Newsletter on the Latest Technologies Developed by RTRI

Railway Technology Avalanche

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GENERAL INFORMATION

ARTICLES

Improving the Safety and Environmental Compatibility for Sustainable Railways

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It is the chief mission of railways to transport many people and large volumes of freight safely to their destinations. The Railway Technical Research Institute (RTRI) is an organization that engages itself in research and development towards building railway systems that are safe, comfortable, economical and compatible with the environment. Employing some 400 researchers, RTRI puts in about ¥3,400 million ($30 million) to carry out 300 or so R&D projects annually. The Research & Development Promotion Division of RTRI is responsible for planning R&D projects, checking progress, and evaluating the results of those projects.

We think that improving the safety and environmental compatibility of railways has become especially important nowadays, from the point of view of making the general public feel at ease, and benefiting railway usersin particular. Two serious railway accidents, such as we had never experienced in Japan before, occurred in the past year. The first was the derailment of a Shinkansen train running at a high speed during a big earthquake, and the second was the overturning of a commuter train due to excessive speed on a sharp curve. In order to restore society's trust in railways, we will tackle research and development towards the safety of railways in cooperation with the railway operators.

Among natural disasters, earthquakes are an especially difficult problem to deal with. This is because preventative measures against earthquakes depend largely on a presupposed maximum magnitude. Leaning lessons from the above accidents, we started research and development on new viaduct and tracks which have greater resistance to earthquakes, and on measures to keep trains on the tracks, even if they derail.

In order to permit railways to continue serving as one of the principal transportation facilities for the next generation, it will be necessary to make them fully compatible with the global environment. As a measure to save energy, we are focusing on research and development for a power-recycling train that reuses regenerative braking power, stored by the train or in wayside equipment. We are also developing a fuel cell car as part of our efforts to reduce emissions as CO_2.

In order to create sustainable railways, we need to promote new projects of safety and environment and to carry out research and development to attain the objectives of improving the safety and environmental compatibility. In this respect, I consider it necessary to build a network that pools the knowledge of railways around the world. Hoping for the lasting progress of the railways of the world, I would ask all concerned people for their cooperation in widening the sphere of joint research activity.

熊谷則道

Fifth China-Korea-Japan Railway Research Technical Meeting June 21st-23rd, 2005, Tokyo, Japan

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1. Introduction

In China, a country that has achieved rapid economic progress under its open, reformative regime, it has become an urgent necessity to develop and maintain high-speed transportation systems, including railways. In fact, the country has launched several passenger railway construction projects. In South Korea, the Korea Train Express (KTX), boasting a top speed of 300 km/h, was opened in 2004. At present, the country is testing a faster train, HSR-350X, whose maximum speed is expected to reach 350 km/h. The China Academy of Railway Science (CARS) and Korea Railroad Research Institute (KRRI) are playing the lead role in the development of railway technology in the respective countries. The Railway Technical Research Institute of Japan (RTRI) had carried out joint studies with each of those research organizations. In August 2000, the three research organizations signed a Memorandum on the Opening of the China-Korea-Japan Railway Research Technical Meeting with the aim of implementing technical interchange among them effectively and efficiently. At that time, it was agreed that a seminar should be held annually in one of the three countries for the presentation of results of joint studies. The first seminar was held under the auspices of KRRI in Seoul in 2001. This year marks the fifth seminar.

2. Fifth China-Korea-Japan Joint Research Seminar

The Fifth China-Korea-Japan Joint Research Seminar was held under the auspices of RTRI on June 21st - 23rd, 2005. The seminar was attended by 14 persons, including vice-president ZHAO, from CARS, and nine persons, including vice-president CHOE, from KRRI, as well as persons from RTRI. At the opening, president AKITA of RTRI delivered a speech of welcome, followed by greetings of vice-president ZHAO and vice-president CHOE. After that, proposals for new research themes were presented. On June 21-22, separate meetings were held on individual themes of joint research. At those meetings, each working group (WG) of researchers of the three institutes presented the results of research and discussed their future activities. The themes of joint research under way, and the new themes adopted at the present seminar are shown in the table. On June 22, a technical tour was also made to Hino Civil Engineering Laboratory and Kunitachi Research Institute. On the final day, keynote lectures on the status of recent activities of the individual research institutes were delivered, and the representatives of the individual working groups presented the contents of discussions at separate meetings, by theme. Finally, at Tachikawa Palace Hotel, director KUMAGAI from RTRI, director SHI from CARS and vice-president CHOE confirmed the minutes of the joint studies and the seminar was closed.

Sachiko YOSHIE Toru MIYAUCHI

3. Next Seminar

It was decided that the next seminar should be held under the auspices of CARS in Beijing in September 2006. It is expected that this seminar, held at regular intervals, will not only promote technical interchange with China and Korea, which are making rapid progress in railway technology, but also help strengthen the international competitiveness of Asian countries in the field of railways, and contribute to interchange among researchers of different countries.

Table 1. Collaborative Research Themes

Institute	Current themes	Newly agreed themes
CARS, KRRI and RTRI	• Research of Railway Intelligent Transportation System • Development of the Improved DC Ground Fault Relay System • Strategy for Improving Operation Efficiency of Railway Transportation in East Asia • Exchange of Information (Business items)	• Study about Abrasion Mechanism of Wheel/Rail Contact • Algorithm of Automatically Processing Schedules for Operation of Vehicles and Crews II
CARS and RTRI	• Tractive Performance of Rolling Stock for High-Speed Trains • Algorithm for Automatically Processing Schedule for Operation of Vehicles and Crews	• Research on Optimizing the Match Relationship of the Rail and Wheel by Improving the Strength of Wheel • The Standard Establishment of Hollow Axles for High-Speed Tractive and Trailing Stock • The Study of Structure-Radiated Noise from High Speed Train on Railway Bridges
KRRI and RTRI	• Application of IT Technologies to Maintenance Work of Railway Facilities	• Floating Precast Concrete Slab Track
CARS and KRRI	• Analysis and Solution of Railway Rolling Stock Wheel Spalling under Different Service Conditions • Research of Safe Evaluation and Risk Defense System of High Speed Railway System • Study of Defend Measures on Train Crash • Standardization Research of Railway Criteria in China, Japan & Korea • Digital Simulation of Air Braking System	

Detection of Concrete Exfoliation by Active Infrared Thermography

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As a means of detecting exfoliation of the concrete covering of a tunnel, viaduct, etc., infrared thermography that measures the difference of temperature at the concrete surface by using an infrared camera is attracting attention. There are two types of infrared thermography: passive infrared thermography that measures a temperature difference caused by meteorological conditions, and active infrared thermography that measures a temperature difference caused artificially by using a heating apparatus (Fig. 1). Although active infrared thermography requires a heating device, it permits measuring the difference of temperature at the concrete surface without being influenced by weather conditions and hence it has been applied to inspect concrete tunnels. In the case of an elevated concrete bridge, however, it is necessary to irradiate the heat onto the concrete surface from the surface of the ground since the heat source can hardly be set close to the concrete surface. For that purpose, we developed a new heat source using a xenon arc lamp and subjected it to laboratory and field tests.

Unlike the tungsten halogen lamp, the xenon arc lamp is a point source, the light-emitting part of which is a small spot offering a highly condensed beam of light (Fig. 2). With the xenon arc lamp, therefore, it is possible to secure a large irradiation energy density even for an object located at a considerable distance. The irradiation energy density measured at a point 10 m away from the xenon arc lamp was $15 kW/m^2$, about three times that of distant infrared irradiation equipment.

Specimens having an artificial void prepared for active infrared thermography using a xenon arc lamp were subjected to a laboratory test. Each of the specimens embedded with a styrene foam block simulating a void in concrete produced by exfoliation was heated by the xenon arc lamp and photographed by an infrared camera. The test results are shown in Fig. 3. The specimens, from left to right, had a simulative void depth of 10 mm, 20 mm and 30 mm, respectively. From the test results, it can be judged that active infrared thermography using a xenon arc lamp permits detecting exfoliation of concrete up to about 30 mm in depth which is a common design concrete covering depth of viaducts.

With the aim of confirming the applicability of the method to actual viaducts, a special inspection vehicle (Fig. 4) was prepared and a field test was carried out by using it (Fig. 5). Examples of the infrared images obtained are shown in Fig. 6. In the passive infrared thermographic image before irradiation by the xenon arc lamp (Fig. 6 (a)), several high-temperature parts which were considered due to exfoliation were observed. In the active infrared thermographic image after irradiation by the xenon arc lamp (Fig. 6 (b)), the exfoliated parts that were observed in the passive infrared thermographic image were observed more clearly. In addition, a high-temperature part which could not be observed in Fig. 6 (a) could be observed in Fig. 6 (b) (the part that is indicated by an arrow). From these results, it was confirmed that active infrared thermography permits detecting concrete exfoliation more accurately than passive infrared thermography. In the future, we have plans to study a technique to judge the soundness of concrete covering using detection results.

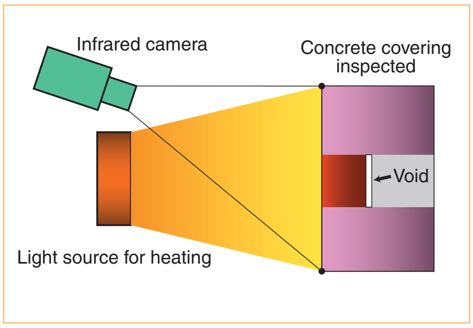

Figure 1. Principle of concrete exfoliation detection by active infrared thermography

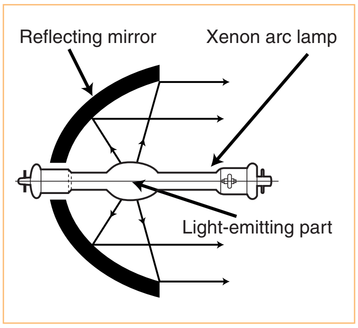

Figure 2. Xenon arc lamp used as light source for heating

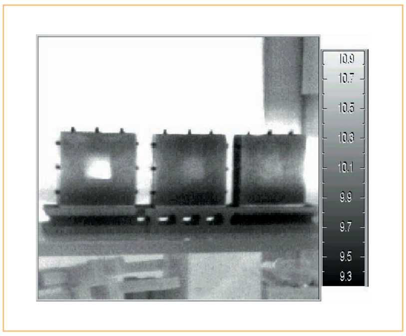

Figure 3. Laboratory test using specimens having simulative void

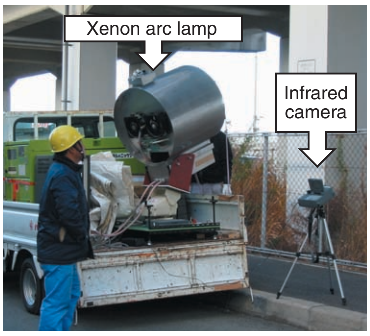

Figure 4. Inspection vehicle

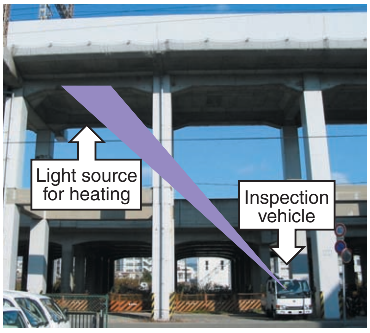

Figure 5. Scene of field test

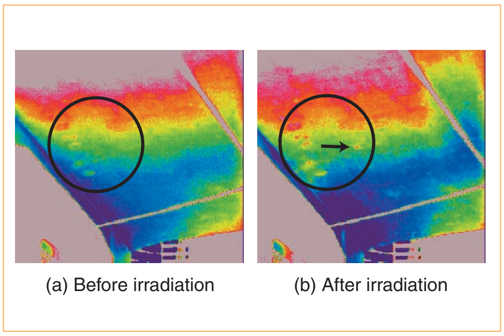

Figure 6. Infrared thermographic images

Development of Concrete Diagnostic System Employing Infrared Camera and CCD Camera

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The exfoliation and falling of concrete linings due to material deterioration or defective work has become a problem. Hammering inspection has been commonly applied to check concrete structures for defects. However, since there are a very large number of concrete structures that need to be checked, the inspectors have a significant burden.

RTRI has developed a diagnostic system that permits the accurately judging of the conditions of anomalies of concrete structures by the combination of images obtained by an infrared camera and a CCD camera. The system offers a new inspection method that is more efficient than hammering inspections.

The system consists of an infrared camera, a CCD camera, a laser range finder and an angle meter (for measuring angle of elevation and angle of deviation). It allows for high-accuracy image processing through integration of the positional information obtained by the range finder and angle meter, the pre-registered information about the infrared camera/CCD camera lenses (aberration and parallax of each lens), etc.

For structures in an open section, such as elevated rigid-frame bridges, the high-sensitivity infrared camera permits checking by a day's change in outdoor temperature alone. In addition, when this system is employed in active infrared thermography, it significantly widens the scope of application of the technique.

The system has been developed specifically for engineers who work at the front line. Therefore, the system is not only easy to use but also provided with application software that permits smoothly executing the inspection, judgment and reporting operations. The main functions of the system are as follows.

- Images obtained by the infrared camera and CCD camera are instantaneously overlapped and displayed on the monitor screen. The density ratio of thermographic and visible images can be set arbitrarily, facilitating judgment on whether the temperature difference shown on the monitor screen is due to the loosening of concrete or whether it indicates loosening of concrete due to cracking.
- By means of orthographic projection (elevation correction) of an image, the image can be automatically transformed into one that was obtained as if it were taken from the right front of the structure.
- By tracing defective concrete parts (loose or cracked parts) displayed on the monitor with the touch pen or mouse, it is possible to automatically measure and calculate their areas and lengths and prepare a list of defective parts.
- The function that displays thermographic images with emphasis on temperatures permits displaying only desired temperature zones in different colors.

The system has made it possible to efficiently and accurately detect the presence and development of loosening or cracking of concrete that can lead to concrete exfoliation in the future, thereby improving the safety of third parties against disasters dramatically.

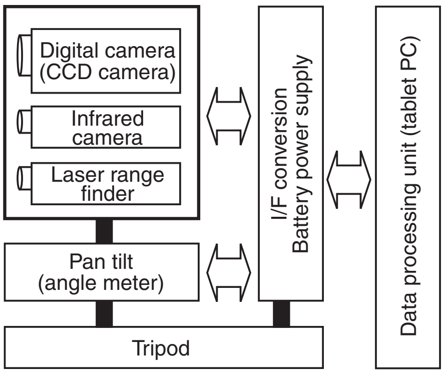

Figure 1. System configuration

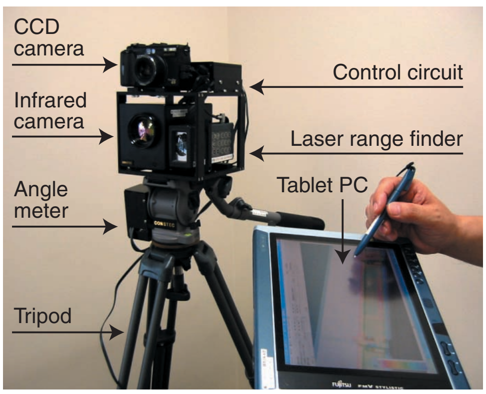

Figure 2. Appearance of system

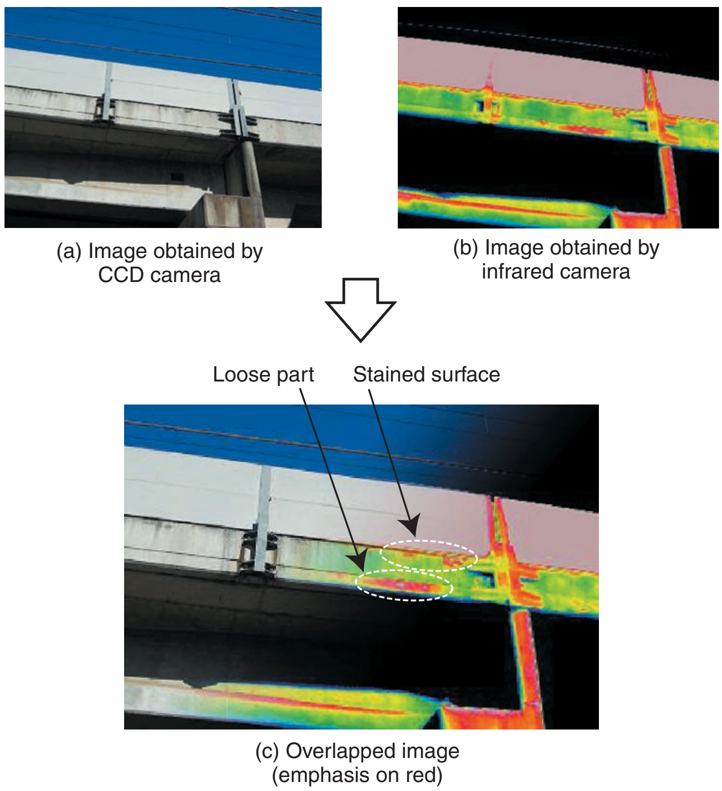

Figure 3. Examples of overlapped images

Tunnel Soundness Diagnostic System

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At railway tunnels, general inspections, which include a judgment on tunnel soundness, are carried out periodically. Since there are many railway tunnels, general inspections take much time and labor. Besides, since the judgment on the soundness of railway tunnels depends much on the manual work of inspectors, it may differ from one inspector to another. We studied a diagnostic system that permits judging tunnel soundness automatically and developed a prototype of the system, with the aim of making it possible to judge the soundness of railway tunnels efficiently and objectively.

The general flow of the diagnostic system is shown in Fig. 1. The main characteristic of this system is that it allows for automatic judgment on both the soundness of the tunnel against concrete spalling and the soundness of the tunnel against anomalies caused by external force and the like by inputting the positions and shapes (length and width) of cracks detected by general inspection to the anomaly development diagram on the system CAD, and selecting the appropriate hammering test results and basic tunnel information by pushing the buttons associated with them.

In terms of tunnel soundness against concrete spalling, the closure, crossing and parallel run of cracks are automatically extracted from the anomaly development diagram on the CAD as shown in Fig. 2 and the tunnel soundness (α, β, γ) judged, with consideration given to the presence or absence of water leakage and the results of hammering tests. This judgment is done for each 1 m × 1 m mesh.

With respect to tunnel soundness against anomalies caused by external force and the like, the system employs an algorithm that judges the soundness from the results of collation with the appropriate pattern of cracks and from the causes of anomalies that are automatically determined from the possibility of occurrence of anomalies. The patterns of cracks show combinations of possible cracks and compressive failure based on three divisions (uneven earth pressure, plastic earth pressure, vertical earth pressure) of anomalies caused by external force and the like and indicate the positions of cracks and compressive failure which belong to each of the divisions. For the diagnostic system, 50 different crack patterns have been prepared based on the results of load tests with small-scale lining models and various field tests. Cracks in the lining inner surface are sequentially collated with the crack patterns as shown in Fig. 3, and when a corresponding crack pattern is found, the cracks are rated and weighted based on the crack length, width, angle and the like. Anomalies caused by external force and the like have strong connections with the topography, geography and so forth of the site of the tunnel, as well as the tunnel structure. Therefore, a flowchart for judging the probability of anomalies due to uneven pressure, plastic pressure or vertical pressure has been prepared from the basic tunnel information for soundness judgment.

For diagnostic results, the system outputs rough soundness and presence or absence of anomalies for each span so that the points of important anomalies can be seen at a glance (Fig. 4). When any of the DETAIL buttons at the extreme right are pushed, the system outputs detailed judgment results and comments on the point of anomaly.

As described above, we have developed a system for automatic judgment on the soundness of railway tunnels that is carried out as part of the general inspection. It has been confirmed that the prototype system is capable of automatically judging tunnel soundness with a fair degree of accuracy using inspection data obtained from actual railway tunnels (100 spans of 30 tunnels).

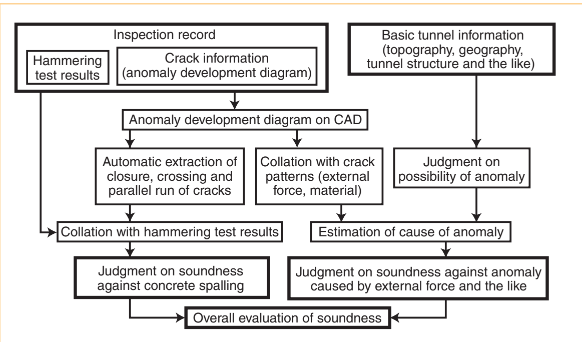

Figure 1. General flow of soundness diagnostic system

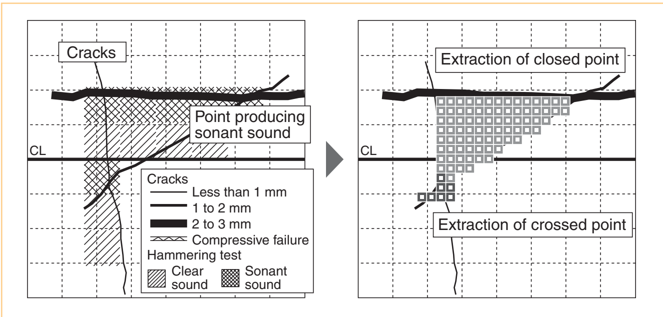

Figure 2. Example of anomaly development diagram on CAD and automatic extraction

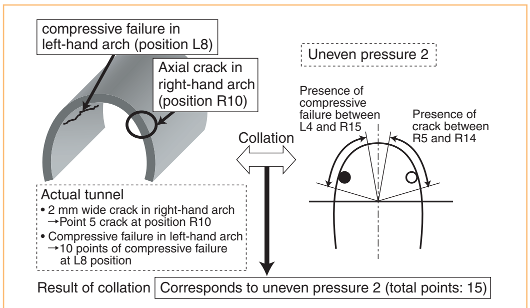

Figure 3. Example of collation with crack pattern

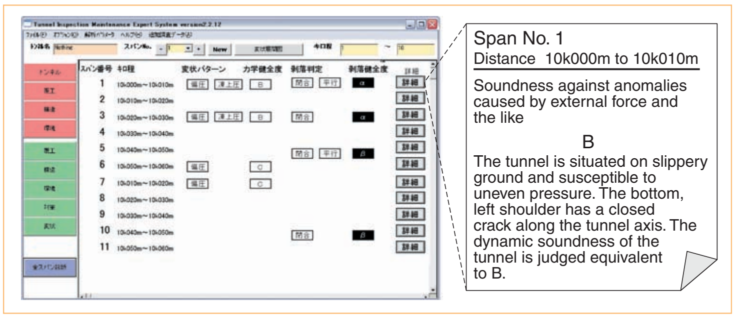

Figure 4. Example of diagnostic result output screen

Fire Resistance Design Method for Structure Built above Railway Track

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From the standpoint of construction work efficiency, most station buildings and other structures utilizing space above railway tracks (Fig. 1) are of steel frame construction. Therefore, due consideration must be given to their fire resistance and safety in a fire. However, if the steel frame is provided with a fire resistive covering as are ordinary buildings, there is a fear that the covering may exfoliate under the vibrations of running trains. Besides, the fire resistive covering may increase the cross-section shapes of the columns, preventing the smooth flow of passengers in narrow places. On the other hand, compared with the other floors, the floor at the same level of the railway track (track floor) is characterized by these facts: ① Flammable objects are limited to the kiosks and cars and it is unlikely that large volumes of unspecified flammables will be brought in, ② The floor height is determined almost entirely by the train cross section and ③ The floor generally offers wide open space with few outer walls. Therefore, establishing a rational fire resistance design method for the track floors that have those characteristics is meaningful from the standpoint of building safety and economy.

The fire resistance design of a building consists of verifying the structural safety of the building against possible fires. In fire resistance design, the fire resistance and safety of the building are evaluated by using the flow shown in Fig. 2. With the aim of establishing a fire resistance design for track floors, we first investigated the flammables on the station yard. As a result, it was found that the kiosks on the platform can be a major origin of fire. Then, in order to grasp the characteristics of a kiosk fire, we carried out a combustion experiment with a full-scale model of a kiosk (Fig. 3). In the experiment, the combustion weight, flame temperature, flame shape, radiant heat quantity, etc. were measured. On the basis of the experimental results, we proposed a fire model that permits calculating the gravitational combustion speed and flame shape.

Fig. 4 shows the measured gravitational combustion speed and the value calculated by using the fire model. The two values agreed fairly well. As shown in Fig. 5, the track floor space is divided into three zones—fire zone, near-ceiling zone and other zone—and the temperature rise of each of the steel frame members of the track floor in a kiosk fire is calculated by using a heat balance equation prepared from the heat balance between each of the zones and structural members (Fig. 6). Finally, the stress and strain produced in the frame by the temperature rise of the members are analytically obtained to demonstrate that the building will not collapse and evaluate the fire resistance and safety of the building.

This fire resistance design method verified that even a track floor without fire resistive covering has sufficient fire resistance and safety. So far, it has been applied to the design of more than 10 buildings utilizing space above the railway track. In the future, we intend to carry out studies on the flow of smoke, the evacuation/safety of passengers, etc. in a fire.

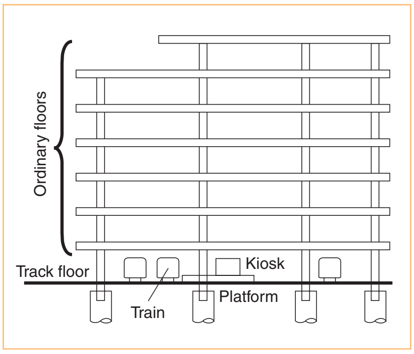

Figure 1. Building utilizing space above railway track

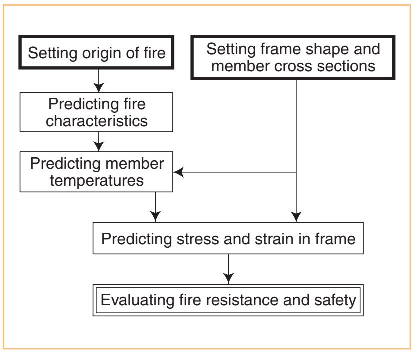

Figure 2. Fire resistance design flow

Figure 3. Combustion experiment using full-scale model of kiosk

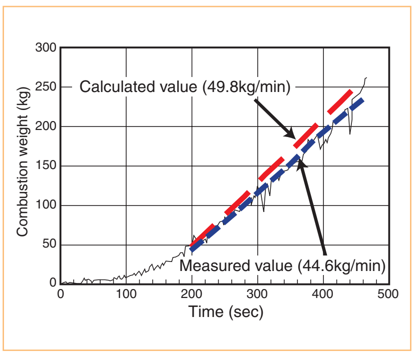

Figure 4. Relationship between combustion weight and time

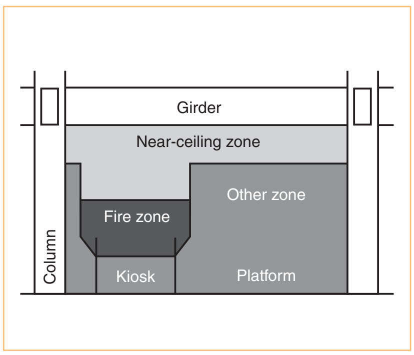

Figure 5. Division of track floor into zones

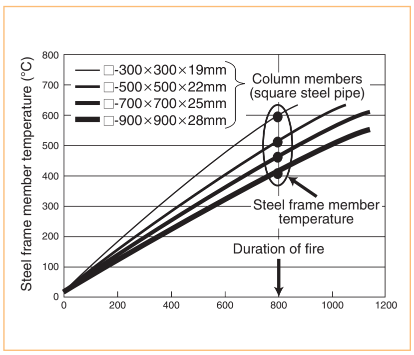

Figure 6. Examples of calculation of steel frame member temperature