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Acoustic characteristics of tunnel-shaped noise barriers

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ABSTRACT
This paper investigated acoustic modelling methods of tunnel-shaped noise barriers (soundproof tunnel). Sound fields characteristics of inside- and outside- soundproof tunnel are estimated using acoustic ray-tracing models. Several road configurations were employed according to bending degree and number of traffic lanes. Soundproof tunnel profile was modelled based on the existing wall-shaped noise barriers. As results, parametric evaluation of sound pressure level distribution inside and outside of the target road was made in accordance with length, height, sectional shape and materials of soundproof tunnel profiles. In addition, effective noise reduction methods are discussed based on the experimental results.

Keywords: Noise reduction devices, Tunnel-shaped noise barriers, Computer simulation
I-INCE Classification of Subject Number: 31

1. INTRODUCTION

Wall-shaped noise barriers are well-known type of noise reduction devices (NRD) for traffic noise[1]. Near high-rise apartment buildings, tunnel-shaped noise barriers, so called soundproof tunnel, are often introduced since the limitation of stacking noise barrier panels not too high[2-3]. However, it is not easy to estimate noise propagation of tunnel-shaped noise barriers using the conventional noise mapping software. Therefore, it is needed to investigate effectiveness of tunnel-shaped noise barriers on reducing traffic noises to nearby residential area in comparison with wall-shaped noise barriers.

In this study, acoustic modelling of tunnel-shaped noise barriers using ray-tracing method was tried as a preliminary study[4]. Sound fields characteristics of inside and outside of various shaped noise barriers were compared in terms of sound pressure level using computer simulation with sound absorption and transmission properties measured in laboratory condition.

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2. METHODS

2.1 Road model in the ray-tracing simulation

A conventional software using ray-tracing method (Odeon v.12) is employed. Boundary enclosure with 100% sound absorption was constructed with a dimension of width 100 m, length 500 m and height 50 m. Road of 6 lanes was modelled as width of 21 m (3.5 m for a lane) with the absorption characteristics of an asphalt pavement[5]. Ground except for road was assumed as rough soil field. Acryl panel of 10 mm thickness was selected for the material of noise barrier panel and roof. However, its sound absorption values were based on properties of paired glass because of the absence of relevant data.

Line sound source characteristics at the height of 1.5 m were applied with a gain of 120 dB with frequency correction from the normalized road traffic noise spectrum[6]. Receivers at the height of 1.2 m were placed horizontally with spacing of 2.5 m. Sectional receiver grid with the same spacing was additionally considered at the middle of noise barrier. A-weighted sound pressure levels were derived with transition order of 2, number of early rays of 2,082 and number of late rays of 1,041 for survey purpose.

Table 1. Acoustical properties of the materials used in the computer simulation

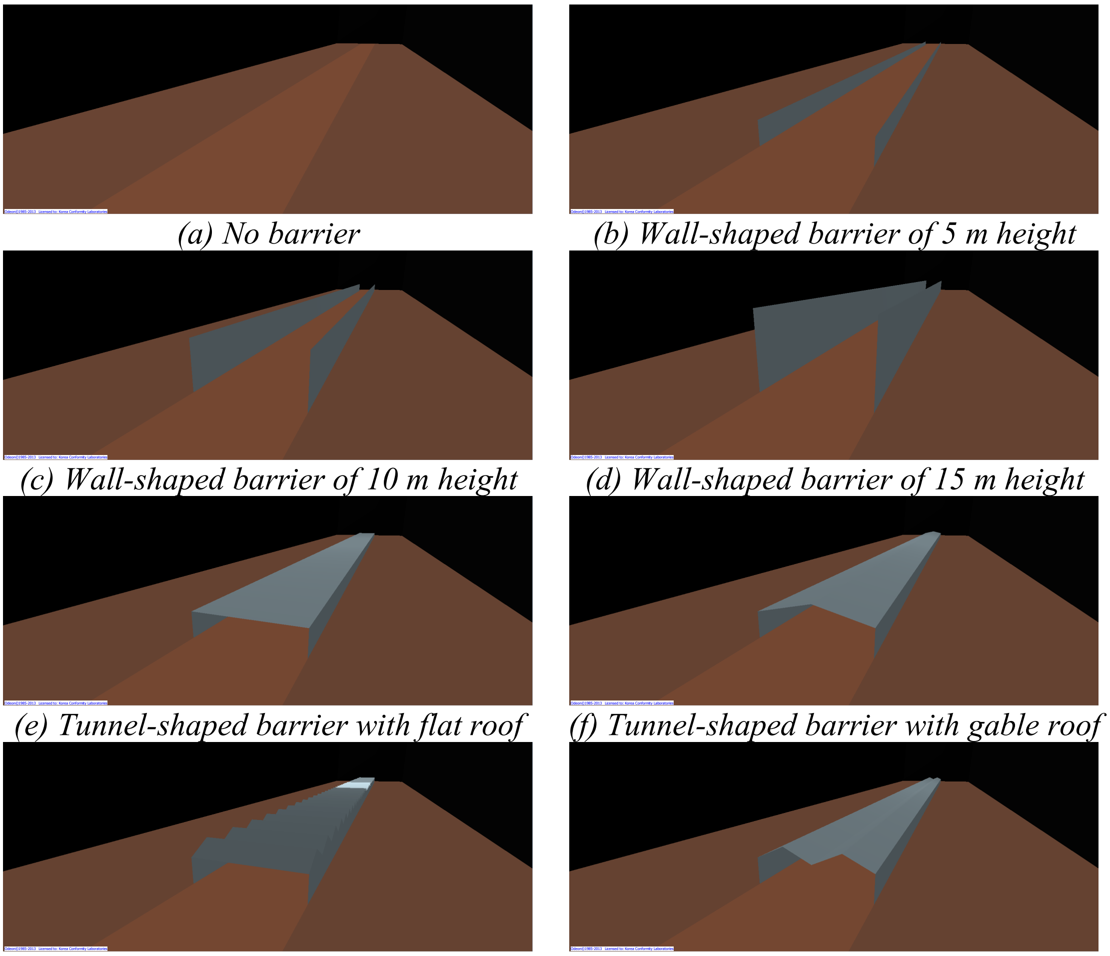
Material names		Sound absorption coefficients of 1/1 octave bands					
		125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
A	Asphalt pavement[5]	0.05	0.07	0.31	0.59	0.60	0.60
	Rough soil (Odeon)	0.15	0.25	0.40	0.55	0.60	0.60
	Paired glass	0.20	0.10	0.08	0.06	0.04	0.02
T	Acryl panel of 10 mm thickness	16.2 dB	24.7 dB	28.9 dB	34.1 dB	37.0 dB	35.0 dB
W	Road traffic noise	-19 dB	-15 dB	-12 dB	-9 dB	-11 dB	-16 dB

A: Sound absorption coefficients
T: Sound reduction index, W: correction level (actually, 1/3 octave band data was applied)

2.2 Experimental configurations with various sectional shape of noise barriers

Based on the practical examples of tunnel-shaped noise barriers as shown in Figure 1, 3D model of the eight simulation configurations with different shape of noise barriers were prepared: no barrier, wall-shaped barriers of various heights of 5 m, 10 m and 15 m, tunnel-shaped barriers of wall height of 5 m with various roof shape of flat, gable of 2.5 m additional height, longitudinally- and sectionally-corrugated with spacing of about 10.5 m (Figure 2). Basic length of noise barrier was 400 m.

Fig. 1. Examples of tunnel-shaped noise barriers[7]



(a) *No barrier* (b) *Wall-shaped barrier of 5 m height*

(c) *Wall-shaped barrier of 10 m height* (d) *Wall-shaped barrier of 15 m height*

(e) *Tunnel-shaped barrier with flat roof* (f) *Tunnel-shaped barrier with gable roof*

(g) *Tunnel-shaped barrier with longitudinally-corrugated roof* (h) *Tunnel-shaped barrier with sectionally-corrugated roof*

Fig. 2. 3D models of various shapes of the simulated noise barriers

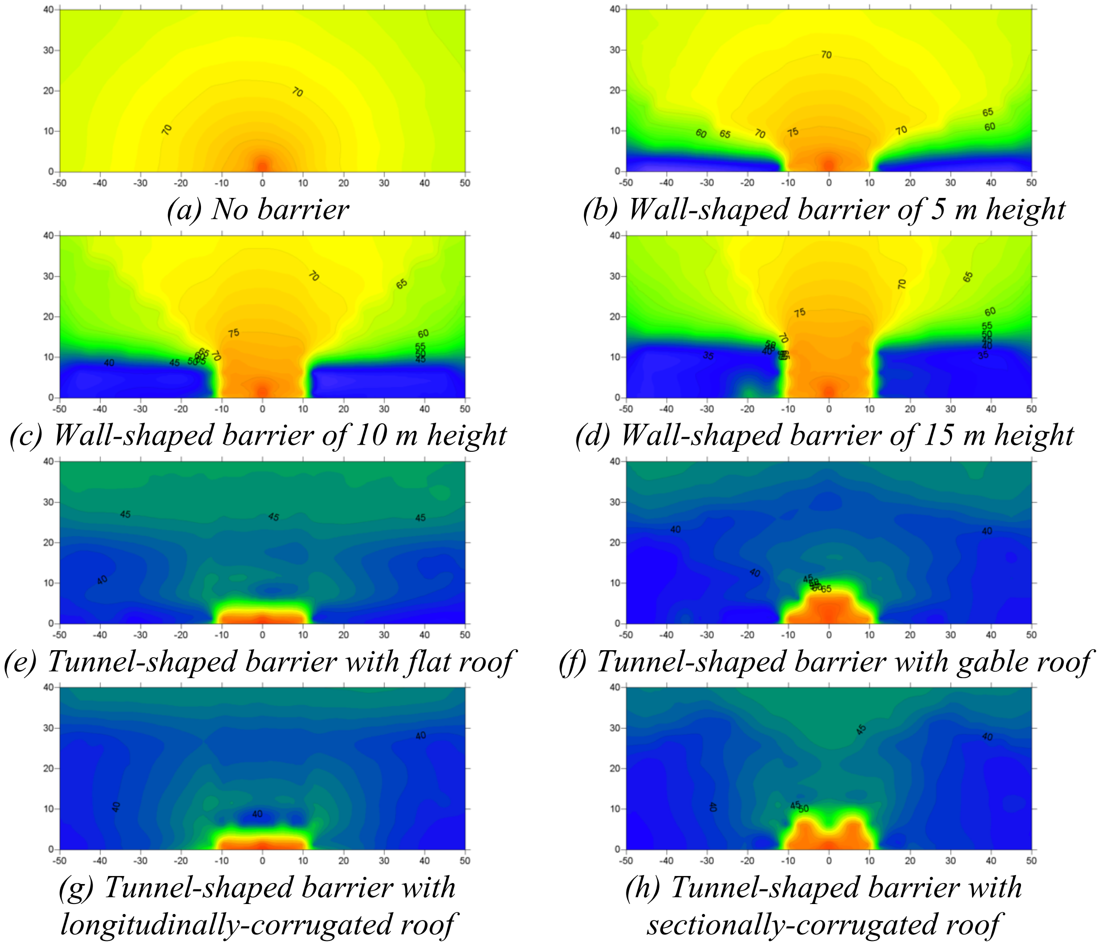
3. RESULTS

3.1 Vertical distribution of sound pressure levels at the same section

Figure 3 shows the simulation results of vertical distribution of sound pressure levels at the same section for each simulation configuration. In case of no barrier, sound pressure level was gradually decreased for all directions. In cases of wall-shaped barriers, sound pressure levels below the upper edge of barrier profile were dramatically decreased, but sound propagations at upper directions were similar to the case of no barrier. In cases of tunnel-shaped barriers, sound propagations at upper directions were also highly decreased in comparison with the cases of wall-shaped barriers. In consideration of nearby high-rise apartment building within 50 m from the centre lane of the road, gable of corrugated shaped roof showed better noise reduction than flat roof case.

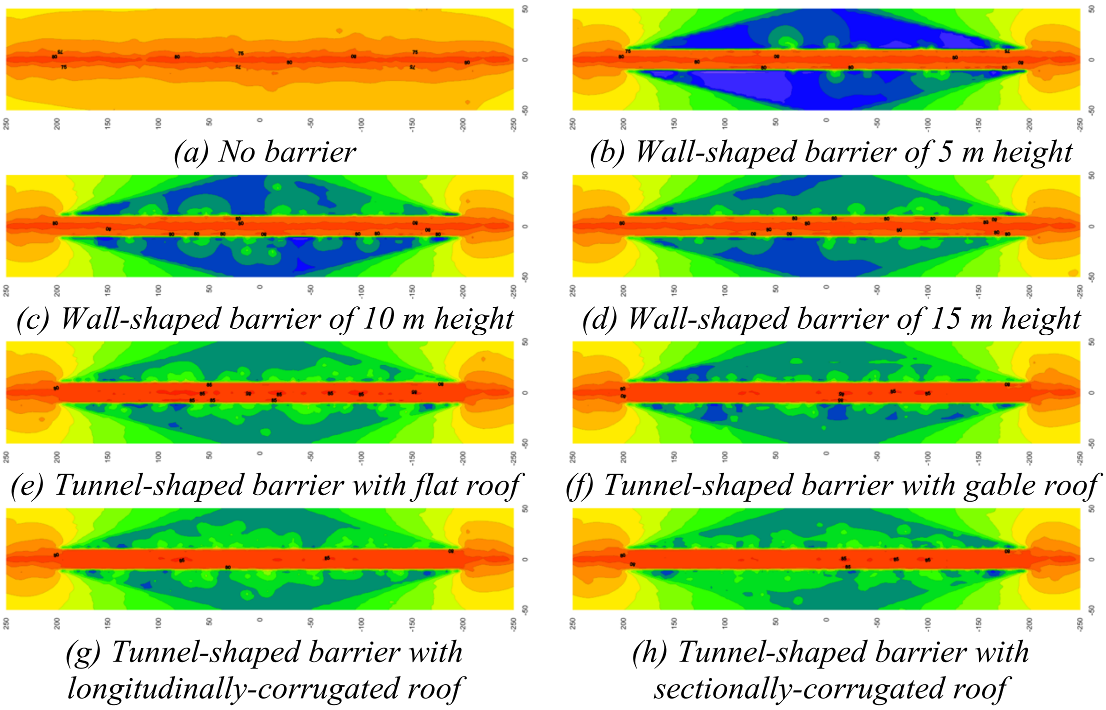
3.2 Horizontal distribution of sound pressure levels at the same height

Figure 4 shows the simulation results of horizontal distribution of sound pressure levels at the same section for each simulation configuration. Middle area of outside of noise barriers in longitudinal direction showed the highest noise reduction. Wall-shaped noise barriers showed better noise reduction in terms of horizontal distribution at the height of 1.2 m. However, sound pressure levels on road area in cases of tunnel-shaped noise barriers were higher than those of wall-shaped noise barriers.



(a) No barrier
(b) Wall-shaped barrier of 5 m height
(c) Wall-shaped barrier of 10 m height
(d) Wall-shaped barrier of 15 m height
(e) Tunnel-shaped barrier with flat roof
(f) Tunnel-shaped barrier with gable roof
(g) Tunnel-shaped barrier with longitudinally-corrugated roof
(h) Tunnel-shaped barrier with sectionally-corrugated roof

Fig. 3. Vertical distribution of overall sound pressure level at the same section according to various shapes of the simulated noise barriers

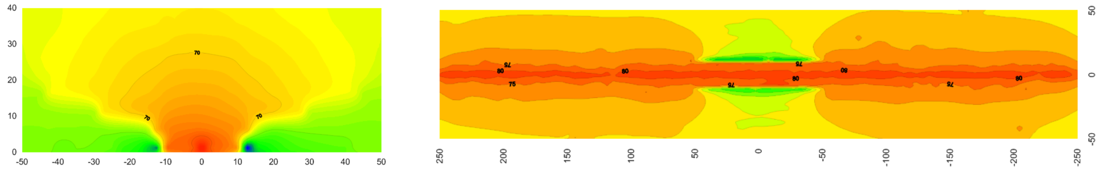


(a) No barrier
(b) Wall-shaped barrier of 5 m height
(c) Wall-shaped barrier of 10 m height
(d) Wall-shaped barrier of 15 m height
(e) Tunnel-shaped barrier with flat roof
(f) Tunnel-shaped barrier with gable roof
(g) Tunnel-shaped barrier with longitudinally-corrugated roof
(h) Tunnel-shaped barrier with sectionally-corrugated roof

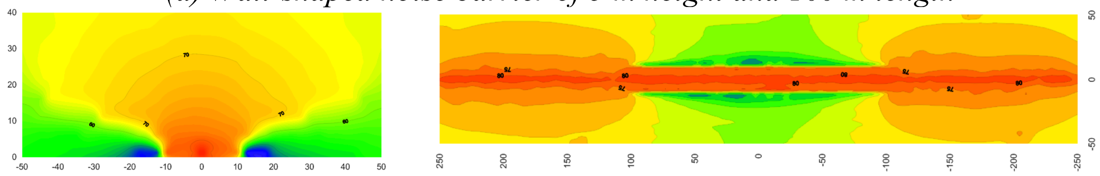
Fig. 4. Horizontal distribution of overall sound pressure level at the same section according to various shapes of the simulated noise barriers with 400 m length

3.3 Effects of length of noise barriers

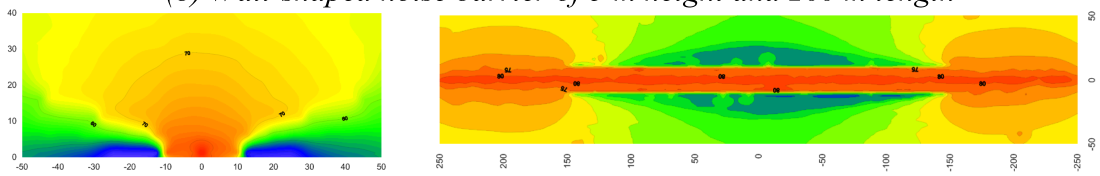
Figure 5 shows the simulation results for the wall-shaped noise barrier of 5 m height in accordance with various length of 100 m to 400 m. Acoustically-shadowed zone was vertically and horizontally changed in terms of barrier length. In case of the barrier length of 400 m, acoustically-shadowed zone was clearly observed.



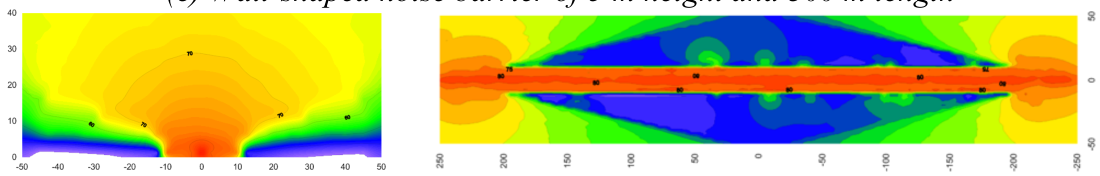
(a) Wall-shaped noise barrier of 5 m height and 100 m length



(b) Wall-shaped noise barrier of 5 m height and 200 m length



(c) Wall-shaped noise barrier of 5 m height and 300 m length



(d) Wall-shaped noise barrier of 5 m height and 400 m length

Fig. 5. Spatial distributions of overall sound pressure level of wall-shaped noise barrier of 5 m height in accordance with various length

4. CONCLUDING REMARKS

In this study, sound propagation properties of noise barriers were investigated using ray-tracing method. Differences between wall and tunnel shapes, and various sectional shapes were effectively compared. As a further study, acoustic fitting with field measurements and scale model testing is needed to improve the prediction method using ray-tracing.

5. ACKNOWLEDGEMENTS

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