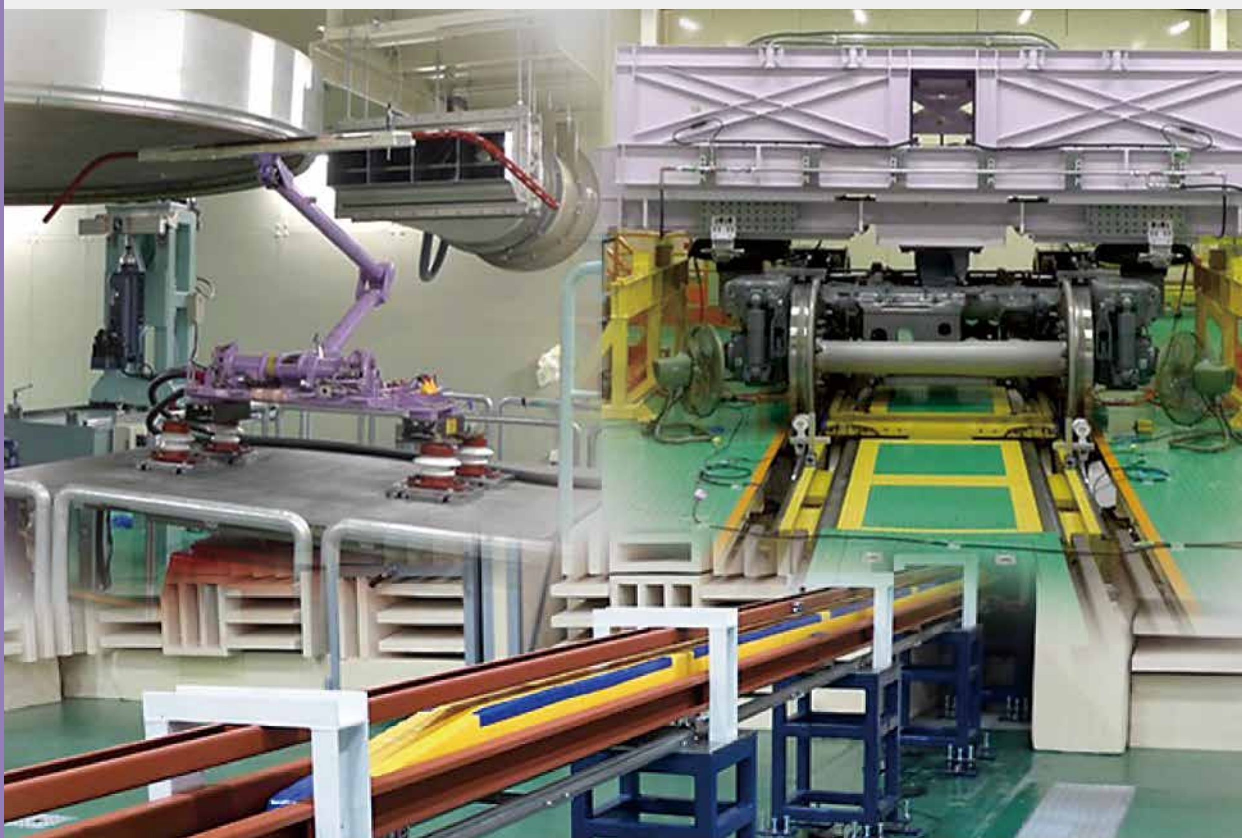
ANNUAL REPORT 2020-2021

For the year ended March 31, 2021

Railway Technical Research Institute



Foreword

Ikuo WATANABE
President of the Railway Technical Research Institute

I am pleased to announce that RTRI Annual Report 2020 is now available. This report outlines and introduces the organization of RTRI, our master plan, research and development and other activities and the data of many research fields as annexes. It would be our great pleasure if you could glance over our progress in fiscal 2020 and it helps deepen your understandings of RTRI.

In fiscal 2020, we made a new step forward. In April, Master Plan, Research and Development for Creating the Future of Railways - RESEARCH 2025 was started. This master plan covering the five years until fiscal 2024 is a roadmap to fulfill our vision “RISING - We will develop innovative technologies to enhance the rail mode so that railways can contribute to the creation of a happier society”. In addition, Prof. Masao MUKAIDONO assumed office as our new chairman in June, at a time I became president, and a new management system was launched.

Meanwhile, in fiscal 2020 our society was hard hit and shaken by the Covid-19 pandemic. Under the impact of this pandemic, all the countries including Japan had to strictly restrain social and business activities in almost all aspects of people’s life and all the industrial sectors. RTRI has been no exception. Now we need to implement our business and research activities in a more careful and discreet manner.

Under these difficult circumstances, however, we were able to steadily implement 271 research and development projects, 92 of which were completed by the end of fiscal 2020. Furthermore, in the disasters caused by the heavy rainfall in July 2020 and another earthquake in Fukushima in February 2021, the researchers at RTRI conducted damage surveys and supported the restoration of the damaged areas. We have adapted our management system to the new-normal life by introducing the work-from-home practice and new ways of living and, as the result, our research activities have been continued without disruption under the renewed work environment.

This unprecedented crisis caused by the pandemic is still ongoing and our society keeps changing while fighting back against the spread of Covid-19 and keeping an eye on the post-Cocid-19 world. At the same time, now a paradigm shift is being accelerated in the global world toward the sustainable society featuring the keyword “decarbonization”. Without doubt, railway operators and industries will be required to further change to attain the same goal. Developing the base technologies that drive the change is the most important mission of RTRI. We will keep changing ourselves drastically and flexibly and keep creating high-quality research results. In fulfilling this mission, continued support and advice from all of you will be most appreciated.

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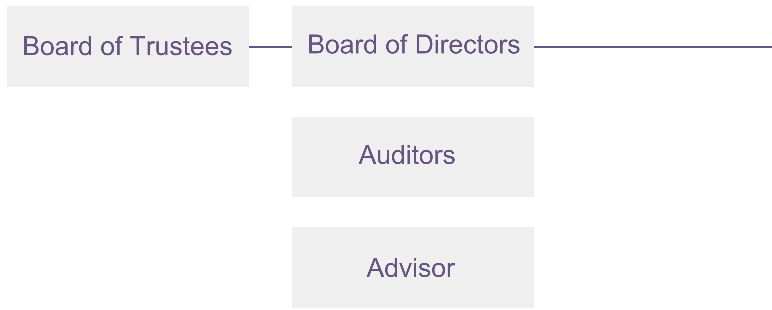
Organization



- Chairman
  - President
    - Executive Vice Presidents
    - Executive Directors
    - Planning Division
    - Compliance Division
    - Administration Division
      - Miyazaki Test Center
    - Accounting Division
    - Information Management Division
      - Health Insurance Systems Center
    - International Division
    - Research & Development Promotion Division
      - Wind Tunnel Technical Center
      - Director, JR Affairs
    - Marketing & Business Development Division
      - Director, Sales
    - Railway Technology Promotion Center
    - Railway International Standards Center
    - Vehicle Structure Technology Division
    - Vehicle Control Technology Division
    - Structures Technology Division
    - Power Supply Technology Division
    - Track Technology Division
    - Disaster Prevention Technology Division
    - Signalling & Transport Information Technology Division
    - Materials Technology Division
    - Railway Dynamics Division
    - Environmental Engineering Division
    - Human Science Division
    - Maglev Systems Technology Division
      - Yamanashi Maglev Test Center
    - Center for Railway Earthquake Engineering Research

(As of July, 2021)

IMPROVEMENT OF SAFETY

1. Seismic reinforcement method for masonry embankment type train platforms

- A method for seismic reinforcement of masonry embankment type train platforms using polyurea resin and soil nails has been developed.
- A reinforcement design method based on the yield seismic horizontal coefficient and a nomogram for calculating residual displacement has been proposed.
- The seismic reinforcement of platforms can be conducted at about 70% the cost of the conventional method for replacing platforms.

In past earthquakes, many of the masonry walls that make up masonry embankment type train platforms have tumbled or tilted, and seismic reinforcement methods to prevent such damage are required. Conventional seismic reinforcement requires the replacement of platforms, which is expensive. Therefore, we have developed a low-cost seismic reinforcement method that does not require replacement of platforms.

The developed reinforcement method combines spraying of polyurea resin to prevent slip-out of stacked stones, soil nails to prevent collapse, and angle materials to connect them (Fig. 1). Since this method does not require the replacement of platforms, it can be conducted for about 70% the cost of conventional methods. We also have proposed a design method for seismic reinforcement of the masonry embankment type train platform that combines the "yield seismic horizontal coefficient" obtained by calculating the stability at each level of the stacked stones during an earthquake and the "nomogram for residual displacement calculation" obtained by large deformation analysis using the meshless method to calculate the residual displacement of the masonry embankment type train platform (Fig. 2).

Using a full-scale model of a masonry embankment type train platform reinforced with the proposed design method, we verified the effect of seismic reinforcement under a large earthquake (maximum acceleration of 1000 gal), and found that the displacement at the top of the masonry wall was less than the limit value, confirming the effectiveness and validity of this design method for reinforcement (Fig. 3).

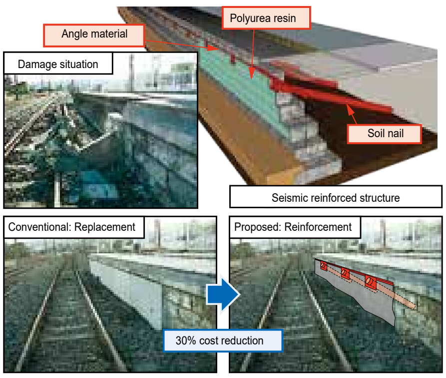


Fig. 1 Seismic reinforcement method for a masonry embankment type train platform

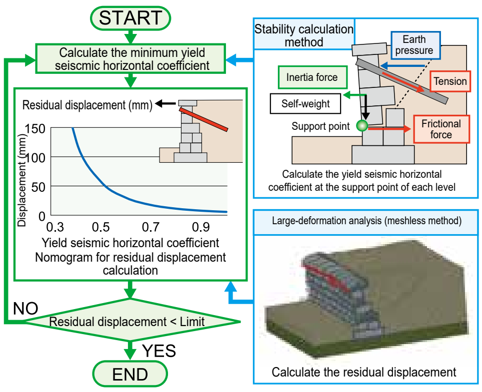


Fig. 2 Seismic reinforcement design method for a masonry embankment type train platform

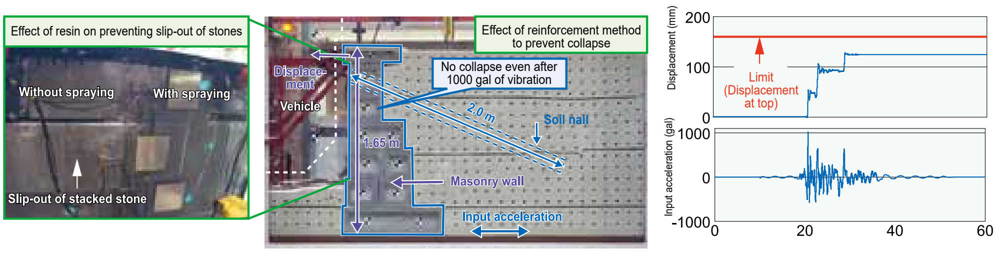


Fig. 3 Results of shaking table test using a full-scale model of a masonry embankment type train platform

2. Anti-bridge-collapse device with seismic control function that can be installed in narrow spaces

- An anti-bridge-collapse device having a seismic control function has been developed for railway bridges with steel piers.
- It is a compact device that can be installed even in narrow spaces, to reduce the response displacement during an earthquake by about 10 to 50% and prevent the bridge from collapsing when excessive displacement occurs.
- The design method of the device has been developed including the mounting part, so it is immediately applicable to actual bridges

Based on the fact that a road bridge with steel piers whose upper and lower ends were pin-supported was collapsed in the Kumamoto earthquake in 2016, the prevention of bridge collapse and the control of girder displacement are required for railway bridges with a similar structure (Fig. 1). Since many of these bridges are built over arterial roads or railways, due to the limited clearance under the girders and narrow spaces at girder bearings, existing counter-measures may not be able to prevent bridge collapse and control girder displacement at the same time. Therefore, as shown in Table 1, we have developed a device to satisfy the following four requirements; (1) to prevent bridge collapse, (2) to control girder displacement, (3) not to obstruct the space under the girders, and (4) possible to install in narrow spaces. As shown in Fig. 2, the developed device has a structure in which multiple steel rods fixed to the substructure by post-installed anchors are integrated into a frame and attached to the girder. The device is so small, about 0.4 m high with a base measuring 1.0 m x 0.4 m, that it can be installed in narrow places and places where the clearance under the girder is limited. It also features a seismic control function that controls girder displacement by absorbing energy thanks to the plastic deformation of steel rods, as well as a function that prevents the collapse of a bridge by controlling girder movement in the event of excessive displacement due to the high ductility of steel rods. By means of dynamic analysis simulating an actual bridge, it has been confirmed that the girder displacement after the failure of girder bearings can be reduced by about 10 to 50% (Fig. 3). A design method including the mounting part has been developed for this approach, and the adoption to actual bridges has been decided upon.

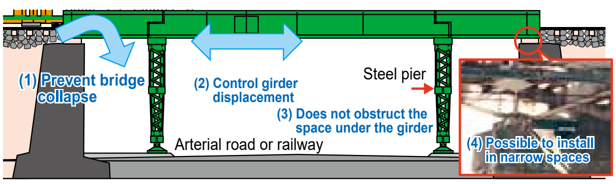


Fig. 1 Target bridge and performance requirements for the device

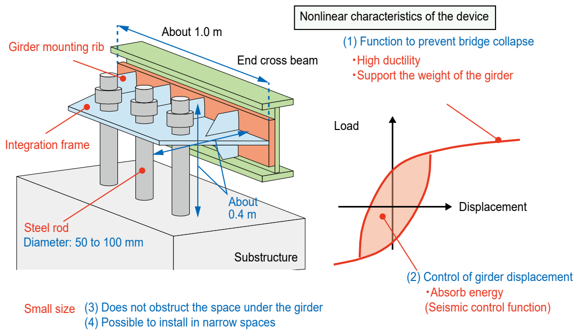


Fig. 2 Overview of the developed device

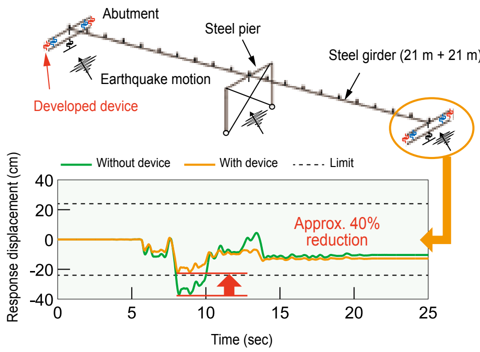


Fig. 3 Example of verification of effect by dynamic analysis

Construction method \ Performance requirements		(1) Prevent bridge collapse	(2) Control girder displacement	(3) No obstruction under the girder	(4) Possible to install in narrow spaces
Existing method	Expansion of girder seat	○	×	×	○
	Damper	×	○	×	△
	Bearing reinforcement	×	○	○	○
Developed device		○	○	○	○

Table 1 Performance comparison with existing methods

3. High-accuracy estimation method for earthquake motion at bedrock during large-scale earthquake

- A method to estimate the earthquake motion at bedrock using seismic observation records at the surface during large-scale earthquake has been proposed.
- It can be used to find out the cause of damage to structures, vehicles, and electric power poles after an earthquake, and to shorten the restoration time.
- Compared with the conventional method, estimation error is reduced to 1/6 and calculation time to 1/30.

In order to evaluate the surface earthquake motions over a wide area, we first need to estimate the earthquake motions at bedrock [Fig. 1 (b)] excluding the effect of the surface layer, and then add the effect of the surface layer in each area to them. The ground motion at surface of large-scale earthquake [Fig. 1 (a)], however, is much affected by the nonlinearity of the surface layer. Furthermore, the observation record on the surface only reflects the local soil character at the set-up point of the seismometer. It is difficult to properly remove this effect and estimate the earthquake motions of bedrock with high accuracy using conventional methods.

To solve this problem, we have proposed a method to estimate the earthquake motions of bedrock from motions at surface with high accuracy by devising a way to search for the solution in the convergent calculation. In the proposed method, single degree of freedom (SDOF) analytical model is used in the initial stage of the calculation. A model would be altered to the detailed analytical model with multi degree of freedom system after the result derived by the simple SDOF model is converged to some extent, by which faster calculation is achieved. As a result of estimating the earthquake motions of bedrock using the proposed method, the large amplitudes of motion, which are difficult to estimate with the conventional method, can be well reproduced. In addition, compared with the conventional method, estimation error can be reduced to 1/6, while shortening calculation time to 1/30 (Fig. 3).

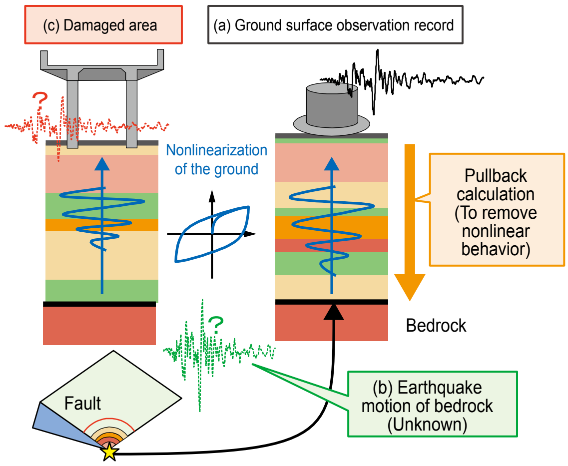


Fig. 1 Propagation of earthquake motion

By using the proposed method, we can improve the accuracy for estimated earthquake motions at the site without observation record during a large-scale earthquake, and find out the causes of damage to structures, vehicles, and electric power poles in more detail. It can also be utilized to improve the accuracy in the spatial distribution of ground motion in the Damage Information System for Earthquake on Railway (DISER), which can be used to efficiently extract the points to inspect after an earthquake and shorten the restoration time.

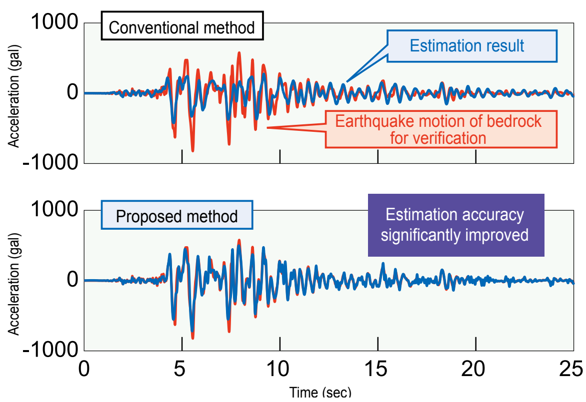


Fig. 2 Estimation results of earthquake motion of bedrock

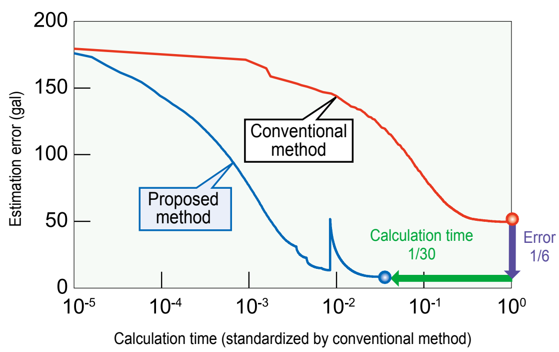


Fig. 3 Relationship between estimation error and calculation time

4. Method to control snow accretion around a bogie using traveling wind

- For Shinkansen, a method to control snow accretion by combining an intake that draws in traveling wind and a nozzle that blows it onto bogies has been developed.
- From model experiment and numerical analysis, it was confirmed that the amount of snow accretion around the body plate behind a bogie was reduced by 30 to 50%.

In recent years, Shinkansen lines have been extended to snow-covered areas such as Hokkaido and Hokuriku, and countermeasures against snow have become an issue in these areas. Therefore, in order to improve safety with respect to snow dropping from vehicles and to reduce the work load of removing snow accretion in snow-covered areas in winter, we have developed a method to control the flow of snow particles around the bogies and reduce the snow accretion mainly around the body panels behind a bogie.

This method consists of an intake that draws in traveling wind from the side of a bogie and a nozzle that blows the drawn-in air out onto the body panel behind the bogie (Fig. 1).

As a result of running tests using a model and snowfall wind tunnel tests conducted to reproduce the advection of snow particles onto bogies and snow accretion, we found that the mass of snow accretion on the body panel behind the bogie could be reduced by about 50% [Fig. 2 (a)]. In addition, the results of a simulation using a shape that was expected to control snow accretion in the model experiment, it was confirmed that the number of accreted snow particles around the body panel behind a bogie was reduced by about 30% [Fig. 2 (b)]. Furthermore, we investigated the effect of intake shape on aerodynamic sound using a large low-noise wind tunnel, and confirmed that the increase in noise due to the addition of countermeasures against snow accretion could be controlled to less than 1 dB.

In the future, we will apply this method to actual vehicles to verify the effect on preventing snow accretion and its impact on the increase in noise.

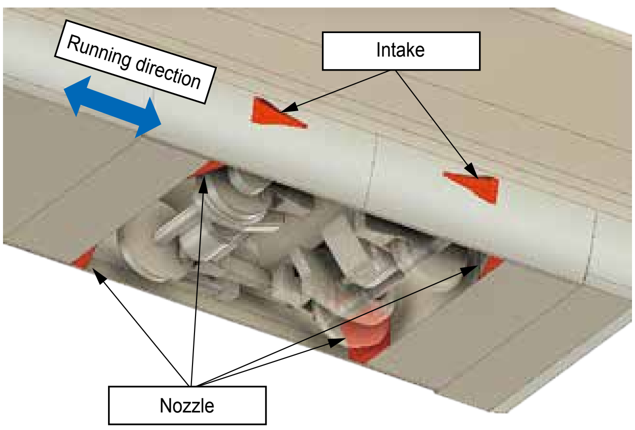


Fig. 1 Intake and nozzle layout

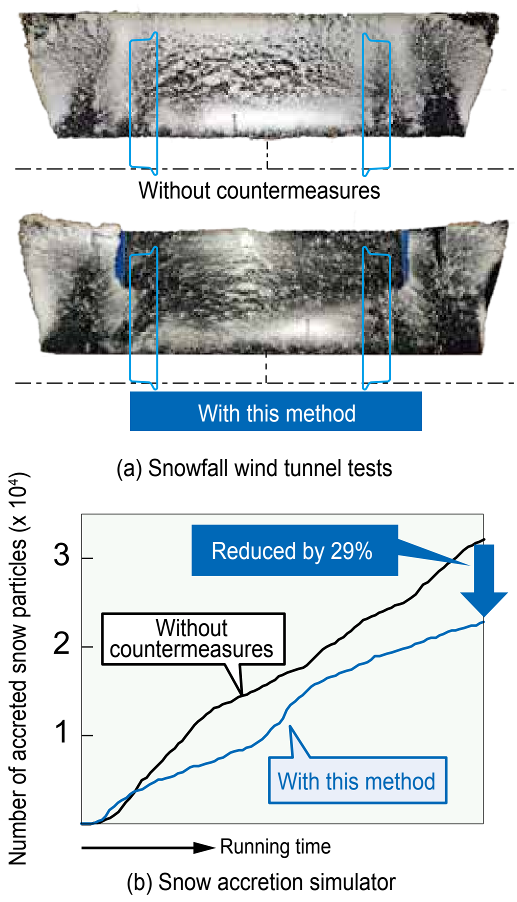


Fig. 2 Estimation of snow accretion control effect

5. Method for detecting obstacle on railway tracks using an on-board monocular camera

- A method for detecting obstructions on railway tracks using a monocular camera mounted in the cab has been developed.
- It was confirmed that the system can detect a person standing in daylight at a distance of 300 meters with a probability of 98%.
- The system can be used to support the driver in detecting obstructions in front of the train.

When drivers detect an obstruction in front of the train, they take measures such as stopping or slowing down. In such cases, if automatic detection of obstacle in front of the train were possible, the burden on the driver would be reduced and safety would be enhanced.

In order to replace or support forward monitoring by visual observation, we have developed a forward monitoring method using an on-board monocular camera that targets people on the platform or on the railway tracks. Unlike sign markers, the person to be detected may differ in shape, posture and clothing, so there is a limit to the detection performance by general image processing methods. To solve this problem, we used deep learning, which learns the characteristics of people based on hundreds of thousands of human images to enable detection.

The developed system using a 4K camera was able to detect a standing person at a distance of 300 m in daylight with a probability of over 98%, and a person at a distance of up to 475 m could be detected (Figs. 1 and 2). It can also be used to support the detection of obstacle in front of the train, as an alarm can be issued within one second after a person enters the railway tracks, whether standing still or moving, and real-time detection is possible.

We will expand the range of detection targets, to include a car on the railway track, sinking of railway track, earth inflow, rockfalls, and fallen trees, and extend the detection distance. In addition, we will develop the system to be able to detect various events in front of the train irrespective of day and night by using it in combination with ground-based monitoring technology for sharp curves where visibility is poor and with LiDAR at night. The system can also be utilized for automatic train operation on general routes with level crossings in the future.

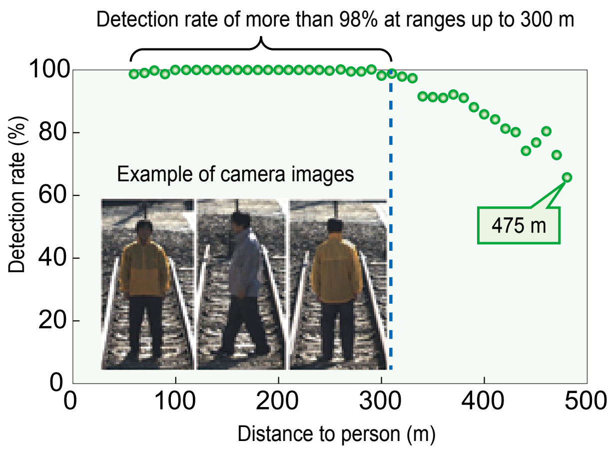


Fig. 1 Detection rate by detection distance for a person standing in daylight.

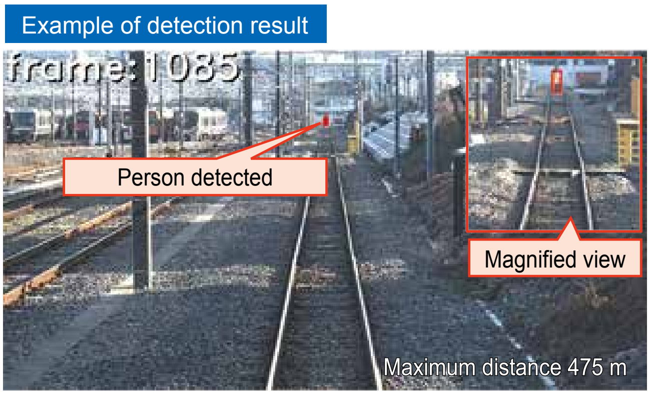


Fig. 2 Example of a person detected by the system at a distance of 475 m

6. Method to detect passengers approaching vehicles using vehicle side cameras

- A method to detect passengers, etc. approaching vehicles using cameras mounted on the sides of vehicles has been developed, and it has been confirmed that no person is overlooked or misdetected irrespective of day or night.
- It has also been confirmed that the maximum detection error of the passenger's position on the platform is about at most 20 cm, which is accurate enough not to overlook the person outside the Braille blocks.
- The system can also be used to support the driver in one-man operation.

Safety confirmation on the platform when a train departs has been done visually by the train crews. In anticipation of the future shift to one-man operation even for a long set of trains, it is required to automate the safety confirmations on platforms. Therefore, we have developed a method to automatically detect the approach of passengers to vehicles by attaching cameras to the side of the vehicles and analyzing the images from the cameras, and thus confirm the safety of the platform when the train departs.
Four cameras are mounted at both ends of the vehicle, front, rear, left and right, per vehicle. At the time of departure, the system detects persons by analyzing images from two cameras on the platform side and estimates where the person is standing on the platform by making station equipment such as Braille blocks as markers and using a coordinate transformation technique called projective transformation (Fig. 1). If the estimated position of the person is judged to be too close to the vehicle, the crews are notified by sound and light. By processing 10 frames of images in a second, it is possible to give notification of any approach in real time. As a result of an evaluation using a prototype device incorporating the developed method, we confirmed that no person was overlooked irrespective of day or night, that the maximum detection error of the person's position was about 20 cm, which is about a half of that of Braille blocks with inward lines, and that it was accurate enough not to overlook a person outside the blocks (Figs. 2 and 3).
This method can be utilized to support the safety confirmation by the driver in one-man operation, as well as for safety confirmation on platforms in future automatic operation. We will expand the detectable targets to include wheelchairs, baby strollers, and running-in passengers and create a system to ensure the safety of all on platforms.

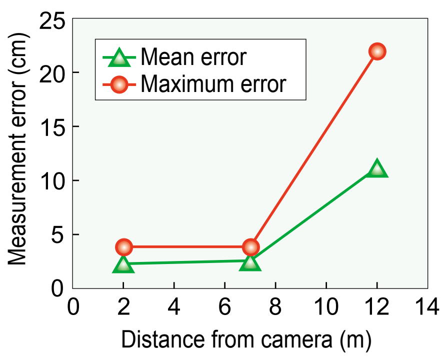


Fig. 2 Measurement errors according to distance from the camera

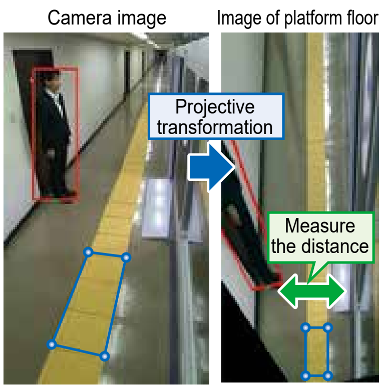


Fig. 1 Coordinate transformation of a person by projective transformation

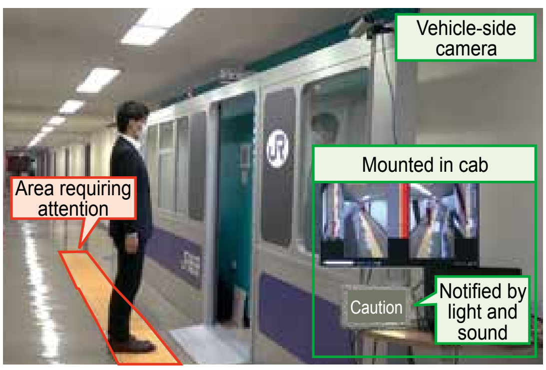


Fig. 3 Testing detection conditions using a prototype device.

7. Brake control method to compensate for reduced braking force

- A brake control method that can be introduced in addition to the existing brake control system to improve the stop position accuracy has been developed.
- The system automatically updates the brake command even when the braking force suddenly drops, maintaining the accuracy of stopping at the target position.
- It can be utilized to assist the driver in improving the accuracy of the stop position and during automatic train operation.

In the current braking system, the deceleration effect is not constant even with the same brake command due to weather conditions and functioning conditions of regenerative brake, etc. So, the driver or the train automatic stop control (TASC) adjusts the brake command to compensate for the variation in deceleration effect and ensure the accuracy of the stop position. In response to this, we have developed a control method that automatically updates the brake commands, aiming to develop a braking system that itself can detect the variation in the deceleration effect to improve the accuracy of the stop position, without relying on the driver's operation or external devices.

For the developed control method, a new control device is added to the existing brake control system, and when this device receives a brake command or the data of distance to the stop position, it updates the control brake command based on the speed fed back from the train and gives it to the system (Fig. 1). This allows the deceleration of the train to follow the target value calculated from the remaining distance to the stop position, and if the braking force is insufficient, the control brake command is updated sequentially (Fig. 2).

As a result of tests including forcibly reducing the braking force while the train was running on the test line within the RTRI, we confirmed that the developed control method was able to control the extension of the braking distance and maintain the accuracy of the stop position even when the braking force was suddenly reduced (Fig. 3).

By adding this method to an existing brake control system, it is possible to assist the driver's operation to improve the accuracy of train stop position. It can also be utilized for automatic train operation to be realized in the future.

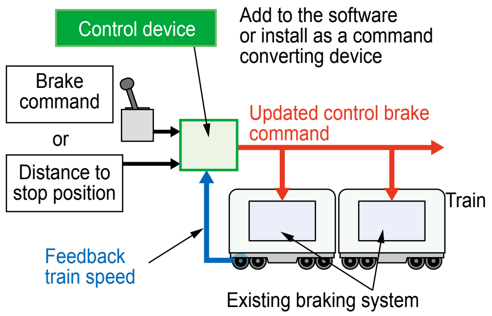


Fig. 1 System configuration of the developed method

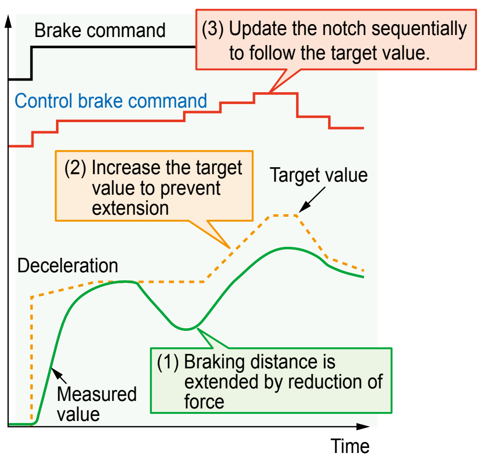


Fig. 2 Control operations of the developed method

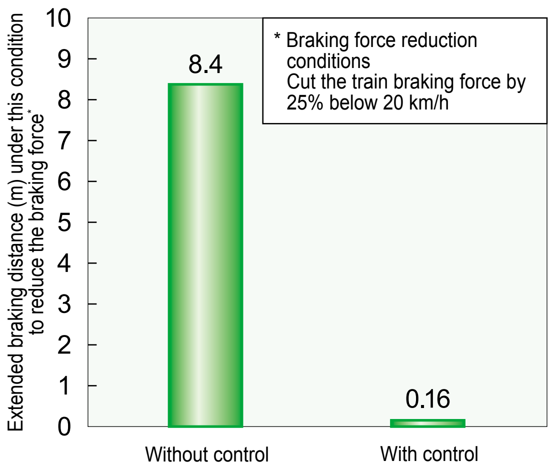


Fig. 3 Controlling braking distance extension when braking force is reduced
(Running test: initial speed 30 km/h)

8. Vehicle-mounted measuring device for gauge and twist under loaded condition

- A low-cost, vehicle-mounted device that can measure the dynamic values of gauge and twist under loaded condition, which often cause derailment accidents, has been developed.
- It can improve the running safety on service lines and in depots where track inspection cars are not used.
- By running tests, it has been confirmed that the variation in the measurement results is about the same as that by track inspection car, and that the measurement results generally coincide with those by track inspection car. Unmanned measurement is also possible.

Because track inspection cars that measure track irregularity under loaded condition are expensive, hand-pushed measuring device is often used to control static track irregularity without applying the load of vehicles. However, such measuring device cannot measure the track irregularity under loaded condition affected by the wheel load and lateral force when the vehicle is running, so significant track irregularity may be overlooked. Therefore, we have developed a measuring device that can be mounted on maintenance cars and commercial vehicles to measure gauge and twist under loaded condition, which often cause derailment accidents. This device is about 1/10 the price of the previously developed on-board inspection device.

This device (Fig. 1) consists of a sensor unit that measures track irregularity and a controller that processes the pulse signals from the Doppler sensor to obtain the running distance and speed. The sensor unit measures gauge, cross level, and twist by combining the output of the angle sensor with the relative irregularity of the rail measured by the two-dimensional sensor.

Through running tests, we have confirmed that the device satisfies the reproducibility required for a conventional track inspection car (error (=standard deviation of the difference between the two measurements): gauge: 0.5 mm, twist: 1.0 mm) and that the results are consistent with those measured by the track inspection car (Fig. 2).

In addition, the detection error of measured position using GNSS positioning results is less than 25 cm (Fig. 3), so unmanned measurement is possible by utilizing the remote control function.

This device enables measurement of dynamic track gauge and twist on service lines and in depots, where track inspection cars have not been used before, thereby improving running safety.

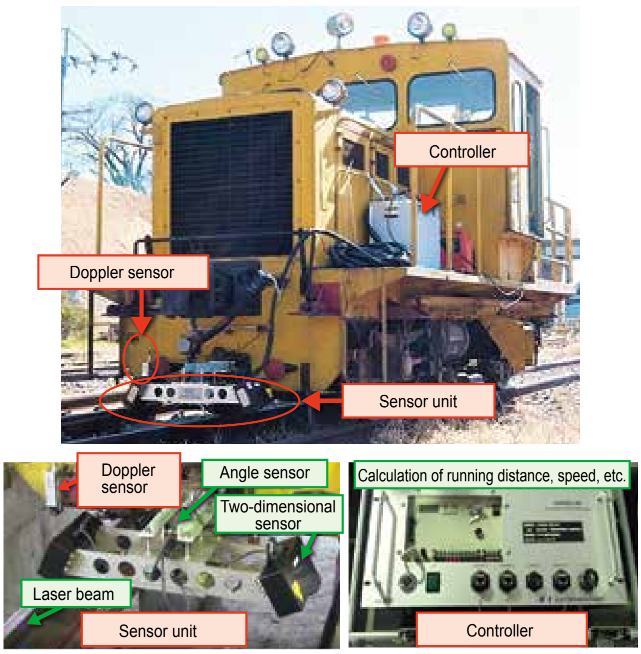


Fig. 1 Vehicle-mounted measuring device for gauge and twist under loaded condition

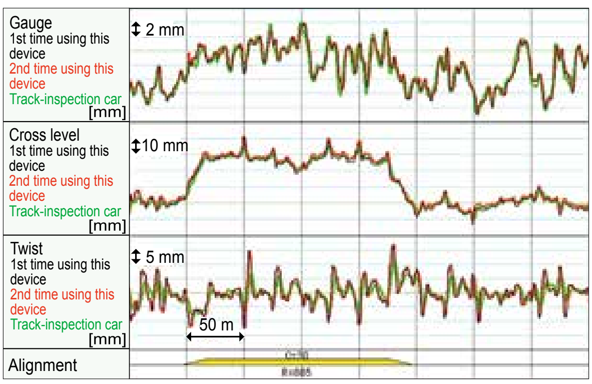


Fig. 2 Measurement results

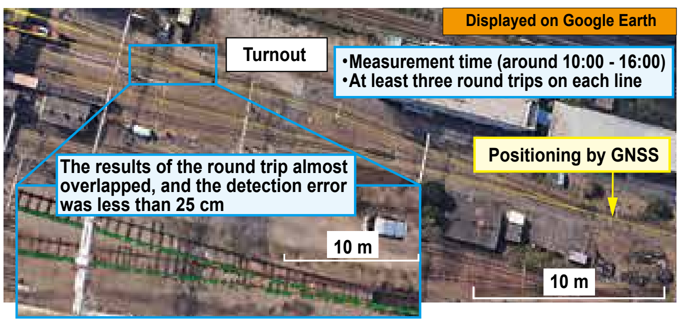


Fig. 3 High accuracy detection of measurement position by GNSS (green line)

9. Restoration techniques for embankments reusing collapsed soil

- A method of restoring embankments by reusing soil collapsed due to heavy rains, etc. has been proposed.
- It takes advantage of the dehydration effect of lime and the increase in the strength of soil due to compaction.
- The construction period and cost required for restoration of embankments can be reduced by 10 to 20% compared to conventional methods.

In recent years, there have been many cases where embankments are damaged by heavy rains, etc. When an embankment collapses due to heavy rain, it is difficult to compact the soil after the collapse again because it contains a large amount of water. In addition, since the materials used to construct the old embankments did not meet the current regulations in many cases, the soil needed to be purchased for restoration, which posed a problem in terms of construction period and cost. To address these issues, we have proposed a method of restoring embankments by adding lime to the soil collapsed due to heavy rains and compacting it for reuse.

This method utilizes (1) the dehydration effect of lime and (2) the increase in the soil strength due to compaction. As for (1), because only the dehydration effect is expected of the lime, an indoor mixing strength test is not necessary, and the required additive rate of lime can be easily calculated by substituting the water content of the soil after the addition of lime into the theoretical formula obtained from the chemical reaction formula of lime and water [Fig. 1(a)]. As for (2), after dehydration with lime, construction is carried out so that the degree of compaction becomes the target degree of compaction obtained from the required strength using the relational expression between the degree of compaction and strength [Fig. 1 (b)]. Since this formula reflects the increase in soil strength due to the increased degree of compaction, even if the collapsed soil is made of materials that do not meet the current regulations, it can be reused by increasing the degree of compaction. With this method, the construction period and cost required for restoration of embankments after heavy rains and earthquakes can be reduced by about 10 to 20% compared to conventional methods. For a case where the embankment collapses due to an earthquake, the collapsed soil can be reused by using only the relational expression between the degree of compaction and strength shown in Fig. 1 (b).

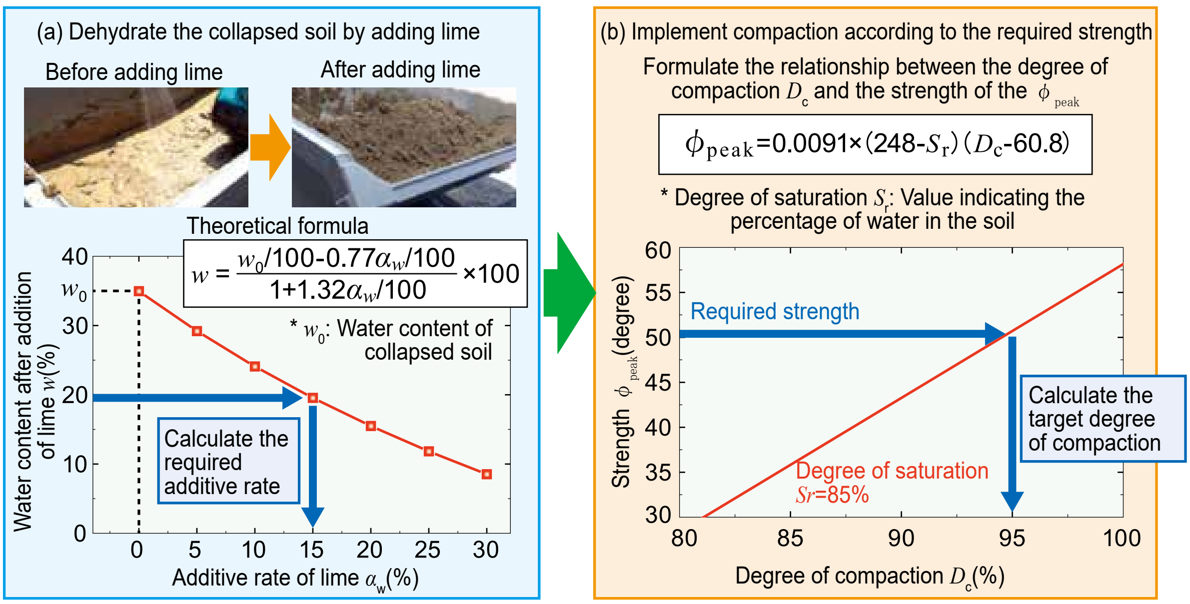


Fig. 1　Restoration method of embankments using the dehydration effect of lime and the increase in the strength of soil due to compaction

10. Structural performance evaluation of existing bridges by acceleration monitoring

- An algorithm that can estimate deflection and reinforcing bar stress of a concrete bridge from its acceleration monitoring waveform in less than one second with high accuracy has been developed.
- Quantitative evaluation of structural performance, such as train running performance and fatigue safety, and determination of the need for repair or reinforcement can be performed without field measurements that require a great deal of labor.

Some of Shinkansen bridges have been observed to have significant vibration due to resonance caused by passing trains. The maintenance of existing bridges is generally conducted only by visual inspection, while quantitative data such as deflection and reinforcing bar stress are periodically required to accurately evaluate structural performance such as train running performance and fatigue safety, posing issues of increased labor and cost.

Therefore, we have developed a method to estimate the deflection and reinforcing bar stress when a train passes by with high accuracy, using the records of acceleration sensors installed on the bridge. The accuracy of acceleration sensors is decreased in the low-frequency range due to noises. To solve this problem, we have developed an algorithm that replaces the low-frequency component of the acceleration waveform with a waveform based on vibration theory and integrates it into the deflection waveform, as well as an algorithm that estimates the stress waveform of reinforcing bars from the deflection waveform without performing detailed cross-sectional calculations, by considering the increase in stress on reinforcing bars due to cracks in the concrete (Fig. 1). This has made it possible to evaluate the train running performance, such as riding comfort due to deflection, and fatigue failure due to reinforcing bar stress, from the measured acceleration waveform of the bridge. This method can estimate the deflections and stresses with an estimation error of less than 10% for an existing standard concrete girder by high-speed processing of less than one second. The validity of this method has been verified by comparing it with numerical experiments and stress measurements on actual bridges.

By applying this algorithm to acceleration monitoring, which is small and can be installed permanently, it is possible to evaluate the structural performance quantitatively and determine the need for repair or reinforcement of bridges that, for example, resonate when a train passes by without much labor (Fig. 2).

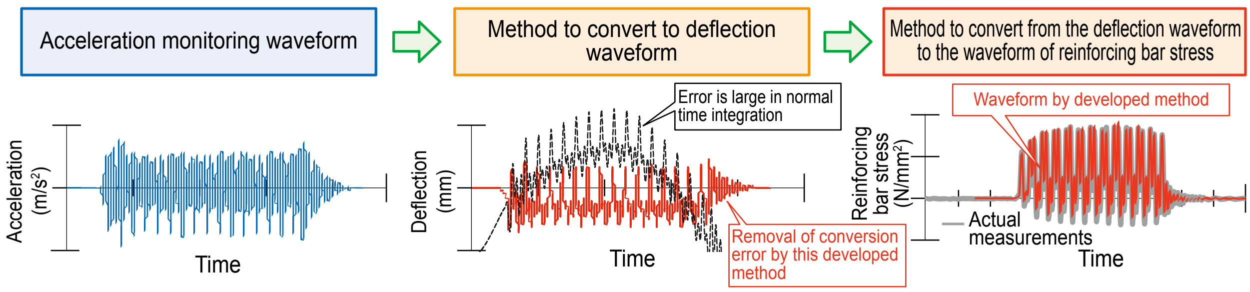


Fig. 1 Method of integrating acceleration waveform into deflection and converting deflection waveform into stress on internal reinforcing bars

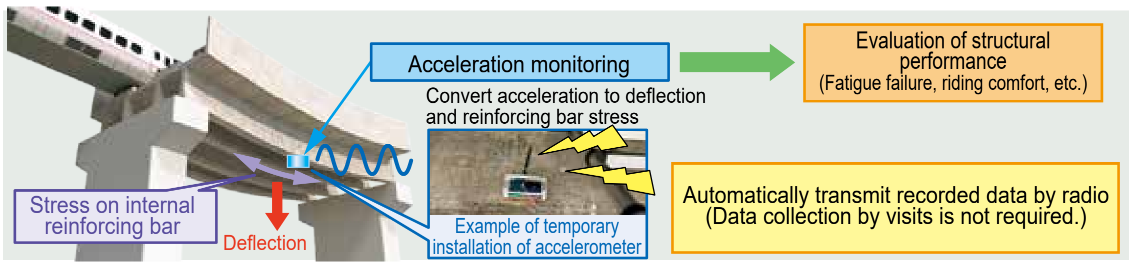


Fig. 2 Evaluation of structural performance of existing bridges by acceleration monitoring

11. Multi-point synchronous measurement system for railway bridge vibration using a video camera

- A system that can synchronously measure the vibration of multiple arbitrary points on a railway bridge using a video camera has been developed.
- The system uses videography to measure the dynamic deflection of railway bridges, the natural frequencies of ancillary structures, and the micro displacements of bearings while trains are passing by, to evaluate their health efficiently.

In order to improve the efficiency and sophistication of inspections using vibration measurement, which can evaluate the dynamic characteristics of structures with objective numerical data, we have developed a multi-point synchronized vibration measurement system using a 4K video camera capable of high-speed imaging (Fig. 1), and applied it to the inspection of railway bridges. The displacement of a railway bridge caused by a running train is calculated from the amount of change in the video image and the ratio of the sizes between the actual size and the image of the object being photographed. With this method, it is possible to measure vibrations at multiple arbitrary points in the captured image synchronously by simply shooting a video without setting up a target on the object being measured.

If the camera is shaken by wind, etc. during shooting, an error is caused. However, the proposed method automatically finds immovable points in the image such as bridge abutments that do not move even when a train passes by, and corrects the error caused by the vibration of camera by determining the relative vibration between the immovable points and the point to be measured. In addition, the displacement by vibration can be obtained in actual amplitude by determining the relationship between the gap and the actual size at any point in the image based on the result of simple measurement using the attached range finder. By shooting a video of the railway bridge when a train passes by from a riverbank, etc., the dynamic deflection and vibration shapes of the railway bridge can be measured (Fig. 2), and the deflection angle and bending moment of the bridge can be estimated from the differentiation of the deflection. It can also efficiently measure multiple posts for overhead contact lines, etc. at once. Moreover, it can measure horizontal, vertical, and rotational displacements of the bearing with an accuracy of less than 0.1 mm and 0.1 degrees, respectively, which is difficult to measure visually (Fig. 3). Periodical measurements will help to find the deformation of bearings, such as damage and movable parts sticking. In this way, this system can achieve sophisticated labor-saving inspections.

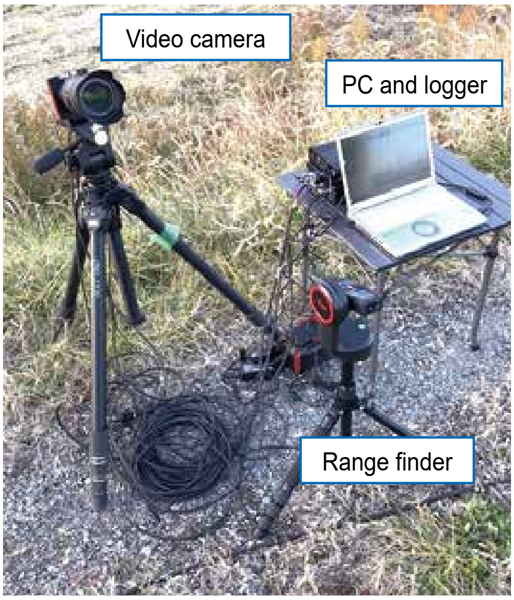


Fig. 1 Multi-point synchronous vibration measurement system using a video camera

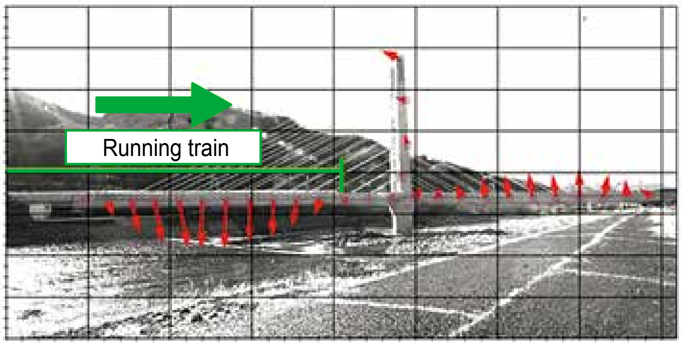


Fig. 2 Visualization of the dynamic behavior of a long span bridge when a train passes by.

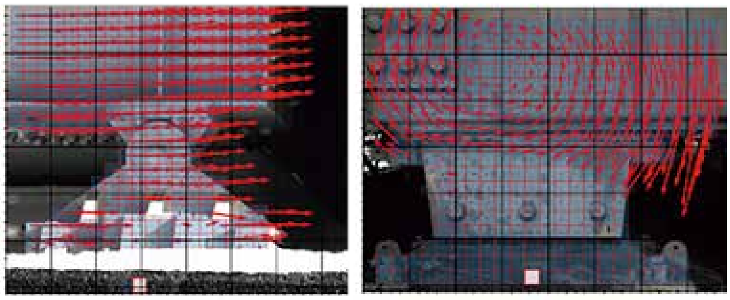


Fig. 3 Visualization of micro-behavior of bearings

12. Low-cost deterioration evaluation method for the backside ground of slope protection works

- A low-cost and short-time test method to evaluate the degree of deterioration of the backside ground of slope protection works has been developed.
- The stability of the slope can be determined according to the result of the above test.
- A maintenance manual for slope protection work has been prepared to outline the main points of the inspection method and countermeasure method.

Since there is a risk of collapse on slopes where the ground of the backside of the slope protection work is deteriorating, it is necessary to maintain the slope protection work according to the degree of deterioration of the backside ground. To address this issue, we have developed a low-cost and easy-to-use horizontal cone penetration test method (Hereinafter referred to as HPT) to evaluate the degree of deterioration of the backside ground and a slope stability evaluation method using a nomogram.

In the HPT, a rod is driven horizontally through existing weep holes in the slope protection work to the backside ground to determine the Ne value (Resistance value of HPT) (Fig. 1). Using the newly proposed conversion formula, this value can be converted to the Nd value of the method for portable dynamic cone penetration test (JGS 1433-2012, Hereinafter referred to as DPT), which is widely used in railways (Fig. 2), and the thickness of the degraded and sedimented part of the ground is determined (Fig. 3). The test can be carried out in about 10 minutes for one point without removing the slope protection work, which is about 1/20th of the cost and 1/30th of the time required for a conventional boring investigation of the backside ground. In addition, by using the newly created nomogram, the stability of the slope protection work can be determined from the test results (Fig. 4).

We have compiled the results of these studies, examples of health judgments to be utilized for visual inspections, and the main points of countermeasure methods to create a maintenance manual for shotcrete slope protection works. This manual also describes the simple elastic wave exploration, which was developed as an inspection method for rock slopes that are not suitable for penetration tests and can be used as a comprehensive maintenance manual.

Fig. 1 Horizontal cone penetration test

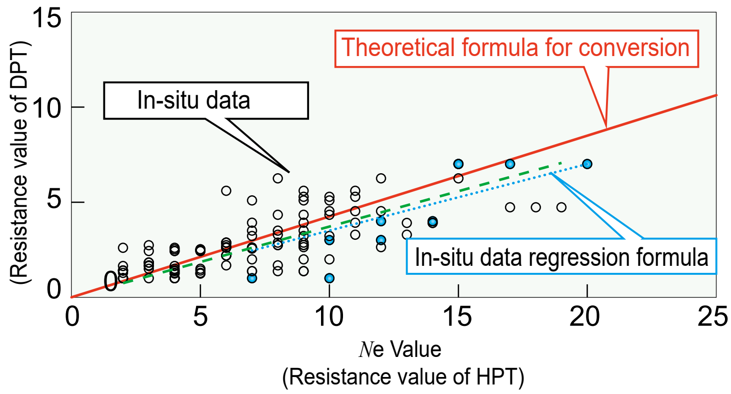


Fig. 2 Conversion of Ne values to Nd values

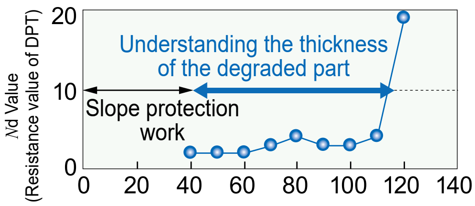


Fig. 3 Example of HPT results

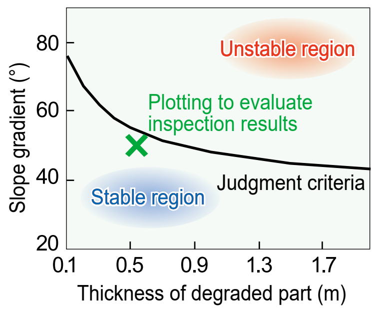


Fig. 4 Example of a nomogram for evaluating slope stability

13. Boring method for constructing a crossing structure under railway tracks making it possible to shorten the construction period

- A boring method for constructing a crossing structure under railway tracks that can control the amount of settlement of the track surface to the same level as before and shorten the construction period has been proposed.
- The cost of measuring and managing tracks during boring and track maintenance can be reduced by approximately 50%.
- A settlement prediction analysis method has been developed to be used to determine whether countermeasures such as grouting are necessary.

Construction of tunnels, including roads that cross under railway tracks, is underway to eliminate level crossings. When constructing a tunnel crossing under railway tracks, a temporary tunnel using square steel pipes is constructed in advance. With the conventional method, square steel pipes are inserted one at a time for boring to create a closed cross-section (Fig. 1), while track measurement and management, track maintenance, and grouting are carried out, so it requires a longer construction period and higher cost compared to general tunnel construction.

Therefore, for constructing a temporary tunnel, we have proposed a stepped boring method that can control the amount of track settlement at the same level as before (Fig. 2). The step-boring method is a method of boring the second square steel pipe simultaneously with a certain "separation" and a time difference from the preceding first pipe. The appropriate amount of separation was clarified by model experiment (Fig. 3). By boring two pipes at the same time, the construction speed can be almost double that of boring one pipe at a time. This can reduce the time required for boring by half and the cost of track measurement and management and track maintenance during boring by about 50%.

If the railway tracks and square steel pipes are in close proximity to each other, it will be necessary to determine whether countermeasures such as grouting to prevent settlement are necessary. In order to do this accurately, we have developed a numerical analysis method that can precisely predict the amount of track settlement (Fig. 4).

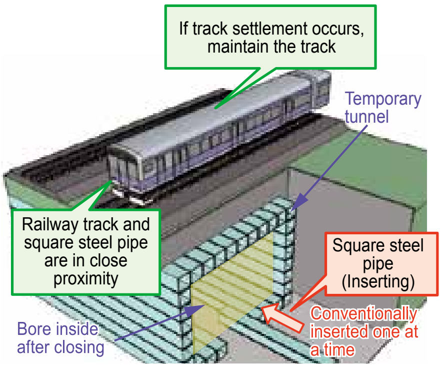


Fig. 1 Overview of constructing crossing structure under railway tracks

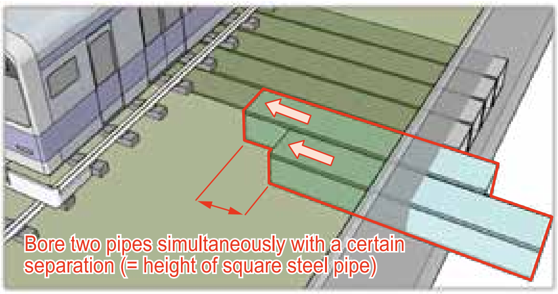


Fig. 2 Step-boring method

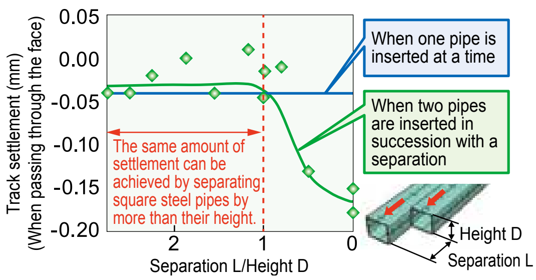


Fig. 3 Relationship between separation and track settlement

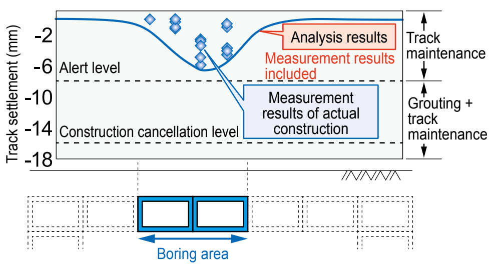


Fig. 4 Verification of the numerical analysis results of track settlement

14. Maintenance method for prestressed concrete sleepers according to the installation environment

- A method to evaluate the soundness of prestressed concrete sleepers (PC sleepers) based on their natural frequencies and the degree of deformation caused by frost damage and salt injury has been proposed.
- A maintenance flow and standard replacement criteria according to the installation environment have been proposed.
- These methods can be utilized for the efficient replacement and maintenance of PC sleepers.

For the maintenance of PC sleepers, visual inspection is used to check the surface condition to determine the need for replacement. In recent years, the number of PC sleepers that have exceeded their designed service life of 50 years is increasing, so systematic maintenance based on engineering evidence is required more than ever before. Therefore, we have proposed a method to quantitatively evaluate the soundness of PC sleepers, as well as a maintenance method according to the installation environment.
For the soundness judgment, we have proposed a method to evaluate the soundness of PC sleepers based on their natural frequencies, which can be obtained by hammering sound, and the degree of deformation caused by frost damage and salt injury. For example, in the case of 3PR-sleepers specified in JIS E1201, in an environment where there is a possibility of frost damage, we found that the standard thresholds for soundness judgment were the natural frequency to be 750 to 800 Hz, and the area where scaling (deterioration of concrete accompanied by flaking and falling) occurred due to frost damage to be 40% of the top surface of the PC sleeper. Furthermore, taking the differences in the environment in which PC sleepers are installed into consideration, we have proposed a maintenance flow by categorizing the areas into general environment and areas with a high risk of frost damage and salt injury (Fig. 1). In areas where scaling due to frost damage (Fig. 2) is observed, the soundness of the sleepers is determined based on scaling and natural frequencies. For other frost damage, salt injury, and general environments, we have proposed replacement criteria based on the cumulative passing tonnage as an index, indicating that the sleepers can no longer satisfy the JIS standard values for bend tests (Table 1).
This enables maintenance according to the installation environment and can be utilized to formulate a replacement plan of PC sleepers.

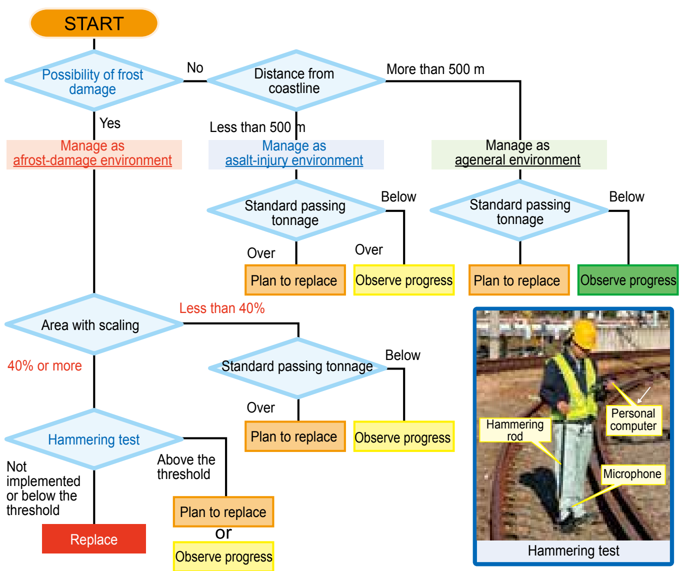


Fig. 1 PC sleeper maintenance flow

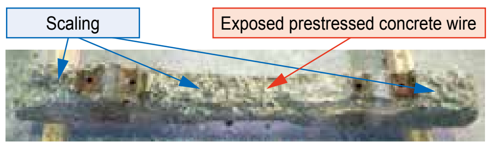


Fig. 2 PC sleeper with scaling damage

■Replacement criteria in general environment

JIS-Sleeper type	Standard passing tonnage (billion tons)	
	Average-base	Lower limit-base
3PR (straight)	30	15
3PO (straight)	12	5
6PR (curve)	30	20
6PO (curve)	15	5

■Replacement criteria for frost-damage and salt-injury environments

Type	Standard passing tonnage (billion tons)
3PR (straight)	15 *
3PO (straight)	5 *
6PR (curve)	20 *
6PO (curve)	5 *

* These values are not applicable to the section where scaling is observed in PC sleepers that do not use air-entrained concrete.

Table 1 Example of PC sleeper standard replacement criteria

15. Low-cost ballastless tracks for existing lines and roadbed improvement method

- A ballastless track for existing lines to fill the ballast layer with superfine-particle-cement fluid has been developed. It is also applicable to a ballasted track that turned into a mud-pumping state by performing partial ballast renewal.
- A post-filling roadbed improvement method that can be carried out with ballastless track construction has been developed, and a design method for roadbed improvement that takes the amount of roadbed settlement and fatigue failure of the grouted ballast layer into account has been proposed.

In order to reduce track maintenance costs, a construction method to convert an existing ballasted track into a ballastless track with low cost is required. As a new elemental technology to address this issue, we have developed the "ballastless track with superfine-particle-cement (SFC) fluid," which utilizes existing ballast, and the "post-filling roadbed improvement method," which can be laid on relatively soft ground.

For the SFC grouted ballastless track, highly permeable superfine-particle-cement fluid, which can be grouted into deteriorated ballast, is used. Normally, the existing ballast is utilized, but if mud pumping occurs, the ballast is grouted after partial ballast renewal (Fig. 1). With this method, the construction cost can be reduced by 40 to 50% compared to the conventional grouted ballasted track that requires renewal of the ballast for the entire track. Especially in mountain tunnel sections where the construction unit price of ballast renewal is relatively high, conversion into a ballastless track with SFC fluid can be achieved at the same cost as ballast renewal. Conversion into a ballastless track with SFC fluid is expected to reduce the maintenance cost in sections where mud pumping of ballast frequently occurs due to the mixture of fine particle soils.

The post-filling roadbed improvement method is to replace the roadbed improvement layer to the new ballast first and then fill the grout material to make the layer more solid later for improving the roadbed to install the ballastless track on soft ground. This can be carried out at the same time as the ballastless track construction (Fig. 2). This makes it possible to install a ballastless track on soft ground even under the condition of a short period of time available for track maintenance. With this method, the construction cost can be reduced by about 60% compared to the conventional roadbed improvement method. In addition, we have proposed a design method that takes the amount of roadbed settlement and fatigue failure of the grouted ballast layer of a ballastless track into account.

These methods will be reflected in the "Guide to Repair and Improvement Methods for Track and Roadbed on Commercial Lines."

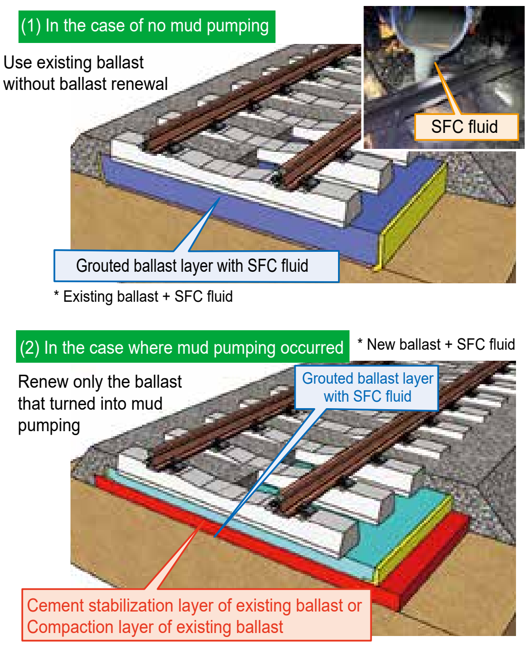


Fig. 1 Ballastless track with SFC fluid

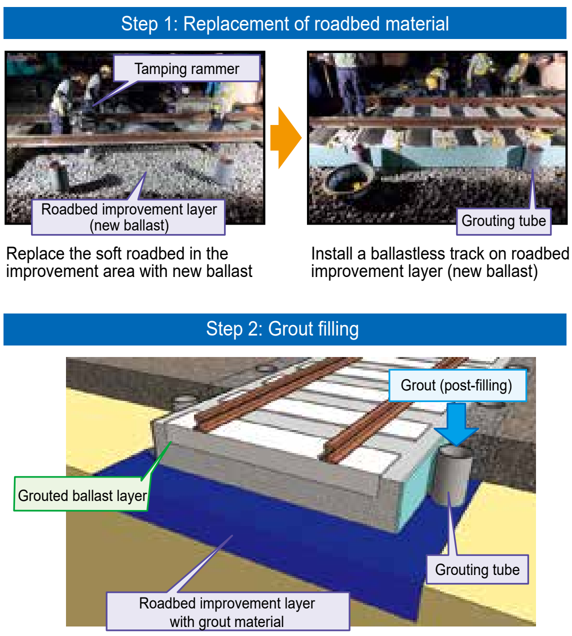


Fig. 2 Post-filling roadbed improvement method

16. The image analysis engine for around track to support train patrol

- An analytical engine has been developed in order to automatically detect objects around the railway tracks and changes in the wayside environment that may interfere with running trains, based on images taken by cameras installed at the front of the train.
- The system can reduce the frequency of train patrols by accompanied persons in charge, and is used as a system to support train patrols on commercial lines.

In order to comprehensively monitor the degradation condition of the railway tracks and changes in the wayside environment, large amount of patrol works are conducted on foot or from the train, therefore it is necessary to introduce a system to reduce the burden on persons for the works while ensuring safety. Aiming to support train patrol works, we have developed an analytical engine for images around railway tracks that can automatically detect objects and changes in the wayside environment that may interfere with running trains.

This analytical engine sets arbitrary spatial regions, such as a clearance gauge, on the 3D data constructed from images taken by a stereo camera installed at the front of the train, and diagnoses the presence of objects existing inside the region. In doing so, by estimating the alignment from the rails in the image, it is possible to set up a spatial region corresponding to the shape of curved line (Fig. 1).

With the difference detection technique to automatically link the images taken at two different times along the same section and detect the differences between the two images, it is possible to detect the appearance or disappearance of objects on the wayside as well as changes in position and shape (Fig. 2).

By automatically extracting areas that require attention with this analytical engine, during train patrol services conducted by persons in charge accompanied on the train, it is possible to not only make diagnosis without depending on the skill level of the person in charge and reduce the number of oversights, but also reduce the frequency of train patrols by persons in charge. A part of this analytical engine (confirmation of interference in clearance gauge) has been introduced into the train patrol support system of JR Kyushu, and has been in operation since April 2020.

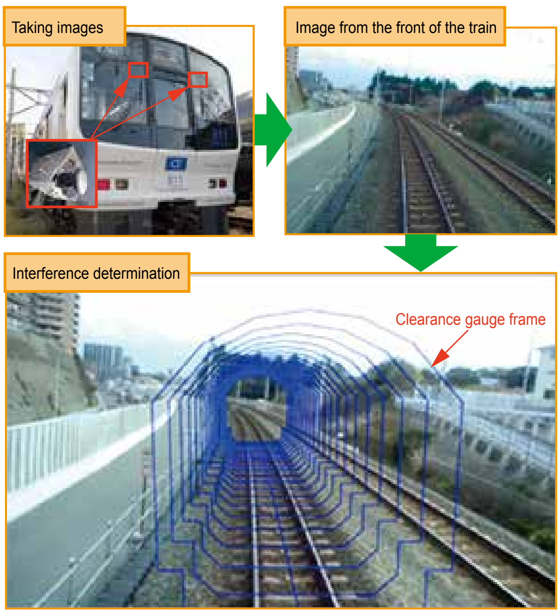


Fig. 1 Example of interference confirmation by 3D measurement

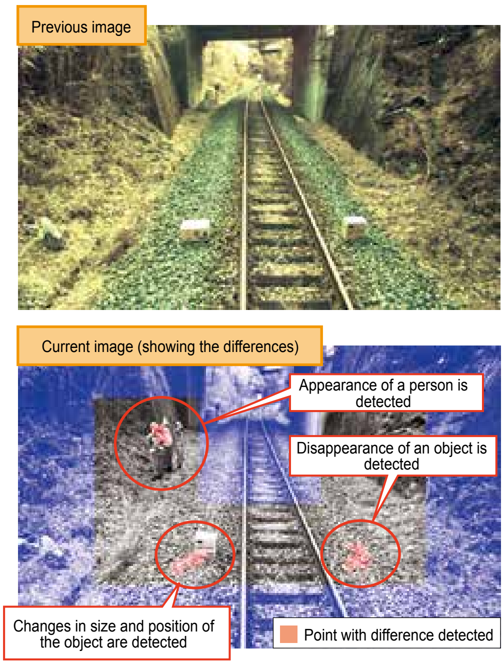


Fig. 2 Example of difference detection between images taken at two different times

17. Insulator contamination estimation method based on public data

- A method for estimating the degree of insulator contamination at any given point and time in an open section, based on publicly available meteorological and topographical data, has been developed.
- It can be used to design equipment with contamination resistance according to the environment and to formulate maintenance methods.

If an insulator is contaminated by salt, etc. adhered on the surface, the insulation performance is degraded, so the equipment should be designed and cleaned according to the degree of contamination. Currently, the contamination level is classified uniformly based on the distance from the coastline. If this can be subdivided, it is expected to improve safety and reduce the labor required for maintenance. In order to do this, it is necessary to continuously monitor the degree of insulator contamination at many points, but a lot of labor is required to do this by actual measurement.

Therefore, we have developed a method to estimate the degree of insulator contamination at any given point and time in an open section using meteorological data such as wind speed, wind direction, and rainfall, and topographical data such as distance from the coastline (Fig. 1). Fig. 2 shows the results of estimating the degree of insulator contamination at the Anti-Salt Testing Station in Gatsugi of RTRI (Murakami-shi, Niigata) over a one-year period, as well as the measured values. For the degree of insulator contamination under an occurrence frequency of 5%, which is used when designing the contamination resistance of equipment, the results based on the estimated values for three years by this method and the measured values for the same period were found to be in good agreement with each other (Fig. 3). From these results, we have confirmed that this method has a practical estimation accuracy. With this method, it is possible to design contamination resistance and maintenance methods according to the environment, such as increasing the size and number of couplings of insulators at points with high levels of contamination, and extending the cleaning interval of insulators at points with low levels of contamination.

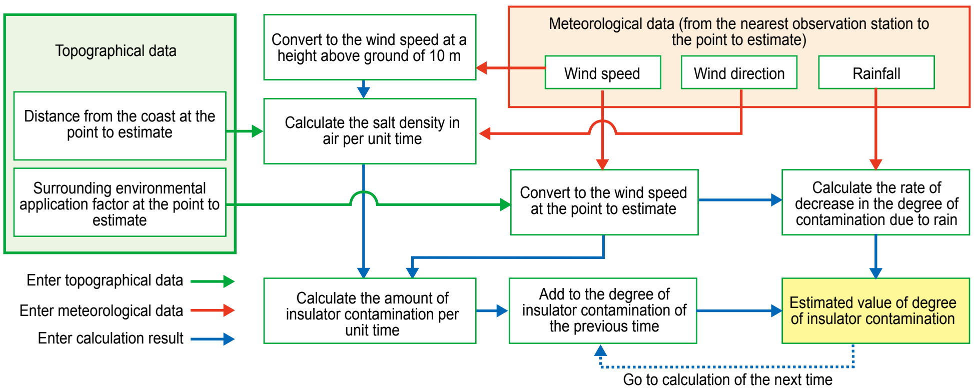


Fig. 1 Proposed algorithm

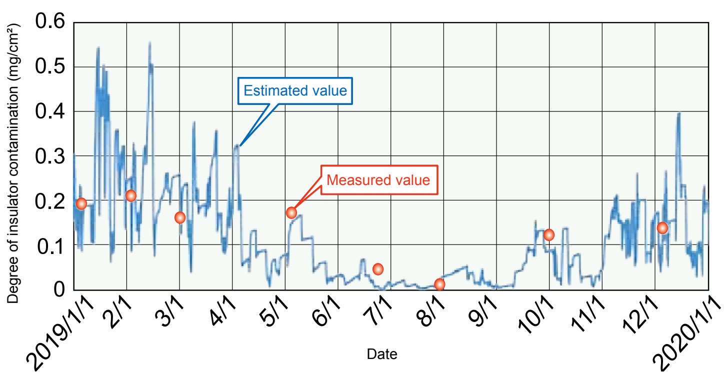


Fig. 2 Example of estimation results for the degree of contamination (on the coast of Japan Sea in Niigata)

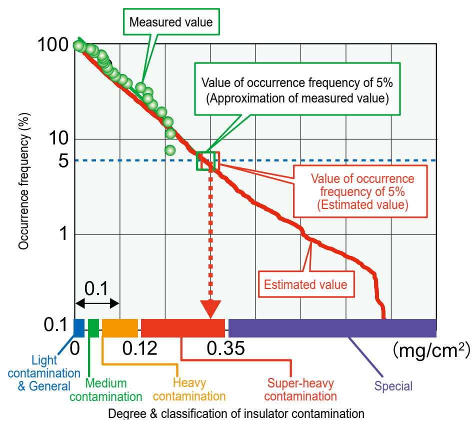


Fig. 3 Relationship between degree of insulator contamination and occurrence frequency

18. Degradation evaluation method for lithium-ion batteries for vehicle control circuits

- A degradation evaluation method has been developed in order to ensure the reliability of lithium-ion batteries for vehicle control circuits and to reduce the labor required for inspections.
- Prediction of lifetime under actual use conditions is possible at the stage of vehicle design.
- Degradation diagnosis after starting vehicle operation can be available by adding filtering process according to the recorded vehicle data.

Lithium-ion batteries have been newly adopted as storage batteries for the control circuits in some Shinkansen trains. Compared to conventional lead-acid batteries, these batteries are lighter and are expected to have a longer lifetime. In order to maintain the performance of the lithium-ion battery over a long period of time and to eliminate the performance evaluation work during periodic inspections, we have developed a degradation evaluation method suitable for the operating environment in the control circuit of a railway vehicle.

First, in order to obtain the degradation trend of the lithium-ion battery, we conducted an accelerated degradation test while simulating the temperature environment and charging/discharging conditions in actual vehicles, and proposed a formula to predict the change from the initial state to significant degradation while taking the fluctuation of the battery temperature into account. We compared the predicted values of battery capacity, an important indicator of degradation, with the measured values, and confirmed that they agreed with high accuracy (Fig. 1). We have also proposed a degradation diagnosis method to easily calculate the degree of degradation of batteries after the start of operation based on charging/discharging data during vehicle operation, without performing measurements during periodic inspections. As a result of comparing the calculated values of the capacity index (differential capacity: value indicating the degree of degradation) using this method with the measured values obtained in the basic experiment, we confirmed that they had a high correlation (Fig. 2).

The developed prediction method for the degree of degradation can be used to predict the battery lifetime according to the actual operating environment in the design stage, in order to apply the same type of batteries to the control circuit. The diagnosis of the degree of degradation after the start of operation can be applied by adding filtering process against the noise and various fluctuations in the recorded vehicle data.

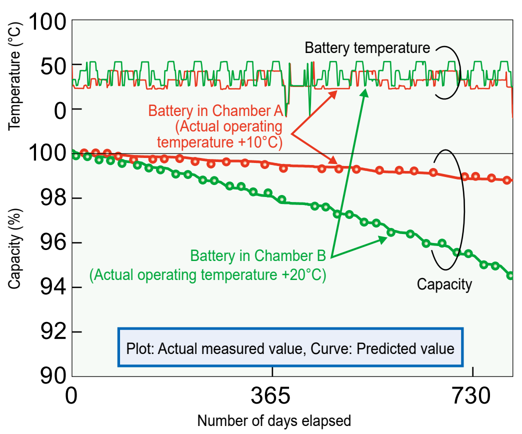


Fig. 1 Comparison of predicted values of capacity and measured values

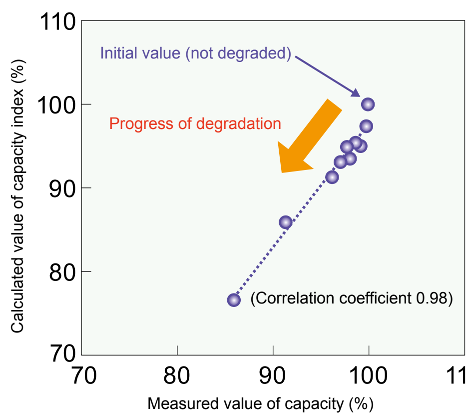


Fig. 2 Comparison of calculated values of capacity index and measured values

19. Wheel tread management method based on wayside noise prediction

- A method for estimating the amount of local wearing depth of wheel treads from rail vibrations in low-speed sections has been constructed.
- A method for predicting wayside noise when running high-speed sections based on the rail vibrations during low-speed sections has been constructed, and the accuracy of the prediction has been confirmed to be less than ±1 dB.
- This method can be utilized for wheel tread management by comparing the results of noise prediction with environmental standards, etc.

When local wear (small hollows occurring in the circumferential direction with a length of about 300 mm) occurs on the wheel treads of Shinkansen vehicles, the wayside noise may increase, mainly due to an increase in bridge noise. The amount of increase in wayside noise due to local wear is greatly affected not only by the local wearing depth of individual wheels, but also by the location and number of occurred local wears in the train set. In order to control the wayside noise below a certain level, it is desirable to have an efficient way to detect the wheel tread conditions of the entire train set. Therefore, we have constructed a method to estimate the local wearing depth of individual wheels from rail vibrations in low-speed sections where trains run at speeds of 100 km/h or less, and then to predict the wayside noise in high-speed sections where trains run at speeds of 200 km/h or more.

Since the position where the part with local wear of the wheel contacts the rail changes each time, the value detected by a single vibration sensor installed on the rail fluctuates greatly each time. Therefore, we have developed a method to accurately evaluate the effect of local wear on rail vibrations by combining rail vibration data from three points (Fig. 1). From the combined rail vibration, the local wearing depth of individual wheels can be estimated. In addition, we have extended the conventional method for predicting the wayside noise of Shinkansens to developed a new method to predict the wayside noise by reflecting the change in rail vibration of each bogie when the train passes through the low-speed section to the acoustic power level of the bridge noise in the high-speed section by each bogie (Fig. 1). The difference between the predicted value and the measured value of wayside noise was within about ±1 dB, demonstrating that it is possible to predict the noise when running in high-speed section from the rail vibrations when running in low-speed section (Fig. 2).

The results of the noise prediction in a high-speed section with this method show the condition of the wheel treads of the entire train set, and it can be utilized for wheel tread management such as the optimization of the wheel turning timing by comparing the results with environmental standards, etc.

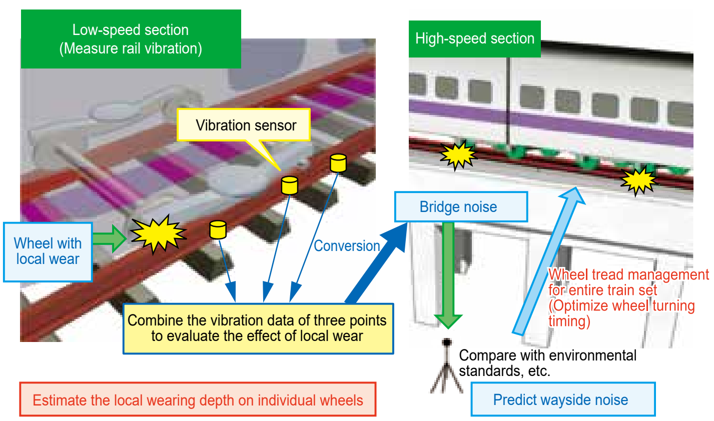


Fig. 1 Method for predicting wayside noise in a high-speed section from rail vibration in a low-speed section

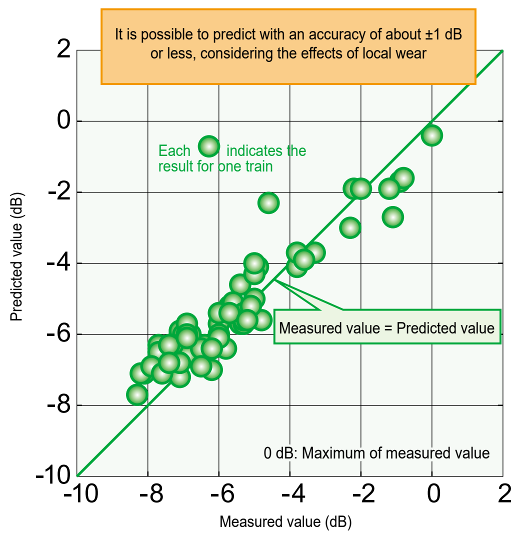


Fig. 2 Relative level comparison of measured and predicted values of wayside noises

20. High-accuracy train positioning system for tilting train

- A train positioning system with a detection error of ±2 m that does not depend on Automatic Train Protection (ATP) beacons has been developed.
- It can extend update period of on-board route data for about 10 years and save the labor for updating.
- The tilting system can be controlled according to the entry and exit in each curved section, to improve the ride comfort.

Tilting train controls the carbody tilted angle according to the position and speed to improve the speed in curves and the ride comfort. In the case of current meter-gauged railway lines, most of them identify the current position based on the location of Automatic Train Protection (ATP) beacons, so it is necessary to constantly update on-board position data for beacons. To improve this cumbersomeness, we have developed a train positioning system that does not depend on the ATP beacon and does not require the maintenance of on-board database for a long time.

In the developed method, the reference curvature data generated by designated signal processing of the curvature of the railway track measured during running in advance is stored in the on-board database as route data. Then these data are compared with the curvature of the railway track calculated from the vehicle's yawing angular velocity measured by the on-board gyro sensor and the running speed to detect the vehicle position (Fig. 1). In a running test, we have confirmed that this method can identify the vehicle position accurately with an error of ±2 m (Fig. 2).

A spatial filter, which is a length-based filter, is applied to the calculation of the curvature of railway track to eliminate the effects of differences in vehicle sway between different types of vehicles and changes in track conditions due to aging. With this method, the update frequency of on-board route data can be extended to about 10 years.

In addition, with the conventional method, there is a chance to miss the vehicle position on the track if it travels on a different track from the database for passing other trains or in a large station. On the other hand, the developed method can continue to detect the vehicle position maintaining an accuracy of detection error of ±2 m, by detecting where the difference between the data of curvature while running and the reference curvature increases sharply to determine the location of the track in the station.

With these methods, tilting trains can be controlled according to the entry and exit in each curved section while reducing the update frequency of reference database of curves thereby improving the ride comfort of vehicle.

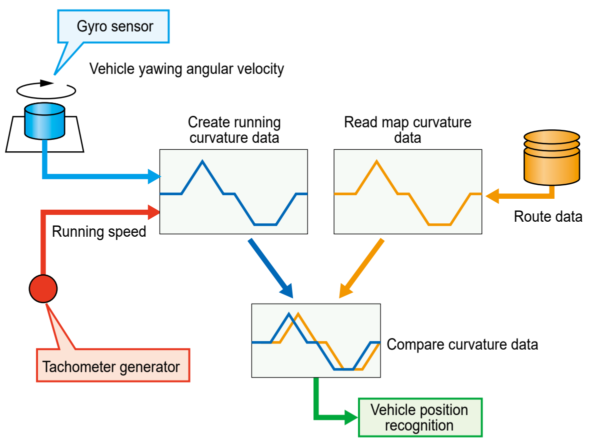


Fig. 1 Train positioning system

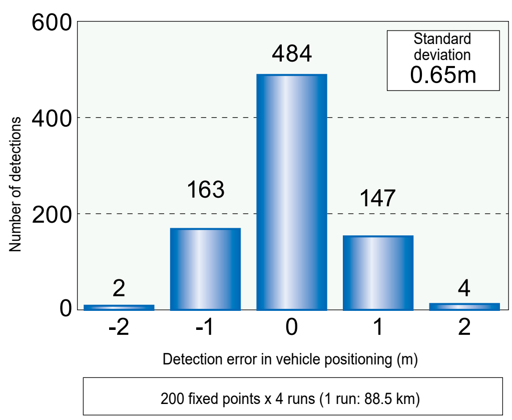


Fig. 2 Distribution of vehicle position detection errors

21. Support system for countermeasures against delay based on the impact of delays

- A support system for countermeasures against delay has been developed to improve the punctuality of train operations and to increase the work efficiency to study measures to achieve this.
- The system extracts the priority locations for countermeasures that can improve punctuality of the rail line, based on the number of sets of train and station likely to be affected by the delay at one location.
- By applying the methods to actual rail lines, the validity of the extracted locations and the improvement of punctuality after the timetable change have been confirmed.

Chronic delay of trains is one of the major causes of reduction of passengers' convenience. Aiming to improve the punctuality of train operations and to increase work efficiency for studying countermeasures to achieve this, we have developed a method to identify the sets of train and station where measures to prevent delays, such as the addition of running time or dwell time supplements, should be prioritized.

In terms of countermeasures against delay, it is empirically known that delays can be effectively reduced with fewer countermeasures if priority is given to locations where delays are likely to spread widely to other trains. Therefore, by newly defining the number of sets of train and station where delays tend to spread as an index of the impact of delay, and identifying the area to which the delay at each location spread based on the recorded data of daily delays, we have constructed a new method to quantitatively evaluate the impact of delays. Next, we have devised a method to extract the locations with a high degree of impact on average over a certain period of time (e.g., one month) as the priority locations for which countermeasures against delay should be considered, and developed a support system for countermeasures against delays implementing this method. This system makes it possible to study and develop effective countermeasures against delays in about one-fifth of the time required for a conventional method, leading to simultaneously improve punctuality and convenience and increase work efficiency.

As a result of applying this system to three actual rail lines, we confirmed that the locations of high impact calculated by the system were the same as the areas that the persons in charge of creating train timetables recognized the need for countermeasures. In addition, we added totally 90 seconds of running time or dwell time supplements to each intermediate station of the train with high impact, and changed the departure track of the train at the starting station as countermeasures at the timetable change, based on the locations extracted by the system. We found that the delays at and around the countermeasure points were reduced, confirming the validity and usefulness of this system (Fig. 1).

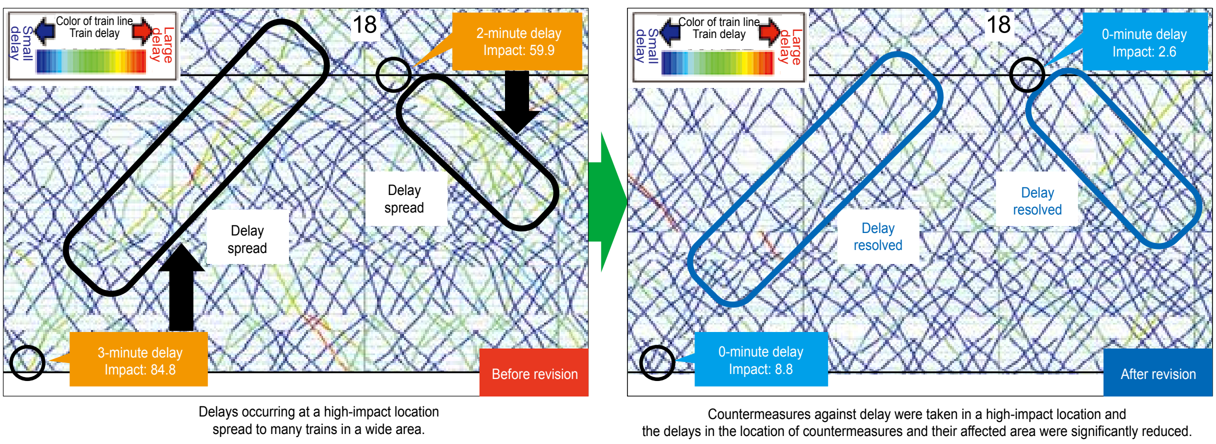


Fig. 1 Application and validation of the method by evaluating the impact of delay for actual rail lines

22. Numerical simulation of ventilation in a vehicle by opening windows while running

- A numerical simulation tool to predict the amount of ventilation by opening windows has been developed.
- Based on the simulation results, a simple prediction formula for the amount of ventilation by opening windows has been proposed.
- The simple prediction formula for the amount of ventilation inside a vehicle can be used to evaluate the measures against “closed space” for railway vehicles.

One of the countermeasures against infectious diseases in commuter vehicles is to ventilate a vehicle by opening windows as one of the “closed space” countermeasures, and a quantitative evaluation of the ventilation amount is required. To address this issue, we have developed a numerical simulation tool that can predict the amount of ventilation in a vehicle by opening windows while running. In addition, by organizing the results of predicting the ventilation amount under various conditions, we have proposed a simple formula for predicting the ventilation amount.

The simulation of ventilation in a vehicle has been realized by introducing a function to evaluate ventilation amount to the previously developed fluid analysis tool “Airflow Simulator” (Fig. 1). The simulation calculates the air flow outside and inside the vehicle at the same time. In doing so, the ventilation amount is evaluated by tracking the air flow using virtual particles generated continuously at 114 locations in the vehicle. The window opening height, seating arrangement, passenger position, etc. are variable, allowing the prediction of the ventilation amount under any given condition. We have confirmed that the simulation results are generally consistent with on-track test results. The simulations revealed that the ventilation amount is proportional to the train speed and window opening area and that there is no significant difference depending on the occupancy rate or seating arrangement when the window opening height is less than half-open. Based on this knowledge, we have also proposed a simple prediction formula for ventilation amount (Fig. 2). This prediction formula can be used to evaluate the measures against “closed space” for railway vehicles, such as setting the amount of window opening according to the window shape.

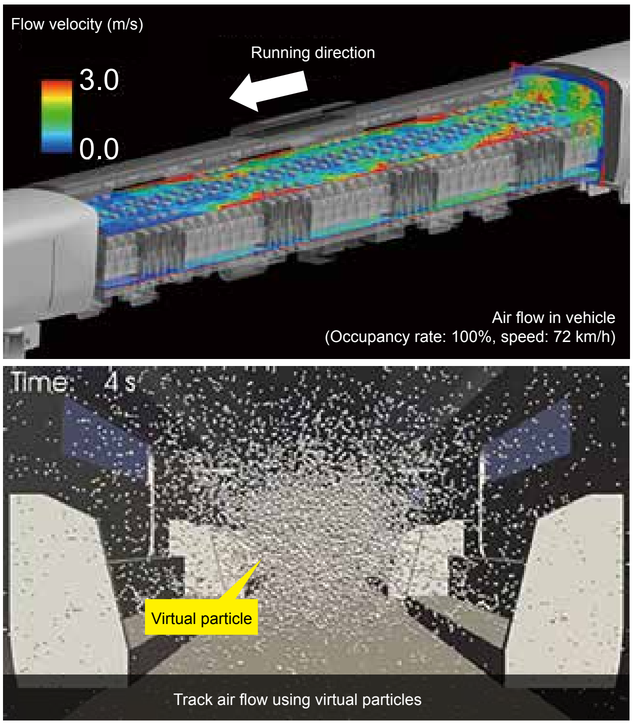


Fig. 1 Simulation to predict ventilation amount

Simple prediction formula

Ventilation amount = 0.026 x train speed x window opening area (total)
(m^3/s) (m/s) (m^2)

(Note) Although prediction accuracy varies depending on the aspect ratio of the window, this formula can be applied to any car classification when the windows are less than half-open.

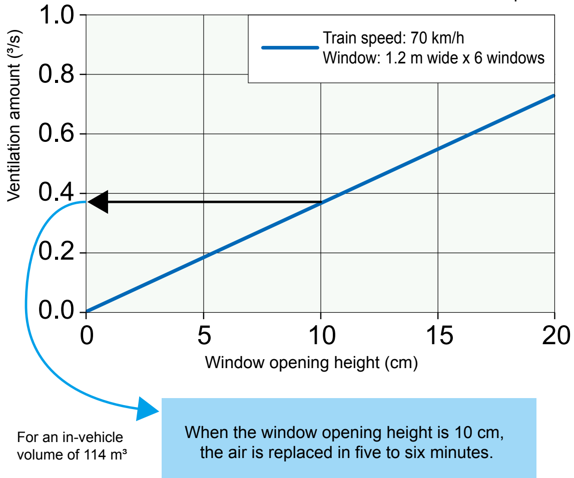


Fig. 2 Proposed simple prediction formula and example of its use

23.Analytical evaluation method for the speed at which hunting occurs

- The relationship between the initial amplitude and the running speed at which hunting occurs has been clarified.
- The speed at which hunting occurs can be efficiently evaluated based on the specifications including the wheel profile

The phenomenon where a bogie suddenly starts lateral movements at a certain speed, which develop into large amplitude oscillation, is called “hunting.” Since hunting has a significant impact on the running safety of vehicles traveling at high speed, the speed at which hunting occurs is confirmed to be sufficiently higher than the operating speed using a rolling stock test plant during the development of new vehicles. However, it is known that the speed at which hunting occurs varies depending on how the initial amplitude of lateral displacement is given on the wheelset in the test. This relationship between the initial amplitude and the speed at which hunting occurs is called the critical hunting curve (Fig. 1). The relationship between these two has not been theoretically clarified before. In this study, we have constructed an analytical method for calculating the critical hunting curve based on the specification of the vehicle and the wheel tread profile.

Fig. 1 shows that an oscillation diverges to the hunting above the critical hunting curve, and one converges below it. It also shows theoretically there could exist a steady state oscillation on the critical hunting curve that neither converges nor diverges. This indicates that the steady state oscillation is unstable, which means that the oscillation will diverge or converge by even slight disturbance (Fig. 2). Therefore, we have constructed a method to calculate the amplitude of steady-state oscillation corresponding to a point on the critical hunting curve by applying a nonlinear calculation method to the vehicle dynamics model. In this method, we can efficiently obtain a solution by using the characteristics of a critical hunting curve that decreases monotonically as a whole when the running speed increases. With this method, it is possible to analytically evaluate the speed at which hunting occurs according to the initial amplitude of the wheelset.

In addition, we have clarified that the speed range in which hunting occurs expands when the nonlinearity increases, as in the case of arc wheel profile where the tread gradient changes depending on the contact position with the rail, compared to the conical wheel profile having constant tread gradient (Fig. 3).

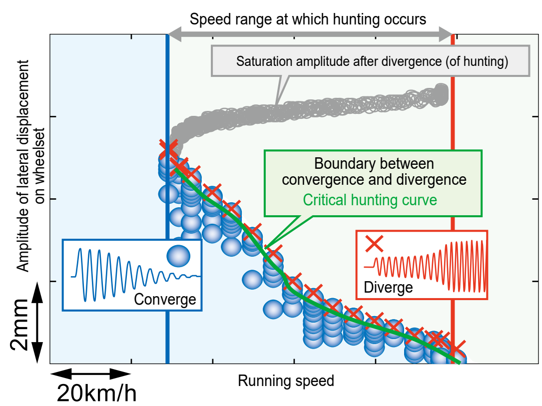


Fig. 1 Critical hunting curve

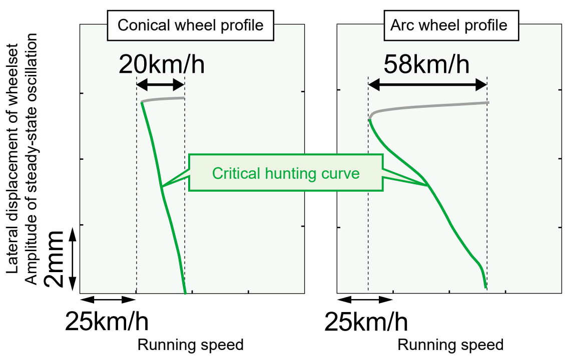


Fig. 3 Example of critical hunting curve calculation

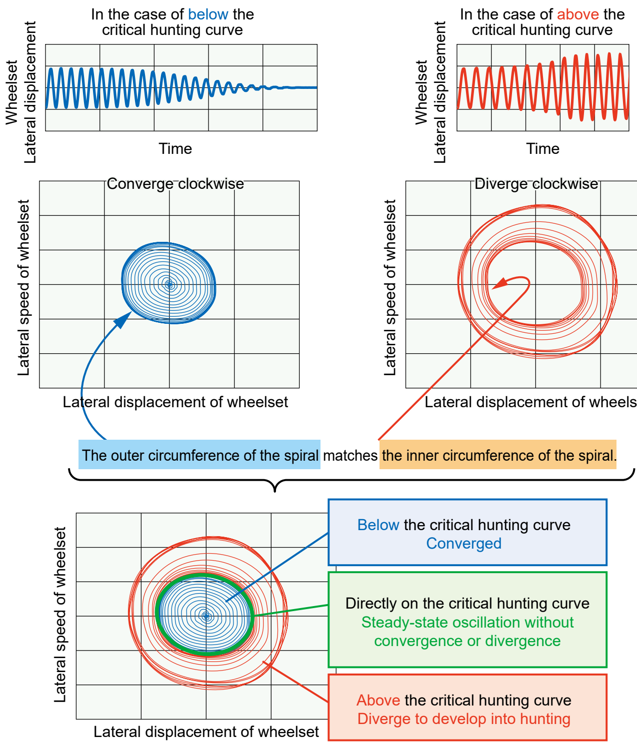


Fig. 2 Steady-state oscillation on the critical hunting curve

24. Evaluation of the influence of wheel machining marks on the friction coefficient by visualizing the contact area

- A technique to visualize the state of contact between wheel and rail using ultrasonic waves has been developed.
- It has been clarified that the friction coefficient between wheel and rail is affected by the degree of gap between the contact areas.

The higher the critical derailment coefficient is, the bigger the margin against vehicle derailment occurs. In order to obtain a high critical derailment coefficient, it is important to keep the friction coefficient between wheel flange and rail low. Since some derailments have occurred just after wheel machining, the friction coefficient between wheel and rail is considered to become higher immediately after wheel machining, but the influence of wheel machining on the friction coefficient has not been fully clarified. Therefore, we investigated the influence of wheel machining on the friction coefficient, by visualizing the contact area between wheel and rail just after wheel machining using ultrasonic waves (Fig. 1).

As a result of the friction test simulating sliding contact between the wheel flange and the rail just after wheel machining, we found that the friction coefficient increased with the increase in number of rollings. Therefore, we have developed a technique to visualize the contact area between wheel and rail in the process where the friction coefficient increases to check the changes in the contact state. As a result, the surface irregularities (wheel machining marks) were deformed by the 20th rolling, and the profile of the contact area tended to change rapidly (Fig. 2). Comparing the change in the friction coefficient with the degree of gap between the contact areas obtained by analyzing the visualization results, we found that the friction coefficient increased as the surface irregularities deformed and the contact areas became closer together (decreasing the degree of gap) (Fig. 3).

As the metal surfaces directly adhere to each other until some contaminants adhere to the wheel surface after wheel machining, the friction coefficient is expected to be kept high as shown in Fig. 3. Therefore, lubricating the wheel flange just after wheel machining is considered to be effective in reducing the friction coefficient.

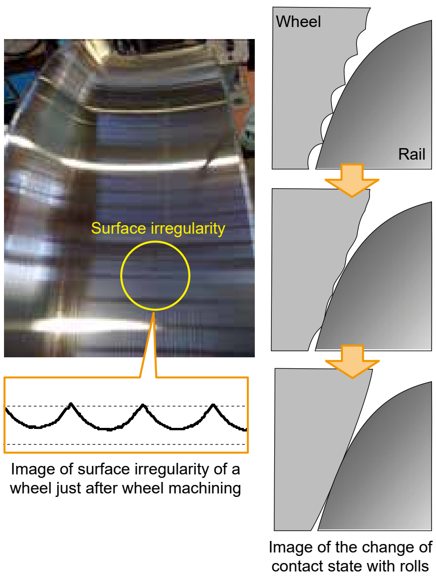


Fig. 1 Image of surface irregularity and contact state just after wheel machining

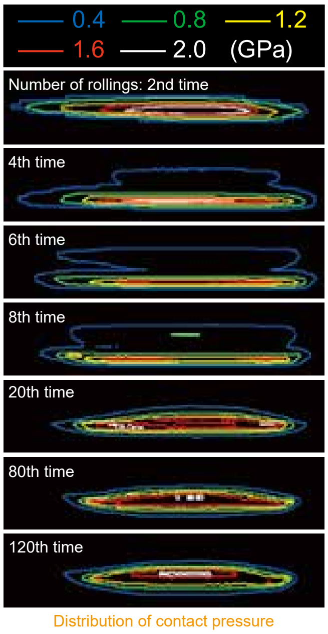


Fig. 2 Changes of contact pressure between wheel flange and rail

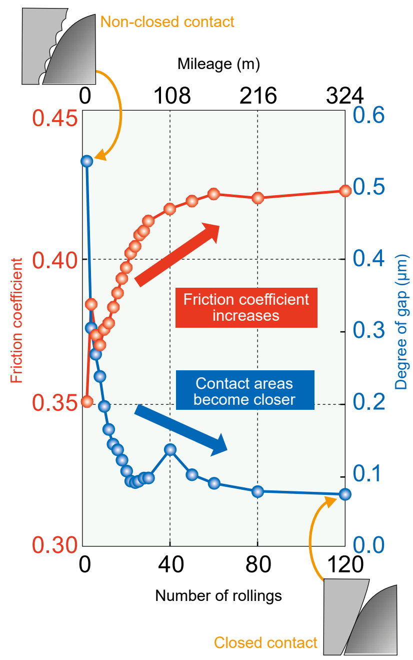


Fig. 3 Relationship between number of rollings and friction coefficient/ degree of gap

25. Wheel slide protection simulator to supplement on-track testing

- A wheel slide protection (hereafter, WSP) simulator that combines actual pneumatic piping for braking and a real-time computer has been developed.
- By confirming the performance of the WSP algorithm in advance, the number of test runs for on-track testing can be halved

Adjustment of the control algorithm through on-track testing is the most important process in evaluating the performance of WSP under braking. However, it is not easy to stably reproduce the low adhesion conditions between wheels and rails in on-track testing, and the algorithm must be adjusted under different adhesion conditions for each run. To solve this problem, we have developed a WSP simulator that combines the advantages of real machine and computer.

The simulator consists of a real machine part that uses the same pneumatic system components as actual rail vehicles, from air reservoirs to brake cylinders, and a computer part that specifies the adhesion conditions, vehicle model, and WSP algorithm (Figs. 1 and 2). The real machine part uses variable length pneumatic piping to make the response of the pneumatic system variable. The computer part calculates the speed information (vehicle and circumferential speed) in real time based on the specified adhesion conditions (Fig. 3) and the vehicle model. This forms a real-time loop, that is, when the speed information satisfies the slide detection conditions of the WSP algorithm, the WSP dump value in the real machine part works to discharge the air in the brake cylinder, and the computer part reads the pressure change and calculates the speed information again.

With this simulator, various verifications can be performed by arbitrarily specifying the adhesion conditions and WSP algorithm, while reproducing the response characteristics using the pneumatic system of the actual rail vehicle. For example, by comparing the distribution of stopping distances for combinations of various adhesion conditions and WSP algorithms, the tendency of each WSP algorithm can be statistically evaluated (Fig. 4). Thus, by comparing the performance of promising WSP algorithms prior to the on-track testing, the number of test runs for the on-track testing can be halved.

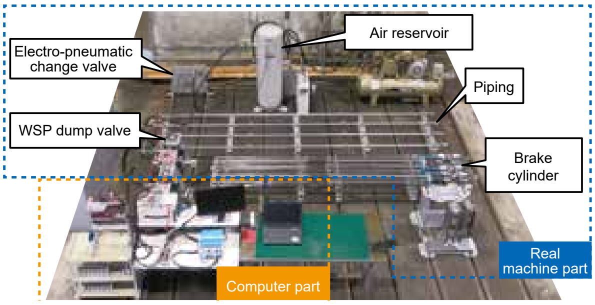


Fig. 1 Overview of WSP simulator

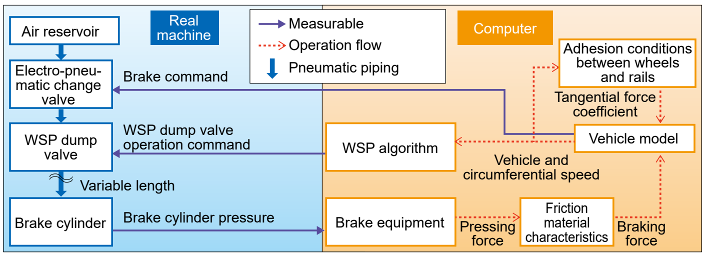


Fig. 2 Functional block diagram of WSP simulator

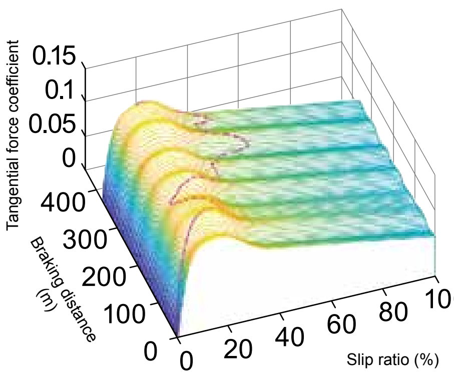


Fig. 3 Specifying low-adhesion conditions

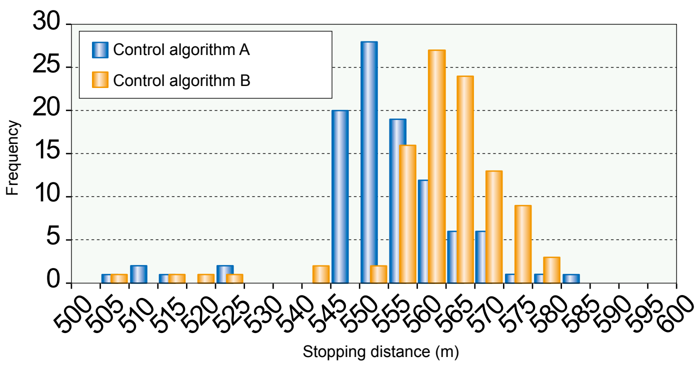


Fig. 4 Stopping distance distribution of WSP algorithm

26. Non-contact method to detect rail openings using aerial ultrasonic waves

- A non-contact method to detect rail openings using aerial ultrasonic sensors has been devised.
- A running test at speeds up to 80 km/h was performed using a testing car equipped with the proposed method to confirm that the ultrasonic intensity at the opening part of rail was lower than that at the middle part.
- A method to analyze rolling contact between a wheel and a rail has been developed to evaluate the thermal stress and plastic deformation, which is necessary to clarify causes of deterioration such as hollow wear and wheel flats.
- By comparative verification with braking test results, it was confirmed that the rise in wheel temperature could be reproduced within an error of 10%.

Currently, rail breakages are detected along with the train position by the track circuit, but if a wireless train control system is introduced, a separate method of detecting rail breakage is required. Therefore, we have devised a method to detect rail openings based on the intensity of ultrasonic waves that were transmitted to the rails from the vehicle and received by an aerial ultrasonic sensor without contact (Fig. 1).

When ultrasonic waves are input from the sensor to the rail through the air, the transmittance is extremely low, about 1/10,000th of the transmittance when the sensor is in direct contact with the rail. For this reason, we have adopted a system that can transmit and receive ultrasonic waves more powerful than those used in general ultrasonic testing, and that can strongly amplify the strength of the received waves. In addition, in order to minimize the attenuation of ultrasonic waves due to sensor separation and vibration, we used a relatively low-frequency band of 100 kHz among ultrasonic waves. In order to facilitate the judgment, we have also proposed a method to distinguish from rail joints and a method to convert the received ultrasonic wave intensity into a time history waveform and display it. In addition, we conducted laboratory test and confirmed that the system could detect even when the rail ends were in contact with each other, which cannot be detected with track circuits.

As the result of a running test conducted on a test line using a testing car equipped with this system at speeds up to 80 km/h, we have confirmed that the system can transmit and receive ultrasonic waves to and from the rail and that the ultrasonic wave intensity decreases at the rail openings (Figs. 2 and 3). At present, we still have some issues, such as the inclusion of noise in the received waveform when a squeal noise is generated on a curve. We will continue to improve the system and aim to put it to practical use.

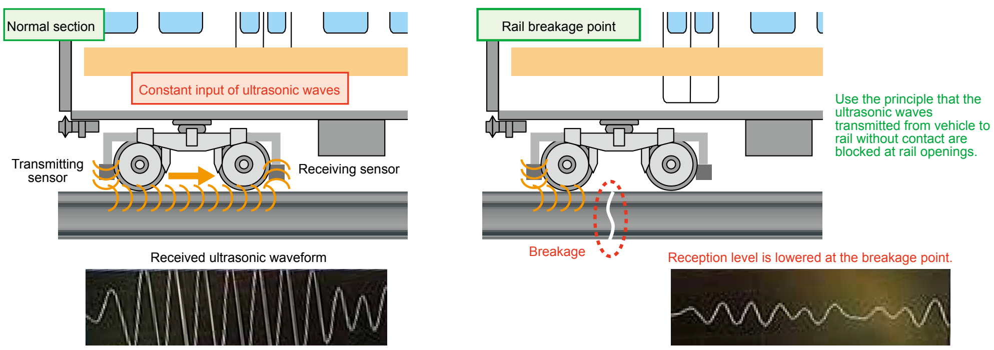


Fig. 1 Image of proposed method

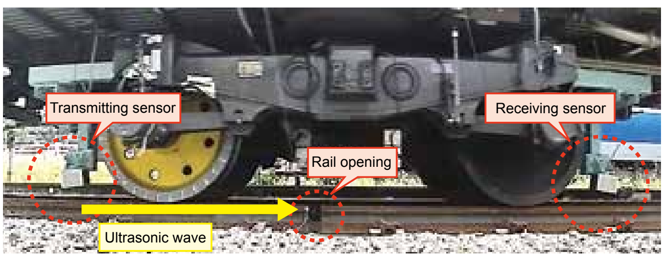


Fig. 2 Testing car equipped with sensor

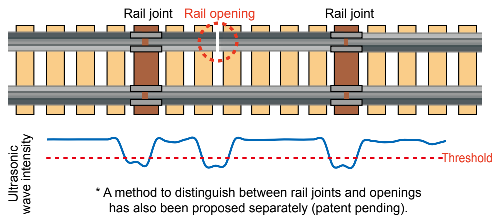


Fig. 3 Waveform when passing through a rail opening

27. Clarification of wear mechanism of current collecting materials caused by frictional heat

- It has been clarified that there are four modes of mechanical wear of current collecting materials depending on the contact temperature, and that softening of the material is an important factor.
- A numerical analysis model that can calculate the temperature of the contact point due to frictional heat has been constructed.

Current collecting materials such as contact wires and pantograph contact strips are subject to wear due to various factors such as contact force, running speed and current. The effect of Joule heat by current has already been made clear, but the mechanical wear mechanism caused by sliding has not been fully clarified.

Therefore, we have developed a new wear-testing machine that can measure the contact temperature between the copper plate and the contact strip during sliding and investigated the relationship between the contact temperature and the wear mode caused by frictional heat. As a result, we found that there were four modes of mechanical wear depending on the maximum and average temperatures, and that the softening of the material due to the temperature was an important factor in the transition of the wear mode (Fig. 1). In particular, we confirmed that the surface of the contact wire was significantly worn, like delamination in wear form II, which is considered to be the cause of significant wear of the contact wire in low-speed sections where the frictional heat is small and the average contact temperature does not rise.

Furthermore, we constructed a numerical analysis model (Fig. 2) that could calculate the temperature rise at the contact point by inputting the frictional heat as heat flux to the contact area, and confirmed by simulation that the measured average temperature of the contact point was consistent with the analyzed value (Fig. 3). In the future, we plan to facilitate the technology development to reduce the maintenance cost of current collecting materials, by integrating this analysis with the analysis of temperature rise due to Joule heat that we have developed so far, to develop a method for predicting the wear mode that will occur in the actual field, and to propose measures to control wear by controlling the wear modes.

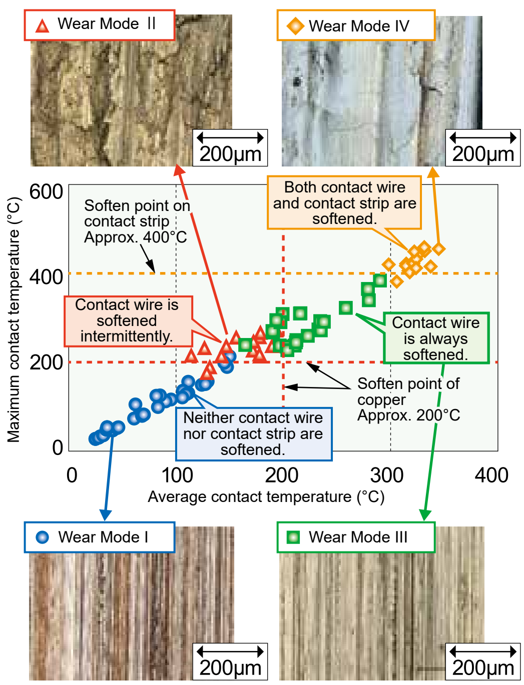


Fig. 1 Conditions for development of wear modes and wear surface on copper plate for each wear mode

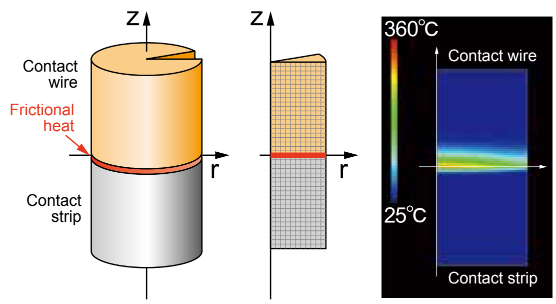


Fig. 2 Contact temperature analysis model and analysis example

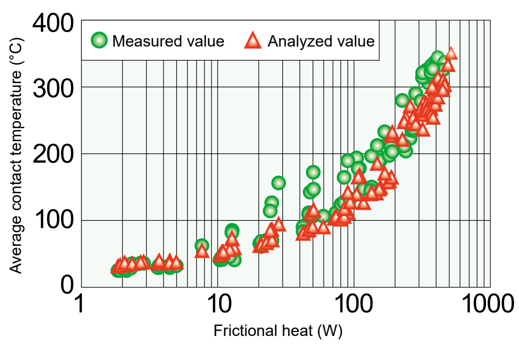


Fig. 3 Measured and analyzed values of contact temperature

28. Method to evaluate physical properties of frictional materials by numerical simulation

- A method to calculate the physical properties of frictional materials by numerical simulation has been constructed based on the created analytical model using CT images of frictional materials to reflect their microscopic structures.
- The constructed method was applied to pantograph contact strip materials to reproduce their physical properties.
- It can be utilized to estimate physical properties before prototyping and to clarify the phenomena on a microscopic scale that cannot be measured.

Frictional materials for railway, including pantograph contact strips and brake pads, are made of several materials. The physical properties and behavior of such materials vary depending on the microscopic structure, such as the combination, proportion, and arrangement of the contained materials. Therefore, it is difficult to estimate the properties with high accuracy by conventional physical property estimation methods based only on material proportions, and it has been necessary to repeatedly make prototypes and measure the physical properties when developing new materials. To solve this problem, we have constructed an analytical model that reflects the microscopic structure using X-ray CT images, and constructed a method to calculate the material properties accurately by FEM (Fig. 1). By applying the constructed method to a copper-impregnated carbon-based material, which is one of the pantograph contact strip materials, we have confirmed that the method can reproduce the physical properties more accurately than the conventional estimation method (Fig. 2). In addition, the obtained analytical model can be used to calculate the distribution of stresses and temperatures on a microscopic scale (Fig. 3).

This method makes it possible to estimate the physical properties of a material before it is prototyped, so we can expect to improve the efficiency of material development. Since we can also estimate the stress and the temperature distributions on a microscopic scale, which is difficult to measure, we can utilize them to clarify the phenomena of wear and damage.

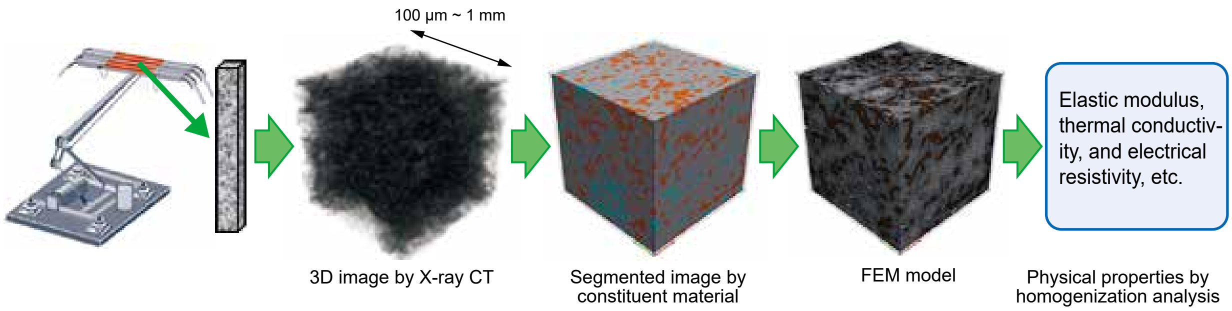


Fig. 1 Overview of the modeling of microscopic structure and physical properties evaluation method for materials

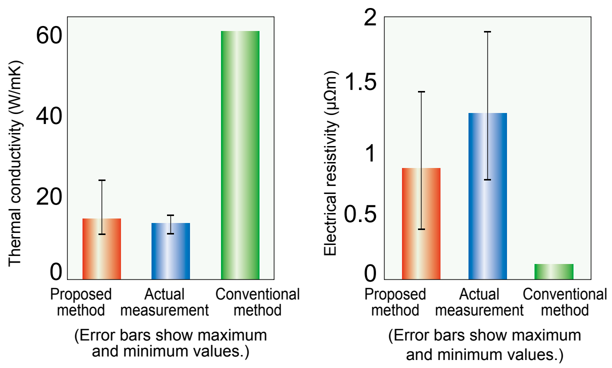


Fig. 2 Comparison of calculated and measured physical properties of pantograph contact strip materials

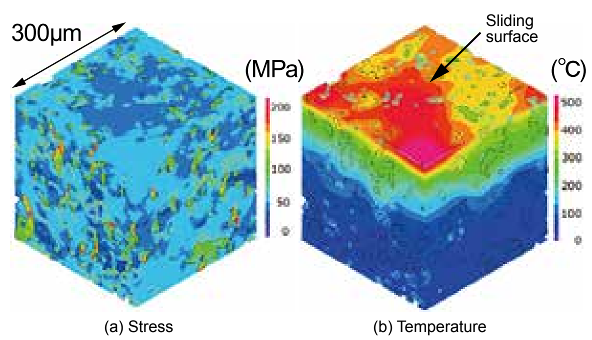


Fig. 3 Example of analysis of microscopic state distribution inside a pantograph contact strip material

29. Detection of changes in drivers' physical and mental state using physiological indicators

- Physiological indicators based on Heart rate and respiration that are suitable for estimating the physical and mental state of the driver have been proposed.
- As Heart rate and respiration are relatively easy to measure, they are suitable for measuring on site.
- A comprehensive judgment method to optimize multiple indicators for each individual has been devised to improve the estimation accuracy.

In order to maintain safe train operations, it is important that the driver, who works alone, is always in good physical and mental condition. Therefore, we have proposed a method for detecting the states that may affect safe operation, such as over-tension like panic and arousal reduction, from physiological data. Realizing this detection method makes it possible to provide appropriate support for the driver to return to good condition.

It has been considered difficult to apply physiological data for safety support which requires a high degree of accuracy, due to the large differences among individuals. Therefore, we have proposed physiological indicators using Heart rate and respiration to estimate the activity of the parasympathetic nervous system of autonomic nerve, which is activated during relaxation and suppressed during tension. Conventional indicators require 15 to 30 seconds for measurement, but the proposed indicators can be calculated in every respiratory cycle (about 3 seconds). The non-tension indicators appear more frequently than conventional indicators in arousal level 1, and they appear less in arousal levels 4 and 5, indicating higher estimation accuracy (Fig. 1). Measurement of respiration also has the advantage of providing information that reflects mental and physical state, such as startle reaction and sighing.

In addition, we have devised a method to automatically select effective indicators suitable for each individual from five indicators including the proposed indicators (Table 1), and determine both tension (including psychological agitation) and non-tension (including arousal reduction) with high accuracy using the selected effective indicators (comprehensive judgment method). As shown in Fig. 2, there are problems with the rate of appearance of correct judgments and the number of false positives in the judgments of individual indicators (in the purple box), but the judgments using the comprehensive judgment method (in the pink box) have both a high rate of appearance and a low rate of false positives for both tension and non-tension, indicating that judgments can be made with a high degree of accuracy.

Arousal level (subjective evaluation)
1. Feeling sleepy
2. Feeling a little sleepy
3. Normal (fit for driving)
4. Feeling a little nervous or upset
5. Feeling nervous or upset

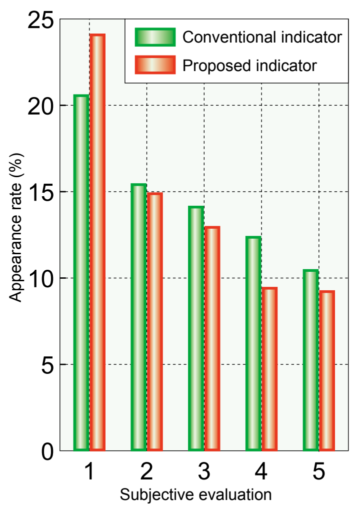


Fig. 1 Arousal level and non-tension judgment

Table 1 Examples of selected effective indicators for each individual (10 persons)

Participant ID	S01	S02	S03	S04	S05	S06	S07	S08	S09	S010
Proposed indicator			● (blue)	● (blue)	● (blue)	● (red)	● (blue)	● (green)	● (blue)	● (green)
Heart rate interval	● (green)		● (blue)	● (blue)	● (green)			● (red)		
Respiratory length	● (green)	● (green)	● (green)	● (blue)	● (blue)	● (blue)	● (blue)	● (blue)	● (blue)	● (blue)
Heart rate regularity				● (red)			● (red)		● (red)	● (green)
Respiratory regularity			● (red)		● (blue)	● (green)	● (green)		● (green)	● (blue)

Five indicators

● (red): Judged to be tension ● (blue): Judged to be non-tension ● (green): Effective for both tension and non-tension judgments

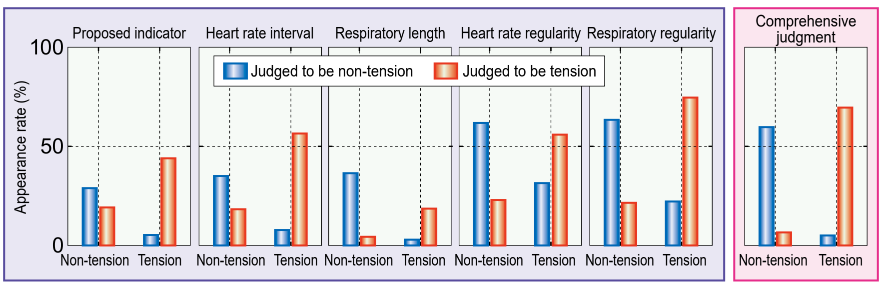


Fig. 2 Results of judgments by each indicator in tension and non-tension situations

News Release

1. Digitalization Technology Innovation Project Started

On April 1, the Railway Technical Research Institute set up the "Digitalization Technology Innovation Project."

1. Purpose of setting up the project

The new master plan of RTRI, RESEARCH 2025, has listed "Innovation of railway systems by digitalizing technologies" as one of its basic policies. In order to proceed with the research and development for this purpose quickly and in a cross-cutting way, RTRI set up and started the "Digitalization Technology Innovation Project". Under this project, all the research staff will work together to promote digitalization of railway systems by conducting basic research into image analysis and artificial intelligence and obtaining the research and development outcomes with the latest digitalization technologies as quickly as possible.

2. Research activities under this project

(1) To propose measures to innovate railway operation using digitalization technologies

Identifying new technical challenges that will contribute to innovating railway systems using state-of-the-art digitalization technologies.

(2) Research and development to address new technical challenges

Promoting research and development on the above-mentioned technical challenges and basic research into artificial intelligence and image analysis by using state-of-the-art digitalization technologies.

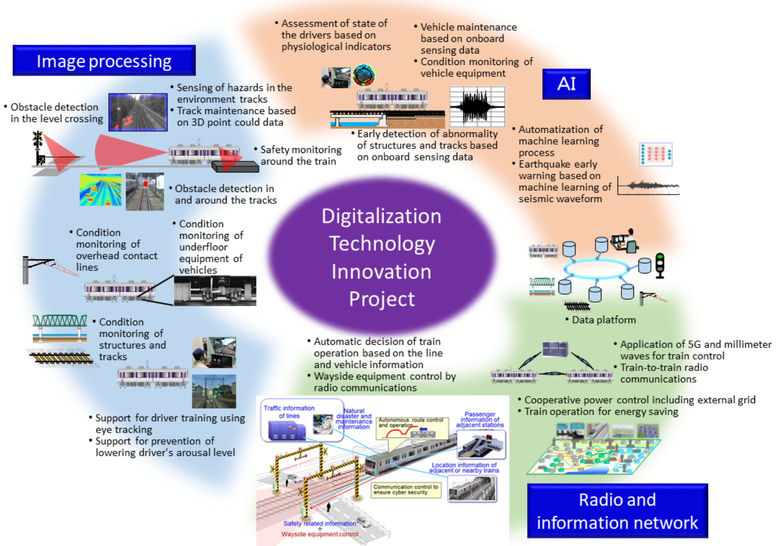
(3) Integrated and cross-cutting research and development

Conducting cross-cutting research and development through coordinating different fields and topics that share the same digital techniques.

(4) Development of the know-how and resources for research

Identifying sharable technologies, promoting cross-cutting use of them and providing researchers training programs

The following figure shows specific research topics regarding digitalization that RTRI has been addressing. In the fiscal year 2020, 40 research projects will be started, aiming to introduce image analysis, artificial intelligence,



telecommunications and networking technologies to railway operations.

【Image analysis】
We will develop techniques using image analysis technologies to detect obstacles lying 600 meters ahead of a train and to visualize objects that are difficult to recognize by human eyes and seek to apply them to railway operation in order to improve the safety and innovate maintenance of railways.

Specifically we will develop a system to detect on-the-track obstacles by analyzing images ahead of and around the train, a system to support visual monitoring of the track and condition-based monitoring systems for vehicles, structures, and tracks.

【Artificial intelligence】
We will develop methods to automatically extract machine learning data which is useful for detecting troubles of railway facilities and a method to trace train control and decision making. We will seek to apply the outcomes to develop automated detection, prediction and decision making on drivers and facilities conditions.

Our research and development includes a method to detect troubles of tracks and facilities early and to estimate vehicle equipment conditions using the digital data measured on board, and a method to estimate conditions of train drivers based on physiological indicators. In addition, basic technologies including a method of early earthquake warnings using machine learning data of seismic waveforms will be developed.

【Telecommunications and networking】
We will address research to apply 5G mobile communication systems and millimeter waves to safety related control. This technology is expected to support autonomous train operation which will be more resilient, with less ground equipment.
We will develop autonomous train operation systems that control the trackside equipment during train running based on digital information on track and trackside conditions, disaster prevention and maintenance and passenger flow. We will also develop energy-conserving technologies such as coordinated power control. We will also develop a data platform that will provide us a shared base for cross-sectional commitment.

Some examples of the 40 research topics are as follows.

Autonomous train control method
We will build an autonomous train control system. In this system, running trains directly control the trackside equipment such as turnout point machines and level crossings and autonomously set the routes and speed profiles. With this system, ground equipment will be reduced and driverless train operation will be achieved.

Early trouble detection method for track and facilities with on-board digital sensing data
This method will be able to detect early troubles and failures of tracks and facilities including track subsidence and bridge pier subsidence and slant only with on-board sensing data. This technology will prevent train running disruptions and accidents and enable more efficient maintenance by planned repair and reinforcement.

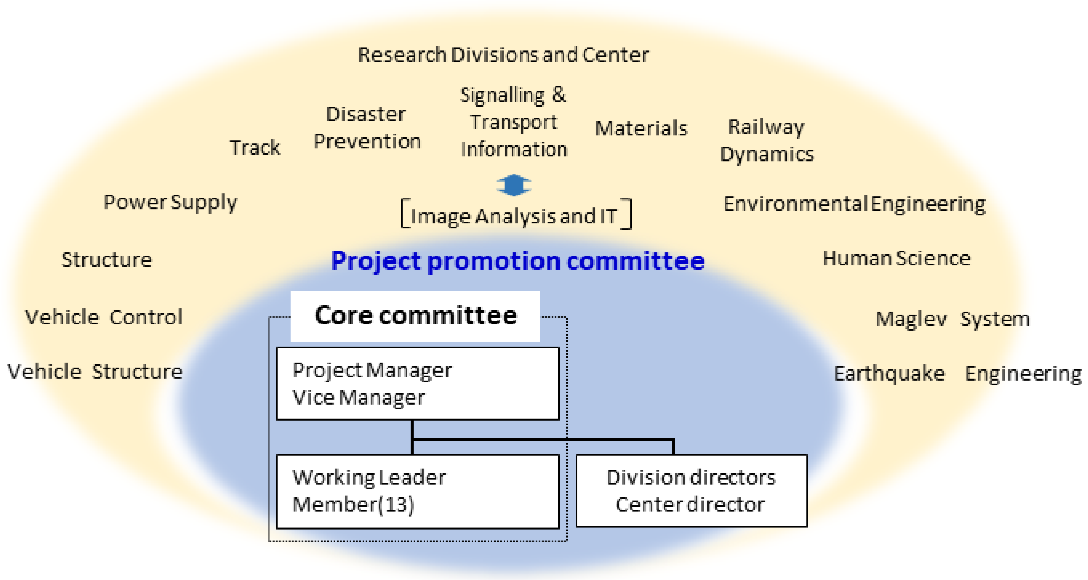
Improved trouble detection method for overhead line fittings
Using the images obtained by on-board line cameras, this method will detect troubles of the fittings such as pull-off arms and crossing bars at crossovers by the information of their shapes and colors. This will save labor in the overhead line maintenance and achieve more efficient facility maintenance.

Early earthquake detection method with machine learning of big data
We will propose a method to apply machine learning data to train operation in real time in order to raise performance of early earthquake warnings. Using a massive amount of waveform data measured by seismometers, this machine learning will make it possible to distinguish between noises caused by earthquake shakings and train vibrations and to estimate earthquake elements.

Automation of the machine learning process in trouble detection
We will aim to apply to commercial train operation a system to detect troubles by applying machine learning to vibration data of vehicle equipment. For this

purpose, we will develop a method to automatically extract machine learning data, for example, to remove abnormal data from among normal data.
We will conduct research and development of the above-mentioned technologies by utilizing basic technologies such as image analysis, artificial intelligence, telecommunications and networking in a cross-sectional manner and coordinating related research projects. Based on the outcomes, we will support railway operators in applying digitalization technologies to railway operations.

3. Organization of the project
The project promotion committee including the core committee will determine the research policies and, based on the policy, each of the research divisions and centers will conduct the research. The Image Analysis and IT Laboratory that was set up in the Signaling and Transport Information Technology Division in 2017 will be the core for utilizing digitalization technologies and developing the research staff.



The members of the core committee are as follows:
Project Manager :
Dr. Norimichi Kumagai, President
Vice Project Manager :
Dr. Ikuo Watanabe, Executive Vice President responsible for the entire research and development
Dr. Shunichi Kubo, Executive Director responsible for the Research and Development Promotion Division
Working Leader :
Mr. Shigeto Hiraguri, Deputy General Director, Research and Development Promotion Division
Members:
5 division directors, 5 laboratory heads and 3 senior researchers

4. Discussions at the first meeting

The Digitalization Technology Innovation Project was set up on April 1 this year and its first meeting was held online on April 28, with a limited number of 10 attendants (Photos 1 and 2).

The meeting was started by President Kumagai's opening note and followed by discussions on the basic policies and the work schedule for this project. The issues discussed there included specific research targets including application of digitalizing technologies to maintenance, coordinated control of power supply network and trouble detection by data. They also discussed the importance of coordinated research among different fields through sharing algorithms, sharing expertise and outcomes, and collaboration with other organizations including overseas ones in order to introduce state-of-the-art technology speedily. In addition, it was proposed that we should conduct on-line research into the latest technologies under this restriction of all the activities due to COVID-19. President Kumagai concluded that sharing and integrating information among different research fields are the key of this project.

【Keynote Message by President Kumagai】

We will be utilizing digitalization technologies quickly in train operation and solving the issues of safety, maintenance, energy and cost. In order to do so efficiently, the role of this project is to share information and show guidelines through integrating relating research topics and projects. The core members and responsible researchers must cooperate and promote this work together. As our research collaboration partner SNCF also has a strong interest in the railway application of digitalization technologies, I would like to proceed with the research together, inspiring each other. I would like to ask for your cooperation and expect all of you to do vigorous research activities.

【Comment by Executive Vice President Watanabe】

In this age of rapid technological advancement, it is important to proceed with this project swiftly. As railway operators have high expectations for the introduction of digitalization technologies, we would like to extensively mobilize our resources covering a variety of technical fields in order to pursue this project.

Online meeting with President Kumagai(right) and committee members

2. RTRI Develops Presstressd Concrete Girder Crack Detection System with Conductive Coating Material

RTRI developed Presstressd Concrete (PC) Girder Crack Detection System with Conductive Coating Material enabling early detection of the cracks and their location on PC girders.

【Overview】

● Fine cracks occurring on PC girders are important clues to assess the performance of the girders but difficult to detect because they are generated only when trains are passing. This system is able to find such fine cracks by measuring the changes in electric circuit resistance caused by the damage of the conductive coating material applied onto the undersurface of the girders.(Fig.1)

● The measured resistance can be checked at a distant places via internet.(Fig.2)

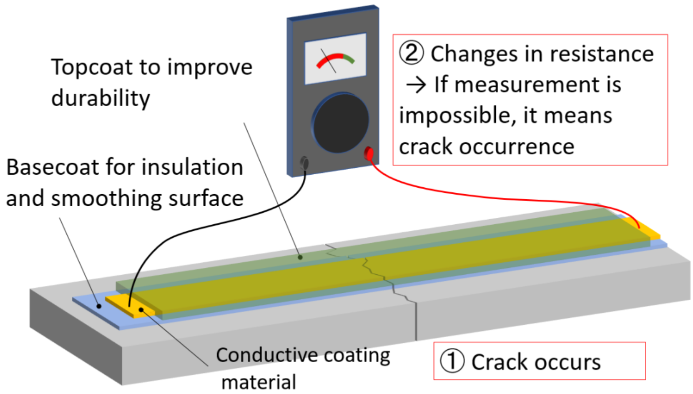


Fig.1 Crack detection with conducting coating material

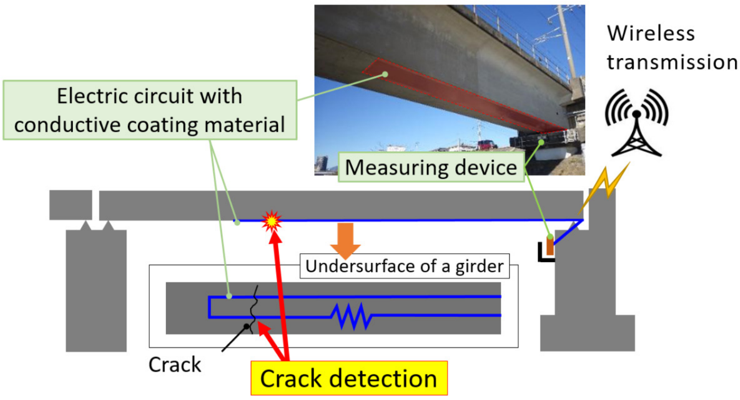


Fig.2 Crack detection system applied onto PC girders

【Advantages of this system】

This system will enable early detection of the occurrence and locations of the cracks that are generated on the undersurface of PC girders and are difficult to find by visual inspections. With this system, railway operators will be able to find such fine cracks by measuring the changes in electric circuit resistance caused by the damage of the conductive coating material applied onto the undersurface of the girders. It leads to more effective repair and reinforcement of the girders and maintenance schedule.

【Background】

The PC girders that have been used for 20 to 50-meter length bridge girders are using PC steel bars. A tensile force applied to the PC steel bars beforehand generates, as a reactive force, a compressive force acting in the longitudinal direction of rails, and it prevents crack generation even under the impacts of train passing. However, the compressive force is diminished if the PC steel is ruptured due to corrosion and other reasons and cracks might be generated on the undersurface of the girders.

At the initial stage, only a small number of PC steel bars have ruptures and cracks occur only when train passes. But the cracks start to occur constantly with the increase as the number of ruptured bars increase, the cracks occur constantly, and PC girders might have seriously damage. Although it is effective for PC girder maintenance to detect the cracks at the initial stage, they are difficult to detect in visual inspections.

【Details of this system】

In this system, electric circuits are built on the undersurface of the PC girders by spraying the conductive coating material. If the surface coated with the material is disrupted by cracks, the circuits are cut off and cracks can be detected.

The circuits consists of a crack detecting section and conducting section. The concrete of the crack detecting section is directly coated with the conducting material in order to detect the number and locations of cracks. On the conducting section, elastic urethane tapes are placed and the tapes are coated with the conducting coating material. Therefore this section is less likely to be cut off even if cracks occur. (Fig.3) If the occurrence of cracks need to be identified in a certain area of the girder, the detecting section is placed and for other areas, the conducting section. By arranging both types of sections like this, multiple cracks and their locations can be detected as is shown in Fig.4. In addition, by analyzing the relationships between the numbers and locations of cracks and the bearing force of the PC girders, it will be possible to estimate the remaining bearing force at the time of crack occurrence.

The measuring device of this system runs on electric batteries for more than 1 year. Since the data of circuit resistance measured 50 times per second can be recorded onto SD cards or other media and is electronically transmitted, it is possible to confirm the data quickly via internet at distant places (Fig.2)

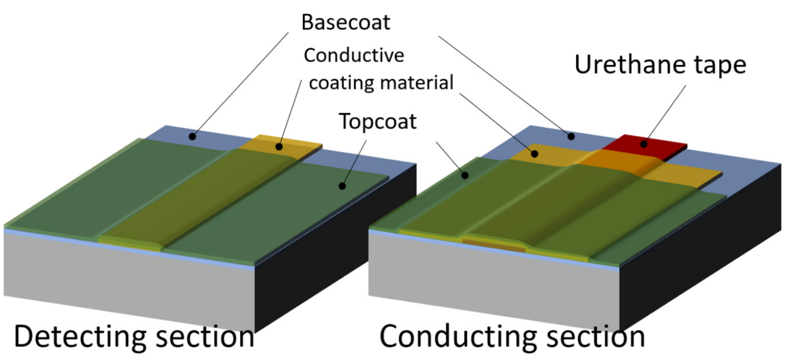


Fig.3 Detecting section and conducting section

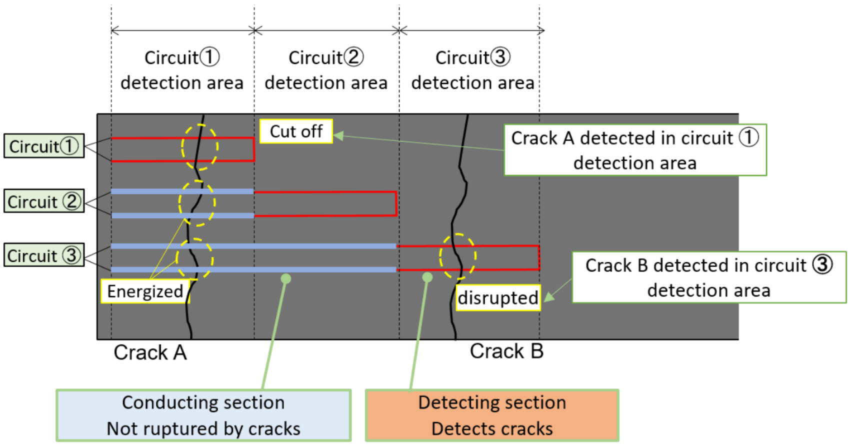


Fig.4 Circuit configuration on the undersurface of a PC girder

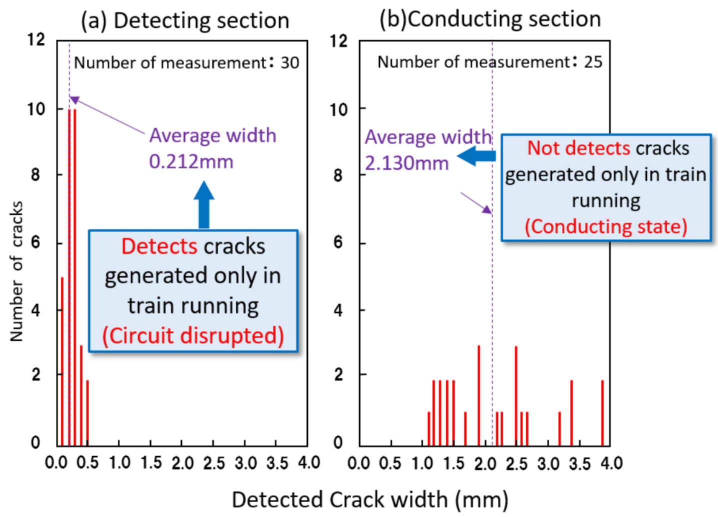


Fig.5 Feature of cracks generated on the coating material applied to detecting section and conducting section

With indoor testing, it has been confirmed that the conducting section circuit is not cut off even if 1mm-wide cracks occur, while the detecting section circuit is cut off by 0.2 mm-wide cracks. (Fig. 5)

Crack generating tests have been conducted on the bridge-model test specimen and it has been confirmed that, when cracks that occur only under train running are generated, only the detecting section circuit is cut off but the conducting section circuit is not and thus the cracks can be detected.

【Test operation on commercial lines】

This system has already been installed to a conventional line facility for a test purpose. It has been more than 3 years since it was applied to the outside facility in December 2016 but the system has been working without any troubles nor maintenance work except battery replacement.

Part of this research has been implemented with the railway technical development grant by the Ministry of Land, Infrastructure, Transport and Tourism.

3. RTRI's initiatives in "Research 2025" for addressing SDGs

The Railway Technical Research Institute started to address Sustainable Development Goals (SDGs).

1. 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.

2. 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.

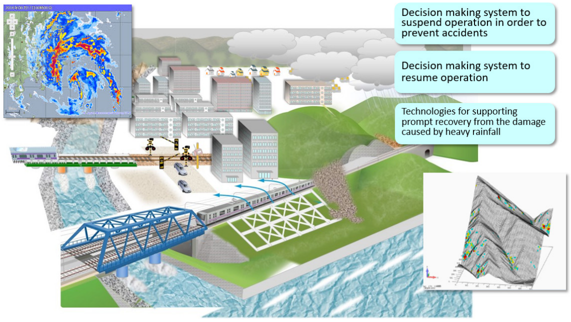
We will communicate our contribution (Fig. 2) in our periodicals and website.

Figure 1:　9 SDGs RTRI is addressing

Table 1: Research activities to achieve SDGs under "RESEARCH 2025"

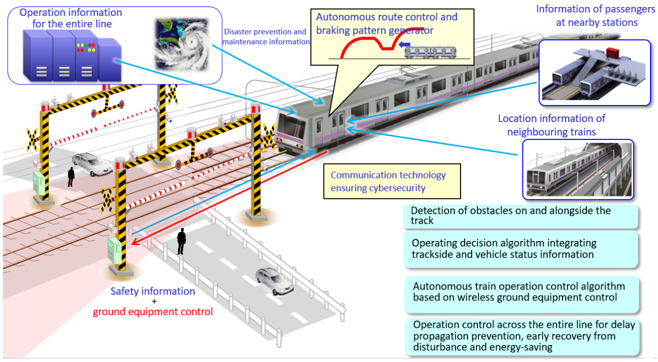
Activities defined in "RESEARCH 2025"	Specific activities	SDGs
1. R&D activities ・ Enhancing safety with an emphasis on improving resilience to natural disasters	・ A particular emphasis on the R&D that contributes to safer and more reliable railway transportation ・ R&D to prevent failures and aging of ground and vehicular equipment. ・ 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 ・ Speeding up Shinkansen while preserving the trackside environment ・ Further energy saving on the railways ・ 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 ・ Development of more advanced simulation technology and original testing and research facilities ・ Accumulating the know-how relating to railway technologies and developing human resources ・ 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 ・ Predicting the future of railways and Identifying technical items for R&D	
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 ・ Providing high-quality R&D results and the information on the activities, using a variety of media ・ 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 ・ Providing systematic training courses for all levels of participants from beginner to expert	・ Further improvement of the contents of periodicals, lectures and technical forums ・ 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 ・ Responding to the severe natural disasters by forming a cross-cutting team.	

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) ・ Active involvement in standardization activities being promoted by international rail-related organizations ・ 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 ・ Promoting the advancement of Japanese railway technologies into the overseas market through the international expansion of technologies developed by RTRI ・ Supporting the international development of railway operators and suppliers	
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 ・ Initiatives for workplace health and safety, mental health, and work-life-balance and support for the next-generation development ・ Fostering an open workplace environment where researchers of different technical fields, generations and positions are able to have free and vigorous discussions	

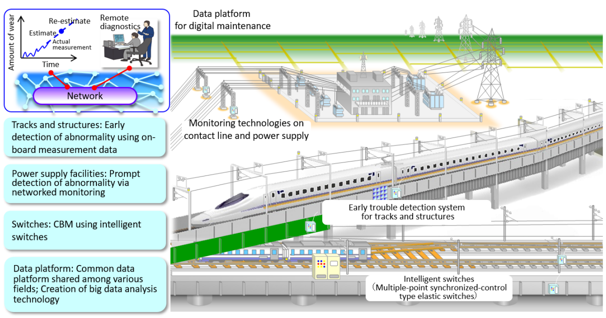


Building resilient railway systems against increasingly severe weather disaster

RTRI supports SDGs



Labor saving by digitalized maintenance



Autonomous train operation

Figure 2: R&D to achieve SDGs

4. New Executive Board Members of RTRI

On June 12, The Railway Technical Research Institute appointed new executives at its 35th meeting of councillors. Accordingly, Eisuke Masada who has served as Chairman since April 2007, Norimichi Kumagai, President since June 2013, Kiyoshi Sawai, Executive Vice President since June 2013, Yoshihiro Suda, part-time executive director since April 2007 and Mitutoshi Inami, full-time Auditor since July 2011 resigned.
Masao Mukaidono, Tomoyuki Koishi and Atsushi Furukawa were newly appointed to full-time executive director, Hiroyuki Ohsaki to part-time executive director and Kiyoshi Sawai to full-time Auditor.

Current board members approved on the 47th meeting of the board members following the councillors meeting are as follows:

Chairman	Representative Director full-time	Masao Mukaidono (New appointment)	RTRI
President	Representative Director full-time	Ikuo Watanabe (Promotion)	RTRI
Executive Vice President	Representative Director full-time	Kimitoshi Ashiya (Promotion)	RTRI
Executive Vice President	Representative Director full-time	Shunichi Kubo (Promotion)	RTRI
Executive Director	full-time	Shunya Shiozaki	RTRI
Executive Director	full-time	Tomoyuki Koishi (New appointment)	RTRI
Executive Director	full-time	Atsushi Furukawa (New appointment)	RTRI
Executive Director	part-time	Masanobu Tabata	Hokkaido Railway Company
Executive Director	part-time	Tomomichi Ota	East Japan Railway Company
Executive Director	part-time	Toshio Otake	Central Japan Railway Company
Executive Director	part-time	Yasushi Neki	West Japan Railway Company
Executive Director	part-time	Eiichi Yata	Shikoku Railway Company
Executive Director	part-time	Youji Furumiya	Kyushu Railway Company
Executive Director	part-time	Yasushi Kamata	Japan Freight Railway Company
Executive Director	part-time	Mami Aoki	Doshisha University
Executive Director	part-time	Yoshifumi Nomura	Japan Private Railway Association
Executive Director	part-time	Hiroyuki Ohsaki (New appointment)	Graduate School of the University of Tokyo
Auditor	full-time	Kiyoshi Sawai (New appointment)	RTRI
Auditor	part-time	Tatsuhiko Yamada	Central Japan Railway Company
Auditor	part-time	Fumiyasu Wakahara	Certified Public Accountant

On the 47th meeting of the board members, it was approved that Norimichi Kumagai and Mitsutoshi Inami are appointed to Senior Advisor and Eisuke Masada was honored with a Fellow of RTRI.

5. Messages from Former and Current Chairmen and Presidents of RTRI

On June 12, The former and current presidents and chairmen of RTRI delivered following messages to all the employees.

(1) Message from the former chairman Eisuke Masada
Since 2007, I have served as chairman of RTRI for 13 years, fulfilling the task of obtaining authorization of RTRI as a public interest corporation by government and hosting WCRR2019. Today I pass my responsibility as chairman to Prof. Masao Mukaidono. During these 13 years, although the world experienced the Lehman Shock, the transport revenue of JR companies steadily increased and we have been able to add some more large-scale equipment to our testing facilities. We have promoted cooperation with overseas research organizations and have been sending a larger number of researchers to these organizations. In addition, the activities and presence of RTRI's Railway International Standards Center have been firmly established and the center has been recognized as an international standardizing organization.

RTRI set and implemented two master plans, RESEARCH 2010 and RESEARCH 2020. Over these years, RTRI contributed to the development of railway technologies even after the first wave of railways speed increase ended. We have established simulation technologies for railways and developed operation and power supply control and maintenance technologies based upon the rapidly advancing information network technology. In the meantime, RTRI has established its reputation as an impartial railway research body through the efforts to restore the damaged areas after the Great East Japan Earthquake in 2011 and a lot of heavy rain disasters and to develop new disaster prevention technologies. I believe this has been achieved by continuous efforts of the management people and all the staff of RTRI and deeply appreciate them.

I have to leave office amid this uncertain, unforeseeable situation due to the Covid-19 pandemic. At this moment, we cannot clearly imagine what shape the world take after Covid-19. But I believe, with RTRI's efficient and flexible response and expertise, we will be able to overcome the radical social change. I hope further development of RTRI and even more energetic research efforts of all the staff members at RTRI.

(2) Message from the new chairman Masao Mukaidono
Since I have served as councilor of RTRI for many years, I know very well what RTRI's researchersare doing and I hope to contribute to RTRI's further development. I am deeply interested in safety and security and have been proposing to build "safety science" that analyzes safety through the integrated research into the aspects of technologies, organization and human resources. Now I am so pleased to get involved in the raiway safety and safety culture.

RTRI has been building trust in the society through establishing advanced technologies as one and only specialized railway technical research organization. We have the responsibility to continue, maintain and develop what has been built so far. In the prospectus of RTRI, it reads "RTRI develops advanced, broad range technologies covering basic ones to practical appliations, accurately responds to the need of the society and cotributes to the development of science and culture of Japan." We have to continue this contribution to the society with united efforts and with pride. The Covid-19 pandemic has drastically changed the world and pushed us towards a new era. No organizations will be able to survive without changing their ways of working. RTRI also has to open a new trail. However, a crisis can be transformed into an opportunity and this is the time to share our wisdom. We need to go forward into a new society.

Although the society is always changing, I believe we should not change our basic principles.
Keeping the respect for the basic principles and ideals, we should read the changing times and the future and respond to them flexibly. Business entities should respect three categories of safety. First one is the safety of customers, that is, product safety in the field of manufacturing and in the world of rail operation, railways' safety itself.

The second is the safety of employees that means labor safety ensuring safe, healthy and happy lives for employees. The third is the safety of the corporate entity which means a sustainability achieved through complying with laws and orders, fulfilling corporate social responsibility and gaining trust of the society. My reponsibility at RTRI is to overview RTRI's activities from a different, broader and longer perspective and to create, with all the board members and staff members, a comfortable workplace where all the employees can work happily and with high motivation.

Former chairman Masada

New Chairman Mukaidono

(3) Message from the former president Norimichi Kumagai

Since I became president of RTRI in 2013, the third year as a public interest corporation, I was keenly aware of the necessity to drive the growth of RTRI as a public interest corporation. This objective took shape as the master plan RESEARCH 2020 and RESEARCH 2025 outlining the direction that RTRI should take in the next 30 years. In addition, a new research division and a laboratory were added during these years. I am pleased that these division and laboratory have been expanding their activities and producing a lot of research outcomes. It was particularly memorable that "Vision" of RTRI was set and our "Mission" and "Strategy" were clearly defined.

Throughout these years, I have been addressing "re-confirming RTRI's unwavering role," "emphasizing safety technology, speed-increasing technology and basic research including simulation technology development," and "fully utilizing RTRI's broad range, crosscutting research capabilities based on the expertise achieved over the long history as a research institute." I have also stressed, as the base of all the activities, "maintaining the trust of the national government and railway operators and providing high-quality research outcomes quickly and flexibly." Setting a research map and readdressing basic research were also important tasks. Now I am confident that the research and development at RTRI has reached a highly advanced level with the dedication and motivation of all the employees.

The new president Watanabe has a multilateral perspective, excellent communication skills and tireless energy and is absolutely the right person for this position to drive the sustainable development of RTRI. I am very much looking forward to his leadership in the years ahead.

Researchers need to seek original inspiration and enhance their research potentials at the same time. In order to solve issues, they have to work together as a team as well as pursuing each one's originality, and this is the crosscutting, collective power of RTRI. Now, we are in the midst of unstable, uncertain reality beyond our expectation, but it is a favorable aspect of this circumstance to be able to arm ourselves with digitalization technologies that will create new railway systems. I hope that the researchers at RTRI will always keep in mind that we need to gain trust of rail operators and the society, face the threatening situation with the wisdom and potentials as a team and overcome challenges. I am looking forward to your renewed inspiration and best efforts under the leadership of the new chairman and president.

(4) Message from the new President Watanabe

I would like to express sincere thanks to the former chairman Prof. Masada who has been providing us valuable advice on the management and R&D over years and the former president Dr. Kumagai who has been managing RTRI under the powerful leadership. Thanks to the dedication of Prof. Masada and Dr. Kumagai, RTRI has been implementing the research and development as an institute trusted by the government and railway operators and enhancing its presence.

Currently, Japanese and global rail industries are facing an unprecedented predicament due to Covid-19 pandemic. However, this year, 2020 is the starting year of the master plan RESEARCH 2025 and we will continue our activities without any changes according to the principles described in the plan, "Enhancing safety with an emphasis on improving resilience to natural disasters," "Developing innovative railway systems based on digital technologies," "Creating high-quality research outcomes by pursuing excellence across all fields of activities," "Enhancing international presence of the Japanese railway technologies," "Creating a work environment to help the employees develop their full potential and undertake challenging tasks". We will steadily continue the research and development aimed at improving safety, cost reduction, environmental protection and improving convenience in order to enhance the value of railways and to provide customers safe and comfortable rail transport services again.

I would like to fulfill the responsibility of managing RTRI, keeping in mind the following three policies.

Firstly, we should keep an adventurous spirit to take on challenges. While digitalization technologies have been showing a spectacular progress, the circumstances around railways are dramatically changing in terms of passengers' behaviors and supply chains business practices. Therefore, we may have to advance into new research fields and we may not be able to produce useful outcomes just by following our conventional ways of thinking and doing research. I hope that RTRI's researchers will be always ready to change things to be changed and address new research fields and challenging tasks.

Secondly, we need to raise the basic research ability of each researcher including the insight to understand the essence of problems or various phenomena, problem solving ability based on scientific and engineering approaches. For this purpose, we will put emphasis on basic research that is important to train researchers' fundamental research capability. Since RTRI needs to conduct investigations into disasters and troubles of railway facilities quickly and to propose effective measures, human development and construction of testing facilities for these activities will be continued.

The third task is to implement RESEARCH 2025. I will be doing this task, adding necessary changes to the plan according to the circumstances.

I am always trying to "think positively and enjoy working". As research and development is to create new values that nobody has come up with before, it's fun. Now is the time for us to enjoy our everyday work and keep going forward together.

Former president Kumagai

New President Watanabe

6. RTRI Develops On-Board Measurement Method to Identify Resonant Bridges

Railway Technical Research Institute developed a method to identify resonant bridges that vibrate intensely due to resonance using the data measured by running trains. This method has enabled to save the labor required for ground measurement and made possible more efficient inspections.

[Overview]

Usually, while a Shinkansen train passes on a bridge, downward displacement occurs due to the moving train load. In the meantime, due to the aging of bridges and increased train speeds, some of the bridges resonate with the vibrations of the running train and the bridge vibrations increase with train passing. [Fig. 1(b)] Since large amplitude resonance affects ride comfort and durability of facilities, preventive measures may be needed. Therefore, it has been necessary to identify bridges that resonate with passing trains (resonant bridges) among a vast number of bridges.

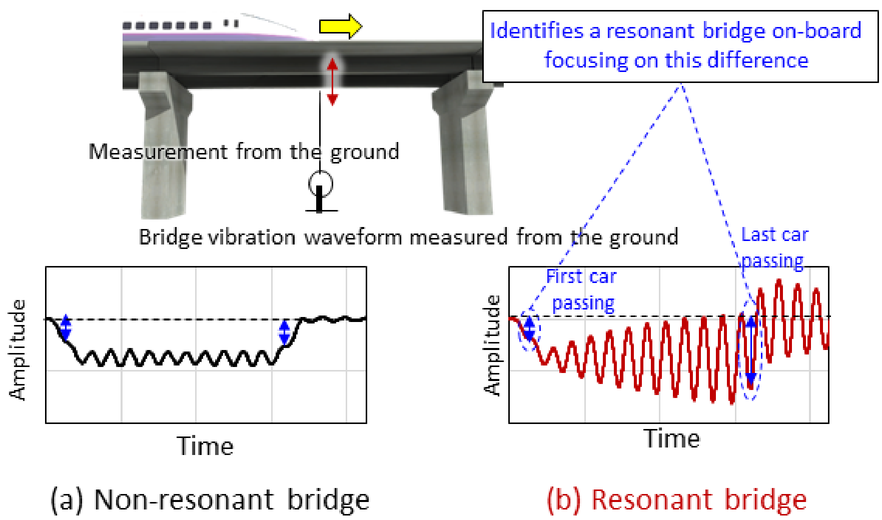


Fig.1 Vibration waveforms of ordinary (non-resonant) bridges and resonant bridges

In order to solve this problem, RTRI developed a new method marked by the following two points:

・The vibration data measured on the passing train includes vibrational components specific to the resonant bridges. We have been able to identify resonant bridges by focusing the differences between these vibrational components measured by the first car and the last one. (Fig.2) Prior to the development of this method, it has been necessary to mount one sensor to each bridge and to measure the vibration amplitude of each bridge from the ground. The newly-developed method has made it possible to measure the entire area that a train runs through and therefore the workload can be greatly reduced.

・This method can be easily introduced to bridge inspections by using the data of the existing track maintenance database system (LABOCS).

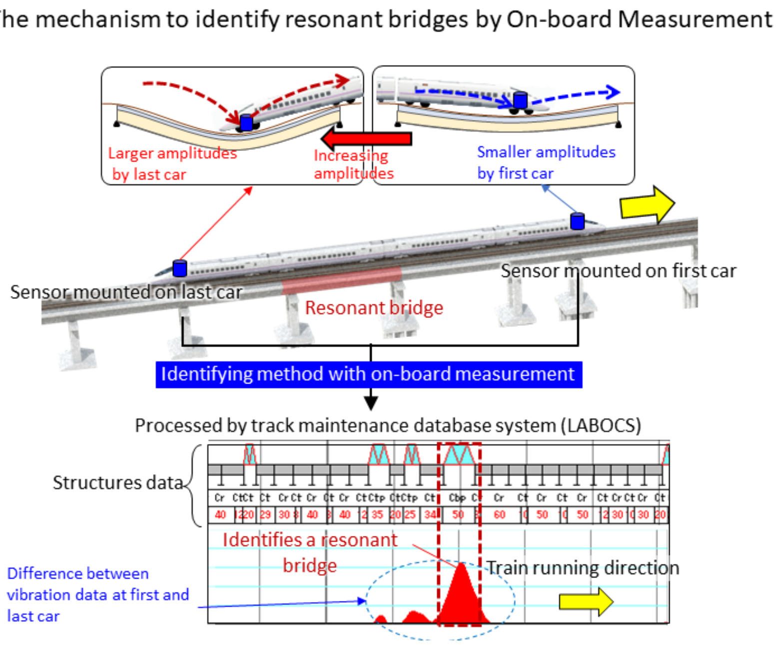


Fig. 2 The method to identify bridges that vibrates intensely using on-board measurement

[Using the method for effective maintenance]

This method has already been used on the Shinkansen track and 10 resonant bridges have been identified. The results help determine the priority in inspecting bridge facilities and enhance the efficiency of maintenance.

Going forward, it is expected as well that this method will be used to evaluate impacts of train speed increase on bridges and their facilities and to determine the necessity of introducing any measures.

***1 Resonance**

Resonance occurs when difference between the frequencies of bridge vibrations cause by a passing train and the natural frequency of the bridge gets smaller.

***2 LABOCS**

A software that analyzes and processes a wide variety of data including the track irregularity and vehicle vibrations. This software was developed by RTRI and used by 6 JR passenger rail companies and other railway operators for the track condition monitoring and maintenance.

7. RTRI's Researcher Receives the Young Scientist Award

Dr. Hirofumi Tanaka, Senior Researcher of RTRI, received the Young Scientist Award for the fiscal year 2020 one of the Commendation prizes by the Minister of Education, Culture, Sports, Science and Technology. On August 25, Dr. Tanaka was handed the commendation certificate by Dr. Masao Mukaidono, Chairman of RTRI.

Award winner:
Dr. Hirofumi Tanaka
Senior Researcher, Track Geometry and Maintenance, Track Technology Division

The award-winning research:
Improving the efficiency of rail roughness maintenance

[Outline of the research]
On rail surface, roughness is generated at the time of manufacturing or by train running. When a train runs on the rough-surface rail, significant noises and vibrations might be generated depending on the extent of roughness. Since the wavelengths and amplitudes of the noises and vibrations are minute, several to hundreds millimeters and less than 1 millimeter respectively, the techniques to detect and measure the roughness efficiently and precisely have not yet been established so far.

Then, Dr. Tanaka conducted the following:
1. Development of the method to evaluate the roughness efficiently using the noise and acceleration data measured on board.
2. Development and commercial application of the ground equipment that is capable of measuring the roughness accurately
3. Proposing an efficient roughness controlling method using the above method and equipment

The result of this research enables quantitative management of rail-surface roughness, and cost reduction and improvement of railway facilities maintenance.

[Comment by Dr. Tanaka]
I am greatly honored to receive this prestigious award. I would like to express sincere thanks to the people at RTRI and other organizations including railway operators who have given to me a lot of guidance and advice.

The subtle roughness on the rail surface generates noises and vibrations and they might damage the trackside environment and the ride comfort in the cabin, and further on, damage facilities. The results of this research will contribute to achieving efficient rail-roughness maintenance to prevent the growth of roughness and to further development of railways.

With this encouraging award, I would like to continue the research in order to contribute to further development of railways and creation of a happier society.

*** Young Scientist Award by the Minister of Education, Culture, Sports, Science and Technology:**
This award was launched in order to support the next-generation researchers' career formation and to contribute to developing original and creative technologies and is given to young researchers who have shown outstanding research abilities by conducting the research into newly-emerging issues or from original perspectives.

Dr. Tanaka (left) handed the award certificate by Prof. Mukaidono

8. RTRI's Researcher awarded the Medal with Yellow Ribbon

Dr. Fumiaki Uehan, Director of Railway Dynamics Division at RTRI, was awarded the Medal with Yellow Ribbon in the spring in 2020.
Since the award ceremony was canceled due to the novel coronavirus outbreaks, Dr. Uehan was handed the award certificate and the medal by Prof. Masao Mukaidono, Chairman of RTRI on August 25 at RTRI.

Award winner:
Dr. Fumiaki Uehan
Director, Railway Dynamics Division

The award-winning research:
Invention of the non-contact vibration measurement system for structures diagnosis

[Outline of the research]
Since Japan has been facing many issues such as increasingly severe natural disasters, aging social infrastructure and decreasing working-age population, it is an urgent necessity to develop labor-saving technologies for structures inspection and diagnosis. Dr. Uehan developed the non-contact vibration measurement system "U-Doppler" and made it available for commercial services. U-Doppler is capable of detecting the structures damage caused by disasters and deterioration by aging. Since this system features a correcting mechanism that compemsates for the effects of winds and ground vibraions, it is capable of measuring subtle vibrations of structures accurately and conducting quantitative structures inspections by irradiating the structures with a lazer from outside remote places.

In addition, a drone has been used for inspections since an earlier stage and it has made it possible to detect local changes on structures and trackside slopes.

Since these techniques enable quantitative inspections without requiring the work at high places or in the areas close to tracks, they have been widely used mainly for railways.

[Comment by Dr. Uehan]
I am greatly honored and pleased to receive this prestigious Medal with Yellow Ribbon and I am so grateful that this award has shed light on the research and development in the field of structures inspection.

I have been focusing on improving the technologies for railway structures inspections for about 20 years. I would like to express sincere thanks to the people at RTRI and affiliated companies for their cooperation in developing and raising the popularity of the U-Doppler and to the staff people of railway operators who have supported me since I was running around railway structures holding a prototype machine.

Being encouraged by this award, I will keep focusing on the structures inspection technologies in order to ensure the safety of railway operation and to save labor for maintenance. I will be most grateful if I could ask for your continued support.

Dr. Uehan (left) handed the award certificate
by Prof. Mukaidono

The non-contact vibration measurement system
Left: U-Doppler II Right: U-Doppler I

9. Numerical Simulation of Train Cabin Ventilation by Open Windows

RTRI numerically simulated the ventilation of an urban commuter train with windows opened, using the airflow simulator which RTRI developed, and evaluated its effect. (Fig.1)

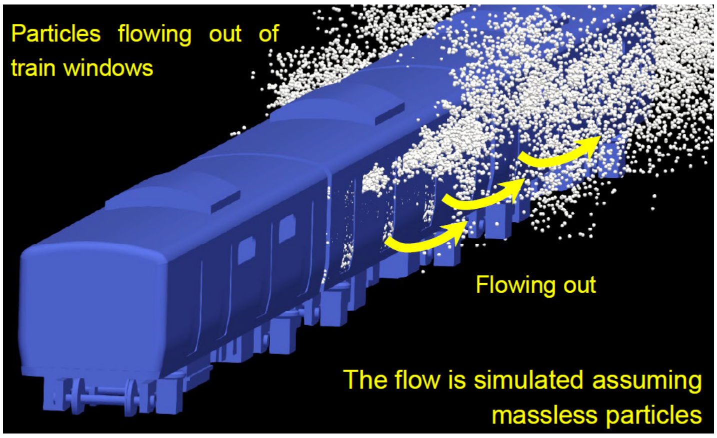


Fig. 1 Cabin air ventilated through open windows

[Outline of the result]

・The volume of the air ventilated from a train window is proportional to the opening areas and train running speeds.

・The volume of ventilated air is not substantially affected by passenger occupancy rates.

・When a train is running at 70 km/h with 6 windows opened by 10 cm, the ventilated volume through the windows is 0.36 m^3/s, which means that the air inside a train cabin is completely replaced with the fresh air once every 5 to 6 minutes. The total ventilated volume combining air conditioners and open windows is 0.78 m^3/s, meaning that the cabin air is replaced once every 2 to 3 minutes.

* Ventiration rate = Ventilated air volume per second

[Evaluation of ventilation rate]

* Posted on the website of the Ministry of Land, Infrastructure, Transport and Tourism on June 5, 2020

Fig.2 and 3 shows some of the simulation results. Fig. 2 shows ventilated volumes from 6 windows with different opening areas at train speeds of 72 km/h and 45 km/h, with the passenger occupancy of 0% and Fig.3 shows the volumes at different speeds. As you can see from these graphs, ventilated volumes are proportional to opening areas and train speeds. For example, if a train is running at 70 km/h with windows pulled down 10 cm (opening area 0.72 m^2, the ventilated volume of the car will be 0.36 m^3/s. It means that the air inside the cabin is completely replaced with the fresh air once every 5 to 6 minutes.

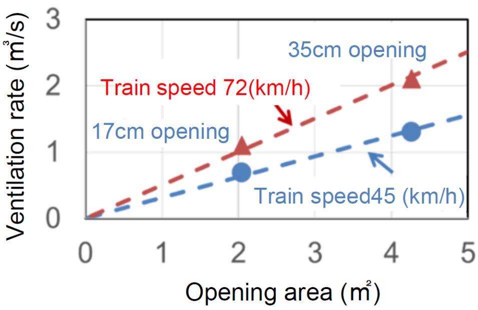


Fig. 2 Ventilation rate by opening area

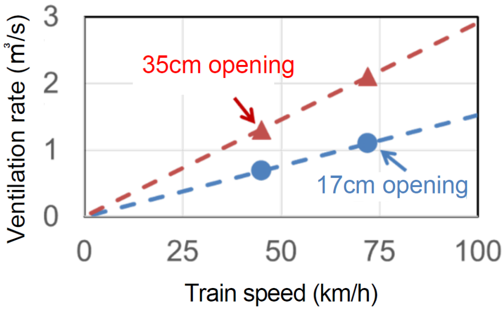


Fig. 3 Ventilation rate by train speed

[Evaluation of the impact by occupancy]
Using the models assuming 50% and 100% passenger occupancy shown in Fig.4, we analyzed the impact of the occupancy on ventilation rate. In the 50% model, all the seats are occupied and passengers are standing near the doors and around the center of the aisles. In the 100% model, passengers are standing with 10 to 20-centimeter distance from each other. The result of ventilation simulation under these conditions is shown in Fig.5, which indicates that the ventilated volumes decrease only a little, even if the occupancy rates go up.

(a) Occupancy（80 passengers）

(b) Occupancy（160 passengers）

Fig. 4　Passenger occupancy model

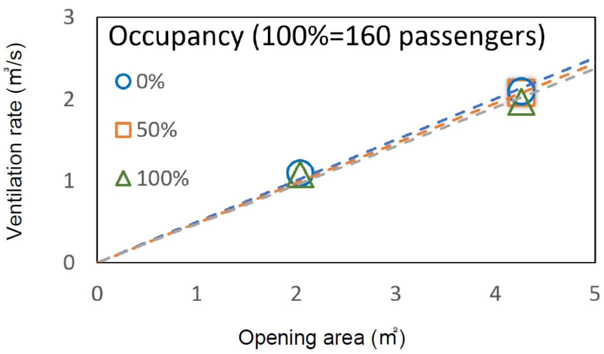


Fig. 5　Ventilation rate by occupancy

[Evaluation of the effects by air-conditioners and fans]

Using a model assuming that air-conditioners and fans are working (Fig.6), we have analyzed the relationship between air-conditioning effects and ventilated volumes. (Fig.7) The result is shown in Fig.8 and indicates that air-conditioning has little impact on the air volumes ventilated through open windows. Therefore, if a vehicle is equipped with air-conditioners taking in outer air, the ventilation rate will be the total of the intake by air-conditioners and the volume ventilated through windows. For example, as is shown in Table 1, if the intake of outer air by air-conditioners is 0.43 m³/s, the air inside a cabin is completely replaced by fresh air every 2 to 3 minutes.

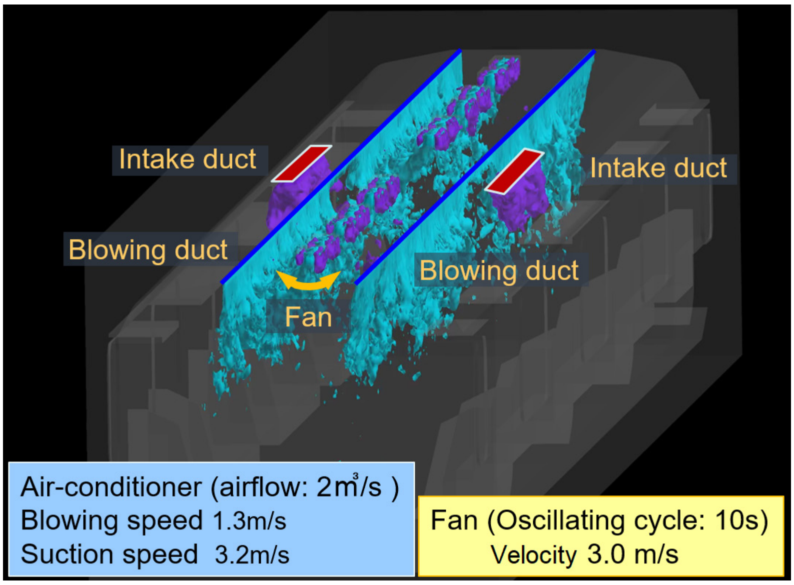


Fig. 6 Air-conditioned and fanned cabin model

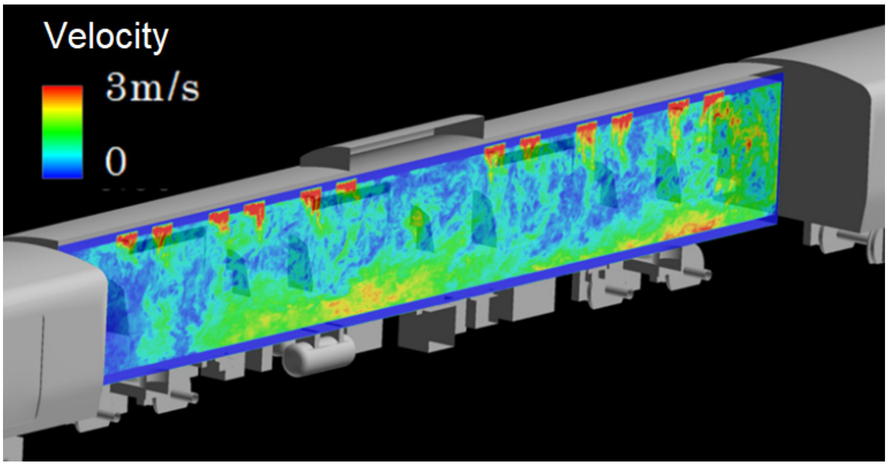


Fig. 7 Velocity distribution in a cabin

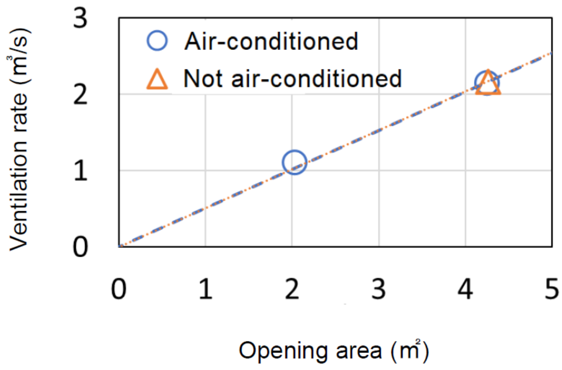


Fig. 8 Ventilation by windows and air-conditioning effects

Table 1 Ventilation effects by air conditioners taking in outer air

	With outer air intake	Without outer air intake
Ventilated volume by windows	0.35 m³/s	0.35 m³/s
Outer air intake by air conditioner	-	0.43 m³/s
Time for complete replacement of air	5.3 minutes	2.4 minutes

[Further confirmation and evaluation]

We will confirm the accuracy of the numerical simulation through measurement on actual train vehicles and analyze the ventilation effects of the sideway seat arrangement and gangways. We will also evaluate in detail the airflow at different areas of such vehicles.

10. Digital Maintenance Technical Seminar Held in Osaka

On October 22, at Hotel Mielparque Osaka, RTRI held Digital Maintenance Technical Seminar focusing on labor-saving and remote operation in railway facilities maintenance.

RTRI has been addressing research into “labor saving by digital maintenance” in order to attain more labor-efficient railway facilities maintenance by fully using digital technologies. Currently, we are in the midst of the Covid-19 pandemic and, in terms of minimizing the infections, remote operation of facilities maintenance is increasingly important.

This seminar was held with sufficient measures taken to prevent the coronavirus infections. 94 participants from 25 companies, mostly railway operators, joined the seminar. Its keynote lectures were live-streamed and 64 viewers from 36 companies watched them.

During the seminar, three keynote speeches in the fields of structures, track and earthquake engineering and eight presentations of our research results were made. Two of the presentations were delivered in “hybrid” style combining live streaming from the test fields at RTRI and presentations at the seminar venue, and six were remotely done by researchers who explained from RTRI about the panels, monitor screens, exhibited materials and models at the seminar venue.

[Keynote speeches]

・Masayuki Koda
Director, Head of Structures Technology Division
“Railway structures maintenance using digital technologies: labor saving in construction work”

・ Hiroo Kataoka
Director, Head of Track Technology Division
“Labor saving and safety improvement in track maintenance using digital technologies”

・Shunroku Yamamoto
Director, Head of Center for Railway Earthquake Engineering Research
“Early reopening of train operation after an earthquake using real-time data”

[Research presentations]

Hybrid style

・Visual inspection support system using 3-dimensional images
・Track maintenance database system LABOCS and its future prospect

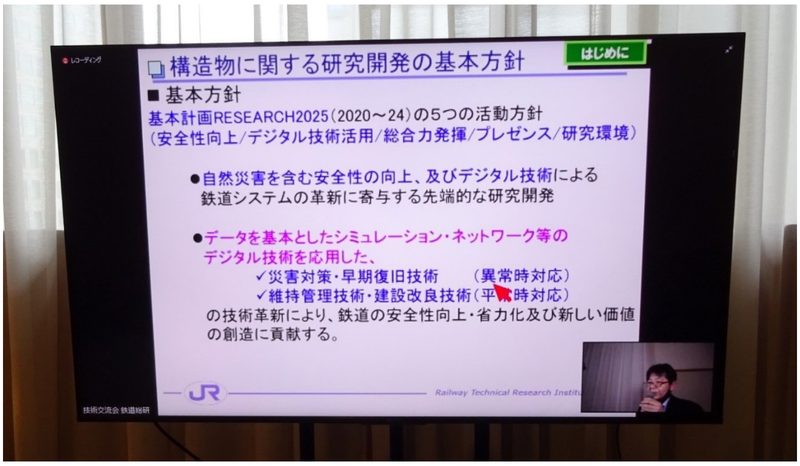
Remote style

・Tunnel inspection support system using image data
・Station renovation support system using passenger flow simulation
・Track2er: low-cost track inspection device
・Degradation assessment system for wood sleepers using deep learning
・Train inspection support system using image analysis engine
・DISER and supporting early reopening of train operation after an earthquake using displacement sensor

For further details please contact:
https://www.rtri.or.jp/sales/inquiry.html

Keynote speech

Seminar venue



Live streaming of a keynote speech
Bottom-right is the speaker
Railway structures maintenance using digital technologies: labor saving in construction work

Hybrid presentation

Presentation at the seminar venue
Visual inspection support system using 3-dimensional images

Live streaming from the test field reproducing railway structures at RTRI
Visual inspection support system using 3-dimensional images

Remote presentation

Participants asking questions at the seminar venue
Train inspection support system using image analysis engine

A researcher making remote presentation and answering questions from RTRI
Train inspection support system using image analysis engine

11. Digital Maintenance Technical Seminar Held in Tokyo

On November 11, at Yurakucho Asahi Square, Tokyo, RTRI held the Digital Maintenance Technical Seminar.

RTRI has been addressing the research into "labor saving by digital maintenance" in order to attain more labor-efficient railway facilities maintenance by fully using digital technologies. Currently, we are in the midst of the Covid-19 pandemic and the need for labor-efficient, remote systems for maintenance work is even more highlighted. This seminar was thus focused on labor-saving and remote operation in railway facilities maintenance.

For holding this seminar, sufficient measures were taken to prevent the coronavirus infections. 95 participants from 35 companies, mostly railway operators, attended the seminar.

[Remote exhibition]

Following nine items of RTRI's research results were presented at this seminar, covering fields of structures, track, power supply and earthquake engineering. Panels and monitors, real and model devices were exhibited at each booth stands in the seminar venue, and the researchers made presentations, answered questions from the visitors and demonstrated the operation of devices remotely from RTRI in Kunitachi.

[Presentations]

- Visual inspection support system using 3-dimensional images
- General inspection support system for tunnels using image data
- Track2er: low-cost track inspection device
- Condition assessment system for wooden sleepers using deep learning
- Condition assessment device for trackbed focusing on the noise transmission property of ballasted track
- Non-contact measurement device for overhead wire using images
- LABOCS, Database System for Railway Track Maintenance, and its future prospect
- Train inspection support system using image analysis engine
- Supporting early resumption of train operation after an earthquake using DISER, Damage Information System for Earthquake on Railway, and displacement sensors

For further details please contact:
https://www.rtri.or.jp/sales/inquiry.html

Remote exhibition at the seminar venue

A researcher delivering a presentation and answering questions remotely from RTRI at Kunitachi

12. High-Speed Pantograph Testing Machine Completed

AT RTRI, a world's highest level pantograph testing machine was completed (Fig. 1). This machine is capable of moving a pantograph at high speeds up to 500 km/h, powered with large current from trolley wire and assessing the performance of Shinkansen's pantographs. This machine will be used to develop a pantograph which has an excellent performance to keep contact with trolley wire and is capable of reducing contact loss. The mechanism of abrasion of pantograph contact strips and trolley wire will be analyzed with this machine as well.

[Outline of the high-speed pantograph testing machine]

The high-speed rolling disk is capable of:

- reproducing the moving state of a pantograph of a high-speed train running up to 500 km/h (Fig.1)
- capable of reproducing contact-loss arcing between a pantograph and trolley wire and increase in the temperatures of parts by applying electrical current (maximum 600 V, 1000 A) to the pantograph and trolley wire, (Fig. 2)
- reproducing lateral and vertical displacement of trolley wire (Fig.3)
- conducting tests with real trolley wire (Fig.3)
- reproducing vertical vibration of a train vehicle by shaking the pantograph stand vertically
- conducting tests under the temperatures and humidities controlled by air-conditioning device

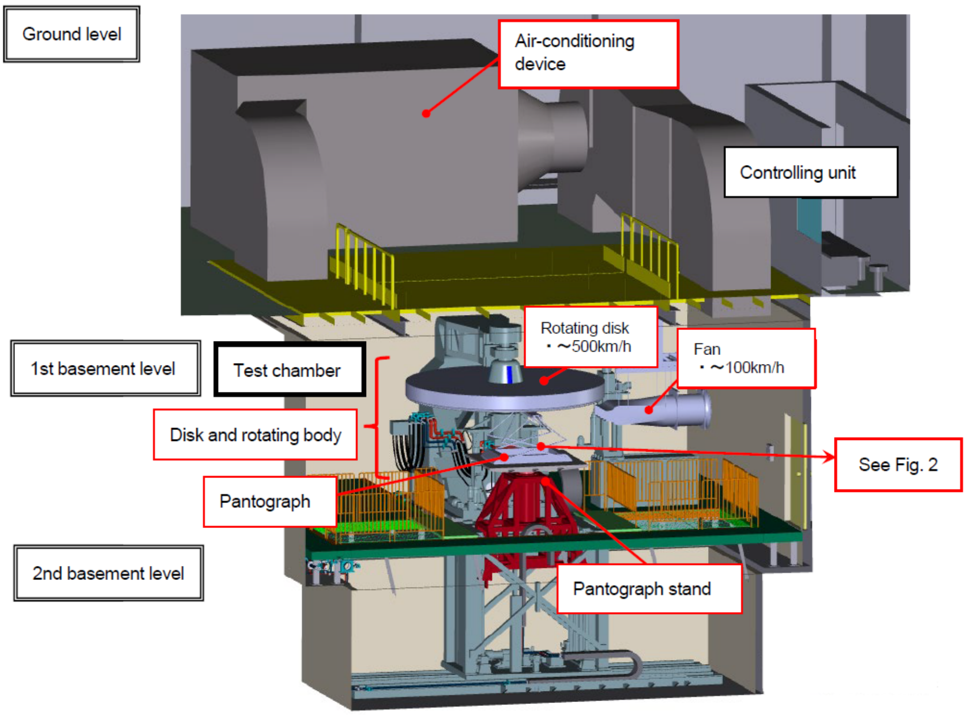


Fig.1: High-speed pantograph testing Machine

Table 1: Specifications

device		specification
Rotating disk	Maximum rotating speed	500km/h
	Vertical disk shaking	Maximum frequency: 27.8Hz Displacement: -100mm to +100mm（depending on frequency） Waveforms can be adjusted
	Lateral disk shaking	Maximum frequency：5Hz Displacement: -300mm to +300mm（depending on frequency） Waveforms can be adjusted
Pantograph stand	Vertical shaking	Maximum frequency: 10Hz Displacement: -35mm to +35mm（depending on frequency） Waveforms can be adjusted
	Elevating distance	1600mm
Air-conditioning device	Temperature	-20℃ to +40℃（When rotating disk is operated）
	Humidity	10%～90%（Humidity can be changed at the temperature of 10℃ or higher）
	Fan	60 to 100km/h
Power unit	Type	AC or DC
	Voltage	100～600V
	Current	100～1000A（Controllable on 1 to 10 scale）

Fig.2: Testing on the high-speed pantograph testing machine
（Rotating speed: 360 km/h, AC200V, 600A）

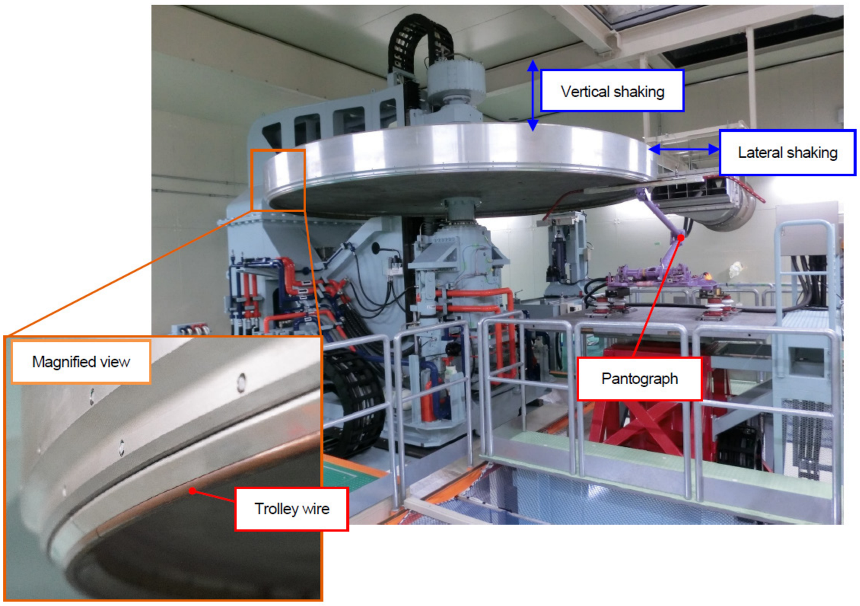


Fig.3: Rotating body and disk

[Further tests and development]

Evaluation of pantograph performance

We will evaluate the pantograph performance such as contact-keeping performance and rate of contact loss.

Development of Shinkansen pantographs

We will efficiently develop pantographs for Shinkansen such as active-controlled pantographs.

Development of sliding plates

We will improve the reliability of tests by properly controlling testing conditions including temperatures and humidities. Under the controlled conditions, we will analyze the mechanism of abrasion of trolley wire and pantograph sliding plates and improve the efficiency in the performance evaluation of sliding plates performance and materials evaluation to extend their service live.

Analyizing causes of failure

By reproducing power supply conditions as well as vertical displacement of trolley wire, we will analyze failure causes and develop preventive measures efficiently.

[Reference]

The performance of a conventional rolling disk machine used before is as follows:

Maximum rotating speed: 300 km/h

Power unit: 100V, maximum current 400A

No air-conditioning device

13. The 9th SNCF-RTRI Collaborative Research Seminar held

The Railway Technical Research Institute (RTRI) and SNCF held their 9th Collaborative Research Seminar on December 3, 2020.

RTRI and SNCF concluded an agreement on collaborative research and related activities in 1995. Since then, both parties have been collaborating in many fields of railway technical research. They jointly organize a research seminar every two years. There, they discuss their management policies regarding collaborative research, deliver presentations of the results of each research project and set the plan and schedule of projects for the next phase.

This 9th Seminar was attended by 40 people, including Mr. Pierre Izard, Vice President, and Ms. Carole Desnost, Director of Innovation and Research from SNCF, RTRI's President Watanabe and Executive Director Furukawa and researchers of each project. The participants from SNCF had planned to visit Japan and attend the seminar, but due to the Covid-19 travel restrictions, the seminar was held online.

(1) Management Meeting

The Management Meeting was attended by Vice President Izard, President Watanabe and other executives. The RTRI participants explained the outline of the master plan started in 2020 “RESEARCH 2025” and their initiative to introduce AI and other digital technologies to railway operation. The SNCF participants explained the outline of their research project “TECH4RAIL”※1 and “SNCF initiative to realize carbon-free railways in 15 years” as one of their energy-saving efforts. Both parties agreed to continue sharing information on the topics to use AI and other cutting-edge technologies.

※1 TECH4RAIL is a research and development plan that SNCF has been implementing since 2016, and Zero Emission is set as one of its goals.

Management Meeting (Upper center: President Watanabe)

(2) Presentation Meeting

Presentations were delivered on two collaborative research projects and eight information exchange projects of the 9th Phase from 2018 to 2020 and on two collaborative research projects and eight information exchange projects of the 10th Phase from 2020 to 2022, followed by lively discussions (Table 1).

In particular, the presentation on the topic "Passenger-driven operation" was followed by active discussions on the amount and accuracy of machine learning data used to predict delays in train operation, reflecting great interest of the participants in applying the state-of-the-art technologies to railways.

The next collaborative research seminar will be held in the fall of 2022 in Japan.

Table 1 9th Phase and 10th Phase Collaborative Research / Information Exchange Projects

Type	9th Phase (2018-2020)	10th Phase (2020-2022)
Priority topics	● Detection of obstacles in the track from the cabin or track side (autonomous train operation) ● Energy storage systems and high-voltage converters (Energy saving)	● Information exchange on AI applications to railways ● Information exchange to analyze cases of scouring disasters (disaster prevention) ● Further utilization of energy storage systems and high-voltage converters, for higher environmental and cost performance (energy saving) ● Human science for safety
Collaborative Research	● Improvement of the analysis of crack growth in rails ● Study on the inspection and predictive maintenance for power supply system	● Study on the inspection and predictive maintenance for power supply systems ● Study on aerodynamic noise of rolling stock bogies by numerical simulation and wind tunnel tests
Information Exchange	● Evaluation of aerodynamic noise of rolling stocks by numerical simulation and wind tunnel tests ● Wear characteristics of bainite rails※2 ● Train-track interaction for running safety ● SIL4※3 high positioning train technology ● Applicability evaluation of superconducting feeder cables for high-speed railway systems ● Passenger-driven operations	● Examination of current property on superconducting feeder systems for high-speed railways ● Optimized train operations to improve passenger's service and punctuality ● Information exchange on recovery mechanism of ballast lateral resistance by stabilizers※4 ● Information exchange on 3D printing application to manufacturing parts

※2 Rail with bainite structure developed to suppress shelling, which is rail damage due to contact with wheels

※3 Safety Integrity Level, defined in IEC61508. SIL4 is the highest level of safety (lowest probability of fatalities due to equipment failure).

※4 Track maintenance machine that promotes the stability of the track by applying vibration to the track on the rail after work such as track bed replacement.

Presentation Meeting (RTRI)

14. RTRI Develops a Risk Assessment System for Snowmelt Disasters

RTRI has developed a risk assessment system for snowmelt disasters. (Fig. 1) This system assesses the risk of slope collapses caused by snowmelt water in early spring, and the first one developed for railways in Japan.

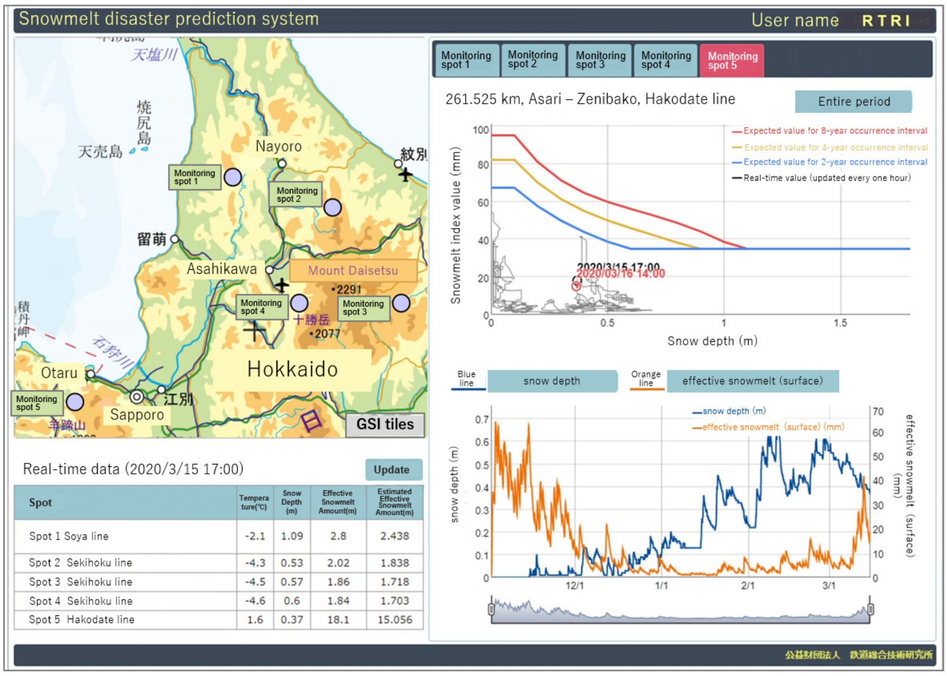


Fig. 1 The display of risk assessment system for snowmelt disasters

1. Background

In early spring, snow areas are sometimes hit by snowmelt disasters as well as avalanche. A large amount of snowmelt water as well as rainwater penetrates the ground in spring and causes slope collapses. Although the slope collapses by snowmelt occur less frequently than landslides caused by rainfalls, they tend to cause serious accidents such as derailments in addition to train delays. Railway operators have intensified trackside patrolling according to temperatures and, if necessary, lower the limit rainfall amount to restrict train operation when snowmelt is progressing, but a method to determine the necessity of patrolling based upon scientific standards have been desired.

2. Characteristics of the system

・The risk of snowmelt disasters is assessed every one hour and the data is provided to railway operators to determine the necessity of patrolling during the snowmelt season.

・As the data necessary to assess the risk is obtained from AMEDAS (Automated Meteorological Data Acquisition System) , building additional meteorological observation facilities is not required.

・By using two indicators, snowmelt amount and snow depth, the risk of snowmelt disasters can be assessed effectively.

3. Risk assessment with this system

(1) Outline

The system consists of servers managed by RTRI and applications with following functions.

- Function to gather AMEDAS data on targeted areas every one hour.
- Function to estimate snowmelt amount every one hour, convert the data to effective snowmelt amount which is an index that has a strong correlation with ground water levels, and then assess the risk level by comparing the index with the preset standard value.
- Function to post estimated effective snowmelt amount on the dedicated website and, if the values exceed the standard value, indicate it on a monitor screen and inform users of the disaster risk level.

Railway operators can check the assessment results for the predetermined spots by accessing the website using computers and tablets. The service is provided fee-based.

(2) The mechanism of snowmelt disasters and effects of the risk assessment system

Snowmelt disasters take place following the 3 steps shown in Fig. 2.

① Snowmelt water and rain penetrate the ground.
② The groundwater level rises.
③ The ground becomes unstable and slopes collapse.

This system estimates amounts of water penetrating the ground using snow depth and effective snowmelt amount and assesses the impact on the step ③, slope stability.

Railway lines extend thousands of kilometers and the risk monitoring needs to cover wide areas. Considering such conditions specific to railways, this system assesses snowmelt disaster risks using four indices, air temperature, precipitation, wind speed and sunlight hours for every hour. The data is obtained from the nationwide AMEDAS network data.

By introducing this system, railway operators will be able to determine the necessity of patrolling based on scientific and quantitative indicators.

[Reference]

Estimation of effective snowmelt amount and other indices

This system uses effective snowmelt amount, as it is an index correlating strongly with ground water levels. Effective snowmelt amount is calculated by subtracting the outflow amount from inflow, that is, assuming that effective snowmelt amount is retained water in a sort of a tank with holes at its bottom. (Fig.3) By checking effective snowmelt amount, it is possible to monitor changes in the groundwater level over time and its peak season. (Fig.4)

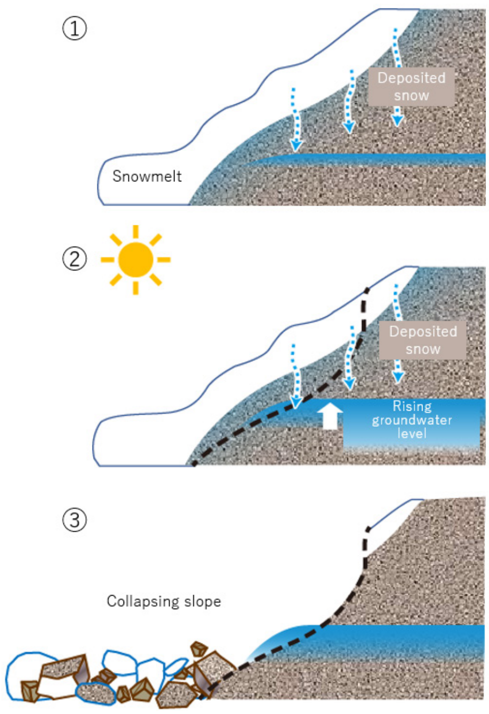


Fig. 2 Mechanism of snowmelt disasters

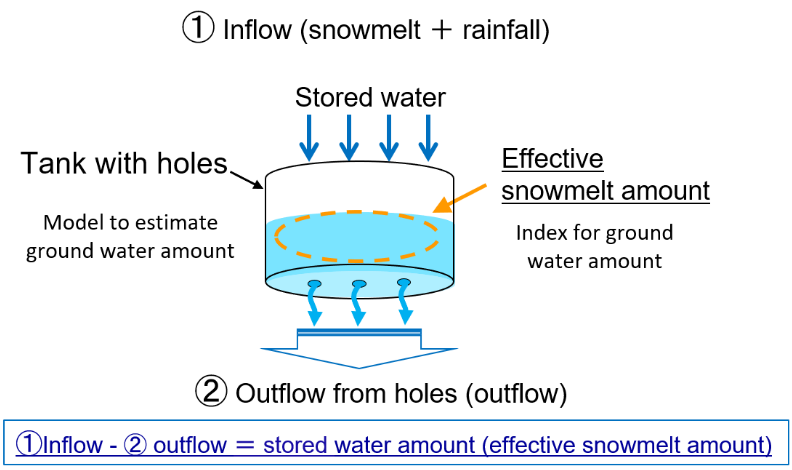


Fig. 3 Calculation of effective snowmelt

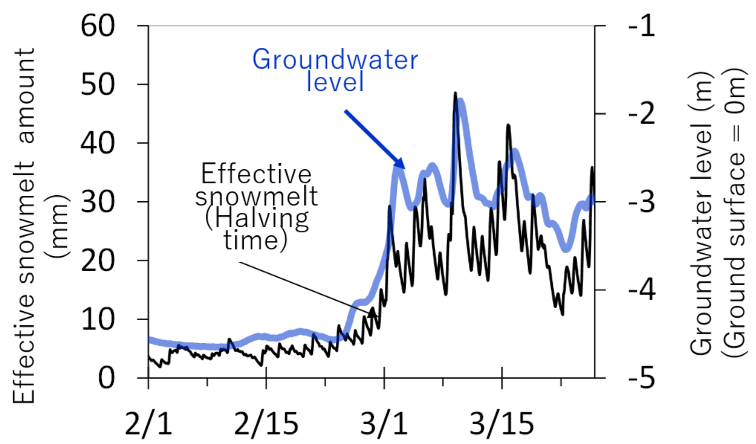
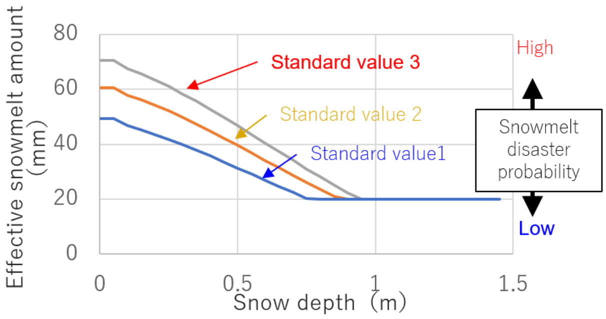


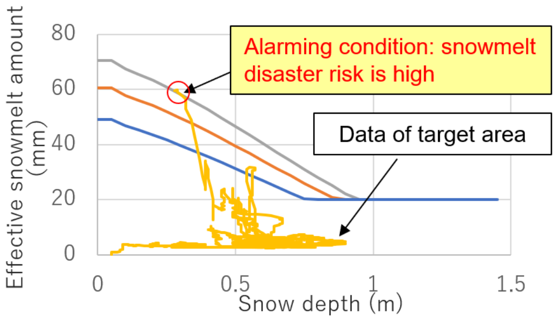
Fig. 4 Changes in ground water level and effective snowmelt

Risk assessment

Since the probability of snowmelt disasters depends on snow depth as well as effective snowmelt amount, each year's maximum effective snowmelt amount for every snow depth is calculated by the AMEDAS data for the target area for the winter in the past 20 years. Based on the results, standard values of effective snowmelt amount for each snow depth depending on reoccurrence intervals (time periods between snowmelt disasters) are predetermined (Fig. 5 (a)). The upper standard values mean higher probability of snowmelt disasters. Then, in order to check conditions of the target area, effective snowmelt amounts for respective snow depth are plotted and connected with line (black line) based on the AMEDAS data for every hour (Fig. 5 (b)). The risk is assessed by comparing the latest one of the plotted lines with the predetermined standard values.



(a) Example of standard values



(b) Risk assessment

Fig. 5 Risk assessment method

Setting standard values

If the standard values are set lower, railway operators need to stay on alert longer, but If they are set higher, disaster risks are less likely to be detected effectively. Thus RTRI determines the standard values for this system through coordination with railway operators.

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International Division, Railway Technical Research Institute
Hikari-cho 2-8-38, Kokubunji-shi, Tokyo 185-8540 JAPAN

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