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The Environmental Engineering Division has focused on research on railway noise and aerodynamics. These include environmental issues, such as wayside noise, micro-pressure waves radiating from tunnels, and air resistance reduction; safety issues, such as vehicle overturning under crosswinds and winds induced by train passage, pressure changes in tunnels, and aerodynamic brakes; and comfort-related issues, such as the thermal environment in tunnels and airtightness of vehicles. We present the recent research conducted by the Environmental Engineering Division.

# Environmental Engineering Division

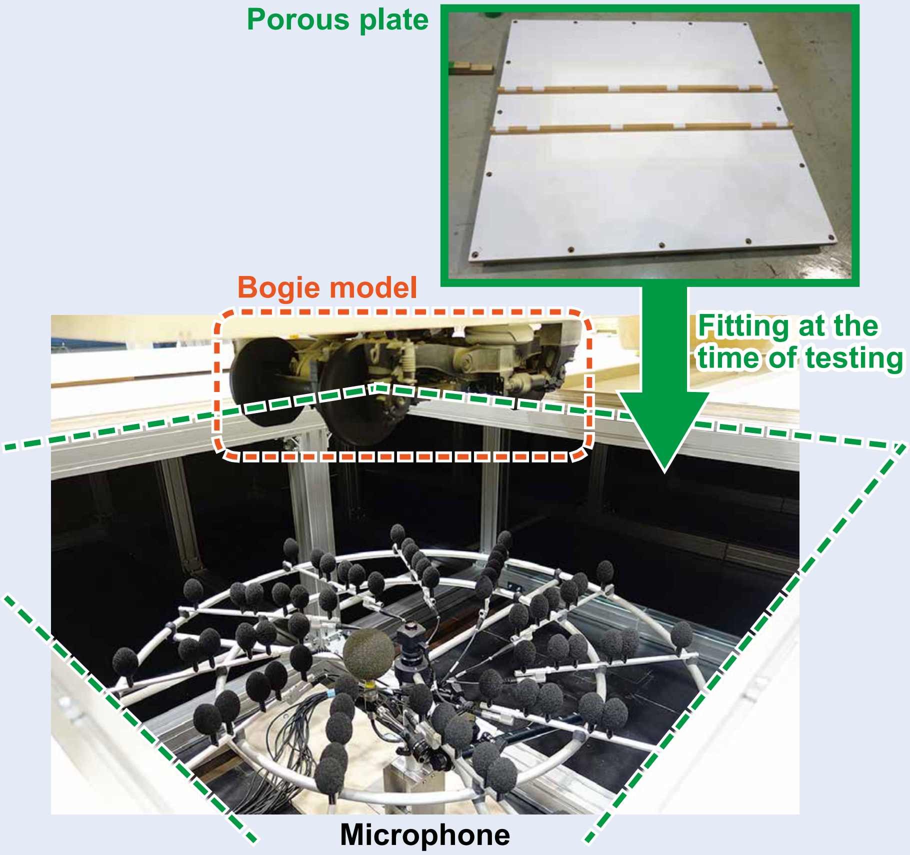
## Introduction

Among the most investigated aerodynamic research subjects in the field of railways is aerodynamic drag, which is represented by the shape of the nose of the Shinkansen train. Aerodynamic drag reduction is particularly important in high-speed trains. However, there exist many aerodynamic issues in railways. Such issues include the overturning of a vehicle owing to strong winds, the aerodynamic sway of a high-speed railway, and winds generated on the platform when a train passes through a station. At times, people may feel an increase in temperature on a subway platform. This is also attributable to the heat generated by the running train and wind generated in tunnels, which is an issue related to heat and airflow. Further, noise is an important environmental issue in railways. There are various types of noises, including noise from wheels and rails, noise generated by structures such as railway bridges and viaducts, and aeroacoustic noise generated by high-speed vehicles such as Shinkansen trains.

As described above, railway noise and aerodynamic issues are remarkably diverse, and all are considered critical issues that affect the wayside environment, safety, and passenger comfort. The Environmental Engineering Division has focused its research and development efforts on elucidating and reducing railway-specific phenomena to propose concrete solutions to these issues. This report covers typical examples of our efforts to improve wayside environments, safety, and passenger comfort.

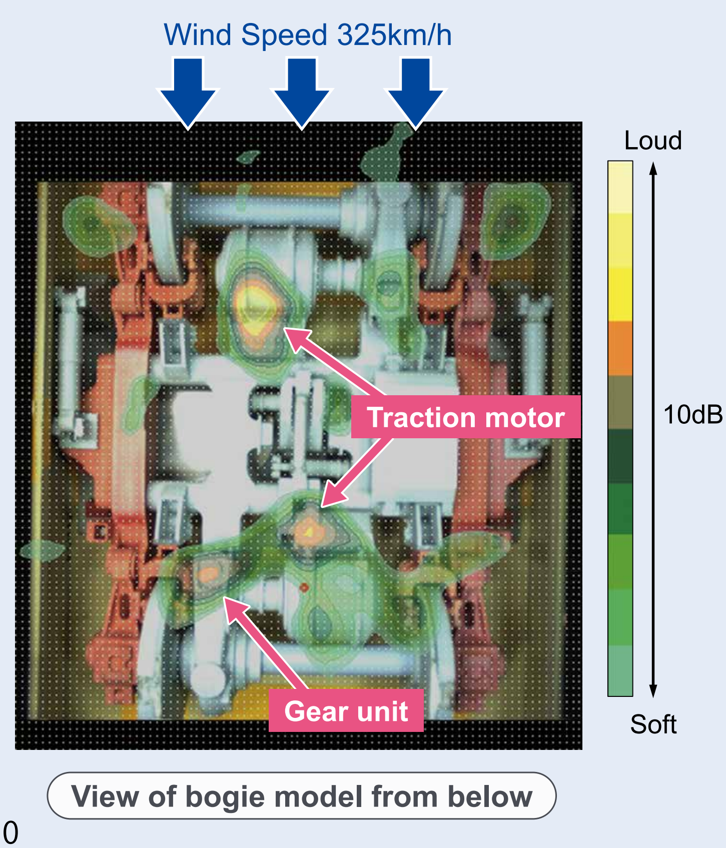
## Wayside Environmental Issues —Wayside Noise—

The noise generated during the running of a Shinkansen train can be divided into noise generated by the vibrations of the wheels and rails (rolling noise) and that by the airflow around the vehicle (aero-




**Wind tunnel test using porous plate**

**Detailed aerodynamic noise source in bogie sections**

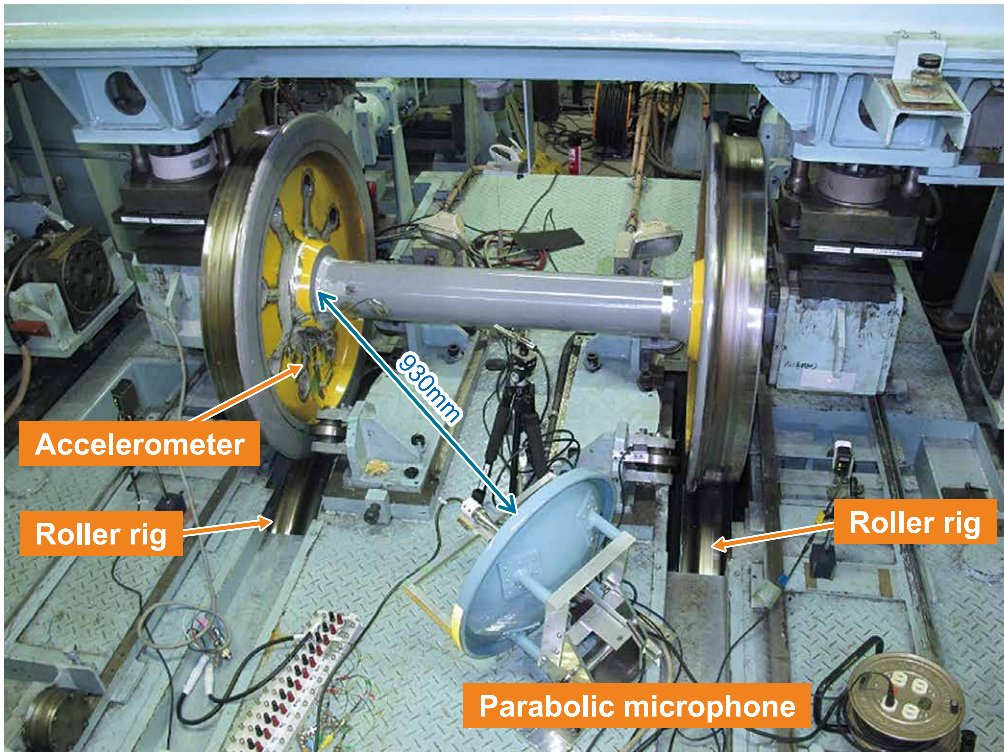



dynamic noise). For Shinkansen trains running at speeds of 300 km/h or higher, aerodynamic noise accounts for a larger proportion than rolling noise. Among the aerodynamic noises emitted by Shinkansen trains, the loudest noise is generated from the lower parts of vehicles, such as bogie sections, followed by the noise from pantographs. To solve this problem, we are currently developing measures to reduce the aerodynamic noise generated from the bogie sections to suppress wayside noise along the Shinkansen line. The large low-noise wind tunnel owned by the Railway Technical Research Institute is effective for conducting aerodynamic noise investigations. We replaced the ground plate directly under the bogie model with a porous plate (a plate that allowed only sound to pass through without disturbing the flow) and installed a microphone beneath it to identify the detailed locations at which aerodynamic noise was generated from the bogie sections (*Wind tunnel test using porous plate*)[1)]. We found that the primary sources of aerodynamic noise were near the traction motor (motor) and gear units (*Detailed aerodynamic noise source in bogie sections*). Based on these findings, we are currently conducting research and development on countermeasures to reduce the aerodynamic noise from bogie sections[2)].

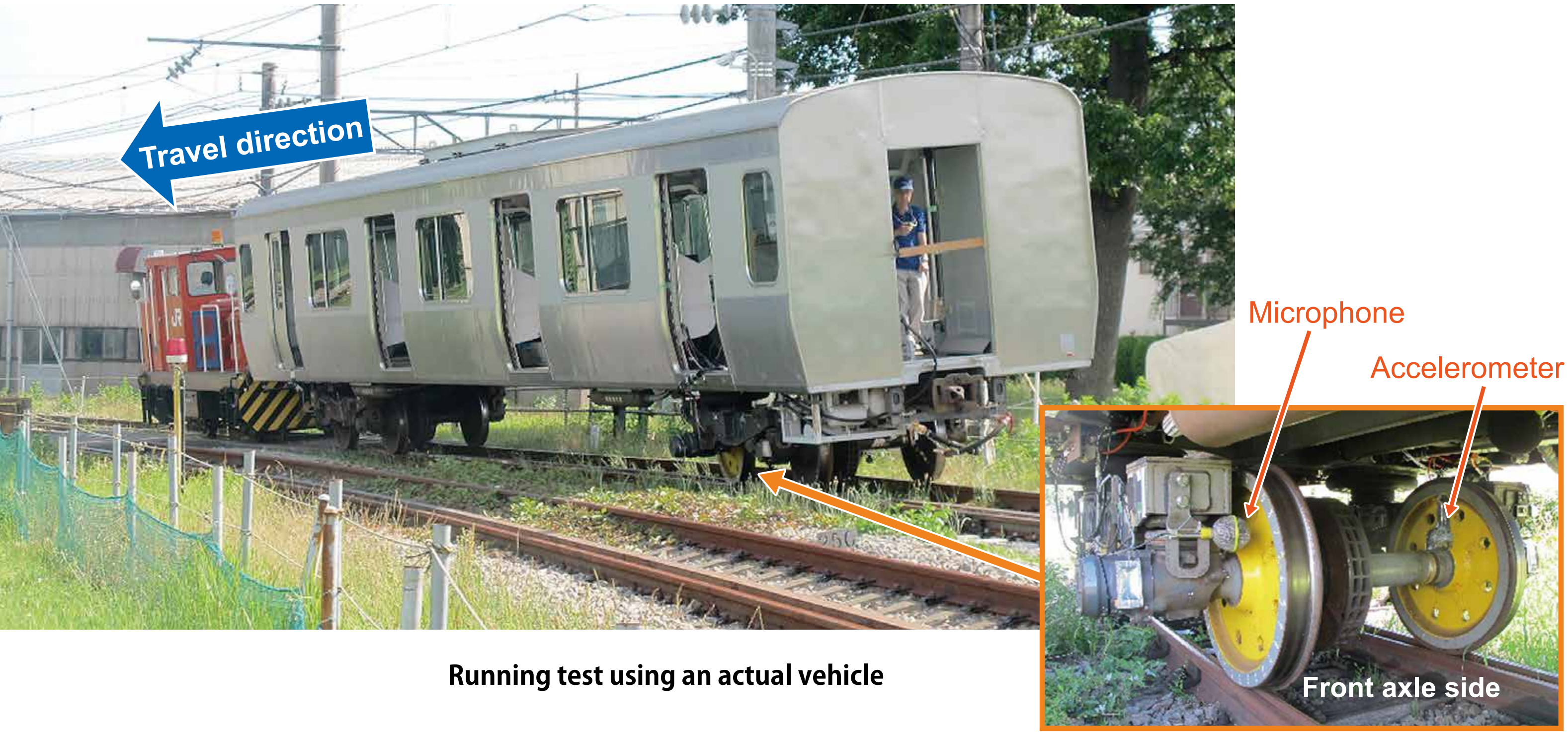
Because the noise generated between the wheels and rails, which is also a problem in conventional lines, is an extraordinarily complex phenomenon, the mechanism of noise generation, particularly on curves, remains unclear. Therefore, we are proceeding with our efforts to understand the underlying mechanism of the noise phenomena generated between wheels and rails, primarily through experimental methods. Through an experiment using an actual wheelset and experimental equipment that simulate the running conditions by rotating rigs (*Full-Scale Experiment with* *experimental equipment*), and a test using an actual vehicle (*Running test using an actual vehicle*)[3][4], we are currently examining the relationship between rail/wheel vibrations and the noise they generate to ascertain the characteristics of the relationship. Consequently, we constructed physical models to identify the cause of the noise.

## Safety Issues — Crosswind Aerodynamic Characteristics of Railway Vehicles —

To ensure safe vehicle operation under strong wind conditions, the crosswind aerodynamic forces acting on vehicles must be determined accurately. Therefore, we are proceeding with our research and development, which will contribute to elucidating the aerodynamic characteristics of vehicles through wind tunnel tests and



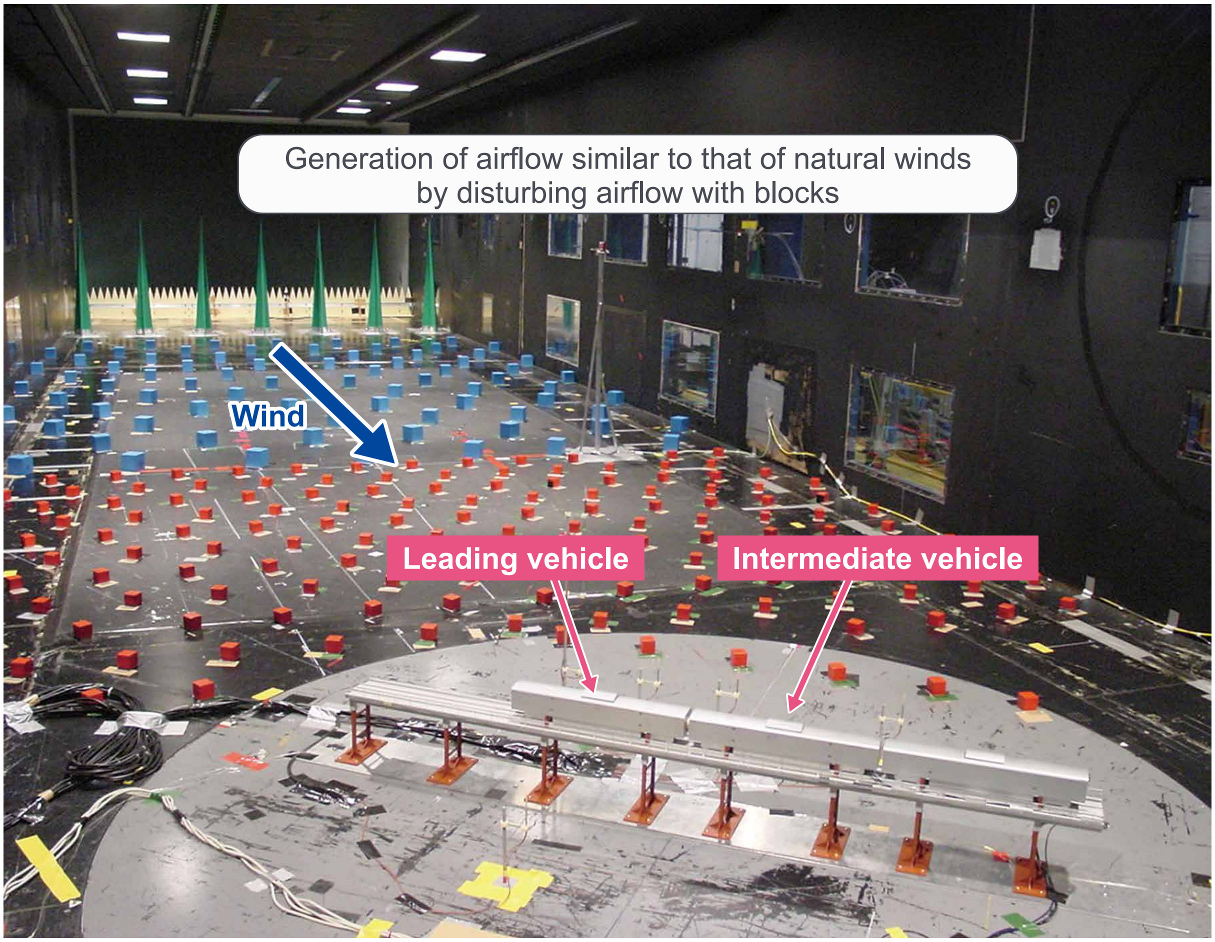

Full-Scale Experiment with experimental equipment




Running test using an actual vehicle

numerical simulations. The crosswind aerodynamic characteristics acting on railway vehicles are dependent on the shapes of the vehicles as well as the crosswind speed distribution and wayside structures, such as bridges, viaducts, and embankments. To resolve this issue, we performed wind tunnel tests at level ground conditions as well as under conditions simulating wayside structures such as bridges and embankments. Further, we simulated the mean wind speed and turbulence intensity distribution of natural winds to apply airflow to the model under conditions as close as possible to the actual conditions (*Wind tunnel test for aerodynamic characteristics of a vehicle against crosswinds*). We are currently working on wind tunnel tests using vehicle models with systematically varied cross-sectional shapes to investigate the relationship between the cross-sectional shapes and aerodynamic forces of the vehicle models and to evaluate and study the effects of windbreak fences[5)6)].

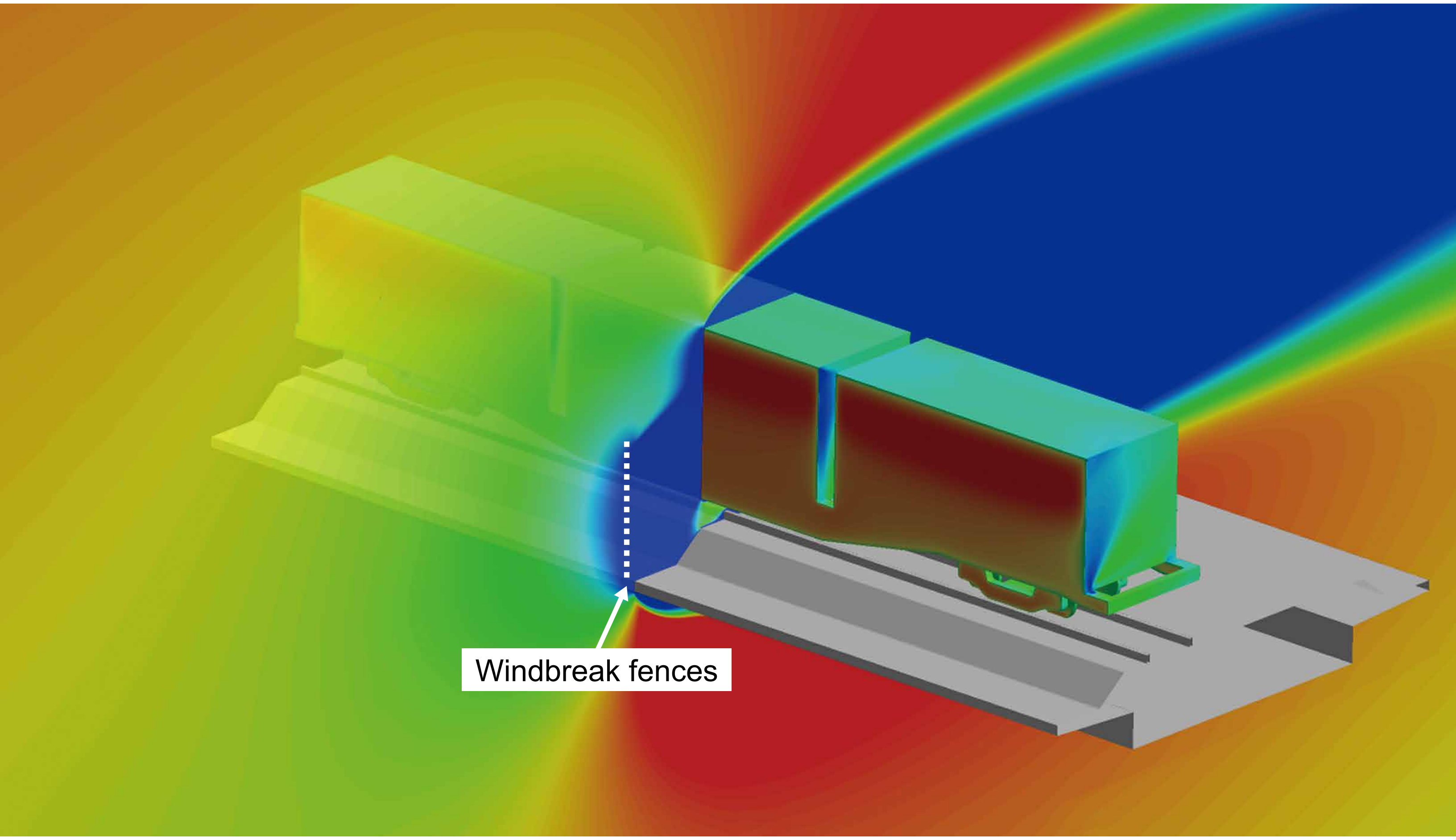
Whereas wind tunnel tests are highly effective tools for evaluating aerodynamic forces, numerical simulations that provide detailed insight into the flow field are effective for identifying the factors that affect aerodynamic forces. We systematically investigated the manner wherein wayside structures and wind direction angles affected the flow field around vehicles subjected to crosswinds (*Numerical simulation reproducing wind tunnel test with windbreak fences*)[6)]. We intended to conduct further studies on effective windbreak equipment while benefiting from the results of the wind tunnel tests and calculations.



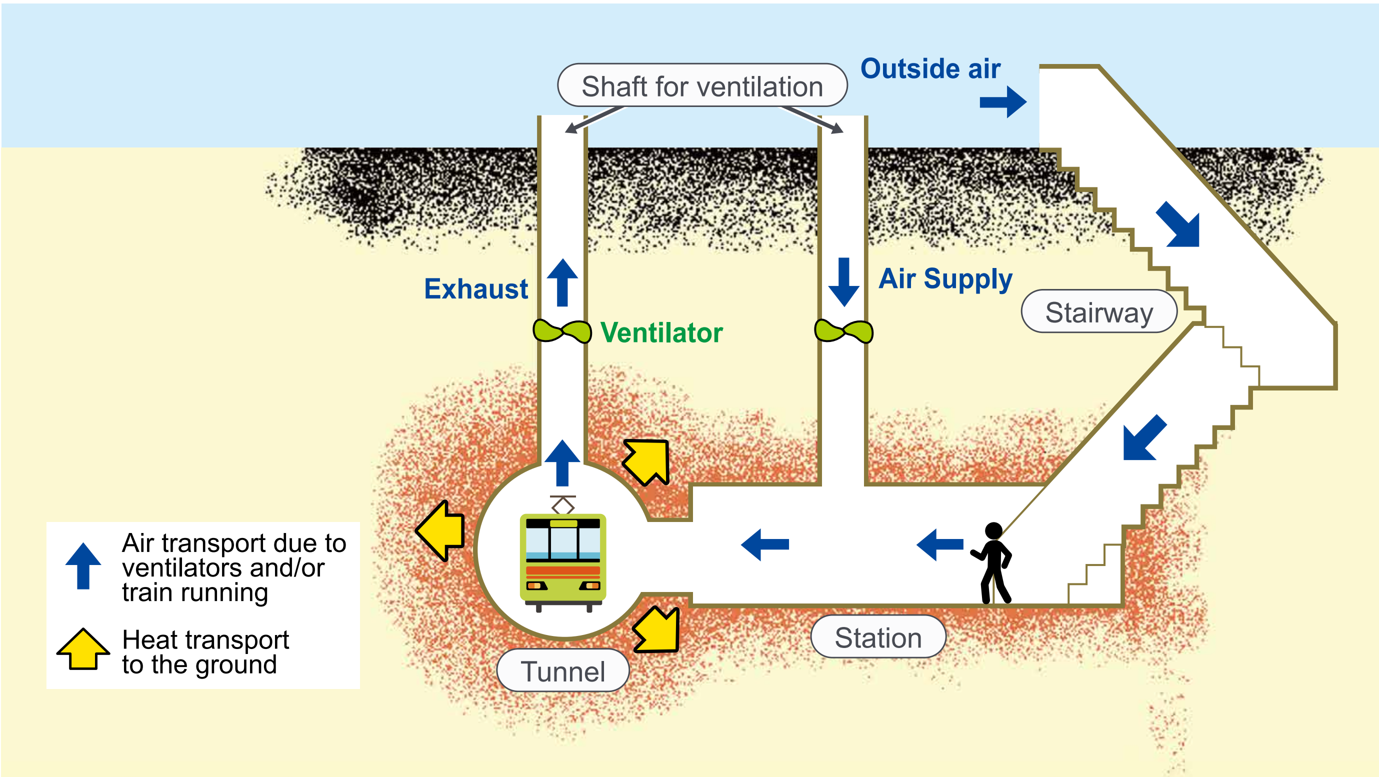

**Wind tunnel test for aerodynamic characteristics of a vehicle against crosswinds**

## Comfort-Related Issues — Thermal Environment in Tunnels —

In urban tunnels, including subway tunnels, the heat generated by trains traveling in tunnels increases the temperature in the tunnels and underground stations. Unless any measures are taken, an increased temperature can compromise comfort on the platform and adversely affect the equipment in the tunnel. To avoid this, urban tunnels are often equipped with ventilation systems for the cooling stations. However, to accurately estimate the ventilation and cooling capacities, the temperature inside the tunnel must be predicted. The Railway Technical Research Institute has been developing simulations to predict the thermal environment in tunnels for ordinary trains running in urban areas as well as tunnels for high-speed railways with ventilation equipment, such as the Seikan Tunnel (*Heat and air transport model for urban tunnels*). The accuracy of the numerical simulations was verified using theoretical analyses and model experiments[7]. In recent years, temperature prediction in the long mountain tunnels of Shinkansen trains has become an increasing challenge, in addition to that in urban tunnels. This is because, on Shinkansen trains running in areas with heavy snowfall such as Hokkaido and Hokuriku, snow clumps that adhere to the train may melt and fall during travel in tunnels with high temperature. The temperature inside the tunnels must be predicted to estimate the location of snowdrops. In contrast to urban tunnels, mountain tunnels do not have ventilation




**Numerical simulation reproducing wind tunnel test with windbreak fences**




**Heat and air transport model for urban tunnels**

equipment. Therefore, they are more likely to be affected by natural winds. We are in the process of improving our calculation models by comparing the measurement results obtained from actual tunnels with those obtained through simulations developed for urban tunnels such that such simulations can be applied to mountain tunnels as well.

## Conclusions

In this report, we covered the recent activities of the Environmental Engineering Division, including representative research subjects in the areas of railway wayside environments, safety, and comfort. We will continue to research and develop various issues related to noise and aerodynamics to contribute to the operations of railway operators.

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