Considering future speed increases, noise reduction is a major issue for railway companies. As a countermeasure against increased noise levels, increasing sound barrier height is the usual approach to noise reduction. However, sound barrier height is limited according to external loads, namely wind pressure and blasting snow. Moreover, too tall sound barriers obstruct passenger’s view from train windows. Thus, sound absorption panels are applied to sound barriers on viaducts to achieve higher noise reduction with lower barrier height. To develop measures against the noise caused by higher-speed trains, we developed and constructed a full-scale model of a viaduct and a Shinkansen vehicle.

**Abstract**

Considering future Shinkansen speed increases, development of noise reduction devices is a major issue for railway operators. Increasing sound barrier height is the usual measure employed to reduce noise. However, there are limits to how much the wall height can be increased due to yield strength of the viaduct and passenger dissatisfaction with poorer view from train windows that come with higher walls. In light of those, we need to develop a new sound absorption panel to be attached to the inside of viaduct sound barriers and to use that in optimized combination with edge-modified barriers where acoustical devices are attached to the top of sound barriers.

Performance of developed items can be verified in field tests where trains are run on a commercial line equipped with the prototype and measurements are taken then; however, verification in field tests poses many issues. For example, we have to check whether the specimen meets conditions for strength, dimensions, and the like in addition to acoustic performance, and considerable cost and labor are required for installation and other work. Even after going through those efforts, data obtained in field tests is often subject to surrounding weather conditions as well as factors such as rolling stock and wheel condition. We therefore produced a full-scale model of a viaduct and of a vehicle (Fig. 1) to facilitate development and evaluation of noise reduction devices. This paper outlines the models.

**Keywords**: High-speed railway, Viaduct, Noise, Shinkansen, Mock-up, Sound absorption panel

1. **Introduction**

Fig. 1  Full View of Full-scale Acoustic Testing Model
2. Characteristics of the Full-scale Models

2.1 Advantages of the Full-scale Models in Development of a Sound Absorption Panel

Noise reduction effect of the new sound absorption panel under development can be checked in tests using a reduced-scale model and/or on-site. Table 1 shows general tendencies in tests using a scale model and in field tests when checking the effect of attaching sound absorption panels to a viaduct. The largest advantage of a test using a full-scale model is that sound absorption panels of the same material as that of the actual panel can be tested. On the other hand, it has disadvantages of limited length of the model and fixed conditions for the sound source. The data obtained in the tests using a full-scale model, however, can be more effectively used when combined with data obtained using a reduced-scale model and by numerical analysis based on analysis of data obtained in field tests.

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Table 1  General Tendencies Seen in Field Running Tests and Tests Using Models

2.2 Characteristics of the Full-scale Viaduct Model

Bearing in mind modeling of a typical Shinkansen viaduct, we used the shape of a viaduct with the standard cross section employed for the Tohoku Shinkansen as reference when designing the full-scale viaduct model. For the live load for the model, we adopted sidewalk live load used as the live load for a girder type or embankment type platform because the model is not a structure to which train load is applied. Furthermore, referencing the construction of the Kawagoe Rolling Stock Center (Fig. 2), we adopted spread foundation as the foundation of the model.

![Location of full-scale model](image1)

![Location of full-scale model](image2)

The location is silty soft ground to around 6 m under the ground surface. At the construction of the depot (1985), approx. 1.2 m-high embankment of rudaceous soil was constructed taking into consideration consolidation settlement of 133 mm.

2.3 Characteristics of the Full-scale Noise Barrier Model

A typical viaduct has sound barriers made of cast-in-place concrete to a height of 2 m from the rail level. However, we adopted a structure where sound barriers including bases can be replaced in order to handle testing with sound barriers being replaced (Fig. 3). Due to restrictions in design wind load, barrier height can be up to 2 m from the rail level when not used in tests.
2.4 Characteristics of the Full-scale Vehicle Model

For the vehicle model part, we modeled a Shinkansen vehicle (Fig. 4). On the measurement side of the model, we secured a distance between the car bottom and the track concrete slab the same as that with a Shinkansen car in order to reproduce noise from the lower part of cars. In contrast, on the other side of the model, the car bottom and the track concrete slab is connected to prevent noise leak (Fig. 5). In order to handle acoustic tests of pantographs and bogies, we divided the lower and upper parts of the model car and made them removable. For workability while producing, we divided the vehicle into three parts in the direction of travel.

3. Measurement Examples

3.1 Placement of Sound Source and Microphones

Fig. 6 shows an example of the placement of microphones in the measurement with noise barriers of a height of 2 m from the rail level using microphones for the source of noise from lower parts of the car, upper aerodynamic noise source, and pantograph noise source. Height from the ground at the rail level of the full-scale viaduct model is 3 m; however, we chose the heights of 9 m, 6 m, and 3 m from the ground to simulate typical viaduct heights from diverse heights of Shinkansen viaducts. Standard height of measurement on the ground in field running tests is specified as 1.2 m from the ground at 25 m from the center of the track. With this full-scale model, however, we set a microphone each at an angle adjusted for each viaduct height at 10 m, 12.5 m, and 15 m from the center of the track. Noise level at 25 m from the track was estimated based on the measured value taking into account range attenuation.
3.2 Measurement Test Example

Fig. 7 shows an example of measurements in a noise test. Fig. 7(a) shows noise measurement values with 2 m-high noise barriers without sound absorption panels in a bubble chart overlaid on a cross-sectional plan of the full-scale model. Sizes of the bubbles correspond to sound pressure levels (dB[A]). While noise reduction effect of noise barriers was seen, no remarkable difference between measurement values at 10 m and 12.5 m from the viaduct can be seen. Fig. 7(b) shows the difference between the noise measurement values with and without sound absorption panels that is obtained by reducing noise measurement values with noise barriers with sound absorption panels attached to the inner side from the values shown in Fig. 7(a). Sizes of the bubbles correspond to differences in pressure levels (dB[A]) here. Fig. 7(b) shows that the difference between the noise measurement values with and without sound absorption panels was relatively larger at the top of the noise barriers and it gradually became smaller at 10 m and 12.5 m from the viaduct.

4. Conclusion

We outlined a full-scale Shinkansen viaduct model for acoustic tests and introduced measurements as above. The model has been used since 2016 for development of noise reduction measures to be implemented to rolling stock and wayside equipment. Using this model, we carried out tests of sound absorption panels that reduce noise from lower parts of cars for the development of measures for wayside equipment. We next are planning to carry out further tests for the development of noise reduction devices. And we hope to effectively use the full-scale model in order to obtain data needed for noise reduction with a view to the next-generation Shinkansen.

Reference:
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