Special edition paper

Countermeasures for noise from the lower car body with sound absorber

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Noise from the upper area of the car body has been reduced with the development of a low-noise pantograph. In order to reduce noise generated by a high-speed train, it is necessary to reduce noise from the lower area of a car body, which contributes comparatively more to the overall noise level than in previous car bodies. Previous research using both a model and an actual operating train (series E2) shows the effect of a sound-absorbing panel attached to the lower area of a car body. In this paper, we evaluated the performance of certain kinds of materials for further improvement of the sound-absorbing panel, and selected a sound-absorbing material which is suitable for high speed trains. Furthermore, the relationship between area and effectiveness of the sound-absorbing panel was examined to decide the optimum area of the panel that will be attached to the actual train. In the design process of a high-speed test train, we developed sound-absorbing panels for the side skirt and covering board under the car body that have sufficient strength to be attached to the high speed test train.

• **Keywords:** Noise reduction, noise from the lower car body, sound-absorbing material, acoustic test with a full-scale model

1 Introduction

Further reduction of the noise from the lower area of a car body is required to reduce the overall noise level of the high-speed test train. To enhance the performance of the sound-absorbing panel, which is effective in reducing noise, it is important to choose the appropriate materials and to increase the area of sound-absorbing panels as much as possible. In this paper, we evaluated the performance of certain kinds of materials used in sound-absorbing panels to be considered for further improvement, and also selected a sound absorbing material that is suitable for use on a high-speed train. Furthermore, the relationship between area and effect of sound-absorbing panel was examined to decide the optimum area of the panel that will be attached to the actual train. In the design process of the high-speed test train, we developed sound-absorbing panels for the side skirt and covering board under the car body that have sufficient strength to be attached to the high-speed test train.

2 Acoustic test with a full-scale model

2.1 Experiment equipment

It is important to grasp quantitatively how a sound-absorbing panel contributes to the reduction of wayside noise to evaluate the effectiveness of the panel. For this purpose, we developed acoustic test equipment with a full-scale model and a noise barrier, and performed experiments aimed at evaluating the effectiveness of the sound-absorbing panels. An outline drawing, noise sources, and measurement locations of the experiment equipment are shown in Fig.1. The equipment consisted of a real scale cut model (6m long, including bogie space) and noise barrier (5m long) made from concrete. The sound-absorbing wall and sound-absorbing material

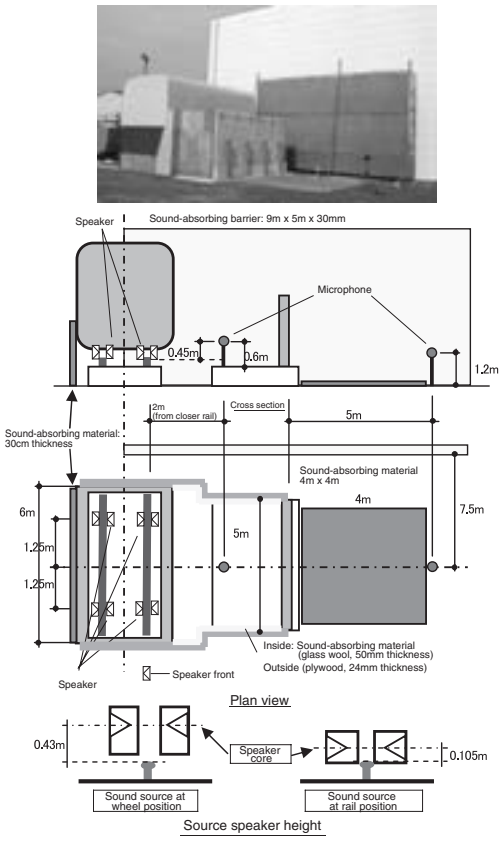

Fig.1: Full-scale acoustic test model

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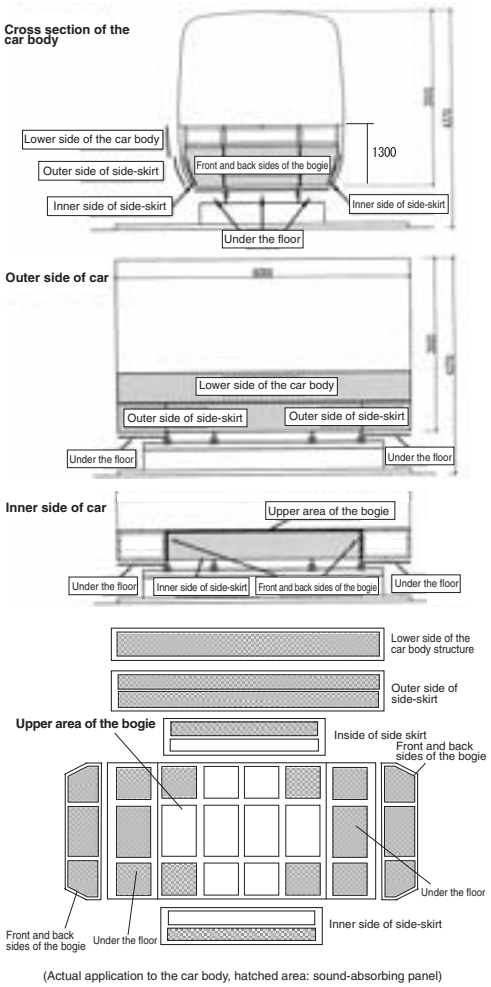
shown in Fig.1 were set to eliminate reflected sound from both the adjacent building and the ground. Noise from the lower area of the car body includes rolling noise generated between wheels and rails, aerodynamic noise from the bogies, and so on. In this experiment these noise sources were simulated with speakers. There are two noise sources on a car (at wheel position and at rail position). Speakers were placed in 4 wheel positions (2 speakers were placed back to back for each location) to simulate the noise source at the wheel position. Noise sources for the rail positionwere placed at the 4 wheel positions as shown in Fig. 1 in a similar way to the wheel position speakers.

Inside the noise barrier, one microphone was located close to the rail as in the on-site experiment. The other microphone was located 5m away from the noise barrier and 1.2m away from the ground, instead of 25m distance used for the actual evaluation of noise from Shinkansen. Pink noise was output, and the noise levels both inside and outside of the noise barrier were measured.

2.2 Position of sound-absorbing panel

Fig2 shows the area of the sound-absorbing panel in the lower area of a car body. The sound-absorbing panel can be attached around the bogie space, under the car body, to the side skirt, and to the lower side of body structure. The panel can be attached up to 1300mm from the rail level (the height of platform) on the lower side of the body structure. The total area used to calculate the ratio of sound-absorbing area is defined as the surface area of the car body below this height. The sound-absorbing material is incorporated into panels and attached to the car body. In this experiment equipment, the control condition without sound-absorbing material was created by covering the sound-absorbing panels with plywood or aluminum plates. Due to the fact that it is impossible to attach sound-absorbing materials to the edges of panels, the maximum ratio of sound-absorbing area is about 76% when all panels are attached. Note that the sound-absorbing material was not attached to the side skirt or the lower side of the body structure opposite the measurement side because doing so would not affect the performance of the sound-absorbing material.



(Actual application to the car body, hatched area: sound-absorbing panel)

Fig.2: Attachment range of sound-absorbing panel

2.3 Conversion methods using on-site measurement data

In this experiment, pink noise was used as the test noise from the lower part of the car body. It was necessary to convert measured data using the on-site measurement data from the Shinkansen to evaluate the results. Data measured inside the noise barrier is converted with on-site measurement data (series E2-1000, speed of 360km/h, a-weighted sound pressure level) from the close to the rail position (the same position as in this experiment). The calculation method is shown below.

$L_{CI} = L_I + \Delta L = L_I + (L_{RI} - L_{IWO})$

$L_{CO} = L_O + \Delta L = L_O + (L_{RI} - L_{IWO})$

$\Delta L = L_{RI} - L_{IWO}$

ΔL: Correction value with on-site measurement data

L_{RI}: On-site measurement data inside the noise barrier

L_I: Measured sound pressure level inside the noise barrier

L_O: Measured sound pressure level outside the noise barrier

L_{CI}: Measured sound pressure level inside the noise barrier after conversion

L_{CO}: Measured sound pressure level outside the noise barrier after conversion

I: inside the noise barrier, O: outside the noise barrier, R: On-site measurement data,

C: Converted data, wo: without sound-absorbing panels

3 Selection of sound-absorbing material

Three types of sound-absorbing material were evaluated in this experiment.

Type1: Aluminum fiber + resonant structure (50mm thickness)

Type2: Punched plate + (porous material + honeycomb) (35mm thickness)

Type3: Aluminum fiber + back air layer structure (50mm thickness)

Noise reduction effect was compared with all panels (except the lower side of body structure) attached so as to distinguish the difference between the three types of material.

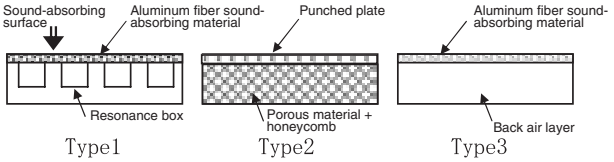


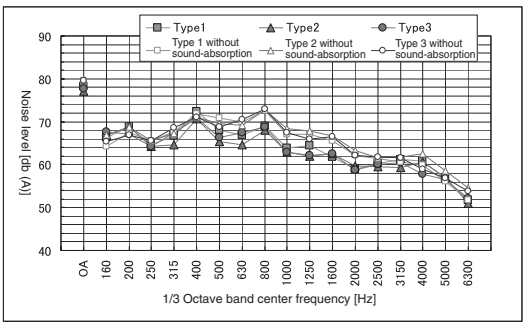
Fig.3: Structure of sound-absorbing panels

Fig.4 and Fig.5 show the noise levels measured outside the sound barrier at two different source positions (rail position and wheel position).

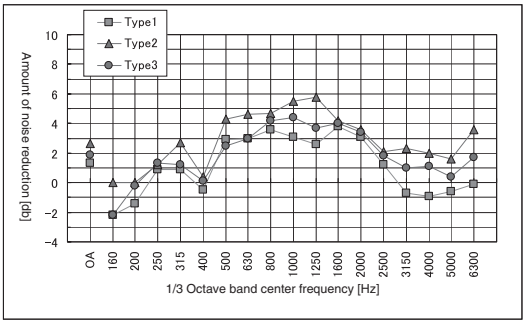
Fig.4 shows that the noise level obtained for type 2 material is lower than both type 1 and type 3 materials in all frequencies, and that overall, the type 2 material reduces the noise level by 1.3dB more than type 1, and by 0.7dB more than type 3. Fig.5 shows that the noise level for type 2 is less than both type 1 and type 3 except at 800Hz and 1.6kHz, and the overall noise level for type 2 is 1.8dB lower than type 1, and 0.7dB lower than type 3. From these results, type 2 material (punched plate + (porous material + honeycomb) was adopted as the sound-absorbing material, and was used in the experiment described below.

4 Effect of lower side sound-absorbing materials

Because the attachment of sound-absorbing panels requires a great deal of change to the body structure, the performance of the sound-absorbing panels attached to the lower area of body structure was evaluated in an acoustic test with a full scale model. The results are shown in Fig.6. Here, data was converted with data from operating trains.

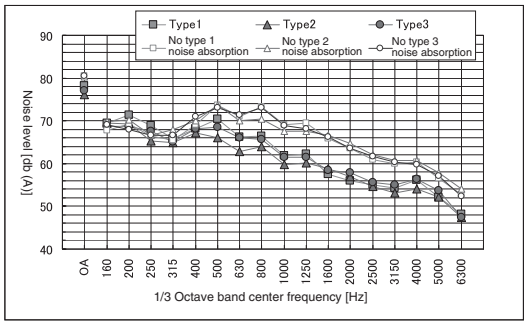


(a) 1/3 Octave band level

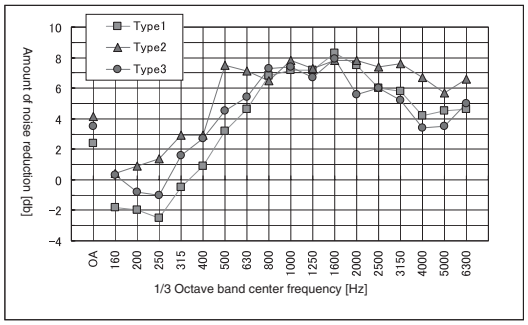


(b) Amount of noise reduction in each frequency band

Fig.4: Comparison of sound-absorbing performance: Outside noise barriers (sound source at rail position)

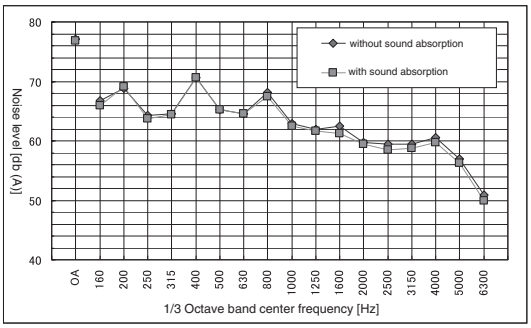


(a) 1/3 Octave band level

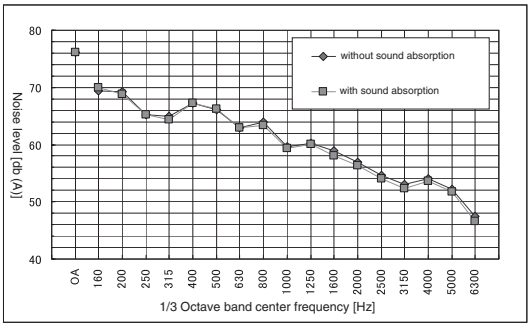


(b) Amount of noise reduction in each frequency band

Fig.5: Comparison of sound-absorbing performance: Outside noise barriers (sound source at wheel position)



(a) Sound source at rail position



(b) Sound source at wheel position

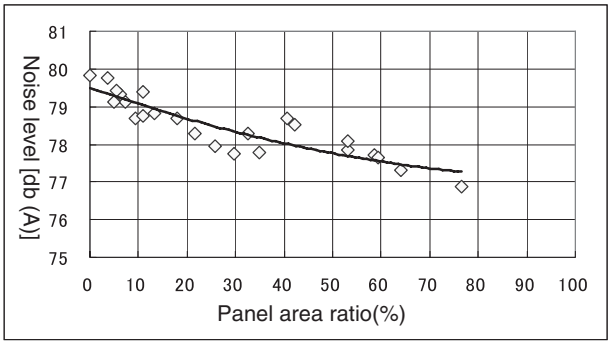
Fig.6: Sound-absorbing effect of the lower side of body structure: Outside noise barriers

A slight reduction in noise was observed in all frequency bands with sound-absorbing panels. The effect of sound-absorbing panels was a reduction of between 0.1 to 0.3dB in overall noise levels. The test also confirmed that expanding the area of sound-absorbing panels was effective in reducing the noise from outside noise barriers.

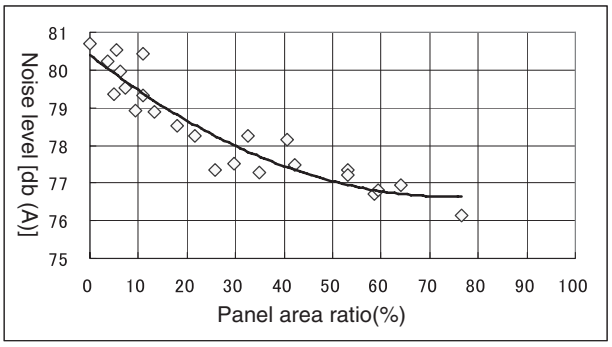
5 Relationship between panel area and performance

In order to clarify the quantitative relationship between panel area and performance of the outside noise barriers, sound-absorbing performance was evaluated with different two panel areas.

Overall levels of outside noise barriers are shown in Fig.7. As the panel area increased, the sound pressure level was reduced in both noise source positions. Up to an area ratio of approximately 50%, expanding the area of sound-absorbing panels effectively reduces noise of the outside noise barriers.



(a) Sound source at rail position



(b) Sound source at wheel position

Fig.7: Relationship between panel area and performance: Outside noise barriers

6 Performance of the sound-absorbing panels on the high-speed test train

When designing the high-speed train, a new sound-absorbing panel was developed using the sound-absorbing material adopted in the acoustic test and with sufficient strength to be used with a full-scale model. The structure is shown in Fig.8. Two types of panel were developed with different thickness (35mm, 50mm). A sandwich-type structure (punching plate + honeycomb+ punching plate) was adopted to ensure the strength of panels.

In the acoustic test with the full-scale model, performance of the prototype and the new panel was compared. In a real train, there are certain areas in which sound-absorbing panels cannot be attached because of the installation of other equipment under the car body or around the bogie. Experiments were performed considering the arrangement of a real train (Fig.2, area ratio 50%).

The results of the experiment showed that the increase in noise reduction was no more than 0.5dB (rail) and 0.7dB(wheel), and the performance of the newly developed panel is almost the same as that of the prototype l.

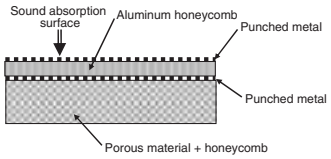


Fig.8: Structure of sound-absorbing panel for the test car

7 Conclusion

Results of the acoustic test with a full scale model to clarify the performance of sound-absorbing panels were as follows:

(1) Type 2 sound-absorbing material (punched plate +(porous material + honeycomb)) was selected as the most effective of the three types of material.

(2) Noise level outside the noise barrier was reduced from 0.1 to 0.3 dB by expanding the area of sound-absorbing panel to the lower side of the body structure.

(3) Expanding the area of sound-absorbing panels up to an area ratio of approximately 50% was effective in reducing noise outside noise barriers.

(4) The performance of the newly developed panel which can be attached to the high speed train is almost the same as that of the prototype.

8 Future work

In addition to evaluating the sound-absorbing panel by performing high speed running tests, we are planning to develop a high standard, lightweight, cost-effective sound-absorbing panel suitable for installation on commercial trains.

References

1) Kaoru Murata, Toshikazu Sato, Koichi Sasaki; Countermeasures of noise reduction for Shinkansen electric-current collecting system and lower parts of cars; JR EAST Technical Review No.1, Autumn 2002, 13-21, 2002