# ANNUAL REPORT 2023-2024

For the year ended March 31, 2024

Railway Technical Research Institute

# Contents

# Introduction

## Message from the President

**Ikuo WATANABE**
President of the Railway Technical Research Institute

I am pleased to announce that the RTRI Annual Report 2022 is now available. This annual report, first published in 2009 (the report on fiscal year 2008), outlines and introduces the organization and activities of the Railway Technical Research Institute (RTRI), its master plan, research and development efforts, and other activities while referring to visualized data on various fields. We have totally redesigned the layout for this fiscal 2022 issue to make it suitable for the integrated information source of RTRI and to provide high-quality information and faster and easier search experiences. It would be our great pleasure if you could take this opportunity to see our progress in fiscal 2022 and deepen your understanding of RTRI.

As many social and business activities were still restricted throughout the entire society due to the influence of COVID-19, tough times continued in fiscal 2022 for railway businesses. Meanwhile, it was also the year when we saw positive signs of recovery in transport demand, such as the inauguration of the West Kyushu Shinkansen and the resumed acceptance of inbound tourists.

Fiscal 2022 is the halfway point of our master plan, RESEARCH 2025, and the third year of our efforts to accumulate the fruits of our research and development. RTRI revised its organizational structure on April 1, 2022. This revision was intended to achieve research and development successes faster and more efficiently and to make our business operations more efficient. By taking advantage of the features of the new research divisions and new research structures and by increasing our research resources, we focused on improving safety, especially in enhancing resilience to natural disasters. We also concentrated on research and development for digital technology-based innovation in railway systems, one of the urgent issues for all railway operators. Moreover, we set up new research and development projects in a new field, decarbonization of railway transport, and focused on promoting the projects. As a result, a total of 273 research and development projects were implemented, and 114 of them were completed. For the heavy rainfall in August 2022, the researchers at RTRI set up a cross-disciplinary team, quickly conducted damage surveys, and provided technical support.

The Japanese railway, celebrating its 150th anniversary since its opening in 1872 between Shimbashi and Yokohama, has been contributing to society as the foundation of the state and a driving force of economic development. RTRI also has been dedicated to playing its part in society for 115 years while changing its name. Under the vision “-we will develop innovative technologies to enhance the rail mode so that railways can contribute to the creation of a happier society”, we will continue to create quality research outcomes by fully utilizing our capacity as an institute covering all the fields of railway technologies, to meet expectations by railway operators and customers. Continued support and advice from all the rail-related people will be greatly appreciated.

# Management Vision “RISING”

### Research Initiative and Strategy—Innovative, Neutral, and Global

## Vision

“We will develop innovative technologies to enhance the rail mode so that railways can contribute to the creation of a happier society.”

## Mission

We will accomplish the following three missions:

- To intensify research and development activities so as to improve railway safety, technology and operation, responding to customers’ needs and social change
- To develop professional expertise in all aspects of railways and, as an independent and impartial research body, to fulfill our tasks using the best science available in an ethical way
- To pioneer cutting-edge technologies for Japanese railways and become a world leader

# Strategies

We will accomplish the three missions using the Business Strategy and the Management Strategy.
Research Initiative and Strategy -Innovative, Neutral, Global-

## Business Strategy

**■ By pursuing excellence across all fields of activity and by conducting creative, innovative and high-quality research and development work:**

- Addressing challenges that demand innovation
- Promoting research in fields where RTRI has significant advantages
- Exploring research frontiers
- Advancing interdisciplinary research projects and fundamental research
- Disseminating research outcomes
- Promoting highly market-oriented research activity to diversify and stimulate research
- Exploring visions of future railways

**■ Acting as an independent and specialist organization, we will be conscientious and dependable, taking advantage of all available scientific knowledge:**

- Investigating accidents and disasters, and proposing preventative measures
- Enhancing technical support activities
- Focusing on preparing railway technical standards
- Communicating information around the world in a timely and effective way

**■ By accumulating knowledge and utilizing networks on a global scale, fostering technical progress which contributes to the development of railways around the world:**

- Enhancing our global presence
- Encouraging our researchers' full commitment to global activities
- Supporting overseas deployment of Japanese railway systems
- Engaging actively in international standardization activities

## Management Strategy

- Strengthening our administration to support the Business Strategy, aiming to fulfill our missions.
- Ensuring legal compliance
- Achieving a working environment in which all employees can be highly motivated
- Developing human resources with the resilience needed for global activities
- Further constructing, improving and updating test and research facilities
- Preparing and implementing a sound budget plan

# Master Plan “RESEARCH 2025”

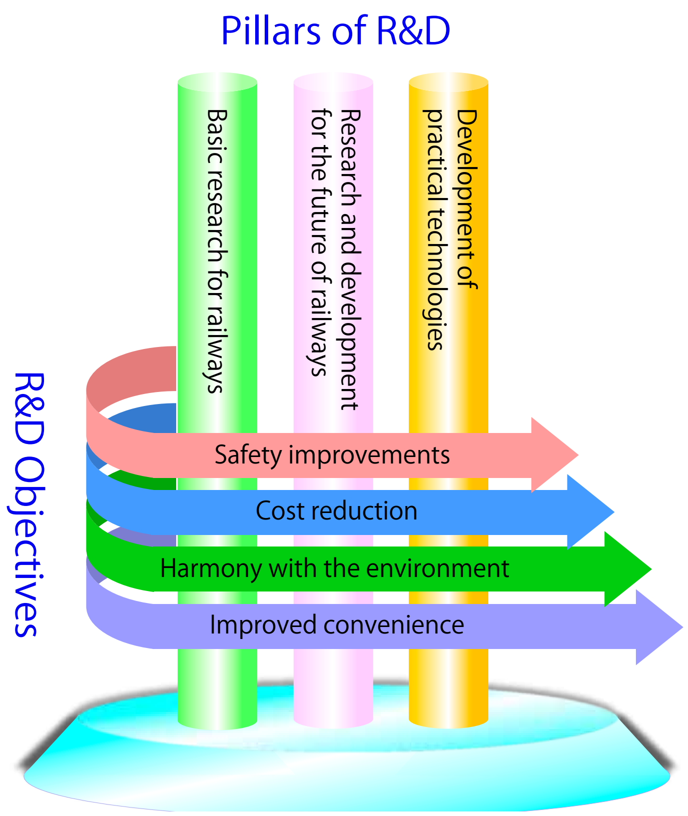
## - Research and Development for Creating the Future of Railways -

The Masterplan is a medium-term action plan embodying the strategy to implement the vision.

## Basic policies

- Enhancing safety with an emphasis on improving resilience to natural disasters
- Developing innovative railway systems based on digital technologies
- Creating high-quality results by taking advantage of our collective strength
- Enhancing international presence of the Japanese railway technologies
- Creating a motivating workplace where staff can demonstrate their abilities

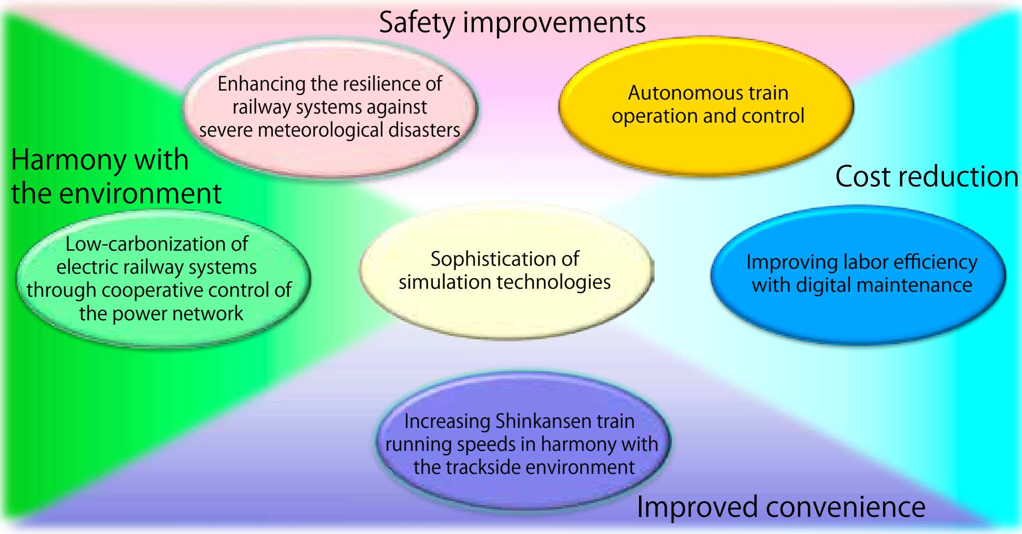
## R&D objectives



# Pillars of R&D

## Research and development for the future of railways

In fiscal 2020, aiming to achieve practical application within about 10 to 15 years, we start the following six major research themes.




## Development of practical technologies

In order to provide timely practical results, we are addressing topics with immediate relevance to the railway business.

## Basic research for railways

To provide solutions to railway-specific issues and to incubate innovative technologies, we will actively engage in basic research as follows; forecast of meteorological disasters, running safety and stability of rolling stock, improvement to trackside environment, deterioration mechanism and inspection methods, human factors in error prevention, friction and wear impacting the service life of facilities, and exploiting the potential of artificial intelligence.

# Major Results of Research and Development

## IMPROVEMENT OF SAFETY

### 1. Method for detecting huge earthquakes using multiple ocean bottom seismometer data

- We have developed a method for detecting huge earthquakes based on exceedances of thresholds by multiple ocean bottom seismometers, which is easy to integrate into earthquake early warning system for railways.
- By using attenuation relations and site amplification characteristics estimated from ocean bottom seismometer data, it is possible to set thresholds with high reliability for each seismometer.

We have developed a method to detect huge earthquakes that utilizes acceleration data observed by multiple ocean bottom seismometers. This method aims to issue warnings more quickly to a wide area on land when a huge earthquake occurs in the ocean (Figure 1). Conventionally, when the observed value of a single ocean bottom seismometer exceeds a specified threshold, an alarm is output to the land area near the ocean bottom seismometer, considering the promptness and robustness of the warnings. In the proposed method, we assume a huge earthquake (for example, M7.5 or greater) has occurred in the ocean and calculate the seismic ground motion at each ocean bottom seismometer near the hypothetical hypocenter. These values are then used as new thresholds for detecting huge earthquakes. When an earthquake actually occurs, if the observed values of the multiple seismometers exceed the thresholds, the system determines that it is likely to be a huge earthquake and issues an earthquake early warning to a wide area on land. The proposed method, which relies on exceedances of thresholds by multiple ocean bottom seismometers, not only ensures that huge earthquakes are not missed but also helps prevent unnecessary detections of minor to moderate earthquakes, making it a highly reliable method. Additionally, since the method relies only on comparing predefined thresholds with observed values, it has a low calculation load and can be easily integrated into the earthquake early warning system for railways.

In setting the thresholds, we estimated attenuation relations (the relationship between hypocentral distance and maximum amplitude) using data from ocean bottom seismometers, along with the site amplification characteristics at each ocean bottom seismometer's location. In addition to the attenuation relations based on land-based seismometer data that have been conventionally proposed, using these estimated results allows for setting more reliable thresholds for each seismometer individually, specifically for earthquakes occurring in the ocean (Figure 2).

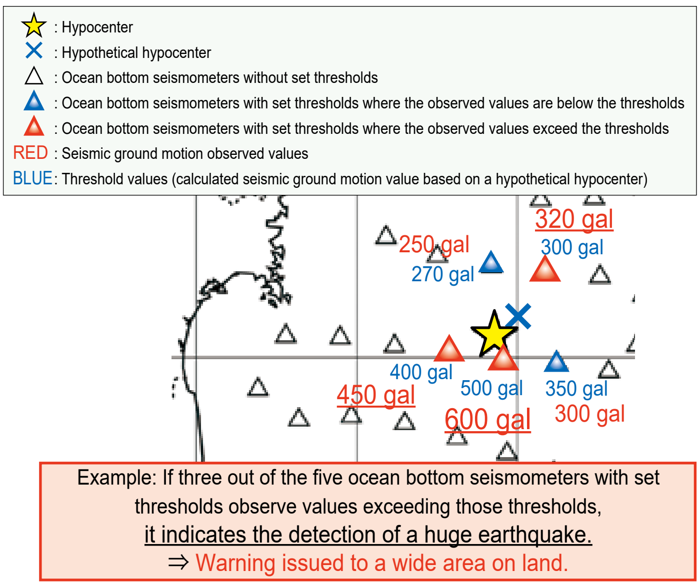



Figure 1 Conceptual diagram of the developed huge earthquake detection method

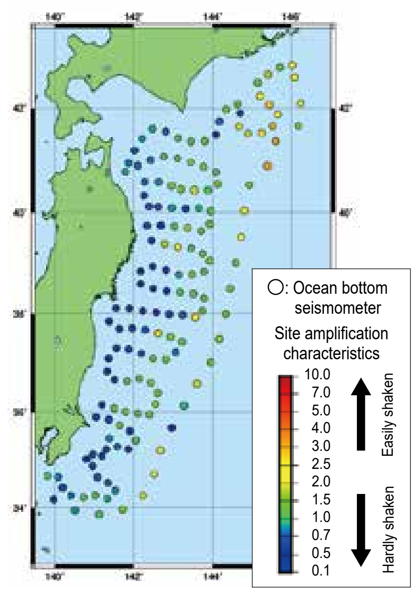



Figure 2 Site amplification characteristics estimated from ocean bottom seismometer data


## 2. A method for efficiently and precisely calculating site-specific design earthquake motions

- We developed a method that can calculate site-specific design earthquake motions within about a day.
- In addition to the existing parameter of earthquake motion amplitude, a new parameter of earthquake motion duration is taken into account to realize precise calculation of earthquake motion.
- It enables the design of railway structures according to the characteristics of earthquake motions at each construction site.

In the seismic design of railway structures, site-specific design earthquake motions must be calculated using the strong ground motion prediction method. In this method, calculations are performed by individually setting (1) the characteristics of the source, (2) the propagation characteristics from the hypocenter to the seismic bedrock directly beneath the construction site, and (3) the site characteristics representing the ground's shaking susceptibility (Figure 1). Calculating the design earthquake motion while considering each characteristic requires an enormous number of computations of approximately 1000 cases, which takes a significant amount of time and money (approximately several months). Therefore, in practice, standard design earthquake motions assumed to be applicable throughout Japan were often used, leading to the use of earthquake motions that could be significantly different from those that could actually occur at construction sites.

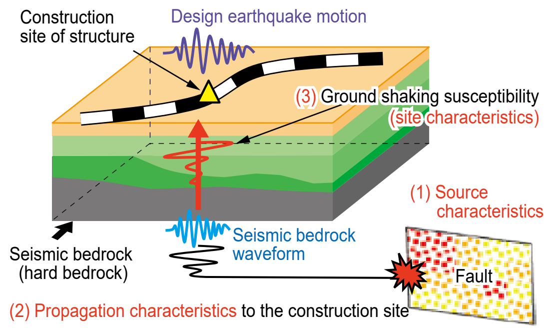



Figure 1 Image of strong ground motion prediction method

In response to this, we developed a method that can calculate site-specific design earthquake motions within about a day. The method involves selecting one seismic bedrock waveform corresponding to the assumed source from a database of ground motion waveforms at the seismic bedrock location, which were comprehensively calculated based on various assumed source characteristics and propagation characteristics, and using that waveform and the amplitude parameter from the site characteristics. We have now introduced a new calculation method that takes into account not only the amplitude parameter but also the duration parameter, making it possible to reproduce the characteristics of earthquake observation records more accurately than before (Figure 2).

Figure 3 shows the structural response (response spectrum) due to earthquake motion calculated at two locations based on the assumption of a magnitude 7.0 earthquake occurring directly beneath the locations. Using these results, the seismic design of railway structures appropriate for each construction site can be performed based on an appropriate understanding of the earthquake motions that may occur at the construction site.

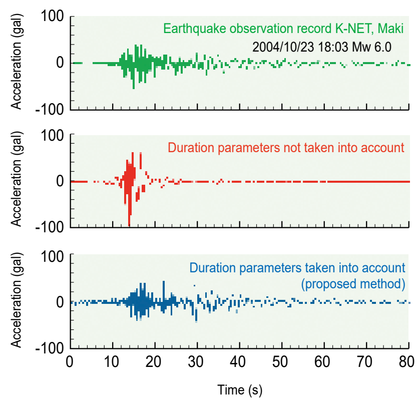



Figure 2 Example of earthquake motion calculation using the proposed method

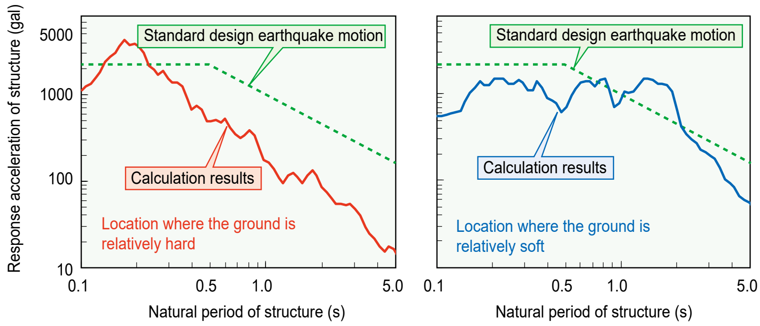



Figure 3 Elastic acceleration response spectrum of design earthquake motion using the proposed method

# 3. Running safety evaluation method for vehicle overturning caused by localized strong winds

- We have developed a running safety evaluation method for vehicle overturning caused by localized strong winds such as building winds.
- Numerical analysis that takes into account the shape and layout of the building enables accurate calculation of wind speed distribution in the wake of the building.
- It can be used to evaluate running safety in locations where localized strong winds are expected (e.g., around high-rise buildings, exits of tunnels, ends of windbreak fences, etc.) and to study effective countermeasures for crosswind.

It is known that localized strong winds, known as "building winds," can occur around high-rise buildings. However, safety assessment methods for trains running in the vicinity of such winds have not been established. Therefore, we proposed an evaluation method for running safety against vehicle overturning caused by localized strong winds.

First, wind tunnel tests (Figure 1) and numerical fluid analysis (Figure 2) using a numerical wind tunnel developed by the Railway Technical Research Institute were conducted for building winds caused by two neighboring buildings. As a result, we confirmed that the wind speed distribution (wind speed increase rate) of the wake generated by the two buildings can be accurately reproduced by the numerical analysis, and also clarified the magnitude and extent of the effect (Figure 3). Next, we developed a vehicle behavior analysis method that takes into account the conditions under which the aerodynamic forces estimated from the wind speed distribution obtained from the analysis act on the running vehicle. The results show that the wheel load decreases as the vehicle enters the strong wind area outside the building from the wind shielded area that occurs downwind of the building (Figure 4). As a result of a parameter study using this method, it was found that the wheel load decreases more easily when exposed to sudden strong winds. In particular, when the vehicle is running at high speed and the rise time of the aerodynamic force acting on the vehicle is shorter than about 2 seconds, the wheel load decrease ratio tends to increase.

This method can be used for evaluating running safety and considering effective countermeasures for crosswind (such as speed controls or the installation of windbreak fences) in areas where local strong winds are expected, such as around high-rise buildings, exits of tunnels, and ends of windbreak fences.

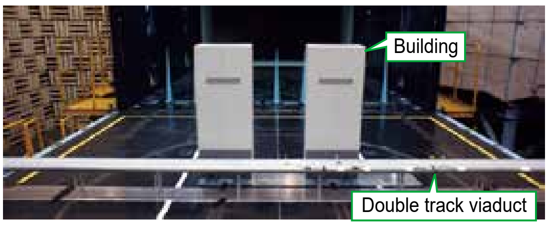



Figure 1 Wind tunnel test simulating building wind

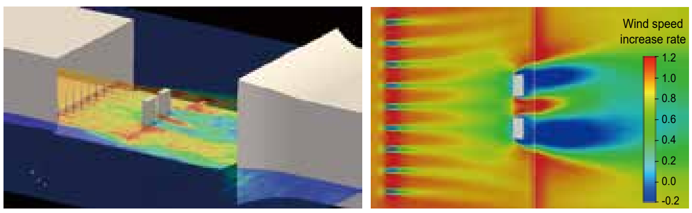



Figure 2 Numerical fluid analysis condition and analysis result

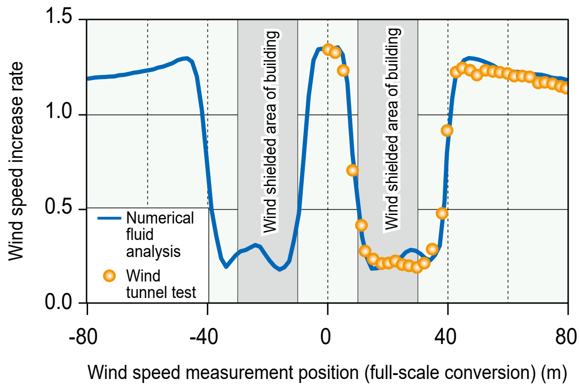



Figure 3 Example of evaluation result of wind speed increase rate

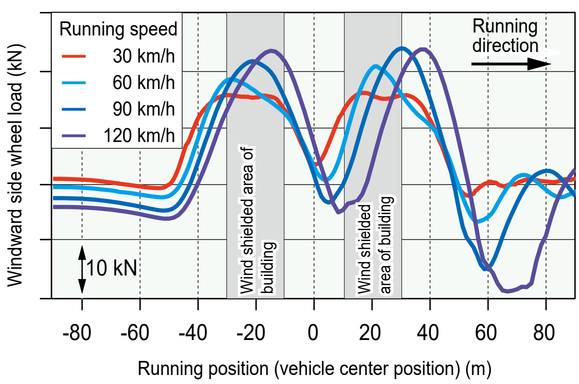



Figure 4 Example of wheel load variation based on vehicle behavior analysis

# 4. Manual for investigating the deterioration degree of the ground behind slope protection work

- We have developed a simple and low-cost test method to investigate the deterioration degree of the slope ground, which is important for the maintenance and management of the slope protection work, and have also prepared a manual for investigating the deterioration degree of the ground.
- The deterioration degree is evaluated by measuring the penetration resistance of the rod if the slope ground is mainly soil, or the drilling resistance of the electric drill if the slope ground is bedrock.

In the maintenance of aged slope protection work, it is important to easily and cost-effectively assess the deterioration degree of the ground behind the slope protection work (which cannot be visually inspected), and to perform repairs and other actions according to its condition. Therefore, we developed the “Free directional dynamic rod penetration test” (Figure 1), in which a rod is driven into the ground to estimate its strength, for cases where the slope ground is either sound or deteriorated. The testing equipment is compact and lightweight. The rod of the testing equipment is driven into the slope ground with a shockless hammer through a small-diameter hole in the slope protection work, and the penetration resistance values are determined from the number of strikes required to penetrate 10 cm of the rod to determine the distribution of loosening in the slope ground (Figure 2). By measuring the striking force, we introduced a function to correct test errors caused by variations in hammering, thereby improving measurement accuracy. Additionally, we developed the “SE-VP test” (Figure 3), which can be applied when the slope ground is bedrock. In this test method, an electric drill is used to drill through the bedrock from the side of the slope protection work, and the drilling resistance SE is measured from the power consumption per drilling depth, and the elastic wave velocity Vp of the ground is measured from accelerometers installed inside the borehole and on the ground surface. SE has a strong correlation with the compressive strength of the rock, and Vp has a strong correlation with the fracture state of the rock. The combination of both test values is used to assess the deterioration degree (Figure 4). These tests can be performed at 1/10 to 1/4 the cost of conventional boring investigations, allowing investigations to be conducted at many sites and improving the safety of the slope protection work. In addition, a manual for investigating the deterioration degree of the ground behind the slope protection work has been prepared. This includes points of focus for visual inspection and the test methods described above to ensure appropriate inspection according to the type of slope ground.

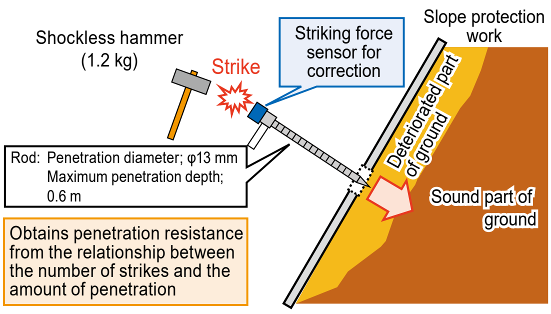



Figure 1 Outline of Free directional dynamic rod penetration test (for ground)

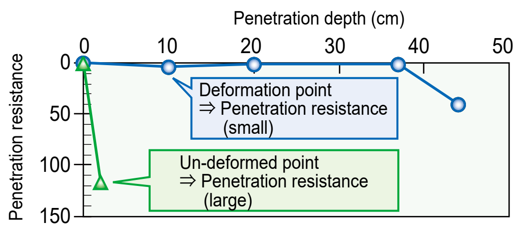



Figure 2 Example of penetration test measurement

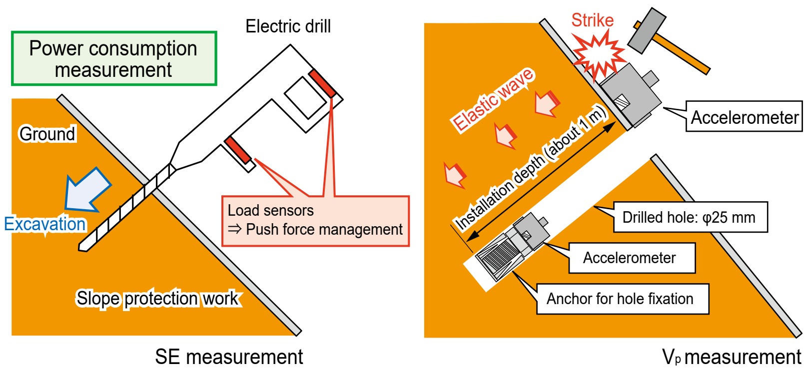



Figure 3 Outline of SE-VP test (for bedrock)

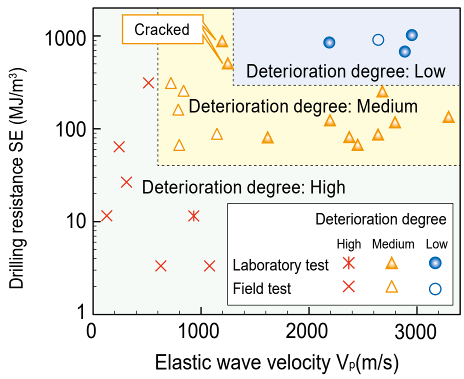



Figure 4 Guideline for determining the deterioration degree of the ground

# 5. Track irregularity estimation system based on looseness detection during for constructing a crossing structure under railway tracks

- We have developed a compact track irregularity estimation system that can make early detection of loosening of ground (which is a sign of track settlement), and estimate the amount of track settlement for constructing a crossing structure under railway tracks.
- Early detection of signs of track settlement and revision of the digging length will improve safety and reduce the cost of track maintenance.

To eliminate level crossings and to widen rivers, tunnel construction projects for roads and other purposes that cross under railway tracks are being carried out in various locations. When constructing such tunnels, square steel pipes are inserted ahead of the main tunnel body to excavate the interior and construct a temporary tunnel. If the loosening of the ground caused by the insertion of these square steel pipes is transmitted to the ground surface due to repeated train loads, it appears as track settlement after excavation. While such settlements are difficult to detect in advance, they affect train running safety and require urgent track maintenance when they occur.

In response to this, we developed a system to estimate the amount of track settlement by detecting ground loosening, which is a sign of potential track settlement. The system consists of a handheld ground survey device and software for calculating the amount of track settlement (Figure 1). In general, when the ground loosens, the elastic wave velocity traveling through the ground decreases. Therefore, the ground survey device measures the difference in arrival time of elastic waves before and after excavation to determine the rate of decrease in elastic wave velocity. The track settlement calculation software uses the relationship between the progress of ground loosening and the rate of decrease in the elastic wave velocity propagating through the ground to estimate the amount of track settlement according to the degree of ground loosening (Figure 2). Through construction tests using real steel pipes and measurements at an actual construction site, we have confirmed that this system can estimate the amount of track settlement on the safe side within a range of about 1 mm (Figure 3).

This system enables early detection of signs of track settlement and reviewing of the digging length to prevent track settlement and improve safety. In addition, cost savings can be expected by reducing the number of days required to secure track maintenance systems.

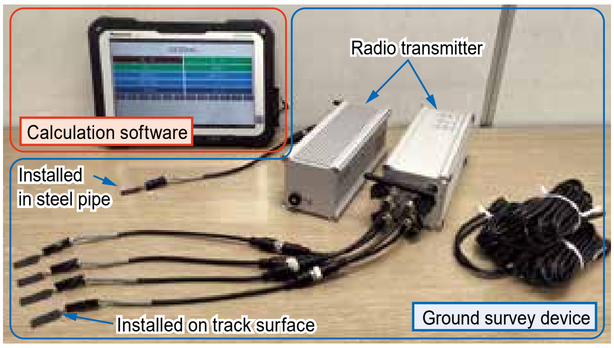



Figure 1 Developed track irregularity estimation system

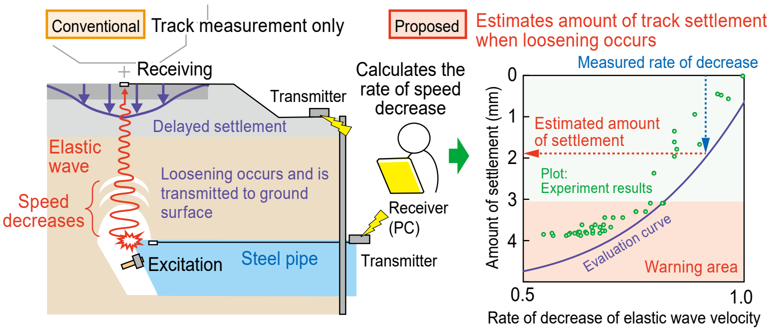



Figure 2 Proposed flow of settlement amount estimation

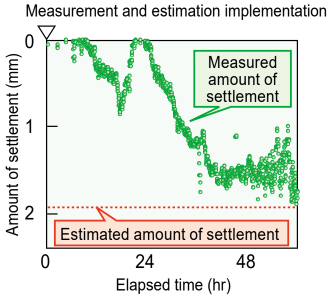



Figure 3 Estimation results at actual construction site

# 6. Measurement method of contact force and contact position between wheel and rail using shear strain

- We developed a method for measuring lateral force using an instrumented wheelset that utilizes shear strain, as well as a method for measuring the contact position between the wheel and rail based on this approach.
- Errors in derailment coefficients are reduced by up to 18%, enabling more accurate evaluation of running safety.
- The contact position can be measured with an error of about 5 mm.

In running tests for evaluating vehicle running safety, the force in the lateral direction (lateral force Q) and the force in the vertical direction (wheel load P) acting between the wheel and rail are measured using a special wheelset called an instrumented wheelset. In the current instrumented wheelset, which converts the bending strain occurring in the wheel plate into lateral force, there is a problem where the position of the wheel load affects the measured value of the lateral force, resulting in errors (Figure 1).

In this study, we developed a "shear strain-based lateral force measurement method" that is less affected by wheel load than the current method (Figure 2), and have proven that it can reduce the error in the derailment coefficient Q/P, which is used as an index for evaluating running safety, by up to 18% (Figure 3). This enables more accurate running safety evaluations at the same cost as the conventional method.

We also developed a method to measure the position at which the wheel contacts the rail from the strain output waveform of the instrumented wheelset, and found that the contact position can be measured with an error of about 5 mm within the range where the wheel does not contact the flange straight section (Figure 4). This method can be used for various technological developments related to wheel and rail contact (e.g., performance evaluation of new wheel profiles).

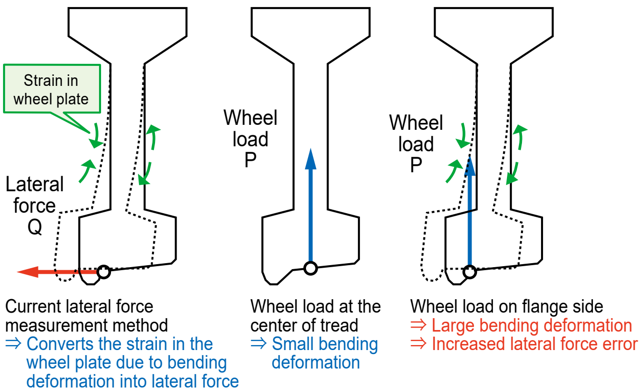



Figure 1 Mechanism of reduced measurement accuracy of lateral force due to the influence of wheel load

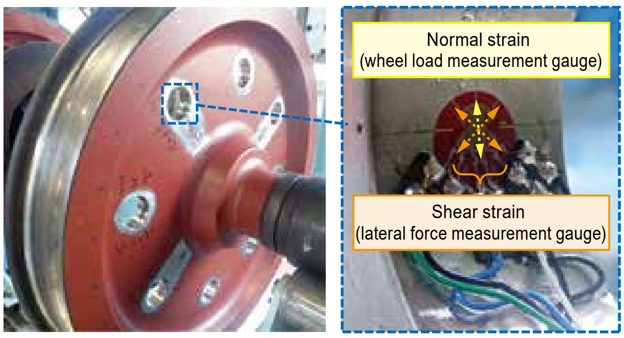



Figure 2 Lateral force measurement method utilizing shear strain

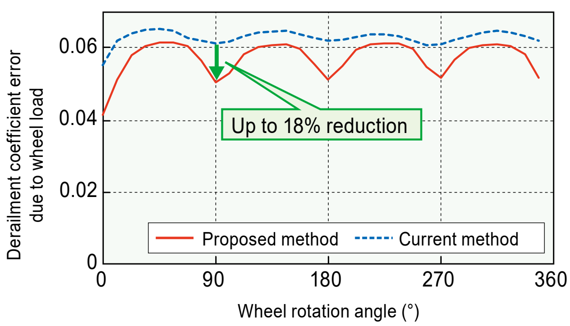



Figure 3 Effect of reducing derailment coefficient error

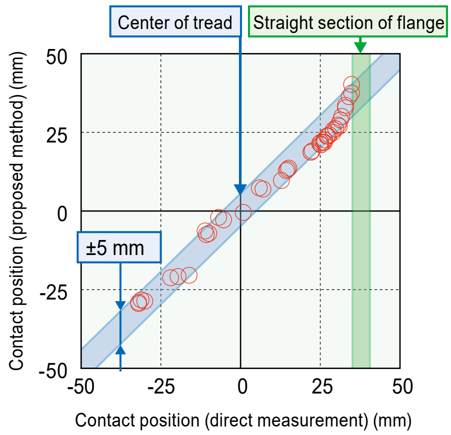



Figure 4 Result of verification experiment of contact position measurement

# 7. Automatic flaw extraction method for nondestructive inspection of bogie parts

- We developed a method to automatically extract flaws by applying machine learning to magnetic particle testing images and ultrasonic testing waveforms. The accuracy of flaw detection is approximately 70% for the surface flaw image of the welding and more than 95% for the internal flaw waveform of the welding.
- The constructed machine learning methods and models will facilitate the de-skilling of flaw detection tasks.

Nondestructive inspections such as magnetic particle testing and ultrasonic testing are used to inspect railway vehicle bogie parts. However, determining the presence of flaws from the images or waveforms obtained through these inspections requires experience. Therefore, we have developed a method to automatically extract flaws by machine learning.

In magnetic particle testing of welding surfaces, false indications due to unevenness on the welding surface appear in addition to flaws, so it is necessary to distinguish between the two. As shown in Figure 1, we developed a method that uses a machine learning model to extract areas suspected of having flaws within small, segmented areas. If multiple suspected areas are connected, the method determines them to be a "flaw." The performance of this method was verified using actual magnetic particle testing images, and it was confirmed that surface flaws in weldings could be detected with an accuracy of approximately 70%.

On the other hand, ultrasonic testing is used to inspect the inside of a welding. As shown in Figure 2, the reflected wave from the surface shape of the welding can be confused with the reflected wave from a flaw (flaw echo), so it is necessary to distinguish between the two. In response to this, we developed a model trained on waveforms obtained from simulations of ultrasonic testing of bogie frames using machine learning. We confirmed that this model can detect internal flaws in weldings with an accuracy of over 95%.

By applying the established machine learning method and model to the inspection of actual bogie parts, it is possible to make a uniform judgment on magnetic particle testing images and ultrasonic testing waveforms, from which determining whether a flaw exists or not can be difficult, and to reduce the skill requirements for the flaw detection process.

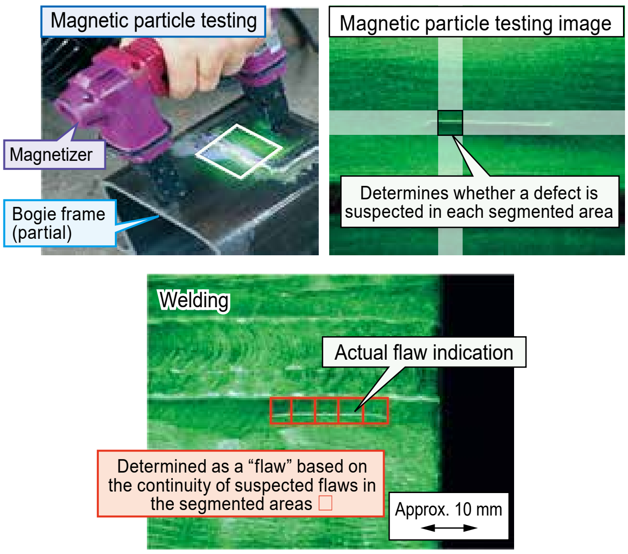



Figure 1 Application of machine learning to a magnetic particle testing image of a welding surface and an example of "flawed" judgment

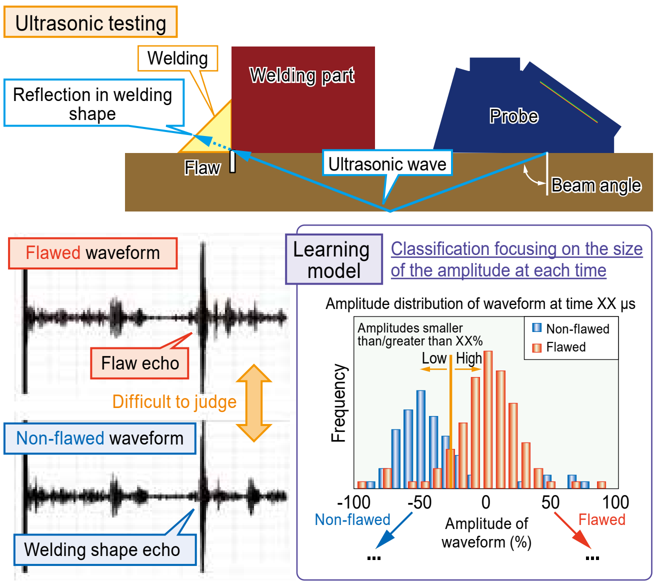



Figure 2 Application of machine learning to simulated waveforms of ultrasonic testing inside a welding

# 8. Light section method contact wire wear measurement system for 360 km/h operation

- We have developed a contact wire wear measurement system that enables measurement from a vehicle running at 360 km/h by means of coordinated control of cameras and laser light sources, and faster calculation of the residual diameter.
- Measurement tests on Shinkansen vehicles have shown that the measurement error of the residual diameter of the contact wire is within 0.3 mm. This measurement system aims to improve the reliability of contact wire wear management and reduce the risk of wire breakage.

Wear management of contact wires is important in the maintenance of overhead contact lines. Since the conventional inspection method, which converts the sliding surface width to the residual diameter, had the issue of large errors in locations with uneven wear, we proposed a contact wire wear measurement method using the light section method in 2019. However, to implement this method on a high-speed train, it was necessary to expand the measurement range and achieve realistic data analysis times.

To solve this problem, we devised a method that synchronizes the capture timings of multiple cameras with the alternating lighting timings of multiple laser light sources. This allows for the measurement of the entire installation range of Shinkansen contact wires while maintaining measurement accuracy (Figure 1). In addition, we developed an algorithm (Figure 2) to select a profile suitable for wear measurement from among several candidate contact wire profiles acquired. Furthermore, we sped up the calculation process of the residual diameter by implementing parallel computation. These improvements made it possible to analyze measurement data for one day of driving within 24 hours. These have led to the development of a light section method contact wire wear measurement system capable of measuring contact wire wear at 50 mm intervals from a vehicle running at 360 km/h.

The results of measurement tests on Shinkansen vehicles (Figure 3) have shown that the error compared to manual measurement at approximately 80 locations, including uneven wear, is generally within 0.3 mm both day and night (Figure 4), confirming that the accuracy is sufficient for practical use. This measurement system is expected to improve the reliability of contact wire wear management and reduce the risk of wire breakage.

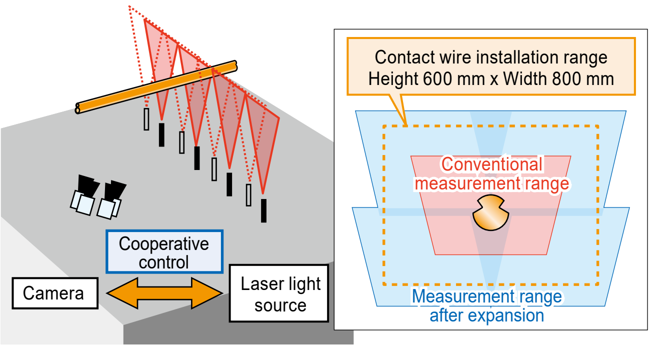



Figure 1  Coordinated control of cameras and laser light sources

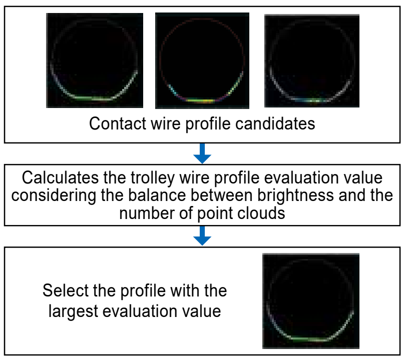



Figure 2  Contact wire profile selection algorithm

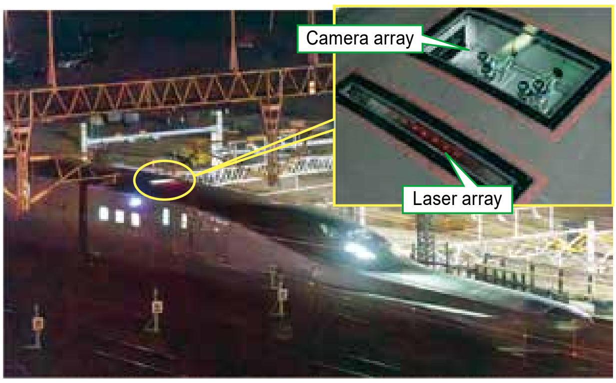



Figure 3  Measurement on an actual vehicle

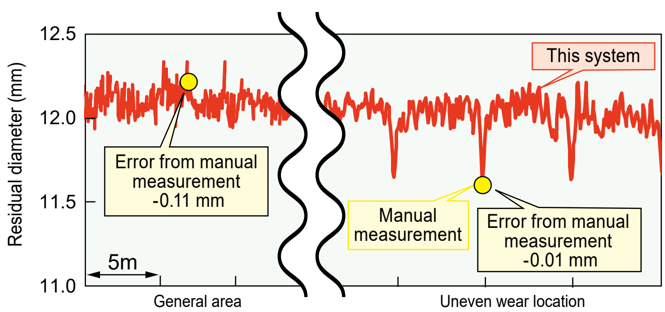



Figure 4  Example of measurement on an actual vehicle

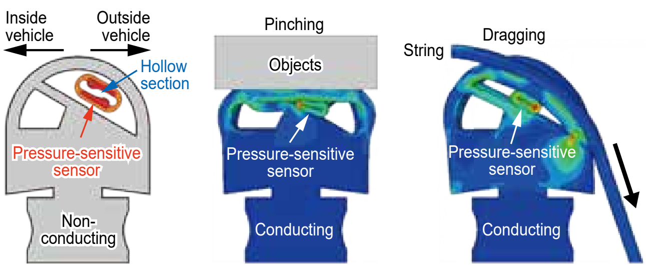
# 9. Door pinch detection system that combines a door end rubber with a built-in pressure-sensitive sensor

- We have developed a door pinch detection system that combines a door end rubber with a built-in pressure-sensitive sensor and a non-contact power supply device to enable simple transmission of detection information to the driver’s seat.
- The door end rubber with a built-in pressure-sensitive sensor can detect dragging due to pinching of intermediate objects or strings, which have been difficult to detect with conventional systems.

We have developed a door pinch detection system that combines a door end rubber with a built-in pressure-sensitive sensor and a non-contact power supply device. This system can transmit detection information between the frequently moving side sliding door and the carbody without connecting by cable.

The pressure-sensitive sensor built into the door end rubber changes from non-conductive to conductive when it detects pinching or dragging (Figure 1). The non-contact power supply device also supplies power from the master unit to the slave unit without contact. Therefore, pinching or dragging can be determined by the presence or absence of power supply from the non-contact power supply device (Figure 2). The shape of the door end rubber with a built-in pressure-sensitive sensor is asymmetrical between the interior and exterior. This design maintains high sensitivity for detecting pinching while making it easier to detect dragging outside the vehicle (Figure 1). Since this pressure-sensitive sensor can detect deformations caused by loads of 10 N or more, it can detect pinching of intermediate objects with diameters of 10 mm or less and the dragging of thin strings, such as cell phone straps, which have been difficult to detect with conventional systems (Figure 3).

The system was tested 1 million times, which is equivalent to more than 10 years of operation in an actual vehicle, with no system malfunctions or false detection. Additionally, after installing this system on an actual vehicle for about a year, it was found that although detection occurred due to contact with the door end rubber in situations with a low risk of dragging and other incidents, there were no instances of missed detection or false alarms.




*When the hollow section of the pressure-sensitive sensor collapses, it is conducted and detected

Figure 1 Door end rubber with a built-in pressure-sensitive sensor

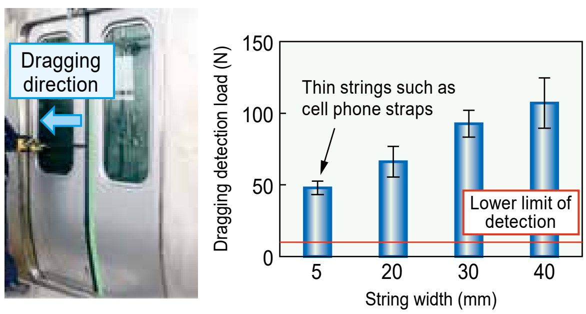



Figure 3 Dragging detection sensitivity

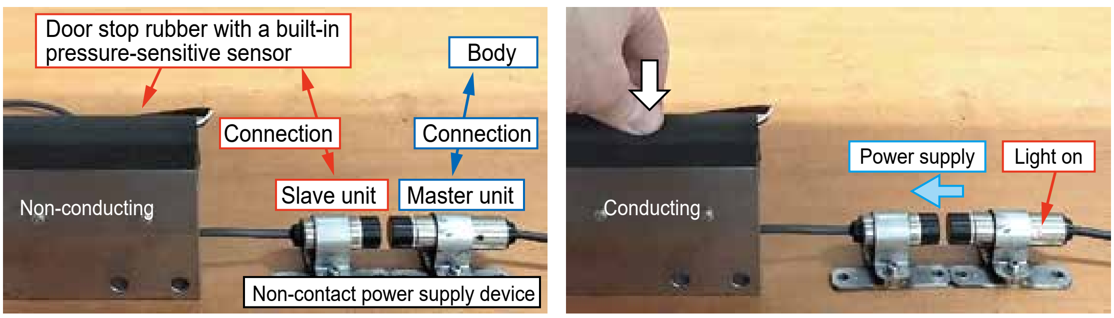



Figure 2 Detection system combined with a non-contact power supply device

# 10. Evaluation method for conductors' safety check skills using VR technology

- We developed a method to quantify conductors' eye movement during platform safety checks using VR technology and to evaluate the differences in eye movements between instructing conductors and trainees.
- Using the results of this study, it is possible to evaluate whether the eye movement of conductors is closer to that of an instructing conductor or a trainee. This allows us to compare the effectiveness of training programs and will contribute to a more effective teaching.

In conductor training, it is important to develop the skills to visually check for safety on the platform. However, there is currently no way to quantitatively determine where the trainees are looking when checking for platform safety, or how their line of sight differs from that of the instructing conductor. Therefore, training sessions provide guidance based on the inferred line of sight from the trainee's actions and behavior, as well as trainee reports of observed locations.

In response, this study attempted to quantitatively capture eye movement using VR technology. Specifically, we created several scenarios using 360° live-action video for platform safety checks, including a normal scenario with no hazardous events and a hazardous event scenario with incidents such as passengers rushing onto the train. Based on the experiences of 66 instructing conductors and 140 trainees, we statistically identified eye movements that showed differences. For example, in the normal scenario, there was a significant difference between the two groups in the eye fixation time looking at the front area from the conductor's position to the front of the train, specifically the area between the Braille block and the vehicle (Figure 1 (1)). In the hazardous event scenario, the time it took for the instructing conductor to notice the area where the passenger was moving just before the rushing onto the train was shorter (Figure 1 (2), left). We also developed a score from the instructor's characteristic eye movements that allows us to assess whether someone's eye movement is closer to that of an instructor or a trainee (Figure 1 (2), right).

The results of these eye movement assessments can be understood in advance by the instructors to enable efficient instruction. The comparison of quantified eye movements can also be used to check the effectiveness of various training programs. Each scenario can be completed in approximately three minutes, helping to improve practical training programs for conductor safety checks and enhancing the effective teaching.

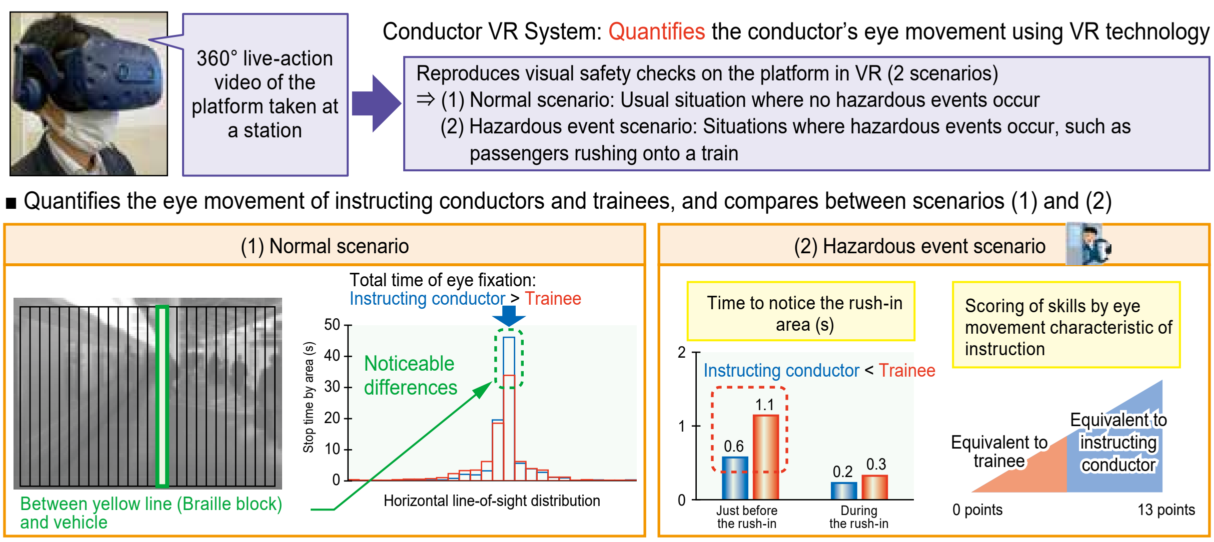



Figure 1 Outline of the conductor VR system and quantification of eye movement

# 11. Emergency diagnosis method for scour damaged bridges

- We have proposed methods for estimating the exposure rate and the bearing capacity of the base of the foundation using an impact and vibration test to evaluate the stability of piers damaged by scour in a short period of time.
- Based on the estimated bearing capacity, the need for loading tests and reinforcement can be determined immediately, potentially reducing the restoration time by up to half.

The stability of river bridge piers is significantly reduced due to a decrease in the bearing capacity of the foundation as a result of reduced penetration from scouring and the base becoming exposed. Impact and vibration tests conducted after water runoff can be used to estimate the extent of penetration reduction based on changes in natural frequencies of the structure, but it is difficult to estimate the exposure rate of the base of the foundation. Additionally, there is no established method for estimating the bearing capacity after scouring, and the stability of the piers is currently evaluated directly by loading tests conducted in the field to resume train operations. As a result, it may take several months to resume operations, even if the deformations are minor (Figure 1).

Therefore, we proposed a method to estimate the base exposure rate by determining the rotation center of the foundation based on the amplitude ratio of vertical responses measured at the upstream and downstream sides of the pier crowns during the impact and vibration test. We verified the validity of this method through model experiments (Figure 2). We have also proposed a bearing capacity calculation method that takes into account the effects of the reduction of penetration depth, the reduction of base area from increased exposure rate and eccentricity, which are causes of bearing capacity reduction due to scour, and confirmed its validity by applying it to actual damaged piers (Figure 3).

By estimating the bearing capacity based on the estimated exposure rate, we proposed an emergency diagnosis method to evaluate the stability of piers subjected to scour and, if a certain level of stability is maintained, to shorten the time required to resume operation. The proposed method eliminates the need for on-site loading tests when the foundation base is exposed but still retains a certain level of bearing capacity. Additionally, if the bearing capacity is found to be insufficient, this method allows for a quick determination of an appropriate restoration approach. With this approach, the time required to resume operation is expected to be shortened by up to half.

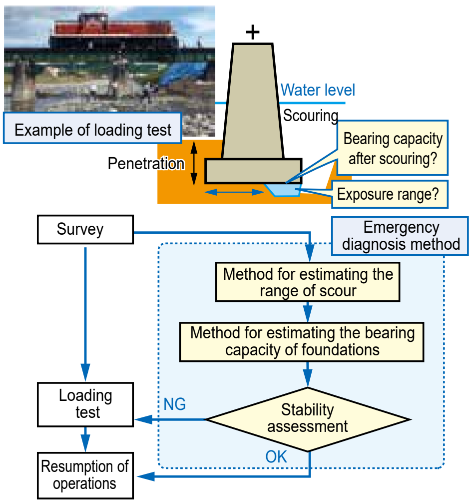



Figure 1  Emergency diagnosis method for scour damaged piers

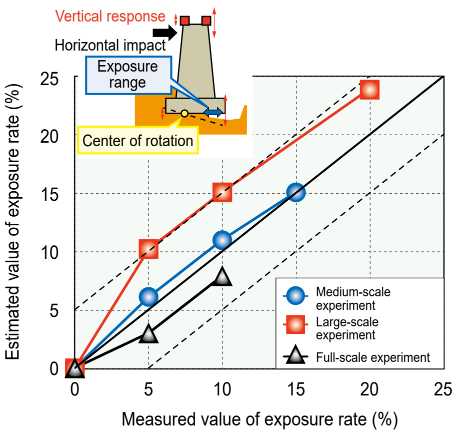



Figure 2  Validation of the exposure rate estimation method

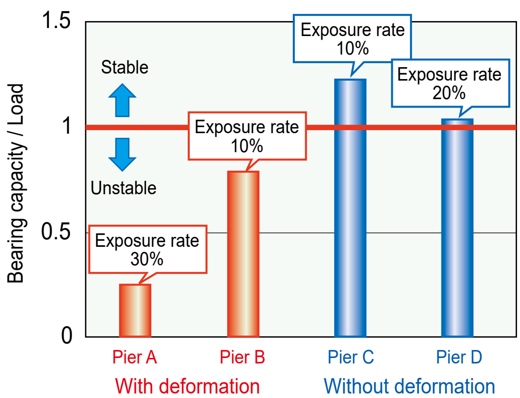



Figure 3  Evaluation results of piers subjected to scour

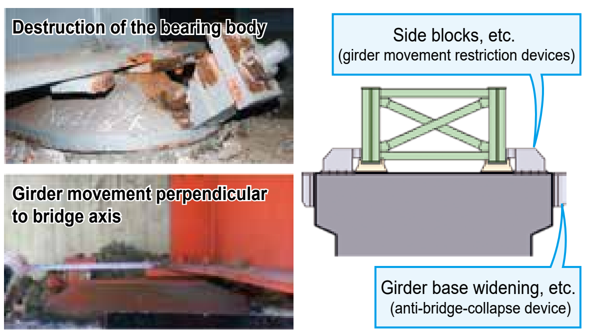
# 12. Low-cost girder movement restriction device provides improved restorability for existing steel railway bridges

- We have developed a girder movement restriction device that uses bolted joints to control girder movement during large-scale earthquakes. This prevents sliding down from bearing caused by the movement and improves restorability.
- This device can serve as an anti-bridge-collapse device during large-scale earthquakes at the same cost as conventional girder movement restriction devices.

In past large earthquakes, the existing bearings of steel bridges failed, causing the girders to move significantly in the direction perpendicular to the bridge axis. As a countermeasure, girder movement restriction devices (such as side blocks) and anti-bridge-collapse devices (such as widening the girder seats) have been implemented (Figure 1). However, while this method helps prevent bridges from collapsing, it has a drawback: during a large-scale earthquake, the girder movement restriction device can break, leading to increased movement. This can cause the girder to slide down from its bearings and make post-earthquake restoration more difficult.

We have developed a device that can absorb the energy of earthquake motion by means of high tensile bolt friction grip connection couplings added to a conventional girder movement restriction device, thereby restraining girder movement and preventing sliding down from the bearings (Table 1). As shown in Figure 2, the couplings of this device have slit-shaped bolt holes to allow greater slippage than conventional couplings, increasing the absorbed energy.

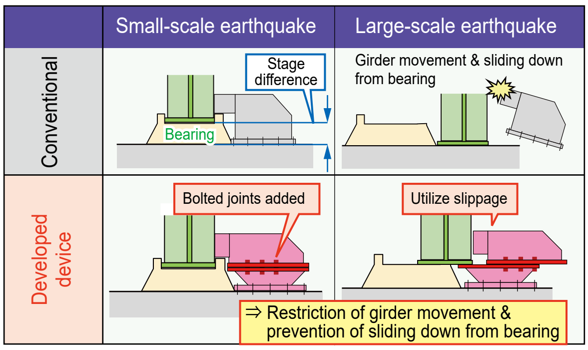
This device can reduce the amount of girder movement during a large-scale earthquake to about 1/3 of that of a conventional girder movement restriction device while maintaining the same cost, and also allows anti-bridge-collapse devices to be omitted (Figure 3). The design methods are also available and can be applied to bridges of various specifications.




(a) Example of damage (b) Example of seismic reinforcement

Figure 1 Examples of bearing damage and seismic reinforcement

Table 1 Concept of the developed device



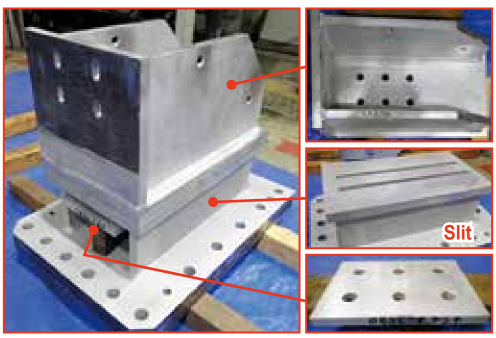
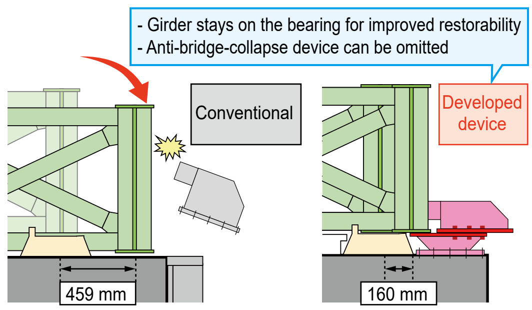




Figure 2 Structure of the developed device




*Maximum response displacement during a large-scale earthquake (L2 earthquake)

Figure 3 Effectiveness verification through dynamic analysis

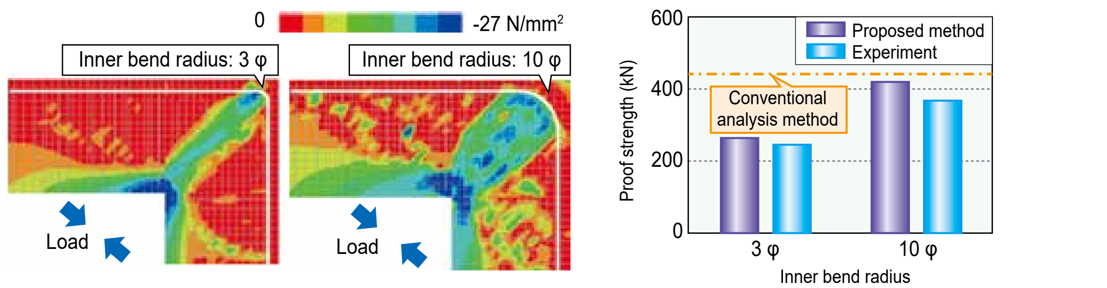
# 13. Rebars arrangement method for joints of RC viaducts with considering the labor saving in construction

- The nonlinear FEM was developed for examining the structural details of column-beam joints in RC viaducts, and clarified that the required proof strength was obtained even the spacing between re-bars in joints being doubled.
- The proposed analysis can reduce the amount of rebar, which are difficult to construct the joints of viaduct, and achieve labor savings in rebar assembly and concrete casting.

In reinforced concrete (RC) rigid-frame elevated bridges, the column-beam joints are designed to include not only the rebar for the columns and beams but also tie and haunch rebars in the joints, as specified in the structural details of the design standards for railway structures. The structural detail requires significant labor for rebar assembly during construction and poses challenges in ensuring quality during concrete casting. Improvement was required due to the decrease in the number of skilled engineers, but the complicated arrangement of rebar made it difficult to study improvement methods using conventional analysis methods.

In response, we developed a nonlinear finite element method (FEM) model that precisely simulates the shape of the rebar and concrete bond. This allows for the evaluation of rebar configurations within the joint based on structural details. Using this method, it is possible to express the stress distribution according to structural details such as the bending shape of the rebar in the joint (Figure 1(a)) and to calculate the proof strength of the joint (Figures 1(b) and 2), as confirmed by model experiments. In addition, we found that the required proof strength can be secured even if the spacing of ties or haunch rebars in a typical viaduct joint is increased to about twice the conventional spacing.

The results of these studies are reflected in the guide for bar arrangement, which not only reduces the amount of rebar in the joint, but also saves labor and ensures quality in construction (Figure 3). The proposed nonlinear FEM can be widely used to solve various problems related to structural details of rebars, such as performance evaluation of joints in existing viaducts.




(a) Minimum principal stress distribution (b) Analytical and experimental values of proof strength

Figure 1 Evaluation of joint proof strength considering rebar bending shapes using nonlinear FEM

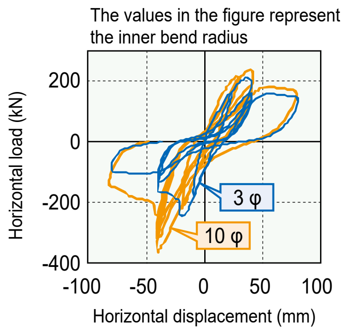
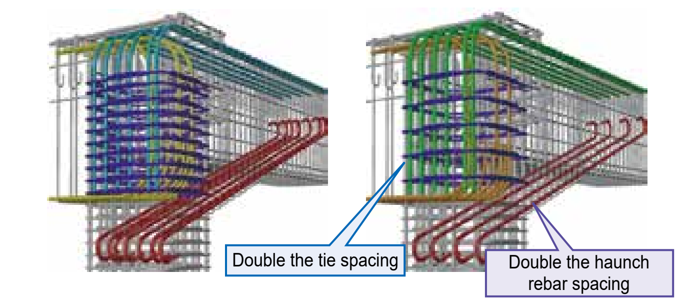



Figure 2 Results of the model experiments on the joint




(a) Conventional rebar arrangement (b) Proposed rebar arrangement

Figure 3 Rebar arrangement plan for joints using nonlinear FEM

# 14. Back-side construction method for reinforced soil retaining walls applicable to narrow areas

- We have proposed a method of constructing reinforced soil retaining walls that can be applied to narrow areas and does not require scaffolding.
- Lightweight buried formwork and settlement-allowing members are combined and installed from the back side of the wall (embankment side).
- This method allows for daytime construction even in areas close to commercial lines, eliminating the need for nighttime work that requires railway track closing. As a result, the construction period can be reduced by 30% and the construction costs by 15%.

Reinforced soil retaining walls (RRR method) are generally constructed in two stages: the reinforced embankment is built (STEP 1 in Figure 1), and the wall is built after settlement has converged (STEP 2 in Figure 1). In STEP 2, the construction of the wall requires scaffolding in front of the wall, making it difficult to construct the wall in narrow areas. In particular, construction work in close proximity to the commercial lines was carried out at night during railway track closing, resulting in prolonged construction and high costs (Figure 1).

In response, we proposed a back-side construction method where formwork is installed simultaneously with the reinforced embankment from the back side of the wall (embankment side), allowing construction without interfering with the front of the wall. The formwork for the wall, which was conventionally installed after the reinforced embankment was constructed, is placed from the back side of the wall (embankment side) using lightweight buried formwork that does not require form removal (Figure 2(a)). On the other hand, when the reinforced embankment and buried formwork are installed simultaneously, the buried formwork is supported by L-shaped steel and anchor materials from the embankment side, which causes deformation as the reinforced embankment settles. In response, we developed a settlement-allowing member that can slide vertically along L-shaped steel. By attaching this settlement-allowing member to the anchor material, it can accommodate the settlement of the embankment (Figure 2(b)). The proposed method can reduce construction time by 30% and construction cost by 15% for the construction of narrow areas close to commercial lines.

For these methods, we have prepared manuals for design and construction, cost estimation, and materials, which are applicable to actual construction projects.

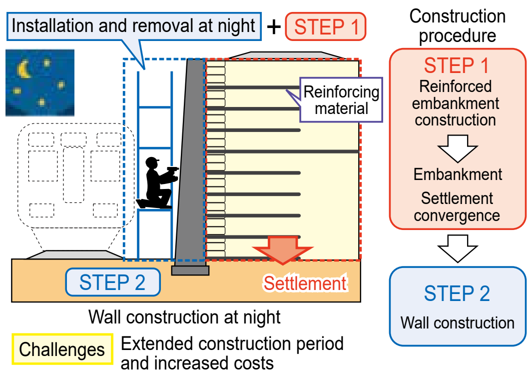



Figure 1 Challenges when constructing in narrow areas

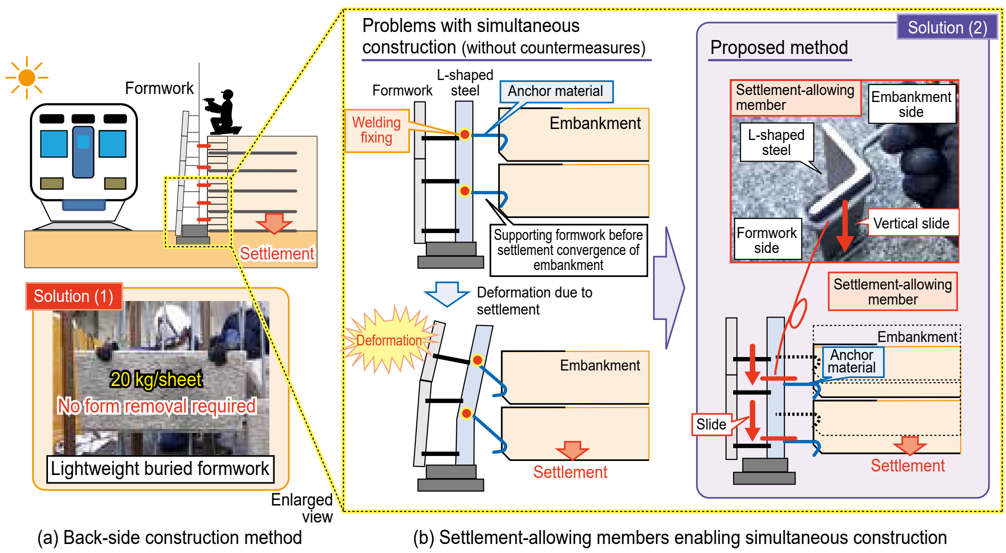



Figure 2 Proposal for wall construction method from the back

# 15. Cylindrical roller bearings with ribs for conventional line electric railcar gear unit and its performance evaluation

- We have developed a pinion support structure for conventional line electric railcars that uses cylindrical roller bearings with ribs. This design allows for an increase in the upper limit of the end play value, which is the total axial clearance of the bearings.
- This approach reduces the need for end play adjustments that involve disassembling the gear unit, thereby allowing for labor saving during maintenance.
- We confirmed that the bearing temperature and vibration of the proposed structure are equal to or lower than those of the conventional structure.

Tapered roller bearings, which are often used as pinion bearings for gear units in conventional line electric railcars, are a burden on maintenance work because strict adjustment of the end play value (the total axial clearance of the bearings, hereafter “EP value”) is essential to prevent damage. In response, to achieve both reduced maintenance effort and improved reliability, we developed a pinion support structure (Figure 1: proposed structure) that uses cylindrical roller bearings with ribs as pinion bearings. This structure allows for a greater range of adjustment for the EP value.

Unlike the conventional structure, the proposed structure does not change the bearing’s radial clearance (the clearance perpendicular to the axis) even if the EP value changes. This allows the upper limit of the EP value to be increased from 0.16 mm in the conventional structure to 0.30 mm (lower limit: 0.10 mm). This expansion of the permissible range for the EP value reduces the need for adjustment work that involves disassembling the gear unit. The proposed structure can be implemented without the need for new construction or significant modifications to the gear unit. It only requires replacing the conventional pinion shaft and bearing housings.

Additionally, we conducted rotation tests with the bearing alone under operational load conditions for the proposed structure. We confirmed that the temperature and vibration acceleration, which are indicators of bearing heat generation and lubrication condition, are equivalent to or lower than those of the conventional structure (Figure 2).

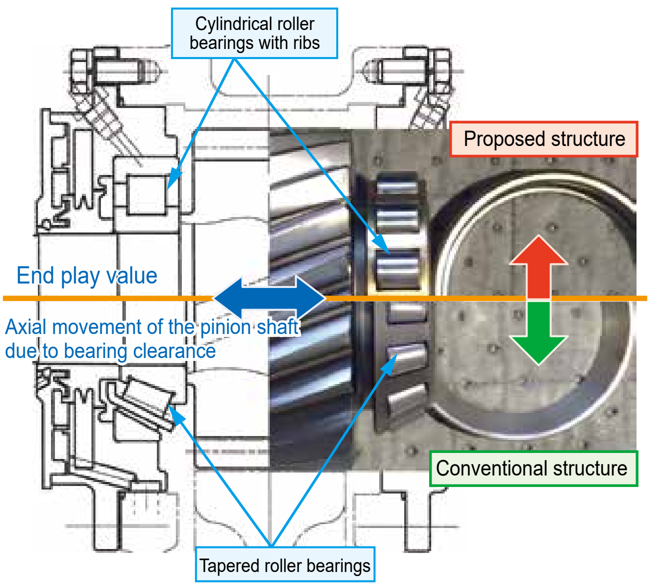



Figure 1 Cross-sectional view of the proposed structure and conventional structure

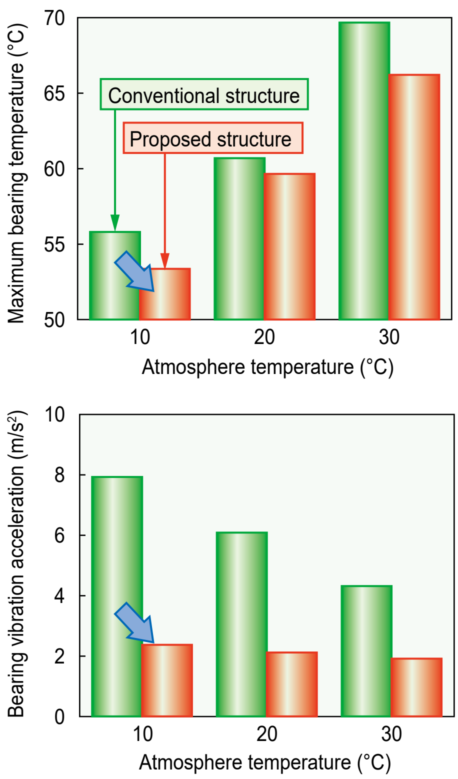



Figure 2 Bearing temperature and vibration acceleration of the proposed structure

# 16. Core image analysis technology for utilizing train-front images

- We have developed and modularized functions for calculating positions on the railway track from train-front images, generating long-length railway track surface images, recognizing railway track side equipment, and assessing degradation levels.
- By combining the developed modules, it becomes possible to efficiently develop applications that utilize train-front images.

In railways, inspections are conducted by staff onboard the train to check the conditions of railway track side equipment and the surrounding environment. In recent years, an increasing number of railway operators have been using video cameras to film from the front of the train so that the conditions during these inspections can be preserved as images. By utilizing these images to understand the location and condition of equipment, we can expect improvements in the efficiency of construction design and a reduction in the labor required for inspection and examination tasks.

To effectively use train-front images across various technical fields such as track maintenance and electrical systems, and to apply them to tasks like construction design and maintenance, the following methods are useful: (1) A method for accurately calculating the position on the railway track corresponding to the distance from train-front images, (2) A method for converting train-front images into overhead view images, (3) A method for generating long-length railway track surface images from multiple overhead view images (Figure 1), (4) A method for recognizing equipment within the images (Figure 2), and (5) A method for assessing the degradation of recognized equipment. Therefore, we developed and modularized methods (1) through (5) as core technologies that can be commonly used when applying train-front images to various purposes.

When each railway operator develops applications to improve operations and safety using train-front images, the development process can be streamlined by combining these groups of modules to form the basic framework (Figure 3).

Figure 1 Example results of the long-length overhead view image generation module


Figure 2 Example of processing results of the equipment recognition module

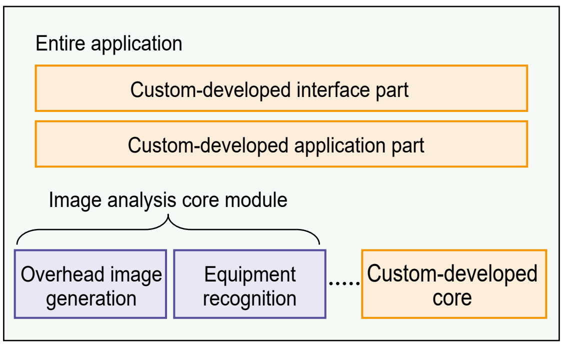



Figure 3 Image showing the utilization of the modules

# 17. Inspection support system using images of tunnel walls

- We have developed an application that uses AI to extract deteriorations from images of tunnel walls and identify the overall health of the tunnel and areas requiring special attention.
- We have developed a mobile projection mapping device that can continuously project the identified areas requiring special attention onto tunnel walls of various shapes.
- This allows for reductions in both the time required for general tunnel inspection and the need for personnel.

Railway tunnels include many that were constructed before World War II or during the period of Japan's rapid economic growth in the 1950s to 1970s. Currently, these tunnels are properly maintained through regular inspections by experienced engineers. However, with a projected decrease in the number of engineers in the future, there is a growing need for automation and reduced reliance on specialized skills.

Given this situation, we have developed a technology that utilizes digital technology to reduce periodic inspection time and minimize the need for personnel. We have developed a technology that uses AI to extract individual deteriorations from images of tunnel walls and identify the overall health of the tunnel and areas requiring special attention that should be inspected intensively (Figure 1). In constructing this AI, we trained it using a database of deterioration data from railway tunnels across Japan. In addition to detecting cracks, the AI can also extract indicators necessary for assessing tunnel condition, such as rust stains, water leakage, water marks, and repaired areas, with over 90% accuracy. Additionally, we developed a portable projection device that can display identified areas requiring special attention on the tunnel wall (Figure 2). The shape of the projected mesh can be corrected based on cross-sectional shape, and the mesh can be moved horizontally based on the distance traveled.

In simulated inspections, the amount of work done at the desk was reduced to about 1/10, and the speed of on-site inspection was improved to approximately twice as fast, achieving reductions in inspection time and personnel requirements (Figure 3).

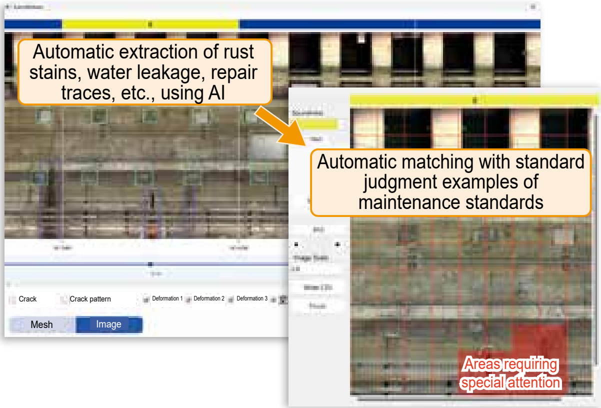



Figure 1 Developed application

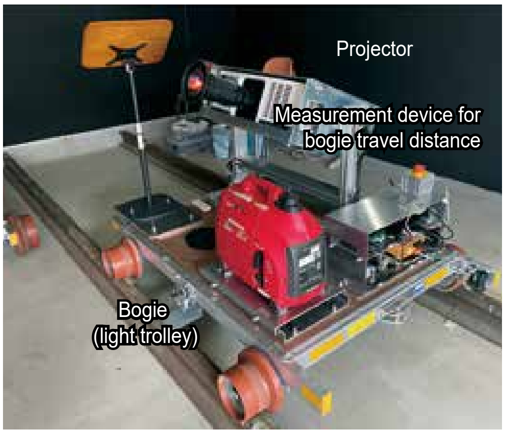



Figure 2 Developed projection system


Figure 3 Inspection situation while projecting

# 18. Simple onboard track patrol support method using smartphones

- We developed an onboard track patrol support application with high operability using smartphones.
- By synchronizing the front-view video captured by the onboard track patrol support application with the measured data such as train speed and vibration acceleration, and displaying this information as subtitles on the video, it is possible to check the track condition at a desk.
- This eliminates individual differences among workers and enables the reduction of skill requirements of onboard track patrol.

To check the overall condition of railway tracks, including maintenance conditions and changes in the track side environment, regular onboard track patrols are conducted by personnel riding in commercial trains. However, this process involves a significant human burden and, due to a decrease in experienced technicians, there is variability in the assessments. To address this issue, we have developed an onboard track patrol support application (Train Patroller) that can be installed on standard smartphones and placed at the front of a train to enable synchronized measurement of front-view video, train speed, and vibration acceleration with simple operation (Figure 1). The smartphone can be easily installed in the driver's cab using a suction cup fixture, allowing measurements to start within three minutes of boarding the train.

Data measured by the onboard track patrol support application are processed using a new feature developed for the track maintenance management database system (LABOCS), which uses an analytical method to synchronize video with train speed. This method assigns distance to the front-view video with an accuracy error of a few meters (Figure 2). Additionally, it allows for the display of subtitles in the video such as train speed and vibration acceleration, and enables the assessment of track members' conditions through overhead images (Figure 3). This allows the acquired vibration acceleration and front-view video to be checked at a desk, enabling confirmation of track conditions independent of the skill level of the onboard personnel. Additionally, it facilitates the formulation of appropriate maintenance plans according to the track conditions. Furthermore, to promote the adoption of this technology by regional railways, we are also advancing the development of data analysis methods that do not require the direct use of LABOCS.

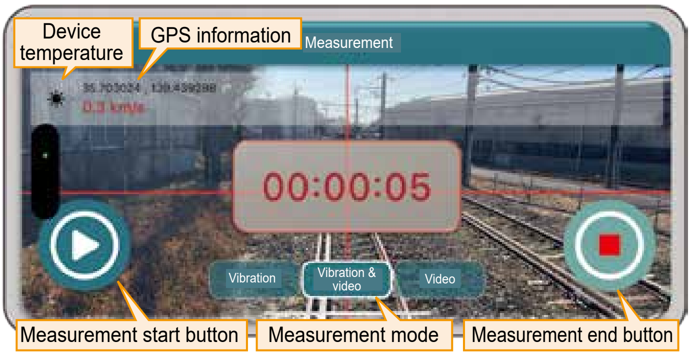



Figure 1 Measurement screen of the developed onboard track patrol support application

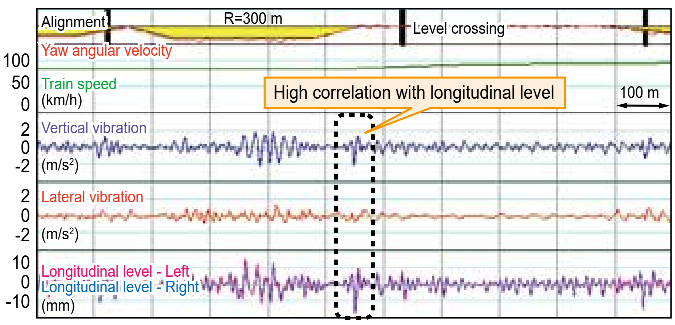



Figure 2 Example of simultaneous plotting of measurement wave-forms of train vibration and track irregularity using the application

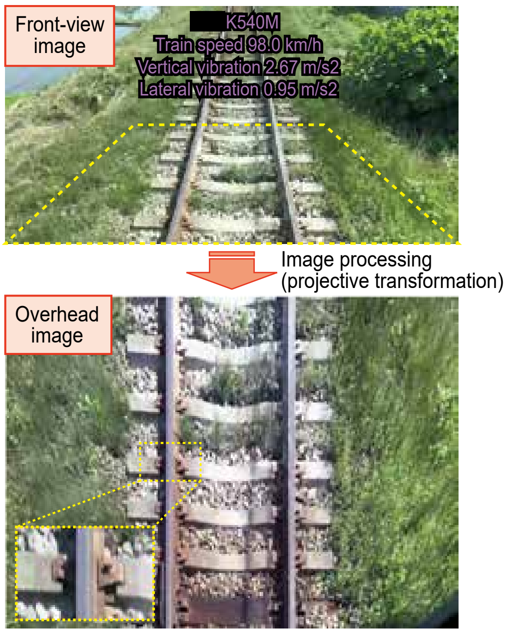



Figure 3 Example of front-view image with subtitle and overhead image by projective transformation

# 19. Non-screw plate-shaped spring clip rail fastening method

- We have developed a non-screw plate-shaped spring clip rail fastening method that eliminates the need for bolt retightening, along with a specialized tool for fastening and loosening.
- The existing springs clips and bolts of the rail fastening system can be replaced with the newly developed specialized plate-shaped spring clips, fixing bolts, and fastening washers, allowing the rails to be secured without the need to replace the existing sleepers.

In Japan, a commonly used and well-established rail fastening system is the screw type, which secures the rail by tightening a plate-shaped spring clip with bolts. This fastening system requires regular inspection for loose bolts and retightening if necessary. On the other hand, non-screw rail fastening systems that do not use bolts, such as bar-shaped spring clips, are also used. However, these require replacing the existing sleepers with ones compatible with the non-screw system. To address this, we devised a method to convert the screw system to a non-screw system without replacing the existing sleepers. This involves replacing the members of the plate-shaped spring clip rail fastening system with a specialized plate-shaped spring clip, a fixing bolt, and a fastening washer (Figure 1).

In this method, the fixing bolts are glued to the sleeper to eliminate the need to retighten the bolts. A fastening washer is then inserted into the gap created by pressing the spring clip downward, and the rail is secured when the pressing force is removed. During maintenance, the fastening washer can be removed by pressing down on the spring clip again to loosen it. This rail fastening method can also be applied to rail fastening systems for ballastless tracks. Additionally, to facilitate the fastening and loosening using the proposed method, a specialized tool has been devised (Figure 2). This allows fastening and loosening in approximately 5 seconds per location.

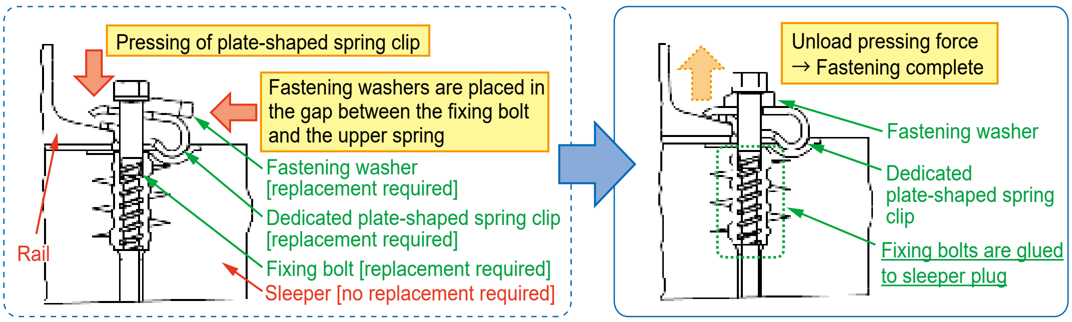
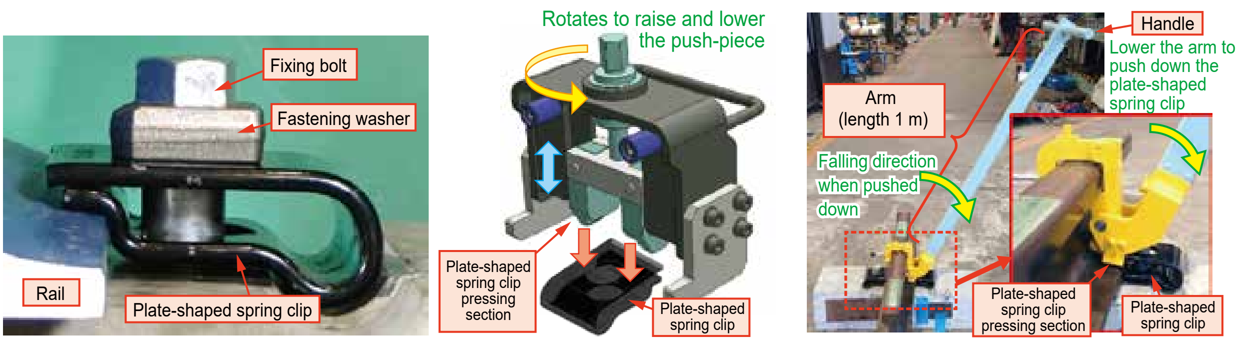



Figure 1 Proposed rail fastening method




(a) Outline of fastening method (b) Fastening tools for machine operation (c) Fastening tools for manual operation

Figure 2 Rail fastening method and fastening tools (example for conventional lines and prestressed concrete sleepers)

# 20. Rail gas pressure welding method of low upset length without the process of bulge removal by hot shearing

- We have developed a rail gas pressure welding method that reduces the upset length by 75% and minimizes the bulge at the weldment, allowing the omission of the bulge removal by hot shearing process.
- By using this method, the weight of the existing welding apparatus can be reduced by 40%, increasing work efficiency, and reducing execution costs by 30%.

Gas pressure welding is a major welding method, accounting for approximately 40% of all rail welding execution in Japan. The current method sets the standard upset length during gas pressure welding at “24 mm or more.” The bulge created by the upset process needs to be removed by hot shearing using a bulge removal device (145 kg) brought to the site. This process of bulge removal by hot shearing requires skilled techniques, and there is a potential risk of hot cracks on the weld interface due to the shear force generated during the bulge removal by hot shearing. With the decrease in skilled technicians in recent years, there is a growing demand for a gas pressure welding method that can eliminate the process of bulge removal by hot shearing.

Therefore, various pressure patterns were examined using numerical analysis methods. By gradually reducing the pressing force during the welding process to reduce the upset length while increasing the temperature of the weld interface, a new method (variable pressure method) was developed that achieves weld strength equivalent to conventional methods (Figure 1). With this method, the upset length can be reduced to 6 mm, and the bulge at the weldment can be reduced by 60% (Figure 2), allowing the bulge to be removed by grinding alone. This results in a 40% reduction in the weight of the existing gas pressure welding apparatus and a 30% reduction in execution costs. In addition, we have also prepared an execution guide that summarizes the above.

In the future, we will work to automate the rail gas pressure welding method using this technique.

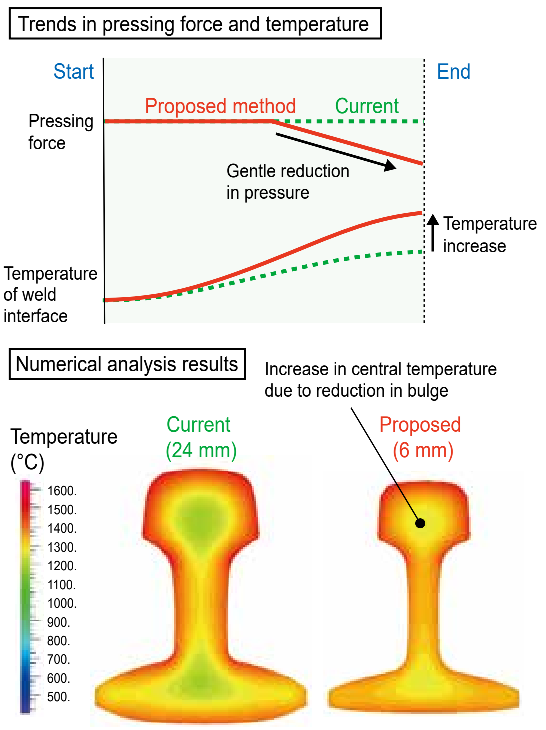



Figure 1 Effects of the variable pressure method

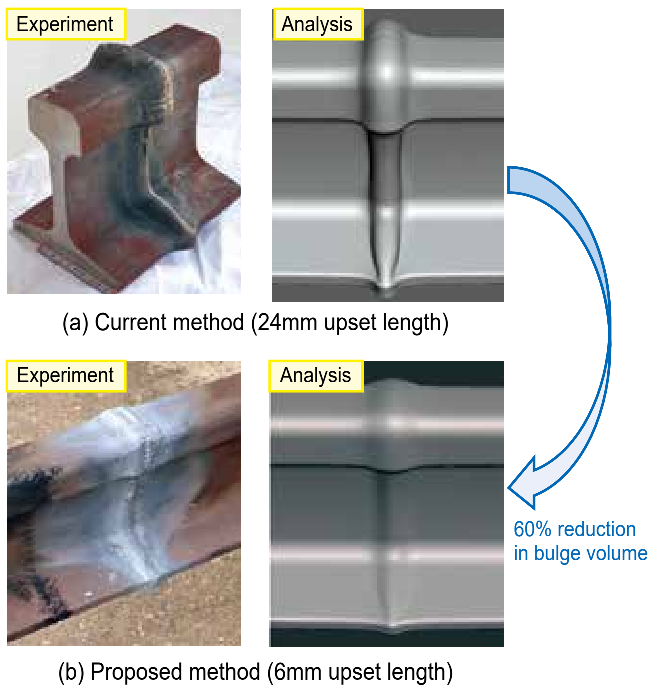



Figure 2 Bulge formation at the gas pressure weld

# 21. System for prestressed concrete (PC) sleeper evaluation of health, focusing on vertical cracks

- We developed a system that automatically extracts longitudinal cracks and evaluates their health using deep learning, in addition to clarifying the relationship between the length of longitudinal cracks and the load-bearing capacity of PC sleepers
- This system makes it possible to monitor the occurrence of longitudinal cracks and evaluate the health of PC sleepers along the entire route, thereby improving safety and streamlining maintenance and management operations.

In recent years, longitudinal cracks have been observed in some aging PC sleepers. It is essential to understand how these cracks impact sleeper performance and to develop an efficient inspection method. Therefore, we conducted a survey of the actual condition of PC sleepers and developed a system that estimates the length of longitudinal cracks from images taken by cameras mounted on maintenance vehicles and other equipment, allowing us to assess the structural health of the PC sleepers.

A survey of the actual load-bearing capacity of 200 aged PC sleepers and 5 new PC sleepers on a commercial line revealed that although longitudinal cracks have only a small effect on bending load capacity, the pull-out load-bearing capacity of sleeper plugs tends to decrease with increasing length of longitudinal cracks (Figure 1). To perform an evaluation of health based on this relationship, we developed a method using deep learning to automatically extract longitudinal cracks from PC sleeper top surface images and estimate their length (Figure 2). Furthermore, using the relationship between the estimated crack lengths and Figure 1, an automatic system was developed to evaluate the health of the PC sleepers (Figure 3).

For example, using this system, it is possible to automatically detect longitudinal cracks and evaluate the health of a large number of PC sleepers—tasks that were previously done via manual visual inspection (Figure 4). This improves safety and streamlines maintenance and management operations.

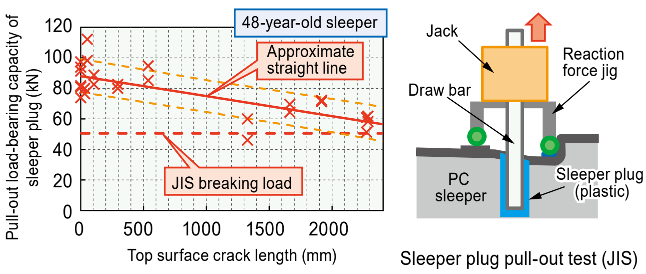



Figure 1 Relationship between pull-out load-bearing capacity and crack length of PC sleeper plugs

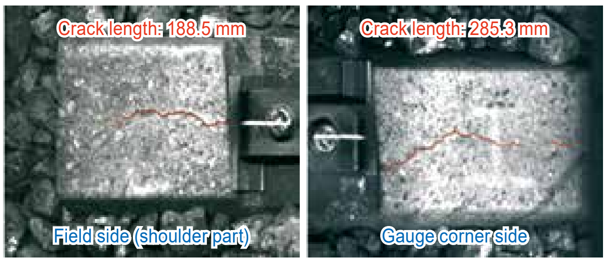



Figure 2 Example of crack extraction using the developed method

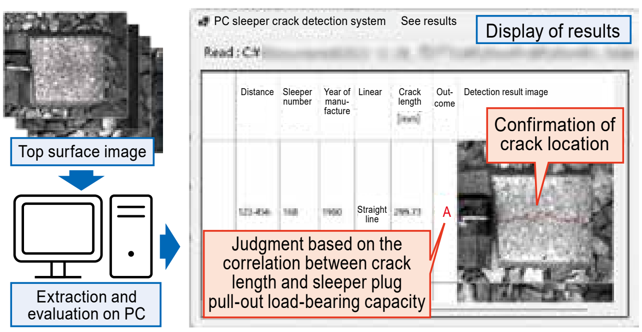



Figure 3 Evaluation of health system

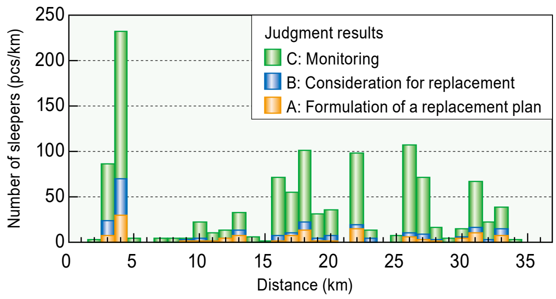



Figure 4 Example of screening for longitudinal cracks (Results of PC sleeper evaluation and number of sleeper (per kilometer))

# 22. An automatic generation method of maintenance worker schedules at stations and depots

- We have developed an automatic generation method of maintenance worker schedules at stations and depots.
- Maintenance worker schedules can be generated within three minutes, taking into account work constraints and their priorities.

For Shinkansen (bullet trains) and other express trains, maintenance work such as cleaning inside the cars is carried out at stations and depots. To accomplish this efficiently, it is necessary to have a maintenance worker schedule that assigns multiple work groups to handle maintenance on various train sets. Skilled personnel manually prepare each day's schedule based on the train schedules and vehicle rosters, which differ daily. It takes approximately three hours to prepare a day's worth of schedules, and it is necessary to save labor and de-skill the preparation process.

The maintenance worker schedule must meet various conditions that vary by station and depot, including work conditions such as arrival and departure times and rest periods for each work group, as well as conditions related to interval time between each job (Figure 1). These conditions have different priorities, and it is not possible to quickly generate high-quality plans by simply formulating and solving them using conventional methods. Therefore, we developed an automatic generation method for maintenance worker schedules by applying a technique called tabu search, which is capable of generating high-quality solutions quickly. The developed method generates a tentative schedule that takes into account the priorities of various conditions, and automatically refines the schedule so that the workload is reduced (Figure 2).

The developed method generates a day's worth of maintenance worker schedules in less than three minutes. A comparison between the automatically generated schedule and the schedule prepared by the person in charge revealed that interval time (a key measure of workload) was reduced by an average of 25% at stations and by an average of 56% at depots (Figure 3). This approach enables labor-saving and de-skilling of scheduling operations, while also reducing the workload for maintenance workers.

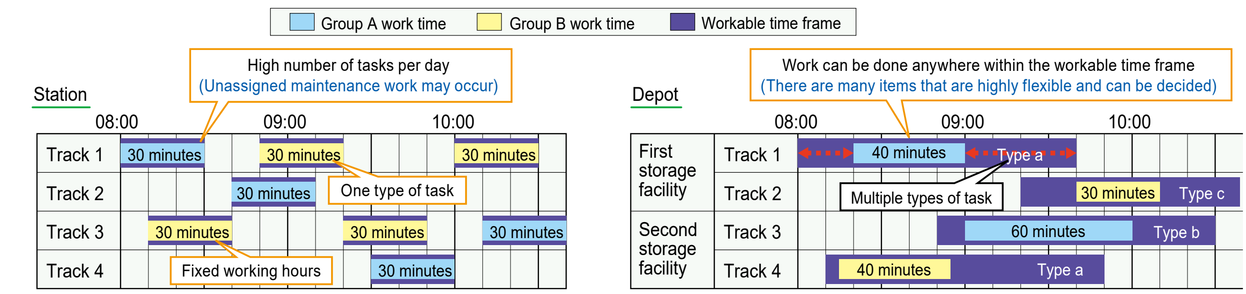



Figure 1 Differences in maintenance worker schedules between stations and depots

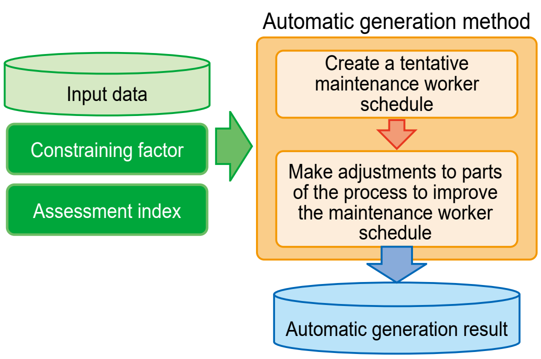



Figure 2 Automatic generation procedure

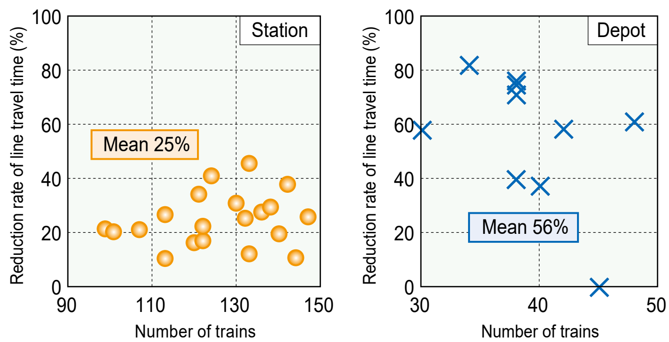



Figure3 Percentage reduction in interval time at station and depot for the developed method

# 23.Verification of commercial line operation using a superconducting feeding system

- We conducted the first operational verification of superconducting power transmission on commercial lines, both in Japan and abroad, with the approval of the Ministry of Land, Infrastructure, Transport and Tourism, aiming for the practical application and widespread adoption of the superconducting feeding system.
- We have developed a compact and highly efficient refrigerator that can be installed along railway lines.

Superconducting feeding systems are expected to consolidate and reduce the number of substations and reduce power consumption through zero resistance power transmission. We have been developing a superconducting feeding system and verifying its functionality on the main line by testing its ability to transmit power to a single test run train without passengers during the night after business hours. However, on actual commercial lines, multiple trains operate under various conditions, such as express train and local train services. Therefore, it is essential to evaluate the system's adaptability and reliability under complex changes in load current. In addition, if the system's installation between substations is assumed, the refrigerator must be downsized to fit along the railway line.

Therefore, we first developed a compact refrigerator with high cooling capacity suitable for installation along railway lines. By efficiently operating the Stirling cycle, the refrigerator's cooling capacity per unit volume has been increased to 0.47 kW/m$^3$, about three times that of the conventional model (0.15 kW/m$^3$). This downsized unit, with a cooling capacity of 1.5 kW, can be installed in a space of approximately 1.8 m$^2$ (Figure 1).

Next, we confirmed that the superconducting feeding system complies with technical standards for operational verification during business hours and obtained approval from the Ministry of Land, Infrastructure, Transport and Tourism. A superconducting feeding system consisting of the developed refrigerator and superconducting cables was installed along a railway line, and it was confirmed that the 102-meter-long superconducting cable could be stably cooled to superconductivity operation temperature (Figure 2). The system supplied power to a total of 135 trains per day (67 trains in the inbound direction and 68 trains in the outbound direction), and it was confirmed that the developed superconducting feeding system can stably transmit the load current, which changes in a complex manner due to multiple trains running during business hours (Figure 3).

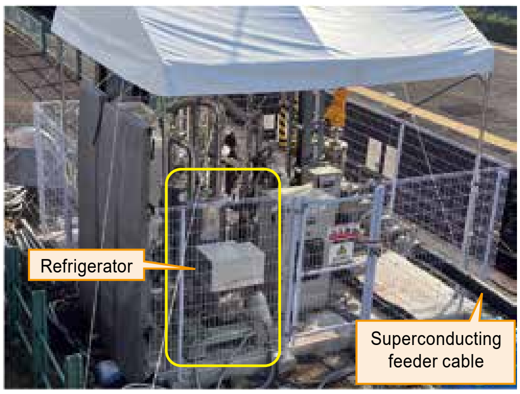



Figure 1 Superconducting feeding system

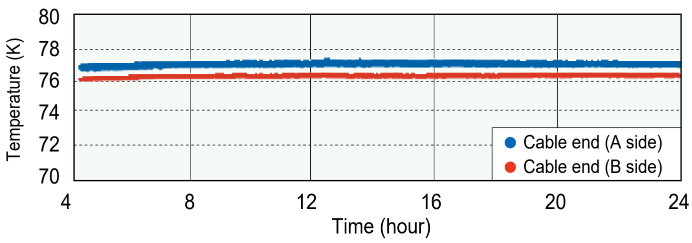



Figure 2 Temperatures at both ends of a superconducting feeder cable

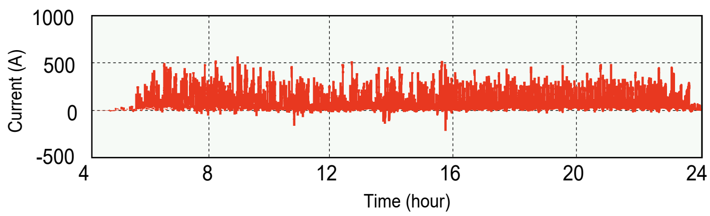



Figure 3 Transmission current by superconducting feeding system

# 24. Automatic method for creating energy-efficient train timetables by reducing powering energy and effective use of regenerative power

- We have developed a method to automatically create energy-efficient train timetables by combining reductions in powering energy and effective use of regenerative power, and confirmed energy saving effects of 4.4 to 7.5% in case studies.
- Reasonable train timetables can be created without altering the total travel time from the starting station to the terminal, while still accommodating speed limits and headways due to signalling facilities and other conditions.

There is a trade-off between improving convenience and reducing energy consumption. We have developed a method for creating train timetables that can save energy while maintaining the convenience of existing train timetables. By solving a mathematical optimization problem that minimizes total powering energy consumption through adjustments in running time between each station, while keeping the total time from the starting station to the terminal unchanged for each train, a “running time adjustment timetable” is created (Figure 1, left). Next, the arrival and departure times of each train are adjusted, and a mathematical optimization problem is solved to maximize the overlap of powering and braking times between trains. This creates an “energy-efficient timetable” that effectively utilizes regenerative power (Figure 1, right). It is also possible to fix arrival and departure times for specific trains and stations in anticipation of transfers to other lines. Additionally, by incorporating restrictions on various conditions, which could not be taken into account in the past, such as speed limits and headways due to signalling facilities and other conditions, it is now possible to create reasonable energy-efficient train timetables.

To validate the effectiveness of the developed method, we conducted a case study of energy-efficient timetables using a full-day train timetable from a metropolitan area with over 400 trains, including connections of local and express services. Simulation of the created train timetable and calculation of energy consumption confirmed that vehicle powering energy consumption can be reduced and regenerative energy can be increased (Figure 2). The amount of energy supplied from substations was confirmed to be reduced by 4.4 to 7.5% (equivalent to 4.2 to 5.1 t/day in $CO_2$ emissions) based on the existing train timetable (Figure 3).

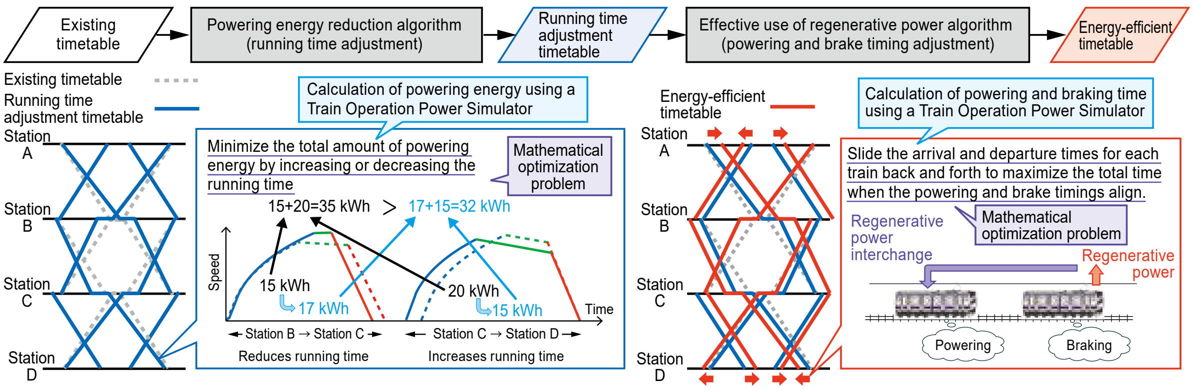



Figure 1 Energy-efficient train timetable creation method

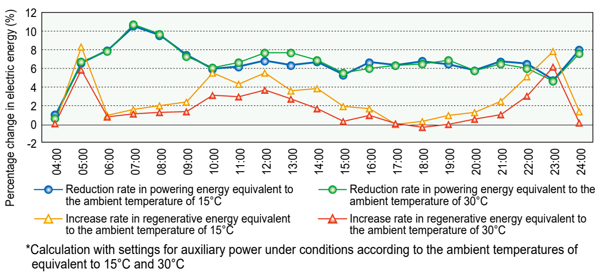



Figure 2 Comparison of vehicle electric energy

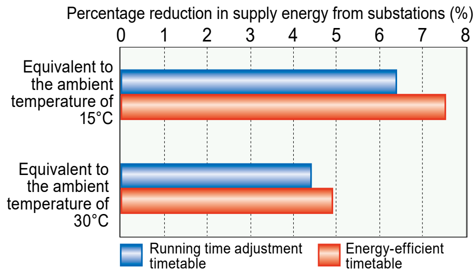



Figure 3 Estimation of energy saving effects

# 25. Next-generation tilt control system compatible with high-speed driving

- We have developed a tilt control algorithm that considers the velocity and acceleration of the carbody tilting, achieving quick and stable tilt control even at high speeds.
- We have confirmed that this algorithm not only significantly reduces the motion sickness evaluation index but also suppresses the yawing motion characteristic of tilting vehicles.
- It improves the ride quality of tilting vehicles in a wide range of train speeds.

The next-generation tilt control system developed by the Railway Technical Research Institute detects current running position using a gyroscope, and precisely matches the tilting behavior of the carbody with the geometry of the curved section. This suppresses low-frequency lateral acceleration and reduces the occurrence of motion sickness. Applying this system to higher-speed trains requires technology that allows the carbody to tilt more quickly and stably.

We developed a new control algorithm that actively considers not only the tilt angle but also the tilt velocity and the tilt acceleration (Figure 1). This algorithm enhances control by increasing force during high-speed curves, when rapid tilting operations are necessary, and when the carbody experiences lateral vibrations, regardless of whether the track is curved or straight. This is an improvement over the previous algorithm, which only accounted for feedback on tilt angle and tilt acceleration.

When the new algorithm was applied to the next-generation tilt control system and running tests were conducted, it was found to suppress low-frequency lateral motion more effectively than both the conventional tilt control system and the next-generation tilt control system using the previous algorithm. Additionally, it reduced the motion sickness evaluation index related to carbody tilting (Figure 2). We also confirmed that the new algorithm effectively suppresses the yawing motion characteristic of tilting vehicles, which often occurs at high speeds on straight tracks, and improves ride quality by reducing higher frequency vibrations.

The next-generation tilt control system, utilizing the new algorithm, can improve the ride quality of tilting vehicles in a wide range of train speeds.

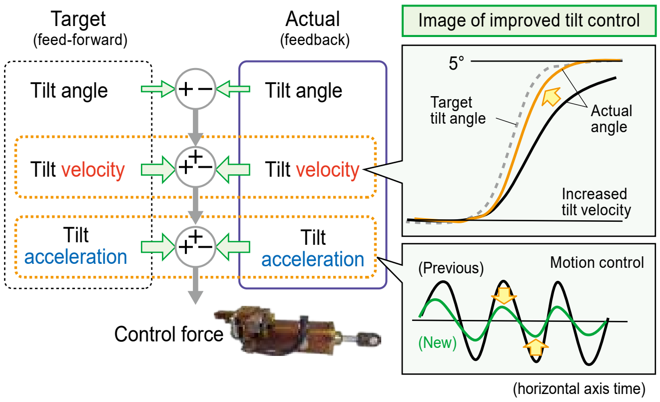



Figure 1 New tilt control algorithm considering tilt speed and tilt acceleration

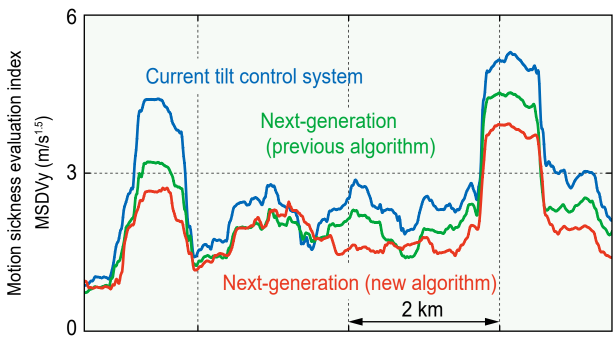



Figure 2 Improvement effect on motion sickness evaluation index

# 26. A method for constructing a three-dimensional vibration analysis model of a carbody for high-frequency ranges

- We have developed a method for constructing a three-dimensional vibration analysis model that accurately reproduces carbody vibrations at high frequencies of 20 Hz and above, addressing issues with accuracy found in existing analysis model.
- Natural frequencies up to 40 Hz can be estimated with an error of less than 5%, and deformed shapes can be reproduced.
- It can be used to improve vibration characteristics by changing the carbody structure during vehicle design.

Various carbody vibration analysis models have been proposed to predict carbody vibration characteristics associated with structural modifications during vehicle design. However, existing analytical models struggled to accurately reproduce vibrations at high frequencies above 20 Hz. To accurately reproduce carbody vibrations at frequencies of 20 Hz and above, which increase at high speeds, we used the finite element method to model each carbody face and the connections between them as a three-dimensional elastic body. To efficiently and automatically adjust parameters not directly obtainable from drawings, such as the apparent Young's modulus when each face of a carbody, composed of multiple members, is represented as a single elastic body, we developed a method to determine these parameters based on measured natural modes of vibration of the carbody (Figure 1).

As an example, we created a three-dimensional vibration analysis model of a Shinkansen carbody and compared the measured values of 14 observed natural modes of vibration up to 40 Hz with those predicted by the model. The results showed that the error in natural frequencies of the structure was less than 5%, and the deformation shapes of the carbody faces were generally consistent (Figure 2). This confirms that the model can reproduce modes of vibration above 20 Hz, which could not be achieved with the existing analysis model.

This analysis model allows for the evaluation of the carbody's elastic vibration characteristics up to approximately 40 Hz, which can be used to improve vibration characteristics by modifying the carbody structure during vehicle design.

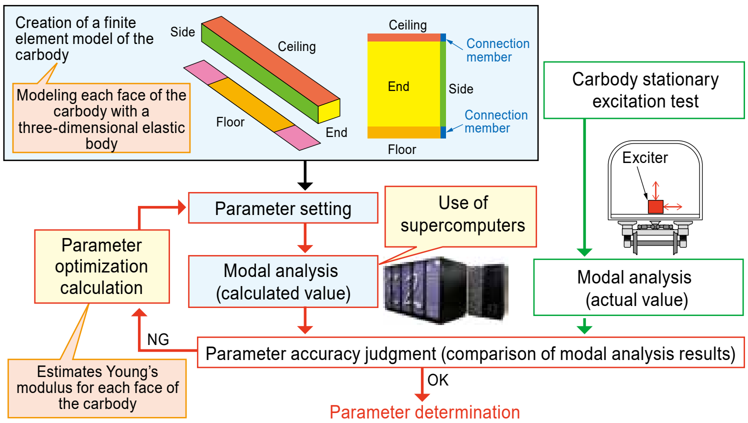



Figure 1 Process of constructing a three-dimensional vibration analysis model of a carbody

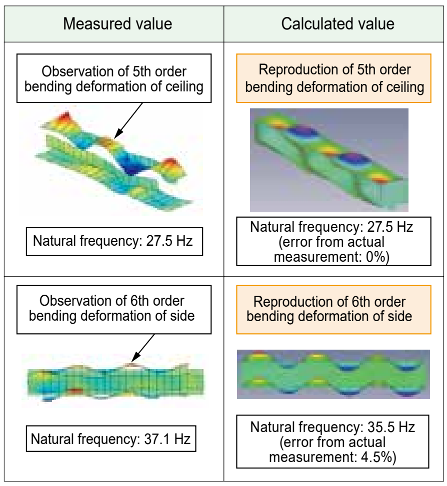



Figure 2 Example of Shinkansen carbody natural modes of vibration (comparison of measured and calculated values)

# 27. Simulation of seismic behavior of a train set

- We have developed an analysis method that can calculate the seismic behavior of train sets, considering the effects of couplers, dampers between vehicles, and other coupling structures between vehicles.
- The method can calculate a series of vehicle behaviors from pre-derailment to post-derailment and can be used as a tool to understand the specifics of derailment phenomena during earthquakes and to develop measures to prevent derailments and deviations.

Railway vehicles are connected by couplers and dampers between vehicles. When an earthquake occurs, the varying characteristics of each vehicle and their positions in the train set lead to different earthquake motions. These motions interact with each other, causing each car to behave differently. The effect of this exchange of forces occurring between the vehicles on the derailment as well as the behavior of the vehicles after the derailment were not well understood.

In response to this, we have developed a simulation method for the seismic behavior of a train set that takes into account the effects of coupling (Figure 1). In this method, individual vehicles are modeled using a combination of multi-body modeling to represent vehicle motion, and finite elements modeling to capture contact phenomena, such as between wheels and rails. By defining the characteristics of springs and dampers that represent the couplings between vehicles, such as dampers between vehicles with attenuation force release functions, it is possible to model the structures to which the vehicles are connected. Additionally, this method can simulate the series of vehicle behaviors from before to after derailment. It can also represent contact phenomena between track members, such as derailment and deviation countermeasures, and vehicle parts, such as motors, while considering their three-dimensional shapes (Figure 1). Figure 2 shows an example calculation (sine wave excitation) for a three-vehicle train set using the developed method. While no derailment occurs when all three vehicles are vibrated in the same phase, if the second car vibrates in the opposite phase, an early derailment is observed due to the significant exchange of forces between the vehicles through the coupling structure. In this method, the calculation of wheel-rail contact during running is partially simplified by omitting creep force calculations to achieve a practical computation speed.

This method can be used as a tool to investigate the causes of derailment accidents during earthquakes under more realistic conditions and to develop measures to prevent derailments and deviations.

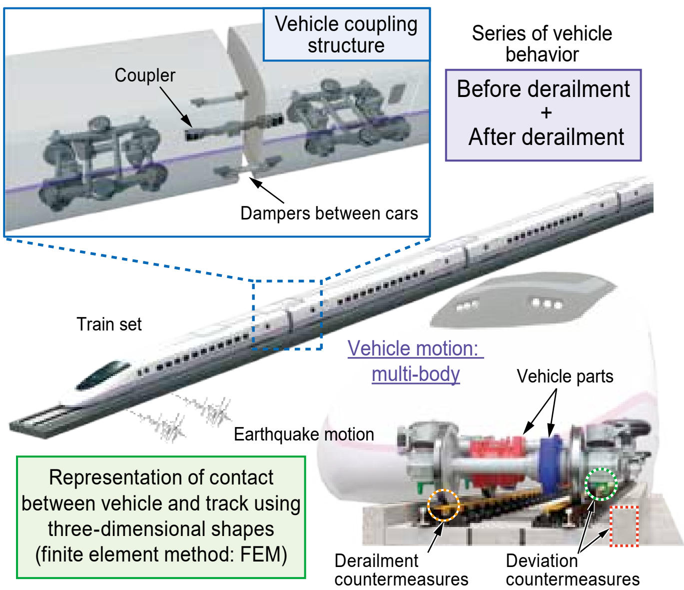



Figure 1 Simulation method developed for the seismic behavior of a train set

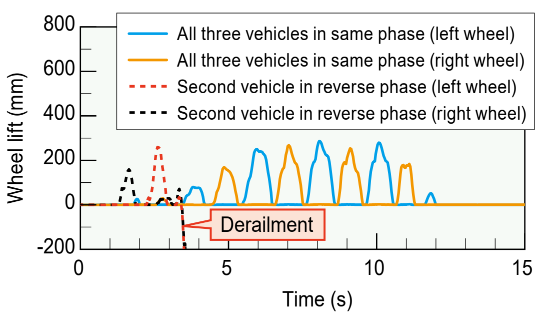



Figure 2 Example of calculation using the developed method (three-vehicle train set)

# 28. Estimation method for factors contributing to decision errors by train forward surveillance AI

- We have developed a method to estimate the factors behind decision errors in AI used for train forward surveillance, with the goal of considering appropriate countermeasures.
- Factor estimation was successfully completed for all 2,668 missed images from approximately 215 hours of train forward surveillance video.
- The method can also be used to check performance when developing AI-based systems.

Efforts are being made to apply AI to train-front images, aiming to automate and reduce the labor involved in diagnostic and decision-making tasks previously performed visually on railways. Furthermore, as AI is expected to make safety decisions during automatic train operation without personnel at the front of the train, it is crucial to understand the causes of accidents that may result from AI decision errors. However, there is currently no adequate method for this. Given this situation, we developed a method to estimate the factors behind AI decision errors, such as missing a detection target, for a forward monitoring system designed to detect obstructions in front of a train.

In the developed method, we estimate the factors by dividing the process into three stages: inspecting input images for errors caused by the photographing method, evaluating the AI's capabilities for errors due to differences in its recognition method, and reviewing the training data for biases (Figure 1). During the inspection of input images, we modify factors such as blurring and brightness to identify conditions that the AI can detect, thereby estimating factors that may cause decision errors related to the image capture conditions (Figure 2). In the inspection of the AI's capabilities, we estimate factors by comparing the performance of different types and mechanisms of AIs and identifying models they can detect. In the inspection of training data, we analyze the distribution of image features and perform similar image searches to determine the proportion of images in the training data that resemble situation images where decision errors occurred. This helps identify any biases in the training data. From 215 hours of train forward surveillance video, we created approximately 75,000 evaluation images for unsafe situations. Applying the developed method to the 2,668 images that the AI had missed, we were able to estimate all the factors contributing to these omissions.

When an accident or incident occurs due to an AI decision error, this factor estimation method can be used to narrow down the target of countermeasures to be considered. It can also be used to check performance when developing AI-based systems.

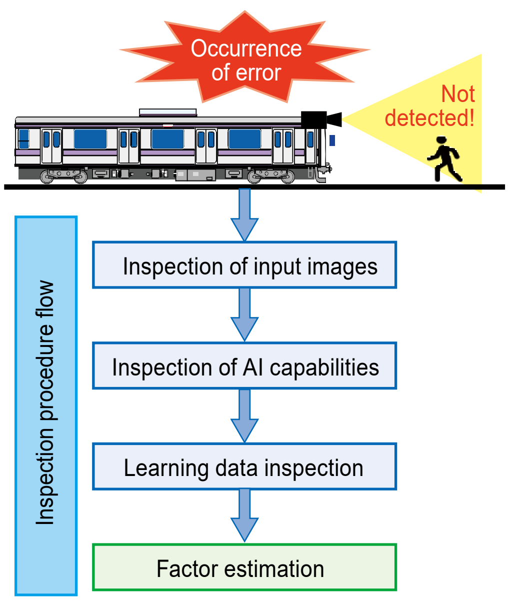



Figure 1 Procedures for tracing AI decision errors

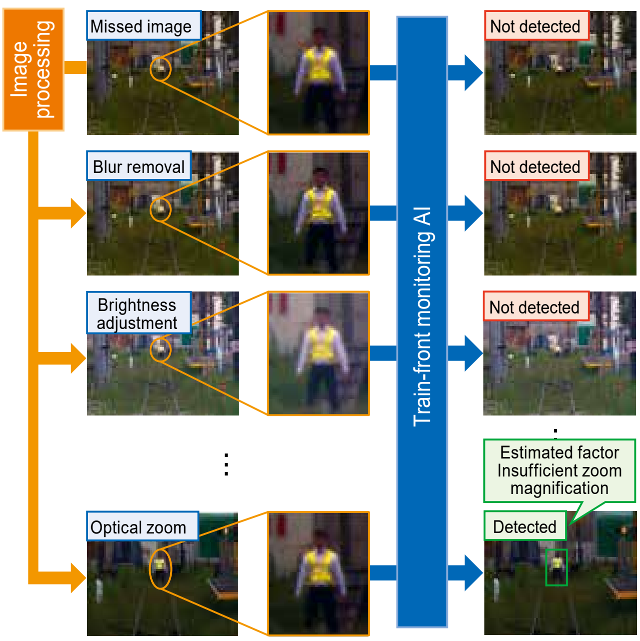



Figure 2 Estimation of decision error factors through input image inspection

# 29. Estimation method for wear mode of current collection materials with the consideration of sliding history

- We have proposed a method for estimating the wear mode of current collection materials by considering not only the temperature rise of the contact points due to friction and current flow but also the heat accumulated in the contact strip and the condition of the wear surface.
- This method can be used to clarify wear phenomena by considering the history of pantograph sliding conditions and contact wire installation configurations, and to explore measures for reducing wear.

Current collection materials, such as contact wires and contact strips, reach the end of their service life primarily due to wear, requiring significant labor for management and replacement. Although the mechanism of the wear mode that determines the wear progress of current collection materials has been clarified by experiments under certain conditions (Figure 1), it is necessary to consider the history of fluctuating sliding conditions in order to explain wear phenomena in the actual field.

Therefore, we concentrated on the accumulation of heat generated by friction, and current flow in the contact strip. We also proposed a method to estimate the contact temperature by accounting for the continuous changes in the condition of the wear surface (Figure 2). This method estimates the wear mode by considering the pantograph's sliding history, including sliding speed and collected current, as well as the installation configuration, such as contact wire stagger. In the stationary test, we confirmed that the wear mode observed with continuously changing sliding speeds (Figure 3, upper row) matched the wear mode estimated from the contact temperature waveform obtained using this method (Figure 3, lower row).

In the future, this method will be developed into a predictive tool for wear progression in actual field conditions by integrating it with overhead contact line-pantograph simulations. Additionally, we plan to use the results of this study to explore contact wire stagger configurations that prevent localized wear, based on the temperature of the contact strip.

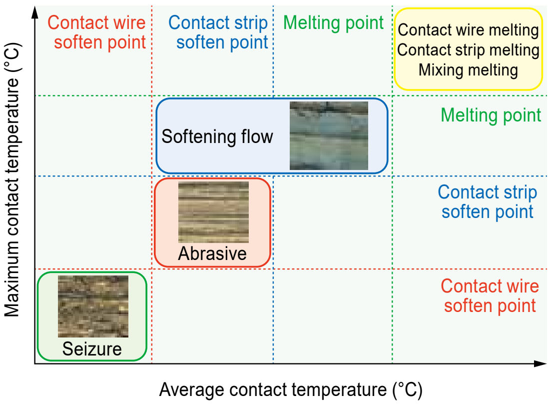



Figure 1 Contact temperature and the resulting wear mode

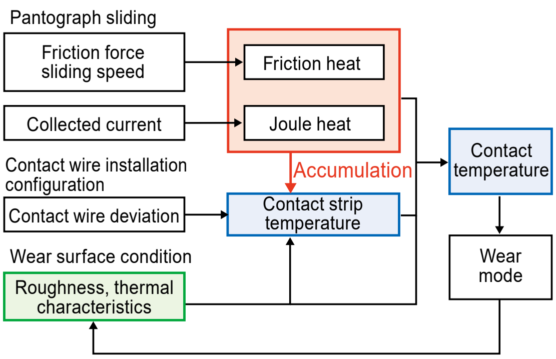



Figure 2 Overview of the wear mode estimation method

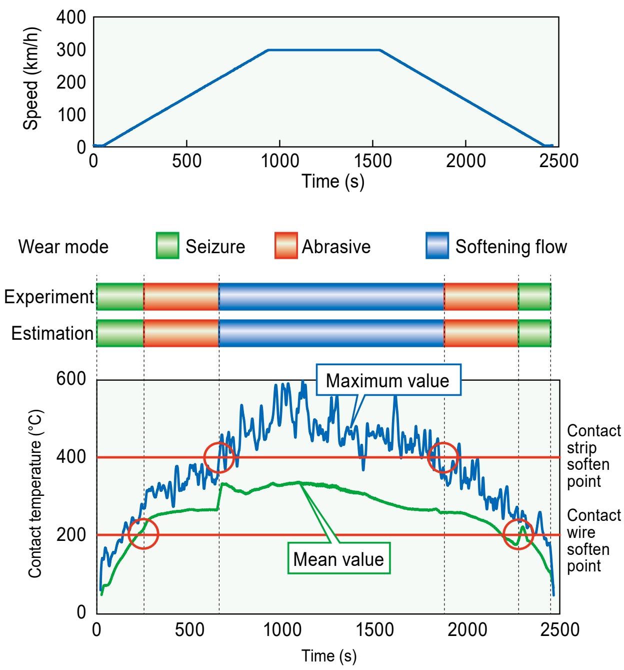



Figure 3 Example of validating the estimation of wear mode occurrence conditions

# 30. Accuracy enhancement of Earthquake Early Warning for railways using optical sensing technology

- We proposed an earthquake monitoring network using optical sensing technology applied to existing optical fiber cables along railway lines and confirmed that seismic activity can be detected every five meters.
- We proposed a method for rapid hypocenter determination, using data from multiple observation points with optical sensing technology, which offers high accuracy and immediacy for Earthquake Early Warnings.

We proposed the use of optical sensing technology (Distributed Acoustic Sensing: DAS) to improve the immediacy of Earthquake Early Warning (EEW) and the accuracy of hypocenter determination.

We established an earthquake monitoring network by applying DAS to existing optical fiber cables on Shinkansen structures. This allowed us to confirm that strain waveforms in the optical fiber cables, reflecting the type of structure and ground shaking susceptibility, can be obtained with high density (every five meters) during earthquakes (Figure 1). Additionally, we proposed a new method to reconstruct earthquake waveforms at each location, which previously had large errors with optical measurement technologies. This method uses the ratio of site characteristics between locations and phase information obtained from accurate waveforms in the vicinity. We calculated the maximum strain at the crown of the structure of the magnitude 6.6 earthquake. Thus, we confirmed that DAS allows for obtaining high-density and accurate seismic waveforms along railway lines. Furthermore, to enhance the accuracy of EEW for railways, we have developed a method for determining the hypocenter using real-time data from multiple DAS observation points. This method enables determining the epicenter with high accuracy (epicenter location error of less than a few kilometers) and speed (within 1 second after detecting the primary wave), compared to existing methods using data from a single observation point (which have an epicentral distance error that can be between half and double the actual distance). This improvement allows for a reduction in false alarms and the issuance of warnings within appropriate ranges, thereby contributing to enhanced safety and stability of railway transportation (Figure 2).

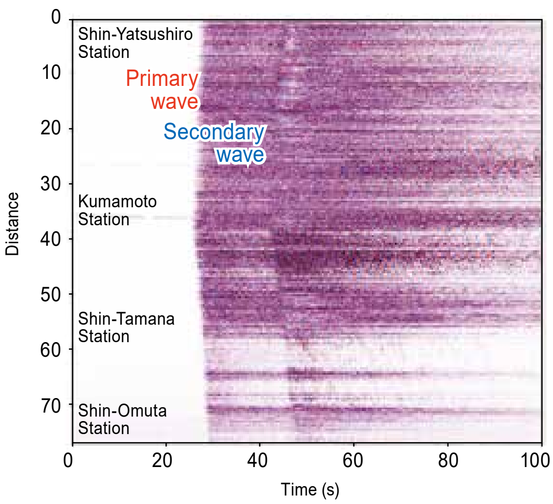



Figure 1 Example of DAS observation record (seismic waveforms of the Magnitude 6.6)

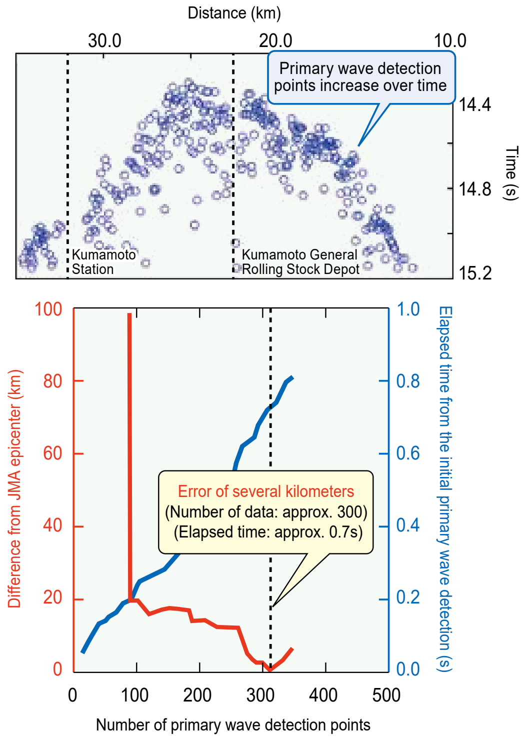



Figure 2 Example of early hypocenter determination (top: distance and primary wave detection time, bottom: epicenter error and elapsed time)

# Notes

## IMPROVEMENT OF SAFETY

- 1 is collaborative research with East Japan Railway Company, Japan Agency for Marine-Earth Science and Technology and National Research Institute for Earth Science and Disaster Resilience.
- 6 is collaborative research with University of Iowa.

## COST REDUCTION

- 11 was accomplished by Railway Technology Development and Promotion System of Ministry of Land, Infrastructure, Transport and Tourism.
- 12 is collaborative research with Kobe University and Nippon Chuzo K.K..
- 13 was accomplished by Railway Technology Development Subsidy of Ministry of Land, Infrastructure, Transport and Tourism.
- 14 is collaborative research with OKASANLIVIC.CO.,LTD. and K.K Enbine.
- 15 is collaborative research with TOYO DENKI SEIZO K.K. and NTN Corporation.
- 17 was accomplished by Transportation Technology Development Promotion System of Ministry of Land, Infrastructure, Transport and Tourism
- 18 is collaborative research with The University of Tokyo.
- 20 is collaborative research with Niigata University.
- 22 is collaborative research with Meiji University.

## HARMONIZATION WITH THE ENVIRONMENT

- 23 was accomplished by Railway Technology Development Subsidy of Ministry of Land, Infrastructure, Transport and Tourism.

## BASIC RESEARCH

- 30 is collaborative research with Japan Agency for Marine-Earth Science and Technology and National Research Institute for Earth Science and Disaster Resilience.

## News Release

### R&D

| M / D / Y | Title | |
|---|---|---|
| Sep 12, 2023 | Steam Weeding Technique with Excellent Weed-Controlling Effect and Usability Is Finally Available | link |
| Oct 03, 2023 | Japan-Led International Standard on Lithium-Ion Batteries for Auxiliary Power Supply Systems Used on Rolling Stock Issued | link |
| Nov 29, 2023 | RTRI Develops Wooden Sleeper Deterioration Evaluation System | link |
| Jan 19, 2024 | RTRI Develops Driver Advisory System for Energy Saving Utilizing Speed Transition Estimation | link |
| Mar 13, 2024 | RTRI Starts Verification of World’s First Power Transmission For Commercial Line Operation Through Superconducting Feeding System | link |
| Mar 18, 2024 | RTRI Develops and Puts into Practical Use Seismic Reinforcement Method for Bridge Abutments Using Ground Reinforcing Nails and Available Even in Narrow Places | link |

## Award

| M / D / Y | Title | |
|---|---|---|
| Jun 14, 2023 | Dr. Ryuichi Yamamoto Awarded ISO Excellence Award | link |
| Oct 20, 2023 | RTRI's Researchers Commended for Their Contribution to Developing Industrial Standards | link |

## Event

| M / D / Y | Title | |
|---|---|---|
| Jun 14, 2023 | ISO/TC 269 12th Plenary Meeting Takes Place in Japan | link |
| Nov 22, 2023 | RTRI and the National Science and Technology Development Agency of Thailand Co-Host Railway Technology Forum | link |
| Dec 07, 2023 | Land Transport Authority, MTR Corporation Ltd. and RTRI Co-Host Information Exchange | link |

# Public Relations

## Publications

### Quarterly Report (QR)

QR is an electronic quarterly journal published in English to present RTRI's research and development achievements to overseas readers.

| Vol. / No. | M / Y | |
|---|---|---|
| Vol.65 / No.1 | Feb / 2024 | link |
| Vol.64 / No.4 | Nov / 2023 | link |
| Vol.64 / No.3 | Aug / 2023 | link |
| Vol.64 / No.2 | May / 2023 | link |

### Ascent

Ascent, an English-language electronic public relations journal published at twice a year, introduces RTRI's research and development efforts to overseas readers.

| No. | M / Y | special feature | |
|---|---|---|---|
| No.14 | Mar / 2024 | The Initiatives of its Technology Divisions 2 | link |
| No.13 | Sep / 2023 | Organizational Revision of the Railway Technical Research Institute and the Initiatives of its Technology Divisions | link |

### RRR

RRR is an bimonthly newsletter introducing railay related technology and RTRI's research topics. (In Japanese only)

| Vol. / No. | M / Y | |
|---|---|---|
| Vol.81 / No.2 | Mar-Apr / 2024 | link |
| Vol.81 / No.1 | Jan-Feb / 2024 | link |
| Vol.80 / No.6 | Nov-Dec / 2023 | link |
| Vol.80 / No.5 | Sep-Oct / 2024 | link |
| Vol.80 / No.4 | Jul-Aug / 2024 | link |
| Vol.80 / No.3 | May-Jun / 2024 | link |
| Vol.80 / No.2 | Mar-Apr / 2024 | link |

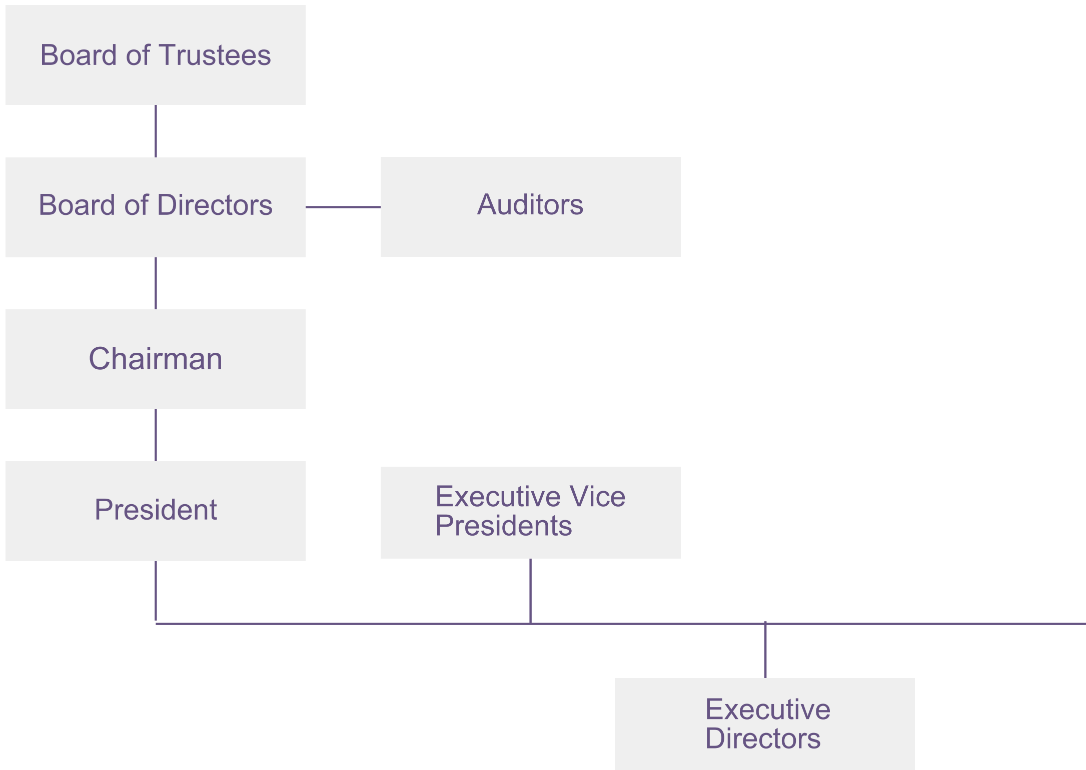
## Collaboration with Other Organizations

Collaboration is in progress with the following railway operators, research institutes, universities, and other organizations for joint research, commission research, technical collaboration, and the like.

| Organisation Name |
|---|
| University of Birmingham |
| Rail Safety and Standards Board (RSSB) |
| International Union of Railways (UIC) |
| Gustave Eiffel University (UGE) |
| French National Railways (SNCF) |
| Polytechnic University of Milan |
| German Aerospace Center (DLR) |
| DB Systemtechnik (DBST) |
| High Speed Railways Innovation Centre (HSRIC) |
| China Academy of Railway Sciences (CARS) |
| Korea Railroad Research Institute (KRRI) |
| Taiwan Railways Administration (TRA) |
| National Science and Technology Development Agency (NSTDA) |

# Data

## Organization



- Planning Division
- Compliance Division
- Administration Division
- Accounting Division
- Research & Development Promotion Division
  - International Affairs
- Marketing & Business Development Division
- Railway Technology Promotion Center
- Railway International Standards Center

- Vehicle Technology Division
- Structures Technology Division
- Power Supply Technology Division
- Track Technology Division
- Disaster Prevention Technology Division
- Signalling and Operation Systems Technology Division
- Information and Communication Technology Division
- Materials Technology Division
- Railway Dynamics Division
- Environmental Engineering Division
- Human Science Division
- Maglev Systems Technology Division
- Center for Railway Earthquake Engineering Research

# Overview of RTRI (as of 1 April, 2024)

## Legal Name of the Organization
Railway Technical Research Institute(RTRI)

## Registered Office Address
2-8-38 Hikari-cho, Kokubunji-shi, Tokyo
(Postal code) 185-8540

## Date of Establishment
December 10th, 1986

## Start of Operation
April 1st, 1987

## Original Purpose of Establishment
The original purpose of the organization was to succeed the research and testing activities of the Japanese National Railways Reform Act (Act No. 87 of 1986). This aimed to conduct comprehensive research and development, ranging from fundamental research to applied studies, as well as investigations in railway technology and railway labor science. Through these efforts, the institute strived to contribute to the advancement of railways and the enhancement of academic and cultural standards.

## External Research Facilities and Locations
Wind Tunnel Technical Center (Maibara-shi, Shiga)
Civil Engineering Testing Station (Hino-shi, Tokyo)
Snow Testing Station (Shiozawa, Minami-Uonuma-shi, Niigata)
Anti-Salt Testing Station (Yamakita-cho, Murakami-shi, Niitgata)

## Workforce Composition
Total personnel: 535
Researchers with Doctoral Degrees: 206
Professional Engineers: 101

# Master Plan

- Research and Development for Creating the Future of Railways -
RESEARCH2025
(2020–2024)

https://www.rtri.or.jp/assets/edga9q00000003x7-att/RESEARCH2025RTRI_E.pdf

# SDGs

## Objective

Through the research activities based on the master plan “RESEARCH 2025”, RTRI will contribute to achieving 9 goals among the 17 SDGs, focusing on “Goal 9: Industry, Innovation and Infrastructure” where RTRI has advantage and enhance its presence as a research institute.

## What RTRI will do

Our society is facing a number of issues including protection of the global environment, increasing social burden due to the aging populations and regional disparity of economy. Radical technological innovation is essential in order to overcome these issues. As a research entity leading technological innovation for railways, RTRI will provide solutions to the difficult problems facing railways in coordination with railway operators, academic and research institutes and industries, and pursue the research and development to achieve a sustainable society and to create the future for railways.

Through the research activities based on “Master plan –Research and Development Creating the Future of Railways - RESEARCH 2025”, RTRI will address the activities to achieve 9 goals among the 17 SDGs including “Goal 7: Affordable and Clean Energy” and “Goal 8: Decent Work and Economic Growth” placing a particular emphasis on “Goal 9: Industry, Innovation and Infrastructure”. (Fig. 1) Our specific activities are shown in Table 1.

Table 1: Research activities to achieve SDGs under “RESEARCH 2025”

| Activities defined in “RESEARCH 2025” | Specific activities |
|---|---|
| 1. R&D activities | |
| • Enhancing safety with an emphasis on improving resilience to natural disasters | • A particular emphasis on the R&D that contributes to safer and more reliable railway transportation<br>• R&D to prevent failures and aging of ground and vehicular equipment<br>• Investigations of the damage and causes of disasters and accidents and proposing recovery methods and prevention measures |
| • Innovating railway systems based on digital technologies | • A particular emphasis on the R&D of labor-saving technologies in order to respond to issues of labor-shortages at railway sectors<br>• Speeding up Shinkansen while preserving the trackside environment<br>• Further energy saving on the railways<br>• Initiatives that contribute to the creation of new customer services such as “Mobility as a Service” (MaaS) |
| • Creating high-quality results by taking advantage of our collective strength | • R&D for the future of railways, the development of practical technologies with immediate benefit to railway businesses, and basic research to understand and analyze railway-specific phenomena<br>• Development of more advanced simulation technology and original testing and research facilities<br>• Accumulating the know-how relating to railway technologies and developing human resources<br>• Interdisciplinary and cross-cutting approaches for resolving various issues in railways |
| 2. Survey Activities | |
| • Reflecting the understandings of the changes in the society, economy, and technologies | • Collecting and analyzing information concerning mid- to long-term trends in railway safety, environmental issues, and the transportation economy and trends in cutting-edge technologies<br>• Predicting the future of railways and Identifying technical items for R&D |

| Activities defined in "RESEARCH 2025" | Specific activities |
|---|---|
| 3.Technical Standards Activities | |
| • Achieving the design that will increase the efficiency in construction and maintenance | • The development of design standards, maintenance standards, and design calculation patterns in consideration of the shrinking labor force |
| 4.Information Services Activities | |
| • Providing timely and appropriate rail-related technical information | • Collecting, compiling and disseminating Japanese and overseas railway technical information<br>• Providing high-quality R&D results and the information on the activities, using a variety of media<br>• Serving as a base facility to provide the information supporting rapid recovery of train operation following earthquakes |
| 5. Publication and Seminar Activities | |
| • Disseminating the results of R&D<br>• Providing systematic training courses for all levels of participants from beginner to expert | • Further improvement of the contents of periodicals, lectures and technical forums<br>• Providing training courses on railway technologies |
| 6.Diagnostics Advisory Activities | |
| • Prompt investigations of the damage and causes of disasters, accidents and equipment failures and proposals of recovery methods and prevention measures | • Responding to the needs of all railway operators carefully and appropriately<br>• Responding to the severe natural disasters by forming a cross-cutting team |

# Data

## SDGs / Histrical Background

| Activities defined in “RESEARCH 2025” | Specific activities |
| --- | --- |
| 7. International Standards Activities | |
| • Developing strategic international standardization activities to maintain and further improve Japanese railway technology and to expand it overseas | • Working actively as a domestic review organization of ISO (International Standards Organization) and IEC (International Electrotechnical Commission)<br>• Active involvement in standardization activities being promoted by international rail-related organizations<br>• Addressing a number of issues including the stipulation and systematization of Japanese technologies and know-how and review of the domestic certification system as part of the entire efforts of standard development |
| 8. Qualification Activities | |
| • Contributing to maintaining and improving technical capabilities of railway engineers and the development of human resources in the entire railway industry | • Review of the professional railway design engineers’ examination in order to make it more accessible for railway engineers. |
| 9. International Activities | |
| • Enhancing international presence of the Japanese railway technologies | • Improving both the quality and quantity of information disseminated overseas through expanding joint research with overseas universities and research institutions and sending a larger number of researchers to overseas<br>• Promoting the advancement of Japanese railway technologies into the overseas market through the international expansion of technologies developed by RTRI<br>• Supporting the international development of railway operators and suppliers |

| Activities defined in "RESEARCH 2025" | Specific activities |
|---|---|
| 10. Job satisfaction | |
| • Creating a motivating workplace where staff can demonstrate their abilities | • Respecting each individual staff member as a valuable human resource, we will develop researchers that are able to respond to the needs of railway operators and to drive creative R&D in a global perspective<br>• Initiatives for workplace health and safety, mental health, and work-life-balance and support for the next-generation development<br>• Fostering an open workplace environment where researchers of different technical fields, generations and positions are able to have free and vigorous discussions |

# Historical Background

## 1986
Dec. 10 : Establishment of the RTRI authorized by the Minister of Transport.

## 1987
Apr. 01 : The RTRI inherited the R&D arm of Japanese National Railways upon its division and privatization.

## 1990
Nov. 15 : New rolling stock test plant completed.

## 1991
Mar. 31 : Test Plant E (human science) completed.

## 1992
Oct. 13 : International railway research seminar on “R&D in World Railway -Today and Tomorrow-” (later developed into WCRR).

## 1993
Jan. 31 : Brake Test Plant completed.

## 1996
Jun. 05 : Large-scale low-noise wind tunnel completed.
Jul. 01 : Yamanashi Maglev Test Center opened.
Jul. 01 : Railway Technology Promotion Center opened.

## 1997
Mar. 21 : First railway design engineer examination administered.

## 1999
Oct. 19-23 : World Congress on Railway Research 1999 (WCRR ‘99) held at the RTRI.

## 2003
Dec. 02 : The world speed record of 581 km/h for a manned train (MLX01) attained on the Yamanashi Maglev Test Line.

## 2004
Nov. 16 : Two-train crossing test at a relative speed of 1026 km/h on the Yamanashi Maglev Test Line.

## 2006
Apr. 26 : Running test of fuelcell railway vehicle succeeded.

## 2007
Oct. 25 : A battery-driven, energy-recycling light-rail vehicle opened to the Public.

## 2008

Oct. 31 : Large-scale vibration test machine completed.

## 2010

Apr. 01 : Inauguration of the Railway International Standards Center

May 18 : Took on the responsibility as the secretariat for national mirror committee of ISO (International Organization for Standardization) / TC17 (Steel) / SC15 (Railway rails, rails fasteners, wheels and wheelsets).

## 2011

Mar. 11 :Great East Japan Earthquake (participation in recovery support activities).

Apr. 01 : Accredited as a public interest incorporated foundation.

## 2012

July 18 : Took on the responsibility as the secretariat for national mirror committee of ISO (International Organization for Standardization) / TC269 (Railway applications).

## 2014

Apr. 01 : Center for Railway Earthquake Engineering Research inaugurated.

Dec. 11 : The vision “We will develop innovative technologies to enhance the rail mode so that railways can contribute to the creation of a happier society” decided.

## 2015

Apr. 01 : Master plan “RESEARCH 2020” that embodied a strategy based on the vision started. (until the end of fiscal 2019).

June 01 : Started operation of an Earthquake Information Disclosure System for Railways.

## 2016

Apr. 14 : Kumamoto earthquake (participation in recovery support activities).

Nov. 30 : “Ascent” a public relations magazine for overseas launched.

## 2019

Oct. 12 : Reiwa 1 East Japan Typhoon (Typhoon Hagibis) (participation in recovery support activities).

Oct. 28 – Nov. 01 : The 12th World Congress on Railway Research “WCRR 2019” held at Tokyo International Forum.

## 2020

Apr. 01 : Master plan “RESEARCH 2025” started (until the end of fiscal 2024).

July. 03 – July.31 : The 2020 Kyushu floods (participation in recovery support activities)

July. 10 : Low-Noise Moving Model Test Facility completed.

Sep. 30 : High-Speed Test Facility for Pantograph/OCL Systems completed.

## 2021

Feb. 26 : High-Speed Wheelset Dynamic Load Test Facility completed.

YEAR 2022-2023: April 1, 2022 - March 31, 2023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