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Reduction Effects of Shaped Noise Barrier by Composition with Adsorbed Filter Panel

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Abstract

The functional soundproof wall is composed of a sound absorption panel with a filter function and flat panel for the top, a zigzag-shaped soundproof panel whose effects were verified through simulation, and a flat panel for the bottom. The functional soundproof wall is 2 m wide and 2 m high, and it will be installed upright up to 1.5 m, forming the bottom, and will then be tilted by 30º from 1.5 m, forming the top. Noise will be generated at the distance of 2 m, 3 m and 4 m from the functional soundproof wall, and the measured noise will be classified into reflected sound and diffracted sound. The reflected sound will be measured for each height from 1 m, 2 m, 3 m and 4 m at the distance of 6 m, while noise measured in front of the soundproof wall will also be collected. The experiment result showed that there was a noise reduction effect by approximately 4 dB according to the composition. In terms of composition, the soundproof wall composing of the sound absorption panel and the shaped soundproof panel showed excellent reflected sound reduction effects, while the soundproof wall consisting of the filter showed overall excellent noise reduction effects. On the other hand, reflected noise and diffracted sound reduction effects of the shaped soundproof wall were shown clearer as the distance from the noise source was longer, especially at the distance of 4 m. The composed soundproof wall was effective for reducing reflected noise and diffracted sound. More importantly, the composition of the sound absorption panel and the shaped soundproof panel showed excellent reflected noise reduction effects, while in the case of composing with only the shaped soundproof panel, the reflected noise reduction effects began to be shown from 4 m from the noise source. Therefore, it is expected that the relevant soundproof measures can be used in the field effectively.

***Keywords**: Shaped soundproof panel, Zigzag soundproof panel, Absorptive Panel, Reflected noise, Diffraction sound*

1. Introduction

A soundproof panel is a facility that reduces damage to the surrounding area by insulating against sounds generated from a noise source through blocking, absorption, and diffraction. It is also mainly installed on roads where a certain level of noise is generated. Generally, a vertical soundproof panel can be imagined. However, it is classified into various types according to the shape on the top, the material, and the function [1]. The shape on the top part is classified into bent type, curved type, T-type or Y-type, reserve L-type, and cylindrical-type (sound absorber) [2]. The sound insulation effects according to the shape on the top part were replicated through numerical simulations, and it has been reported that a more complicated shape brings higher sound insulation effects [3, 4].

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The sound insulation effects according to the front shape of the soundproof wall have been evaluated from field experiments prior to the development of simulation technology, and it has been reported that the uneven scattered-type structure showed excellent reduction effects. The simulation for the shaped soundproof wall was carried out by the research team through the replication of road conditions for the reflected noise effects of wing-type, zigzag-type, and curved type, and the maximum sound insulation effects were obtained through detailed design factors [5~8].

Recently, air pollution due to fine dusts is getting worse in the country, and has already influenced the industrial complexes, surrounding areas of the roads, as well as on a nationwide scale, so countermeasures for such problems are urgently needed. More importantly, because fine dusts generated on the roads result from friction with the road and fuel emissions from traveling vehicles, it is expected that the atmosphere of the country will deteriorate considerably within a certain period of time because of stable vehicle distributions and operations. Therefore, the installation of a facility that can reduce air pollution on the road should be considered, and the utilization of soundproof walls, which already exist, would be most effective in this area [9].

In this study, the functionality of the soundproof wall for reducing that combined with a filter panel was established and its sound insulation effects were evaluated. The soundproof wall consisted of the filter panel and the zigzag type soundproof panel was evaluated in effectiveness for reducing reflected noise and its sound insulation sound. It was also compared with the flat soundproof wall regarding the sound insulation effects. In this study, the sound insulation effects according to the composition of combination including filter panel, shaped panel and flat panel were compared, and the detailed purposes are as follows.

1. Comparison of soundproof effects between each composition according to the distance from the noise source
2. Comparison between the filter panel effects and the shaped panel effects
3. Comparison of reflected noise per height
4. Evaluation and comparison of sound insulation effects in front and rear of top filter and diffracted sound in the rear

2. Methodology

2.1. Production of Filter Module

A filter panel for removing dust has the size of 1830 × 340 × 60T with the multi-layered structure of electrostatic mechanism in polypropylene, which was produced by DEAYOUNG Air Filter. This filter has a hydrophobic property, so repels water and dehydration, and it also has a mesh structure that has excellent air permeability. Therefore, the adsorption by air current in the site and its maintenance were considered.

For the shaped panel, the evaluation result of soundproof walls in various shapes through the simulation method was adopted, and its reduction effects were confirmed through a field experiment in a previous study [7]. The sound insulation effects of the filter panel and the shaped panel were compared with the flat as the control group.

The soundproof wall was installed separately into the top soundproof wall and the bottom soundproof wall. The total length of this soundproof wall was 2 m and it was installed upright up to 1.5 m to form the bottom panel, while it was tilted by 30° from 1.5 m for the length of 0.5 m. This is a physical design to reduce the reflected noise or diffracted sound delivered to high-rise buildings, supported by various relevant studies and actual installation cases [1, 2, 10].

The composition of the top soundproof wall included the filter panel and the flat panel were replaced according to the experiment conditions, and the composition of bottom soundproof wall included the shaped panel and the flat panel were replaced as follows according to the experiment conditions (**Table 1**).

Table 1. Soundproof Composition by Top and Bottom Part Change

Bottom＼Top	**Filter panel**	**Plane panel**
Plane panel	Top Filter-Bottom plane (Fil-Pl)	Top Plane-Bottom Plane (Pl-Pl)
Shaped panel (zigzag)	Top Filter-Bottom Shaped (Fil-Zi)	Top Plane-Bottom Shaped (Pl-Zi)

The location of microphones with the purpose of evaluating the sound insulation was shown in **Figure 1**. The thick line in the middle is the soundproof wall produced in this study. The upright part is the bottom part and the bent part at the top is the top part. The sound insulation was evaluated separately into the reflected noise, noise right before the soundproof wall, and the diffracted sound. The microphones were installed 1 m, 2 m, 3 m and 4 m high at 6 m away from the soundproof wall in order to evaluate the reflected noise. The microphones were installed in front of and at the rear of the soundproof wall in order to measure the noise reduction effect in front and at the rear of the soundproof wall. The microphones were installed 1 m and 3 m high at 5 m distance for evaluating the reflected noise. For the generation of noise, white noise was generated at 2 m, 3 m and 4 m distance and the measurement frequency band was 63 ~ 20,000 Hz, 1/3 octave band.

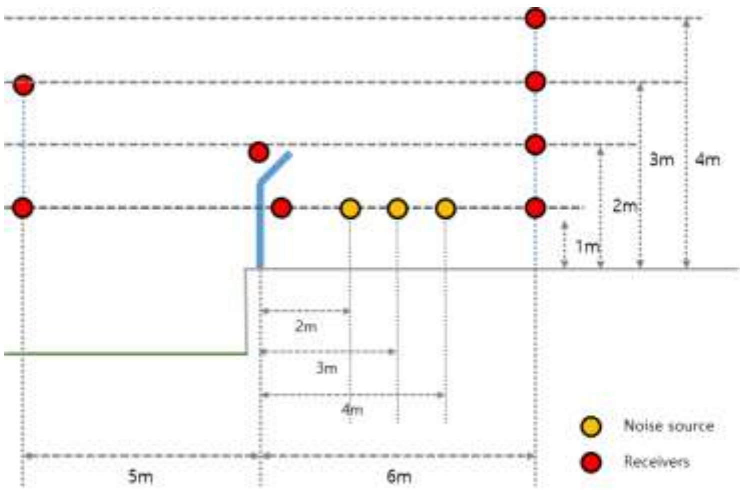
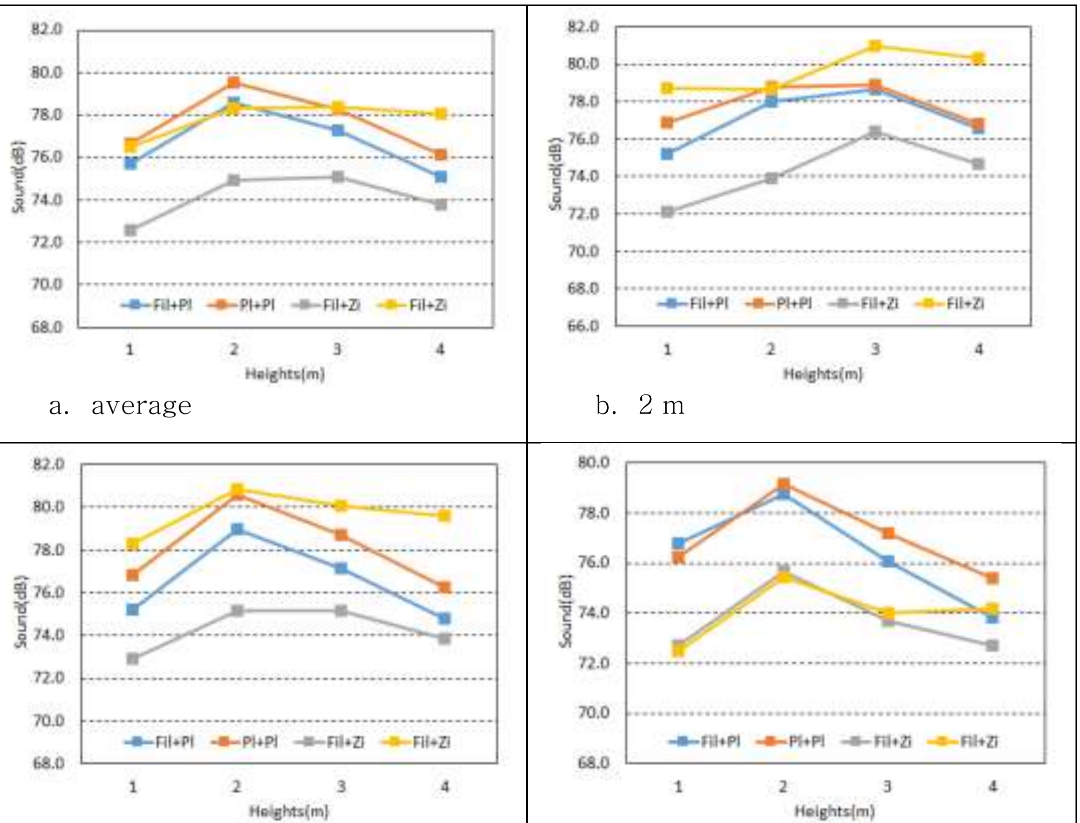


Figure 1. Scheme of Noise Source and Receiver Set

3. Result and Consideration

3.1. Evaluation of Reflected Noise: Comparison of Measured Noises by Height According to a Change in the Distance from the Noise Source

The average measured noise for the distance from the noise source was shown in **Figure 2a**. The combination showing a low generated noise was (top filter+bottom shaped), which showed 74.1 dB on average for the height. In case of other combinations, a lower noise was shown in order of (top filter+bottom flat) < (top flat+bottom flat) ≃ (top filter+bottom flat) in consideration of average noise level, although it varied partially. A relatively high noise level was shown at the height of 2 m and 3 m. Except for the combination of (top filter+bottom shaped), the noise at the height of 2 m was highest. The combination of (top filter+bottom shaped) showed the highest noise at the height of 3 m.



a. average
b. 2 m
c. 3 m
d. 4 m

Figure 2. Reflected Noise Barrier by Composition at 6 m Distance (a~d: the distance of noise sources)

The case of distance of 2 m wherein the noise occurrence was relatively close was shown in **Figure 2b**. In such cases, the combination of (top filter+bottom shaped) also showed the lowest noise as 74.3 dB, while a lower noise was shown also in order of (top filter+bottom flat) < (top flat+bottom flat) < (top flat+bottom shaped). Generally, the highest noise was measured at the height of 3 m and the combination of (top flat+bottom shaped) showed a high noise also at the height of 4 m. The same trend of noise occurrence was shown at the 3 m distance and the average noise of the combination (top filter+bottom shaped) was 74.3 dB (**Figure 2c**). A different trend was shown at the 4 m distance where the noise occurrence was furthest (**Figure 2d**). For the average measured noise, the combination of (top filter+bottom shaped) showed 73.7 dB, which was slightly lower. However, the combination of (top flat+bottom shaped) also showed a low noise as 74.0 dB, and the lowest measured noise was recorded at 1 m and 2 m high very closely.

By assuming that the reflected noise was measured aside from the noise generated from the noise source, the combination showing the highest reflected noise reduction was (top filter+bottom shaped). Except for that, a higher effect was shown in order of (top filter+bottom flat) < (top flat+bottom flat) < (top flat+bottom shaped), but (top flat+bottom shaped) showed an excellent effect when the noise source was far away.

3.2. Evaluation of Reflected Noise: Filter and Shaped Effects

The representative effects were compared by calculating the average between the combinations with the panel as each element technology. In other words, "filter" as the average between (top filter+bottom flat) and (top filter+bottom shaped), "top flat" as the average between (top flat+bottom flat) and (top flat+bottom shaped), "bottom flat" as the average between (top filter+bottom flat) and (top flat+bottom flat), and "shaped" as the average between (top filter+bottom shaped) and (top flat+bottom shaped) were considered as the effects of each composition, and the average of the relevant composition is shown in **Figure 3** for each distance from the noise source.

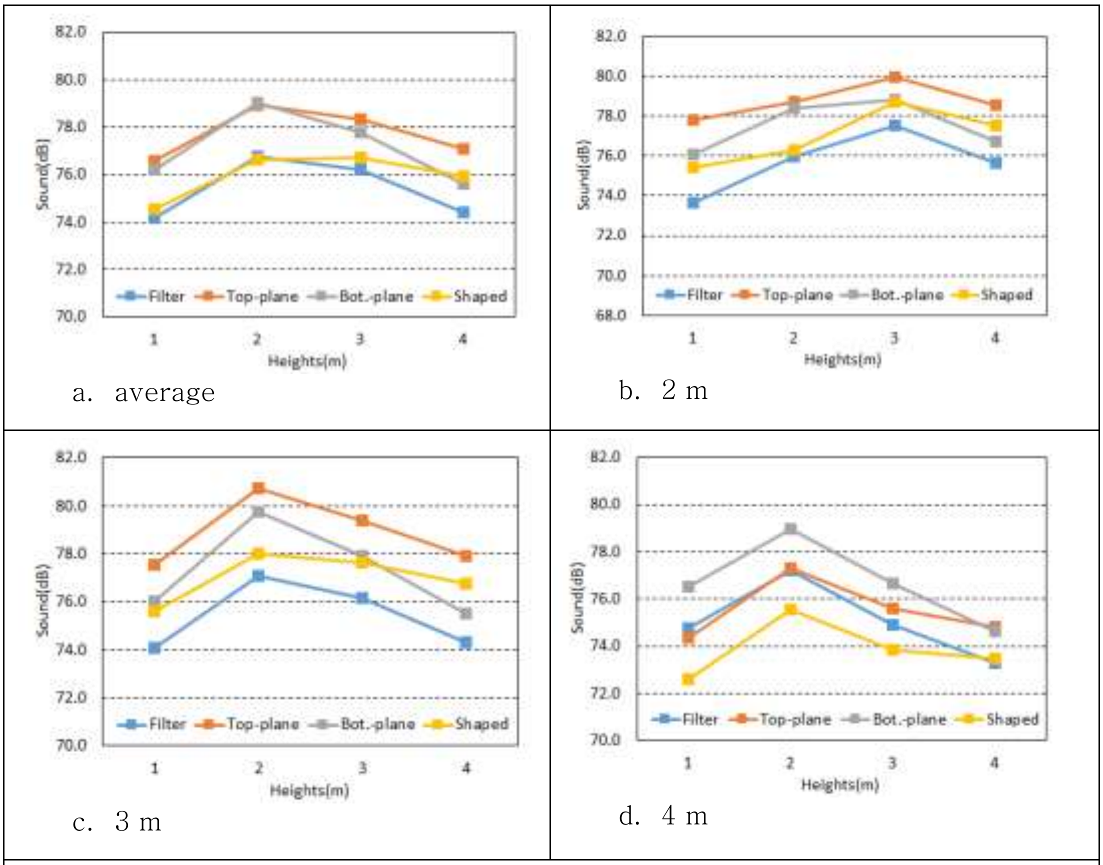
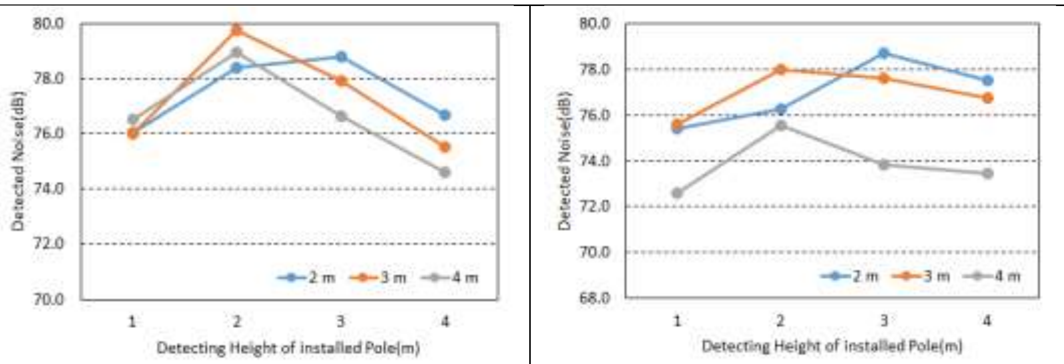


Figure 3. Reflected Noise Barrier by Element Panel at 6 m Distance (a~d: the distance of noise sources)

At first, the average measured noise for the distance from the noise source was shown in **Figure 3a**. The filter effect showed the lowest noise as 75.4 dB, and the shaped showed the close effects as 76.0 dB. Then, a lower noise was measured in order of bottom flat < top flat. The measurement result for 2 m distance from the noise source was shown in **Figure 3b**. The filter showed the lowest measured noise value as 75.7 dB. Then, a lower noise was shown in order of shaped < bottom flat < top flat, and the range of numerical value was between 77.0 dB and 78.8 dB. At 3 m from the noise source, a difference for each of the effects was clear in order of filter < shaped < bottom flat < top flat (**Figure 3c**). In case of noise occurrence at 4 m, the shaped panel showed the highest effects in order of shaped < filter < top flat < bottom flat. (**Figure 3d**) This showed that the effects of shaped panel were higher as the distance from the noise source was longer.

3.3. Evaluation of reflected noise: Effects by height

The trend of noise occurrence according to the distance where the noise source was created was summarized in **Figure 4** separately into the flat (bottom) and shaped (bottom). At first, in the case of the flat, a high noise over 78 dB based on the height of 2 m was measured, and a relatively low noise was shown at the height of 4 m. In case of the shaped, a relatively high noise was shown near the height of 3 m, although a low noise was recorded generally in comparison to the flat. More importantly, when the noise source was at 4 m distance, the measured noise was 73.9 dB on average, showing a 2.8 dB decrease in comparison to 76.7 dB for the flat. Also, a significant difference of 3.4 dB was shown near the height of 2 m. In other words, it was confirmed that the reflected noise jamming effects of the shaped soundproof wall showed the noise reduction effects when the distance from the noise source was 4 m.



a. plane

b. shaped

Figure 4. Comparison of Shaped and Plane Panel by Distance

According to **Figure 5** summarizing the measured noises for each combination according to the height, the combination of (top filter+bottom shaped) showed the highest effect for the reflected noise. For the height, a relatively low noise was measured at 1 m and 4 m, and the noise measured at 4 m high was significantly influenced by the combination of panels in the soundproof wall. In other words, the combination of the filter and the shaped showed the lowest noise while the combination of the flat and the shaped showed a relatively high noise.

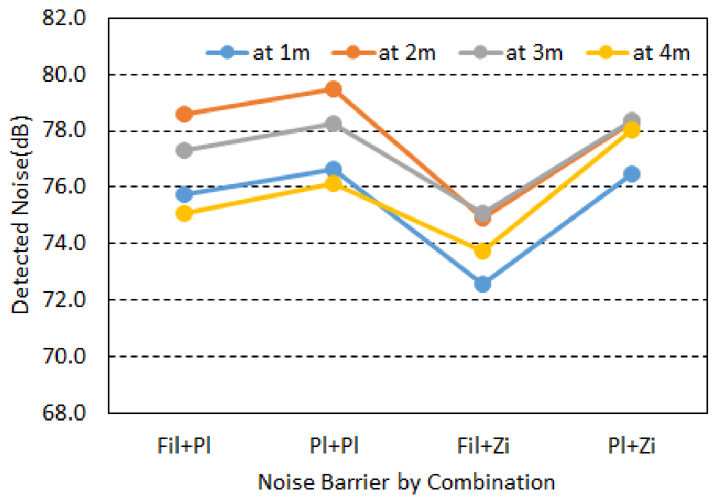


Figure 5. Comparison of Height by Noise Barrier Composition

3.4. Evaluation of Diffracted Sound: Noise Evaluation in Front of and Rear of the Filter

The noise level was compared by installing a noise-measuring device in front of and at the rear of the top panel (**Figure 6**). When the filter was installed, there was a noise difference of 9.9 dB between the front and rear of the panel on average, although it varied according to the distance from the noise source. On the other hand, the flat showed a difference of 20.3 dB so that the insertion loss by the flat, which had the sound insulation effects, was also significant. Also, it was confirmed that the insertion loss was higher in case of the bottom shaped. It is assumed that this resulted from a certain synergy effect between the filter panel and the shaped panel. However, it was confirmed that there was no significant difference in the insertion loss between the front and rear of the top panel from the evaluation of diffracted sound measured at 3 m from the rear.

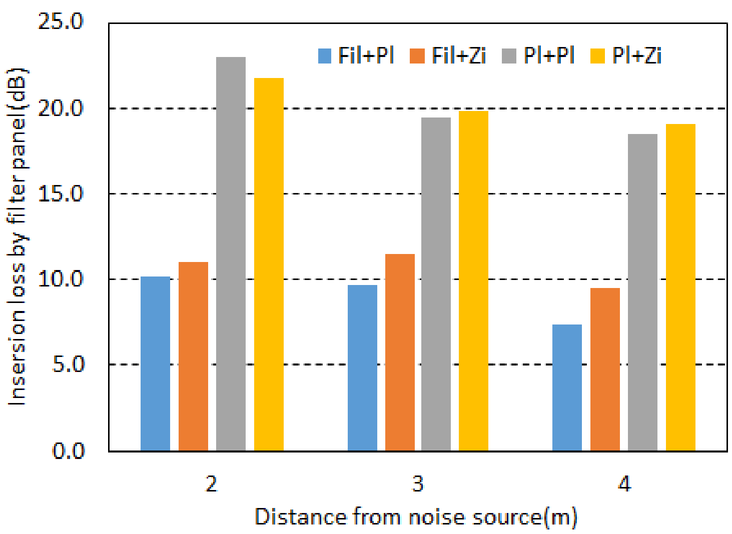


Figure 6. Insertion Loss Directly after Top Panel by Composition

3.5. Evaluation of Diffracted Sound: Comparison of Rear Diffracted Sound

Low noise measured right at the back of the top panel was recorded since the flat panel showed a significant insertion loss, but the noise measured at 3 m rear regardless of combination (**Figure 7**). At this time, the noise measured at the rear was 63.1 dB at 1 m and 65.5 dB at 3 m, and in consideration of standard deviation, there was no significant difference for each combination (**Table 2**). The effects according to the type of top panel are temporary, and the diffracted sound effects at a certain distance from the rear don't seem to be influenced significantly by the type of top panel or the reflected noise.

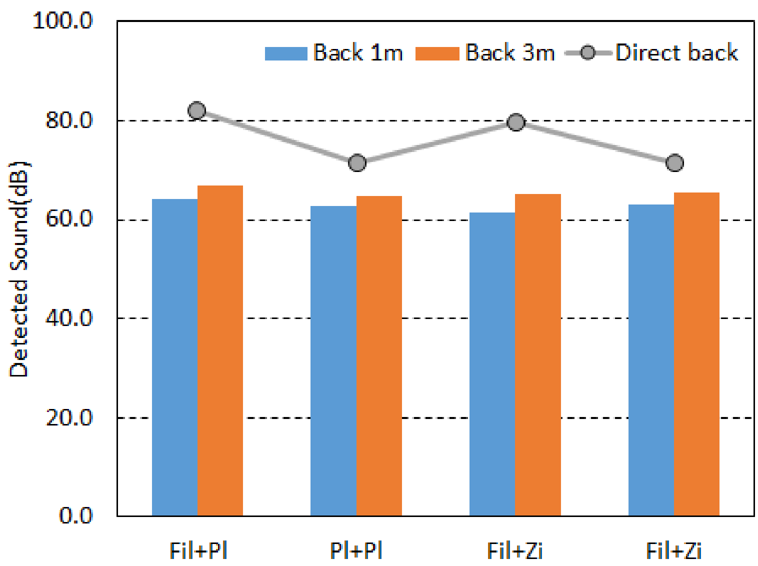


Figure 7. Diffraction Sound from Noise Barrier by Composition

Table 2. The Average Deviation by Combination in Diffraction Sound (dB)

Hegiht		Filter + Plane	Plane + Plane	Filter + Plane	Plane + Shaped	Average
Rear side	1 m	1.2	1.1	1.3	1.6	1.1
	3 m	2.0	2.0	2.1	1.4	1.0

4. Conclusion

In this study, the reflected noise and diffracted sound were evaluated and compared for the soundproof wall composed through the combination of filter panel, shaped soundproof panel, and flat soundproof panel. The zigzag-type shaped soundproof panel was applied and its reflected noise reduction effects have been confirmed in previous studies. The conclusion according to the purpose of this study is as follows.

1. Comparison of reflected noise reduction effects between each composition according to the distance from the noise source:

The reflected noise reduction effects were compared by combining 4 combinations including (top filter+bottom flat), (top flat+bottom flat), (top filter, bottom shaped) and (top flat, bottom shaped). In the comparison according to the distance from the noise source, the combination of (top filter+bottom shaped) showed the highest reflected noise reduction effects. Also, the combination of (top flat+bottom shaped) showed no reduction effects when the distance from the noise source was 2 m and 3 m, but it showed the equivalent reduction effects to (top filter+bottom shaped) when the distance from the noise source was 4 m.

2. Comparison between the filter panel effects and the shaped panel effects

When the reflected noise reduction effects of each composition were compared, the effects of the filter panel were the highest. This showed that the sound insulation effects of the filter panel created a certain synergy effect along with the basic reflected noise function. Meanwhile, the effects of the shaped panel were higher than the effects of the filter panel when the distance from the noise source was 4 m. In other words, a relatively excellent reduction of reflected noise can be expected from the shaped panel when a proper distance from the noise source is given.

3. Comparison of reflected noise per height

In case of the flat, a similar noise was created according to the distance for each height, but in case of the shaped, a relatively low noise was created when the distance from the noise source was 4 m.

4. Evaluation and comparison of sound insulation effects in front and rear of top filter and diffracted sound in the rear

Insertion loss in front of and rear of the top soundproof panel, that is, the sound insulation effects was higher at the flat, which was the reflected panel. The filter panel showed insertion loss below 10 dB by considering it as the adsorbed type. However, noise measured at 3 m at the rear showed almost a similar level regardless of the composition of soundproof wall. This was because the sound insulation effects of the filter panel and the reflection effects of the flat reflected panel had similar influence on the diffracted sound.

The soundproof wall can create reflected noise or diffracted sound reduction effects according to its front shape, material, and structure. The filter panel for reducing dust functioned as the adsorbed soundproof panel and showed the reduction effects through the interaction with reflected noise, while the shaped zigzag type soundproof wall started to show the reflected noise effects from 4 m distance from the noise source.

Acknowledgments

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