Recent Studies on Wayside Environmental Problems

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Environmental problems along railway lines, caused by passing trains, include: noise, ground vibrations, micro-pressure waves radiating from tunnel portals, etc. It is necessary to mitigate the impacts of these phenomena to build more environmentally-friendly railways. This paper describes some recent studies on this subject carried out by the Railway Technical Research Institute.

Keywords: wayside environment, noise, ground vibration and micro-pressure wave

1. Introduction

There is an urgent need to address sources of trackside environmental problems, such as noise, ground vibrations, micro-pressure waves radiating from tunnel portals (hereinafter referred to as “micro-pressure waves”). As such, the Railway Technical Research Institute is conducting research and development to identify noise generation mechanisms, and find ways to predict, evaluate and mitigate these phenomena by conducting field tests, laboratory tests, numerical simulations, etc. This paper describes some of the key work carried out over recent years.

2. Wayside noise

2.1 Shinkansen noise

Trackside noise from passing Shinkansen trains may be classified as the noise generated by lower parts of the car body (hereinafter referred to as “lower-body noise”) including the rolling noise, aerodynamic noise generated from the upper body part of cars, the pantograph noise and the bridge structure noise (Fig. 1). The results of a noise source analysis based on field test data from one of the most advanced Shinkansen trains running at a speed exceeding 300km/h, demonstrated that lower-body noise was most significant, followed by pantograph noise. These results also revealed that the contribution of aerodynamic noise to lower-body noise grew as running speed increases (Fig. 1) [1]. Consequently, to control the increase in trackside noise caused by the rising running speed of Shinkansen trains, efforts are being made to identify how aerodynamic noise is produced by bogies and pantographs. In order to clarify the generating mechanism of aerodynamic noise from the bogies, the flows beneath a running Shinkansen train were measured during field tests, and a method was developed to reproduce these flow fields in wind tunnel experiment conditions. The experimental method was validated by estimating aerodynamic noise from the bogies based on the results obtained through the experimental method, and then used to estimate lower-body noise by aggregating the contribution of rolling noise, estimated using an existing prediction model, and the contribution of noise from devices on the vehicle, obtained through field tests, to check whether estimated results coincided with actual measured values (Fig. 2)[2]. Development work now is focusing on the identification of the mechanisms causing aerodynamic noise from bogies, and on ways to mitigate these phenomena through the use of the developed experimental methods. Research into aerodynamic noise generated from the pantograph relates to various objectives, namely: the compatibility between reduction in aerodynamic noise and stabilization of aerodynamic lifting characteristics by improving the shape of the pantograph head support; mitigation of aerodynamic interference between the pantograph head and the articulated frame by improving the shape of the pantograph head support; application of porous materials to parts which are not easily reshaped, etc. (Fig. 3) [3]. In addition, basic research is also being conducted on new measures [4, 5, 6] using flow field control technologies, such as synthetic jet actuators, plasma actuators, etc. (Fig. 3). The aim is to find solutions for reducing noise by combining and improving these elemental technologies, which may then be applied to actual devices.

Fig. 1 A preliminary estimation of the contribution to overall noise of Shinkansen noise sources at a point 25m away from the track and 1.2 m above the ground (concrete viaduct, slab track, R.L.+2 m sound barrier, at a speed of 320 km/h)
2.2 Conventional railway noise

On conventional railways, noise generated by the main electrical motors and other devices on the vehicle has been reduced, wheel/rail noise such as rolling noise as a proportion of overall noise has increased. This is especially true for trains passing over discontinuous track parts such as rail joints, which produces impact noise, which is more significant than ordinary rolling noise. Consequently, research was focused on impact noise from rail joints, to identify its frequency characteristics and the relationship between its amplitude and the vehicle speed, vehicle weight, etc. This was done by measuring noise and rail vibrations on an in-service line, to investigate contributions of wheel noise, rail noise and sleeper noise to total impact noise, and the effects of noise abatement measures, etc. by building physical models [7]. Some case examples have been reported of a particularly high frequency noise of 10 kHz or more being generated by passing trains in some curved sections, adversely influencing overall noise along the railway line. As such, noise and rail vibrations were measured in some curved sections on a conventional line to investigate how this noise was generated. Results revealed that the major source of noise as trains went through the section was from the wheels on the outer side of the curved track (Fig. 4), and from the outer rail after the train had passed [8].

2.3 Noise propagation

In order to understand the propagation property of railway noise, a study was conducted to understand the influence of wayside structures, such as slopes along cut sections and bridges spanning railways, etc. on noise propagation. Insight into this influence was obtained from...
field tests and scale model tests, and a prediction model was proposed, so that this noise could be evaluated quantitatively. In the case of bridges built over railway lines, field tests were carried out to measure noise levels before and after bridge construction, confirming that the increase in noise was due to the presence of the bridge. These results correlated with the estimated results obtained through the prediction model (Fig. 5) [9]. A noise prediction method is now being developed which is more accurate than conventional ones and suitable for more complex wayside conditions, involving multiple factors.

3. Ground vibrations

Ground vibrations are generated as excitation forces acting between wheels and rails vibrate the track or structures and vibrations are then propagated from the structures to the ground. If a building is located near the track, the vibrations are propagated from the ground to the foundation of the building and eventually the entire building vibrates. In addition to conventional empirical methods, numerical simulation methods are being developed as tools for predicting vibrations occurring in the ground and buildings along railway lines and for studying measures to mitigate such vibrations. Due to computation size and computation speed limitations, etc. two methods were adopted and then combined: a coupled vibration analysis model of a running train, track and structures, and a 3-dimensional vibration analysis model of the structures, ground and wayside buildings (Fig. 6) [10]. Comparison of simulation results and actual measurement values, showed that they coincided with each other in terms of structures, ground and wayside buildings. However, there are still issues with the method for modeling the propagation characteristics of vibrations between structures including railway structures and buildings, and the ground, and the method for identifying appropriate ground property values, etc. Efforts are being made therefore to improve the accuracy of the analysis by tackling those issues and carrying out analyses for predicting ground vibrations and studying measures to prevent railway induced vibrations.

4. Micro-pressure waves

When a high-speed train enters a tunnel, a compression wave is generated and propagates through the tunnel at the speed of sound. At the moment it arrives at the tunnel exit, an impulsive pressure wave is emitted from the exit portal into the surrounding area. This phenomenon, known as micro-pressure waves, may cause environmental problems along a railway line such as an explosive sound, an abrupt rattling of window frames or shutters of houses near the tunnel portal, etc. In principle, basic measures against micro-pressure waves are taken at the formation stage of the compression wave, by means of a hood installed at a tunnel entrance, stretching or optimization of the nose shape of each train, etc. However, as plans are made to increase the running speed of Shinkansen train in the future, it may be necessary to take further measures at the compression wave propagation stage, inside the tunnel and the emission phase of the micro-pressure wave, from the tunnel exit. The Railway Technical Research Institution is therefore conducting research into mitigation measures and prediction and evaluation methods for each of these phases.

Fig. 6 Basic design for vibration simulation of structures, ground and buildings

Fig. 7 Micro-pressure wave reduction after introduction of ballast onto slab track in a tunnel (The magnitude of the micro-pressure wave is proportional to the maximum pressure gradient at the tunnel exit)
length, by properly selecting the hood cross section, side windows, etc. [13].

5. Conclusion

As running speeds for Shinkansen and conventional railway lines increase, there is a growing need for research and development on the wayside environment. The Railway Technical Research Institute shares the idea that wayside environment issues are important. As such, RTRI is now actively promoting research which will clarify phenomena, develop methods to predict and design measures to reduce aerodynamic noise, pressure variations in open sections, micro-pressure waves and ground vibrations. As part of this effort, ongoing support from other research entities, and cooperation is always highly appreciated.

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