

Shinkansen Noise Reduction by New Wayside Equipment Development



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JR East has developed a noise reduction device to be installed on the top of existing upright sound barriers as a wayside equipment approach to noise reduction with increased Shinkansen speeds. That device utilizes diffraction and interference of sound to improve noise reduction. In its development, we first studied the shape of the device by numerical analysis, then verified noise reduction through speaker tests using a full-scale model built based on the results of that numerical analysis. We next installed the device on existing upright sound barriers in high-speed running tests to confirm the noise reduction effect in actual operating situations.

●Keywords: Noise reduction device, Diffraction, Interference, Sound barrier, Shinkansen noise

1 Introduction

As noise increases with faster Shinkansen speeds, noise reduction becomes a technical issue that must overcome in speed increase. Increasing sound barrier height is the usual approach to noise reduction using wayside equipment. To raise the height, concrete or polycarbonate panels are added to the top of sound barriers. Increasing of the height by 1 m is considered to bring about approx. 2 dB noise reduction at a height of 1.2 m from the ground 25 m from the center of the track (hereinafter “25 m point”). But, in order to achieve further Shinkansen speed increases, a new noise reduction approach is needed that can produce a higher effect than that of the approach presently used.

Noise reduction devices utilizing sound interference as shown in Fig. 1 have been installed to the top of sound barriers in some sections as a noise reduction approach for the Shinkansen, in addition to increasing sound barrier height. But those interference type noise reduction devices project by more than 800 mm from the sound barrier towards houses along the track. Thus, the devices can be installed only where there is extra space under the viaduct.

An effective type of sound barrier has been studied and already put into practical use as a noise reduction approach for roads. That has a structure that reduces noise by utilizing the effect of multi-diffraction of sound and effect of interference to incident sound and reflected sound on the upper part of barriers (hereinafter “multi-diffraction and interference”). Unlike with road noise, Shinkansen noise has characteristics particular to railway noise such as many noise sources near rails and around pantographs as well as multi-reflection of sound in a small area between car bodies and sound barriers. Thus, it was not clear whether multi-diffraction and interference sound barriers for roads would work for Shinkansen noise reduction.

In light of those circumstances, we aimed to verify the noise reduction effect of multi-diffraction and interference sound barriers for roads when applied to Shinkansen noise. We also worked to develop a new noise reduction device applicable to existing upright sound barriers along Shinkansen tracks that would produce a greater noise reduction effect than that of increasing the sound barrier height and is free from restrictions of space.



Fig. 1 Interference-type Noise Reduction Device

2 Noise Reduction Tests of Existing Multi-Diffraction and Interference Sound Barriers

First, in order to check the effect of the multi-diffraction and interference sound barriers that have been put into practical use for roads, we installed a device shown in Fig. 2 to the top of the upright sound barriers in an elevated Shinkansen section and checked the Shinkansen noise reduction effect. The device was installed on a section 200 m long. For comparison purposes, we also attached 200 m-long sound absorbing material to other side barrier walls. The sound absorbing material used is a polyester type that is usually attached on sound barriers of the Shinkansen.

We measured noise at the 25 m point in sections with multi-diffraction and interference-type noise reduction devices, in sections with sound absorbing materials and in sections with no devices/materials. That was done by measuring the A-weighted sound pressure level, which is the 25 m point sound pressure level adjusted to actual auditory sense (hereinafter “noise level”).

The measurement results showed that the noise levels in all sections increased as the train speed increased. But the increase in the section with multi-diffraction and interference noise reduction devices was smaller than the increase in the section with sound absorbing material. Those results demonstrate that noise reduction devices are less dependent on speed than the sound absorbing material. The noise reduction effect recoded for the peak noise at 240 km/h running with the multi-diffraction and interference noise reduction devices was 1.5 dB¹⁾.

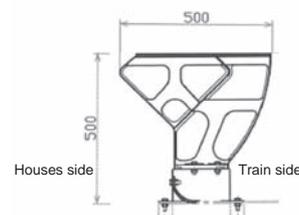


Fig. 2 Multi-diffraction and Interference-type Noise Reduction Device

3 Numerical Analysis of Shape of Upper Part of the Sound Barrier

In order to develop a noise reduction device that reduces Shinkansen noise more effectively, we carried out numerical analysis of different shapes of the upper part of the sound barriers. That analysis was done based on a two-dimensional boundary element analysis method using the simplified model shown in Fig. 3. We specified size of the noise reduction device to have a maximum height of 500 mm and maximum width of 800 mm so as not to obstruct the view through train windows and walking along the barrier. To compare the effects of a variety of shapes of upper part of the sound barrier, we selected a representative evaluation point. That point was set at 8 m lower than the rail level (1.2 m high from the ground) 25 m from the center of the track, assuming a viaduct of standard height.

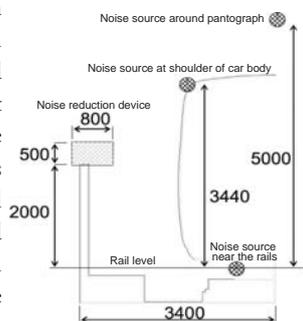
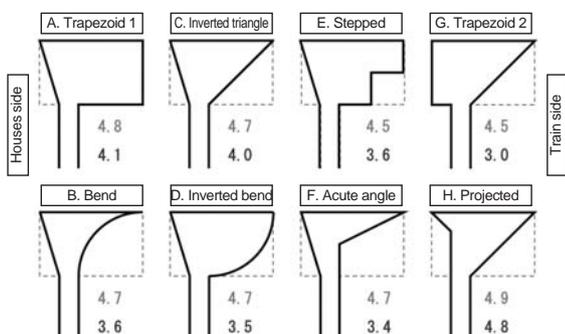


Fig. 3 Simplified Numerical Model

We made calculations for frequencies per 5 Hz and added the results to each other per octave band to evaluate the calculation results in overall values.



* Numbers in the figure are the noise calculated reduction effect (dB) compared to the upright sound barrier without noise reduction measures at the point 8 m lower than the rail level and 25 m from the center of the track. Upper numbers are noise at the shoulder of the car body, and bottom numbers are noise at the rails.

Fig. 4 Outline Examples and Noise Reduction Effects

The numerical analysis results of the eight outlines for the top of the sound barrier in Fig. 4 confirmed the following.

- (1) Comparing A through F that have a different shape on the train side, we found that A with a shape perpendicular to the noise source on the rails and C with an oblique shape were almost equally effective.
- (2) Comparing C, G and H that have a different shape on the houses side, we found that H with a small projection at the edge on the houses side was effective.

Based on the above results, we assumed that the outlines effective for noise reduction were H with a small projection at the edge on the houses side and A with a perpendicular shape or C with an oblique shape on the train side. Furthermore, we thought C would be better than A, taking into consideration the feeling of pressure when walking on the route along the sound

barriers.

Next, we studied the internal shape of the upper part of the sound barrier. The results of numerical analysis for the shape of the projection on the houses side proved in the end that a pentagonal shape like a Y with the ends bent was most effective. The numerical analysis results of the shape of the projection on the train side confirmed that the most effective shape was the shape shown in Fig. 5 with a separation between that pentagonal shape and the tilted panel on the train side²⁾.

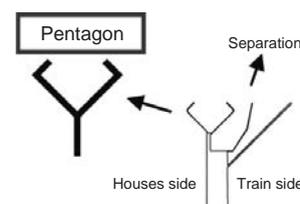


Fig. 5 Optimal Shape Obtained by Numerical Analysis

4 Verification of Noise Reduction in the Full-scale Model Test

As shown in Fig. 6, we made full scale test samples of noise reduction devices with the optimal shape based on the numerical analysis results. The samples were approx. 500 mm high, approx. 800 mm wide and 5 m long, made of 1.6 mm galvanized steel plate.

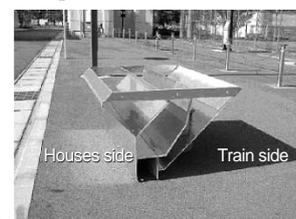


Fig. 6 Prototype Noise Reduction Device

With those test samples, we carried out model tests using full-scale models of a car and the sound barrier (hereinafter “full-scale model test”). We also modified the tilted panel on the train side to enable attachment of sound absorbing material (polyester 40 mm thick with 70 kg/m³ density). Fig. 7 shows main test cases using the full-scale models. Fig. 8 shows a photo of the test and the measurement point layout.

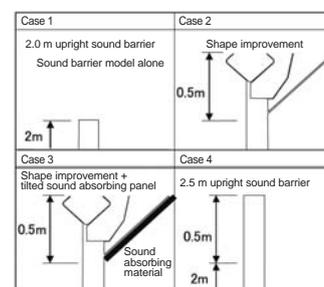


Fig. 7 Example of Full-scale Model Test

In the tests, we set speakers as noise sources at three locations: by the pantograph, on the shoulder of the car body and near the rails. Measurement points were located at 30 cross points of the mesh in the area shown in Fig. 8. The noise levels were measured at each measurement

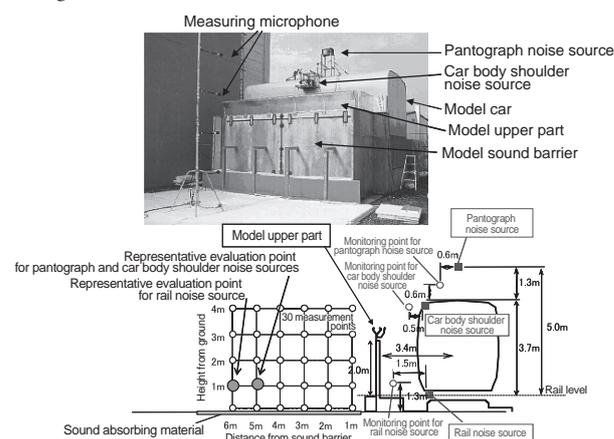


Fig. 8 Full-Scale Model Test Photo and Layout

Table 1 Noise Reduction Effect per Noise Source (dB)

Noise source	Case 2	Case 3	Case 4
Pantograph	-0.5	-0.6	-0.2
Car body shoulder	5.0	5.2	4.8
Rail	6.0	6.7	1.5

point in 200 Hz to 4 kHz frequency bands when outputting pink noise from each speaker.

We also set representative evaluation points for each noise source as shown in the measurement layout diagram in Fig. 8. Considering that the change of the frequency characteristics of noise is small in shorter distances, we selected a point from the 30 measurement points that had frequency characteristics most similar to that of the 25 m point. That selection was made using the analysis model shown in Fig. 3.

Table 1 shows the noise reduction rate for the representative point in the cases shown in Fig. 7 compared to Case 1. Positive values mean larger reduction than that in Case 1. The results confirmed the following.

- (1) Reduction of the noise of the rail noise source was the largest in Case 3. This means noise reduction devices have a greater effect than that of increasing of height (Case 4).
- (2) The effects of reduction of noise of the car body shoulder noise source were almost equal in all cases.
- (3) Since the noise source around the pantograph was not blocked for representative evaluation points, no reduction was measured in any cases.

We further confirmed that noise was reduced at points other than representative evaluation points, and such noise reduction was large in Cases 2 and 3 in particular³⁾.

5 On-Site Measurement of Noise Reduction Effect

In order to confirm the effectiveness of noise reduction devices, we measured their effect in fast running tests using a Shinkansen high-speed test train by installing noise reduction devices on the top of existing upright sound barriers in a 200 m long area on an elevated section of the Tohoku Shinkansen. The measurement location was a 25 m point for the outbound line on a section on a viaduct of RC rigid frame structure. For comparison purposes, we measured the noise with and without sound absorbing material on the tilted panel on the train side of noise reduction devices and without noise reduction devices³⁾.

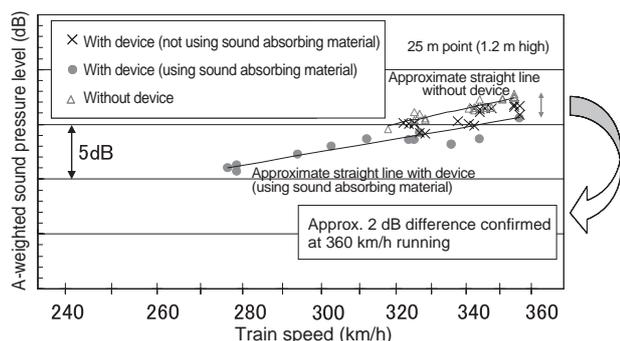


Fig. 9 Noise Measurement Results at 25 m Point

Fig. 9 shows the distribution of the noise level of the Shinkansen high-speed test train at the 25 m point. Values on the vertical axis are noise level values and the values on the horizontal axis are the train speeds. Comparison of noise reduction by sound barriers having noise reduction devices with sound absorbing material and sound barriers not having such devices shows that the noise reduction devices had a noise reduction effect of approx. 2 dB.

6 Verification of the Effect of Noise Reduction Devices Installed on Height-increased Sound Barriers

In the pursuit of further noise reduction, we verified the effect of noise reduction devices installed on height-increased sound barriers using the full-scale model in Fig. 8. The main cases verified are shown in Fig. 10. For each of those cases, we measured the noise levels at the representative evaluation points and compared those to the estimated noise levels at 25 m points calculated by the noise prediction formula by Railway Technology Research Institute⁴⁾.

With noise level in Case 1 as the benchmark, a comparison with Case 2 shows a 2.7 dB reduction and Case 3 a 5.4 dB reduction. Those results verified that the approach of “sound barriers raised in height by 1.0 m + noise reduction devices” can be applicable to noise reduction equivalent to reduction by 5 dB.

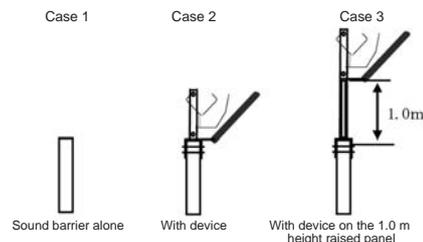


Fig. 10 Example of Full-Scale Model Test

7 Conclusion

We developed a noise reduction device for the Shinkansen by wayside equipment utilizing diffraction and interference of sound. The high-speed running tests showed an approx. 2 dB noise reduction. Combining the device with sound barriers of increased height will allow for further noise reduction.

Reference:

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