Newsletter on the Latest Technologies Developed by RTRI

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"Incredible" and "Inevitable" Events

Mitsutoshi INAMI
Vice President

On March 11, 2011, a great earthquake and tsumani struck the Tohoku district, a north-eastern part of Japan, destroying hundreds of towns and claiming 28,000 lives.

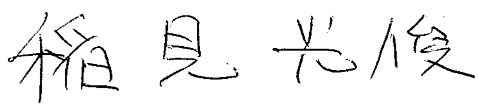
If accidents and disasters are classified into "inevitable" and "incredible" events, the earthquake that occurred in the off-shore area of the Sanriku district was an "inevitable" event, as earthquakes have frequently occurred in that area. However, its magnitude of M9 was certainly an "incredible" figure. The subsequent tsunamis represented an "inevitable" event, as some towns had constructed 10 m-high seawalls to prepare for such tsunamis. Nevertheless, the fact that the tsunamis were far higher than that was an "incredible" event.

At the Fukushima Nuclear Power Plant No.1, the nuclear reactors were subject to an emergency shut down when the earthquake occurred. This was an "inevitable" event at the initial stage, which turned into an "incredible" event, however, when subsequent tsunamis completely deprived the plant of power and reactor cooling capabilities. It is anticipated that it will take a long time for normal operations to be completely restored at the power plant.

Railways and other social infrastructures have to be constructed and maintained on the assumption that they are subject to earthquakes at some time in the future. This is believed to be the fate of the Japanese archipelago as it rests on earthquake nests. Although all conceivable countermeasures were taken as far as possible against earthquakes, "incredible" events have taken place every time that an earthquake has occurred, causing serious damage and loss of invaluable human lives. If people do not forget "incredible" events that have happened and utilize them as a valuable lesson, however, even an "incredible" event will turn out to be "inevitable", and "inevitable" events will be prevented with human efforts and wisdom.

For the Shinkansen railway that has been designed to withstand earthquakes since its inauguration in 1964, the railway operators are carrying out work to reinforce the structures and make the railway more earthquake-resistant based on lessons learnt from the Great Hanshin-Awaji Earthquake disaster that seriously damaged the high speed railway network in 1995. Thanks to these precautionary measures, no passengers were injured or killed when the Mid Niigata Prefecture Earthquake occurred in 2004, though few cars of the train was derailed. The railway operators have been introducing a high-performance emergency stop system and other measures to prevent moving trains derailing or leaving the track. As a matter of fact, all the trains in service stopped safely when the East Japan earthquake occurred on March 11 this year. This is a case where "incredible" disasters were prevented, based on the lessons learnt from "inevitable" disasters.

Along the Tohoku Shinkansen line, a number of ground facilities were damaged by the Earthquake. However, the total route was restored to the original state on April 29, with trains now running on this important transport artery to contribute to the restoration of the Tohoku district.



On April 1, 2011, the Railway Technical Research Institute (RTRI), a juridical foundation, became a public interest corporation authorized by the Prime Minister.
At this juncture, RTRI proclaims its intention to further enrich its research activities, thereby aiming at contributing to the development of railways, science and culture of the country. Your unchanged support and encouragement from now on will be highly appreciated.

Great East Japan Earthquake Disaster

Koichi GOTO
Director, International Affairs Division

A great earthquake, magnitude 9.0, occurred around 14:46 pm on March 11, 2011, at a 24 km-deep submarine epicenter in the sea of the Sanriku District, an area in the north-eastern part of the Main Island of Japan. This was followed immediately afterwards by raging tsunamis that completely destroyed the earthquake-stricken towns and villages. When the Earthquake struck that area, a seismic intensity of 7 was observed at Kurihara City, Miyagi Prefecture, and a level of 6 or slightly more was recorded in wide areas in Miyagi, Fukushima, Ibaragi and Tochigi Prefectures. In view of the chaos and disaster caused by the Earthquake and tsunamis along the Pacific coast, extending from the Kanto District to the north-eastern (Tohoku) part of Japan, the Earthquake was named “the 2011 off the Pacific Coast of Tohoku Earthquake” and the ruins in its aftermath “the Great East Japan Earthquake Disaster.”

The amount of energy released by the Earthquake was about 1,000 times that released by the Hyogo Prefecture Southern Part Earthquake that devastated Kobe City and its surrounding areas in 1995. Figure 1 illustrates the acceleration waveforms of these two earthquakes and reveals that the seismic motion of the Earthquake with large amplitudes lasted for more than 100 seconds. The source mechanism is a reverse fault having a west northwest – east southeast pressure axis at the boundary between the landside and sinking Pacific plates. Figure 2 shows an estimated breaking process of the fault (a distribution of fault slips). Large slips were observed at three points: (1) the epicenter and its vicinity, (2) an offshore area of Iwate Prefecture and (3) the offshore region of Fukushima and Ibaragi Prefectures. Three to four focal regions that had been assumed to trigger earthquakes separately were seemingly interlocked to cause the Earthquake that was unprecedented in the past 1,000 years, with the maximum slippage reaching 23 m. The fault was about 450 km x 200 km in size.

The Earthquake, which completely destroyed the railway networks in the affected area, forced the just opened Hachinohe - Shin-Aomori section of the JR-East Tohoku Shinkansen, to totally suspend train operation. A number of narrow-gauge lines were also wrecked, with many station buildings and tracks lost or washed away on the coastal lines hit by the tsunamis. On Shinkansen lines, however, the Earthquake Early Warning System developed and implemented with support of RTRI effectively cut the power supply immediately after detecting the minor vibration at the initial stage of the earthquake and activated emergency brakes to safely stop all the trains in passenger service (except one derailed in deadhead operation near Sendai station located in an area subjected to large-scale seismic motion). As a result, no human beings were injured either on Shinkansen or on narrow-gauge lines.

After the Earthquake, RTRI immediately started the Disaster Recovery Support Task Force to support the recovery activities of the railway operators. At the request of JR-East, RTRI also surveyed the conditions of landslide areas, examined damaged facilities and derailed rolling stock and assessed the structural vibration experienced in the Earthquake. Then, it proposed recovery work to the railway operator. Thanks to the whole-hearted efforts of railway companies, the damaged railways, both the Shinkansen and the narrow-gauge networks, have steadily been restored to their normal condition, with the Tohoku Shinkansen resuming train operation along the entire route on April 29, 2011. However, it is anybody’s guess when full train operations will restart along the coastal lines in the areas which were decimated and thrown into turmoil. As ever, RTRI will support the railways in their recovery work, promote analysis of the seismic incidents experienced in the Earthquake and launch activities to further improve technological measures to counter the effects of earthquakes.

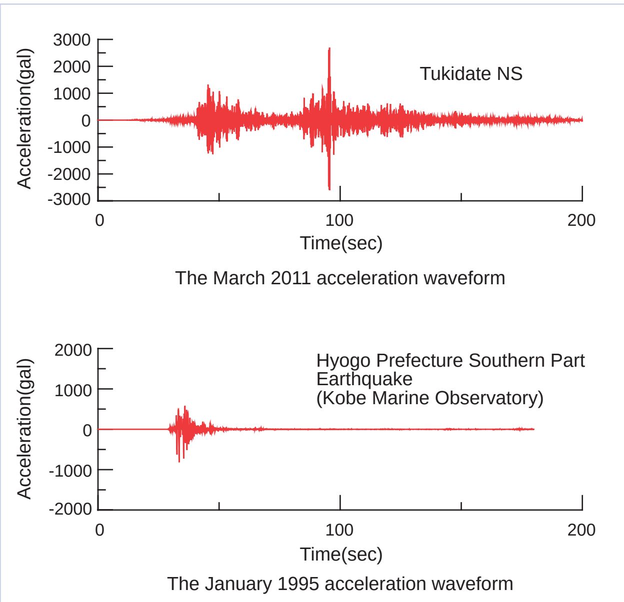


Fig.1 Comparison of seismic acceleration waveforms (source: National Research Institute for Earth Science and Disaster Prevention (NIED))

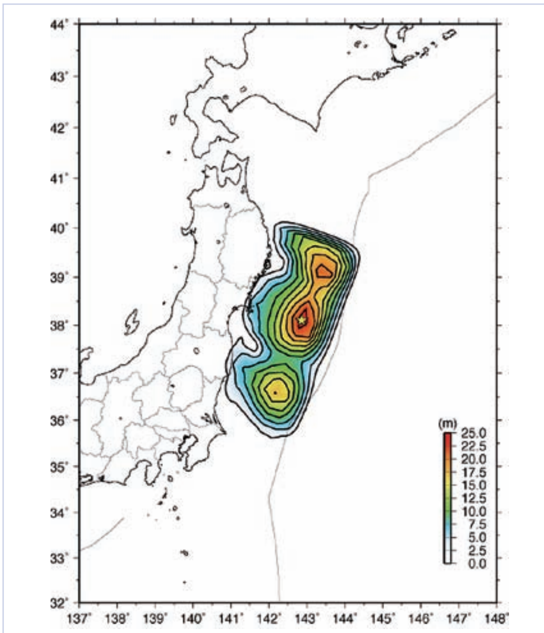


Fig.2 Distribution of fault slips (source: Dr. Yagi, Associate Professor, University of Tsukuba)

Development of the Prestressed Ballast Track

Katsumi MURAMOTO
Senior Researcher, Laboratory Head, Track Structures & Geotechnology, Track Technology Division

A great deal of labour is required for ballast maintenance work on important lines in Japan including the Shinkansen to ensure that they remain fit for high-speed and high-density train operation. One measure to solve this problem is to replace ballast tracks with directly fastened (ballastless) tracks to eliminate ballast repair work, the aim being to achieve a significant reduction in maintenance costs. If the substructure supporting the track has deformed, however, ballastless track necessitates large-scale repair work due to the difficulty of reconstruction thereby potentially increasing the costs of track maintenance. Furthermore, ballast track is far superior to ballastless track in terms of the time and cost required for reconstruction, should the soil structure be damaged to a large extent by a major earthquake or for any other reason. In the circumstances, therefore, the author is now developing the Prestressed Ballast Track (hereinafter referred to as “PSB Track”) as a track structure that allows reconstruction to be carried out easily and with significantly less track settlement than that exhibited by ballast track.

PSB Track has a structure to connect the sleepers and an anchor buried in the track bed with tie rods to provide the required tension and to continuously apply confining pressure on the ballast (Fig. 1). Granular materials, such as ballast, tend to increase in rigidity and strength when placed under confining pressure. According to the results of previous research, it is known that track settlement dramatically decreases when confining pressure equivalent to about 30% of train loads is applied constantly on the ballast. Figure 2 illustrates the results of a repeated loading test of a full-size PSB Track model conducted by RTRI, which proves that track settlement is much less than that of ordinary ballast track. PSB Track also exhibits excellent earthquake resistance because its horizontal resistance is far greater than that of normal ballast track as the sleepers are pressed onto the ballast all the time. Figure 3 shows the results of a test to measure the horizontal resistance (per/sleeper) of a section of PSB Track in the direction perpendicular to the track axis. It also indicates that PSB Track exerts horizontal resistance at least four times greater than that of normal ballast track.

Furthermore, PSB Track allows repair by tie tampers as the need arises. At the same time reconstruction can be carried out easily even when the soil structure has become greatly deformed. In other words, PSB Track is an ideal track structure to rival ballastless track in terms of earthquake resistance and ability to reduce maintenance work, while also enabling reconstruction to be carried out as easily as with ballast track.

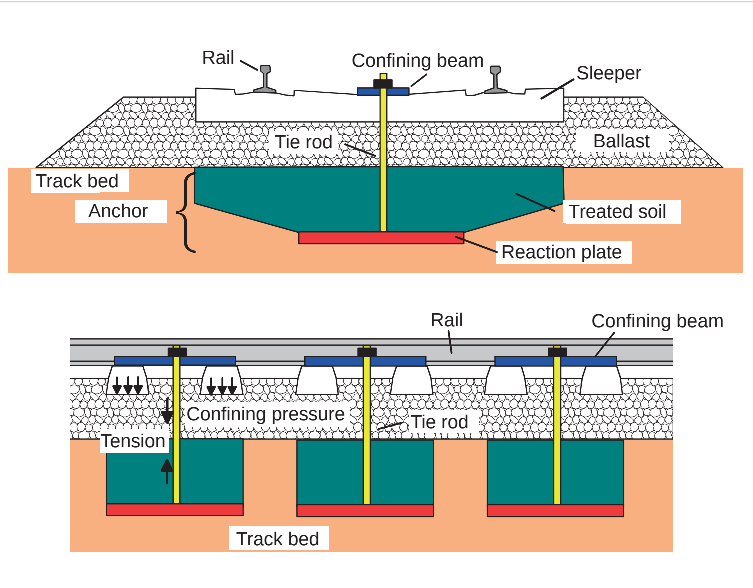


Fig. 1 Basic structure of the Prestressed Ballast Track

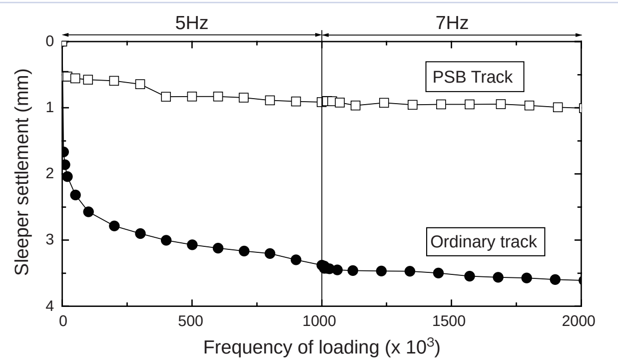


Fig. 2 Results of a repeated loading test on PSB Track (axle load 160 kN)

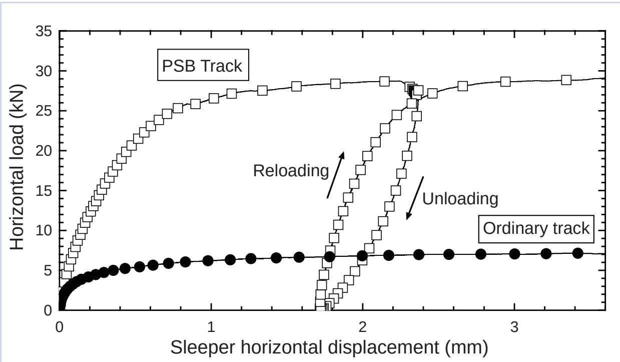


Fig. 3 Results of a horizontal resistance test with PSB Track

Evaluation of the Stability of Rocks on Slopes in Consideration of Weathering

Tomokazu ISHIHARA
Researcher, Geology, Disaster Prevention Technology Division

1. Introduction

The rockfall is one of the slope disaster besides railway lines. In contrast to other types of slope disaster, because rockfalls are caused by various factors including earthquakes, rainfall, and the repetition of freezing and thawing, it is difficult to predict when and where the phenomenon will occur. To evaluate the stability of rock slopes where the phenomenon is anticipated to occur, railway operators conduct site surveys and, based on the results, estimate the risk of rockfalls and implement countermeasures to prevent rockfalls occuring. In most cases, however, these procedures is based on a qualitative judgment through visual observation by expert engineers. In the circumstances, therefore, it is desirable to develop a method to evaluate the stability of rock slopes quantitatively in the usual inspection process.

Bearing in mind the above, in this study the author looks at the case of separation type rockfall, introduces a method to estimate the maximum length (L_a) of falling rocks in a simple manner from the density and tensile strength of the rocks and evaluates the stability of the rocks by comparing the estimated maximum length with the observed length (L_b) of the rocks at the site.

2. Estimation of the size of falling rocks

On rock slopes where columnar joints have developed, unstable columnar rocks are frequently observed, often overhanging and suspended with only the top connected to the base rock. This state can be modelled as rocks are held with the tensile strength at the base rock (Fig.1). Figure 1 indicates that the equation (1) expresses the conditions for a rock having a tensile strength of S_t to hold its own weight W when it is held by the base rock with the tensile strength at the top alone.

$$S_tA \geq W = LA\rho g \quad (1)$$

$$\therefore\ S_t \geq L\rho g \quad (2)$$

The equation (2) gives the maximum length of the rock held by the base rock as:

$$L_a = S_t/\rho g \quad (3)$$

This equation indicates that the maximum length of falling rocks can be estimated based on their density and tensile strength. Figure 2 shows a nomogram to determine the maximum length of a rock having an arbitrary tensile strength and dry density.

3. Estimation of the degree of the decrease in the tensile strength

Weathering usually causes the strength of rocks to decrease. When an unstable rock is separated from a rock slope, it is thought that the weathering causes the strength of the separating plane to decrease.

If the decrease in the tensile strength due to weathering is expressed as the ratio of the tensile strength of the weathered part to that of the non-weathered part, the more a rock has been weathered when assessed observed in macroscopy, the more the tensile strength has decreased. Based on the Fig.3, therefore, it is possible to estimate the tensile strength of the separating plane of a rock from the tensile strength of the non-weathered rock and the degree of weathering observed in macroscopy.

4. Evaluation of the stability of rocks on slope

Figure 4 illustrates a flow chart of the process needed to evaluate the stability of rocks based on the descriptions in the paragraphs 2 and 3.

First, the macroscopic degree of weathering and the tensile strength of non-weathered rocks should be grasped. Next, the tensile strength of the separating plane from Fig.3 should be estimated. Then Fig.2 can be used to determine the maximum length (L_a) of the falling rock based on its density and its tensile strength. Finally, the length (L_b in Fig. 5) of the rocks distributed on the rock slope and the maximum length (L_a) can be compared to evaluate the stability (Fig. 4).

5. Conclusion

It will be necessary to verify the procedure described above by taking measurements in the field and improving the precision of this method in the future.

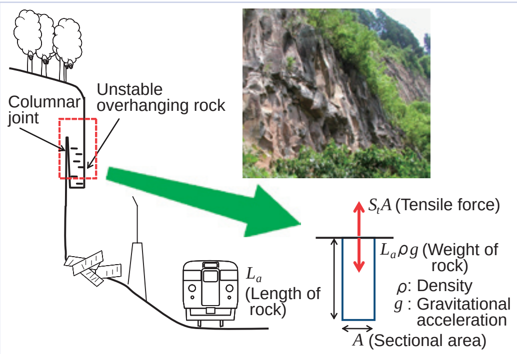


Fig. 1 Schematic diagram and a photograph of unstable rock on slope

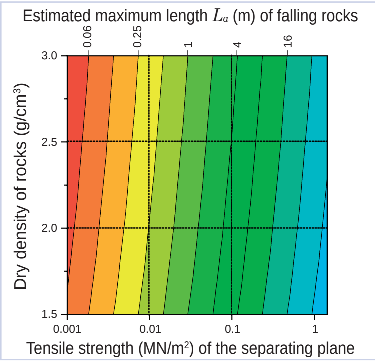


Fig. 2 Nomogram for the estimation of maximum length of the falling rock

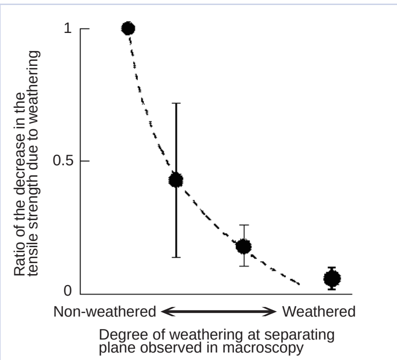


Fig. 3 Degree of the decrease in the tensile strength due to weathering

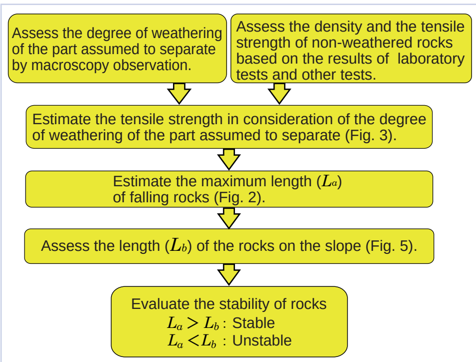


Fig. 4 Flow chart showing the process needed to evaluate the stability of rocks

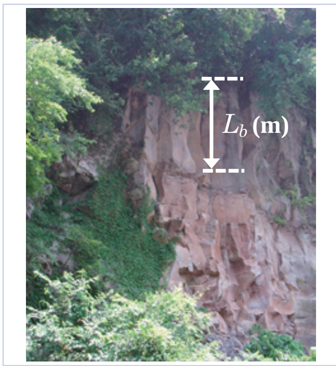


Fig. 5 Length (L_b) of the rocks observed at the slope

Development of a Low-Frequency Track Circuit with Improved Noise-Resistant Features

Mitsuyoshi FUKUDA
Senior Researcher, Laboratory Head, Signalling System, Signalling & Telecommunications Technology Division

1. Introduction

To improve the efficiency of signaling systems maintenance/construction work by integrating track circuits of different types and to enhance the efficiency of the development of rolling stock by making track circuits insusceptible to the influence of return current ‘downstream’ of trains that are running, RTRI has developed a highly noise-resistant low-frequency track circuit. This is intended to be used for different tracks regardless of their conditions, thereby facilitating the aforementioned integration of track circuits.

2. Discussions to make the new track circuit immune to track conditions

To make the new track circuit adaptable to any line conditions, the circuit length shall be about 2.0 km or the same as that of existing track circuits. This requires carrier waves in comparatively low frequency bands.

To ensure noise-resistant performance in the environments of DC and AC(50/60 Hz) electrified systems, the frequency of the track circuit shall avoid frequencies that are the same as or an integer times as high as that of the frequency of the electrification power supply (50/60 Hz) or those in frequency bands lower than 50 Hz. For these reasons, the author adopted the three carrier waves in Fig. 3.

3. Guarantee of the noise-resistant features

To guarantee the noise-resistant features and prevent the wrong-side failure if something unusual should occur, the author adopted an MSK modulation method to code track circuit signals and perform code tests. This makes the allowable return current 1 A or higher in each frequency band, thereby solving the problems otherwise anticipated in developing rolling stock.

On the other hand, as high speed transmission is difficult in the frequency bands in Fig. 1, the author adopted a cyclic code method to enable the reception of cordword in a short period of time (Fig. 2). The cyclic code method recognizes bit strings that have rotated a codeword as

the same as the original codeword. This makes synchronizing from any position of bit strings. The author also took advantage of the special features of cyclic codes to devise a method to implement codeword verification by sectioning the massage frame at arbitrary bit positions irrelevant to the fixed massage frame (Fig. 3). With the help of these methods, the author achieved a sufficiently high capability for codeword verification while maintaining the time taken to operate the track circuit at the present level.

4. Verification through a field test

The author overlaid a prototype track circuit of the type described onto an existing track circuit used for a revenue service line for a one-month monitoring test. This field test verified that the prototype functioned in a stable manner while recording no disagreements in train detection with the existing track circuit. Furthermore, the bit error rate originally designed as 1.0×10^{-4} was as low as 1.0×10^{-6} or less, so verifying that the new track circuit has sufficiently high transmission quality and excellent performance for practical applications.

5. Conclusion

Introduction of signalling systems without track circuits has long been called for. Nevertheless, the needs of railways still relying on track circuits remain unchanged. The author wishes to promote research on systems using new media and to apply new technologies to conventional track circuits and equipment, thereby aiming at contributing to the improvement of safety and reliability of signalling systems.

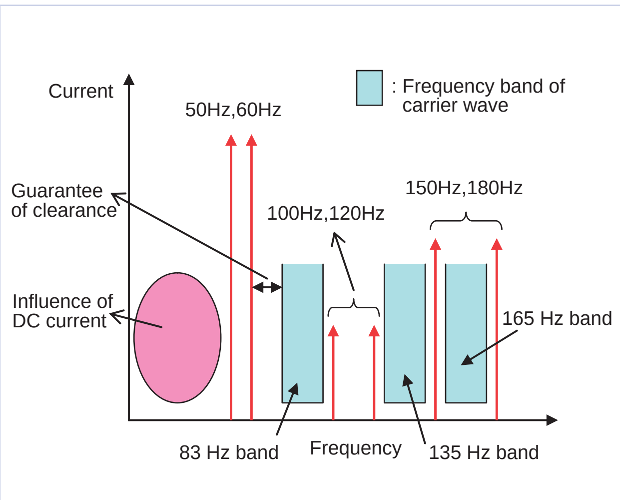


Fig. 1 Frequency band versus power source harmonic noise

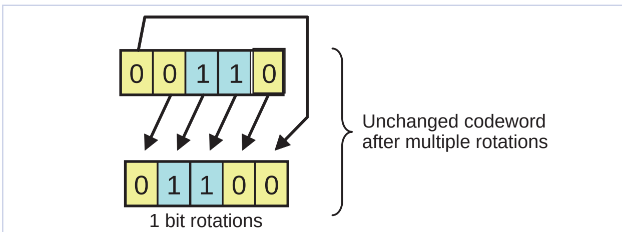


Fig. 2 An image of the cyclic code method

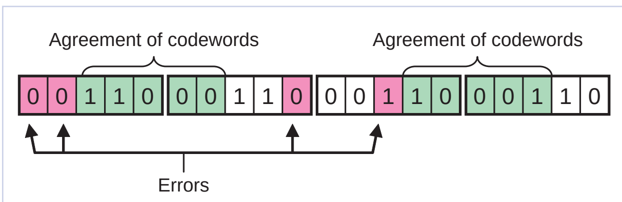
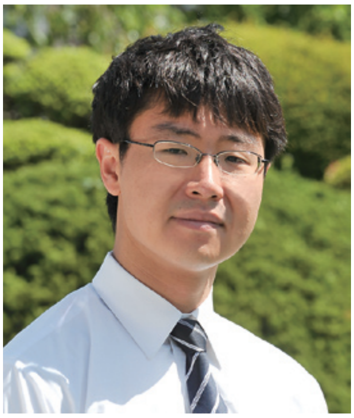


Fig. 3 An example of the test at an arbitrary frame position

Development of a Train Operation/Passenger Behaviour Simulation System

Taketoshi KUNIMATSU
Assistant Senior Researcher, Planning Systems, Transport Information Technology Division



Train timetables are core products for the railway company, and they should be evaluated from the viewpoint of passengers. For this purpose, it is necessary to estimate the conditions of train operation and passenger behaviour in detail from the origin to the destination, i.e., which trains each passenger selected: at which stations he/she changed his/her train: how long it took for him/her to arrive at their destination: and what degree of congestion he/she experienced during the trip. In urban areas with high levels of commuter traffic in particular, concentration of passengers in certain trains causes delays of the train, which leads to further passenger concentration in the trains, thereby generating a vicious circle. To evaluate timetables effectively, therefore, it is essential to estimate precisely the actual state of train operation including the aforementioned snowballing effect of passenger concentration.

In the circumstances, therefore, RTRI has developed "train operation/passenger behaviour simulation system" to estimate the state of train operation (train arrival/departure time and degree of congestion) and the behaviour of each passenger (selection of the first train or following trains at an interchange station, if any) when a particular train timetable is implemented.

This system conducts three principal estimations: (1) each passenger's choice of trains, (2) congestion of each train and (3) train arrival/departure time (Fig. 1). The first estimation determines the trains selected by each passenger from the boarding to the alighting station based on passenger data collected at automatic ticket gates and other sources, while reflecting each passenger's desire, such as reaching the destination as early as possible or minimize the times of changing trains. The second estimation summarizes the information about the trains selected by each passenger, and calculates the number of passengers on board along with the number of boarding/alighting passengers at intermediate stations. The third estimation calculates the time required for boarding/alighting at each station based on the estimated number of boarding/alighting passengers, thereby calculating the delay of each train due to the boarding/alighting action taken by passengers. These three estimations are conducted in parallel on a time series basis starting with the first train of the day. Through this process, this system represents the aforementioned complicated phenomenon whereby the delay of an overcrowded train at a certain station increases at the successive stations, thereby making it possible to estimate the state of train operation closer to what actually happens in practice.

Figure 2 shows the screen of this simulator. The display of train timetable highlights the trains estimated to be overcrowded and/or delayed, while the display showing the status of stations indicates the number of passengers waiting on the platform at each station. This allows the operator of the simulator to easily assess the results of the simulation.

Figure 3 illustrates the comparison between an existing train timetable for a specific route providing commuter services and a revised one. The revised one is designed to make express trains stop additionally at Station 4 to improve the convenience of Station 4 passengers. In contrast, however, those who do not use station 4, for example those travelling from Station 1 directly to Station 6, may consider the revised one to be less convenient. Therefore, we want to analyze the result of the simulation to study how many passengers feel the revised one to be convenient or inconvenient as a whole (Fig. 4). For this purpose, we adopt the concept of "disutility" as a comprehensive index for evaluation. This is calculated from the travel time experienced by each passenger, waiting time, the number of changing trains and the degree of overcrowding. As a result, it has been proved that there are about 3.5% more passengers who feel the revised one to be convenient compared with those who feel otherwise.

This article has introduced a train operation/passenger behaviour simulation system. In the future, we are planning to apply this system for the evaluation of a train rescheduling plan to be adopted under disturbed train operation.

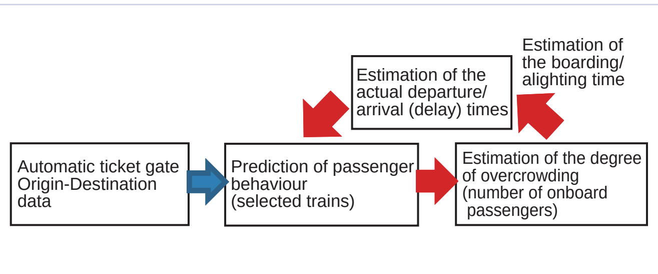


Fig. 1 Flow of simulation

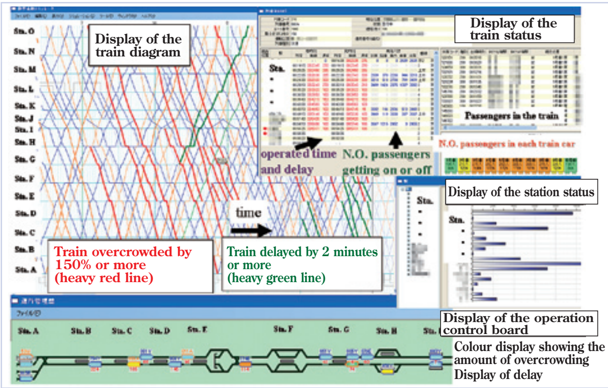


Fig. 2 Screen of simulator

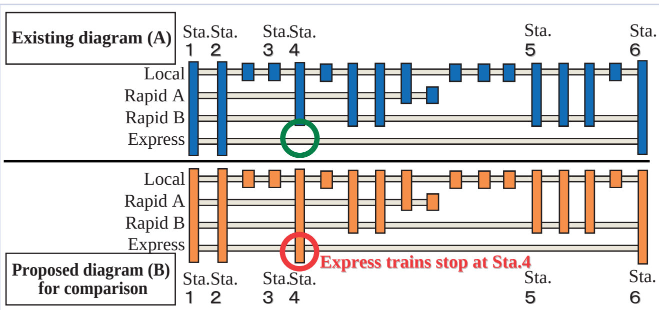


Fig. 3 Comparison of train operation diagrams

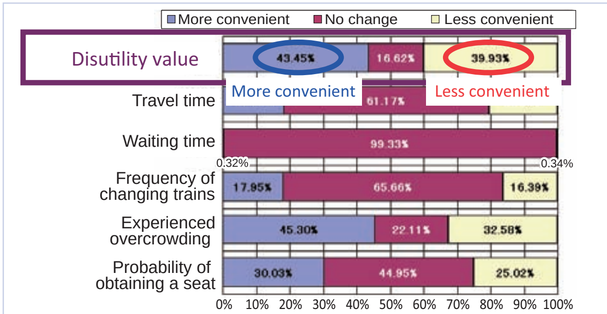


Fig. 4 Results of comparison