Newsletter on the Latest Technologies Developed by RTRI

Railway Technology Avalanche

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2-8-38 Hikari-cho, Kokubunji-shi
Tokyo 185-8540, JAPAN
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GENERAL INFOMATION

ARTICLES

Preface

Koichi GOTO
Director, International Affairs Division

My name is Koichi GOTO. Since April 2010, I have been in charge as Director of the International Affairs Division. I returned to the Division after spending three years working at the Transport Information Technology Division.
During those three years, the international activities of RTRI have undergone significant changes. One of these changes was the launch in April of the International Railway Standards Center as an independent organization. This was formed from an expanded subsidiary division of the International Affairs Division which dealt with international standards. Although the Center is responsible for activities relating to international standards, the International Affairs Division intends to co-operate with the Center, helping to provide Japan' s contribution in the development of international standardization.
While Japan has achieved a state of advanced development with its domestic railway systems, it cannot be denied that activities focusing on overseas development were in some respects poor. Recently, the entire railway industry in Japan has started to give more serious thought to globalization and internationalization, and railway operators also consider it important to utilize Japanese railway technologies on a global basis.
It is also important to introduce advanced technologies from overseas. With the increase in the use of railways caused by the development of the world's railway technologies and the improvement in safety and convenience of rail travel, we can expect to see improvements with regard to global environmental problems such as CO_2 emissions and energy issues. In order to do this, however, co-operative activities on a world scale are essential. To this end, RTRI has promoted joint studies under agreements with overseas railway R & D organizations. In addition to joint studies among three Asian railway research organizations (CARS: China Academy of Railway Science, KRRI: Korea Railroad Research Institute and RTRI), and joint studies with SNCF (French National Railway Corporation), RTRI started joint study activities with RSSB (Rail Safety and Standards Board) in the U.K. in 2008. I expect that these activities will lead to further progress, including the exchange of human resources, and that positive co-operation with railway-related organizations and academic organizations such as universities will contribute to the future development of railway technologies.

Reviewing RESEARCH 2005

Kiyotaka SEKI
Deputy Director, Planning Division

During the five years from 2005 to 2009 RTRI worked on a basic plan called RESEARCH 2005. As part of the plan, RTRI promoted research and development by setting priority objectives in several fields: "Research and Development for the Future of Railways", "Development of Practical Technologies" and "Basic Research for Railways". The intention of these targets was to achieve "Highly-reliable Railways", "Railways which are More Convenient", "Low-cost Railways" and "Environmentally-friendly Railways". Most of the expected aims of the plan were achieved and the plan was finished successfully.

1. Research and development

(1) Research and development for the future of railways

The research and development programme concerning the future of railways corresponds to a number of tasks which are aimed at achieving technical breakthroughs, with a view to practical applications in the next 5 to 10 years or more. There were 13 tasks in total which were implemented as mini-projects. These tasks proceeded almost as planned. Most of the expected aims were achieved, and the tasks were finished. Examples of achievements from the various tasks are as follows:

In the task entitled "Development of a method of evaluating vehicle dynamic characteristics using a hybrid simulator," RTRI developed a system for evaluating the performance of vehicle components by combining test equipment for vehicle components such as dampers and air springs with a real-time simulator which reproduced the running conditions on main lines. Moreover, RTRI made it possible to simulate the running tests with a trainset by adding an inter-car dynamics simulator to the rolling stock test stand (which is designed for a single car) and combined with the real-time simulator. Furthermore, RTRI developed a bogie that can reproduce arbitrary characteristics, and RTRI's work also made it possible to ascertain the necessary performance characteristics before building a prototype of the bogie.

In the task entitled "Development of human simulation technologies to improve safety and riding comfort," RTRI developed the education programme to improve drivers' abilities to respond to difficulties, by making them aware of driving actions in abnormal situations, etc. Furthermore, RTRI developed a passenger flow evaluation technique and a simulation technique to assess the behaviour of passengers evacuated in emergency situations in station yards, etc. based on the results of measurements obtained using a station simulator and actual stations.

In the task entitled "Development of an analytical tool to predict rolling noise and structure-borne noise, and measures for noise reduction," RTRI clarified the mechanism whereby rolling noise and structure-borne noise (the main noise sources in railways) are generated, and established a method to predict the generation of noise. Furthermore, RTRI drew up suggestions for noise-reducing measures and demonstrated how effective these measures were in quantitative terms.

(2) Development of practical technologies

Regarding the development of practical technologies, RTRI carried out the tasks that contribute to the solutions of specific problems at field sites of the JR companies. It also carried out tasks in those specialist fields where RTRI has greater expertise than other organizations.

(3) Basic research for railways

Basic research for railways comprises research that generates practical railway technologies or serves as a foundation for them; this work is essential in solving a variety of railway-related problems. RTRI carried out research aimed at better understanding of railway-inherent phenomena, research into the application of new technologies and new materials to railways, and research into technologies for the maglev transportation system.

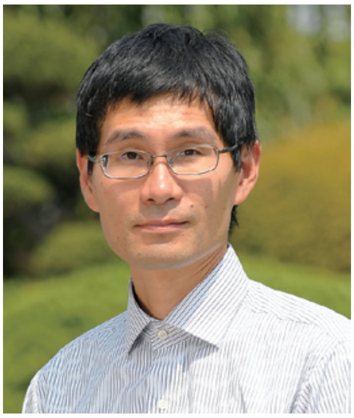
2. International activities

RTRI promoted collaborative research programmes between Japan and France and between Japan, China and Korea, and also started collaborative research between Japan and England. Further, RTRI participated in the organization of and arrangements for the World Congress on Railway Research (WCRR).

Regarding international standards for railways, RTRI participated in the establishment of international standards, as the domestic council organization responsible for electric railway technologies. Moreover, RTRI set up a task force to establish the Railway International Standards Center in July 2009, establishing the Preparatory Office for the Railway International Standards Center. The Center, which was established in April 2010, has the objective of obtaining a broad response to deliberations about international standards affecting railways.

Improvement of the Interference Performance of Low-frequency Track Circuits by Simple Code Transmission

Natsuki TERADA
Senior Researcher, Signalling System, Signalling & Telecommunications Technology Division



1. Foreword

The current necessary for driving electric rolling stock flows from overhead wires, then passes through vehicles and rails before returning to substations. However, there is a possibility that the current may induce a malfunction of the track circuits. Although allowable values have been specified for vehicles so that track circuits do not malfunction even in abnormal situations such as broken rails, there are some low-frequency track circuits which have small allowable values, and this has started to restrict the development of new vehicles. Accordingly, RTRI studied/investigated ways of preventing malfunction in abnormal situations, by encoding track circuit signals and verifying the code with a simple method so as to increase allowable values. Then, RTRI experimentally manufactured the equipment and performed the validation.

2. Outline of measures to prevent interference

In its investigation of ways to prevent interference, RTRI considered the use of simple encoding without changing signal frequencies, and studied/investigated a method that minimizes replacement of the equipment, as far as possible. Finally, RTRI adopted BPSK (Binary Phase Shift Keying) modulation by switching the polarity of transmitted signals through the use of a semiconductor switch, according to the codes (Fig.1). A modulator is added, while the conventional transmitter is used without change. Although the receiver has to be replaced, it is not necessary to replace the peripheral equipment on the rails (Fig.2). Regarding the codes, the speed of operation was increased by continuously flowing fixed codes in a seamless manner, and by starting to read the codes from an arbitrary position at the receiver. There is no fixed code, and the code is chosen so that any shifted code can be treated as the same code.

RTRI studied/investigated codes, modulation speed, and the verification method under a condition where the track circuit was configured with a length of up to 5 km, using a frequency of 25 or 30 Hz. (1) The time required for the track circuit to operate from the cut-off status when the train began moving is set at about 2 – 3 sec. (2) The probability of malfunction caused by interference where the track circuit should normally be cut off at the imbalance of 100% is set at about $1 \times 10^{-9} - 10^{-10}$/h. (3) In the case of setting the C/N (carrier to noise ratio) at 10 dB and the BER (bit error rate) at 2.27×10^{-5} in the normal state, the probability of track circuits being operated incorrectly due to interference where the track circuits should normally continue to operate, is set at about once in 100 years, and in 100 track circuits.

3. Evaluation by RTRI

Through the use of prototype equipment, RTRI validated the characteristics regarding transmission/reception levels and the characteristics regarding short circuits, and confirmed that there is no change compared with the conventional characteristics.

In addition, RTRI also evaluated the transmission error characteristics. RTRI evaluated the characteristics for sinusoidal disturbance and white noise disturbance (Fig.3), and confirmed that no problem exists even if the current data obtained at a substation is reproduced as additional disturbance.

4. Evaluation by tests at the site

RTRI provisionally installed the test equipment on a commercial line and operated it for about one month. Although the distance was 6.17 km rather than the 5 km used in the tests, RTRI confirmed that transmission was definitely performed, and also confirmed that train detection was carried out in the normal way. The BER was 2.77×10^{-5}, which was smaller than the assumption in the experiments. However, it is considered that this is because the interference generated by the vehicles was small. Regarding the operation of the track circuit when the train began moving, the time taken to operate was also confirmed to be two to three seconds.

5. Conclusion

By applying this technique, the allowable value was able to be set as 0.9 A instead of 0.3 A, and the effectiveness was confirmed. From now on, RTRI plans to promote practical application of the technique. Further, BPSK modulation can be used to carry multiple information on the track circuit, but this is a future challenge.

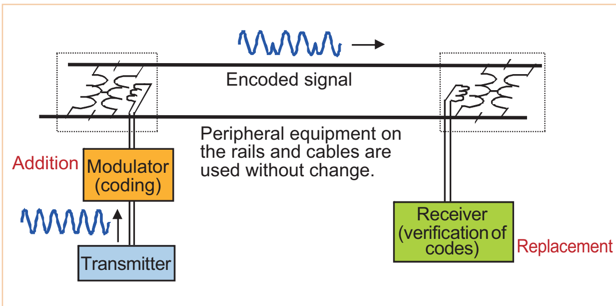


Fig.2 Application method of interference countermeasures

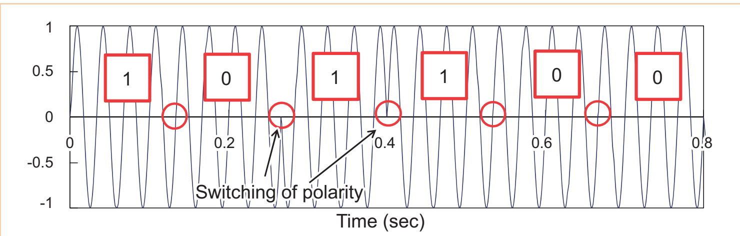


Fig.1 BPSK modulation waveforms by polarity switching

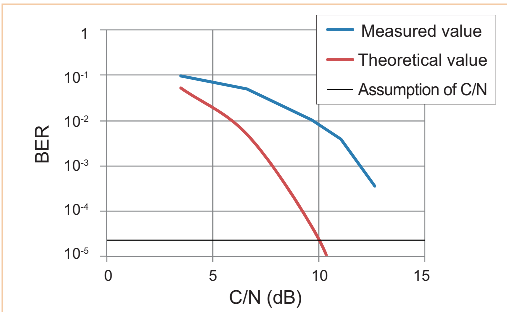
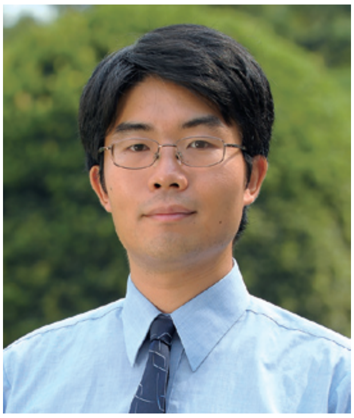


Fig.3 BER against the white noise

A Study on the Practical Application of High Capacity Laser Communication Technology to Railways

Shingo NAKAGAWA
Researcher, Passenger Information Systems, Transport Information Technology Division



1. Introduction

Recent years have seen remarkable progress in mobile communication technologies. On Japanese railways, in-train internet connection service has begun. In such circumstances, having an eye to the laser communication technology that is already proven in the field of fixed section-to-section communications, we have carried out research and development work for a high capacity optical communication system offering practical application of this technology as a means of ground-to-train communication.

2. Developed system

The system we have developed, as shown in Fig.1, is a so-called laser scan communication system. Both the on-train communication device (mobile station) and its ground counterparts (base stations) emit beacon infrared lights as their identifying signals and transmit data between them by sending out a laser beam to each other with their beacon signals as the targets. Even in a situation where the relative positions of the ground and the on-train communication units change rapidly, they can keep track of each other through adjustment of their internal movable mirrors. Also, the system contains a handover function to switch rapidly and dynamically from one base station to another in response to the running speed of the train, which enables continuous communication.

Shown in Fig.2 is an external view of the device. The communication devices were designed so that they could be easily installed on the train and at the trackside. The design parameters also include a transmission distance of approximately 300m and a transmission rate of approximately 1Gbps as the theoretical values. A communications test was conducted with two settled communications devices. This achieved a data transmission rate of 923Mbps using TCP at a transmission distance of 320m.

3. Field test on a railway line

To investigate the feasibility of applying laser communication technology to railways, we tested the system we had developed with the co-operation of JR-West (West Japan Railway Company) using a commercial train on a conventional line. As shown in Fig.3, with three devices set up on the ground and one device in the conductor's cabin of the last car of the train, continuous communication was tested while a handover was being implemented from one base station to another. As a result, we could obtain a transmission rate ranging from approximately 500 to 700Mbps at a train speed of approximately 130km/h. (Fig.4) The handover took approximately 0.4 seconds due to vibrations of the train as shown in Fig.5. In a bidirectional transmission test with high-definition video, however, little disturbance was observed in the pictures. It was particularly evident, in the test using TCP, that we could see the video without observing any effect caused by the handover.

Furthermore, similar communication tests were conducted on a Shinkansen line. Since there was only one base station, we did not evaluate the performance of the system during a handover. Although in all of our six tests no communication could be established and data transmission was not possible, the two devices could track each other for a maximum of approximately 0.7 seconds at train speeds up to 270km/h.

By conducting these tests, we were able to verify the applicability of the system we had developed to railway environments. At the same time, problems that will need to be solved in the future were identified, such as the handover time and the influence of glass in train windows. We intend to continue our efforts to bring the system to perfection in pursuit of its practical application.

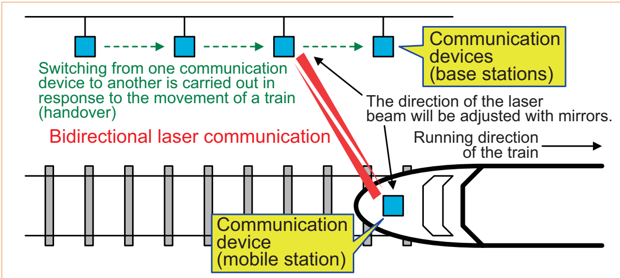


Fig.1 Optical communication using laser scan communication system on a railway line

Fig.2 Appearance of the communication device

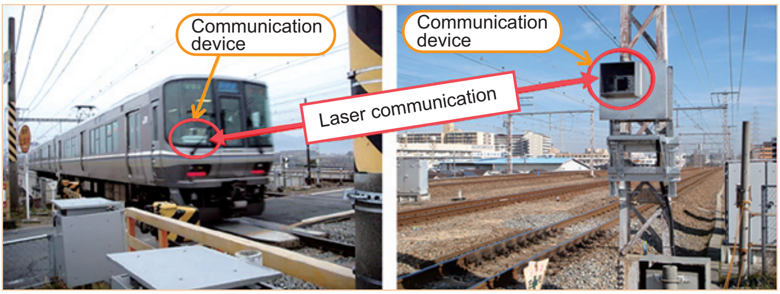


Fig.3 View of the field test on a railway line

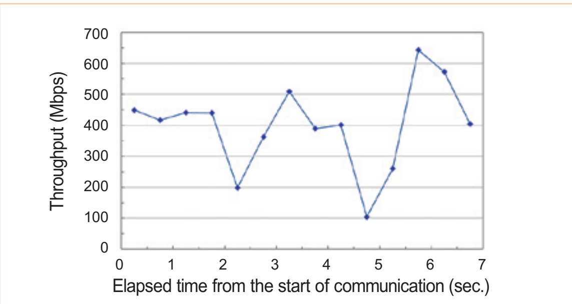


Fig.4 Result of throughput measurement test

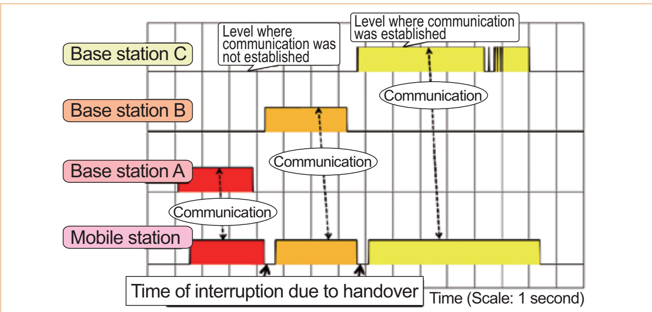
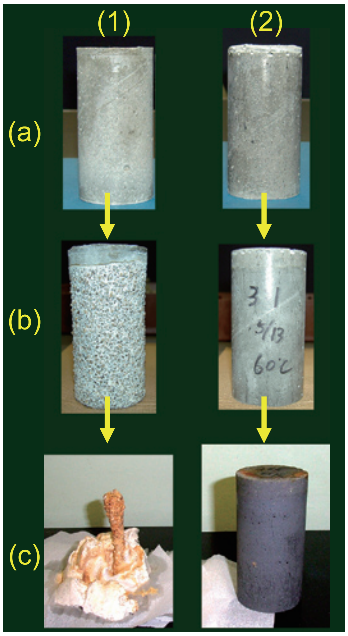


Fig.5 Result of handover performance test

Research Regarding New Environmental Load-Reducing Concrete Using Coal Ash by Employing Geopolymer Method

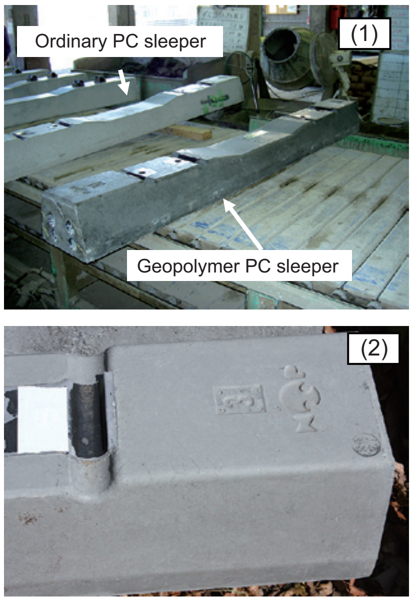
Motoki UEHARA
Senior Researcher, Concrete Materials, Materials Technology Division

Global warming has developed rapidly in recent years, and the reduction in carbon dioxide emissions has become an important theme in all sectors of industry. In particular, Portland cement is known to discharge a huge amount of carbon dioxide of approximately 750 kg when one ton is manufactured, and the reduction in carbon dioxide emissions has been studied actively. Recently, geopolymer cement, which does not use Portland cement, has drawn attention as new material to suppress the generation of carbon dioxide. This is a technology to react active powder with the alkali silicate solution in a polymerization and curing process with respect to the alkali such as coal fly ash, sewage calcined sludge and calcined kaolin, and can reduce carbon dioxide by approximately 80% compared to ordinary cement. Furthermore, the geopolymer concrete is material superior in reducing the environmental load in that a large amount of industrial by-products such as coal fly ash can be used. This geopolymer concrete has characteristics of superior durability compared with ordinary concrete as shown in Fig.1 and various applications are studied. In order to utilize this geopolymer concrete for the railway, we manufactured geopolymer PC sleepers made mainly from coal fly ash on a trial base by mix proportions in Table 1 in conformity with the standard of the post-tensioning type No. 3 PC sleeper specified in JIS E 1202. Figure 2 shows photos of the manufactured geopolymer PC sleeper. In comparison with sleepers made using ordinary cement, the geopolymer PC sleeper shows a slightly dark color reflecting the color of unburnt carbon in the coal ash fly, and a dark gray color in a water-wet state ((1) in Fig.2), and a gray white color in a dry condition ((2) in Fig.2). Generally, in the PC sleeper production cycle in a Japanese sleeper factory, hardening treatment is performed by steam curing in the nighttime and after a sleeper is demolded from the form the following day, prestress is applied. The compressive strength of geopolymer concrete manufactured on a trial base was 69.3 N/mm^2 at the age of one day, which is higher than the basis value of 14.7 N/mm^2 at the point of demolding and higher than that of 39.2 N/mm^2 at the point of prestress application. This means that geopolymer PC concrete can be manufactured in an ordinary production cycle of a sleeper factory in Japan. In addition, no problems with PC steel rod elongation were recognized at the point of prestress application, which clarified that geopolymer PC sleepers can be manufactured in a process similar to that for ordinary sleepers. Table 2 shows the results of performance confirmation testing for the sleeper conducted in accordance with required performance specified in JIS E 1202. All tests showed no cracks a the guarantee load level, and produced a larger breaking load than the basis value, thereby confirming that the load-bearing capacity of the manufactured No. 3 geopolymer sleeper satisfied the required level of performance in JIS E 1202. Currently, we are proposing an improvement method of workability and proceeding with its practical application so that sodium silicate solution, which is inferior to potassium silicate solution in workability but is low in price and from which cost reduction can be expected, can be used.



(1) Ordinary cement mortar, (2) geopolymer mortar, (a) Before soaking test, (b) one week later, (c) four months later

Fig.1 Geopolymer mortar and ordinary cement mortar exposed to 10% H_2SO_4 solution



(1) Immediately after completion (damp)
(2) One month later (dry)

Fig.2 Photos of the geopolymer PC sleeper

Table 1 Mix proportions of geopolymer PC sleepers

Unit weight (kg/m^3)						
FA	BS	KOH	SiO_2	Water	C	S
456	24	140	47	109	850	659
		Water glass*1 = 296				

FA: JIS Grade 1 fly ash; BS: blast furnace slag (Blaine specific surface area = 4,000 cm^2/g) *1 : water glass was manufactured by mixing and dissolving KOH, SiO_2 and water; C: coarse aggregate; S: fine aggregate

Table 2 Results of sleeper performance confirmation tests conducted in accordance with JIS E 1202 (Prestressed concrete sleepers-Post-tensioning type)

	Bending test at rail position		Bending test at center of sleeper		Pull-out test of fastening insert	
	Guarantee load	Destruction load	Guarantee load	Destruction load	Guarantee load	Destruction load
Acceptance value	77 kN	159 kN	45 kN	92 kN	30 kN	50 kN
Geopolymer PC sleeper	127 kN (No cracks*)	193 kN	66 kN (No cracks*)	142 kN	No cracks*	108 kN

* No cracks occurred at the guarantee load.
Numerical values in parentheses show loads at which cracking occurred.

Development of a Silent Steel Railway Bridge

Tsutomu WATANABE
Researcher, Structural Mechanics, Railway Dynamics Division

A number of steel railway bridges have been constructed in Japan.

The advantages of steel railway bridges are: the feasibility of a long span structure due to the high-tension strength of the steel, the ease of on-site construction, and the ease of quality control that comes with factory manufacturing. On the other hand, it has been pointed out that steel railway bridges generate a large amount of structure-borne noise since the bridge members have thin plate structures that are likely to vibrate. Therefore, depending on the circumstances, the construction of steel railway bridges in urban areas tends to be avoided. In developing measures to limit or prevent structure-borne noise, RTRI focused on improving the performance of insulation to reduce the vibration generated by trains running across the bridge, and then developed a new type of steel railway bridge where the track and the reinforced concrete (RC) deck are elastically supported by resilient materials.

1. Outline design of a silent steel railway bridge

Figure 1 shows the outline design of a silent steel railway bridge. We adopted floating ladder track which offers excellent performance in terms of reducing vibration, and the RC deck is supported by resilient materials. The floating ladder track has a load distribution effect due to the high bending rigidity of the ladder sleepers in the longitudinal direction and a load transfer reduction effect thanks to a low supporting coefficient of the track. The floating RC deck constitutes a heavy mass spring system which supports the RC deck by means of resilient materials, and the deck reduces the effects of acceleration forces being transferred to the structure mainly in the range of frequencies below 100Hz.

These structures improve the insulation performance against the vibration generated by trains running over the bridge and they can also reduce the vibration of each member of the steel railway bridge which becomes a source of structure-borne noise.

Further, we are assuming that this type of bridge would be constructed in urban areas where there are strict limitations on structure-borne noise. In Japan, the type of bridge constructed in urban areas tends to be a through bridge on which the track is carried by the lower horizontal members of the structure. Therefore, the floating bridge is a type of through bridge. As floating ladder track has been adopted for the track structure, the level of the rails can be kept low, so permitting this type of bridge to be used even where there are severe restrictions on the space available such as below girders in urban areas.

2. Vibration reduction effects of a silent steel railway bridge

Figure 2 shows the full-scale model bridge installed on the test track inside the premises of RTRI. We demonstrated in quantitative terms how effective a steel railway bridge is in reducing structure-borne noise. We did this by performing impact experiments and train-running experiments. In order to check the structure-borne noise reduction effect for the steel railway bridge, the impulse vibration experiment and train-running experiment were conducted using different supporting conditions for the ladder sleeper and the RC deck.

Figure 3 shows an example of the results of the experiments. We can see that compared with the vibration velocity level of the main girder web of a rigid support structure, that of the silent steel railway bridge is reduced by 10.1dB(A) at a train speed of 40 km/h. Moreover, we can see that compared with the accelerance of the main girder web of the rigid support structure, that of the silent steel railway bridge is reduced by around 50Hz.

This study received subsidies from the Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

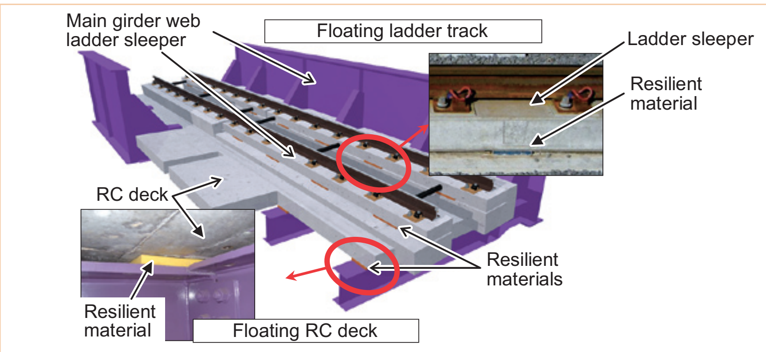
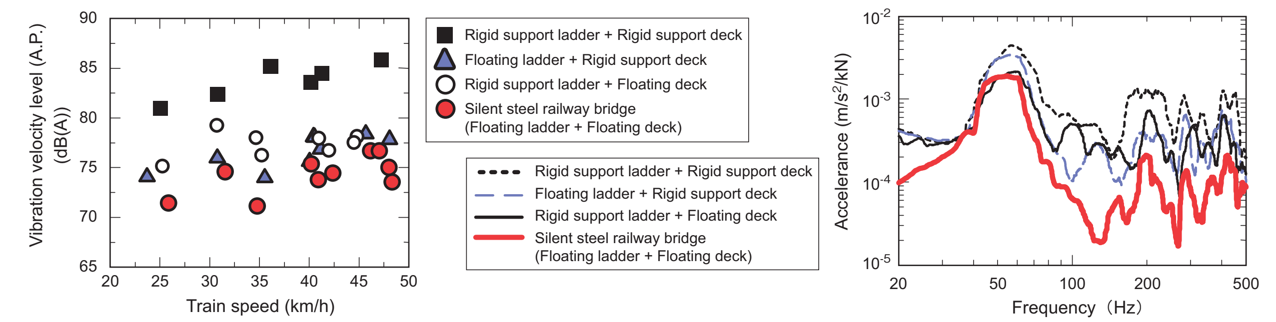


Fig.1 Outline of the silent steel railway bridge

Fig.2 Full-scale model bridge



(a) Vibration velocity level of the main girder web with a train speed of 40 km/h

(b) Accelerance of the main girder web

Fig.3 An example of results from the experiments