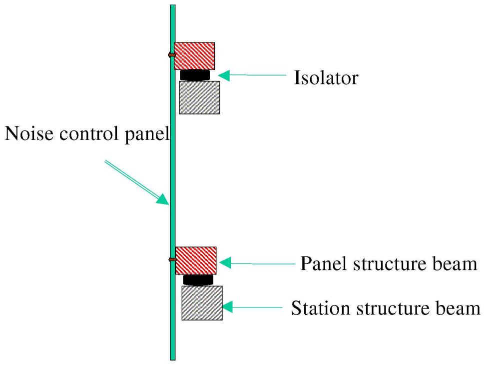


Figure 6. Vibration isolation of the wave trapping structure.

Control System Installation

The external view of the control system is shown in Fig. 7. It can be seen that most parts of the transfer station are now enclosed by the absorptive wave-trapping noise panels.


Figure 7. Noise control system overview from north.

Figure 8 shows the control system in the ground floor. Noise control panels with absorptive layer are now installed almost down to the ground in this floor. A 200-mm gap from the panel end to the ground is for the ventilation and cleaning.


Figure 8. Noise control system in the ground floor.

The noise insulation and absorption treatment on the ceiling and walls of the first floor can be seen in Fig. 9. It should be noted that the noise absorptive treatment on the ceiling is under the concrete slab of the top floor. This not only effectively blocks the noise transmission from the first floor to the top floor, but also absorbs the noise being bounced back from the ceiling and decreases the noise energy inside the station.


Figure 9. Noise control panels in the first floor.

The wave trapping structure and the concrete slab layer on the top floor are shown in Fig. 10. To reduce the noise leakage from the first floor, all the gaps and openings on the floor are sealed with absorptive materials.

Figure 10. Noise control panels and wave-trapping caps and floor treatment on the top floor.

The noise panel structures on each floor have been treated with vibration isolation. The isolators used for the isolation are shown in Fig. 11. It clearly shows that most of the vibration energy from the station structure is blocked from being transmitted into the noise control panel structure by the isolators. Totally, there are over one hundred isolators used in the control system.

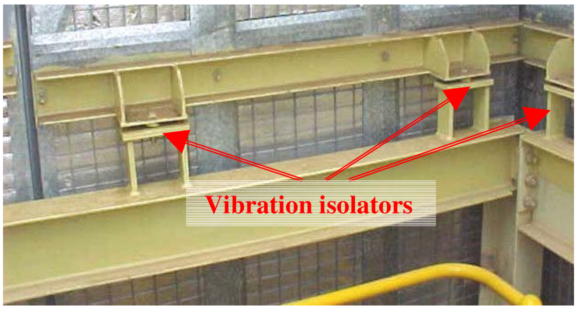


Figure 11. Vibration isolators.

Control Performance Assessment

The performance of the control system was assessed during and after the installation. Although noise reductions in close area around the transfer station and in far field are the most concern, the performance of the noise control system is assessed in three areas: internal noise reduction, external noise reduction, and vibration reduction.

Noise Reduction Inside the Station

Both the noise intensity and the noise level measurements inside the transfer station demonstrated that noise intensity levels and noise levels are reduced after the installation of the control system. However, the noise reduction on the top floor is much more significant. A big difference in dB and dB(A) level changes on this floor is recorded at all the sites, and the reduction is in all frequency range. The noise spectrum reduction at one of the sites on this floor is shown in Fig. 12.

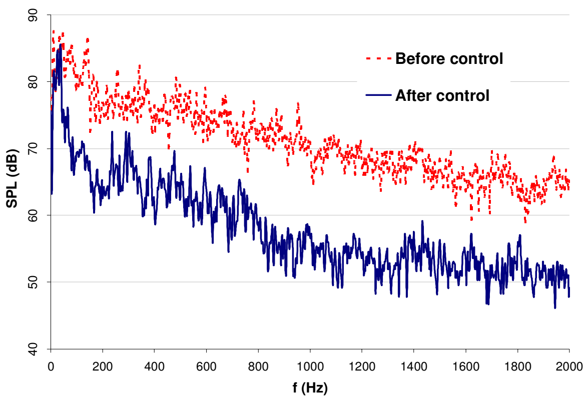


Figure 12. Comparison of linear noise spectrum before and after control on top floor.

Noise level reductions on the first floor are also seen after control, though not as significant as those on the top floor. Figure 13 compares the noise spectra before and after control at a location on the first floor - a noisiest location close to the chute opening. The noise reduction occurs at higher frequency, which is more effective for dB(A) reduction.

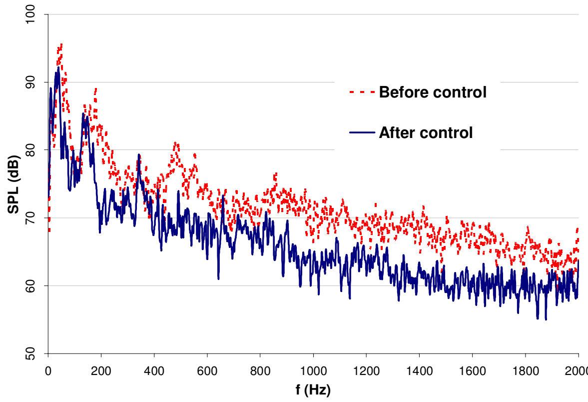


Figure 13. Comparison of linear noise spectrum before and after control on first floor.

The totally level reductions in dB and in dB(A) at all five internal locations are show in Fig. 14. The noise reduction on the top floor is very big, around 8-12 dB(A) at three sites close to the chute head. The reduction on the first floor, though the dB value is not significant, the dB(A) reduction is distinctive - from 2-7 dB(A).

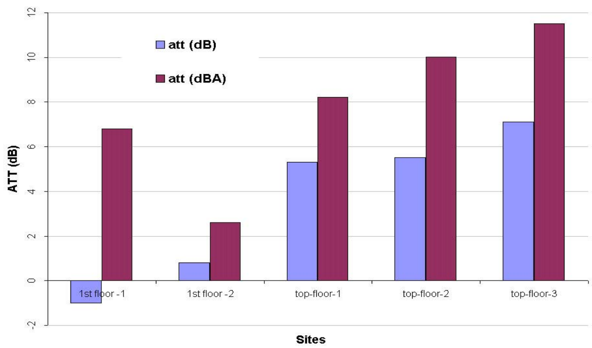


Figure 14. Linear and A-weighted noise reduction on the first and top floors.

Structure Vibration Reduction

The efficiency of the vibration isolators was assessed by measuring the vibration levels on the structure beams under and on the isolators, and on the inner and outer sides of the noise panels, and by comparing the results to the data measured before the installation of the isolators. The results show that the isolators work very well, which reduce the vibration level by about 10 dB.

Figure 15 compares the vibration levels of the structure beams before and after isolators. The efficiency of isolators is very obvious, which are able to reduce the vibration level by over 10 dB in almost all the frequency range.

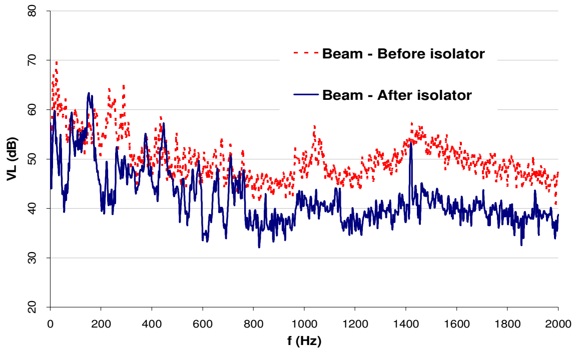


Figure 15. Comparison of vibration levels of the beams before and after isolators.

The purpose for the installation of isolators, as discussed in the design proposal, is to reduce the structure-borne noise, especially from the outer surface of the noise panels. The measurement and comparison of vibration levels on the outer surface of noise panels indicated that vibration isolators are very effective in reducing the vibration level, as shown in Fig. 16, which, in return, reduce the noise radiation from the vibration of the panels.

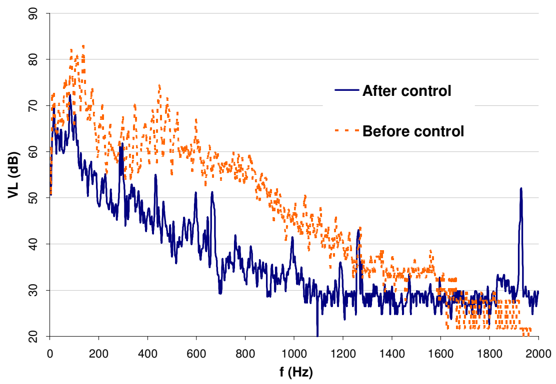
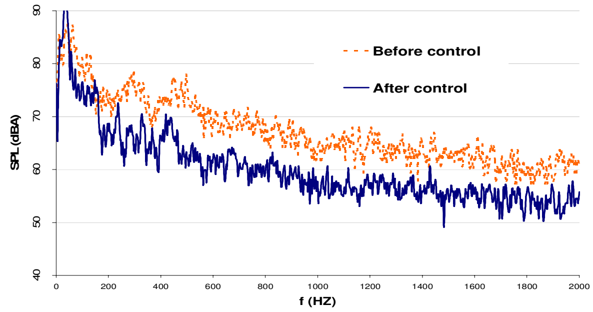


Figure 16. Vibration levels on the outer surface of noise panels before and after vibration isolators.

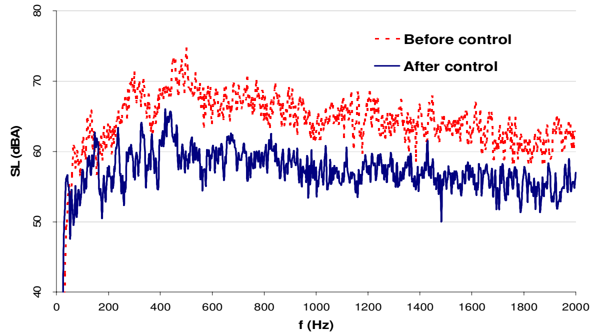
Noise Reduction Outside the Station

Noise levels were measured at external eight sites, seven sites were at south to the transfer station and one at north. They are the same sites that were measured to assess the noise before control.

Significant noise reduction was recorded at all sites after the installation of the control system. The wave trapping structure is very effective in reducing the noise propagation to the environment with frequency higher than 200 Hz, which will then lead to a large A-weighted level reduction. Figure 17 compares the noise spectra at a near field site - 3 m away from the bottom chute. Significant noise reduction after the installation of the control system starts from the frequency of 200 Hz, as shown in Fig. 17 (a). Almost overall reduction is seen in the A-weighted spectrum in Fig. 17(b). The same conclusion is also shown at a typical far-field site - 48 m away from the station, as shown in Fig. 18.

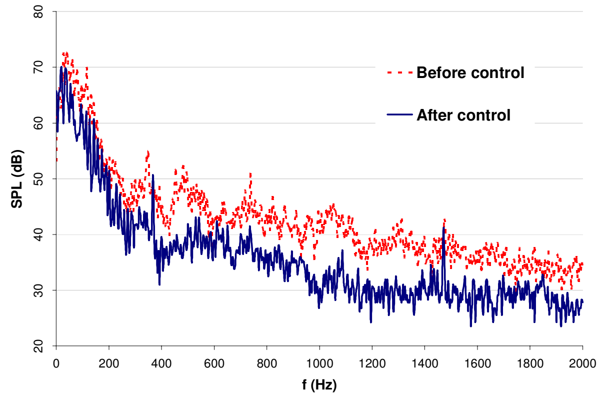


(a)

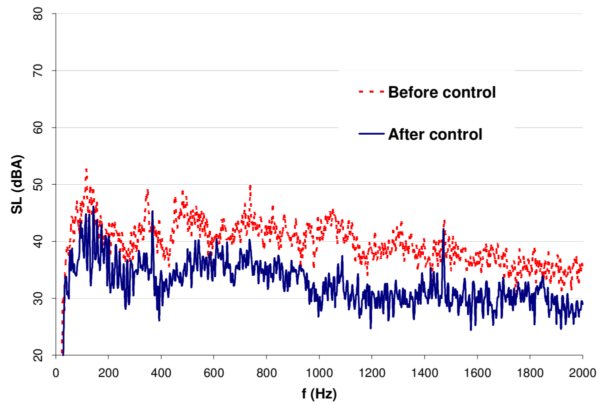


(b)

Figure 17. Comparison of (a) linear spectrum and (b) A-weighted spectrum before and after control at 3 m.



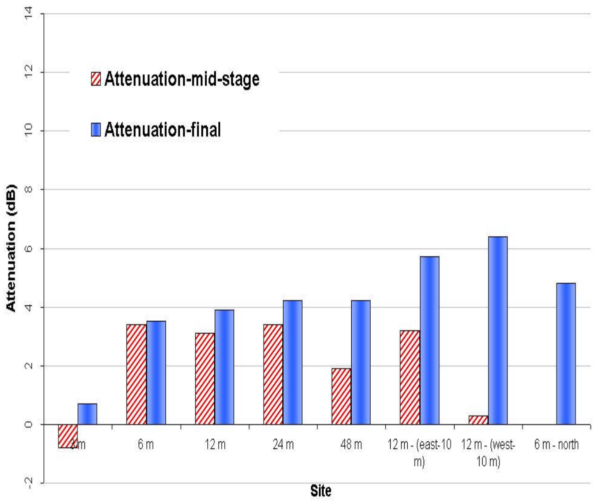
(a)



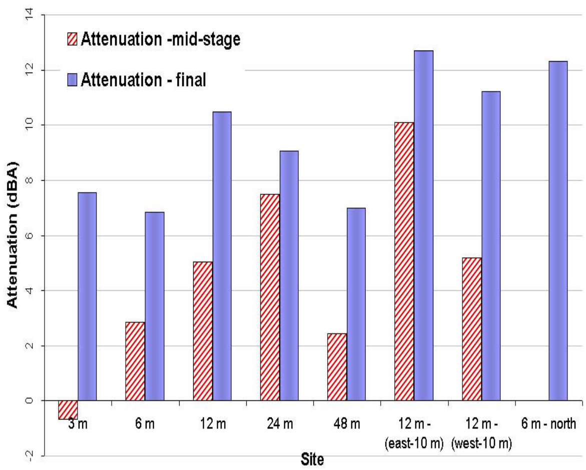
(b)

Figure 18. Comparison of (a) linear spectrum and (b) A-weighted spectrum before and after control at 48 m.

Overall linear and A-weighted level reductions after control at all eight external sites are shown in Fig. 19. The results from the mid-stage assessment are also listed as references. Although linear noise reductions at those environmental sites are only several dB - from 0.7 - 6.4 dB, A-weighted noise reductions are very huge - from 6.8 - 12.7 dB(A). This is because the control system is very good at reducing the noise at frequencies higher than 200 Hz, which is also the sensitive frequency range to A-weighted level.



(a)



(b)

Figure 19. Overall (a) linear and (b) A-weighted noise reductions at eight environmental sites in the middle and after the installation of the control system.

Figure 19 also indicates that the noise reduction reaches the maximum at the distance of 12 m away from the station, then decreases with the distance. This does not mean that the control system is not good at reducing the noise in far field. The A-weighted noise levels at 12 m and 24 m have almost been reduced to the background noise level - the noise level that the transfer station is running without ore[1]. Therefore, at locations far away from the transfer station, the dominant noise is not from the transfer station anymore after the installation of the control system. It is mainly from other noise source like the conveyor and the tail-end station. In this area, the noise control system for the transfer station has reached its limitation. Further noise reduction depends on the control of other noise sources.

Noise levels at various internal and external measuring sites before and after control and their reduction (ATT) are summarised in Tab. 1. It can be seen that the A-weighted level reduction has been achieved at all locations both inside and outside the transfer station.

Table. 1. The noise levels and their attenuation.

	External Sites						
	6m **South**	12m **South**	12m **SE**	12m **SW**	24m **South**	48m **South**	6m **North**
Before	90.6	86.7	88.6	85.1	80.8	70.4	88.9
After	83.8	76.2	75.9	73.9	71.7	63.4	76.6
ATT	**6.8**	**10.5**	**12.7**	**11.2**	**9.1**	**7.0**	**12.3**
	Internal Sites						
	Ground	1st Floor	1st Floor	1st Floor	2nd Floor	2nd Floor	2nd Floor
Before	94.7	98.1	97.5	99.0	98.5	98.9	102.1
After	87.1	90.9	90.7	96.4	90.3	88.9	90.6
ATT	**7.6**	**7.8**	**6.8**	**2.6**	**8.2**	**10.0**	**11.5**

Conclusions

The designed objective of this noise control project has been successfully achieved. Noise and vibration of the transfer station have been trapped, absorbed, and isolated. The noise radiation from the transfer station to the environment has been significantly reduced to the level that complies with the relevant environment regulation at residential area.

As a result of this effort, the transfer station noise is no longer a dominant noise at the residential area, which is now almost not audible. However, the further improvement of the acoustic environment in the area depends on the control of other noise sources, such as the conveyors tail station.

References

[1] "Measurement Report - Noise Control in the Transfer Station at Willowdale Mining Site," UWA, December 2000.

[2] "Design Proposal - Noise Control in the Transfer Station at Willowdale Mining Site," UWA, February 2001.

[3] J. Pan, R. Ming, and J. Guo, “Wave trapping barriers”, Acoustics 2004, Gold Coast 2004.