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Developed by RTRI

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GENERAL INFOMATION

ARTICLES

RTRI Celebrates the 25th Anniversary of its Foundation

Hideyuki TAKAI
Executive Director

Research and development on railways in Japan have a 105-year long history as they started in 1907 when a railway survey office was organized as a division of the national railway. Nearly 80 years later, in December 1986 the Railway Technical Research Institute (RTRI) was incorporated just before the division and privatization of Japanese National Railways. On the occasion of the 25th anniversary of the founding of RTRI in December 2011, an organization-wide commemorative symposium “RTRI - Foreseeing the Coming 25 Years” was held with all employees present. The event is described in a separate article.

RTRI, an organization for comprehensive research and development of railway technologies, has contributed in conjunction with Japan Railway companies to the improvement of railway functions. Examples include the development of Shinkansen railways, a harbinger of high-speed railways in the world, increasing the curve-negotiating speed of rolling stock having tilting bodies, speedup of Shinkansen trains by using lightweight bolster-less trucks and the development of a magnetically levitated railway system aiming at having a maximum speed of 500km/h.

In Japan, a country frequently hit by natural disasters, it has been an important mission as well for RTRI to promote research and development to minimize the damage on railway assets by earthquakes, heavy rains and strong winds, with the outcomes applied to railways as disaster preventive measures in various forms. As a matter of fact, it is thought that such efforts led to the minimization of the damage on railways at the Great East Japan Earthquake (Tohoku Region Pacific Coast Earthquake) in March 2011.

The operation of RTRI is based on the five-year “Master Plan – RESEARCH 2020 – Toward the Sustainable Development of Railways,” in which RTRI is making its utmost effort to upgrade simulation technologies aiming at developing “virtual test tracks” in several years to implement tests on a supercomputer instead of operating under impractical conditions on actual lines. Constructing a “railway simulator” to simulate the running conditions of rolling stock along with peripheral circumstances is planned for several years thereafter.

Note: “Tohoku Region Pacific Coast Earthquake” is the official naming by the government of Japan.

高井秀之
Hideyuki Takai

A Commemorative Symposium
The 25th Anniversary of the Foundation of RTRI
Preparing to Meet the Challenges of the Next 25 Years

Haruo YAMAMOTO
Deputy Director, Planning Division

On December 9, 2011, the Railway Technical Research Institute (RTRI) held a special symposium to commemorate the 25th anniversary of its foundation with about 430 executive and other members in attendance. The purpose of the symposium was to consider what we should do in the coming 25 years. This included reviewing the history of RTRI from the incorporation to the present time amid the progress and changes that occurred during the 25 years after the division/privatization of Japanese National Railways.

Panel discussion

In a three part program to deal with the themes of the past, the present and the future, two lectures and a session for panel discussion were arranged. In the lecture 1, we reviewed the activities from the incorporation to the present time with photos and charts referred to as necessary. In the lecture 2, we summarized the directions to follow and subjects to adopt in order to enhance the presence of RTRI based on the current status of railway businesses. In the panel discussion, we discussed the management, operation and need for research and development in the future based on the results of lectures 1 and 2. Questions/answers and opinions were actively exchanged between panelists and other participants, and led to a renewal of our resolve for the success of RTRI in the coming 25 years.

A scene of the discussions at the symposium

Moderator: President Tarumi

Lecture 1	Theme: Twenty-Five Years to Upgrade the Function of Railways Lecturer: Hideyuki Takai, Director, Planning Division
Lecture 2	Theme: What should we do now? Lecturer: Norimichi Kumagai, Vice President
Panel Discussion	Theme: Foreseeing the Coming 25 Years for RTRI Moderator: Hisashi Tarumi, President Panelist: Norimichi Kumagai, Vice President, and other five members

Program at the symposium to commemorate the 25th anniversary of the foundation

Development of a New Railway Simulator

Hiroaki ISHIDA
Director, Railway Dynamics Division

We are developing a computer-based railway simulator to reproduce various events taking place during train operation for use in the future as a tool to evaluate the safety, reliability, comfort and economics of railway operations. It is designed to support management of the whole railway with the aid of computers. As the first step, in fiscal 2010 we started the development of a core software system of railway dynamics simulations to begin the eventual construction of "a virtual railway test line" and "an earthquake disaster simulator." The latter is discussed elsewhere in this newsletter. The virtual railway test line software will be built to reproduce and predict the vibration, noise and track failure experienced in normal train operation (Fig. 1), using a high performance computing (HPC) technology lying in the background. The test line not only reproduces field tests of trains but also enables investigation of hitherto difficult-to-observe phenomena through the application of HPC technology. We are now developing the following four subsystems that will function under the core system, each through the modeling techniques specified below within the affixed brackets.

(1) Vehicle and track dynamics simulator (Multi-Body Dynamics (MBD))
(2) Wheel/rail/track dynamic interaction simulator (Finite Element Method (FEM), Distinct Element Method (DEM)), Fig. 2
(3) Pantograph/catenary dynamic interaction simulator (FEM), Fig. 3
(4) Aerodynamic force and noise simulator (Finite Difference Method (FDM)), Fig. 4

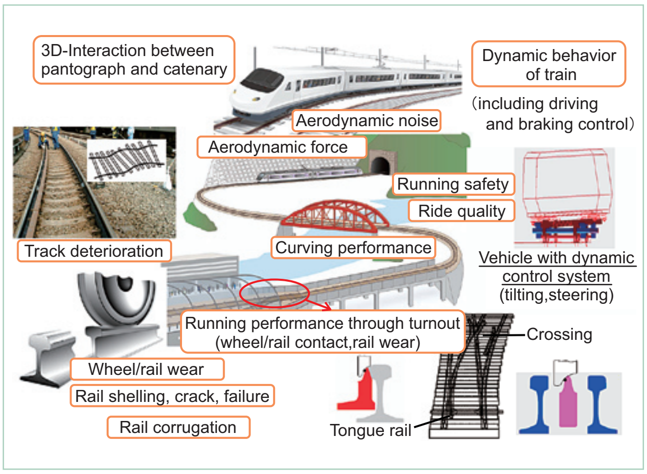


Fig. 1 Virtual Railway Test Line

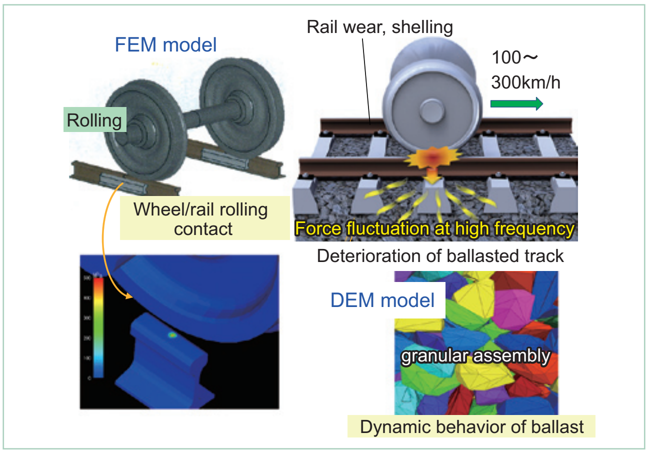


Fig. 2 Wheel/rail/track dynamic interaction simulator

We will use the subsystem shown in Fig 2 to analyze the rolling contact between wheel and rail, determine the wheel/rail creepages and forces at very high frequencies, reproduce the dynamic behavior of track components when the changing load propagates to the ballast and sleepers, and clarify the mechanisms of rail wear/damage and track deterioration. We will use the simulator shown in Fig.4 to reproduce the air flow around trucks, roof-top current collecting devices and other objects with complicated profiles with the train running at high speed, and predict aerodynamic force and noise generated on cars. As these models for analysis feature a tremendous number of elements, 100 million or more, a parallel computation technology is used to reduce the calculation time.

The virtual railway test line will exhibit its true power in the prediction of long-term deterioration, wear/damage of wheel/rail and track irregularities that will progress as train passes increase. To reproduce and evaluate countermeasures against these phenomena, it would take several years on revenue service lines, whereas simulators will complete the task only in several days. Therefore, we are now doing our utmost to develop the subsystem in Fig.2. We have already established an elasto-plastic FEM model that can be accelerated up to 300 km/h with wheels subjected to vertical loads and driving torque. We have also developed a model to enable analysis of the wave transmission phenomenon with loads fluctuating at high frequencies applied on an assembly that has reproduced a three-dimensional ballast configuration (Fig. 2).

After completing the subsystems, we will integrate them into a virtual railway test line in the future.

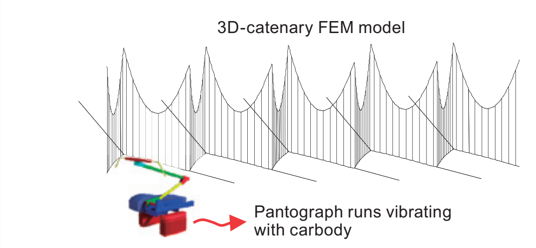


Fig. 3 Pantograph/catenary dynamic interaction simulator

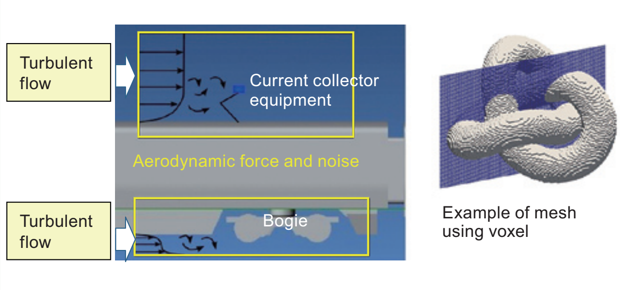


Fig. 4 Aerodynamic force and noise simulator

Development of an Earthquake Disaster Simulator for Railways

Yoshitaka MURONO
Senior Researcher, Laboratory Head, Earthquake and Structural Engineering,
Structures Technology Division

1 Purpose and background

After the Southern Hyogo Prefecture Earthquake in 1995, Japan has frequently been hit by large-scale earthquakes across the country. It is said, therefore, that Japan is now in a high seismic activity age. Railways are strongly associated with public interests and it is very important for them to continue to function even after earthquakes. The railway system features long routes and diversified component elements and it is difficult to imagine what sorts of disaster risks exist at any particular location. However, it is important to be prepared for earthquakes by doing the following.

(1) Determine potential earthquake disaster scenarios and earthquake risks to appropriately implement measures against earthquakes in order to protect the railway system.

(2) Establish common recognition against earthquake disaster risks among railway promoters, users and the Railway Technical Research Institute (RTRI) and construct a mechanism for these parties to evaluate and quantify earthquake disaster risks.

RTRI has been developing a "railway simulator" under its five-year plan since 2010. As a part of this overall program, RTRI is developing an "earthquake disaster simulator" to evaluate the safety of the total routes during earthquakes and, to use as an effective tool to appropriately visualize and mitigate earthquake disaster risks.

2 Features of the simulator

Figure 1 shows the primary features of the earthquake disaster simulator for railways and Fig. 2 a visual depiction of the simulator's capabilities.

This system can broadly be divided into four components: (1) a "database", (2) a "simulator of earthquake motion", (3) a "software to construct a model of a group of railway structures (hereinafter referred to simply as structures)" and (4) a "simulator of the behavior of railway structures."

The "database" stores the data on the ground and structures. It consists of data possessed primarily by RTRI at the moment and will be updated in the future. The "simulator of earthquake motion" calculates the propagating process of the earthquake motion generated at faults. The seismic motions in hundreds-kilometer square are calculated. The simulation is conducted not by the conventionally-used finite difference method (FDM) but by the voxel finite element method (FEM) that enables sophisticated calculations for mountain and ground-surface profiles. This method is considered appropriate to accommodate the required speed and data volume of the calculation. See Fig. 3 for the results of a simulation conducted to reproduce the behavior of the Southern Hyogo Prefecture Earthquake in 1995.

The "software to construct railway structures" is one that automatically compiles a numeric calculation model of structures including information on the ground in a several hundred-meter-long section. The data is based on the information in the database. In normal cases, models for structural calculation are manually created by human beings by referring to design drawings, a process which cannot cope with a great number of structures. Therefore, RTRI has developed a new block assembling method to disassemble a structure into blocks first and then assemble into a new structure model in the same way as children stack blocks to construct a structure (see Fig. 4). This method enables construction of a large-size model.

The "simulator of the behavior of railway structures" is a simulator to calculate the earthquake response of the model of structures constructed by the "software to construct railway structures" against the earthquake motion predicted by the "simulator of earthquake motion."

3 Conclusions

RTRI will complete the basic portion of the earthquake disaster simulator in fiscal 2014.

In the future, RTRI will use this simulator to evaluate various scenarios caused by huge earthquakes that might occur in years ahead and predict risks existing in the railway system. In this way, the simulator will be utilized to better guarantee the safety of railways.

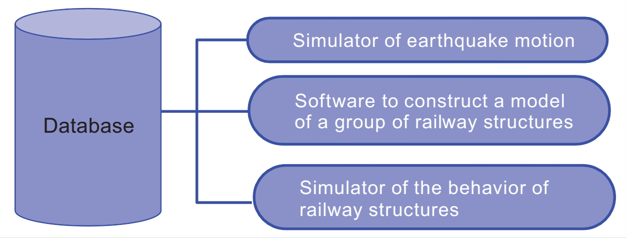


Fig. 1 Construction of the earthquake disaster simulator

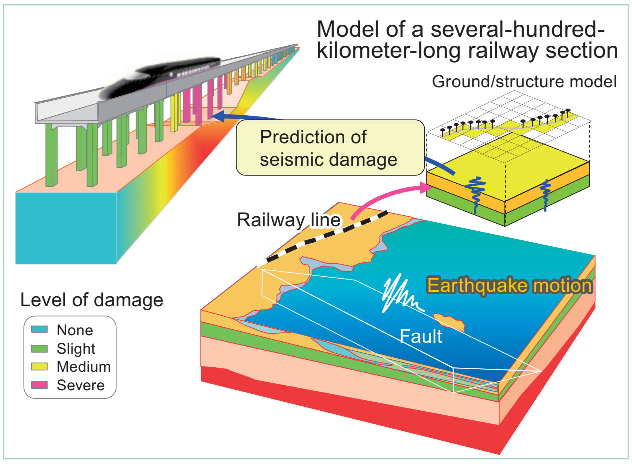


Fig. 2 An image of the earthquake disaster simulator for railways

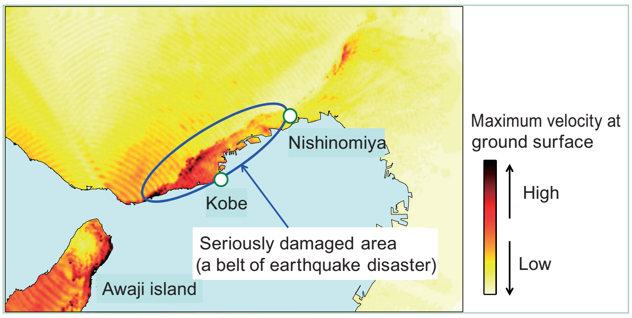


Fig. 3 Simulation to reproduce the behavior of the Southern Hyogo Prefecture Earthquake in 1995

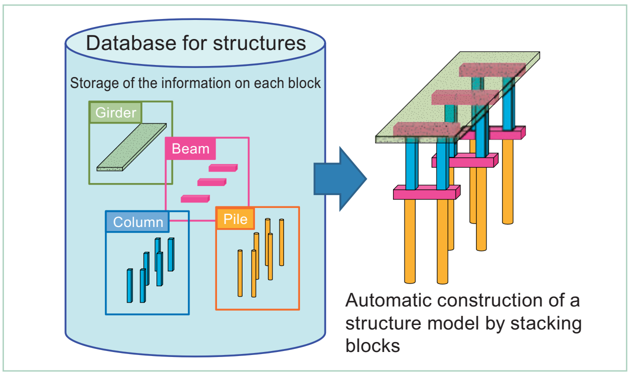


Fig. 4 Automatic modeling of structures by the block assembling method

A Study on Intelligent Trains to Improve Safety and Reliability of Operation

Kiyotaka SEKI
Principal Researcher, Signalling and Transport Information Technology Division

To improve the safety and reliability of train operation further, it is possible to collect safety information of various categories on trains by utilizing sensing and telecommunication technologies. The Railway Technical Research Institute (RTRI) is now studying methods, therefore, to develop “intelligent trains” with heightened safety awareness to prevent accidents by detecting dangerous conditions based on the information obtained through sensors or other instruments incorporated in trains or installed on the ground (Fig. 1).

The subsystems to detect abnormalities currently under discussion are those to monitor bogie conditions for soundness, detect obstructions on tracks and detect mental/physical abnormalities of train drivers. The obstruction detecting system monitors tracks through the sensors on trains. It uses instruments installed on the ground to monitor the conditions of platforms and track where rock and stone falling is anticipated, with the monitored results transmitted to trains. To raise the detecting performance, the system combines the technologies of radars/distance sensors and camera image processing. So far, RTRI has developed basic algorithms such as those to extract track from the images photographed with cameras installed on trains and obtain true bird’s-eye views converted from the forward photographic images (Fig. 2).

As a basic technology required for implementing intelligent trains, RTRI is also developing a method to detect position and speed at high precision without installing new facilities on the ground (Fig. 3). This is achieved by combining the technologies of existing tachometer-generators, inertia sensors, Global Positioning System(GPS) and millimeter wave to aim at position detecting errors of 5 m or less. For this purpose, RTRI is now evaluating the performance of component sensors and discussing applicable algorithms. Regarding inertia sensors, RTRI has already developed an algorithm to determine positions by making the detected angular speed corresponding to track curvatures and gradients. As the precision of tachometer-generators is not sufficiently high in low-speed ranges affected by wheel skids and slips, RTRI has also developed an algorithm to use inertia sensors to compensate for the errors in the position detected with tachometer-generators and confirmed its applicability in running tests at about 60 km/h on a test track (Fig. 4). RTRI has confirmed that the millimeter wave speed meters, used to calculate moving speeds based on the Doppler frequency of reflected waves, predict almost the same speeds as those obtained with tachometer-generators at a moving speed of about 60 km/h without being affected by soil or dirt staying thereon.

RTRI will promote development of component subsystems and a prototype unit including an intelligent device to integrate the outputs from the subsystems.

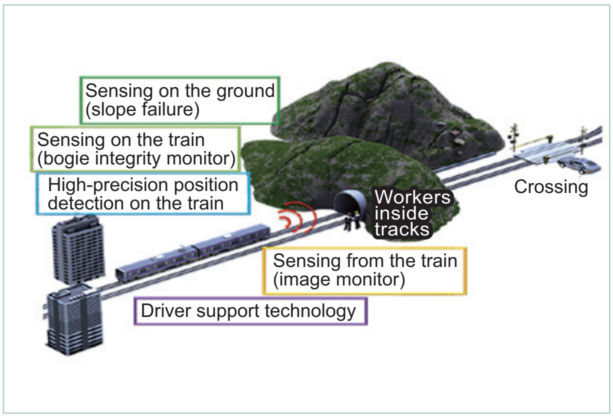


Fig. 1 An image of intelligent train

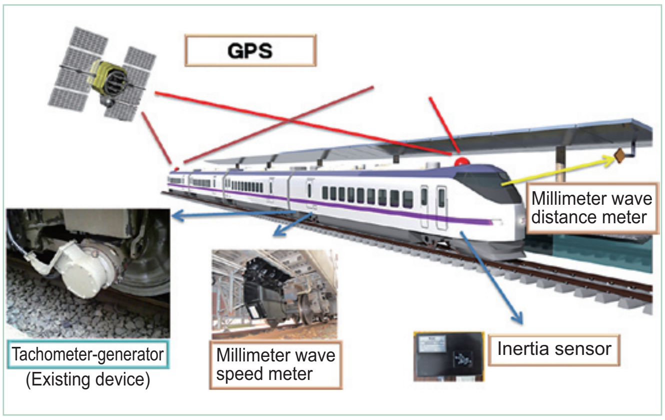


Fig. 3 Composite type high-precision position/speed detecting device

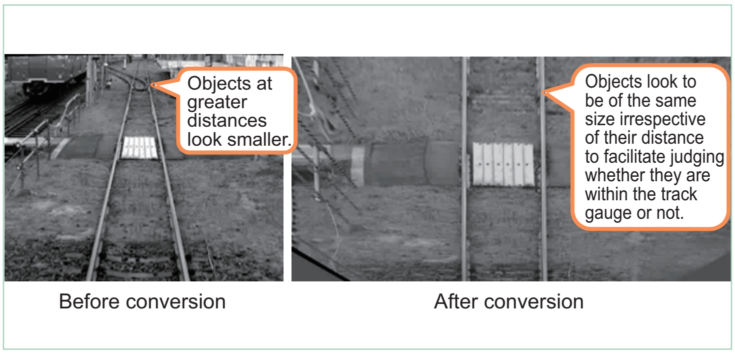


Fig. 2 Conversion by the “viewpoint converting algorithm”

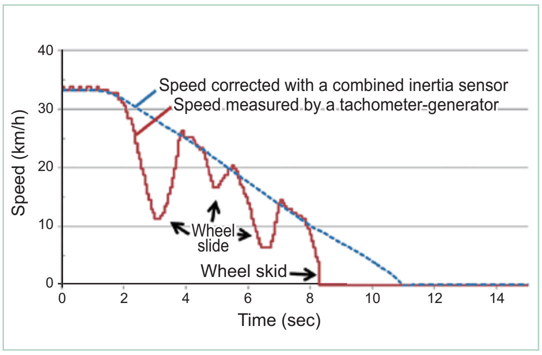


Fig. 4 Correction of speed with an inertia sensor

A Technology to Restore Deteriorated Steel Bridges
-Development of Bridges Integrated with Nail-Reinforced Soils-

Masayuki KODA
Senior Researcher, Laboratory Head, Foundation and Geotechnical Engineering, Structures Technology Division

Since Japan started railway operations about 170 years ago, a number of steel bridges have been constructed for railways across the country, with the majority now reaching 50 years or more in service. It is likely, therefore, that the number of steel bridges requiring repair, reinforcement or replacement will continue to increase in the future.

To replace a deteriorated bridge with a new one requires time-consuming construction work at an enormous cost, as it necessitates construction of temporary tracks, erection beams and abutments.

In the case of conventional steel-beam- and abutment-type bridges, as the construction of backfills follows that of abutments, the backfills tend to cause sinking and lateral displacements of abutments. After completed bridges are put into use, various problems are tend to occur including:

(1) Malfunctions caused with corrosion of supporting parts and steel beam flanges under bridge sleepers, settlement of backfills, and
(2) Damage given by earthquakes, for example, abutments inclined, backfills settlements and breakage of shoes.

River bridges are also with following disadvantages:

(1) The horizontal resistance at the front of the abutment decreases due to river bed scour, and
(2) Abutments incline or slide to cause large relative displacements against steel beams, which potentially lead to steel beam failures (fall accidents) (Fig. 1, Table 1).

The outline of the concept

To extend the life and strengthen the earthquake resistance of deteriorated steal-beam- and abutment-type bridges without replacing steel beams, RTRI proposes a method to integrate the following structures:

(1) Abutments and backfills with reinforced concrete (RC) walls that are rigid with nail-reinforced soils (NRSs), and
(2) Connecting steel beams and abutments with reinforced concrete.

These measures improve the functions of steel beams, abutments and backfills in normal service periods. The bridges having such a structure are called “the bridges integrated with NRSs (NRS-integral bridges)” (Fig. 1).

This eliminates the necessity of the maintenance of supporting parts and fixes steel beams at both ends, which hitherto have been a simple support structure. The process reduces the moment generated under live loads, significantly increases the load-carrying capacity and eventually extends the life of deteriorated steel beams.

In addition, passive resistance can be expected from the abutment backfill on the opposite side with the rigid-frame structure. Elimination of the structurally weak supporting parts also considerably improves the earthquake resisting performance of bridges. Steel beam fall accidents due to the damage of supports can be prevented. Elimination of structural joints significantly enhances the safety of train operation during and after earthquakes.

It is also recognized rigid-frame support-less structures cause abutment backfills to sink owing to the elongation/contraction of steel beams resulted from temperature changes and abutments to crack due to the increases in the backfill earth pressure as a result of bridge behavior accumulated for long years. In the case of NRS-integral bridges, however:

(1) Suppresses the horizontal displacement of the abutment crown due to temperature changes,
(2) Decreases the settlement of backfills and the earth pressure by improving the self-supporting performance for abutment backfills. (Table 1).

Proof of the concept

RTRI constructed a 13 m-span actual size test bridge, and integrated steel beams/abutments and abutment/backfills with NRSs to simulate the actual integration work that would be performed in practice. A test of this bridge span was conducted to confirm the viability of the concept (Fig. 2). RTRI measured the long-term behavior of the test bridge by conducting repeated horizontal loading tests to simulate thermal elongation/contraction of steel beams and similar tests with alternating loads to confirm the earthquake resisting performance. Table 1 summarizes the results of the tests that confirm the practicality of the NRS-integral bridge. RTRI will apply this technology to the renewal of steel bridges having comparatively short spans less than 20 m.

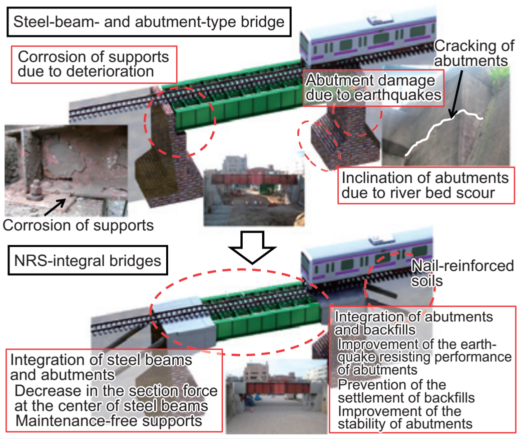
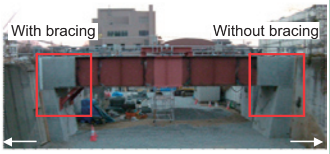


Fig. 1 An outline of NRS-integral bridges

(a) A steel-beam- and abutment-type bridge (before reinforcement)



(b) A NRS-integral bridge (after reinforcement)

Fig. 2 Appearance of the actual size test bridge

Table 1 Subjects for the steel-beam- and abutment-type bridges and features of the bridge integrated with nail-reinforced soils

	Object point	Subjects for the steel-beam- and abutment-type bridges	Features of the bridge integrated with nail-reinforced soils
Under construction / reinforcement		- As backfills and beams are constructed/laid after abutments have been constructed, abutments are subject to settlement or lateral displacements.	- Bridge integration work can easily be performed without manufacture of a new bridge or construction of temporary tracks, beams, abutments or track rerouting, unlike the method to replace beams and abutments after constructing temporary tracks. - Bridge integration work can easily be performed to improve abutment functions without constructing temporary pedestals when compared with the method to laterally replace steel beams.
In the normal state	Steel beam - abutment	- Upkeep and control are required for supports. - Corrosion due to rain water starts from the supports.	- Elimination of the upkeep and control of supports - Decreases in the section force of steel beams generated under train loads extend the fatigue life of the bridge.
	Backfill - abutment	- Backfills sink; abutments incline or supports may lose their functions. - Relative displacements may occur between backfills and abutment crowns to compromise train operation, which requires upkeep and control of backfills.	- Nail reinforced-soils strengthen the self-supporting of backfills and suppress their settlement. - Relative displacements between backfills and abutments are prevented to save the man power in the upkeep and control of backfills.
In abnormal states (earthquakes, abnormal floods)	Steel beam - abutment	- Supports and abutments may be damaged at earthquakes. - Large relative displacements between backfills and abutments potentially cause bridges to fall.	- The rigid-frame structure of steel beams and abutments improves the earthquake resisting performance of the whole bridge. - Prevention of bridge fall accidents at earthquakes
	Backfill - abutment	- Abutments may incline or backfills sink at earthquakes. - Large relative displacements between backfills and abutments potentially compromise the safety of train operation during and after earthquakes.	- Nail reinforced-soils improve the earthquake resisting performance of abutments and backfills. - Relative displacements scarcely occur at earthquakes to ensure the safety of train operation.
	Foundation	- River bed degradation or abutment scour may occur with river bridges to potentially cause abutments to incline.	- River bed degradation and scour do not directly cause decreases in the supporting force, inclination of abutments or bridge fall accidents.