Proceedings of the Seventh International Conference on
Railway Technology: Research, Development and Maintenance
Edited by: J. Pombo
Civil-Comp Conferences, Volume 15, Paper 19.2
Civil-Comp Press, Edinburgh, United Kingdom, 2026
ISSN: 2753-3239, doi: 10.4203/ccc.15.19.2

Development of Sound Barriers With Perovskite Solar Cells

N. Sugita[1], S. Taya[1], K. Yoshida[1], M. Nishii[2] and T. Hara[2]

[1]Technology Research and Development Department, Central Japan Railway Company, Japan
[2]Performance Material Technical Section, Sekisui Chemical Corporation, Japan

Abstract

This study develops and validates a method for integrating film-type perovskite solar cells into railway sound barriers along the Tokaidō Shinkansen. Leveraging the modules' thin, lightweight and flexible characteristics, a detachable guide-rail mounting system, which preserves the acoustic performance of the barrier, was developed while enabling independent replacement of the photovoltaic layer. Prototype units were designed, fabricated and installed at the Komaki Research Facility for demonstration tests in January 2025. Structural safety was verified by conducting vibration tests equivalent to thirty years of cumulative train passages and wind-pressure tests up to 40 m/s – exceeding the operational suspension threshold. The test results showed that the developed prototype units worked well as we expected, and also no fatigue damage, structural failure or detachment was observed.

Keywords: perovskite solar cell, sound barrier, carbon neutral, vibration resistance test, wind resistance test, demonstration experiment, prototype.

1 Introduction

Our company has long regarded global environmental conservation as a central pillar of its corporate management strategy. By systematically introducing energy-efficient rolling stock and related technologies, it has continuously enhanced the inherent environmental advantages of rail transport, which are high energy efficiency and relatively low environmental impact compared with other modes of transportation.

In alignment with Japan's national objective of achieving carbon neutrality by 2050, our company is intensifying its efforts to further reduce greenhouse-gas emissions. Guided by the government's '2050 Carbon Neutral' policy, the corporate group aims to achieve virtually zero CO_2 emissions by 2050. As an intermediate milestone, it targets a 46% reduction in CO_2 emissions by fiscal year 2030 relative to fiscal year 2013 [1] (Figure 1).

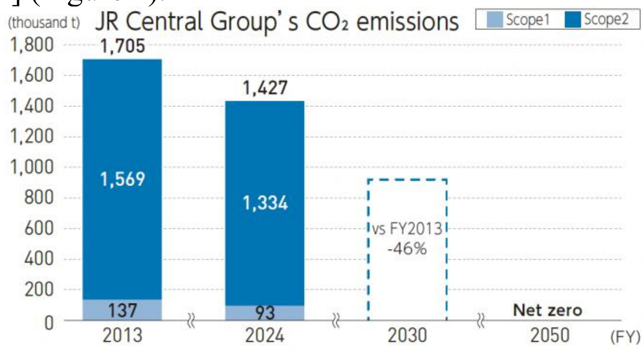

Figure 1: JR Central Group's CO_2 emissions.

In fiscal year 2024 our company emitted approximately 1.3 million tonnes of CO_2. Of this total, around 5% originated from direct emissions associated with the use of fuels, while the remaining 95% stemmed from indirect emissions associated with electricity consumption [1] (Figure 2). To mitigate direct emissions, our company has implemented environmentally conscious rolling stock solutions—most notably the HC85 hybrid series, which reduces fuel consumption relative to conventional diesel trains [1] (Figure 3). In parallel, development of hydrogen-powered rolling stock with associated supply infrastructure are underway, and research on battery-electric rolling stock and carbon-neutral fuels is progressing.

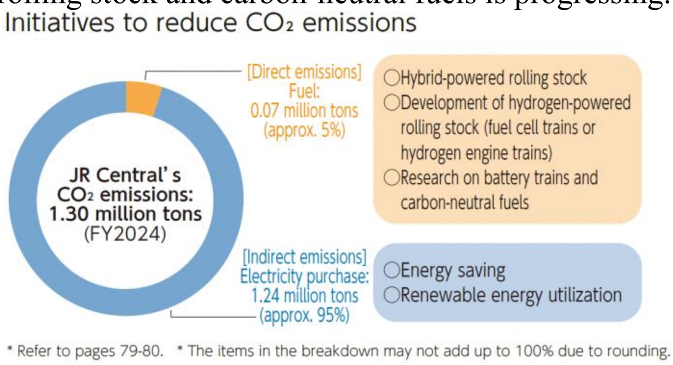

Figure 2: Initiatives to reduce CO_2 emissions.

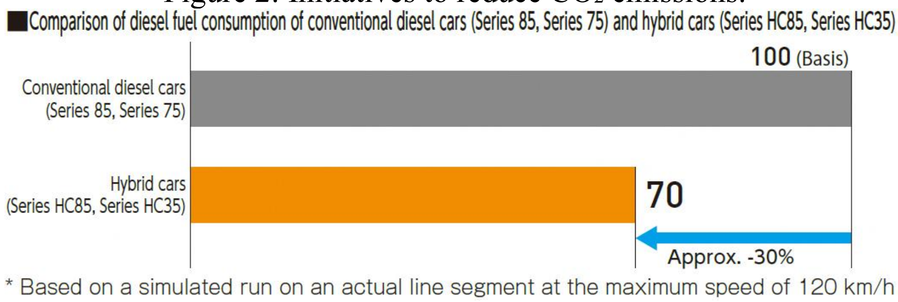

Figure3: Comparison of diesel fuel consumption of conventional diesel cars (Series 85, Series 75) and hybrid cars (Series HC85, Series HC35).

To address indirect emissions attributable to electricity consumption, our company is expanding the deployment of high-efficiency rolling stock, such as the N700S and the Series 315 [1] (Figures 4–6). These initiatives are complemented by the systematic replacement of frequency-conversion systems along the Tokaidō Shinkansen with models that exhibit reduced power losses. Simultaneously, a broader transition towards decarbonisation necessitates increased utilisation of renewable energy sources.

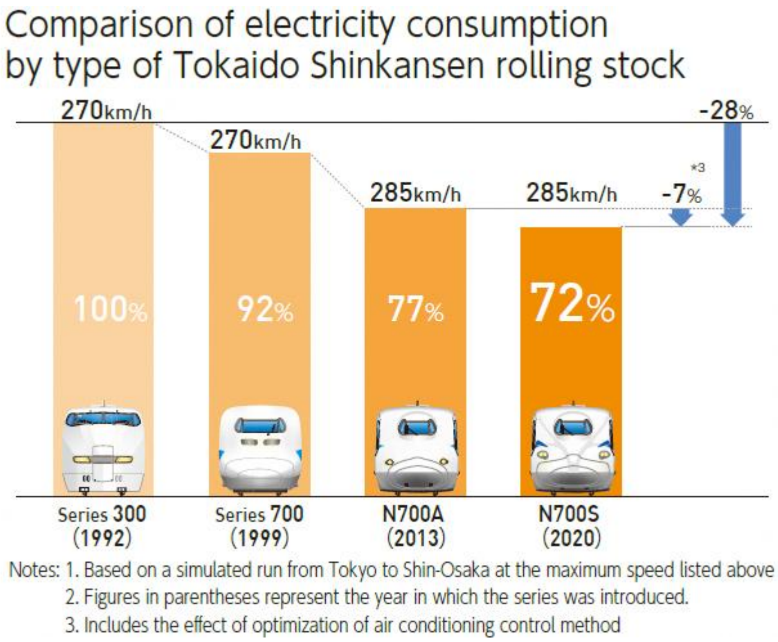

Figure 4: Comparison of electricity consumption by type of Tokaido Shinkansen rolling stock.

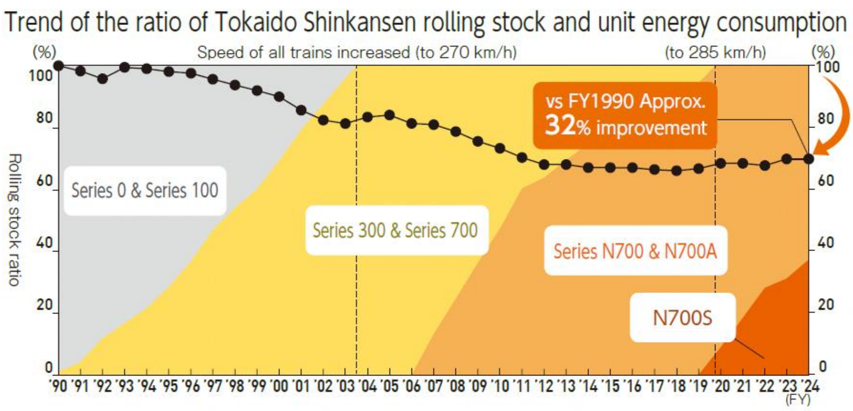

Figure 5: Trends of the ratio of Tokaido Shinkansen rolling stock and unit energy consumption.

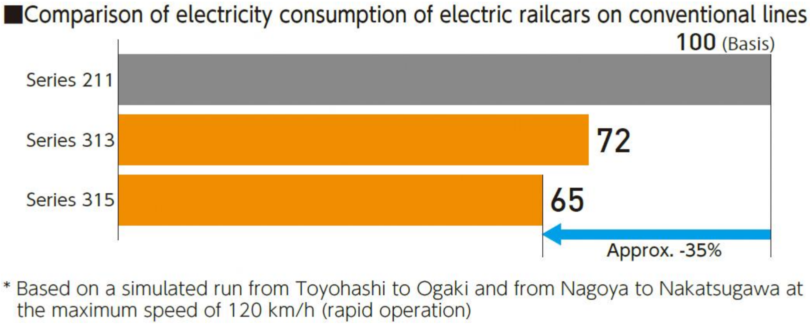

Figure 6: Comparison of electricity consumption of electric railcars on conventional lines.

With this background, we have initiated the development of sound barriers equipped with perovskite solar cells, thereby integrating renewable-energy generation into existing railway infrastructure and contributing to long-term CO_2-emission reductions.

2 Overview of Perovskite Solar Cells

2.1 What Are Perovskite Solar Cells?

Perovskite solar cells have emerged as a prominent next-generation photovoltaic technology owing to their thin, lightweight and mechanically flexible structures. These characteristics enable installation in locations unsuitable for conventional rigid modules and have prompted extensive research aimed at performance enhancement and practical deployment. The term ‘perovskite’ denotes materials that exhibit a crystal structure analogous to calcium titanate (Figure 7), with the perovskite compound serving as the photoactive layer in these devices.

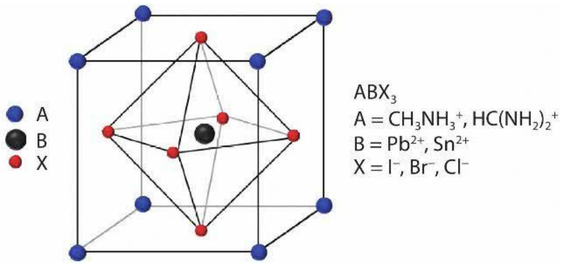

Figure 7: Crystal structure diagram for the perovskite material [2].

Perovskite solar cells can be broadly categorised according to the substrate: film-type, glass-type and tandem-type. Film-type and glass-type cells use polymer films and glass substrates, respectively, while tandem-type configurations stack multiple photovoltaic layers—for example, combining perovskite and silicon to improve power-conversion efficiency.

2.2 Characteristics of Film-Type Perovskite Solar Cells

The present development adopts the film-type configuration.

First, the modules are exceptionally light and flexible: relative to conventional silicon-based modules, perovskite film devices weigh roughly one-tenth as much and are approximately one-twentieth as thick. These attributes allow installation on vertical wall surfaces, roofs with limited load-bearing capacity and curved elements such as pillars002E

Second, a key constituent—iodine—benefits from robust domestic production, with Japan accounting for roughly 30% of global output, thereby supporting a stable supply chain less exposed to external dependencies.

Third, film-type perovskite solar cells can be manufactured for large-scale production via roll-to-roll processes, in which the base film is unwound, coated with functional layers, and rewound (Figure 8). Such high-throughput routes are advantageous for scalability and cost reduction as industrialisation progresses.

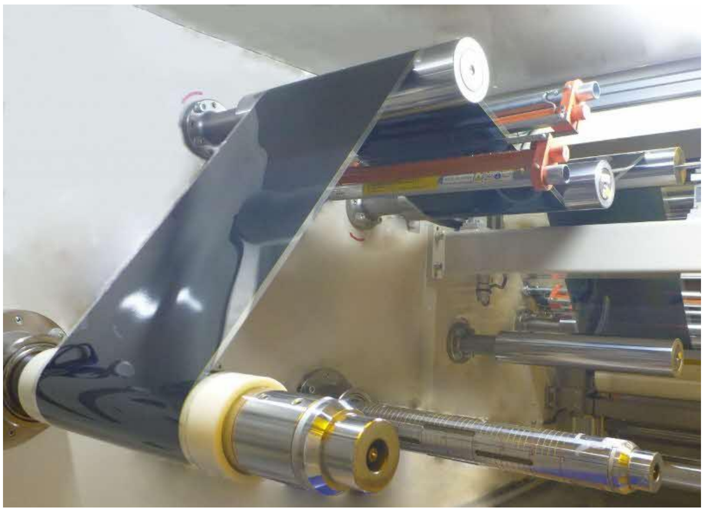

Figure 8: Roll-to-roll manufacturing process [3].

3 Implementation, Results, and Discussion

3.1 Application to Sound Barriers Along the Tokaidō Shinkansen

Motivated by two key considerations, we focused on sound barriers as targets for installation.

First, the available surface area is extensive: the Tokaidō Shinkansen spans approximately 500 km between Tokyo and Shin-Ōsaka (Figure 10), and its sound barriers extend for roughly 650 km across both inbound and outbound tracks, implying substantial potential photovoltaic area.

Second, many barriers face south due to the line's east–west alignment, affording favourable solar exposure. A directional survey subdivided into eight sectors indicates that about 300 km of outbound-track (toward Shin-Osaka) barriers face between south-east, south and south-west, corresponding to roughly 90% of that side's total barrier length (Figure 11).

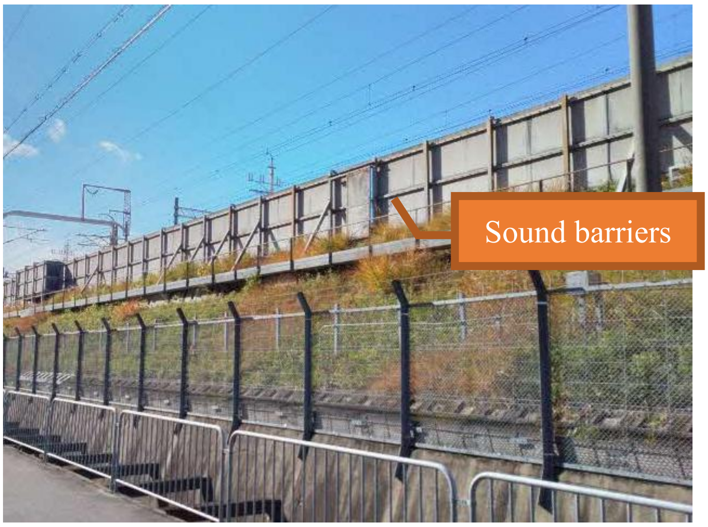

Figure 9: Sound barriers along the Tokaido Shinkansen.

Figure 10: Company service area and the Tokaido Shinkansen route.

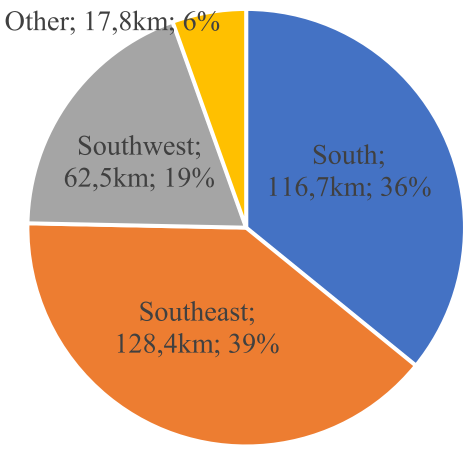

Figure 11: Ratio of sound barriers length by orientation (outbound-track).

3.2 Challenges for Practical Implementation

In order to implement the developed Perovskite Solar Cell units on sound the barriers in practice, we faced the following three challenges.

First, service lifetimes differ: sound barriers are expected to last ~30 years, whereas perovskite modules currently exhibit lifetimes of ~10–20 years. Consequently, the photovoltaic layer must be replaceable independently of the barrier structure to optimise life-cycle cost.

Second, the assembly must withstand vibration and wind pressure generated by passing trains, given the barriers' proximity to the track.

Third, the influence of vibrational loading and non-ideal orientation on generated energy must be evaluated, since barriers are not uniformly south-facing.

3.3 Design Concept for Sound Barriers with Perovskite Solar Cells

A detachable guide-rail mounting structure was developed. To preserve acoustic insulation and absorption, modules are mounted on the side opposite the track. Exploiting the film's thin, light and flexible characteristics, the module is inserted from below along the guide rail and clamped on all four sides (Figure 12), providing resistance to wind pressure and train-induced vibration. A representative panel size of 1 m (width) × 2 m (height) is assumed.

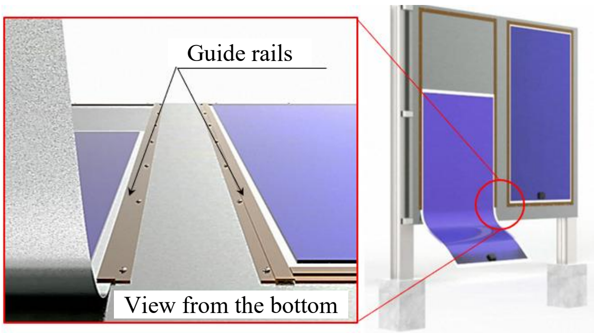

Figure 12: Mounting configuration of perovskite solar cells using guide rails.

3.4 Fabrication and Installation of Prototype Units

Prototype units were fabricated accordingly and installed at the Komaki Research Facility. Demonstration testing, including power-generation monitoring, commenced in January 2025 (Figure 13). To assess orientation effects highlighted in Section 3.2, units were installed facing south and east. The planned verification period exceeds two years.

Figure 13: Overview of the installed prototype at the Komaki Research Facility.

3.5 Pre-Deployment Testing for Operational Lines

Before considering installation along commercial lines, vibration-resistance and wind-pressure tests were conducted to verify structural robustness.

3.6 Vibration-Resistance Testing

Using a vibration testing system, loads equivalent to thirty years of cumulative train passages were applied. Additional tests simulated strong-wind-induced vibration over the same period. Specimen dimensions are shown in Figure 14, with evaluation criteria summarised in Table 1. The results confirmed that stresses in the guide-rail assembly under train-induced wind pressure remained below thresholds and that no damage occurred after the prescribed cycles.

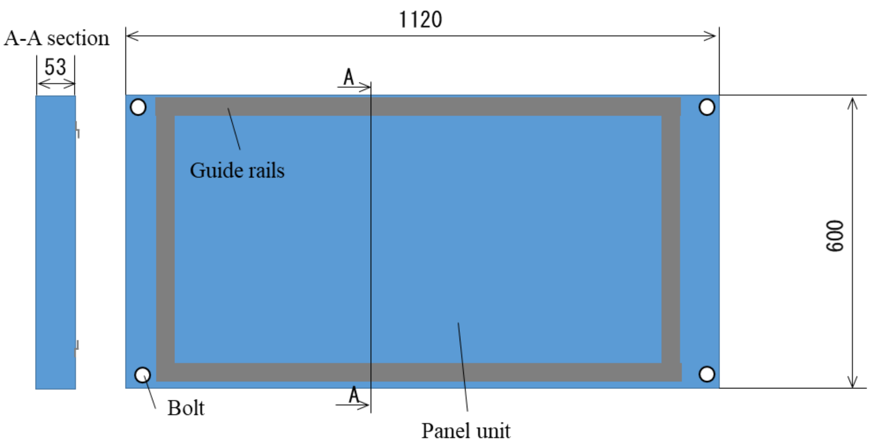

Figure 14: Dimensions of the vibration test specimen.

	Assumed train wind conditions	Assumed storm conditions
Static load test	Load ±1.49 kN/m²	Load ±3.0 kN/m²
	115 MPa or less	Allowable stress: 177 MPa or less
Cyclic load test	Load ±1.49 kN/m²	Load ±3.0 kN/m²
	No failure after 4.38 million cycles	No failure after 173,000 cycles

Table 1: Evaluation criteria and judgment standards for vibration testing.

3.7 Wind-Pressure Testing

Because the modules are not rigidly bonded to the barrier, ingress of strong wind into the module–barrier gap could pose a detachment risk. Wind-pressure tests applying up to 40 m/s—exceeding both train-induced wind and the 30 m/s suspension threshold—were conducted at 0°, 90° and oblique angles of 30°, 45° and 60° (Figure 15). No detachment or scattering was observed.

Figure 15: Wind-pressure testing setup for prototype sound-barrier units.

4 Conclusions

A practical method for integrating film-type perovskite solar cells into railway sound barriers was developed and validated. Prototype units were installed for long-term demonstration, and dedicated vibration-resistance and wind-pressure tests confirmed adequate durability and safety.

References

[1] Central Japan Railway Company, “Integrated Report 2025”, 2025.

[2] Melissa Davis, Zhibin Yu. A review of flexible halide perovskite solar cells towards scalable manufacturing and environmental sustainability[J]. Journal of Semiconductors, 2020, 41(4): 041603

[3] Sekisui Chemical Corporation