Interpretive Article

Development of Low-maintenance Tracks

Railway Track Structure Group Technical Center Research and Development Center JR East Group
Kazuhiko Murao, Hirotaka Aihara

The railway track maintenance unit has been involved in the research and development of reduced maintenance tracks since before 1965 (i.e., since the days of the former Japan National Railways (JNR)) in order to reduce the amount of work required to maintain existing ballast tracks used for operations. In order to minimize the effects on train operations on operational lines, following requirements have to be cleared two to three hour-installtion time, which is available for track maintenance and rational track-laying costs that help to reduce maintenance costs after track-laying. The Technical Center has developed the "TC Type Low-maintenance Tracks" that have superior labor-reduction characteristics and cost-effectiveness. These tracks were introduced on the Yamanote Line, the most heavily used line within the JR East Group, in 1998, and the total length of track that has been laid has been gradually extended. This article presents an overview of the TC Type Low-maintenance Tracks, and technical initiatives concerning the expanded use of these tracks.

1 Introduction

Railway tracks are made up of rails, sleepers, and track ballast (Figure 1). This construction efficiently distributes the load of the trains to the roadbed. Repeated loads on the structure by trains repeatedly going over it cause the track ballast and roadbed to gradually sink. When the rail surface of the tracks that the trains run on become uneven, this adversely effects the ride and can even lead to trains jumping the tracks in the worst cases.

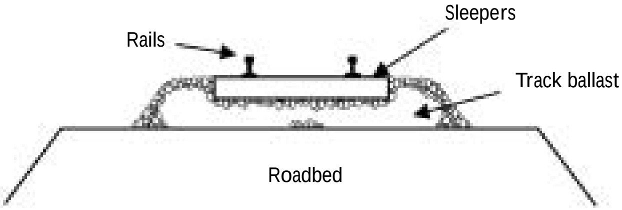


Fig. 1: Elements Making Up Railway Tracks

The railway track maintenance unit periodically inspects the tracks for unevenness and the rails and other materials for functionality. When the inspections show that tracks are outside the safety margins, appropriate maintenance work is conducted to assure the safe operation of trains. This maintenance work involves the use of large machinery such as multiple tie tampers (MTT) to harden the track ballast, and track ballast that has become too fine is replaced. These inspections and repair work are conducted continuously while trains are running, and they are an indispensable part of railway track maintenance.

Therefore, if track maintenance work, such as the hardening of track ballast, can be reduced while maintaining safe operation of trains, then costs can be reduced considerably.

Research and development on reduced maintenance tracks to reduce the amount of maintenance work required for track ballast has been conducted since before 1965. The Technical Center has been involved in the research and development of reduced maintenance tracks since it was opened in 1991, and it developed the "TC Type Low-maintenance Tracks" in 1997 (Figure 2).

Fig. 2: TC Type Low-maintenance Tracks

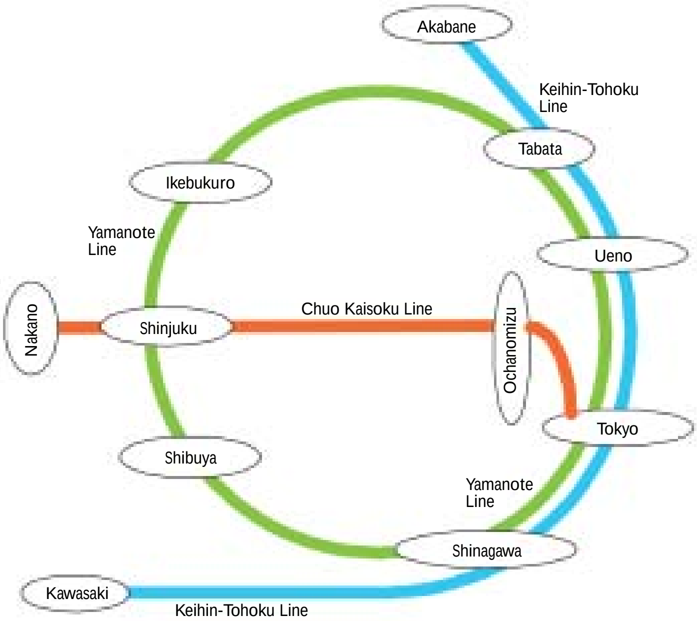


Fig. 3: Lines Using the TC Type Low-maintenance Tracks (When Phase 2 construction is completed)

Starting in 1998, TC Type Low-maintenance Tracks were laid on the Tabata-Shinjuku-Tamachi sections of the Yamanote Line as part of the Phase 1 construction. As part of the Phase 2 construction that was started in 2002, they are being laid along the Tabata-Tokyo-Tamachi section of the Yamanote Line, along the Chuo Kaisoku Line, Sobu Kankou Line and the Keihin-Tohoku Line (Figure 3).

2 Past Developments

Research and development of reduced maintenance railway tracks was started before 1965 in the days of the former JNR. Many different types were proposed and laid, including paved tracks that used asphalt filler material injected into the track ballast. However, because these tracks were laid on soil roadbeds, sinking of the roadbeds led to uneven tracks and it was difficult to lay sufficient track within the short periods of work allowed. In addition, material costs were high and this led to high installation costs. Because of these various reasons, none of the proposed methods were widely adopted.

E-Type Paved Tracks (Figure 4) were developed by the Railway Technical Laboratory in 1983. These tracks were modified to allow laying within the short maintenance periods available. These tracks were laid experimentally in Harajuku Station of the Yamanote Line in 1990. However, there were a number of problems: the costs of laying the tracks were high, trains had to run slowly over the tracks while they were being laid, and it was difficult to finish the tracks to the precision required. Because of these reasons, these tracks were never widely adopted.

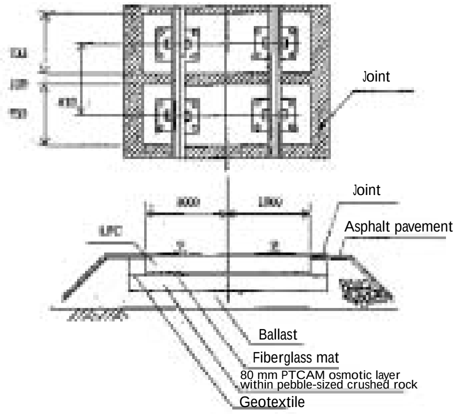


Fig. 4: E-Type Paved Tracks

3 TC Type Low-maintenance Tracks

TC Type Low-maintenance Tracks make track ballast and 400 mm width prestressed concrete (PC) sleepers into single units with cement filling material. This creates a track structure that has a 200 mm thickness non-reinforced concrete layer (Figure 5).

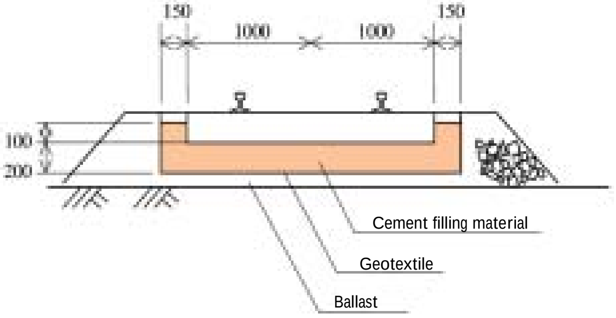


Fig. 5: Cross Section of a TC Low-maintenance Railway Track

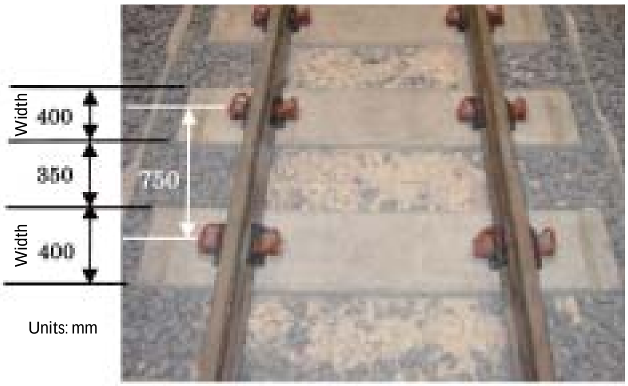
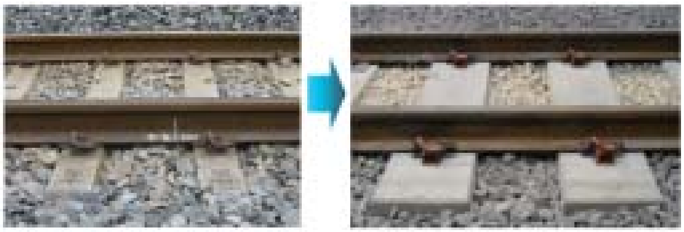


Fig. 6: Sleeper Layout Diagram

3.1 Development of Materials

The main goals in developing these tracks were as follows: achieving maintenance reduction that was equivalent to E-Type Paved Tracks; installation costs that were a reasonable investment; and installation methods that did not require trains to slow down.

(1) Prestressed Concrete (PC) Sleepers



240 mm width sleepers (No. 3)

400 mm width sleepers (TCP6H)

Fig. 7: Development of PC Sleepers

Dispersion of train loads was increased by enlarging PC sleepers from the conventional 240 mm width (No. 3) to a width of 400 mm (TCP6H). This also allows the use of large machinery (MTT) for track maintenance, and it is possible to install tracks with a high degree of precision.

(2) Cement Filler

Changing from an asphalt filler to a cement filler made possible a non-reinforced concrete layer, and this led to reduced material costs. The filling work is conducted from on-rail filling plant cars, and this increases workability.


Water car
Mixer car
Cement silo car

Fig. 8: Configuration of Filling Plant Cars

3.2 Installation Procedure

The following are the main procedures for laying TC Type Low-maintenance Tracks.

①Track ballast is excavated with a backhoe or other unit, and existing PC sleepers and track ballast are removed.

②After the surface of the excavated track ballast is sufficiently packed, the geotextile that acts as the retainer for the cement filler is laid.

③The new 400 mm width PC sleepers are laid.

④New track ballast is added from a hopper ballast wagon (small-sized hopper car). Then, railway track maintenance for that day is conducted.

⑤On a latter date, in order to improve the finished precision, large machinery (MTT) is used for track maintenance.

⑥Cement filler is poured into the tracks from the filling plant car that mixes the filler material.

Fig. 9: Installation Procedures for TC Type Low-maintenance Tracks

3.3 Development of Installation Machinery

In order to reduce installation costs, we developed various installation machinery.

(1) New Ballast Excavation Machine and Large Ballast Transporter

The ballast excavation machine has a boomerang shaped excavating cutter to excavate the track ballast. It has an excavating capacity of 50 meters (length) per hour. We also developed a new large ballast transporter (hopper car) in order to cope with the increased roadbed excavating capacity.

Due to the development of this machinery, the average length of track that can be installed in one night has been increased to 45 meters. This is a significant improvement when compared with

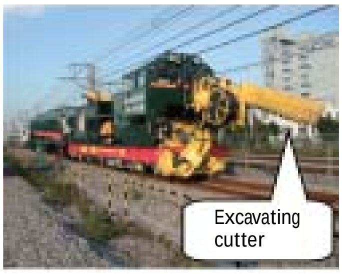


Fig. 10: New Ballast Excavation Machine

Fig. 11: Large Ballast Transporter

backhoes and the like. A pair of these units was introduced in January 2003.

(2) New Filler Plant Car

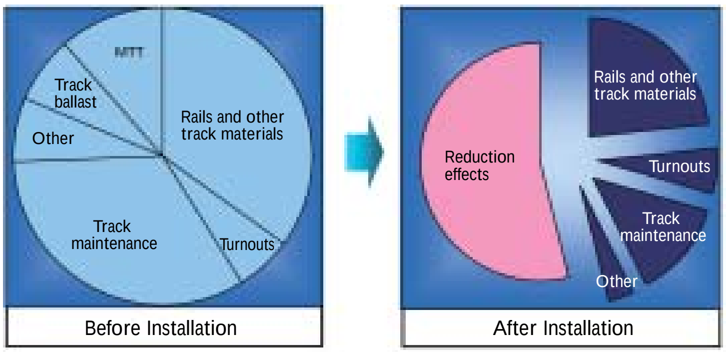
In order to increase the filling work capacity, we also developed a large filler plant car. Conventional filler plant cars had an installation capacity of 60 meters in one night. (Figure 8 shows a 60 m plant car.)

By enlarging the silos that hold the cement and the agitators that mix it, we were able to make a filler plant car with a capacity of 100 meters in one night. One configuration was introduced in March 2002.

3.4 Maintenance Cost Reducing Effects

By laying TC Type Low-maintenance Tracks, the cost reductions are especially large for items concerning track ballast.

The main areas in which costs reductions are possible are as follows: track material replacement expenses related to track ballast; track maintenance expenses related to tamping the track ballast; and machinery expenses, such as those for large machinery (MTT).



Before Installation

After Installation

Fig. 12: Maintenance Cost Reducing Effects

4 Overview of the Full-Size Railway Track Testing Unit

In December 2001, the Research and Development Center JR East Group introduced a Full-Size Railway Track Testing Unit to confirm the effects of train loads on railway tracks and confirm the performance of newly developed track structures. This Load Testing Unit can apply loads to full size test tracks, and measure the stress applied to the various sections of the track. In addition, progressive tests in which continuous applied loads simulating the operation of trains over the tracks can also be conducted.

4.1 Load Testing Unit

In order to allow application of vertical and horizontal loads in four locations per row, the Load Testing Unit has eight hydraulic actuators in the vertical direction (4 units x 2 rows) and four in the horizontal direction for a total of 12 actuators. Although the tracks have left and right rails, loads in the horizontal direction are applied with four actuators because the force is transmitted through the sleepers.

Fig. 13: Comprehensive View of the Testing Unit

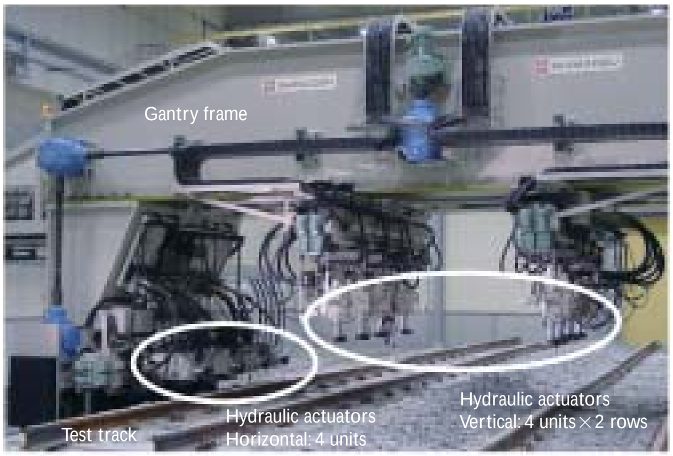


Fig. 14: Load Testing Unit

The maximum load that can be applied by a hydraulic actuator is, for vertical units, 125 kN dynamic and 160 kN static. For horizontal units, it is 65 kN dynamic and 80 kN static. Overlapping waves that are equivalent to about ten percent of the applied load can be superimposed up to 100 Hz. By simulating the fluctuations of wheel loads that the tracks experience with overlapping waves, the behavior of the tracks when actual train loads are applied can be understood more effectively.

Table 1: Main Specifications of the Testing Unit

Item	Content
Number of load testing units (actuators)	Vertical: 8; Horizontal: 4
Maximum load (per load testing unit)	Vertical: 125 kN dynamic, 160 kN static; Horizontal: 65 kN dynamic, 80 kN static
Maximum amplitude	±50 mm in both the vertical and horizontal directions
Vibration frequency	0 – 35 Hz; As an overlapping wave, a sine wave of up to 100 Hz can be superimposed.
Concrete pit	L = 20 m×W = 7 m×D = 3 m; 10 m: A soil roadbed can be created. 10 m: A slab track can be installed.
Gross weight	Total for both the testing unit and concrete pit: Approximately 2,800 tons

4.2 Vibration-Prevention Unit

During testing loads will be applied over long periods, so the vibrations that are created by the testing unit must not be allowed to be transmitted to the outside. Therefore, the 69 pneumatic springs that are placed under the concrete pit support both the testing unit and concrete pit. Load tests are conducted with these pneumatic springs activated to hold the entire concrete pit up about 30 mm, and this prevents vibrations from escaping to the outside.

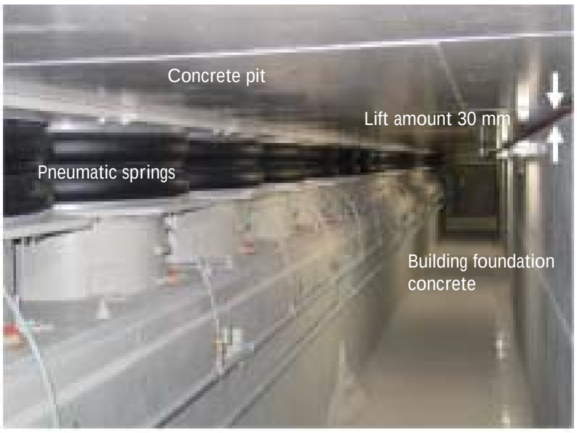


Fig. 15: Vibration-Prevention Unit

5 Development of Variations of TC Type Low-maintenance Tracks

In order to increase the number of lines for which TC Type Low-maintenance Tracks can be used (Figure 16) and to further decrease costs, we are studying variations of the TC Type Low-maintenance Tracks to meet various track conditions.

5.1 TC Type Low-maintenance Tracks that can Cope with Freight Loads

By expanding the lines that TC Type Low-maintenance Tracks can be used from electric train tracks to locomotive-running tracks, the following advantages can be gained:

①The amount of ballast work in the greater Tokyo area can be reduced.

②Less noise and vibration is created during maintenance work, thereby creating a better environment.

③By expanding the areas in which these tracks are used, the number of MTT units required in the greater Tokyo area can be reduced.

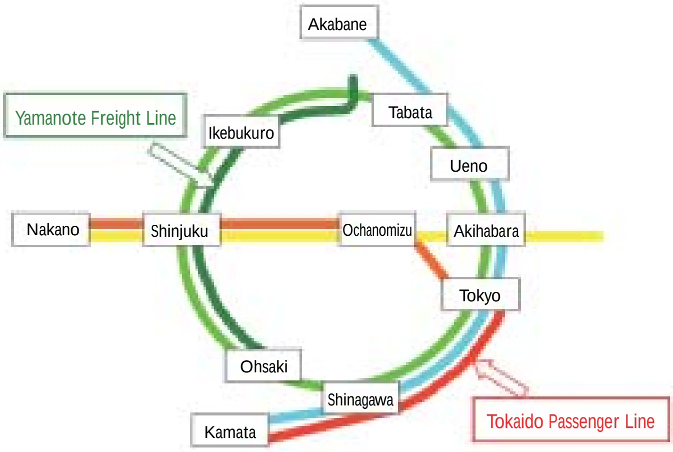


Fig. 16: Future Expansion Plans

(1) Examination of Track Structure

Compared with electric trains, locomotives and freight trains place far greater loads on the tracks. In order to develop TC Type Low-maintenance Tracks that can cope with freight loads, we used the study flow procedure (Figure 17) for track structure design.

(2) Model Analysis Using the Finite Element Method

In developing a new track structure, we used an analysis model (Figure 18) to confirm which sections will be subjected to the most stress. From the model analysis, we found that the bottom of the filler layer will be the structural weak point. In order to correct this, it will be necessary to increase the strength of the filler layer material or improve it.

(3) Examination of Filler Material Strength Improvement

In order to improve the strength of filler material that was required by the model analysis, we have conducted various material tests with the cooperation of the manufacturers. Then, we also examined the

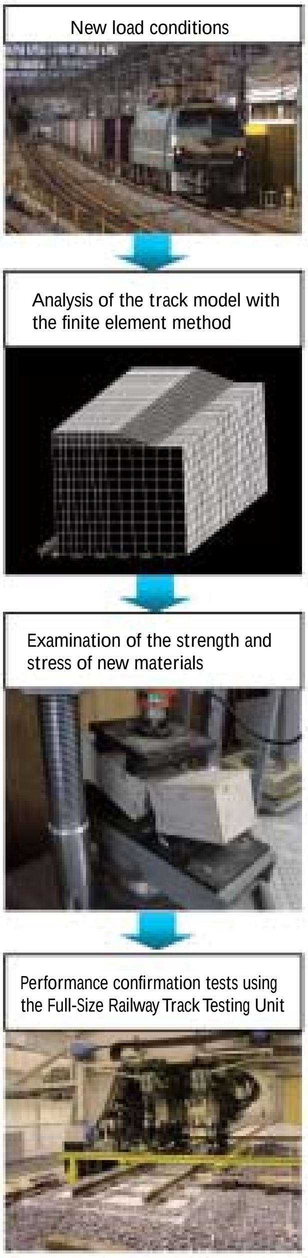


Fig. 17: Study Flow for Track Structure Design

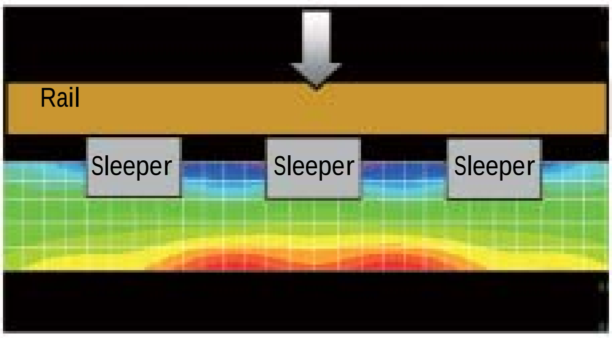


Fig. 18: Conceptual Diagram of the Model Analysis

workability of the materials (mixing and fluidity of the materials in the filler plant cars) and the ease with which the materials can be used in installation. The improved strength of the filler material was confirmed in the material tests, and performance confirmation tests were conducted using the Full-Size Railway Track Testing Unit.

(4) Performance Confirmation Tests using the Full-Size Railway Track Testing Unit

The Full-Size Railway Track Testing Unit is used to conduct static load tests in which loads are gradually applied and dynamic load tests that repeat the passing of trains over the tracks.

In the static load tests, the stress on and displacement of various sections and other mutual effects of the overall track structure are confirmed.

An instrument (strain gauge) was embedded in the bottom of the filler layer that was found to be the weak point in the structure in the model analysis. By analyzing and assessing the data, we confirm that it matches that of the model analysis as well as confirming the safety of the structure.

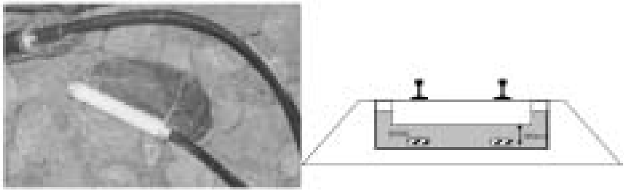


Fig. 19: Filler Layer Strain Gauge and Placement

In dynamic load testing, we conduct progressive tests. The train load that is equivalent to one year of trains that travel on the assumed line (referred to as annual passing tonnage) is used as the base load, and this load is repeatedly applied for an equivalent of 20 years. This allows us to apply 20 years worth of train load in about three months. After repeated train load testing is completed, the test tracks are carefully examined to confirm various aspects of performance, such as displacement and durability.

(5) Consistency Confirmation Tests on Operational Lines

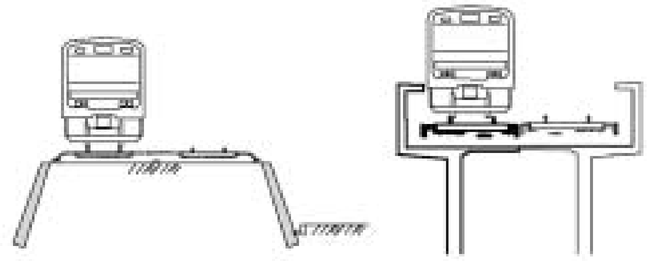
The test tracks with the newly developed structure are laid on an operational line. The test data that is collected from the Full-Size Railway Track Testing Unit and from the operational line are compared to see that they are consistent.

Fig. 20: Test Tracks Laid on an Operational Line

5.2 TC Type Low-maintenance Tracks on Viaducts

In order to achieve even further cost reductions in structure, we are developing reduced maintenance railway tracks for viaducts.

Soil roadbeds are soil structures that can be excavated and built up. Concrete roadbeds are roadbeds with high rigidity such as viaducts. Because the rigidity of the roadbeds are greater, the bending (distortion) of the filler layer is not as great, so that tensile stress is also reduced. We have focused on those points to study cost reductions in materials and construction.



Elevated section (soil roadbed)

Viaduct (concrete roadbed)

Fig. 21: Low-maintenance Railway Tracks for Viaducts

6 Conclusion

The Technical Center developed the "TC Type Low-maintenance Tracks" in 1997, and after full-fledged introduction in 1998, we have been trying to reduce costs through the development of new installation machinery.

Even today, we are developing variations of this technology. In order to expand its usage, we are developing TC Type Low-maintenance Tracks for freight loads, and in order to achieve further cost reductions we are studying application of the technology to viaducts.

We shall continue to develop new track structures through model analysis using the finite element method and the Full-Size Railway Track Testing Unit.

References:

1) Mitsuo Hanawa: "Development of Low-maintenance Railway Tracks for Operating Lines," Collected Papers of the Japan Society of Civil Engineers (October 1999)

2) Hideaki Abe, et al: "Research on Track Status Testing Methods Using the Full-Size Railway Track Testing Unit," Collection of Abstracts from the 58th Japan Society of Civil Engineers Lectures, IV-051, pp. 101-102, 2003

3) Tatsuo Odaka, et al: "Development of Low-maintenance Railway Tracks Using the Full-Size Railway Track Testing Unit," JREA, No. 46, November edition, pp. 23-25, 2003

4) Shigeyuki Hojo: "Implementation of the Phase 2 TC Low-maintenance Railway Track Construction," Shinsenro, No. 57, July edition, pp. 8-11, 2003