ANNUAL REPORT 2015-2016

For the year ended March 31, 2016

Railway Technical Research Institute

Foreword

Norimichi KUMAGAI
President of the Railway Technical Research Institute

In FY2015, to fulfil the responsibilities placed upon us by the railway industry and by society in general, RTRI set out its vision for the future entitled “RISING: We will develop innovative technologies to enhance the rail mode so that railways can contribute to the creation of a happier society”.This vision includes three missions – “dynamic research and development”,“neutral activities based on technological common sense” and “world leading activities in technology”.A business strategy, supported by a strengthened management policy, has been devised to accomplish these objectives.

Specific measures for implementing the strategies were set out in a five-year Master Plan drawn up by RTRI entitled “RESEARCH 2020 – Aiming at Creation of Innovative Technologies”. Starting in FY2015, the Master Plan sets out five basic policies: “Implementation of intensified research and development aimed at innovation for railways”,“Creation of high-quality research results with excellence across all fields of activity”,“Activities based on the best science available conducted in an ethical way”,“Supporting overseas deployment of Japanese railway systems and enhancing our global presence” and “Achieving a working environment in which all employees can be highly motivated”.Under the Master Plan, RTRI is endeavouring to improve safety by implementing significant measures to prevent or mitigate the effects of major natural disasters, including derailment prevention measures. The Master Plan also seeks to determine ways of reducing the cost of maintenance and other factors, as well as aiming for harmony with the environment by more efficient use of energy and making travel more convenient thanks to a further increase in train speeds.

Based on these efforts, RTRI will develop innovative technologies that can contribute to railway advancement while solving various problems that confront the railway industry today. These challenges constitute the four R&D Objectives of the Master Plan. In addition, the Master Plan is built on three R&D Pillars:

“Research and development for the future of railways”, under which four major topics will be addressed for practical application in 10 to 20 years’ time: further improvements in the safety of railway systems, modernisation of railway systems using information and communication technologies, acceleration of services on the Shinkansen, and enhancing the role of railway simulators;

“Development of practical technologies”, a programme designed to offer solutions that deliver rapid results when dealing with problems affecting the railway business; and

“Basic researches for railways” which aims to solve various railway problems and address challenges related to sources of innovative technologies.

In FY2015, the first year of the RESEARCH 2020 Master Plan, we strove hard to produce high-quality results for dissemination across Japan and overseas, pursuing R&D activities in line with the business plans based on the Master Plan’s basic policies as well as working on innovative test facilities such as high-speed pantograph testing equipment and low-noise model train running test equipment.

I am confident that we can enhance RTRI’s reputation and achieve greater recognition of the value of its services by earning trust through high-quality results. We will not only tackle the challenges of safety, energy, and greater speed, but also invest our limited research resources in an effective way, thereby creating benefits that will rapidly and accurately meet the needs of railway companies. In order to achieve this goal, guidance and advice from all railway stakeholders are most appreciated.

Contents

2 Overview

4 Major Results of Research and Development

34 Results from individual R&D divisions

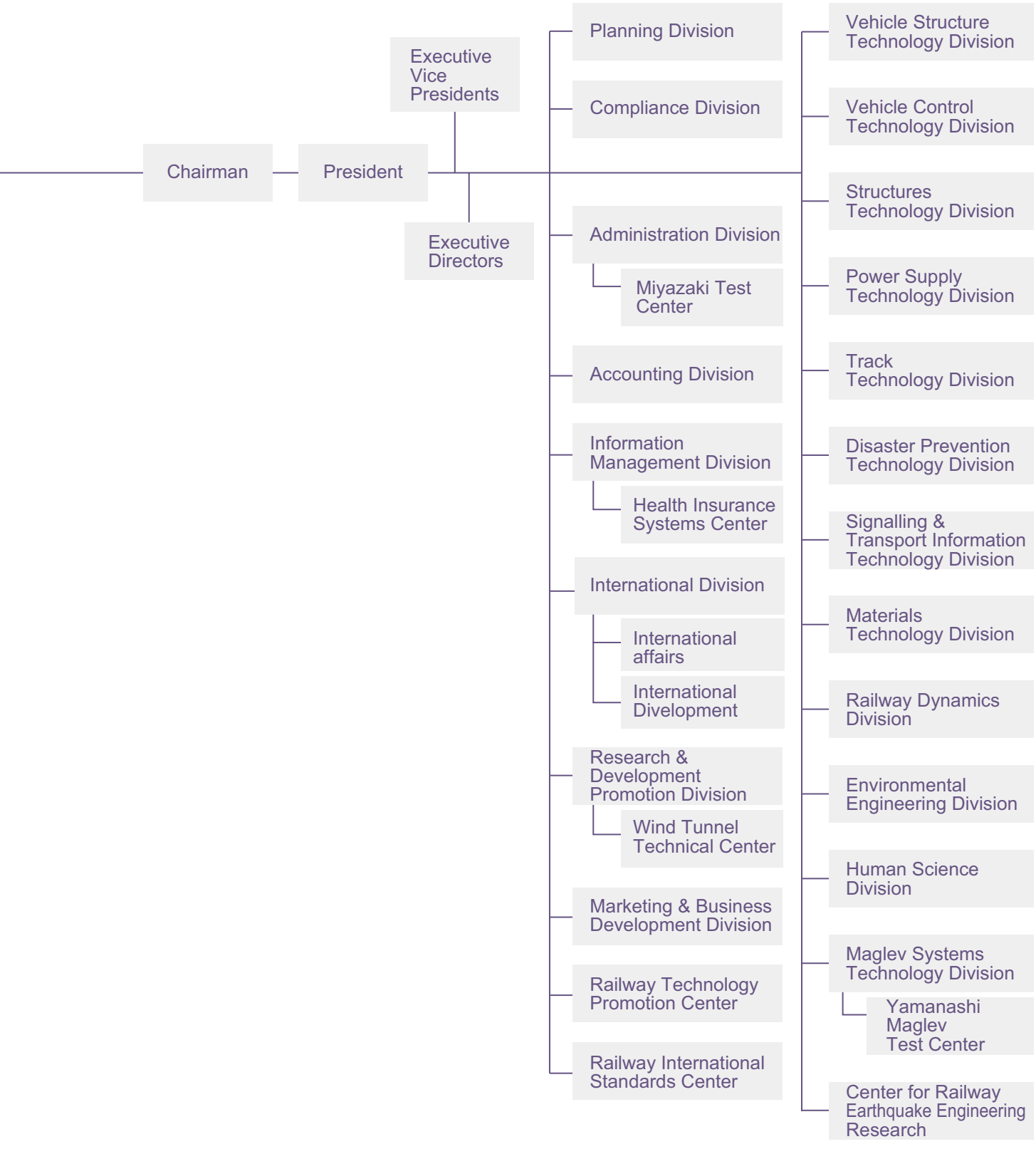
60 Outline of Activities FY 2015

Overview

Organization

Board of Trustees — Board of Directors

Auditors



(As of July 1, 2016)

Major Results of Research and Development

This publication is a collection of the major results obtained from research undertaken by the Japanese public body, the Railway Technology Research Institute, in 2015.

We would like to take this opportunity to thank all JR companies in particular and all the research centers, universities, industrial partners and other entities which have offered their cooperation, commitment and support to achieve these results and without whom none of this work would have been possible.

IMPROVEMENT OF SAFETY

1. Advanced seismograph for earthquake early warnings

- A seismograph was developed to issue earthquake early warnings, offering more accurate seismic parameter estimation and timing, and improved noise discrimination functions.
- The new advanced seismograph makes it possible to cut the time between warnings being issued to the arrival of seismic motion, by one second.
- Noise discrimination was improved by 7.4% compared to existing devices.

In order to increase the resilience of railways to natural disasters, a seismograph which uses a single-station was developed for issuing earthquake early warnings with more accurate seismic parameter estimation and timing, and improved noise discrimination functions.

Algorithms for earthquake detection and estimating epi-central distance, back-azimuth and magnitude were revised to improve the estimation accuracy and timing. Results from simulations using post-earthquake data confirmed better estimation accuracy. Using the improved algorithms, the time from earthquake to warning can be reduced from two seconds to one second. In order to distinguish between seismic motion and train-induced vibration, a method was developed taking into account frequency characteristics in addition to amplitude characteristics. Results from simulations applying this new method confirmed that noise discrimination performance was improved by 7.4%. On-site tests focusing on the performance of the newly developed seismograph to distinguish between seismic motion and train-induced vibrations demonstrated that train vibration was correctly recognised as being noise in over 99.9% of cases (Fig.2). Practical tests with the seismograph also confirmed their stable operation over long periods of time.

Given that these seismographs offer the opportunity to increase the accuracy and reliability of earthquake early warnings, it is planned to introduce these devices into service. The objective now is to work with seismograph manufacturers to produce the device commercially by the end of 2016.

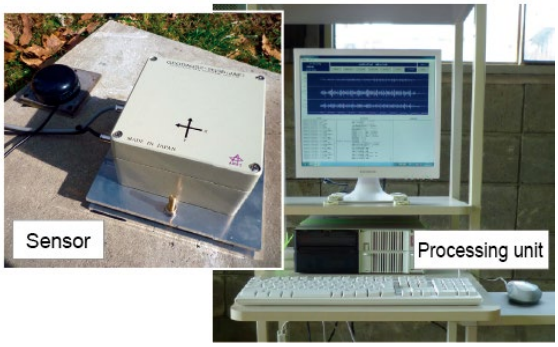


fig.1 Picture of prototype advanced seismograph for earthquake early warnings

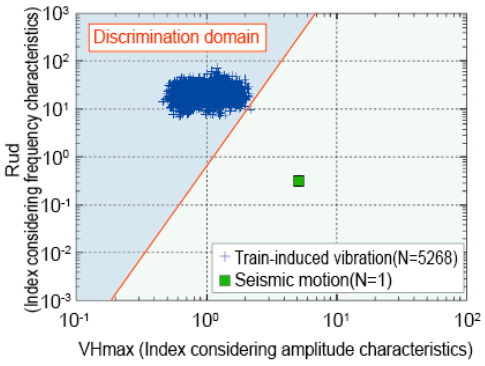


fig.2 Results from practical tests showing noise discrimination

2. Method for extracting vulnerable structures during earthquakes

- A method for identifying vulnerable structures on long-distance lines has been proposed, where the running safety of trains can be compromised.
- This method does not require large scale measurements or surveys and can be used with simple data found in design documents, drawings and specifications.
- In cases of tall structures on stiff ground, it was possible to improve accuracy of estimated damping by over 50%.
- The proposed method indicates the supplemental damping required to assure the running safety of trains.

In order to understand the damping characteristics of structures for which little observation data is available, vibration measurements were carried out on 136 actual structures. An estimation formula was derived from observed data as a function of the natural period ratio of the structure to the ground (Fig.1). In the case of tall structures built on stiff ground (Fig.2), whose damping ratio was practically assumed to be 5% in the seismic design standard, the accuracy of estimated damping was increased by approximately 50%. In addition, a simple nomograph was proposed to estimate whether a given structure was likely to vibrate significantly or not, due to poor damping (Fig.3). This figure was composed on the basis of response analyses, assuming various structural and ground conditions while using actual damping measurements (Fig.1). The key feature of this method is that it requires data which is easily obtained from design documents and drawings such as height of structure and ground condition, which means that large scale measurements or surveys are not necessary.

A nomograph was also been proposed for estimating the supplemental damping needed for a structure to meet requirements in the “Design Standards for Railway Structures: Displacement Limits” (Fig.4). This nomograph can be employed in the seismic retrofit design of structures with poor damping performance.

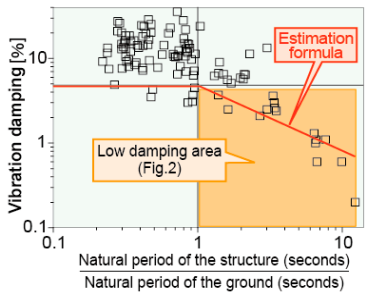


Fig.1 Nomograph estimating the damping performance based on actual measurements

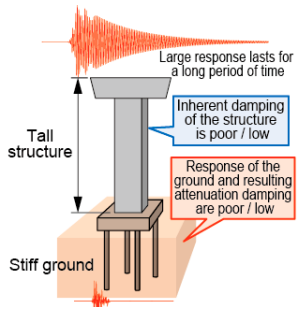


Fig.2 Example of small damping structure

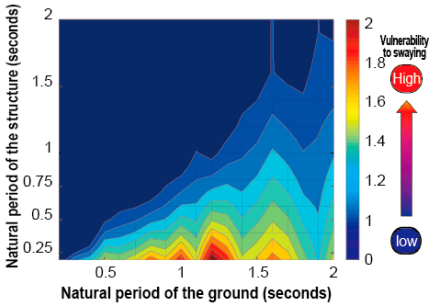


Fig.3 Evaluation nomograph of actual structural response as a ratio to structural response with damping of 5%

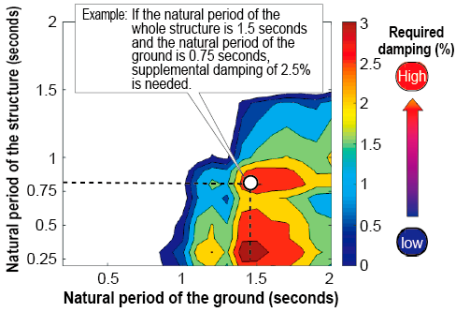


Fig.4 Nomograph showing damping needed to meet train running safety requirements

3. Seismic reinforcement technology for earth retaining walls in narrow locations

- A technique has been developed to adapt natural ground seismic reinforcement measures to steeper and narrower locations
- Confirmation was obtained that the present reinforcement method doubles seismic resistance
- A design manual was produced containing all the methods for selecting which kind of seismic reinforcement measure to apply to earth retaining walls

There are over 200 000 earth retaining walls across Japan that were built according to the standard design used by the former national railways. The preponderant seismic reinforcement measure to prevent collapse during large earthquakes, involves pouring natural ground reinforcement material on near-horizontal planes to increase the safety of the earth retaining walls. However, in cities in particular, the crown of the retaining wall is often close to buildings. Given the lack of space, it is difficult to pour reinforcement material along the full length required, which means that even in places which desperately need seismic reinforcement, it is impossible to apply existing remedies.

As such a new technique was developed (Fig.1) using smaller sized equipment suited to narrower locations and capable of pouring reinforcement material at steeper angles and along the full required length. Results from tests on a 1/10 scale model showed that a wall without this seismic reinforcement collapsed under vibrations at 400 gal, whereas as the wall which had been reinforced using this technique resisted to 800 gal vibrations, with horizontal displacement stopping at 4%. These results demonstrate that the new technique offers greater seismic resistance than existing methods, and confirm that seismic resistance is doubled when the method is applied. In addition to proposing a design method taking into account the flexural resistance of reinforcement material poured on steep gradients, a design manual was produced containing all the methods for selecting which kind of seismic reinforcement measure to apply to earth retaining walls.

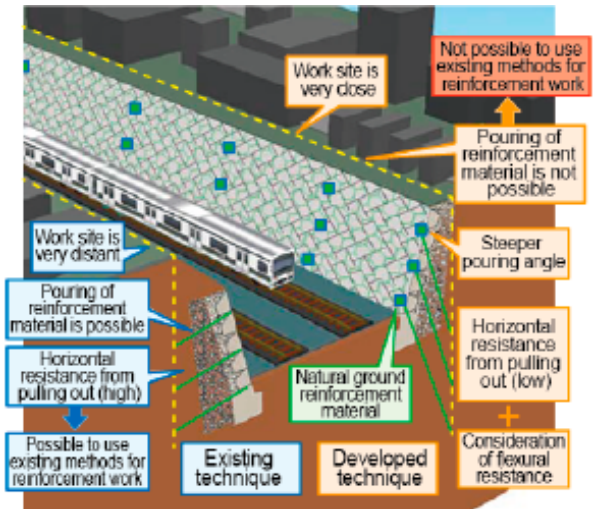


Fig.1 Comparison of existing methods and the new technique

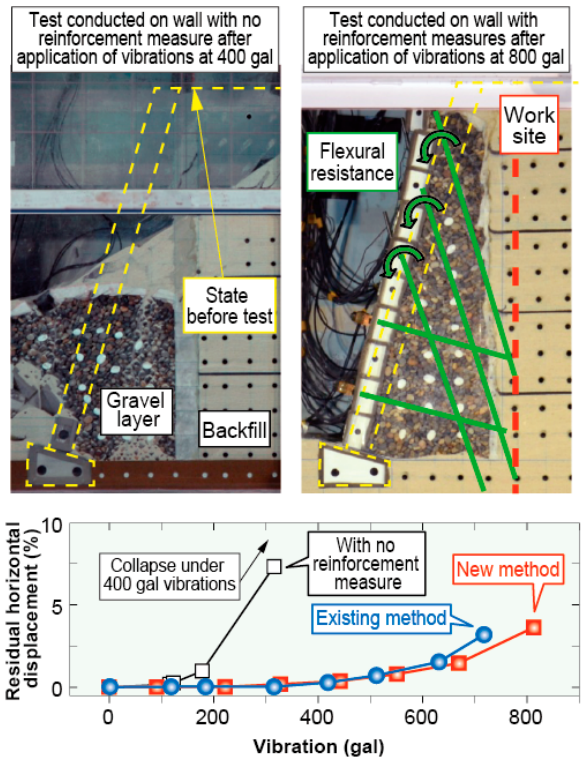


Fig.2 Comparison of residual horizontal displacement after each vibration excitation test.

4.Method for assessing tsunami damage to concrete bridges

- A method has been proposed to calculate the fluid forces acting on concrete bridges, from tsunamis
- A method has been proposed to assess tsunami damage to bridge piers and concrete girder outflow
- The assessment and calculation methods can be used to design girder outflow prevention work and bridge pier reinforcement against tsunamis.

In order to counter the impact of large scale tsunamis caused by subduction-zone earthquakes, and to understand the damage caused by tsunamis to railway bridges, methods were proposed to diagnose damage and to calculate the effect of fluid forces acting on bridges.

In the course of this research, tsunami tests were conducted, providing insight into the fact that in the area close to concrete bridge girders, the water level rose as the flow speed fell, and that there was a difference in water levels between the upper and lower flow around the girders (Fig. 1); a method was then proposed to calculate fluid forces acting on girders.

The proposed methods can calculate fluid forces exerted on the bearing surfaces between concrete girders and bridge piers, using information about the bridge, and the height and speed of the assumed tsunami (Fig. 2). The lower resistance forces of the bridge pier and the bearing (girder-dropping prevention devices) are taken to be bridge resistance, which in turn is compared to the calculated fluid force, in order to evaluate tsunami damage to the concrete bridge in terms of girder outflow and damage to piers. Tsunami tests were carried out on a concrete bridge mock-up equipped with girder-dropping prevention devices and steel bearings. The proposed method calculated the fluid force using the wave height and speed under which bridge damage occurred, which corresponded more or less with bridge resistance, confirming that it was possible to estimate the damage to the bridge (girder outflow, pier collapse) using tsunami data (Fig. 3). Estimating damage prior to an event will facilitate the preparation of recovery plans, and is also useful for developing the girder-outflow prevention devices and bridge column reinforcements against tsunamis.

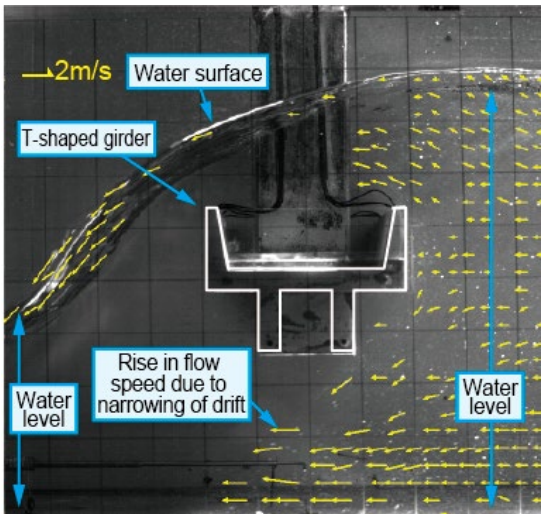


Fig.1 Tsunami engulfing girder and increase in flow speed

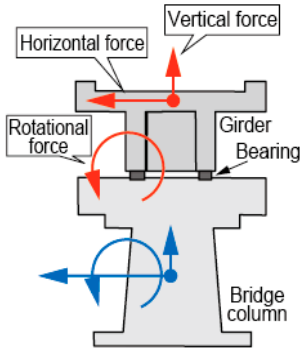


Fig.2 Modelisation of fluid forces acting on bridge

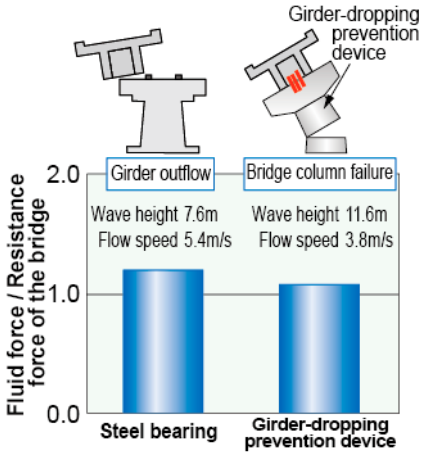


Fig.3 Results of bridge damage assessment

5. Management of snowmelt for landslide prevention

- This method can be used to predict critical periods during the snowmelt season, using meteorological data to estimate run-off volume from snowmelt to evaluate the safety of slopes.
- A surveying method is proposed using topographical and ground condition data to identify vulnerable landslide prone locations.

On slopes adjacent to railway lines covered with thick snow, runoff from melting snow seeps into the ground and can sometimes cause landslides. Current operating rules only have provisions based on rainfall volumes and do not offer a means to predict critical periods or locations vulnerable to landslide disasters, which is a problem. As such, a safety evaluation method has been developed based on the volume of runoff from snow, which is the main cause of landslides during the snowmelt period, along with a survey method which then identifies vulnerable locations.

There is a close correlation between slopes becoming unstable and water saturation of the ground. Consequently, using temperature and other meteorological data from the met office, a model was designed to estimate the amount of runoff seeping into the ground from melting snow. The volume of runoff from melting snow is converted into a suitable indicator to show water saturation of the ground (hereafter “effective snowmelt volume”) and when this effective snowmelt volume indicator exceeds a set alert threshold, this means that the slope in question has reached critical instability. Fig. 1 shows a typical example of slope inspection using this method. The alert threshold value is set according to maximum snowmelt runoff volumes based on past data.

Data from previous landslides was then collected to identify which ground conditions made a slope particularly vulnerable to this kind of disaster. Following this, a survey was conducted of the ground conditions where landslides have occurred in the past. Then, using topographical conditions and ground conditions, a method was developed to quantitatively assess the safety of slopes. By applying these processes, it should be possible to identify critically vulnerable landslide prone spots during snow melting periods (Fig. 2).

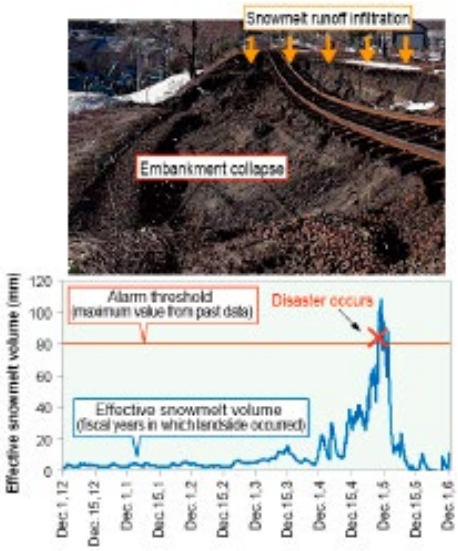


Fig.1 An example of an inspection of an earth-bank slope in critical condition.

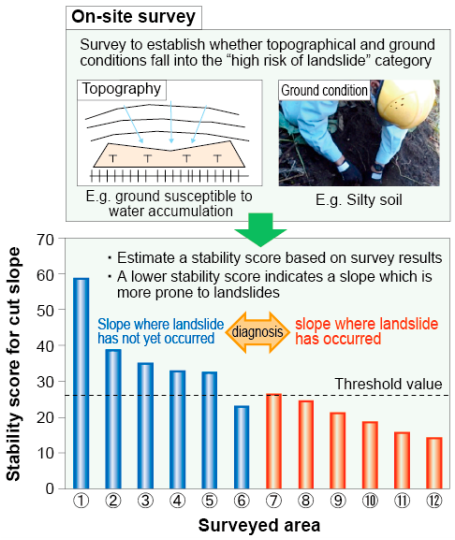


Fig.2 Example of excavation of a critical area on a slope after applying the survey procedure.

6. Calculation of the aerodynamic coefficient on trains in half-bank half-cut line sections

- A quantitative evaluation was made of the aerodynamic coefficient of trains on half-bank half-cut sections of line
- For winds acting at an angle of 90 degrees on intermediate carriages, it was observed that running safety was higher with cut banks of a height of 10 m or half-bank half-cut embankments of 15 m.
- A proposal was made to use the aerodynamic coefficient as an indicator for evaluating safety in high winds on sections with half-bank half-cut embankments.

Evaluation of running safety in high winds is carried out using an aerodynamic coefficient obtained from wind-tunnel tests. There are many types of section topography along actual railway lines, however, the aerodynamic coefficient is sought for seven standard types of track-side structure. Many lines close to the coast or rivers are often on tracks flanked by a slope on one side and a bank on the other (half-bank half-cut sections), and are treated as embankments. However, on sections with high embankments on the downwind side, the lateral force acting on the train is lower than on normal embankments, which means that the aerodynamic coefficient is probably smaller.

Therefore, wind-tunnel tests were conducted to obtain the aerodynamic coefficient on a half-bank half-cut section. During the wind-tunnel tests, the angle and height of the cut slope was varied along with the distance between the cut slope and the train center (Fig.1).

Results showed that in cases where the cut slope was 10 m or 15 m, as the distance grew shorter between the side of the train and flanking cut slope, and as the angle of the slope became steeper, the lateral forces acting on the intermediate carriages of the train at 90 degrees fell between 5-100% (Fig. 2).

The outcome of these experiments shows that safety evaluation of half-bank half-cut sections can be carried out more suitably than simply applying the standard embankment evaluation method used previously.

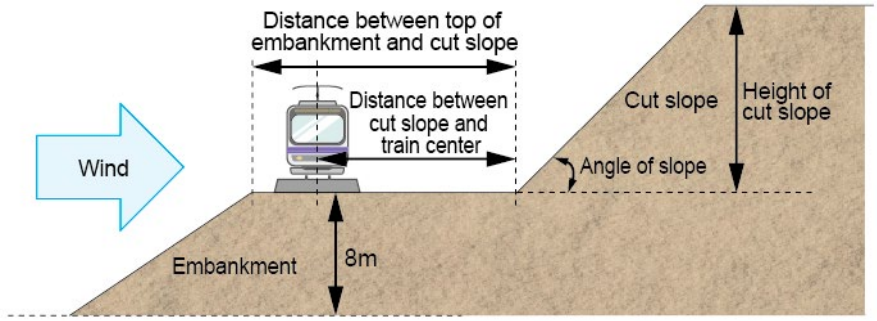


Fig.1 Wind-tunnel experiment and parameters for tests on a (actual scale) half-bank half-cut section (Reduced scale: 1/60, Train: roof curvature radius of 5000 mm (actual scale) of a commuter train)

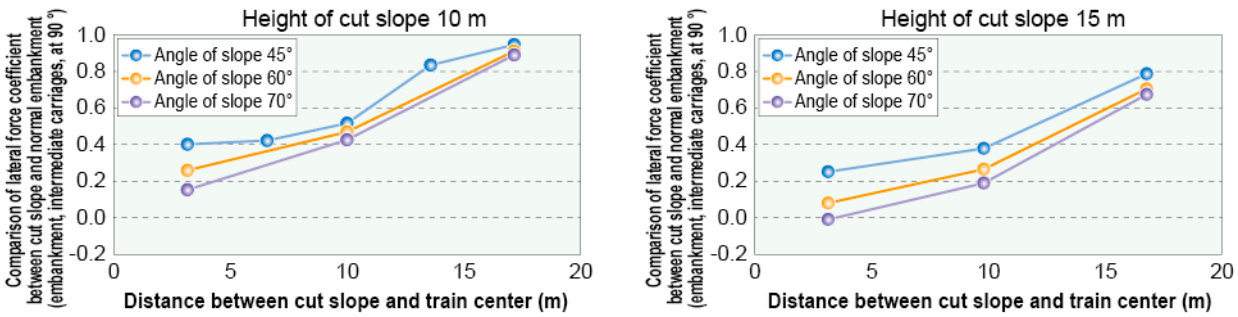


Fig.2 Comparison between aerodynamic coefficients on a half-bank half-cut section and a normal embankment (intermediate carriages, wind angle 90 degrees, top of cut slope and distance to slope of 20m)

7. Revision of evaluation criteria to check deterioration in lubricating grease used on trains

- The values used in criteria applied for managing the grease used in axle boxes and traction motors have been revised.
- Lithium complex soap grease is used for lubricating traction motors on approximately 80% of conventional line trains. A new indicator has been proposed for the thermal tolerance of this grease to replace 'changes in dropping point value'.
- New criteria values have been proposed as the new standard for evaluating deterioration in the grease.

Lubricating grease is critical for bearings to function normally on conventional and high speed trains (Fig. 1). It is therefore necessary to be able to diagnose accurately any signs that indicate deterioration in the grease in order to be able to replace it in time. As such, the predecessor institute to RTRI established a set of standard reference values for replacing the grease, relating to grease deterioration.

Recent years have seen an increase in the use of high thermal-resistance lithium complex soap grease with the introduction of induction motors on trains, which have faster bearing rotational speeds and higher temperatures. As a result, cases have been discovered where the level of deterioration in the grease does not correspond to the reference value, i.e. changes in the dropping point, for determining the thermal resistance of that kind of grease.

In addition, it has become clear that there is a need to understand the effect of increases in ferrous particles in the axle bearings from fretting wear, and the impact of differences in oil separation calculation methods, on the reference value. Then, based on insight gained into deterioration mechanisms during laboratory tests (Fig. 2) and results of surveys into the deterioration of grease used on actual trains, a new set of reference values were proposed for managing the grease in relation to the three exposed problems (Table 1). The new criteria make it possible to correctly evaluate the state of new types of grease being used, which the existing criteria could not achieve. They can also be used to determine when the grease should be replaced (frequency), and periodicity of inspection.

Fig.1 Grease in use

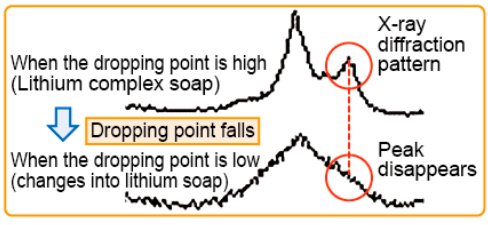


Fig.2 Change in dropping point mechanism

Table 1 Revised grease management criteria

(: modified criteria)

Management headings (targeted deterioration)	Grease management reference values		Analysis method
	Traction motor bearings	Axle bearings	
Consistency (hardness change)	150~350 (25℃, unworked penetration)	100~400 (25℃, unworked penetration)	Axle: 1/4 consistency - NLGI number (3) Traction motor: spread-diameter consistency
Oxidation (oxidation degradation)	Below 5.0% (Oleic acid conversion)		Infrared spectroscopy
Oil wear-out rate (1) (oil consumption)	Below 15.0% (to be handled with caution over 6.0%)		Membrane filtration (4)
Dropping point (thermal resistance)	Lithium complex soap : Over 215℃ (to be handled with caution below 240℃)		Dropping point test (3)
	Others : ±20℃ (variation)		
Iron content (detecting bearing abrasion)	Below 0.5%	Below 1.0% (2)	Fluorescent x-ray spectroscopy
Copper content (detecting bearing abrasion)	Below 0.3%		Fluorescent x-ray spectroscopy
Water content (detecting contamination)	Below 5.0%		Karl Fischer Moisture Titrate(5)

(1) name changed from previous oil-separation rate
(2) different arrangement for handling fretting
(3) based on JIS K 2220
(4) the Soxhlet method is used for verification if necessary
(5) based on JIS K 2275

8. Method for detecting step-shaped wear on contact strips on pantograph heads

- In order to prevent damage to overhead contact lines, a method for detecting step-shaped wear on contact strips on pantographs has been developed. In addition, a data acquisition device suited to this method has also been developed.
- RTRI then drafted some technical recommendations for railway operators on the practical application of the system.

Step-shaped wear on pantograph head contact strips can cause serious damage to the pantograph and catenary system. A method for detecting step-shaped wear has therefore been developed. In this method, step-shaped wear can be detected by measuring the axial forces acting on steady arms installed on three adjacent supporting points (Fig.1). This method has few constraints with regards to where it can be applied. In addition, a compact light-weight and power saving data acquisition device consisting of a dynamic strain amplifier and data telemetry system were also developed (Table 1, Fig. 2) to suit this new detection method. Fig.3 shows an example of the application of the new method and the device to a commercial railway line. When the system detects certain specific features in the forces exerted on the steady arm, the system immediately triggers and alert to the transport control centre etc.

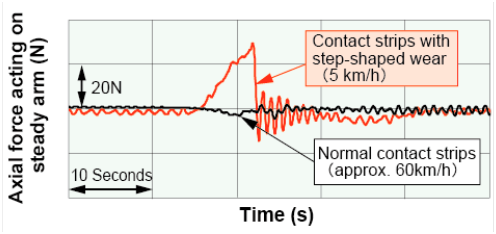


Fig.1 Axial force fluctuation acting on steady arm (result of field tests)

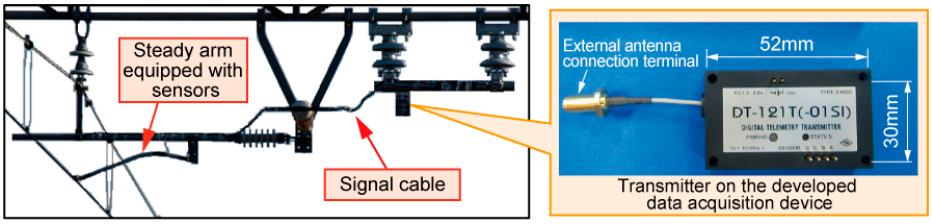


Fig.2 Example of the method applied in practice

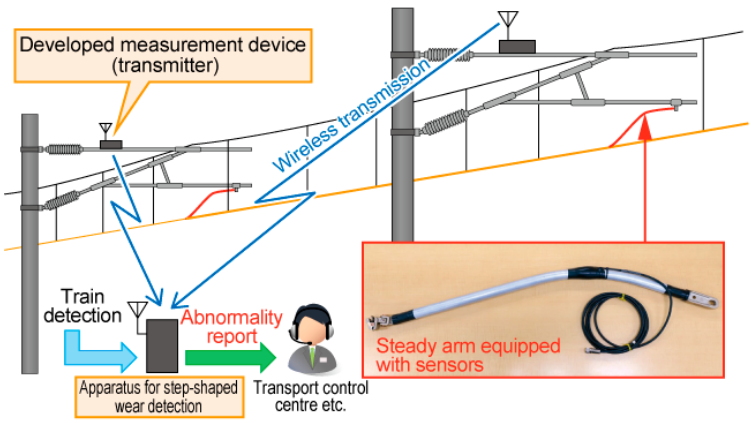


Fig.3 Example of developed data acquisition

Table 1 Specifications of the developed data acquisition equipment

Energy consumption of the transmitter	230mWh (during measurement) 8.5mWh (during standby)
Maximum transmittable distance	200m
Effective measured frequency	1kHz
Weight	Approx. 17 g
License of the radio wave low	Not necessary

9. Improving lightening resistance of electrical equipment using new grounding structure

- A new grounding structure was developed to improve the lightening resistance of electrical equipment.
- Compared to existing structures, the potential-rise due to lightning strikes is reduced by approximately 50% and voltage difference by about 60%, cutting the frequency of estimated lightning damage by approximately 20%.

As a countermeasure to earth fault and lightning strike damage to substations etc, wire mesh (bare copper stranded cables) is often buried around/under the equipment and connected to earthing rods to form a grounding structure (Fig.1). However, this existing structure was optimised for use with low frequencies, and is no longer offers adequate protection for today's substations equipped with information communication technology (ICT).

As such, a new grounding structure has been designed. Given that potential rise in the grounding structure when lightening strikes may damage electrical equipment, flat rectangular section bare copper wires, which facilitate the flow of high frequency current were employed to reduce this problem (Fig. 2).

Experimental set ups were installed in the ground, as shown in the figures, for comparative tests. Results showed that the maximum voltage at the injection point to the new structure could be made 50% lower than in existing structures (Fig. 3).

Following on, voltage difference which occurs in grounding structures reduces the effectiveness of lightning protection devices such as lightning arresters, and is another cause for damage to equipment. Therefore, coated rectangular-section copper wires, with better voltage transfer charcteristics were connected in parallel. As a result, the maximum voltage difference between the injection point and the the end point was reduced by approximately 60% (Fig. 4).

Considering past data and the two results described above, it is expected that lightning damage can be decreased by 20%. Since the proposal requires changing the type of wire and double layered wires, introucing the the system will incur some cost, however, in relation to overall work on substations, the cost is relatively small.

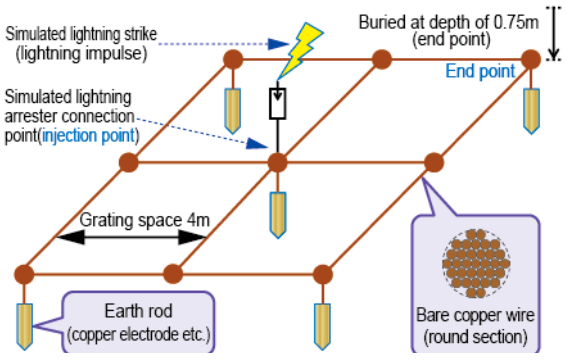


Fig. 1 Existing grounding structure and test conditions

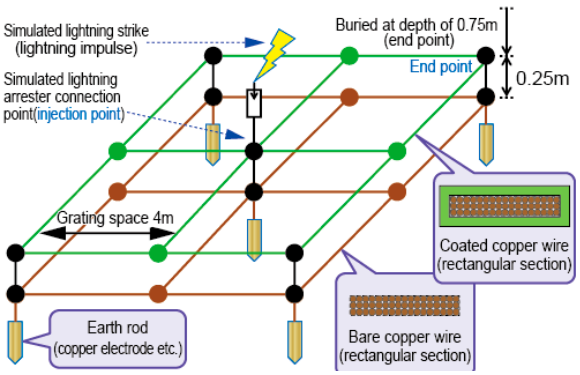


Fig. 2 Proposed grounding structure and test conditions

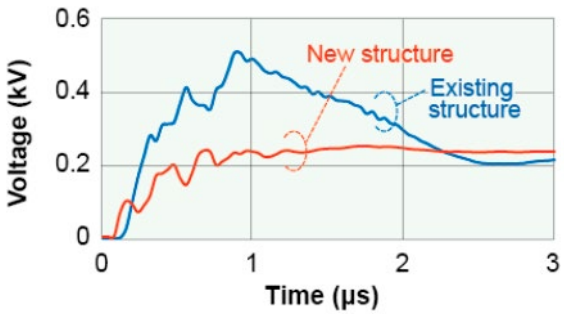


Fig. 3 Reduction of voltage rise at injection point (in relation to 100% being the maximum voltage under existing system)

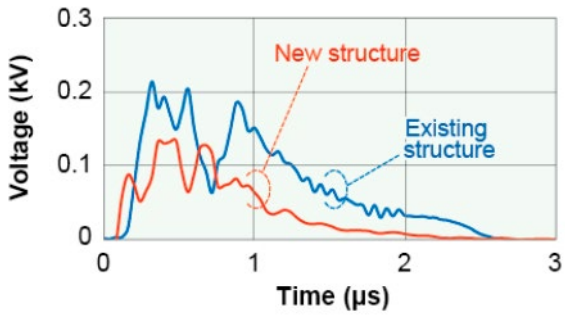


Fig. 4 Reduction of voltage difference between injection point and end point (in relation to 100% being the maximum voltage under existing system)

10. Proposal of method for diagnosing health of concrete masts for maintenance

- Through surveys on the health of concrete masts, conducting bending strength tests and materials analyses, insight was obtained into the processes involved in concrete mast deterioration.
- A new method was subsequently proposed to diagnose the health of concrete masts.

Concrete masts (hereafter 'masts') have been in mainstream use on the railways for over 50 years, and there is a need to determine what criteria and grounds should be used, in terms of degradation, to decide when to replace these masts.

To this end, the state of health of 500 masts was surveyed along a stretch of commercial line, including bending strength tests and materials analyses. Results showed that the main process generating mast damage was 'crack precedence' i.e. the appearance of cracks followed by deterioration of the construction material, for example rebar corrosion in the cracked areas.

Based on this deterioration process, a method was proposed for diagnosing the health of masts, for maintenance (Fig. 1).

The diagnosis is made in several steps, starting with the existing visual inspection of masts. When there is no apparent alteration, a 'materials evaluation' is conducted, whereas a 'strength evaluation' is made if alteration is observed.

The materials evaluation carried out when no apparent alteration is observed involves testing for neutralization of the concrete surface, which is a typical sign of concrete deterioration. The progress of neutralization in masts is significantly slower than on civil structures, therefore thorough testing is required with testing of the surface to a depth of 1 mm.

In the case of strength tests conducted when apparent alteration has been observed, a 'strength evaluation sheet' was designed showing the correlation between bending strength and external circumference of the mast, making on-site diagnosis possible by checking whether the mast meets level 2 safety requirements contained in the regulations for railway technical standards.

If the external circumference of the mast is within the admissible limits, then the mast can remain in place, otherwise, it is marked as needing to be replaced.

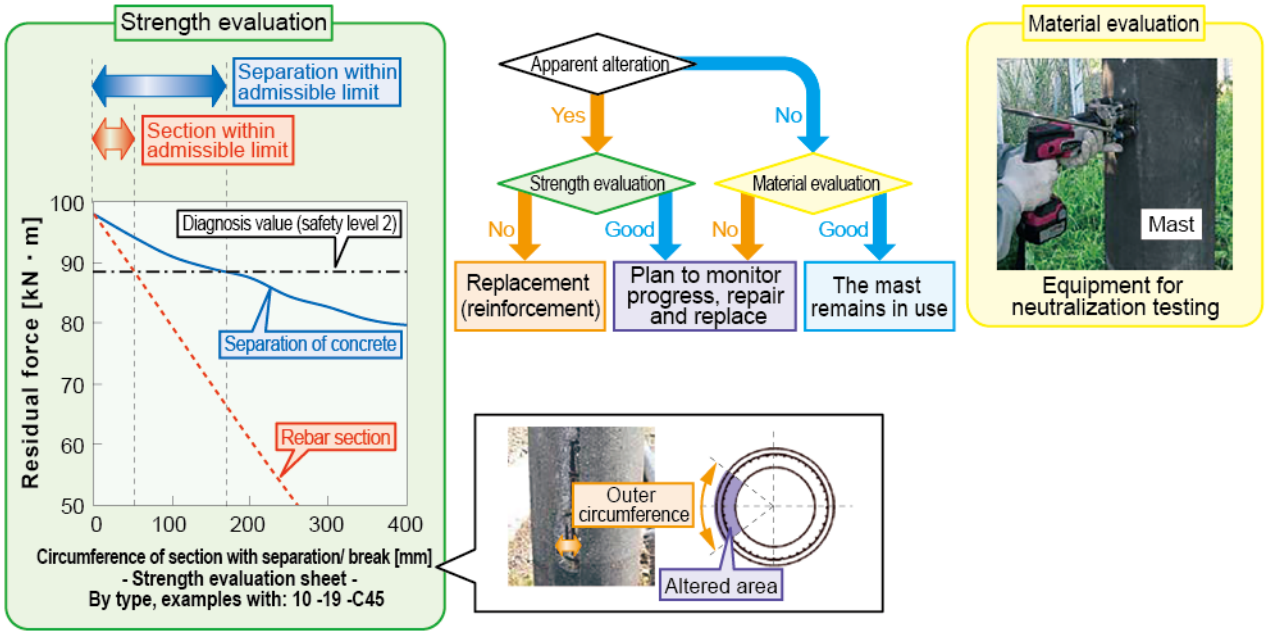


Fig. 1 Outline of diagnosis flow chart to check the health of concrete masts

11. On-board platform detection device to assist train crew in train door operation

- A device was developed to identify which side of the train the platform is on by image detection of the train stopping position signs.
- By adding gyro-sensor and GPS functions, the platform can be detected in over 90% cases even when covered in snow.
- A device was proposed to assist on board staff operating train doors.

In order to prevent train doors being operated incorrectly, image analysis using an onboard camera and sensor technology have been used to develop a system to detect the presence of a platform alongside a train, and help train staff operate train doors.

Detection through image analysis offers significant advantages compared to ultrasound sensors and tags, since it does not need special sensors on the platform side, functions regardless of the shape and height of the platform and operates even in deep snow.

Given the potential influence of environmental conditions on image processing, such as changes in lighting, the stopping position sign is detected using contour data based pattern matching, and an algorithm has been developed to identify the platform side of the train (Fig.1).

In addition, a method was developed to identify the platform at which the train arrives, by combining data collected by the gyro-sensor on the yaw angle of the train as it passes through points which helps determine the path taken by the train, with GPS and station layout information (Fig.2).

Field test results showed that the presence of a platform was correctly detected in over 90% of cases (Fig.3).

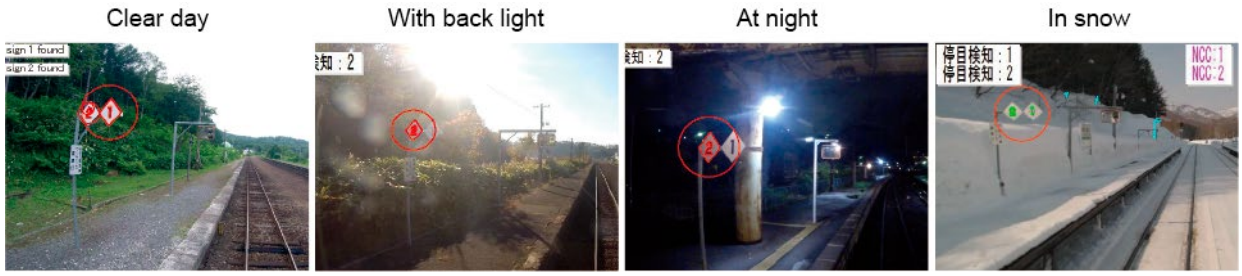


Fig 1 Results detecting train stopping position sign using the pattern matching method

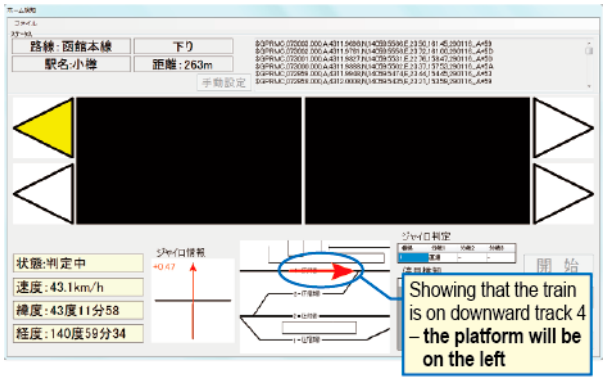


Fig 2 Onboard platform detection display

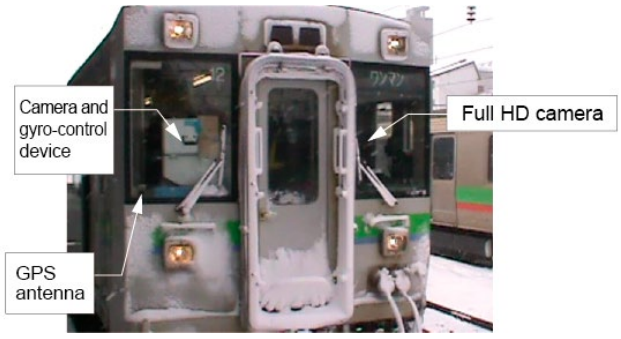


Fig 3 Test conditions for platform detection in winter with Full HD camera

12. Human factor analysis method using Potential Incidents Reports

- A method has been proposed to improve the effectiveness of analyses conducted using the RTRI Human Factor Analysis method
- Employing Potential Incidents Reports to promote better organizational and work systems.

Applying the RTRI Human Factor Analysis method for analysing the underlying human factor related causes becomes time consuming when a large number of error incidents have to be examined and analysed. As such a new procedure has been developed to improve processing efficiency using potential incidents reports (Fig. 1).

In the existing method, time series contrastive analysis was applied based on the difference between “Objective required by the system” and “actual action” to identify “deviations”, whereas in the new method the object of the analysis is limited to identify errors carrying a major risk using potential incidents reports (Hiyari-Hatto).

A “Root Cause analyses (Why-Why analyses) support tool” was developed to extend the investigation into the theoretical causes leading to the detected human error.

Then, based on the analytical results of the causal analysis hand of 900 error cases and their causes, an iterative process using the question “why” is used to elucidate possible origins of the case in hand.

A “Human Factor countermeasure design flow chart” was devised to ensure that corrective measures were more than just a one-off remedy and contributed to lasting improvements in the organisation of work (Fig. 2), with additional considerations such as “raising awareness of relevant parties” etc. The process is divided into 9 steps organised in hierarchical order, aimed at ensuring that the applicable measures are feasible can be implemented in suitable conditions.

This method uses potential incidents reports for safety management system and theoretical human factor analysis aims to promote better organisation of work.

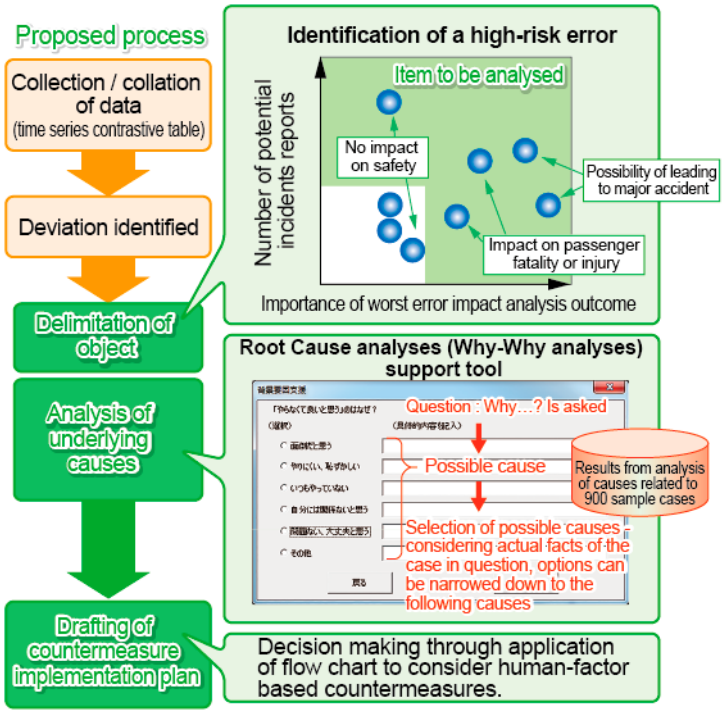


Fig 1 Outline of human factor analysis method using potential incidents reports

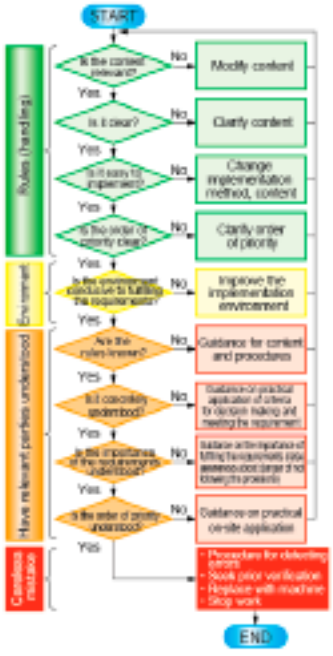


Fig. 2 Outline of flow chart to consider human-factor based countermeasures

13. Sheet pile reinforcement work on pile foundations during ground liquefaction

- A reinforcement technique has been developed using the addition of steel sheet piles with closed sections at the bottom to existing pile foundations during ground liquefaction.
- Confirmation was obtained that this new technique can reduce the working load on existing pile foundations by 30%, and a guide to use of the technique was compiled.
- This reinforcement technique costs approximately 20% less to apply than existing methods.

When liquefaction occurs during earthquakes, the ground suddenly loses its rigidity and hardness, leading to extensive pile foundation damage (Fig. 1).

Existing countermeasures to protect pile foundations from ground liquefaction, such as additional pile systems and soil improvement methods involve a major increase in the basic dimensions of the structure, which is difficult to apply when limited space is available.

Work was therefore undertaken to find a new method which would not require a great amount of space, and which was practical and economical to implement. As such a sheet pile reinforcement method was developed using steel sheet reinforcement which improves both the supporting force and rigidity of the structure (Fig. 2).

After clarifying the reinforcement mechanisms of steel sheet piles during shaking table tests on models using the new technique, confirmation was obtained that the developed method reduced shearing forces on the pile head by approximately 30% and axial force by approximately 20% (Fig. 3).

A manual for the technique was then compiled using insights gained from tests. Test designs produced following the manual showed that the cost of reinforcement work could be reduced by about 20% compared to existing methods.

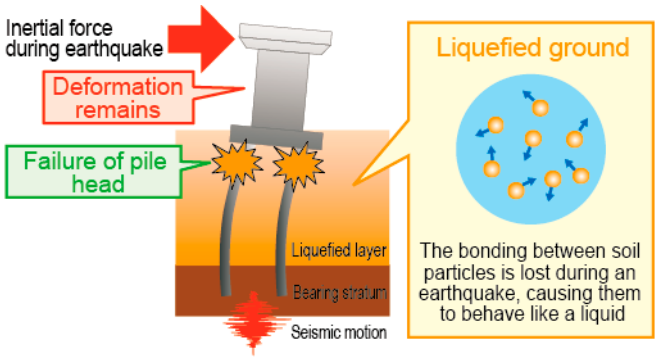


Fig. 1 Damage to pile foundations from ground liquefaction

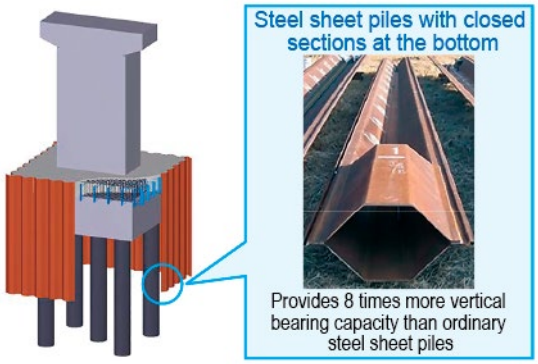


Fig. 2 Sheet pile reinforcement method

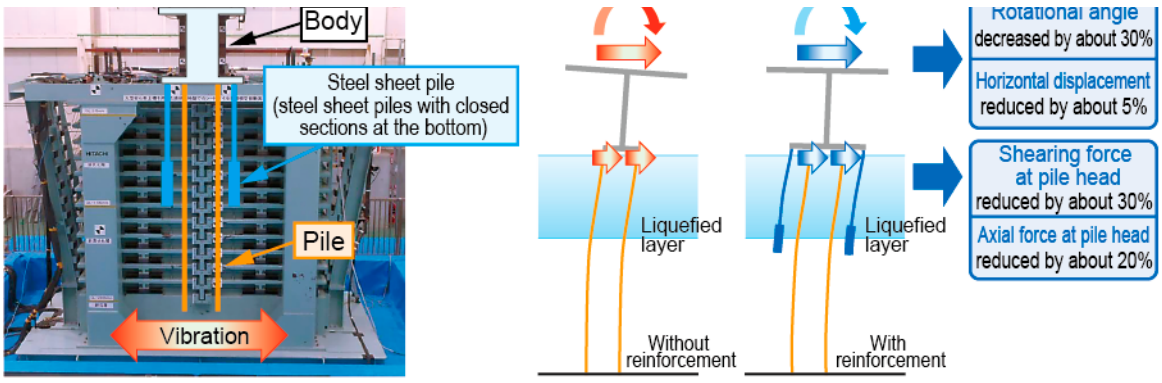


Fig. 3 Large shaking table tests confirmed the effectiveness of reinforcement work during ground liquefaction

14. Countermeasure for fatigue cracks around I-beam bridge supports

- A method has been developed to repair fatigue cracks around I-beam bridge supports by covering the end of the girder with concrete.
- The method can be applied to most I-beam bridges which have a span of less than 7 m.
- The repairs can be completed quickly, and represent approximately 1/3 of the cost of replacing the bridge.

I-beam bridges are short span bridges built with small-section I-shaped steel beams, and often suffer fatigue cracks around the bridge supports (Fig 1).

It is difficult to patch the beams with repair plates over the fatigue cracks since crack initiation is located in transition area between the bottom flange and the web of the bridge support. Since no other effective countermeasure to this problem existed until now, this type of damage often led to the replacement of the bridge. Therefore, to solve this problem a new repair method has been developed whereby the end of the girder is covered with concrete (Fig. 2).

The method can prevent the fatigue crack propagation because the stress around the crack is drastically reduced by the concrete which supports the train load (Fig. 3 and 4).

This method was developed for small-section structures, and is applicable for most I-beam bridges that have a girder length of less than 7 m.

Fatigue cracking is caused by damage to the bearing seat mortar (Fig. 2), so existing methods require large scale work such as girder jacking to repair the bearing seat mortar. With this new method, it is not necessary to repair the bearing seat mortar, nor is it necessary to jack the girders. Repairs using the new method can be conducted fairly rapidly and reduce the costs by one third compared to bridge replacement.

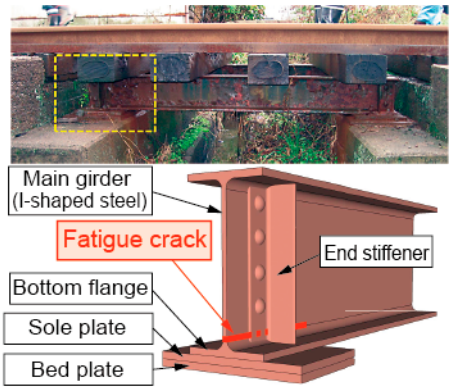


Fig.1 Fatigue cracking around the I-beam bridge support

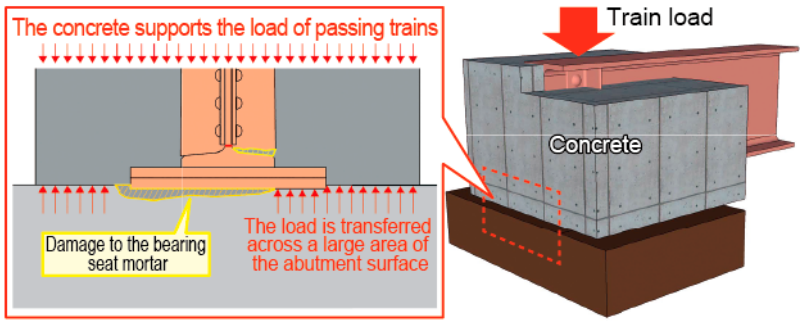


Fig. 2 Concrete casing method

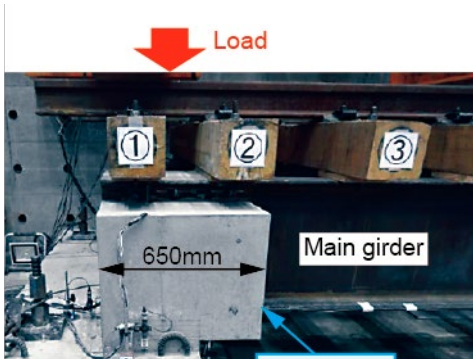


Fig.3 Loading tests (full scale)

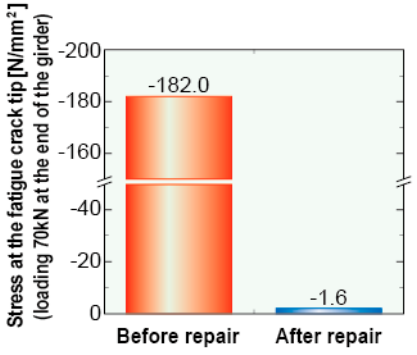


Fig.4 Effectiveness of the method (test results)

15. Countermeasure work on ballasted Shinkansen track to prevent ballast migration

- Ballast migration on a ballasted Shinkansen track was reproduced by vibration machine, producing insight into the mechanisms leading to this phenomenon.
- A countermeasure was developed using biodegradable aqueous polymer solution to stabilize the ballast on the track.
- This measure manages to reduce costs by 50%, and allows tamping work to be conducted after the procedure.

On ballasted Shinkansen track, in curves with large cant the surface ballast flows from the outer rail towards the inner rail due to the passage of trains, which can cause “ballast migration”, and lead to a frequent need for maintenance work.

As a measure to counteract this phenomenom, a vibration machine was employed with controllable load direction, to conduct repetitive tests taking into account the excessive centrifugal force which occurs when a train runs through a curve (Fig. 1). The results of these tests showed that it was possible to reproduce ballast migration through tests conducted inside (Fig. 2).

Results from investigations into the mechanisms producing ballast migration revealed that dynamic displacement of the sleepers was causing the ballast to shake, and that using rectangular section sleepers and track bed improvement were effective. An additional low-cost countermeasure involved using a biodegradable aqueous polymer solution to stabilise the surface of the ballast (Fig.3 and 4). This method is approximately 50% more economical than frequent ballast scraping work, and allows tamping once work has been completed.

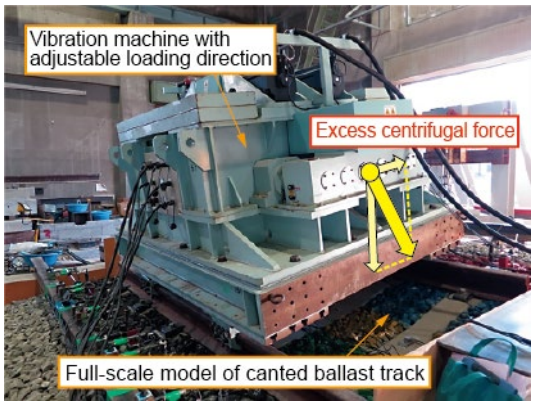


Fig 1 Loading tests taking into account excessive centrifugal forces

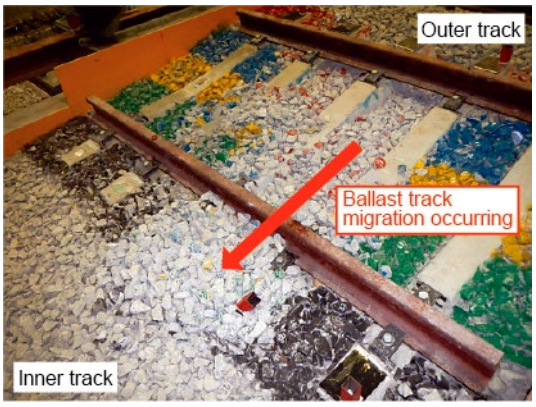


Fig 2 tests to reproduce ballast migration

Fig 3 Stabilization of ballast using polymer solution

Fig 4 Confirmation of effectiveness of ballast migration countermeasure

16. Method for detecting damage and repairing slab track cement asphalt mortar layers

- A method has been proposed to use track inspection data to detect damaged sections in the CA mortar layer under slab track.
- A method for repairing the gaps in the upper CA mortar layer was developed, which reduces material costs by 40% compared to existing renovation methods.
- A method was then developed to carry out repairs on large-scale damage to the CA mortar layer. This new renovation method reduces costs by 50% compared to present methods which completely replace the CA mortar layer.

Slab track can be subject to major damage due to gaps forming underneath it or erosion on its sides up to several dozen centimetres in size, due to frost damage etc. This kind of damage is very cumbersome to repair. The change in support due to deterioration appears on each 5m track slab. Using this characteristic, a more efficient method by 5m-chord longitudinal level irregularity was proposed to detect deteriorated slab track sections from track inspection data (Fig. 1).

Gaps under track slabs can be repaired using resin injections. However, due to cost of materials and workability, this method is seldom employed. As such, a new method for renovating slab track was developed which reduces costs by 40% compared to existing materials. The method uses high-fluidity CA milk (slurry) injected using a sandy mould to fill the gap (Fig. 2).

A new method was then developed to renovate large sectional areas, whereby an inspection rod is used to estimate the extent of the deteriorated area, which is subsequently cleared using a water jet and then injection-filled using frost-damage resistant renovative CA mortar (Figs. 3 and 4). This method reduces the cost of repairing damaged sections by 50% compared to present methods which completely replace the CA mortar layer.

Results from applying the gap repair and large-section renovation work to a commercial line demonstrated that dynamic displacement of the track was reduced, and could be kept below 1/10 (Fig. 5).

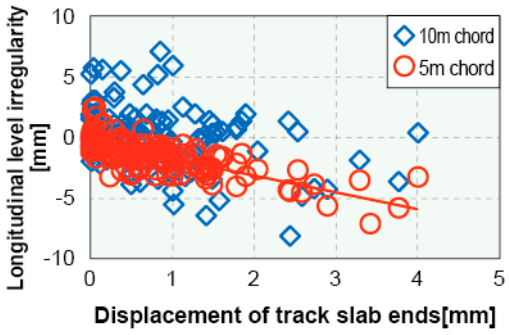


Fig.1 Correlation between longitudinal level irregularity and track slab displacement

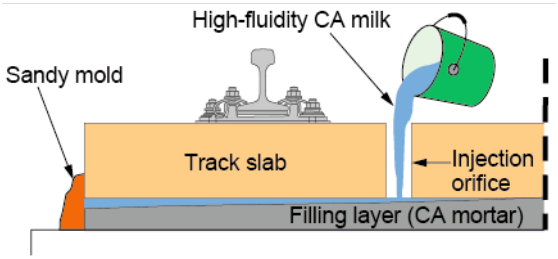


Fig.2 Gap repair method

Fig 3 Example of extensive deterioration (condition at the surface)

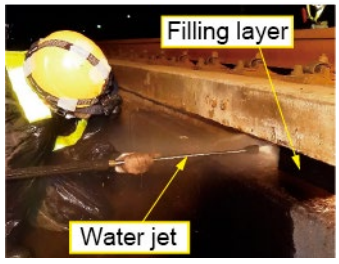


Fig 4 Work with the water jet

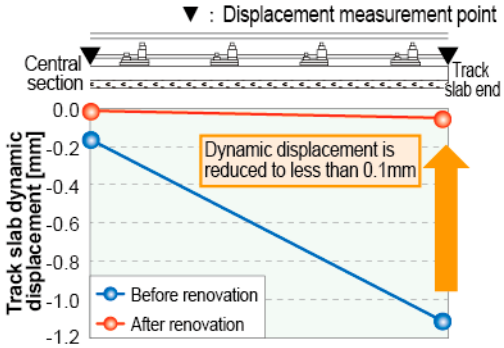


Fig 5 Reducing dynamic displacement through large section repair

17.Decision-making support system for planning replacement of wooden-sleepers with PC sleepers in curved sections

- A system has been developed to help plan replacement of wooden sleepers with PC sleepers according to the specific characteristics of each curved section, its track structure, rolling stock and operating conditions.
- This system can also be used to calculate the most appropriate distribution of PC and wooden sleepers when carrying out partial replacement work.
- By using the system, it is possible to reduce the length of curves requiring replacement of wooden sleepers with PC sleepers by approximately 15% compared to taking curves in order of radius size starting from the smallest.

On curved lines with wooden sleepers, the lateral resistance of track panels is low, which can lead to excessive lateral displacement of the track, and rotting of sleepers which can then lead to derailment due to gauge-widening, therefore wooden sleepers are gradually being replaced with PC sleepers. Therefore, in order to prioritize which curves should have replacement PC sleepers first, a decision-making support system was developed to plan replacements considering the conditions of each curved section (Fig. 1).

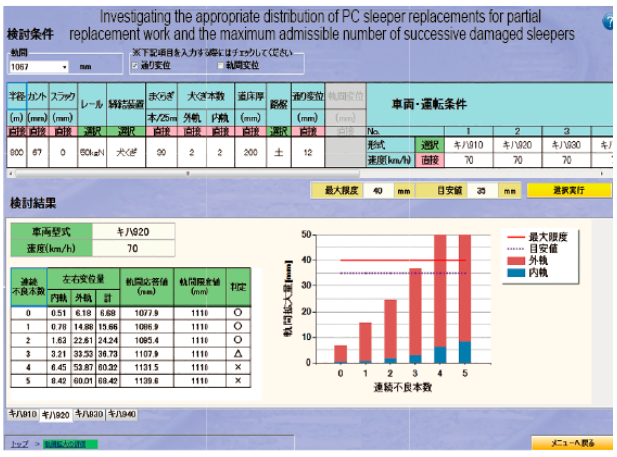


Fig 1 Decision-making support system for planning replacement of wooden sleepers with PC sleepers

This system takes into account curve and track structure characteristics, rolling stock and operating conditions and the deterioration of the track. It calculates which curves should be classed as high priority for installation of PC sleepers through evaluation of several running safety related factors, such as derailment due to gauge-widening, track panel displacement and extrusion or falling out of rail spikes.

Moreover, the system sets limit conditions, namely budget and length of track requiring replacement work, and helps to plan replacement work efficiently by selecting those curved sections which would most benefit in terms of safety improvement by having PC sleepers laid.

In addition, when wooden sleepers are partially replaced with PC sleepers (Fig 2), the system can calculate the appropriate distribution of PC sleepers to be installed etc. This function can be also used to set maintenance criteria in terms of admissible number of successive damaged sleepers, when carrying out sleeper inspections.

After trying the new system with data from a few line sections, it was found that compared to tackling wooden sleeper replacement by order of curve radius, starting with the smallest, the length of track work on could be reduced through this system by 15% whilst achieving the same improvements in safety (Fig.3).

Fig 2 Example of partial installation of PC sleepers

Fig 3 Curves selected for replacement with PC sleepers

18.System for inspecting obstruction warning signals

- Using image processing technology, a system for inspecting Obstacle Warning Signals has been developed.
- By applying the new system, signals can be inspected during daytime operating hours, thus reducing the inspection time to 30% of the existing method, according to estimations on a model line.

Obstruction warning signals do not emit light during normal service hours and therefore it is necessary to turn them on to check their visibility during inspection. In order not to affect railway operations, these inspections therefore have to be conducted after normal operating hours. This work is time and labour consuming and therefore a costly problem.

As a solution, an inspection system has been developed using near-infrared light invisible to the naked eye and a camera capable of picking up this near-infrared light, which allows verification of the light emitted from the obstruction warning signal from onboard a running train (Fig. 1).

The new system can be used to carry out inspections during daytime operating hours, making the procedure efficient and cost effective. The prototype of this system, (Fig. 2: onboard measurement device; Figs. 3 and 4: Obstruction warning signal) were monitored over an extended period of time, confirming that the device can function unimpeded by the weather, season or time of operation.

Image data for the whole line can be obtained in just one return journey, reducing the overall inspection time in terms of days, to nearly 30% of the time required with the existing method, according to calculations on a model line. In addition, the new inspection method is more accurate, since the obtained image is continuous and therfore visibility can be inspected right up until the train has passed the signal.

In order to implement the new method, it will be necessary to replace existing obstruction warning signals with the newly developed signals and equip trains with the portable onboard inspection device.

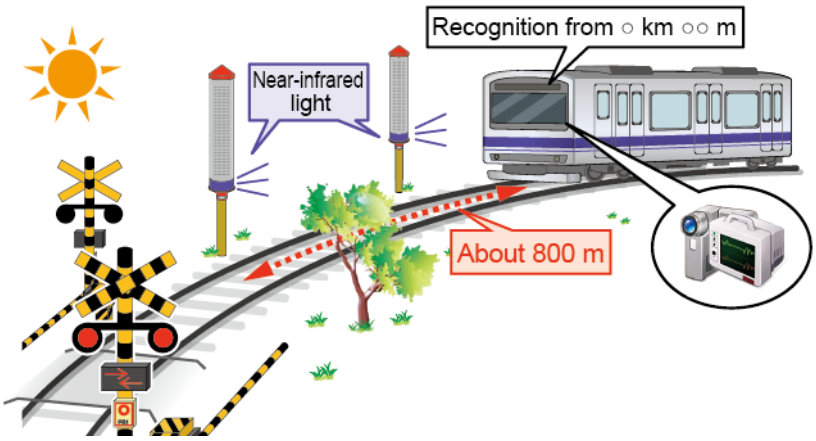


Fig 1 Outline of the new system

Fig 2 Onboard device

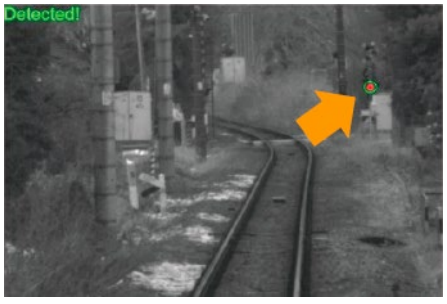


Fig 3 Detection

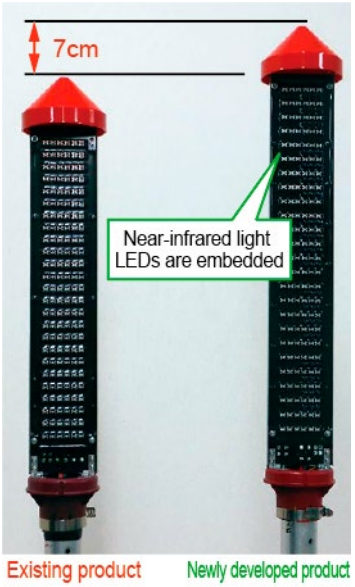


Fig 4 Comparison between existing and new obstruction warning signal

19.Possibility of practical application of a 920MHz bandwidth network

- It has been demonstrated through experiments that wireless network technology using a 920MHz frequency band has the potential for broad application in the monitoring of railway infrastructure and equipment, such as structures and railway vehicles.
- This type of network is unaffected by weather conditions and is capable of successfully transmitting over 95% of various kinds of data.

In line with the growing use of the Internet of Things (IoT), wireless network technology is increasingly being introduced for infrastruture monitoring systems using different frequency bands.

However, there is no standard network technology yet which can be broadly applied to both structures in zones where maintenance is difficult and to running trains.

As such, Wi-SUN (Wireless Smart Utility Network) technology, which was developed in Japan for the automatic collection of gas and electricity meter data, and became an international standard in wireless technology in 2012, was evaluated in tests to assess its transmission capacity in a railway environment to monitor the state of railway infrastructure.

Wi-SUN is designed to carry data in small packets, and therefore only consumes tens of mWs, which is a fraction of electricity consumption in other systems. Furthermore, the radio waves in the 920MHz band for which it is designed, can propagate over longer distances than in the 2.45 GHz band used by other communication systems, and suffer very little interference. Results of tests conducted at RTRI on a temporary test network set up using the test line, test vehicle, heavy rain rig and snow obstacle test area, to evaluate data transmission performance of the network (Fig.1) confirmed that under various meteorological and climatic conditions which can affect radio propagtion characteristics, on average over 95% of data was successfully transmitted (Fig. 2).

Results from this study demonstrate that Wi-SUN specifications can be broadly applied for the monitoring of railway infrastructure, and will the technology will therefore be instrumental in developing a railway network technology standard in the future.

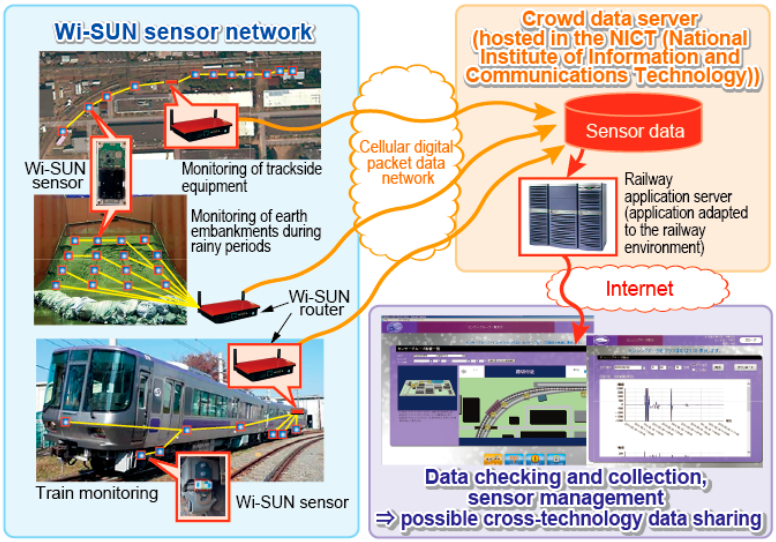


Fig. 1 Structure of crowd based wireless sensor network and Wi-SUN in verification tests

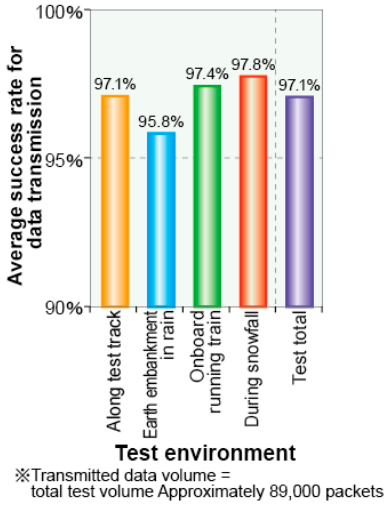


Fig.2 Results of evaluation of successful data transmission

20. Characteristics of long-term fuel cell deterioration

- Before introducing fuel cells onto trains, their endurance for long-term use be tested through 3600 train runs and ten years of power generation tests.
- This paper proposes new fuel cell design guidelines based on risk assessments in the light of defect reports.

The introduction of clean energy fuel cells to trains is being eargerly awaited. In fuel cells a platinum catalyst causes oxygen and hydrogen to react, generating electricity. The catalyst however suffers wear, which can cause a fall in fuel cell output voltage and efficiency. Therefore, a ten-year continuous running test was conducted using a test train with a fuel cell (Fig. 1) to investigate output voltage and efficiency.

The experiment was carried out using a large capacity fuel cell, capable of propelling a train, which showed the same type of wear as smaller sized fuel cells, with a fall in output voltage of about 5% compared to initial values. Efficiency however remained at about 52%, and it was demonstrated that even over a long period, there was no significant decrease in fuel cell performance nor were there any notable driving failures (Fig. 2).

Based on fuel cell problem reports, assessments were made to establish the presence of unacceptable risks in the fuel cell due to age-related deterioration or an accidental defect.

This process made it possible to identify the areas requiring improvement, and made it possible to draft a set of new guidelines for a safer and more reliable new generation fuel cell (Table 1).

Fig 1 Fuel cell test railway vehicle

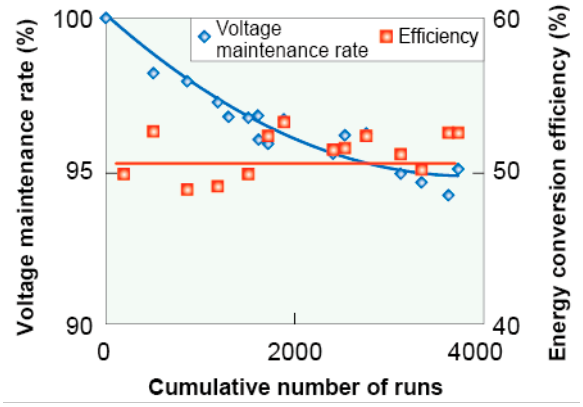


Fig 2 Change in fuel cell characteristics over the long term

Table 1 Example of Fuel cell risk assessment

Possible hazard	Risk (before countermeasure)			Countermeasure	Risk (after countermeasure)		
	Frequency	Damage	Assessment		Frequency	Damage	Assessment
Water repelling properties of the catalyst decrease hindering oxygen supply	Low	Moderate	△	Install voltage sensor	Low	Low	○
Shortage of coolant causes abnormal overheating of the fuel cell	High	Moderate	×	Install water level sensor	High	None	△
The seals begin to wear causing water to leak from tube connections	Moderate	Major	×	Install earth leakage breaker	Moderate	Minor	△

○ : No hazard △ : Measures need to be taken × : Cannot be admitted (Inadmissible)

21. Quantification of impact noise due to local wear on wheel treads on Shinkansen railway noise, and method for detecting local wear.

- A quantitative investigation was made into the effect of impact noise due to local wear on wheel treads, on Shinkansen railway noise.
- A method has been developed for detecting local wear above 0.1mm on wheel treads from vibrations induced on viaducts.
- This method can contribute greatly to detecting local wheel wear, which affects wayside noise.

The impact noise due to local wear on Shinkansen train wheel treads, when the trains are running at high speed, contributes significantly to railway noise (Fig. 1). The contribution of the noise has not been understood properly, nor has it been possible to detect local wear through visual inspection. Therefore, it is necessary to develop a method which can identify the state of wheel treads.

Through the investigation of a large number of wheels, the geometry of those which affect wayside noise were examined carefully, and it was found that the width of typical local wear on the tread is about 300 mm, with a maximum depth of 0.5 mm.

Then, based on the relationship between bridge noise and wheel roughness levels, based on the collected geometries, e.g. wear depth, it was confirmed that, when the roughness level is greater than that corresponding to a wear depth of about 0.1 mm, bridge noise increases siginificantly (Fig. 2).

Examination of the correlation between the maximum depth, δ, of local wear on the wheel tread and vibrations induced on concrete viaducts suggests that the vibration was approximately proportional to δ^1.8 (Fig. 3).

It is confirmed that, based on these results measured with an accelerometer placed on the concrete viaduct, it is possible to quantitatively estimate the depth of local wheel tread wear above 0.1 mm in a single bogie.

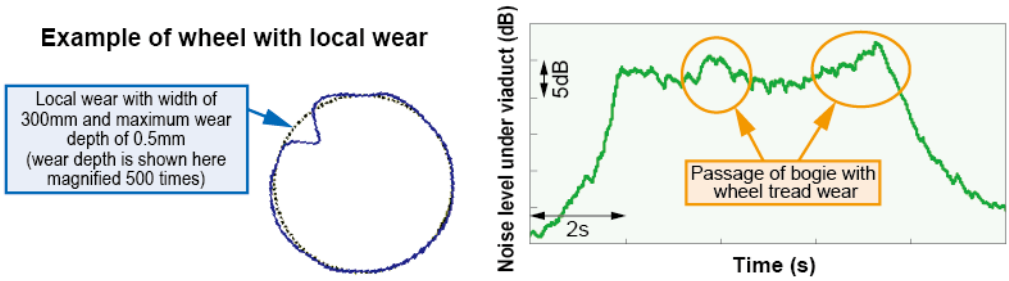


Fig.1 Example of local wear on a wheel and influence on bridge noise

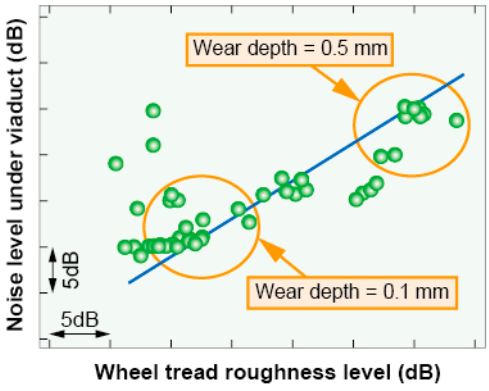


Fig 2 Correlation between trackside noise (noise directly beneath structure) and wheel tread roughness

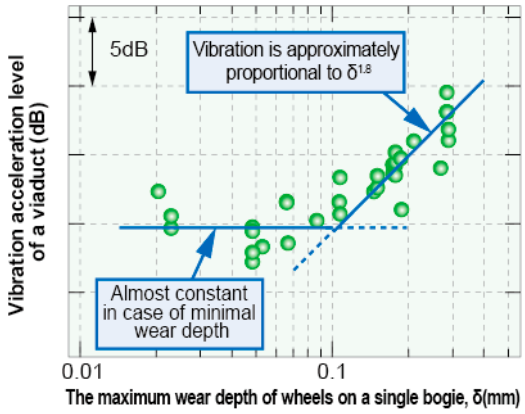


Fig 3 Relationship between vibration of a viaduct and wear depth (extracting the component generated by local wheel wear)

22. Verification of High Temperature Superconducting Flywheel Storage Systems

- A machine has been developed for verifying high-temperature superconducting flywheel storage systems with contactless flywheel support, using high-temperature superconducting magnetic bearings.
- Confirmation was obtained using the verification equipment that a small high-temperature superconducting magnetic contactless bearing was capable of supporting a 4-ton flywheel in a system with an output power of 300kW, and storage capacity of 25kWh.

Flywheel Energy Storage Systems work by having an in-built flywheel (rotor), which changes the electric power to kinetic energy which is then stored, and can release electric power on demand by reconverting the kinetic energy back into electricity.

The specificity of the flywheel energy storage system being verified in this paper is that it uses high-temperature superconducting magnetic bearings. The system has a high-temperature superconducting bulk body rotating shaft and high-temperature superconducting bearings, which produces a step-change improvement in supporting force and means that the bearing can be made relatively much smaller than before for the load it must support (Fig. 1).

The demonstration machine used for verification tests (Figs. 2 and 3) had a 2 m diameter and a mass of 4 tons, supported by a CFRP superconducting magnetic-bearing flywheel. Rotations were adjusted through the generator motor; therefore, it was possible to test the system's capacity to absorb and release 300 kW of power, and verify it could store 25kWh of power.

The superconducting magnetic bearing was cooled with a commercially available compact cooler, removing the need for liquid nitrogen etc., and electric power consumption was less than 1% of output power. Since September 2015 this demonstration machine has been used in verification tests to equalize solar photovoltaic power output (at the Yamanashi prefecture facility).

This storage system, apart from the fact that it does not suffer wear from repeated charging and discharging, is low-loss, long-life and low-maintenance and is suited for use on the railways for regenerative power purposes and as a measure to prevent voltage dropping. The next step will be to design the energy storage system for use on the railways.

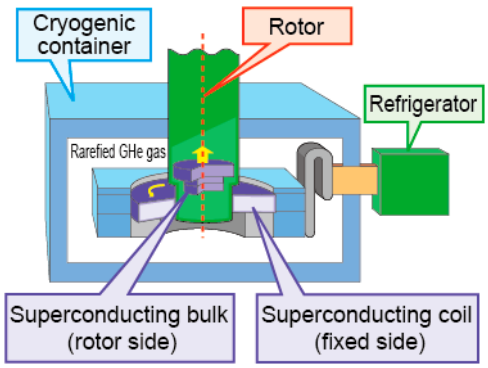


Fig. 1 High-temperature superconducting magnetic bearing structure

Fig.2 Outside view of the demonstration machine

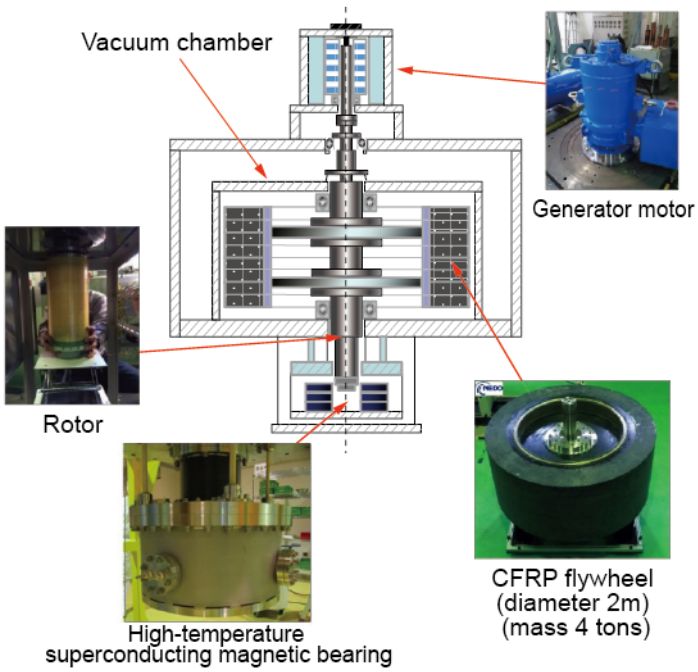


Fig.3 Structure of the demonstration machine

IMPROVEMENT OF CONVENIENCE

23. Car-body tilt control system for better ride comfort

- A control system was developed for tilting trains to mitigate motion sickness.
- The new system can reduce the motion sickness dose value in sharp curves by 30% and be installed on existing tilting trains.
- It is proposed that the system can be installed on not only new trains but also existing tilting trains travelling through sections with successive sharp curves during their overhaul periods.

The car-body tilting mechanism with tilting bolsters and rollers, while it is more complex than the mechanism with air-spring systems, offers a larger tilt angle and optimal reactivity, and is designed for trains which require better ride comfort or that must pass through sections with successive sharp curves.

The tilt control system was designed to provide improved ride comfort and reduce motion sickness through (1) precise train positioning, (2) tilt patterns offering better ride comfort, and (3) optimal response pneumatic tilt actuators.

Table 1 compares the new mechanism with the existing system. Ride comfort is improved thanks to a “Tilt pattern” function which responds to curve radius, cant size and running speed, and produces successive predictions of the accelerations exerted on passengers in order to suppress the low frequency swaying action which causes motion sickness.

Results from test runs confirmed that compared to the existing system the new mechanism could reduce the motion sickness dose value (MSDV-y) by 30%, i.e. from a current average of 4.2m/s1.5 to 3.0 m/s1.5 with the new system (Fig 1).

It was also verified that if the tilt actuator could be applied then existing tilting dampers were no longer required.

Based on these findings, further developments were made to the device to incorporate features needed for the system to be installed on commercial trains, such as connectivity with monitoring equipment and failsafe performance (Fig. 2).

Table 1 Comparison with the existing system

	Existing system	New system
Tilt patterns	With consideration of tilting rate	With consideration of tilting rate and motion sickness
Tilt actuator	Pneumatic type (response – low)	Pneumatic type (response – high)

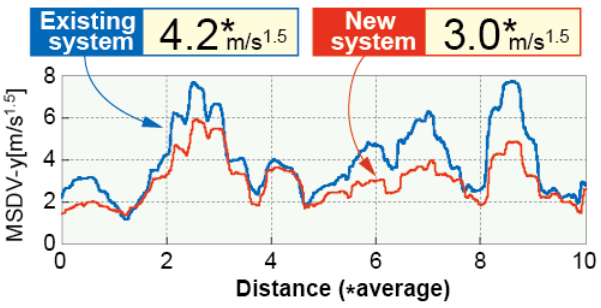


Fig. 1 Reduction in motion sickness dose value (MSDV-y)

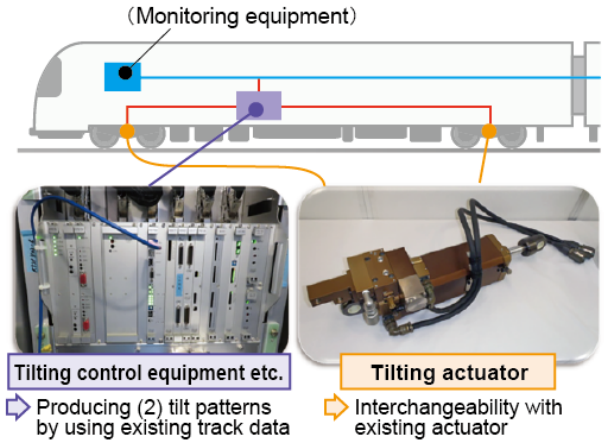


Fig. 2 Tilting control device adapted for use on commercial trains

24. Design method and performance verification for linear rail brakes used on high-speed trains

- A design method has been developed to produce contactless, compact and light-weight linear rail brakes which can still function during power cuts and can be used on high-speed trains.
- Based on model tests and simulations, it is expected that the new model linear rail brake will be able to reduce the stopping distance after application of brakes at nearly the maximum running speed, by about 10% compared brake systems using adhesion alone.

While plans are being made to increase train speed, there is a concomitant need to increase the braking force when wheel/rail frictional forces (adhesive force) decrease at these higher running speeds.

A contactless and non-adhesive linear rail brake has therefore been designed with this objective in mind. The new brake utilizes the electromagnetic interaction with the rail to produce the braking force while generating itself the power required for excitation. This means that it can operate stably even in bad weather and through power cuts. A design method was then devised and is proposed to build a compact light-weight version of this brake especially adapted for high speeds.

The iron core for passing the magnetic flux in the present design method is much smaller than in existing systems which are designed to operate even at low speed. The present design is geared to maintain braking force which influences greatly the stopping distance at high speed.

After conducting detailed magnetic field value and structural analyses and proposing a reinforced support structure, the new design can reduce the iron core by approximately 60% compared to the existing system.

A prototype suited for testing on a roller rig was then built applying the new design method described above (Fig. 1). Results after tests during a mock power cut confirmed that the same braking force could be obtained at high speed as with the existing design, despite the lower weight (Fig. 2). Using the test data, simulations were then conducted using the system together with adhesive braking to measure stopping distances when running at nearly maximum speed. The simulations demonstrated that the stopping distance could be shortened by approximately 10% compared to when adhesive braking (applied at the adhesive limit in dry conditions) is used alone.

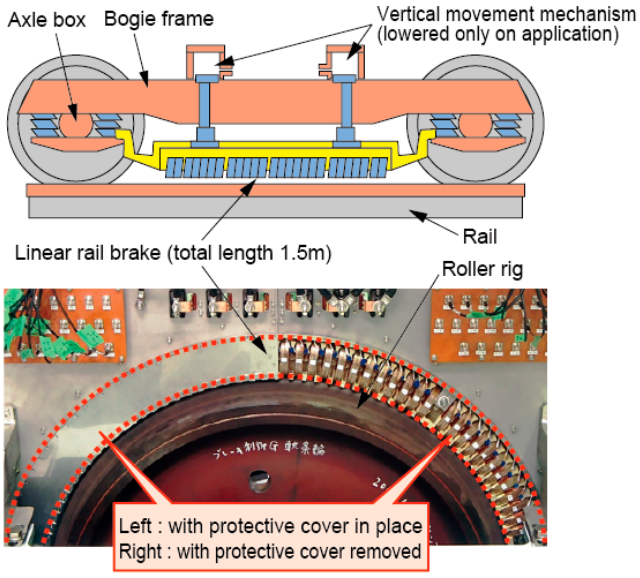


Fig.1 Picture of basic structure of the linear rail brake (top) and prototype built for tests on the roller rig (bottom)

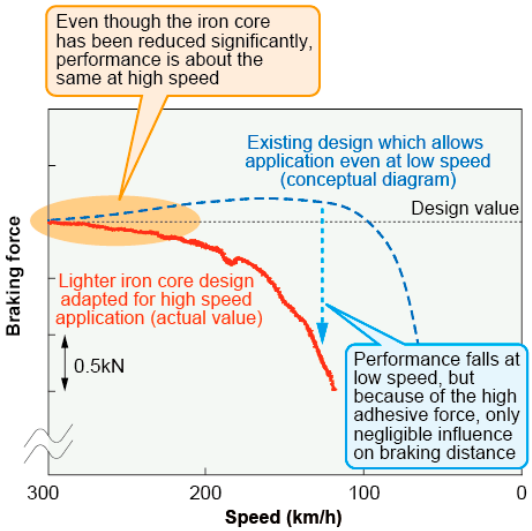


Fig. 2 Braking force test results

25. Method for predicting passenger thermal comfort in railway vehicles

- A method has been developed to predict passenger thermal comfort which correlates closely with the physiological and psychological state of passengers.
- Subjective experiments in thermal environments were conducted in main line and commuter vehicles. Results demonstrated that the proposed prediction method reflected passenger thermal comfort accurately, with a correlation of over 0.8.

In order to improve the on-board thermal environment for rail passengers, it is important to be able to accurately evaluate and predict thermal comfort levels. A method for determining thermal comfort already exists for indoor spaces in the ISO 7730. However, there is no standard specifying a similar method for the railway environment which has specific characteristics, for example, contrary to indoor spaces, temperature and humidity variation in railway vehicles can be very drastic, and there are also significant differences in thermal comfort from season to season. Consequently, taking these specificities into account, a new method has been proposed for determining thermal comfort levels specially adapted to railway rolling stock (Fig. 1).

The proposed method is made up of physiological and psychological predictions. A human thermal model with a built-in body temperature regulation function is used to estimate the various thermal physiological states of the passenger, such as skin temperature and perspiration in various thermal environments in railway vehicles. It is also possible to take into account the clothing and posture of the passenger in these estimations. To estimate psychological states, a statistical model is built on data collected from subjective experiments conducted in railway vehicles stationed at rolling stock centers in different seasons (a total of 350 people for a temperature range of 20□□32□), and this is applied to predict passenger thermal comfort (level of discomfort and percentage of dissatisfied customers).

Comparing predicted thermal comfort results with the actual comfort of subjects participating in a simulated thermal experiment revealed a correlation of over 0.8 between them (Fig. 2, Fig. 3). This method will make it possible to quantitatively evaluate air-conditioning adjustment from the passenger thermal comfort perspective in railway vehicles.

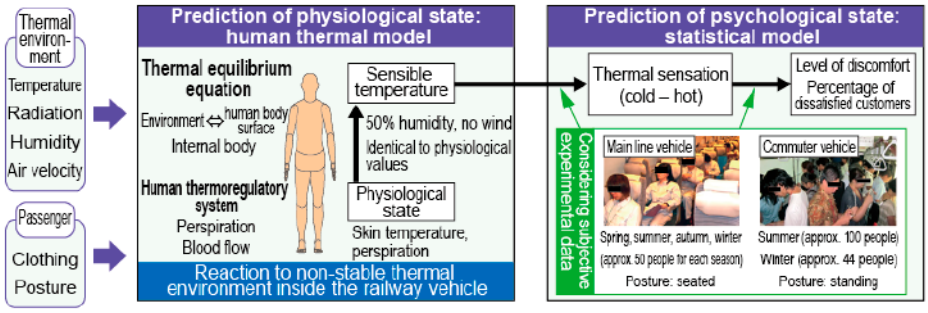


Fig. 1 Overview diagram of the proposed thermal comfort prediction method for thermal environments in railway vehicles.

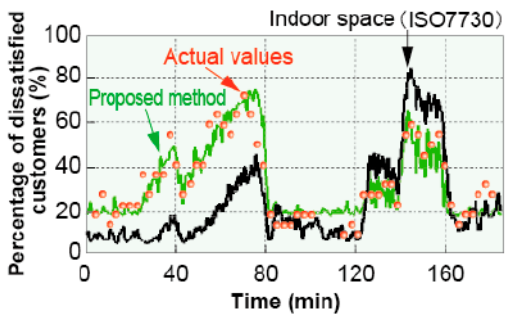


Fig. 2 Example of dissatisfaction level prediction in relation to thermal environment, using the proposed method

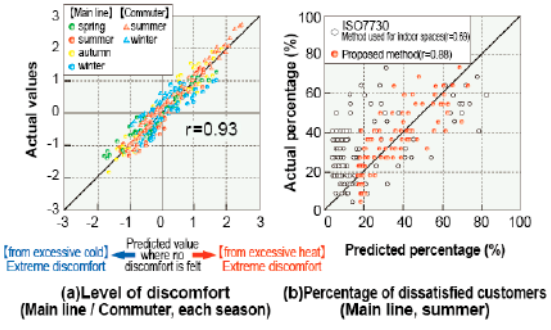


Fig. 3 Comparison between actual comfort level values and predicted comfort levels using the new method

26. Training support program to foster resourcefulness when making PA announcements during disruptions

- A training method has been proposed to encourage train conductors to be more resourceful when making PA announcements during disruptions, and a training program has been devised to support trainers when conducting on-site practice sessions.
- After training train conductors with this method, their resourcefulness improved by approximately 20 points on the evaluation scale.
- The method has been proposed in the form of “study support material” and “trainer and evaluation support material” for trainers.

A method has been proposed to improve the level of resourcefulness among those having to make announcements during disruptions. In addition, a training support program has been devised (Fig. 1) aimed at trainers conducting on-site practical sessions. Part of the support program includes two types of teaching material to help trainers in learning, teaching and evaluating the subject.

Learning support material (bird’s eye approach to learning how to make announcements in DVD, handbook and practical study format)

Trainer/ evaluation material (Step-by-step slides, study topics, announcement evaluation sheet)

The proposed training program was tried as part of conductor training in the railway companies in metropolitan areas (approximately 400 participants).

The conductors’ announcing skills were measured in practical tests before and after the training by asking them to make improvised announcements for mock cases, such as an interminable disruption requiring repeated updates of the situation, or other possible difficult scenarios. Their performances were given a score reached on a set of check-list items from existing manuals for the ‘basic score’, and according to another set of check-list items to measure resourcefulness, for the ‘responsiveness score’ (Table 1).

Comparison of their scores before and after the training (Fig.2) showed that their basic score had improved by 10 points, whereas resourcefulness had improved by 20 points on the scale. This confirmed that the newly proposed program aimed at improving the announcing skills of railway staff is effective.

Fig.1 Outline of training support program

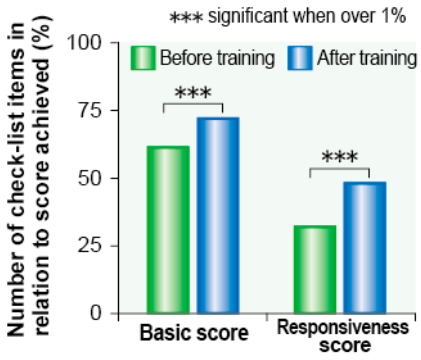


Fig.2 Number of check-list items in relation to score achieved in practical skills test

Table 1 Example of practical skills test score reached and check-list items

Basic score (12 check-list items)	Responsiveness score (based on a total of 30 check-list items)
・When / where did what happen?	・First announce whether the information is new or old
・Is there any information about when services will resume?	・Inform passengers about possibility of further delay
・Transfers	・Tell passengers what actual transfer options / routes there are (stations, lines)
・Apologies	・Explain how the trial run train works or inspection methods are carried out

27. Improvement of visibility of Tactile Walking Surface Indicators (TWSIs) for people with low vision

- Investigations were conducted into suitable specifications for the continuous adjoining bands (CAB) to improve the visibility of tactile walking surface indicators (TWSIs).
- A proposal was made to make CABs about 5-15 cm wide, with a luminance ratio of about 3, at least, when used with TWSIs.

Visibility of tactile walking surface indicators (TWSIs) is important for people with low vision when they walk by themselves, since people with low vision, approximately 90% of the blind and vision-impaired persons, use residual vision in their independent travel. Visibility of TWSIs is determined chiefly by the luminance contrast between TWSIs and their surrounding surfaces. In this study, three investigations were conducted concerning the luminance ratio, an index of luminance contrast, between TWSIs and their surroundings, as follows.

First, the relationship between the luminance ration of TWSIs and the surrounding surfaces, and the visibility of TWSIs was examined. Forty-six people with low vision participated in this investigation. Results demonstrated the relationship between luminance ratio and the percentage of those with low vision who find the visibility of TWSIs to be unacceptable (Figure 1).

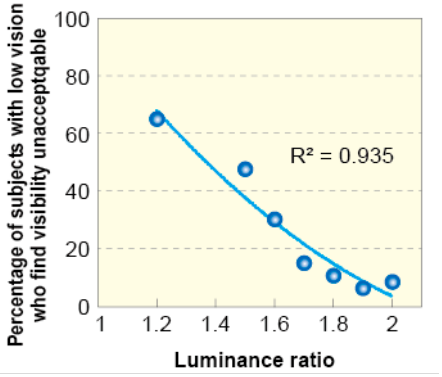


Fig.1 Proportion of subjects with low vision who find visibility unacceptable

Fig.3 Example of continuous adjoining bands (CABs) with TWSIs

Second, some previous studies showed that when the luminance ratio is insufficient (Fig. 2), continuous adjoining bands (CAB) of dark color can be used to improve the visibility of TWSIs (Fig. 3). Some other previous studies however warn that bands of dark color on the walking surface may be falsely recognized by people with low vision as street gutters, depending on their color and/or width. Investigations were conducted to identify the optimal color and width of CABs which improve the visibility of TWSIs without being mistaken for street gutters. Forty-four people with low vision participated in this investigation. Based on the result, it was proposed to make CABs 5-15 cm wide with a luminance ratio of about 3, at least, when used with TWSIs (Figure 4).

Finally, a manual was proposed containing methods for measuring the luminance ratio between TWSIs and their surrounding surfaces, taking the environmental characteristics of railway stations into consideration.

Fig.2 Example of location with low luminance ratio

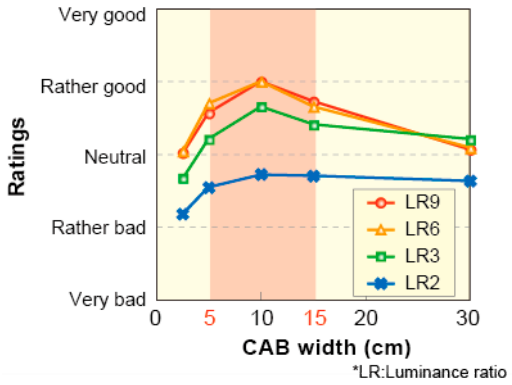


Fig. 4 Ratings for different CAB width/luminance ratio combinations

28. Obstacle monitoring system using 90GHz band millimeter wave

- A new monitoring system has been proposed which combines a 90 GHz band millimeter wave not yet used in the railway environment and Radio over Fiber technology.
- It has been confirmed that the system can detect the presence of a small group of people from a distance over 100m with a resolution of 50cm.

The characteristics of 90 GHz band millimeter waves include low attenuation due to dry air and the fact that they can be used in a wide frequency range. Therefore it can be applied to radar systems able to detect obstacles with high resolution from a long distance.

By applying Radio over Fiber (RoF) technology which transmits radio frequency signals through over optical fiber, it is possible to bring together control units which have the function of costly millimeter-wave signal sources and signal processing units, simplifying the configuration of the radar nodes installed on the trackside, in order to transmit and receive the radio waves. Compared to the existing systems, it is expected that the proposed new system will cut installation costs by more than half (Fig. 1). A prototype system constituted by combining a 90 GHz band millimeter-wave and RoF technology was installed and the verification test was carried out. As a result, it was confirmed that a group of several people can be distinguished from a distance of over 100m and people and concrete blocks can be detected from a distance of about 200m (Fig. 2 and Fig. 3). These research results have demonstrated that it is possible to apply available radio resources in the form of 90GHz band millimeter waves that were not used until now in the railway environment to detect obstacles on railway tracks.

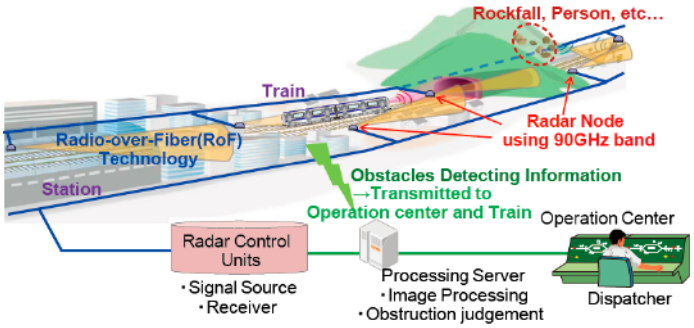


Fig.1 Configuration of the proposed future track monitoring system

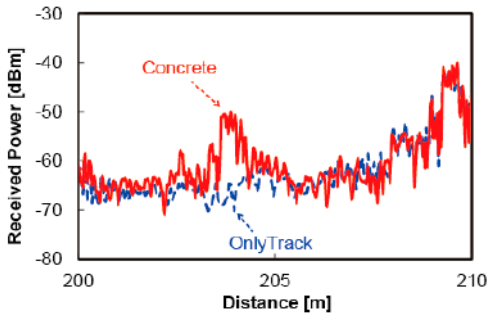


Fig. 2 Received power of radar

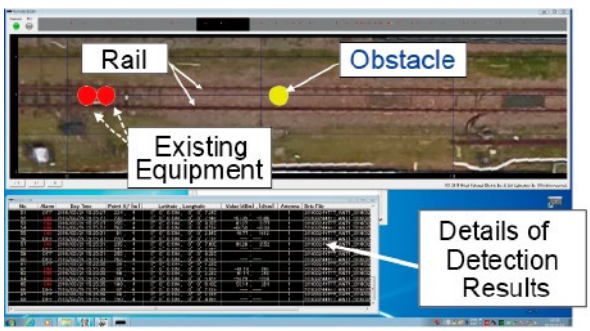


Fig. 3 Example of display of detection result

29. Simulation of contact between running railway vehicles and railway structures during earthquakes

- Previously, due to unfeasible calculation times required, it was not possible to analyze contact between running railway vehicles and railway structures during earthquakes. However, a new method has now been developed with feasible calculation times to analyze such situations, in order to evaluate the effectiveness of derailment damage mitigation measures such as L-guides and vehicle guide guards during very large earthquakes.
- The new method can be used as a tool to evaluate the effectiveness of derailment damage mitigation measures and analyze vehicle contact with railway structures in case of a derailment.

In order to carry out efficient simulations of running trains coming into contact with railway structures, a new algorithm was developed (Fig. 1). The new algorithm calculates contact between contact points placed on a multiple-body vehicle model and contact surfaces on 3D FEM-model railway structures.

Since this method significantly decreases the degrees of freedom in the analytical model, calculation times are significantly shorter than in the previous method where only FEM models were used. This means that practically, contact phenomena can be calculated in units of tens of seconds using this analytical method. The vehicle/railway structure contact model was also constructed using results from other detailed FEM analyses and actual large scale model experiments.

Integration of this new contact-algorithm into the dynamic interaction analysis program DIASTARS for Shinkansen trains and railway structures, has made it possible to quantitatively evaluate railway vehicle behavior and contact forces, taking into account contact with railway structures (Fig. 2 (a)). This method can also perform stable calculations in cases with non-linear contact force characteristics (Fig. 2 (b)).

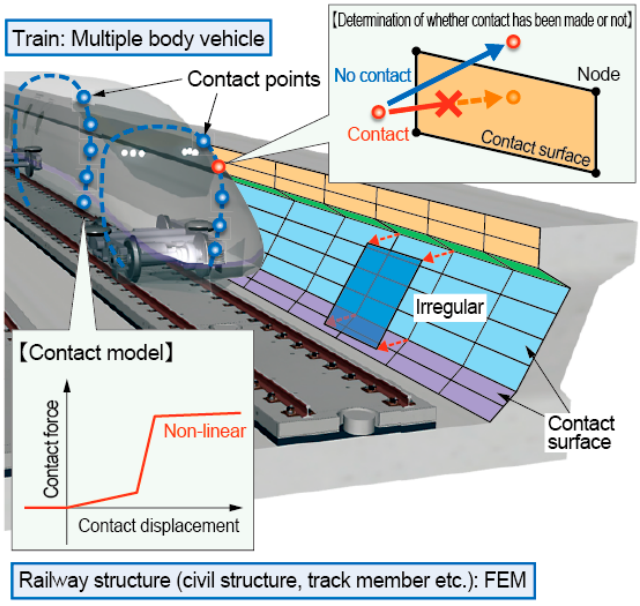
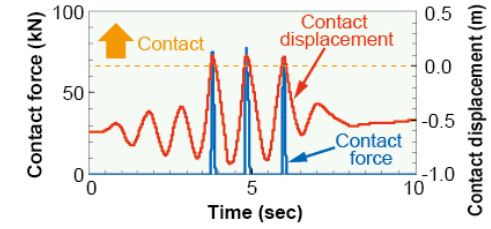
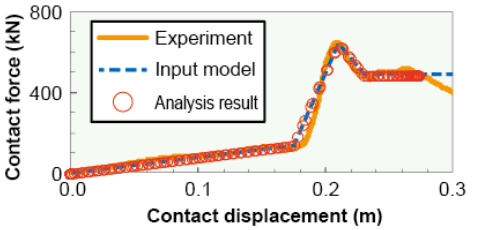


Fig. 1 Schematic diagram of proposed algorithm



(a) Time-history waveform of contact force



(b) relationship between contact force and contact displacement

Fig. 2 Analysis using the constructed analytical method (Derailed running vehicle coming into contact with through girders)

30. Aerodynamic characteristics simulation method capable of reproducing crosswind wind tunnel tests

- A numerical flow simulation method has been developed capable of reproducing crosswind wind tunnel tests.
- It was confirmed that the simulation method could predict the side force coefficient in wind tunnel tests within a maximum 20% error margin.
- This simulation method can be used to narrow down certain test conditions and thereby be used as a tool to improve testing efficiency.

To ensure the operating safety and stability of trains in strong crosswind, it is important to understand the aerodynamic characteristics of railway rolling stock exposed to crosswind, and currently these are evaluated in wind tunnel tests. However, it is very difficult to verify all necessary conditions in wind tunnel tests, and therefore a numerical simulation method capable of reproducing crosswind wind tunnel tests was developed.

The computational domain was a wide area including the turbulent boundary layer generation installations (Fig. 1), which meant that the computational cost was formidable. However, by separating calculation of the turbulent boundary layer from calculation of flows around the railway vehicles (Fig. 2), it was possible to shorten calculation times.

Using the simulation method to calculate flows around a railway vehicle on a viaduct and then an embankment showed that the calculated results were within a maximum error margin of 20% in relation to wind tunnel experiment results, demonstrating its ability to effectively reproduce flows (Fig. 3 and Fig. 4).

This simulation method can therefore be used to narrow down certain test conditions and thereby be used as a tool to improve testing efficiency.

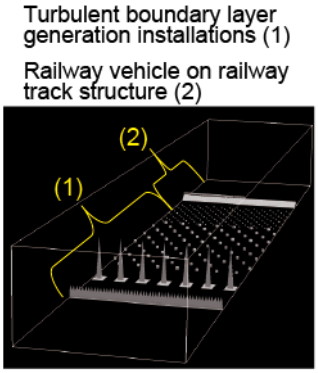


Fig. 1 Computational domain

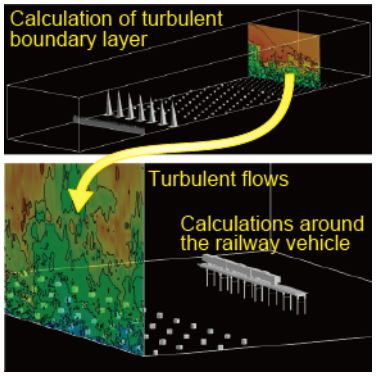


Fig. 2 Separation of computational domain

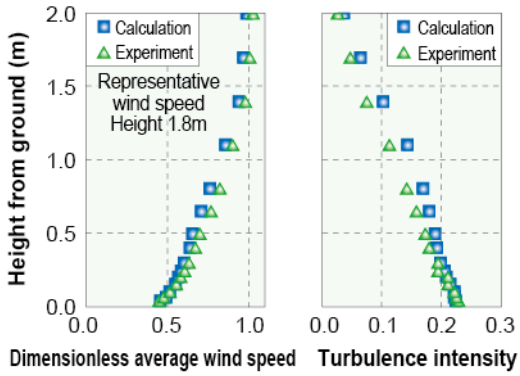
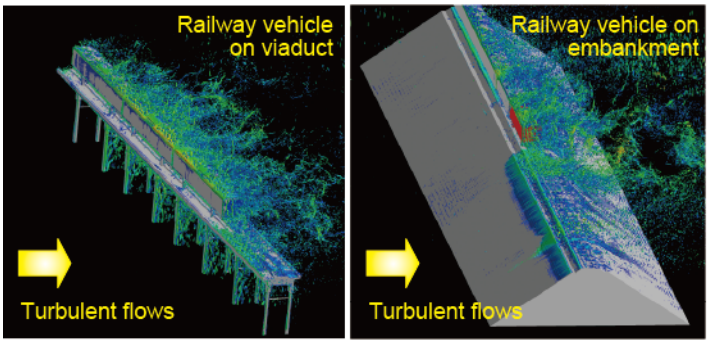


Fig. 3 Results of turbulent boundary layer calculation



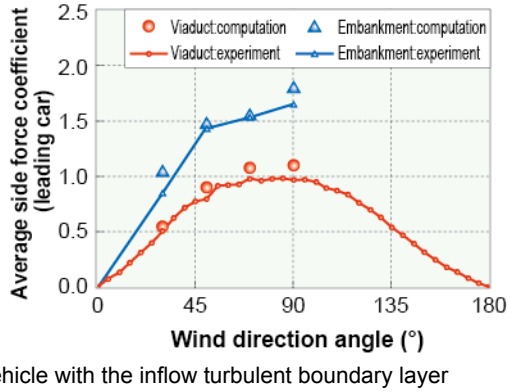


Fig. 4 Computational results for the flow around the railway vehicle with the inflow turbulent boundary layer

Results from individual R&D divisions

1 Vehicle Structure Technology Division

The Vehicle Structure Technology Division consists of four laboratories, namely, the Vehicle Dynamics, Running Gear, Vehicle Noise and Vibration, and Vehicle Strength Labs. They are responsible for a wide range of matters related to safety, stability, comfort, durability etc. The following is an outline of various research activities of the Division in FY2015.

The Division worked on a total of 23 research and development themes, of which 3 were related to “Research and development for the future of railways”, 5 to “Development of practical technologies”, and 15 to “Basic research for railways”.

The Division responded to requests for consulting advice from railway business operators including investigating incidents such as equipment failures and accidents, studying countermeasures, and clarifying the performance of new vehicles. Contract work, in addition to individual requests from railway business operators, included conducting survey research (entrusted by the national government) on the impact of vibration of vehicle equipment.

■ Vehicle Dynamics

The Vehicle Dynamics Lab develops safety evaluation methods and simulation technologies related to the running safety of vehicles. In a development project titled “Clarification of wheel wear generation mechanisms,” wear analysis found that wheels exhibited more wear when shaken laterally at frequencies higher than 1 Hz, while running stability analysis found that even light concave wear affected running stability and ride comfort. In a study titled “Clarification of the amount of container car vibration,” a method for estimating separation between container cars and the track clearance envelope was proposed based on running test results.

In a study titled “Method for improving vehicles’ anti-overturn performance against cross wind,” vehicle specification impact sensitivity analysis found that the vehicle’s anti-overturn performance was affected significantly by the mass of the carbody/bogie, the heights of the carbody’s center of gravity and the carbody’s lateral area. In a study titled “Carbody suspension system using air springs with less air consumption,” preparations were made for a stationary test by developing a hybrid simulation environment with a combination of test equipment and simulation.

■ Running Gear

The Running Gear Lab works to develop ways to improve the functions of vehicles and riding comfort. In a development project for carbody tilting technology, a tilt control system was developed that reduces motion sickness. A pneumatic centering cylinder was developed that dampens lateral bump stop contact for vehicles which tilt their bodies with air springs (Figure 4-1-1).

In a development project for a rapid prototyping bogie, an actuator control method was developed that prevents dynamic coupling between actuators. A bench test confirmed the method is capable of reproducing bogie motions. Also, a prototype vertical vibration control system was developed to improve the ride comfort in high-deck vehicles. The improvement was confirmed in a running test.

Two development projects were conducted for steering bogies. In one project, running tests confirmed that an axle box suspension using magnetic elastomers that have a variable coefficient of elasticity depending on magnetic fields achieved the expected improvement in curving performance. Secondly, specifications were considered for a bogie angle steering system where hydraulic actuators can supplement the active

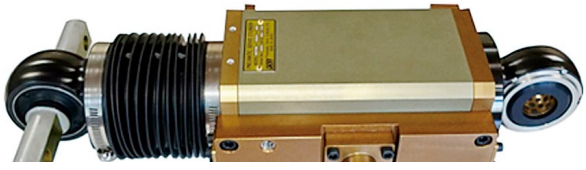


Fig. 4-1-1: Pneumatic centering cylinder

steering force of the ordinary bogie angle linked steering mechanism. In another development project, it was confirmed through field tests that multiple wireless modules formed a mesh topology of a wireless network. This work is related to the implementation of bogie condition monitoring systems.

Two further evaluations are notable. In one, simulations verified the impact of wheel diameter on axle box acceleration that is generated on a wheelset with flats. In the second study, on running stability evaluation methods using rolling stock test equipment, a review was made of excitation methods and evaluation criteria. Excitation methods were examined to determine possible impact on the critical speed of hunting.

■ Vehicle Noise and Vibration

The Vehicle Noise and Vibration Lab conducts research and development to reduce vibration and interior noise for higher standards of interior comfort. In a project to reduce the elastic vibration of carbodies, a vibration test using a rolling stock test stand confirmed that vibration was reduced with a movable yaw damper and multiple axle deforming elastic torus, both of which were developed in the project. Also on the subject of vibration, in a study on improving the accuracy of a carbody vibration analysis model, a method was proposed for estimating parameters for the analysis model based on measurements taken during vehicle running. The accuracy of the analysis model was verified by comparing calculations based on input of measured track irregularity with the measurements.

In a study to reduce interior noise on Shinkansen trains that join its bogie and carbody, the contribution of components to interior vibration and noise was clarified by a transmission route analysis. The contribution of interior vibration to interior noise was calculated based on the velocity of acoustic particles near the interior decoration and floor boards. An independent one-piece interior decoration structure, which had been proposed as a measure to reduce interior noise, was made about 3.2 times more rigid by improving the structure of the bottom surface reinforcement of the decoration's floor board. A vibration test using a test vehicle fitted with the interior decoration confirmed the effectiveness of the decoration structure in reducing the vibration and noise of the suspended floor.

■ Vehicle and Bogie Parts Strength

The Vehicle and Bogie Parts Strength Lab conducts research on the evaluation of the strength of car bodies and bogie components and on non-destructive inspection technologies. In a study on vehicle crashworthiness, quasi-static compressive failure tests using an actual coupler were carried out in order to achieve crash behavior of a coupler under extremely large compressive loads. Four different angles of a coupler body were applied for these tests. FEM analyses were carried out to validate the test results (Figure 4-1-2). Moreover, the FEM analysis model of a train set including this coupler model was built for the purpose of evaluating the crash behavior of train sets, and a study on the improvement of crashworthiness was conducted using this model.

In a study on the evaluation of axle strength, a fatigue testing methodology under variable amplitude tests based on an in-service stress spectrum was proposed to evaluate the crack

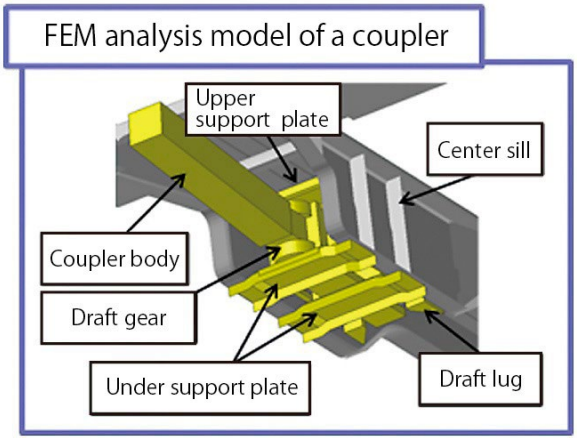


Fig. 4-1-2: FEM analysis model of a coupler

growth behavior of railway axles. Full-scale axle specimens with a fatigue pre-crack for crack propagation tests were fabricated.

2 Vehicle Control Technology Division

The Vehicle Control Technology Division consists of four laboratories, namely, the Traction Control, Hydrogen and Sustainable Energy, Drive Systems and Brake Control Labs, which are primarily responsible for research and development, consulting and contract work on instruments and control; technologies to evaluate and reduce running resistance and energy consumption; and new circuit technologies, such as hybrid systems, storage battery systems and fuel cell power generation systems, related to traction and braking.

■ Traction Control

In a study on storage battery charge control for a wider use of battery-powered railcars on commercial lines, a thermal model of a storage battery was developed to reflect the heat dissipation structure of the storage battery box on actual vehicles. Using the model, the temperature rise during a quick charge was computed.

An electric train set simulation model was developed as part of an effort to control the traction motor of an electric train set in response to changes in tangential force during re-adhesion control. Results from the simulation model were found to agree with actual vehicle data.

In a study to simplify the inductive obstruction test, maximum noise values were computed for a converter and an inverter in a return current test for AC electric railcars. It was confirmed that noise components could be estimated up to the maximum speeds of three car types based on measured data.

As part of a study on a new traction circuit for AC electric railcars (commissioned by the New Energy and Industrial Technology Development Organization (NEDO)), an experiment using a mini model showed a possibility that a proposed flying capacitor method could be used for the traction circuit systems not equipped with a traction transformer.

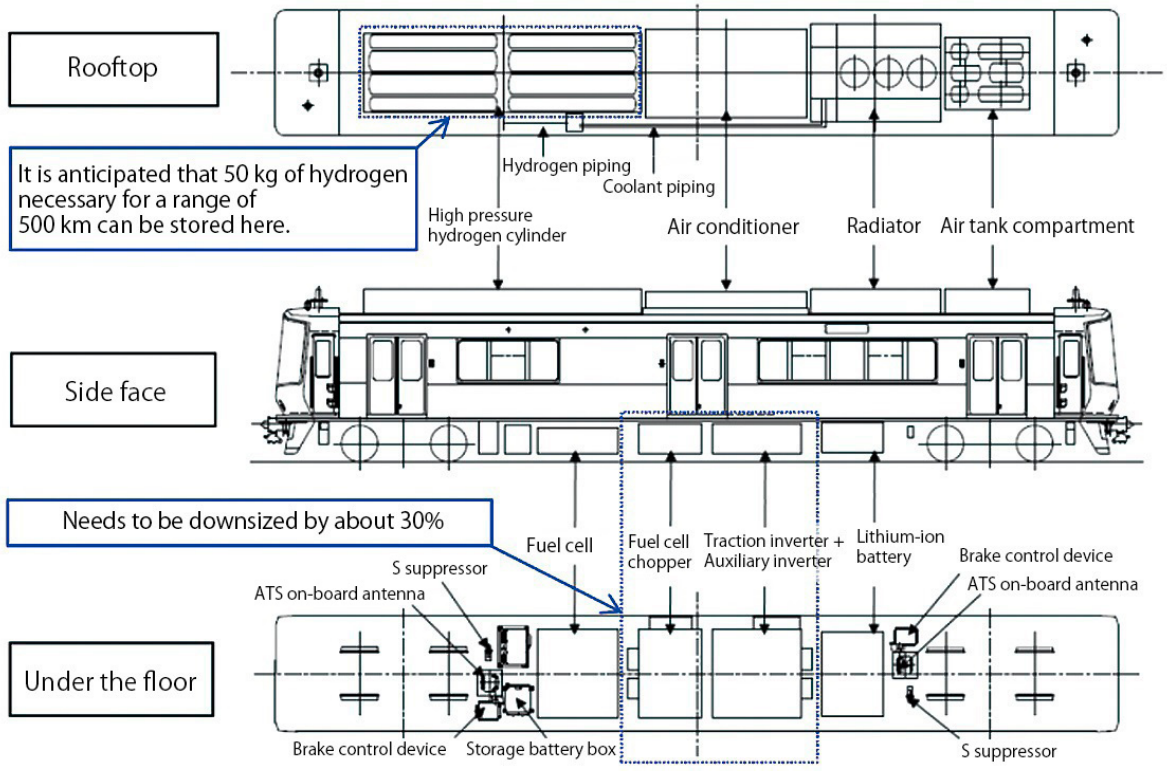


Fig. 4-2-1: Trial design of equipment for fuel cell railcars

■ Hydrogen and Sustainable Energy

The Hydrogen and Sustainable Energy Lab was set up in May 2015 to conduct comprehensive research and development for practical applications of energy saving technologies and new energy sources.

The laboratory has been pursuing the development of fuel cell powered railcars and energy saving operations to help reduce the railway sector's impact on the environment. Related activities conducted in FY2015 included determining the long-term deterioration mechanism of fuel cell systems using an RTRI electric test vehicle, downsizing of devices and trial designing of equipment for fuel cell railcars operating on commercial lines (Figure 4-2-1). Energy consumption simulations were conducted for specific revenue lines including the development of novel computation methods for computing running resistance by analyzing mass data from train information recorders on actual vehicles.

■ Drive Systems

The Drive Systems Lab has been working on the development of methods for monitoring the condition of engines, transmissions and other drive systems for diagnostic purposes, reduction of gear unit noise and for other research themes.

To help monitor drive systems, an error detection method based on octave band analysis of vibration was developed. A prototype condition monitoring device was made for collecting vibration data and a stationary test was conducted in which engine lubrication oil was contaminated with foreign matter to wear down sliding parts of the engine. The results showed that the method was effective in detecting errors.

In studying methods to reduce gear unit noise, a gear unit rotation test was conducted to identify the distribution of vibration on gear box surfaces while a sound source search found that noise was generated around plates near the gear bearings. In a related gear mesh sound simulation, the noise reduction effect from changing gear box materials was computed.

■ Brake Control

The Brake Control Lab conducts research and development on the structure and control of

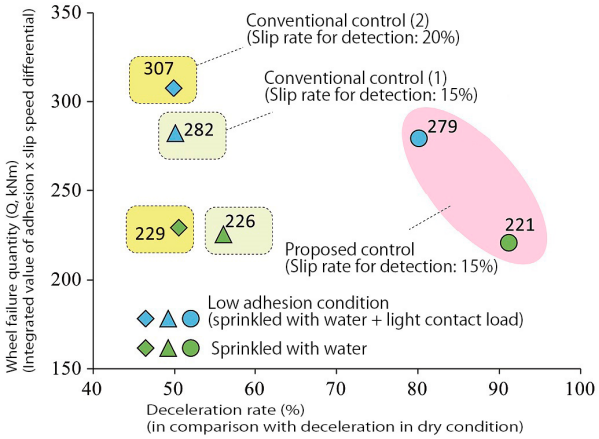


Fig. 4-2-2: Results of bench test in low-adhesion condition

mechanical braking systems on Shinkansen and conventional line railcars. In an effort to develop an improved slip control method that would prevent both stopping distance becoming longer due to slipping during braking and wheel flats due to wheel lock, a control method was proposed that features a control function for adhesion in macro slip regions where adhesion is unstable. In a low-adhesion bench test, the proposed method showed that in a braking test with an initial braking speed of 130 km/h, it could nearly halve the decline in the deceleration rate of the existing slip control (Figure 4-2-2).

In a project to develop a brake system for Shinkansen consisting of a combination of non-adhesive brakes that do not rely on force acting between wheels and rails, efforts were made to reduce the current emergency braking distance for next-generation high-speed Shinkansen. It was found that a combination of a disk brake system and a small air drag brake has the potential to stop trains within today's typical distances but from higher speeds even in low-adhesion condition.

3 Structures Technology Division

The Structures Technology Division consists of five laboratories, namely the Concrete Structures, Steel and Hybrid Structures, Foundation and Geotechnical Engineering, Tunnel Engineering,

and Architecture Labs, which are responsible for research and development, forming the relevant technical standards, and consulting and contract work related to these structures. Research and development covered such areas as improving the efficiency of structure maintenance, aseismic countermeasures including earthquakes that might directly hit the Tokyo area in the near future, and design methods and structures resistant to tsunamis. Technical standards work included developing a draft version of the cut-and-cover tunneling section in order to bring the design standard for tunnels into alignment with performance based design methods, while the processes to draft the technical standards sections on shield tunneling and mountain tunneling methods were started.

■ Concrete Structures

The Concrete Structures Lab conducts research and development of technical standards for concrete structures and is working on the preparation of related manuals. It is also involved in structural design methods and maintenance technologies. On technical standards, the laboratory worked on design methods for cut-and-cover tunnels in consideration of tunnel durability and effective measures to prevent the peeling of concrete structures.

Research and development projects included clarifying the wave force that concrete beams are subjected to in tsunamis and the mechanism involved when concrete beams are washed away. These activities made possible the prediction of damage to bridges in tsunamis. In addition, methods for preventing bridges being washed away in tsunamis were proposed (subsidized by the Ministry of Land, Infrastructure, Transport and Tourism in its railway technology development scheme). On maintenance technologies, research was conducted on methods for accurately predicting the harmful and long-term deformation of reinforced concrete structures.

■ Steel and Hybrid Structures

The Steel and Hybrid Structures Lab prepares technical standards for steel and hybrid structures and conducts research and development related to design, maintenance. Regarding technical standards, the laboratory has cooperated with the Concrete Structures Lab to publish the design standards for steel and concrete hybrid structures and to conduct training sessions. It also supplemented the maintenance standards, and completed the manuals on steel bridge inspection and repair, which bring together information of use in maintenance work.

Research and development work resulted in a concrete jacketing method being developed to repair fatigue cracks which often occur in supports for short span steel girders (Figure 4-3-1). Research was also conducted on design methods for steel framed reinforced concrete through girders and rectangular section concrete filled steel pipe columns as well as on redundancy inspections of steel bridges.

■ Foundation and Geotechnical Engineering

The Foundation and Geotechnical Engineering

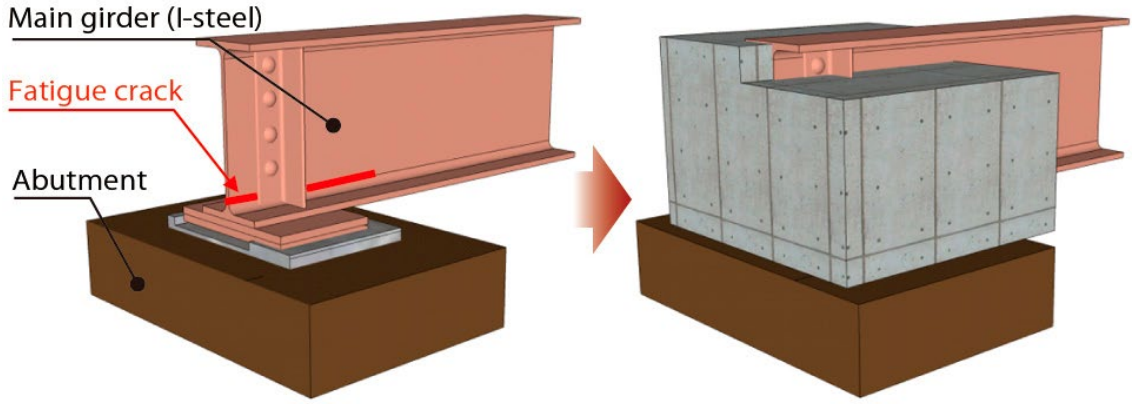


Fig. 4-3-1: Concrete jacketing method for short span steel girder supports

Lab conducts research and development work to revise technical standards related to foundations and earth structures and to develop soundness evaluation methods and lifetime extension technologies for ground structures and reinforced soil structures. The laboratory advanced the revision process for the technical standards on cut-and-cover tunnels (guidelines on base unit structure and soil retaining), published a manual for aseismic diagnosis of railway earth structures and held training sessions. It also published a manual for pile design based on the 2012 foundations standards as well as examples of design calculations for steel pipe soil cement piles.

Research and development efforts resulted in developing a liquefaction countermeasure technical method for existing pile foundations using steel sheet piles with a closed section at the bottom (Figure 4-3-2). Aseismic reinforcement technology for existing stone masonry retaining walls using net and ground reinforcement material was also developed. Systematic tests were conducted on the strength and rigidity of geo-materials and on the characteristics of partially saturated soil in order to contribute to the design of new earth structures and aseismic reinforcement of existing earth structures. The studies required the use of laboratory equipment and machines such as a medium-sized shaking table, a dynamic and static foundations loading machine and a soil element tester for the torsional shear test.

■ Tunnel Engineering

The Tunnel Engineering Lab performs research and development to enact technical standards and to provide maintenance technologies, design methods, and construction technologies for railway tunnels. To provide technical standards, it conducted studies to revise the design standards for cut-and-cover tunnels into performance based design methods while also revising standards for shield and mountain tunnels. Research and development resulted in the laboratory proposing lining reinforcement techniques for mountain tunnels under earth pressure and evaluating the effects of reinforcement for mountain tunnels. The Lab also worked on methods for evaluating the health of existing shield tunnels with deformation and for evaluating the ground deformation of thrusting elements on constructing structures crossing under railroad track.

■ Architecture

The Architecture Lab performs research and development to improve the safety, convenience and comfort of stations. From the viewpoint of safety, the laboratory is working on a seismic resistance diagnosis tool for platform sheds and a seismic design tool for suspended ceilings in stations. The laboratory also proposed concepts

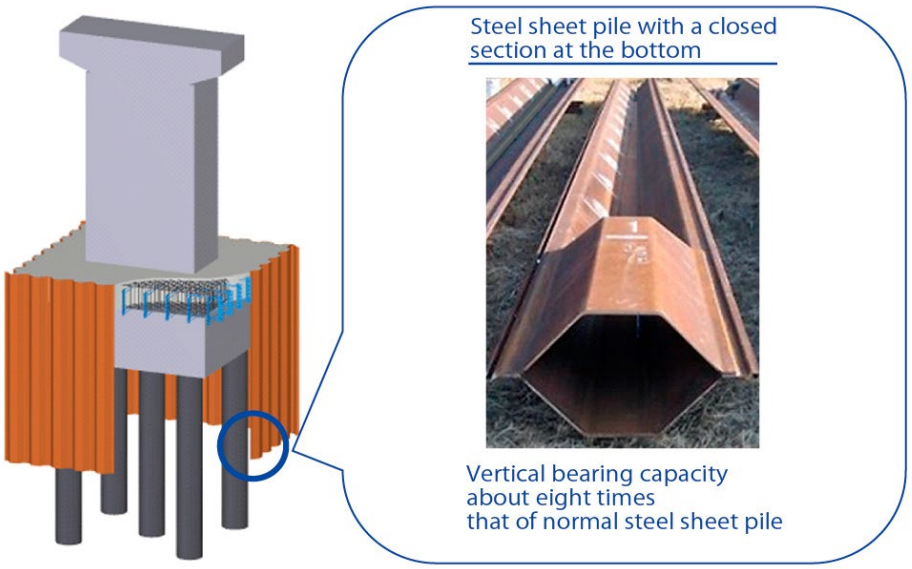


Fig. 4-3-2: Liquefaction countermeasure technical method for existing pile foundations using steel sheet piles with a closed section at the bottom

of load fluctuation caused by passing trains and passengers on falling protection facilities on conventional line platforms. On improvement in convenience and comfort, efforts were made to develop improved public address methods for large concourses and methods for measuring the relationship between passenger density and walking speed in stations.

4 Power Supply Technology Division

The Power Supply Technology Division consists of three laboratories, namely, the Power Supply, Current Collection Maintenance, and Contact Line Structure Labs. They are in charge of research and development, consulting, and contracted work intended to provide stable power to electric railways. In FY2015, under one of the three R&D Pillars, “R&D toward the future of railways,” the laboratories tackled two individual R&D programs in one of three major challenges involved in the pillar: “Save energy by making better use of energy networks” which aimed to achieve higher levels of energy saving through concerted efforts by the ground, vehicle and operation divisions, and “Efficient maintenance with ICT” which aimed to develop a maintenance system that offers more efficient and accurate inspection.

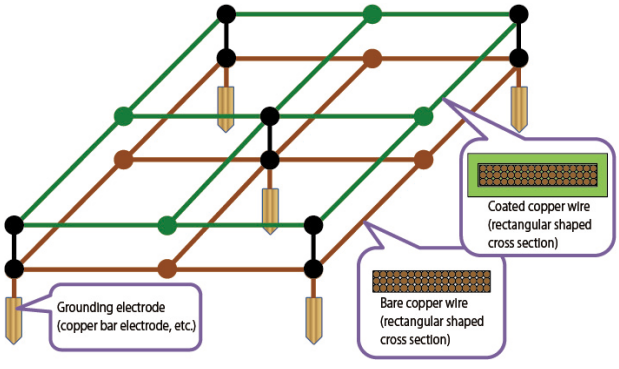


Fig. 4-4-1: Ground system for enhanced lightning resistance

■ Power Supply

The Power Supply Lab undertakes research and development to improve the energy efficiency of the railway power supply system, reduce equipment maintenance labor requirements, and enhance equipment protection. Under the “R&D toward the future of railways,” energy efficiency improvement efforts were launched to develop a high-tech rectifier capable of continuously controlling DC voltage using a variable reactor. On reducing equipment maintenance labor requirements, under the“R&D of technology for practical use,” research was conducted on the evaluation of the remaining life of oil-immersed transformers in which criteria suitable for train operation were proposed regarding methods for estimating the degree of degradation of insulating paper based on the analysis of insulating oil.

On enhanced equipment protection, a new earth system was proposed that excels in limiting the potential rise in a lightning strike while maintaining equipotential at substations. The proposal is based on a past theoretical review and verification through on-site testing of grounding methods for enhanced lightning resistance for substations (Figure 4-4-1).

On the theme of substation protection from inverter controlled vehicles, a proposal was made to eliminate unwanted trips of protection relays caused by transient current generated when pantographs re-make contact after contact loss. In addition, a further theoretical review

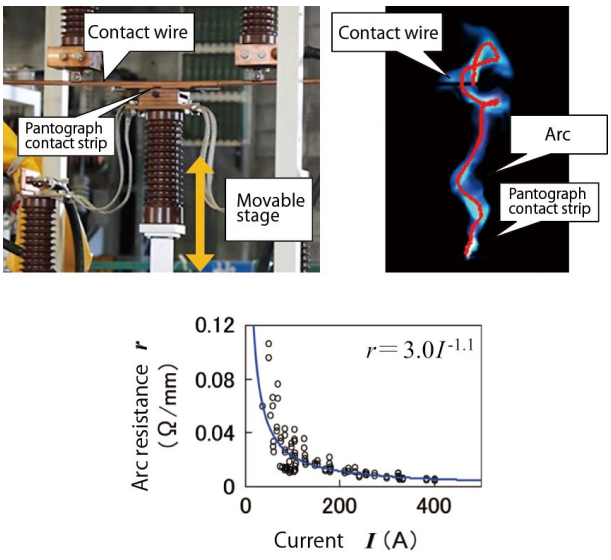


Fig. 4-4-2: Identifying the characteristics of arc in basic research test

was conducted on control methods for feeding voltage harmonics in conjunction with inverter controlled vehicles. Research and development was launched on the coordination of insulators in addressing ground faults in the boosting transformer feeding system and in simplifying related facilities.

■ Current Collection Maintenance

The Current Collection Maintenance Lab conducts research and development on preservative measures and overhead contact line materials for current collection systems comprising overhead contact lines and pantographs. Under the "R&D toward the future of railways," efforts were made to develop basic technology for image-based contact line inspection. Under the "R&D of technology for practical use," review was made on the fatigue resistance of steel wire strands of overhead contact lines while fouling categories for contact lines were re-defined. Under the "basic research for railways," a fatigue mechanism of the contact wire material was determined while a technique was developed to estimate arc-discharged damage to the pantograph that is caused when a frosted contact wire loses contact.

In the estimation of arc-discharged damage to the pantograph, basic research was conducted to identify the characteristics of the arc (the relationships between its length, voltage and current) to estimate its behavior (Figure 4-4-2). In addition, the behavior of the arc during wire contact loss was estimated by an electromagnetic field analysis. Furthermore, simulation of arc-discharged damage to the pantograph was conducted using a scale model of a pantograph head and sophisticated pantograph test equipment, the results of which indicated a possibility to compare the effects of damage prevention proposals.

■ Contact Line Structure

The Contact Line Structure Lab performs research and development to improve the current collection process to prepare for higher speed, reliability and seismic resistance. As part of "R&D of technology for practical use research to develop "replacement standards for concrete poles" was conducted. Typical degradation processes of concrete poles were identified through a survey of concrete poles for damage, bending strength and material analysis while a new process flow for maintenance was proposed that includes strength and material evaluations based on external harmful damage and alterations (Figure 4-4-3).

As a part of this effort, new items were developed to enable railway business operators to easily implement the maintenance process

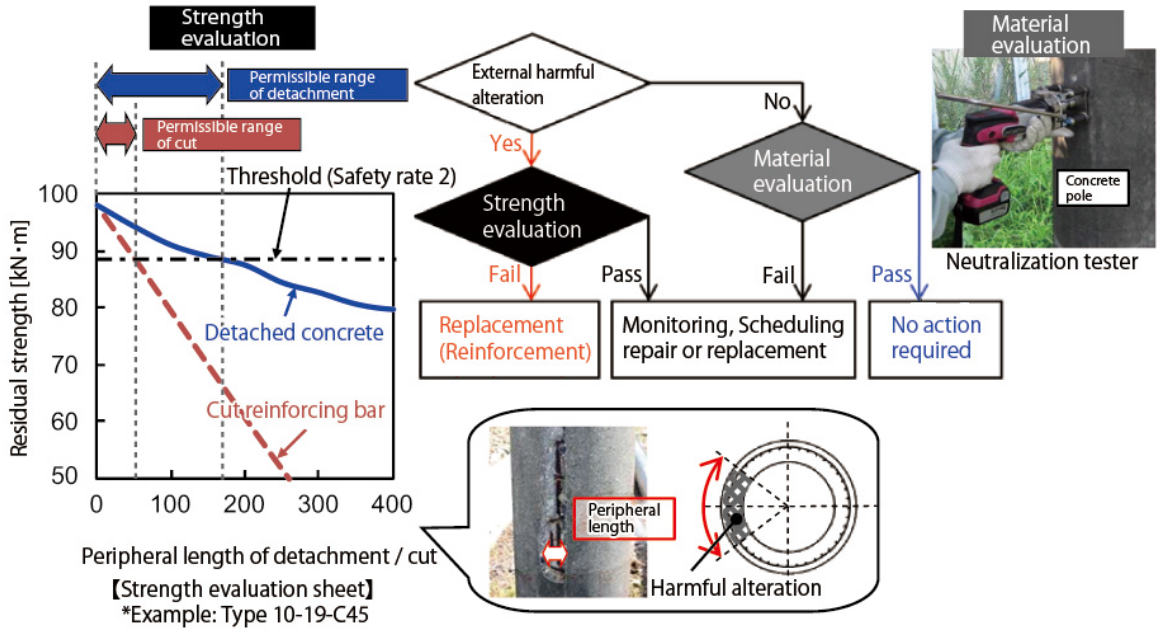


Fig. 4-4-3: Outline of the flow of concrete pole maintenance

flow including: a strength evaluation sheet which shows the relationship between the peripheral length of harmful alteration and the strength of concrete pole; and a neutralization tester capable of accurately measuring the neutralization depth of concrete material.

Under the project "methods for setting the wire tension and deviation of overhead contact line," the impact that various types of tensioners can have on current collection performance was clarified and appropriate use was suggested for all types of tensioners based on their characteristics.

In another project entitled "identification of temperature rise and wear mechanisms of a current collection component," the cause for stepped wear of carbon composite contact strips was clarified based on the graphitization degree of the strip material and preventive measures were proposed. In the research "evaluation of the behavior of overhead contact line during earthquake," a coupled analysis of the contact line and railway structure was conducted to evaluate the contact line's seismic performance. Guidelines were proposed for improvement of the contact line.

5 Track Technology Division

The Track Technology Division consists of four laboratories, namely, Track Structures and Components, Track Structures and Geotechnology, Track Geometry and Maintenance, and Rail Welding Labs. They are in charge of research and development on "safety improvement," "speeding up", "making maintenance more efficient and lower cost" and "reduction of noise and vibration" with respect to the track and its structure. In FY2015, the research and development centered on improved maintenance of rails, ballasted track and ballastless track.

■ Track Structures and Components

The Track Structures and Components Lab performs research and development of track components such as rails and rail fastening systems that form tracks, turnouts, expansion joints and continuous welded rail.

Corrosion protection methods were proposed for rails laid in corrosive environments such as in tunnels: to select highly effective corrosion protection measures;, to evaluate durability under repeated wheel loads; and to mitigate damage to the coating by rail fasteners (Figure 4-5-1).

To study "speed limitation measures based on track conditions with rail failure," the influence of track irregularities, curve radius and speed on running safety were evaluated by simulating a train running over a rail gap. Also, in the "development of a running simulator with consideration for turnouts," a running test was conducted using a motor car to evaluate the behavior of the car running over set-off equipment and the force acting on the track components.

■ Track Structures and Geotechnology

The Track Structures and Geotechnology Lab conducts research and development on directly fastened and ballasted track, roadbeds of new and existing lines, embankment materials and management, noise and vibration countermeasures, and the reuse of building and industry by-products.

A new, low cost structure with a thinner concrete

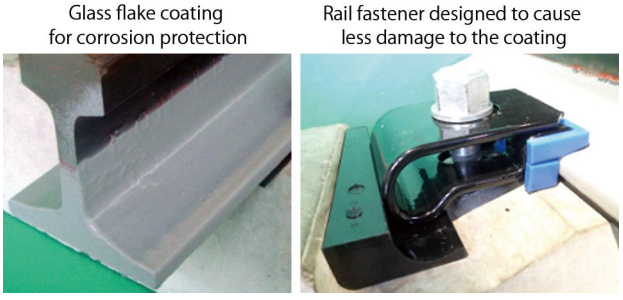


Fig. 4-5-1: Proposed corrosion protection methods for rails

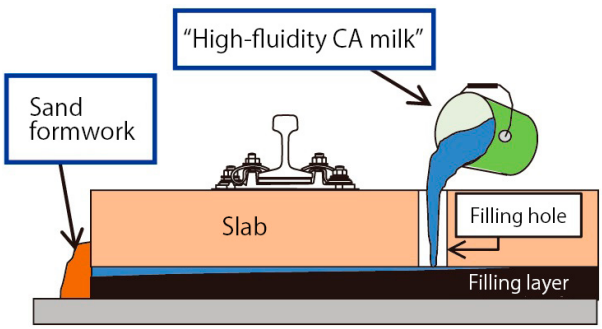


Fig. 4-5-2: Method for filling gaps in slab filling layers

bed was developed as part of the “development of low cost directly fastened tracks with resilient ties” initiative. The performance of the new structure was verified in a loading test.

In the “development of a method for evaluating the condition of slab filling layers based on onboard-measured data and related repair methods,” a method for filling gaps in slab filling layers using high-fluidity cement asphalt grout, so called “High-fluidity CA milk” in Japan, (Figure 4-5-2) was developed and its effectiveness was verified in an on-site test.

Ballast migration was reproduced in a loading test using an exciter with variable loading direction and a low cost prevention method using biodegradable polymer was developed. These efforts were part of the “development of rational ballasted track structure for steep cant curves.”

A device capable of swiftly measuring the stiffness of track while running on track was developed in a project subsidized by the Ministry of Land, Infrastructure, Transport and Tourism in its railway technology development scheme. An evaluation was made of changes in the rigidity of track bearing beds under repeated loading using a full scale model.

■ Track Geometry and Maintenance

The Track Geometry and Maintenance Lab conducts research and development on track maintenance methods, systems and machines to improve both train running safety and ride comfort.

In a project subsidized by the Ministry of Land, Infrastructure, Transport and Tourism in its railway technology development scheme, a track structure improvement planning system for local railways was developed for tracks with wood sleepers by considering safety parameters which are evaluated for each curve type. These parameters include gauge-widening derailment, spike failure and lateral shift of the track panel. Based on the results, conversion to pre-stressed concrete sleepers can be prioritized and a conversion plan prepared (Figure 4-5-3).

To help understand the mechanism of rail corrugations, a vehicle running simulation model was developed based on a track excitation model capable of reproducing varying degrees of rigidity of track bearing beds with directly fastened sleepers and the dynamic behavior of a multi-body vehicle. Simulation model results confirmed that the use of low elastic track pads and the smoothing of inner rail corrugation are effective in preventing the generation of outer rail corrugations.

■ Rail Welding

The Rail Welding Lab conducts research and development on rail welding technologies, rail head repair welding technologies, and non-destructive inspection technologies for rail and rail welds.

Thermite weld internal defect generation mechanisms were identified by understanding

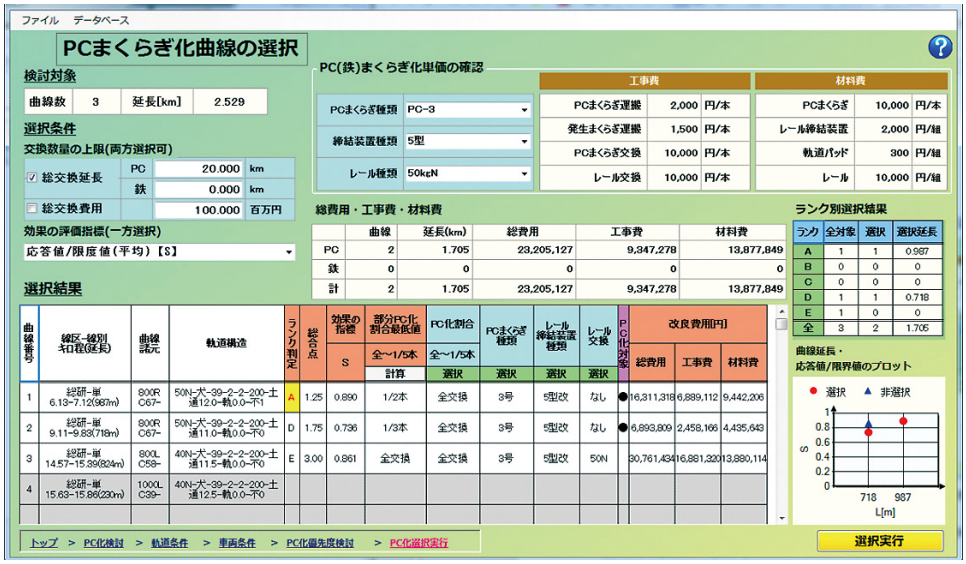


Fig. 4-5-3: Planning support system for conversion to pre-stressed concrete sleeper

how the thermite weld solidifies in a temperature measuring test and in a numerical analysis using a solidification analysis model. Further research examined the wider application of thermite welding as a rail head repair method by proposing the conditions for using the repair method for head hardened rails. Test pieces were produced, subjected to various solvent and forced air cooling and then examined for hardness and structure to determine their potential as a possible repair technique.

6 Disaster Prevention Technology Division

The Disaster Prevention Technology Division consists of three laboratories, namely, the Meteorological Disaster Prevention, Geo-hazard and Risk Mitigation, and Geology Labs, which are responsible for research and development, consulting work, and contract work concerning mitigation of natural disasters caused by rain, wind, and snow, surveying and evaluation technologies for ground vibrations caused by the running of trains.

In FY2015, efforts were made to advance the "realization of practical applications for a meteorological disaster hazard mapping system" to produce practical applications of the fruits of the laboratory's activities gained thus far under the "Research and development for the future of railways." Also, two new projects were initiated under the "sophistication of railway disaster prevention and mitigation technologies," namely the mitigation measures for disasters caused by local meteorological phenomena such as wind gusts and mitigation technologies for disasters caused by heavy rainfall of short duration.

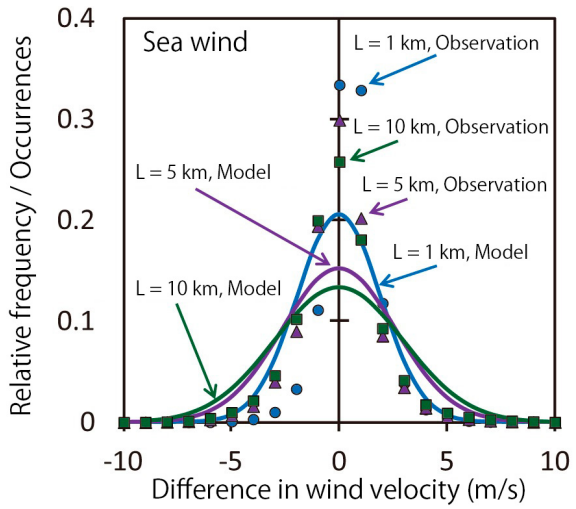


Fig. 4-6-1: Example of 2-location, wind-velocity-difference model

■ Meteorological Disaster Prevention

The Meteorological Disaster Prevention Lab conducts research and development activities on methods for determining weather conditions to take meteorological disaster countermeasures, and on methods for disaster risk evaluation.

The laboratory continued to advance the correlation analysis of precipitation intensity obtained by weather radar and by ground observation measurements, and the sophistication of snowfall intensity estimation techniques. In addition, an evaluation was made of the space-time representation of wind velocity and wind direction obtained by an anemometer on flat ground (category I – II surface roughness). Then a model was developed to estimate the wind direction and velocity at locations up to 10 km away based on the wind direction and velocity at one point (Figure 4-6-1).

On the mitigation of wind gust disasters, an evaluation was made on the possibility of detecting gusts using data obtained by anemometers and by analyzing wind data at locations near to previous gusts. A project was also launched to develop a gust detection method using weather radar data. Also, as part of the research on disaster risk evaluation, a basic experiment was conducted to develop methods of evaluating damage by flying objects caused by tornadoes.

Based only on Japan Meteorological Agency's AMeDAS data two models were developed as part of the research to help mitigate slope disasters caused by avalanches or snowmelt water in the snowmelt seasons: a snow properties model which estimates snow depth and snow density; and a snow melt model which estimates outflow from the bottom of the snowpack on slopes.

■ Geo-hazard and Risk Mitigation

The Geo-hazard and Risk Mitigation Lab conducts research and development for preventing or mitigating slope disasters and river disasters. To assist slope management during the snowmelt period, we developed a method that can evaluate slope stability based on calculations of a parameter (effective snowmelt) that takes into account the impact of snowmelt and rainfall (Figure 4-6-2).

To help restore cracked embankments caused by an earthquake, we presented analytical results to demonstrate that the rainfall durability of a cracked embankment could be restored to its previous level by backfilling the cracks. We developed an injection method as a countermeasure for the roadbed caving problem on the back side of abutments, and developed the relationship between the viscosity of grout and the void-filled area in the case of injecting grout into an embankment based on gravel.

In research to reinforce masonry walls with harmful deformations, a model experiment was conducted to obtain essential coefficients for developing a reinforcement method. And, in an attempt to determine the destabilization mechanism of bridges by scouring in swollen rivers, a hydraulic model experiment was conducted to understand changes of water pressure and other parameters in the ground with ongoing scouring.

■ Geology

The Geology Lab conducts research and development on large-scale slope disaster evaluation methods, evaluation of geological factors concerning deformation of tunnels, prediction of the quality of water leached from waste/surplus soil, basic studies on the impact of volcanic disasters on railways, and ground vibration phenomena clarification and prediction methods.

On large-scale slope disaster evaluation methods, the topographic and geological characteristics of collapsed slopes were studied based on the findings of site inspection, aerial survey data, etc, and rainfall records were analyzed for any relationship with disasters (conducted as part of the Cabinet Office's Strategic Innovation Promotion Program). Geological factors for tunnel deformation were studied in a rock laboratory test and by numerical analysis to develop a proposed inspection plan for deformation due to plastic pressure.

In the project to predict the quality of water leached from waste/surplus soil, the validity of a model developed in the previous fiscal year was verified in experiments and calculations. On the topic of the impact of volcanic disasters on railways, the following were clarified: situations anticipated for railways following volcanic eruptions; and related subjects that must be studied further.

To compare results of different modeling methods for analyzing the ground vibration problem on structures near railway lines, different analytical models were tried on the same rigid-frame viaduct. Numerical analysis found that the frequency characteristics of the response acceleration are different between dynamic components and static components of axle load.

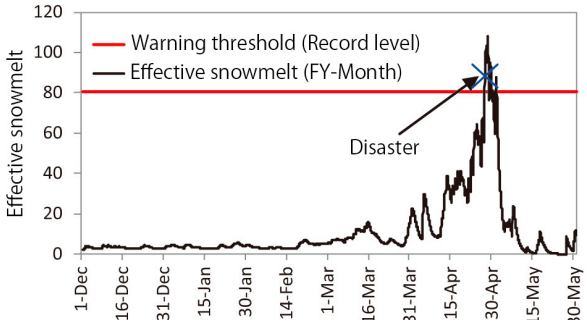


Fig. 4-6-2: Application example of slope stability evaluation method

7 Signalling and Transport Information Technology Division

The Signalling and Transport Information Technology Division consists of five laboratories, namely, Signalling Systems, Train Control Systems, Telecommunications and Networking, Transport Operation Systems, and Transport Planning and Marketing Labs. They perform research and development, consulting and contract work related to developing and improving signalling and communication systems, clarifying phenomena, evaluating technologies, increasing the efficiency of train and traffic operation and enhancing the convenience of passengers. The experts from this Division also participate actively in international standard development and activities of academic societies.

■ Signalling Systems

The Signalling Systems Lab works to develop and improve signalling systems, clarify causes of malfunctions, apply image processing technologies, and evaluate the service life of signalling equipment. With the aim of saving labor required for visual inspection of obstruction warning signals, an inspection system consisting of an obstruction warning signal fitted with near infrared LEDs that emit invisible light and an onboard camera was developed (Figure 4-7-1). It was found in a long-term, on-site test that the system's inspection accuracy is unchanged regardless of the season or time.

A reference model for train protection systems was developed to provide a means of ensuring security for railway signaling software. The project was conducted as part of the effort to develop formal methods that describe specifications based on mathematics and logic. To enhance the safety of level crossings, a prototype system for controlling level crossings primarily via onboard equipment was developed and the system's following functions were tested: issuing commands via onboard equipment to close a level crossing; and controlling speed by a protective speed profile for a level crossing after detection of an obstacle.

■ Train Control Systems

By using information communication technology, the Train Control Systems Lab worked on future train operation systems that offer flexible and safe train services, evaluated safety and reliability of signaling systems, and provided design support for signaling systems. On future train operation systems, basic specifications for a system that controls individual trains and their routes were developed. The system integrates train operation and protection controls and performs real-time recalculation of station arrival and departure times and train performance curves. A system combining an inertial sensor and a tachometer generator was proposed to calculate train lengths for radio based train control systems.

A prototype system that controls train routes primarily via onboard equipment while not relying on the conventional interlocking device was developed for local railways (subsidized by the Ministry of Land, Infrastructure, Transport and Tourism in its railway technology development

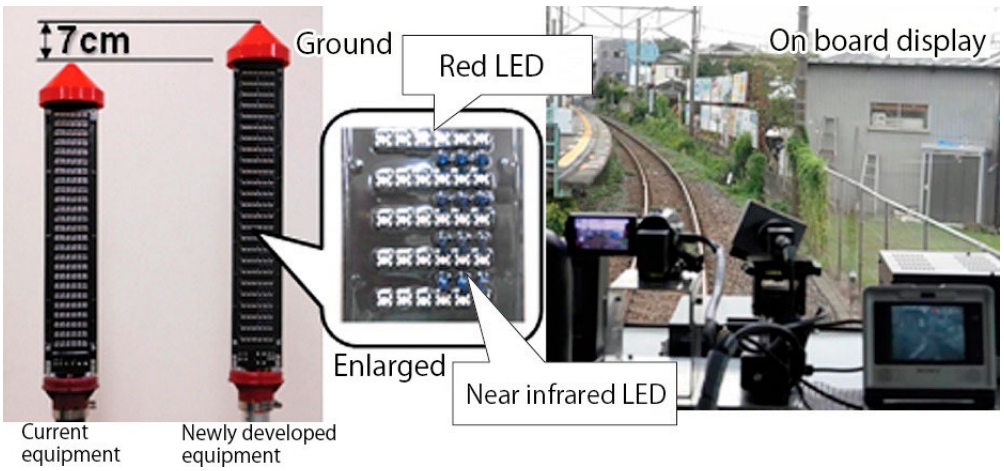


Fig. 4-7-1: Obstruction warning signal inspection system

scheme). A running test conducted on the RTRI's test track verified that the system is capable of controlling trains safely even in non-normal situations.

■ Telecommunications and Networking

The Telecommunications and Networking Lab works on telecommunication technologies such as wireless and wired communication and sensor networks, researches mathematical analysis and prediction methods on structure monitoring data to support maintenance work, and develops prediction and evaluation methods for electromagnetic environments on electric railways.

On telecommunication technologies, an experiment was conducted to examine the possibility of adopting the 920 MHz Wi-SUN network technology for facilities monitoring. Its practical performance was verified in the experiment in accordance with the theme offered by the National Institute of Information and Communications Technology for open participation (Figure 4-7-2). Also, software that predicts train radio call quality by simulation and supports radio link design was developed.

A method for analyzing the relationship between monitoring data sent from multiple sensors and predicting changes in facilities status was developed. In work on the electromagnetic environment, a system that simulates voltage and current applied to communication facilities in a lightning surge was developed, and a method was proposed for quantitatively evaluating the effect of protection measures such as changing grounding methods and installing a surge protective device.

■ Transport Operation Systems

The Transport Operation System Lab develops methods to improve the efficiency and convenience of transport planning and traffic control. A train performance calculation function for energy consumption evaluation was included in the system for predicting energy consumption from train operations. It was confirmed that the calculated power supply generally agrees with measured data. (The study was subsidized by the Ministry of Land, Infrastructure, Transport and Tourism in its railway technology development scheme.) In developing train operation simulators to accommodate the sophistication of train control, calculations were made possible to accommodate moving block and prediction-based control. On railway traffic operation arrangement with delays caused by speed control, a cancellation method proposed by the laboratory proved to be effective in restoring train operation to normal within a short period of time. Additionally, the interface for the train performance calculation system SPEEDY was upgraded.

■ Transport Planning and Marketing

The Transport Planning and Marketing Lab conducts research and development programs related to the analysis of passengers' decision-making

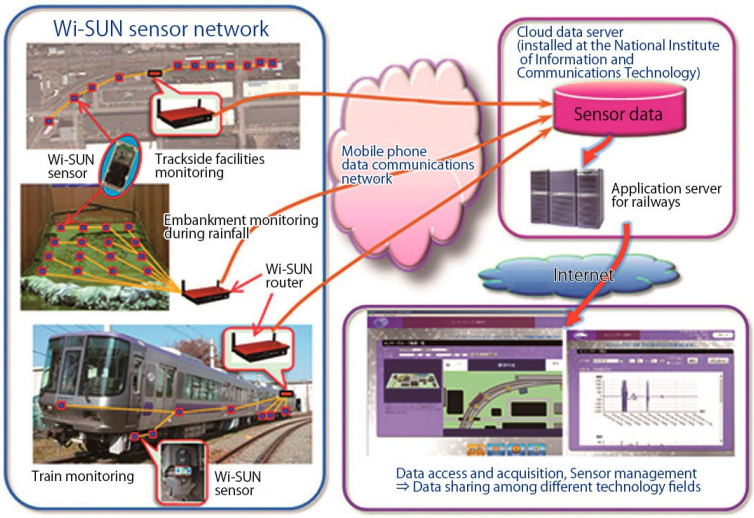


Fig. 4-7-2: Verification test of wireless sensor network

structures such as transport mode choice behavior and route choice behavior, and quantitative evaluations of services in stations. In the project "methods for predicting passenger traffic taking into consideration appealing features of and around the station," a method was developed that quantitatively evaluates the change in a station's appeal due to renewals around the station as well as the development of commercial operations and facilities improvement at the station. A method to predict passenger traffic was also developed.

In the project "methods for flexibly arranging reserved and non-reserved seats in higher class trains," two models were developed: one for estimating potential demand not shown in demand data; and another for estimating passengers' best choice in congestion or other unexpected situations. In further developments, two other items were developed: a passenger traffic simulator; and a seat type planning and allocation system.

In the project "methods for measuring windfall benefits of railway investment," a quantitative evaluation was made using the stated choice method on windfall benefits of an investment in maintaining or improving limited express services for those who live near a station in a local city but typically do not use limited express trains. This is a concept that has not been considered in the past in railway investment processes.

8 Materials Technology Division

The Materials Technology Division consists of five laboratories, namely, Concrete Materials, Vibration-isolating Materials, Lubricating Materials, Frictional Materials, and Applied Superconductivity Labs. They are responsible for research and development, consulting work and contract-based work concerning railway materials, and also for searching, introducing, researching and evaluating the environmental impacts of various new materials. With the aim of adopting flame-retardant magnesium alloy for body structures, structural analyses were conducted to propose members with optimally shaped cross sections while a basic study was conducted on laser welding.

■ Concrete Materials

The Concrete Materials Lab works on methods for evaluating technologies related to the maintenance and building of concrete structures and the development of new materials. The results of the Lab's research included determining the relationship between the composition and basic properties of low-environmental-load geopolymer concrete. Research on the deterioration of concrete resulted in determining the mechanism of sulphate expansion and showed that expansion can be triggered even with small amounts of sulfate, Other studies on the mechanism of concrete structure degradation caused by chemical reactions demonstrated that the quality of surface layers is strongly affected by curing conditions and that moisture penetration causes reinforcing bars to corrode about 10 times faster in the neutralization zone. Additionally, Spray Test Method A was developed as a simple non-destructive inspection method to determine surface quality by visual observation of water absorption.

■ Vibration-isolating Materials

The Vibration-isolating Materials Lab conducts research and development of new materials related to rubber and resin/plastic used in railways and investigates evaluation methods for their performance and durability. One research project on materials for vehicles concerned the plastic window glass used for vehicle weight reduction purposes, whereby a method was developed to evaluate the yellow discoloration of polycarbonate using a quick and non-destructive way to measure the color change. In an attempt to adopt piezoelectric rubber, known for its flexibility and moldability, for sensors of foreign matter on sliding doors, a material durability test was conducted and the results showed the rubber has the required durability. Also, as part of data gathering for the development of a life cycle cost (LCC) method to evaluate repainting of steel structures in a corrosive environment, the criteria for rusting was refined while the knowledge about the nature of rusting was developed further.

Table 4-8-1: Revised criteria values for control (Only the revised items are shown.)

Control item	Criteria values	
	Traction motor bearing	Axle bearing
Oil depletion rate (formerly oil separation rate)	15.0% or less (Alert level: 6%)	
Dropping point	Lithium complex soap: 215 ºC or higher (Alert level: 240 ºC)	
	Other than the above: +/−20 ºC (variation range)	
Iron content	0.5% or less	1.0% or less Handling of fretting wear is specified separately.

■ Lubricating Materials

The Lubricating Materials Lab conducts research and development of bearings and other machine components that play a part in the running of vehicles and of lubricant oils and greases that maintain their operation. As a result of research into the degradation of grease for vehicles, especially for axle and traction motor bearings, the criteria values for control established by JNR and existing guidelines on evaluating degradation, were revised. These revisions (see Table 4-8-1) are based on the current knowledge of grease degradation mechanism and the results of degradation analysis of grease used in actual vehicles. To investigate fretting wear between the axle bearing inner ring and the backing ring, a bench test was conducted where contact pressure between the components was measured. This work resulted in a hard film coating being suggested as a probable resolution for the wear. With the aim of further understanding the seizure of gear unit bearings, a test machine capable of running pinion bearings under varying load and at varying speed was developed.

■ Frictional Materials

TThe Frictional Materials Lab conducts research and development to improve the functionality and performance of railway components involved in tribology phenomena, including friction, wear and rolling contact fatigue, and clarifies the mechanism of damage caused by these phenomena Rail research activities included investigating the use of a portable X-ray stress measuring device for the proper control of rail axial force. It was found that the measurement accuracy of this device can be improved by mechanically polishing a target area for the measurement. In a research project to reduce the wear of a wheel flange, resulted in solid lubricants were prototyped and their wear performances were evaluated in wear tests. Basic tests of the wheel and rail interface were conducted to monitor the behavior of the tangential force coefficient under test conditions with longitudinal and lateral tangential forces applied. Research of carbon composite contact strips included evaluating the bolt fastening axial force as a function of the thickness of the contact strip to determine wear limits.

■ Applied Superconductivity

The Applied Superconductivity Lab works on the application of high-temperature superconducting material to railways, carrying out development projects including superconducting feeder cables and superconducting magnets. Superconducting feeder cable fabricated by the laboratory was laid at a substation on Izuhakone Railway's Sunzu Line and power was transmitted via the cables to trains. This was the first trial of its kind conducted

Fig. 4-8-1: Train running test using superconducting feeder cable

on a commercial line in the world (Figure 4-8-1). In research to develop high-temperature superconducting materials, small superconducting magnets were fabricated using rare-earth bulk material and attempts were made to make the magnetic field homogeneous using shim coils that were fabricated. To investigate possible applications of the new MgB2 material, a bulk version of the material was made to evaluate the current conduction characteristics of a wire version in a magnetic field. In addition, efforts were made to develop elements for a superconducting quantum interference device to detect weak magnetic fields.

This work was supported by the Ministry of Land, Infrastructure, Transport and Tourism of the Government of Japan, and the Japan Science and Technology Agency (JST), Strategic Promotion of Innovative Research and Development, Advanced Low Carbon Reduction Technology, Grant-in-Aid for Scientific Research (A) from the Japan Society for the Promotion of Science (JSPS) under grant No. 16H01860.

9 Railway Dynamics Division

The Railway Dynamics Division consists of five laboratories, i.e., Vehicle Mechanics, Current Collection, Track Dynamics, Structural Mechanics, and Computational Mechanics Labs. These laboratories are in charge of research and development to understand the phenomena associated with dynamic behavior occurring in railway systems and various deterioration consequences of these phenomena, and to propose appropriate, specific resolutions. In FY2015, the laboratory worked on the development of a method for detecting stepped wear of contact strips of a pantograph and a method for analyzing contact behavior between car bodies and ground facilities during earthquakes. These and other projects are described below.

■ Vehicle Mechanics

The Vehicle Mechanics Lab conducts research and development related to the safe running of vehicles. To reduce the risk of derailment, the development of a new type of bogie with a mechanism for controlling wheel load reduction was continued. A running performance test of the prototype bogies was planned at the Mihara Test Center of Mitsubishi Heavy Industries in 2016. Hence, a coupler was developed for the test in which the narrow gauge test vehicle will be pulled by a standard gauge towing vehicle on a 3-rail track.

In order to better understand the dynamic behavior of a vehicle when its wheels are in contact with the guard angle, a test vehicle running test was conducted on RTRI's test track. In addition, a new research project to develop a wheel lift measuring method and a next-generation wheel-rail contact force measurement system was initiated to establish new running safety evaluation procedures. On the development of vehicle parts resistant to derailment during earthquakes, a compact crushable lateral displacement stopper was developed as a practical proposal.

■ Current Collection

The Current Collection Lab conducts studies on prediction methods of dynamic behavior of the pantograph/catenary system, condition monitoring methods for the catenary, and development of high-speed pantographs. To better predict dynamic behavior of the pantograph/catenary system, the three-dimensional dynamic pantograph/catenary simulator was improved to enable calculation of static geometry of catenaries in curves. On condition monitoring of the catenary, a

method that detects step-shaped wear of contact strips of a pantograph based on measurements of strain in the pull-off arms and a power saving digital telemeter suitable for this system were developed (Figure 4-9-1).

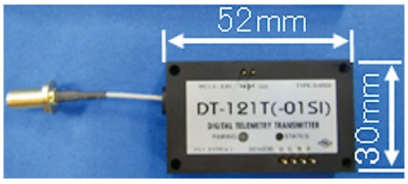
For the development of high-speed pantographs, a newly developed pantograph HILS test confirmed that active control can halve low-frequency contact force fluctuation. It was found that aerodynamic noise can be reduced by an appropriate arrangement of the pantograph head and the articulated frame which affects aerodynamic interference between them.

■ Track Dynamics

The Track Dynamics Lab conducts research and development activities on ballasted track deterioration, rail damage, wheel/rail adhesion and lubrication. As part of research on ballasted track deterioration, a repeated loading test using a life-size ballasted track model and numerical analysis simulating the loading test revealed that impact load can be reduced substantially by adopting improved resilient sleepers. Motor car running tests and simulations using a discrete model were conducted to evaluate whether the impact load generated at rail joints has any effect in causing ballast settlement. Also, efforts were made to improve the estimation accuracy of the measurement of axial force of the rail.

In researching damage to rails, on-site investigations and laboratory tests were conducted on the white layer. Specifically, the relationship between the thickness of the white layer and the hardness of rail top surface as well as micro-cracking originating from the white layer were investigated. On wheel/rail adhesion and lubrication, a vehicle running test was conducted to clarify the effect that substances between the wheel and rail can have on wheel/rail adhesion behavior.

(a) Pull-off arm for monitoring



(b) Power saving digital telemeter

Fig. 4-9-1: Contact strip stepped wear detection sensor and its dedicated telemeter.

■ Structural Mechanics

The Structural Mechanics Lab builds advanced simulation and analysis technologies, and measurement technologies. It uses these technologies to conduct research to improve running safety and to advance the design and maintenance strategies for railway structures.

In simulating vehicle running performance during earthquakes, an algorithm capable of efficiently calculating the contact force between a running train and ground facilities was proposed while an analytical tool capable of quantitatively evaluating the behavior of vehicles before and after derailment was developed (Figure 4-9-2).

For remote non-contact evaluation of railway bridges, a method was proposed to efficiently estimate the natural frequencies of cable stayed bridge cables and continuous rigid-frame viaducts using a long-distance U-Doppler system. Also an unmanned aerial vehicle (UAV) for structural inspection was developed to run under the structure surface by caterpillar tread and inspect areas with damage or harmful alteration. On evaluation of the remaining life of prestressed concrete sleepers, a remaining life evaluation method was proposed based on examination results of 165 aged prestressed concrete sleepers.

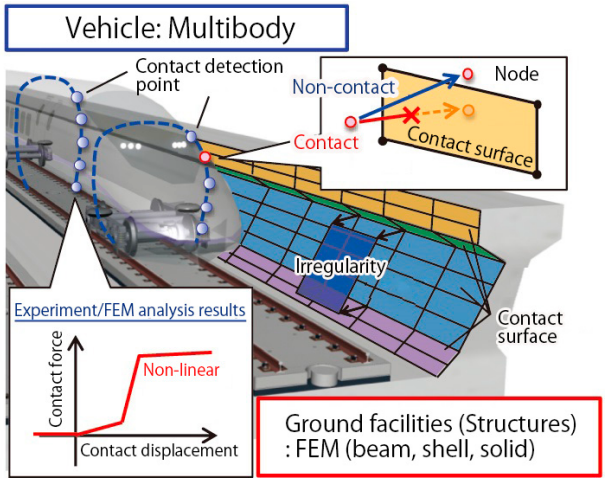


Fig. 4-9-2: Analysis of contact between vehicle and ground facilities

■ Computational Mechanics

The Computational Mechanics Lab has constructed a wheel-rail rolling contact analysis method based on finite element method to clarify the long-term deterioration phenomena of wheels and rails. A bogie model capable of simulating the wheelset's lateral movement and yawing was developed to enable more realistic analysis.

On the development of an air flow simulator, a RANS/LES hybrid analysis method (DES) of turbulence calculation based on the Reynolds averaged model (RANS) and turbulence calculation by spatial averaging (LES) was introduced with the aim of efficiently conducting analysis of the turbulence in a flow field around the train set

A common platform was built to allow any railway simulators to work independently. Also, on the optimization of carbody structures, a press molded structure for the side body structure was optimized by using the results of stress analysis of a whole single-vehicle structure model.

10 Environmental Engineering Division

The Environmental Engineering Division consists of three laboratories, namely, the Vehicle Aerodynamics, Heat and Air Flow Analysis, and Noise Analysis Labs. They are responsible for research and development, consulting, and contract work concerning wayside environments and aerodynamic phenomena. In FY2015, the Division worked on subjects related to environmental impact and safety of railways including "reduction in wayside environmental impact caused by faster Shinkansen," which is a part of one of the 4 major challenges,Research and development for the future of railways.

■ Vehicle Aerodynamics

The Vehicle Aerodynamics Lab works on problems related to the aerodynamic characteristics of railway vehicles. A number of projects were conducted on vehicle aerodynamic characteristics in cross winds: clarification of the aerodynamic force coefficient for trains on coastal half-bank and half-cut structures; evaluation of the reduction in aerodynamic force by windbreak fences; and evaluation of the effect of a running vehicle using a commuter type vehicle model. Numerical simulations were conducted to reproduce a cross wind tunnel test (Figure 4-10-1).

To examine the aerodynamic forces acting on a vehicle due to a turbulence field, a wind tunnel test was conducted to measure lateral flow velocity under the vehicle floor as well as air resistance caused by an irregular underfloor profile.

The Lab has air flow simulators capable of handling real train set configurations and this capability was improved by: a program updated to accommodate GPU (Graphics Processing Unit); the introduction of a Reynolds averaged turbulence model; and the introduction of DES (Detached Eddy Simulation), a hybrid of Reynolds averaged turbulence model and LES (Large Eddy Simulation) turbulence model. It was found that these methods produce reliable calculations.

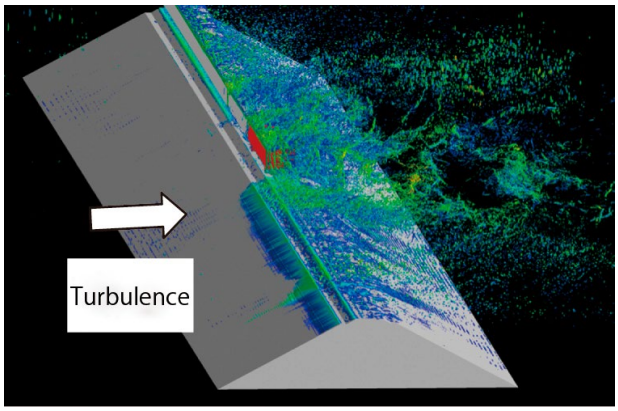


Fig. 4-10-1: Numerical simulation of turbulence around a vehicle on an embankment (Visualization of vortex structure)

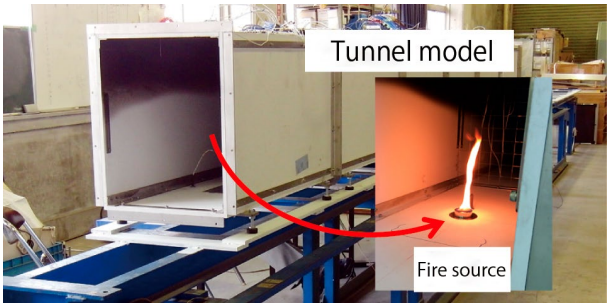


Fig. 4-10-2: Tunnel fire experiment device

■ Heat and Air Flow Analysis

The Heat and Air Flow Analysis Lab works on aerodynamic phenomena related to railways including: pressure waves and pressure variation caused by trains traveling through tunnels; the thermal environment inside tunnels; and hot-gas flow in a tunnel fire.

In a project involving micro-pressure waves, the Lab conducted quantitative evaluations of proposed measures to accommodate further increases in Shinkansen speed. The proposed measures are concerned with compression wave propagation and micro-pressure wave radiation.

On the thermal environment inside tunnels, a numerical simulation model of heat transfer to the tunnel wall was improved for higher accuracy based on results of theoretical analyses and model experiments. Comparison with results of a long-term on-site test found that quantitative analysis of the cooling capacity of underground stations is important in predicting the tunnel temperature of underground railways. For the prediction of the flow of hot gases in a tunnel fire, a model experiment was conducted whereby the temperature, propagation speed and temperature distribution of the flow of hot gases were examined (Figure 4-10-2). The test was conducted to verify the results of numerical calculations based on a general-purpose CFD code.

■ Noise Analysis

The Noise Analysis Lab works to clarify and predict railway wayside noise and to develop countermeasures. To examine wheel/rail noise and other structure borne noise, the impact noise due to rail joints and high frequency noise above 10 kHz in curve sections were examined. Also, the relationship between the geometries of the localized wear of wheel treads and the resulting bridge noise was investigated. The effect of tread wear on wayside noise was estimated and a method to estimate the depth of the localized tread wear based on the vibration of a viaduct was developed (Figure 4-10-3).

In order to understand suitable rail grinding intervals, rail roughness, rail vibration and wayside noise were measured for long term evaluation after rail grinding. Based on the measurements by track inspection cars, it was found that rail grinding intervals could be extended.

On aerodynamic noise, a wind tunnel test was carried out in order to investigate the contributions of specific components of the bogie to total aerodynamic noise generated around a bogie. It was found that, apart from wheels and axles, traction motors, brake units and other components within the bogie have moderate contributions to the total noise. In the work on low frequency noise in open sections, scale model experiments using a train model launcher and full-scale field tests were carried out. Through the field tests, it was found that aerodynamic noise in the range of 20 - 50 Hz has a greater contribution than other ranges above 5 Hz. For research related to noise propagation, in order to investigate the acoustic behaviors at a cut section along a Shinkansen line, scale model experiments were made and the reflection and diffraction of sound on the slope in the section were examined. Then, based on the results obtained in the experiment, a noise prediction model was developed.

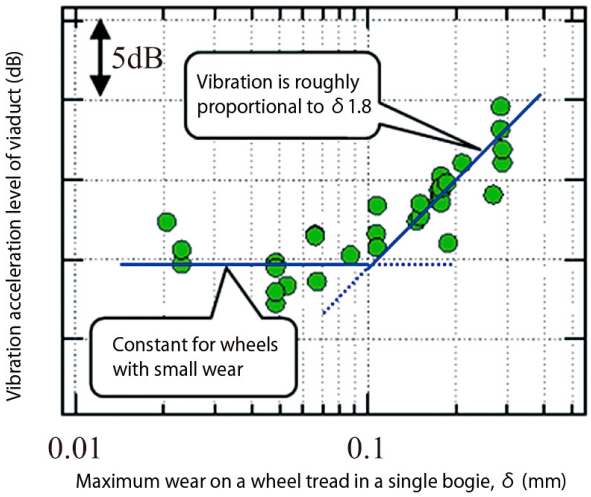


Fig. 4-10-3: Relationship between the vibration of a viaduct and localized wear of a wheel

11 Human Science Division

The Human Science Division consists of four laboratories, namely, Safety Psychology, Ergonomics, Safety Analysis, and Biotechnology Labs, which are responsible for research and development on human factors to contribute to the improvement of the safety and comfort of railways. In FY2015, the Division carried out research on the prevention of human error, education and training, train operator support, skills for coping with accidents and malfunctions, in-car comfort, and support for safety management, and convenience of railway station. It also provided technical guidance for train operation aptitude tests and supported safety activities of railway companies.

■ Safety Psychology

The Safety Psychology Lab develops training methods to prevent human error. It also provides technical guidance for train operation aptitude tests.

On the prevention of human errors, tasks designed to measure decision-making skills were drafted to help develop education methods for improving these skills. And, to develop education methods for preventing errors in communication, a survey and experiment were conducted on the occurrence of errors. In a project to develop education and other methods for preventing level crossing accidents involving elderly automobile drivers, a survey and experiment were conducted to understand the participants' knowledge about correct ways to cope with emergencies and other issues at a level crossing.

The Lab provided technical guidance for train operation aptitude tests by providing lectures to 353 individuals from private railroad operators and district transport bureaus of the Ministry of Land, Infrastructure, Transport and Tourism.

■ Ergonomics

The Ergonomics Lab conducts research and development on driver monitoring methods, vehicle safety enhancement in accidents, improved information provision to passengers and improvement in in-car comfort.

On driver monitoring methods, a driving simulation experiment was conducted to measure brain and other physiological activities. In researching vehicle safety enhancement in accidents, the conditions for passengers in longitudinal seats to sustain severe injuries in accidents were identified

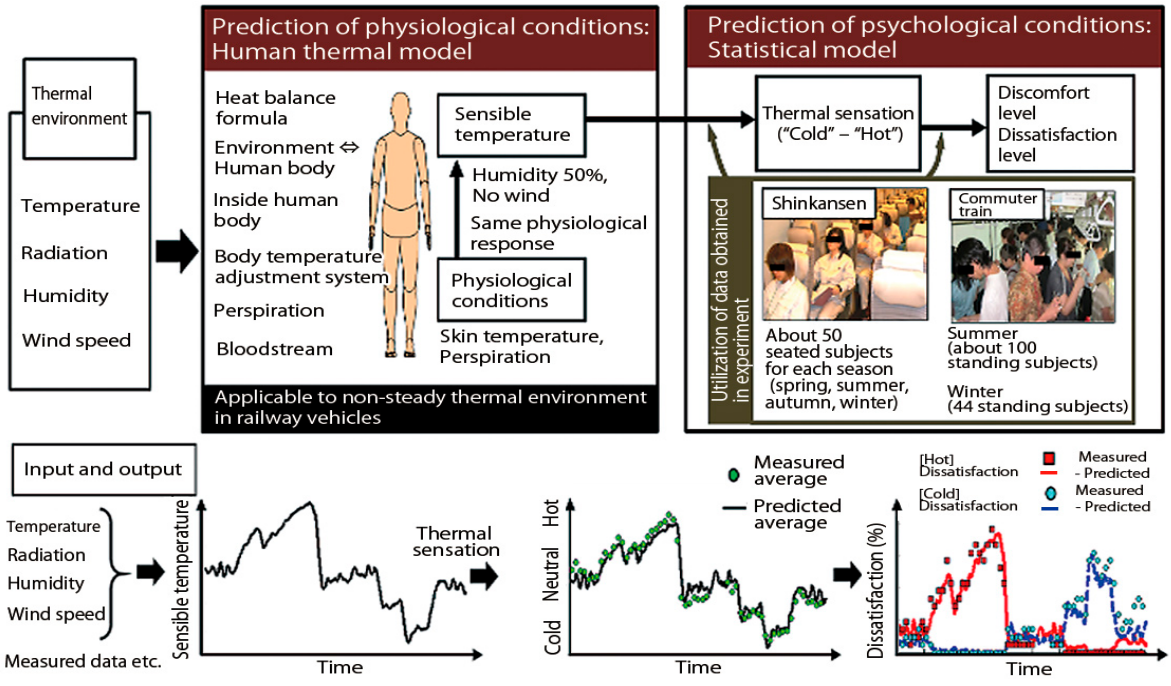


Fig. 4-11-1: Entire scope of in-car thermal comfort prediction model

based on the results of a sled impact test and simulation analysis.

In work to provide information to passengers, education programs were proposed that are designed to improve skills to be more flexible in providing instructions to passengers when train services are disrupted. Also, in order to improve the visibility of blocks for Tactile Walking Surface Indicators (TWSI) that guide visually impaired persons, the requirements for a continuous adjoining band that is laid on both sides of the TWSIs were clarified.

To improve in-car comfort, a thermal comfort prediction model applicable to the non-steady thermal environment of railway vehicles was proposed based on the results of thermal sensation experiments (Figure 4-11-1). In an effort to monitor unpleasant vibration of running trains, tracks that had undergone maintenance were identified as having improved ride quality levels and the Unified data-relevant-ride-comfort indication system was upgraded.

■ Safety Analysis

The Safety Analysis Lab helps railway companies evaluate railway risk and improve safety.

As a tool to efficiently use the RTRI Human Factor Analysis Method designed to analyze underlying factors for human errors, new procedures were proposed for facilitating improvement in operation and organization based on reports of potential incidents and other risk-related information and logical analysis of human factors (Figure 4-11-2). To help railway business operators implement safety enhancement activities, technical guidance was provided on the RTRI Human Factor Analysis Method and the Hearing Investigation techniques. Also research projects have been conducted on the Safety Climate in the Work Site.

■ Biotechnology

The Biotechnology Lab works on the evaluation of short-term health impacts of magnetic fields to help ensure the safety of magnetic fields emitted from railway systems, mold prevention measures and utilization of fragrance to improve comfort, and measures to reduce problems with wild animals to ensure safe operation and suppress

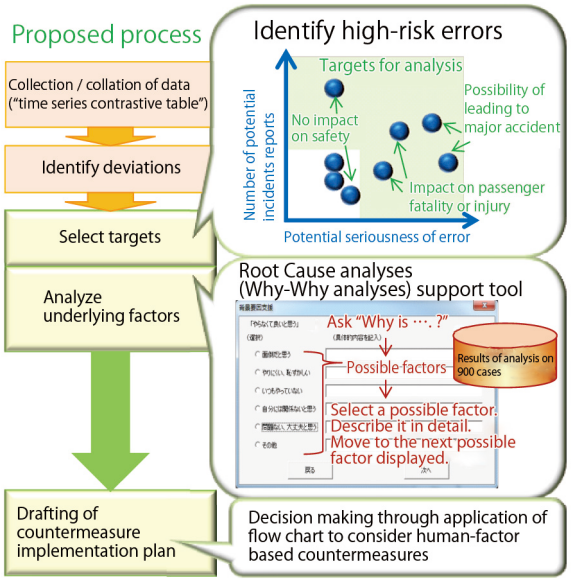


Fig. 4-11-2: Human Factor Analysis Method using risk-related information

crew workload.

To help evaluate the health impact of magnetic fields, cultured mammalian nerve cells were studied to monitor their reaction to stimulation of magnetic fields while their thresholds were studied. To help prevent mold, a method was proposed for evaluating mold prevention measures that uses surface water content as a parameter for plasterboard, one of widely used interior materials. On the utilization of fragrance, a survey was conducted on the impact of fragrances that cause cooling sensations for improvement of the heat environment in railway stations in summer.

In dealing with collision of trains and wild animals, investigations were carried out to understand the behavior patterns of deer around railway facilities. Several types of sound were found effective in scaring away deer when the sound was transmitted from the front of a vehicle in operation.

12 Maglev Systems Technology Division

The Maglev Systems Technology Division consists of two laboratories, namely the Electromagnetic Systems Laboratory and Cryogenic Systems Laboratory, and the Yamanashi Maglev Test Center, which are responsible for basic research on superconducting magnetically-levitated transportation (Maglev) systems. They also conduct research on the application of technologies created by research and development of Maglev systems (such as superconducting technology, cryogenic technology, and linear motor technology) to conventional railways and related contract work. Additionally, they conduct vehicle running tests and manage the assets of the Yamanashi Maglev Test Center and other related operations.

As part of basic research on Maglev systems, the Division has worked on vehicle dynamics, made efforts to reduce the cost of introducing new technologies to superconducting coils and ground coils, and researched equipment diagnosis and maintenance technologies for commercial lines. As part of research on application to conventional railways, the Division has developed high-speed linear induction motor (LIM) type eddy-current rail brakes, flywheel energy storage systems for railways using superconducting magnetic bearings, and non-contact power supply technologies.

At the Yamanashi Maglev Test Center, the total distance traveled by the Maglev vehicles in the long-term durability tests on the entire 42.8-km track in the Japanese fiscal year of 2015 was 344,422 km (about 4 times the greatest total distance recorded on the priority section) in a total of 247 testing days. These achievements represent the greatest number of vehicle-running days and the greatest total distance traveled by the Maglev vehicles in any single year. With the contribution of this annual record, the cumulative Maglev vehicle running distance on the entire 42.8-km track exceeded 1.5 million km. On April 21, 2015, the Maglev vehicle achieved a maximum speed of 603 km/h in a manned running test.

■ Electromagnetic Systems

The Electromagnetic Systems Lab conducts vehicle dynamics analysis and ground coil evaluation of Maglev systems, develops linear induction motor (LIM) type eddy-current rail brakes for high-speed trains and non-contact power supply technologies for railway vehicles, and works on conventional railway vehicle magnetic field evaluation methods.

In anticipation of the adoption of rare-earth high-temperature superconducting magnets on Maglev vehicles, electromagnetic characteristics were estimated for an environment with smaller electric gaps, as part of the Maglev vehicle dynamics initiative. This study led to the observation that lower ground coil current and power consumption can be realized. In research on ground coils, a non-contact insulation tester for propulsion coils and cables was developed and its performance verified. Vibration characteristics of propulsion system cables were identified in electromagnetic vibration tests. Also, proposed methods for extending the service life of ground coils such as by repair were put to durability tests using resin molds for ground coils as test pieces.

On the development of LIM-type eddy-current rail brakes for high-speed trains, a small, lightweight armature that operates even during power outages was designed and prototyped. Subsequent roller tests showed that the prototype was effective in shortening the braking distance (Figure 4-12-1).

For non-contact power supply technologies for railway vehicles, calculations were made including required power capacity for continuous power feed to vehicles. It was found that the twist of conductors is a contributing factor to reduced efficiency of the power feed, an issue

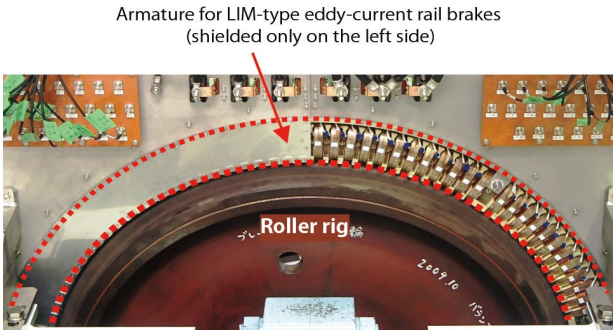


Figure 4-12-1: Roller test rig for linear induction motor (LIM) type eddy-current rail brakes

associated with the lengthening of power feed sections. And, in developing evaluation methods for conventional railway vehicle magnetic fields, an alternating magnetic field visualization device was fabricated to enable efficient searches for complex alternating magnetic fields in vehicles.

■ Cryogenic Systems

The Cryogenic Systems Laboratory develops high-temperature superconducting magnets for Maglev systems, and flywheel energy storage systems for railways using superconducting magnetic bearings. On high-temperature superconducting coils, a coil case resistant to 700 kA excitation stress was designed and fabricated based on the results of numerical analysis and evaluation of mechanical vibration and eddy current heat generation characteristics, as well as related sample testing. A full size high-temperature superconducting coil capable of generating corresponding magnetomotive force was fabricated using rare-earth high-temperature superconducting wire. (The research was subsidized by the Ministry of Land, Infrastructure, Transport and Tourism in its railway technology development scheme.)

On flywheel energy storage systems, tests were conducted on a test unit installed in a system test facility at a photovoltaic power plant (Figure 4-12-2) including: levitation and rotation tests on the large-diameter flywheel with superconducting magnetic bearings; tests on related systems; and non-normal performance tests in which the refrigerator was stopped by conditions such as power outages. These tests proved that the unit demonstrated stable levitation and rotation and that the unit was appropriately designed for safe operation. (The project was funded by the New Energy and Industrial Technology Development Organization (NEDO) and conducted jointly by Kubotek Corporation, Furukawa Electric Co., Ltd., Mirapro Co., Ltd., the Public Enterprise Bureau of Yamanashi Prefecture and RTRI.)

In other projects, it was found that: the current design of superconducting magnetic bearing for the heavy duty railway flywheel can be upgraded for practical application; a proposed method for estimating the internal temperature of resin using heat flow sensors on the coil surface was found effective as a diagnostic tool for ground coils; and the communication range and reception rates in the guideway were identified for low-power-consumption Bluetooth Low Energy as a wireless tool for interchange communication.

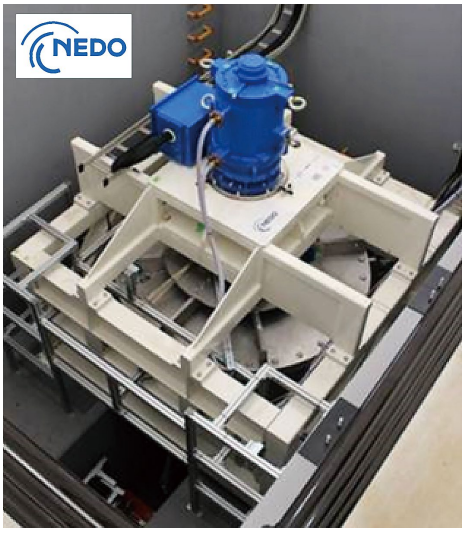


Fig. 4-12-2: Test unit for flywheel energy storage system

13 Center for Railway Earthquake Engineering Research

The Center for Railway Earthquake Engineering Research consists of three laboratories, namely, Seismic Data Analysis, Soil Dynamics and Earthquake Engineering, and Structural Dynamics and Response Control Labs, which are responsible for earthquake-related research and development, consulting work and contract testing work.

The Earthquake Information Distribution System was developed, and launched in June 2015. Under the system, information released from the Japan Meteorological Agency and the National Research Institute for Earth Science and Disaster Resilience after an earthquake is sent to RTRI. Based on this information, RTRI swiftly calculates the seismic ground motion (acceleration and seismic intensity) across Japan using the Center's ground database. The information is then distributed on the Internet free of charge to the subscribers to help them with repairs and restoration of service.

■ Seismic Data Analysis

The Seismic Data Analysis Lab undertakes research and development to improve early earthquake warning capabilities and its reliability, to provide instantaneous predictions of tsunamis, to estimate earthquake motion and damage with high precision and offer draft specifications/ regulations to achieve early restoration of railway services.

To improve early earthquake warning capabilities, the laboratory produced and tested a prototype seismograph that incorporates a new P-wave based earthquake specification estimation

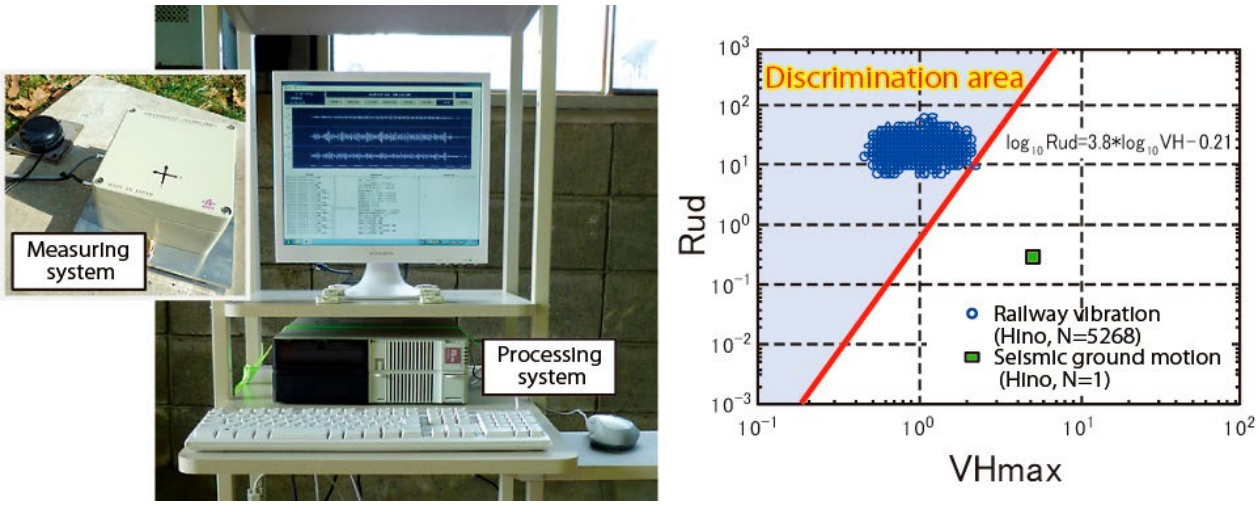


Fig. 4-13-1: Prototype seismograph and noise discrimination method

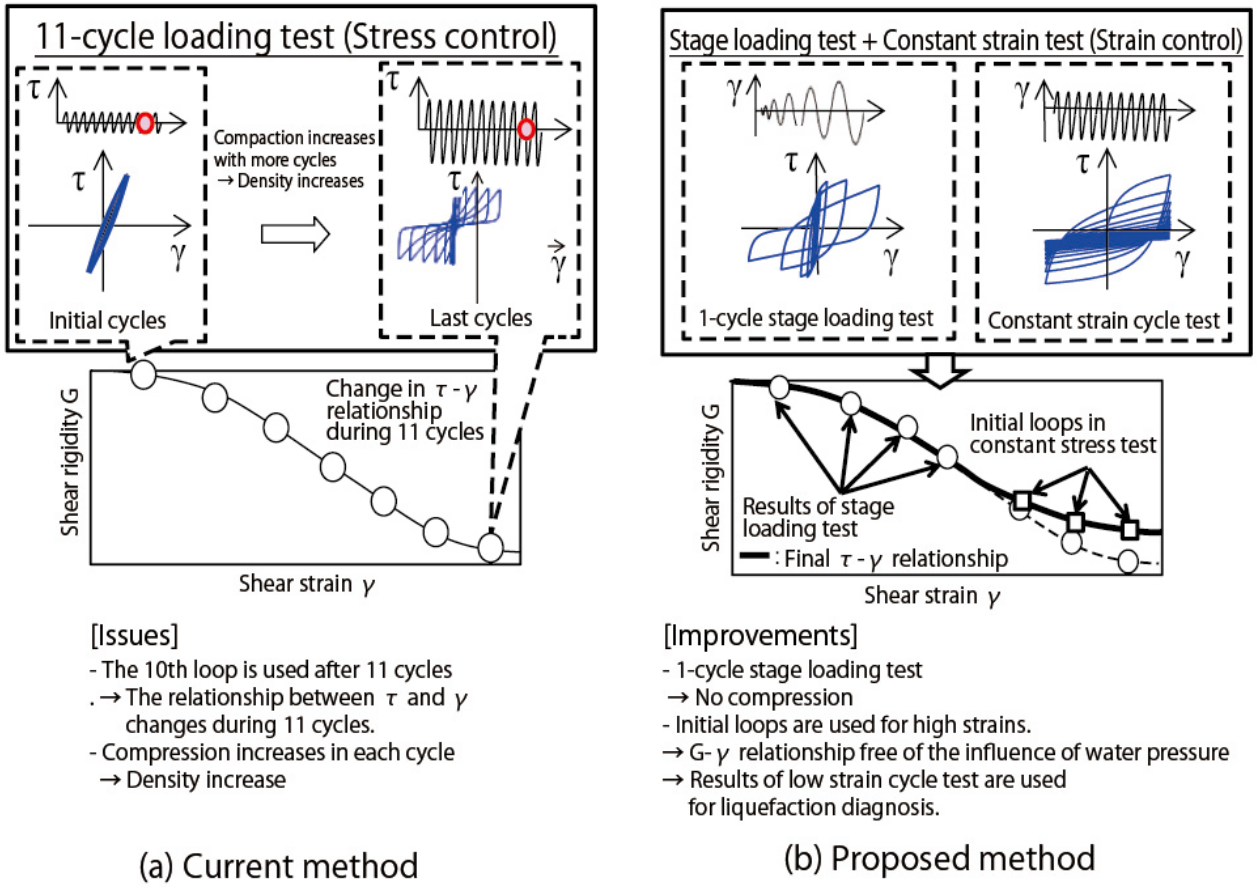


Figure 4-13-2: Deformation characteristics test methods

algorithm and a noise discrimination method. The test found that the proposed algorithm runs in a stable manner (Figure 4-13-1). Characteristics of vibrations from construction/maintenance work that may affect seismometers for early warning were analyzed. Also a study of the behavior of sea-bottom seismometers during strong earth motions was started.

To help improve instantaneous predictions of tsunamis, a simulation was conducted to evaluate the applicability of early tsunami height prediction methods that are based on the characteristics of tsunami propagation with respect to earthquake faults other than those related to major fault slips. In a study to develop highly precise earthquake motion estimation and regulations, it was found that the spatial change in earthquake response measured around railway lines can be quantitatively evaluated with knowledge of relevant underground structures.

■ Soil Dynamics and Earthquake Engineering

The Soil Dynamics and Earthquake Engineering Lab conducts a wide range of basic and applied research and development on the ground behavior near to earthquakes from the basic properties of earthquake motion to its impact on the ground when an earthquake occurs. On projects that can be immediately put to practical applications, the laboratory has been working on the development of a seismic design method for railway structures as well as on the development of economic countermeasures against liquefaction.

In the project on the ground behavior during earthquakes, in an effort to establish more accurate methods for obtaining the deformation characteristics of the soil for use in dynamic response analysis, a laboratory soil test method was proposed that is capable of evaluating more accurately the stiffness and hysteresis damping of soil from low to high strains (Figure 4-13-2).

■ Structural Dynamics and Response Control

The Structural Dynamics and Response Control Lab works to determine the seismic behavior of structures, power poles, vehicles etc.

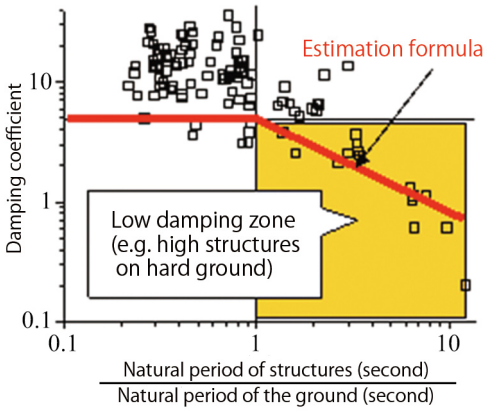


Fig. 4-13-3: Evaluation graphs of damping constants

and develops sophisticated methods to evaluate their behavior. It has conducted research and development of seismic design methods and seismic retrofitting work methods. To evaluate the behavior of structures and vehicles, it has measured the damping constants/coefficients of about 130 railway structures and produced graphs of their evaluations (Figure 4-13-3; subsidized by the Ministry of Land, Infrastructure, Transport and Tourism in its railway technology development scheme). An evaluation was made on the relationship between the magnitude of the damping constant and vehicle running safety. Based on the results of these activities, a method was proposed whereby structures lacking good seismic performance can be identified from among those along a specific railway line based on low marks in damping constant.

On seismic design, research was conducted focusing on input loss effect, one of phenomena resulting from dynamic interaction between the ground and structures. It was found that the foundations restrain ground motion, which likely dampens the seismic force applied to the structure on the foundations. Additionally, a method for correcting design spectra with respect to that damping effect was developed. This makes it possible to provide rational designs especially for structures with short periods.

Outline of Activities FY 2015

1 Basic policies

To contribute to the advancement of railways and help bring about an affluent society, RTRI actively promotes R&D activities geared towards railway innovation, delivering high-quality results by fully deploying its comprehensive capabilities.

In addition, to fulfil its social responsibilities as a public interest incorporated foundation, RTRI is active in promoting engineering and legal compliance and carrying out neutral activities, such as providing technical support in the event of a disaster or an accident, based on technical knowledge and experience. Moreover, in order to be the leader in global railway technologies, RTRI helps with the effective deployment of Japanese railway technology in foreign countries, simultaneously increasing its presence in the global market.

To achieve these goals, RTRI adopts the following basic policies:

(1) Dynamic R&D to encourage railway innovation

RTRI should respond to the changing times and the various needs of society and carry out innovative technical development as a matter of urgency. It should strongly promote advanced R&D and R&D in new fields, including enhancement of simulation technology and active use of information and communications technology, by allocating more resources to such activities. Also, it should steadily pursue basic research that can be a source of innovative technology.

(2) Achieving high-quality results by fully demonstrating its comprehensive capabilities

RTRI should rigorously accumulate know-how and pursue the development of human resources in preparation for solving various problems in the railway industry and developing innovative technology, and at the same time combine the strength of researchers and experts in different fields. Together with these actions, the organization's original facilities and equipment for research should be rebuilt or revamped.

Building on these measures, RTRI should achieve high-quality results and disseminate them widely around the world.

(3) Trusted activities based on technical knowledge and experience

RTRI should accumulate deep insights across the railway industry and carry out investigations into the causes of accidents and the damage caused by disasters, presenting methods to guard against their reoccurrence, and formulating technical standards based on its technical knowledge and experience as an independent third-party specialist organization.

(4) Support for overseas deployment and enhancement of the Japanese presence in the international railway sector

To become a leader in the field of railway technologies, RTRI should effectively support the overseas deployment of Japanese railway technology and simultaneously enhance its global presence by disseminating information and building close relationships with foreign railway operators and research institutes. It should also actively propose the adoption of international standards from Japan.

(5) Ensuring that the working environment allows all employees to be highly motivated

RTRI should foster an environment where free-minded researchers and experts can perform to their full potential and produce results that will bring a sense of accomplishment. It should also promote a pleasant workplace culture that allows unfettered discussions while respecting diversity in terms of age, sex, culture differences and other considerations.

2 Business Activities

(1) Research and development

(a) Basic principles of R&D

RTRI pursues the improvement of safety by developing better measures to prevent or mitigate the effects of major natural disasters and implementing derailment prevention measures. It also seeks to reduce the cost of maintenance and other elements of the rail business, to attain harmony with the environment by using energy more efficiently, and to enhance the convenience of rail travel thanks to further increases in train speeds. Drawing on these activities, RTRI will create innovative technologies that can contribute to railway advancement while solving various problems confronting the railway industry today. These challenges constitute the four "R&D Objectives" that RTRI should follow.

R&D Objectives
- Improvement of safety
- Cost reduction
- Harmony with the environment
- Improvement of travelling convenience

In order to promote R&D, resources should be augmented in leading-edge technical fields such as advanced simulation and information and communication technologies, as well as in specific technical fields relating to safety, energy, and faster running, and in other new areas.

In addition, in order to deliver high-quality results, original facilities and equipment for research and testing should be enhanced; studies should be carried out across various specific areas; accumulated know-how and data should be actively used; and the ability to offer a comprehensive service should be leveraged through networks with railway operators and domestic and overseas universities and research organizations.

Furthermore, aiming at reaching a balanced distribution of resources and achieving effective R&D, the following three agendas are adopted as the "Pillars of R&D" (Figure 2-1-1).

Pillars of R&D
- R&D toward the future of railways
- Development of practical technologies
- Basic research for railways

(b) Research and development toward the future of railways

With the objective in mind of achieving practical applications in 10 to 20 years' time, research topics should be carefully selected according to the following principles:

○ Respond to the needs of the JR companies and other railway operators, and respond to social trends

○ Point to advanced R&D and the future of railways

○ Leverage RTRI's expertise in fields and areas where RTRI has higher R&D capability and unique features

○ Pave the way for practical R&D and solve critical problems in practical R&D, and encourage research staff to make academic contributions.

○ Pursue challenges that will have a large spin-off effect when put to practical use

In FY2015, RTRI will start to implement the four major challenges: "Pursuit of Safer Railway Systems," "Revolutionizing Railway Systems with Information Networks," "Speed-up of the Shinkansen," and "Construction of Railway Simulators." In each major challenge, two or three individual R&D projects have been set. Within each of these there are two or more detailed R&D projects. There will be links between the individual R&D projects so that they are implemented in a logical and systematic way (Figure 2-1-2).

(c) Development of practical technologies

Research issues affecting the railway business that will yield rapid results should be tackled so as to achieve a practical outcome in a timely and satisfactory way.

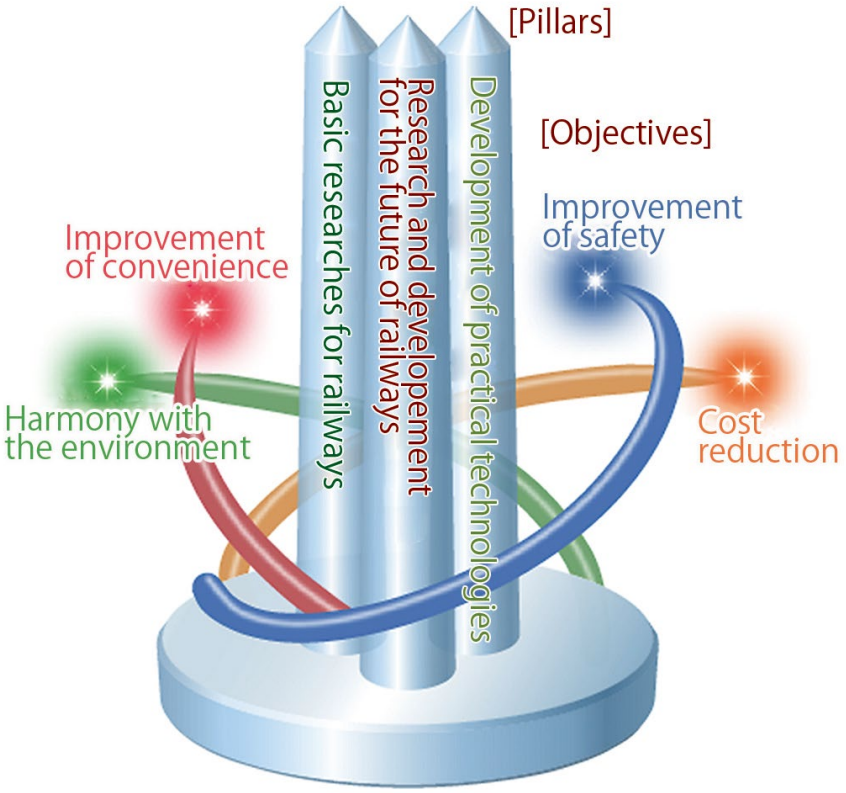


Figure 2-1-1

(i) R&D designated by JR companies

R&D that can contribute to the on-site solution of problems should be carried out, in response to various requests from JR companies and for which they have specific requirements. In R&D, sufficient resources should be mobilized so as to meet the needs of the railway business and to ensure that results are provided promptly.

(ii) R&D initiated by RTRI to investigate technology for practical use

R&D into novel technology should be pursued, taking fully into account the needs of railway operators, leveraging RTRI's specialist facilities and analysis technology, and aiming at practical application in actual fields of the railway business.

In addition, for dealing with issues that require an immediate response, such as accidents or disasters, an organization should be formed to manage two or more issues so that it has an overview of the situation, and solutions should be proposed quickly.

(iii) R&D commissioned by the Government or the public sector

R&D commissioned by the Government or the public sector should be undertaken in order to put results to practical use and make them widely available.

(d) Basic research for railways

In order to solve various railway problems and address challenges related to sources of innovative technologies, basic research for railways should have high-level backing and support. It should include the following objectives: clarification of mechanisms and phenomena; establishment of analytical, experimental, and evaluation methods; development of sophisticated simulation technology; and the development of new technologies, new materials and of different approaches to research.

In the process of promoting research, the following five items should be allocated higher priority, while research in new areas such as brain science is pursued.

Figure 2-1-2

- Prediction, detection, and prevention of phenomena that cause disasters
- Clarification of dynamic phenomena caused by rail travel
- Elucidation of deterioration/damage mechanisms
- Improvement of the environment along railway lines and the global environment
- Improvement of safety with a focus on human factors

Furthermore, research activities on Maglev Systems should be conducted continuously with a focus on the application of superconductivity, linear motors, and other technologies to conventional railways as a primary objective. Simultaneously, as part of the basic research programme, R&D should be carried out for maintaining the technical capabilities needed for such activities.

(e) Facilities and equipment for research and testing

Original facilities and equipment for research should be replaced where necessary; the selected facilities should be directly connected to R&D activities in fields where RTRI intends to introduce innovative technologies. In addition, where the performance of test facilities has declined over time so that they no longer meet R&D needs, they should be improved or renewed, in addition to construction of new buildings for experiments.

(2) Investigation of railway technologies and science

RTRI should grasp social, economic and technological changes, and then collect and analyze various types of information generated in Japan and foreign countries that is needed in order to contribute to the technical development of the railway business. Once this has been completed, the results of such activities should be transmitted to the parties concerned. RTRI should also predict the future status of railways and conduct investigations necessary to choose technical issues for its R&D objectives.

(3) Preparation of drafts of railway technology standards

In accordance with the rising importance of the management and maintenance of society's infrastructure and the Japanese Government's movement towards performance specification of technology standards, RTRI should promote the formulation and arrangement of design standards, maintenance management standards, and design calculation examples of infrastructure. Technical fields, such as vehicles, where new technical standards should be formulated, and therefore where systematization is needed, should be clarified. This should ensure that tasks such as the formulation of design standards in these fields can proceed smoothly.

(4) Collection and release of railway-related documents, materials and statistics

RTRI should collect and collate information on Japanese and foreign railway technologies. It should also leverage various channels, such as mass media and the Internet, and transmit R&D results and activity status in a planned and timely manner. It should play a role as a source to send timely and precise railway technical information to the public.

(5) Publications and lectures to raise the profile of railway technologies and science

RTRI should expand the contents of its periodicals, such as the RTRI Report and RRR, lecture presentations, and technical forums. Through these instruments, the results of RTRI's R&D work should be offered widely to the public. The courses of lectures on railway technology and other lecture presentations should be systematic, and designed to meet the needs of all, from beginners to experts.

(6) Diagnosis, advice and guidance on railway technologies and science

RTRI should respond precisely to requests from railway operators to continuously and positively carry out its mission. Especially in offering a consulting service in response to a disaster or an equipment failure, a quick response should be agreed in a tie-up with the railway businesses or operators involved. Furthermore, consulting services for local railway companies should be enhanced by making site visits and giving technical advice.

(7) Drafting of original plans and proposals for standardization with regard to international railway standards

RTRI should promote, in a strategic way, activities related to the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO). In particular, RTRI should actively participate in the operation of TC 269 (Railway Applications), newly established in ISO in April 2012. It should also strengthen its resources, and press on with projects such as "rail project planning" which Japan proposes. At the same time, RTRI should exercise leadership in standardization activities in the fields of operations and services where Japan has technical predominance.

(8) Authorization of qualifications with respect to railway-related science and technology

With a focus on accreditation tests for Professional Railway Design Engineers, RTRI should build up and arrange improvements in examination opportunities for applicants through overall verification of the tests, thereby contributing to the enhancement and maintenance of the level of technical expertise of railway engineers.

(9) Railway Technology Promotion Center

RTRI should contribute to an improvement in the level of technical expertise in the railway industry by promoting related business while taking, as pillars, systematization of technologies and problem solving, enhancement and maintenance of technical capabilities, and technical information services. For this purpose, it should tackle new research and study topics that are useful for systematization of vehicle technology, and simultaneously offer technical support to local railways and encourage technology succession by positively applying the knowledge of "Rail

Advisers." In addition, the contents of the safety database should be enriched through intensified research and analysis activities in the human factors field.

(10) Railway International Standards Center

RTRI should promote strategic activities aimed at introducing Japanese technical specifications and concepts into international standards. It should actively exchange information with European and Asian standardization bodies and intensify its partnerships with them, and also boost educational activities on international standards for the parties concerned and human resource development activities.

(11) International activities

For the purpose of further improving the technical capabilities and presence of RTRI, joint research programmes with foreign universities and research bodies should be expanded. Exchange of researchers should be promoted by sending more RTRI researchers abroad and receiving more foreign experts in Japan. RTRI should actively take part in the World Congress on Railway Research (WCRR) as a member of the Organizing Committee, going ahead with preparation and management of the WCRR meeting to be held in Tokyo in 2019. RTRI should also aspire to organize international workshops and join various types of international conferences to exchange information on the latest railway technologies. RTRI researchers should be sent overseas to investigate global railway conditions and technologies.

RTRI should contribute to the wider application of Japanese railway technologies across the world by providing active support for railway operators and related businesses, assisting overseas deployment of intellectual property, and offering guidance to engineers in foreign countries.

YEAR 2015-2016: April 1, 2015 - March 31, 2016

Published by Kimitoshi ASHIYA , Executive Director

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