Maintenance and Management of JR East Civil Engineering Structures

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Introduction

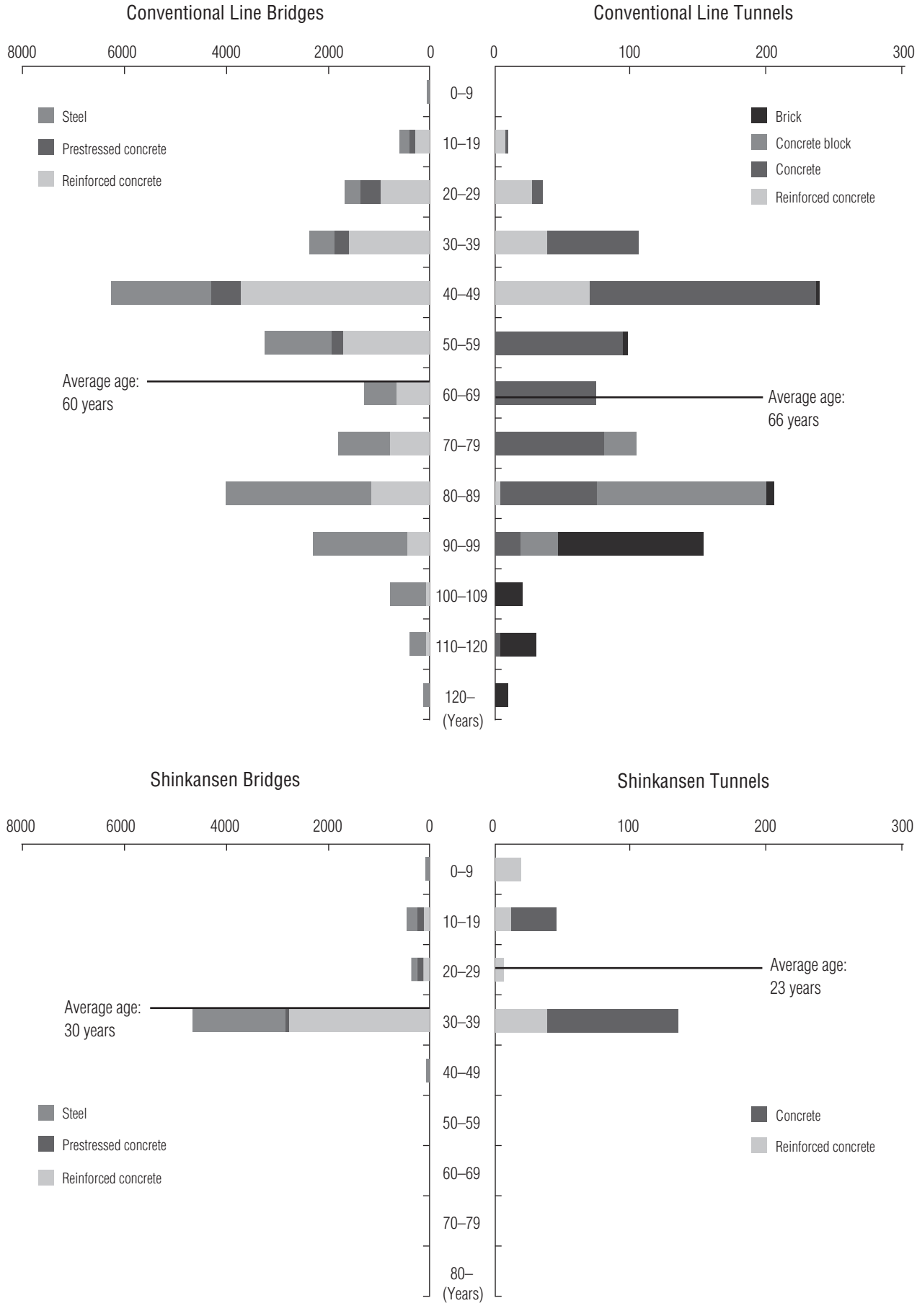
Japan's problem of aging population and declining birth-rate has been known for years and the labour force, along with the general population, has been declining from the peak in 2005. With the declining workforce, no future increase in railway income not be expected, so limited resources must be used effectively to maintain and manage the social capital of railways. Social capital includes ground facilities, such as track, station, electrical, and train protection equipment. Track equipment is classified as rails, sleepers and ballast plus the civil engineering structures of roadbed, as well as bridges, tunnels, etc. This article describes the maintenance and management of civil engineering structures at JR East.

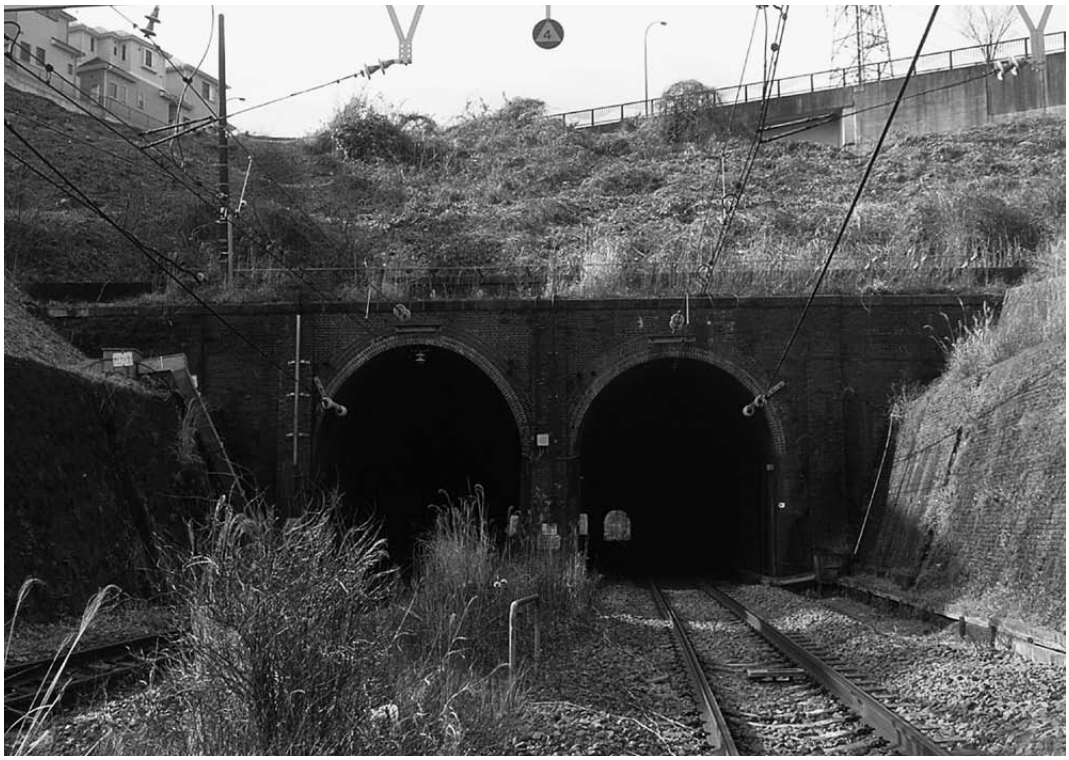
Current State of Civil Engineering

Major civil engineering structures in JR East's business area include about 30,000 bridges (including viaducts), 1300 tunnels, and 5500 km of embankments and other earthworks (as of March 2013). Figure 1 shows the age of bridges and tunnels on conventional (narrow gauge) and shinkansen lines and their construction materials. Railway civil engineering structures were built before other existing social capital, and many constructed in the late 19th and early 20th centuries are still in service. For example, more than half of the bridges exceed the legally mandated service life stipulated by the Ministry of Finance ordinance (50 years for concrete bridges and 40 years for steel bridges). JR East's oldest bridge is 127-year-old Mogami River Bridge (double

127-year-old Mogami River Bridge (JR East)

Figure 1 Average Age of Civil Engineering Structures





126-year-old Shimizuyato Tunnel (JR East)

Warren truss (pin jointed) through bridge) on the Aterazawa Line between Uzen-Nagasaki and Minami-Sagae. The oldest tunnel is the 126-year-old Shimizuyato Tunnel (brick arch and concrete internal wall)on the Tokaido main line between Hodogaya and Higashi-Totsuka.

JR East periodically inspects this huge number of civil engineering structures of different ages and constructions, and it takes necessary measures such as replacement or repair according to the inspection results to maintain and manage structures while securing passenger safety and reliable train operation.

Maintenance and Management Cycle

Detours and long-term service suspension are difficult for railways to accomplish, so maintenance and management has to be done quickly in the short time between trains. For that reason, civil engineering structures cannot be replaced like rails and overhead catenary. The basic concept is that even if a civil engineering structure has been in service for more than 100 years, its lifespan can be lengthened by appropriate inspections to find defects at an early stage, and dealing with those defects quickly.

Civil engineering structures at JR East are maintained and managed by the following procedures.

1. Identify and diagnose condition of structures (inspection, hammering test)
2. Take measures based on inspection results (repair, improve, replace, restrict use, monitor)
3. Keep records of results of inspections and measures (save results)

An important point in maintenance and management is noticing changes in civil engineering structures by repeating the above procedures.

Inspections

Civil engineering structures at JR East are inspected according to ministerial ordinance and internal criteria. Table 1 shows the type of inspections. The office personnel at local branches (structure maintenance offices) perform the actual inspections.

Ordinary general inspections (equivalent to regular health check-ups for people) are visual checks required to secure safe train operations. The purpose is to catch defects, particularly in major functions, and defects that may affect safety. If such defects are confirmed, a hammering test is made based on the criteria in Table 2. Also, every 10 years (20 years for tunnels on conventional lines), special general inspections (equivalent to detailed health check-up for people) are conducted using vehicles with platforms and work platforms for close-up visual checks and hammering tests, leading to more precise inspections.

Civil engineering structures ranked A for soundness at

Table 1 Inspection of Civil Engineering Structures

Inspection Type		Purpose	Frequency
Initial inspections		Inspections to identify initial condition of new and renovated/replaced civil engineering structures	Before putting into service
General inspections		Inspections carried out periodically for civil engineering structures in general, classified as follows	
	Ordinary general inspections	General inspections carried out periodically to find defects, etc.	Carried out with 2 years as standard interval
	Special general inspections	General inspections carried out to raise soundness judgement accuracy	Carried out at intervals not to exceed 10 years (20 years for conventional line tunnels) Can be carried out in place of ordinary general inspections
Individual inspections		Inspections carried out when results of general inspections and extraordinary inspections show detailed inspections needed	Carried out as needed in light of factors such as status of individual defects
Extraordinary inspections		Inspections carried out at abnormalities to identify broad-ranging environment, and as otherwise needed	Carried out at following times: • After typhoons, heavy rains, earthquakes, and tsunami • For bridges, etc., during and after high water levels • After accidents • When head of Structure Maintenance Office deems necessary

Table 2 Judgement Classification of Civil Engineering Structures

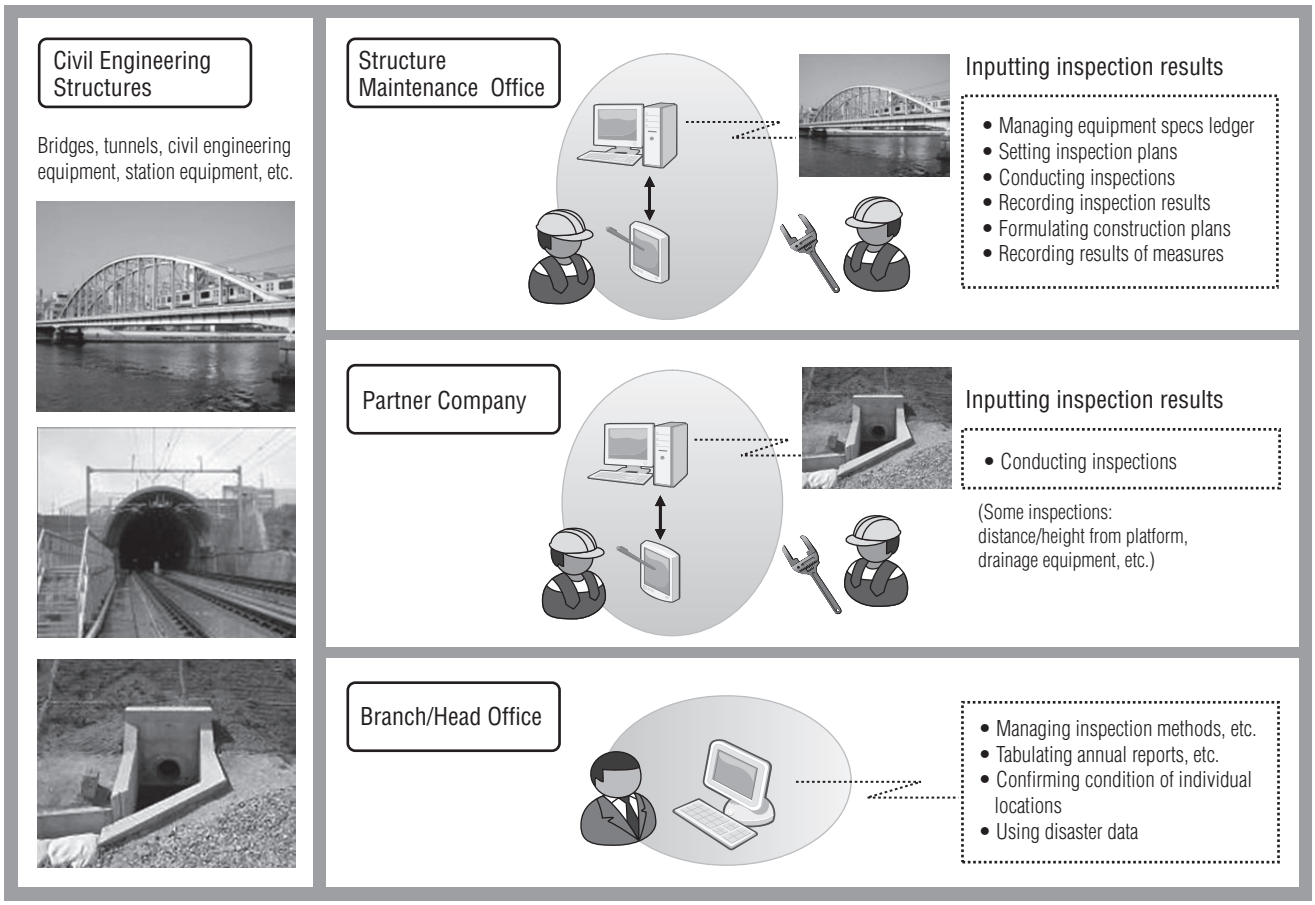
Judgement Classification		Condition
A		Defects present that threaten or may threaten train protection, safety of passengers and public, and normal operation of trains
	AA	Defects present that threaten train protection, safety of passengers and public, and normal operation of trains, which need immediate measures
	A1	Developing defects, etc., present and performance declining, or risk of performance loss due to heavy rains, inundation, earthquakes, etc.
	A2	Defects, etc., present risking lower future performance
B		Defects, etc., present risking class A soundness in future
C		Slight defects, etc. present
S		Sound

general inspections are individually inspected (equivalent to detailed examination for people). They involve more detailed inspection and identification of causes and development of defects for high-accuracy soundness judgement. They are used for formulating plans for measures.

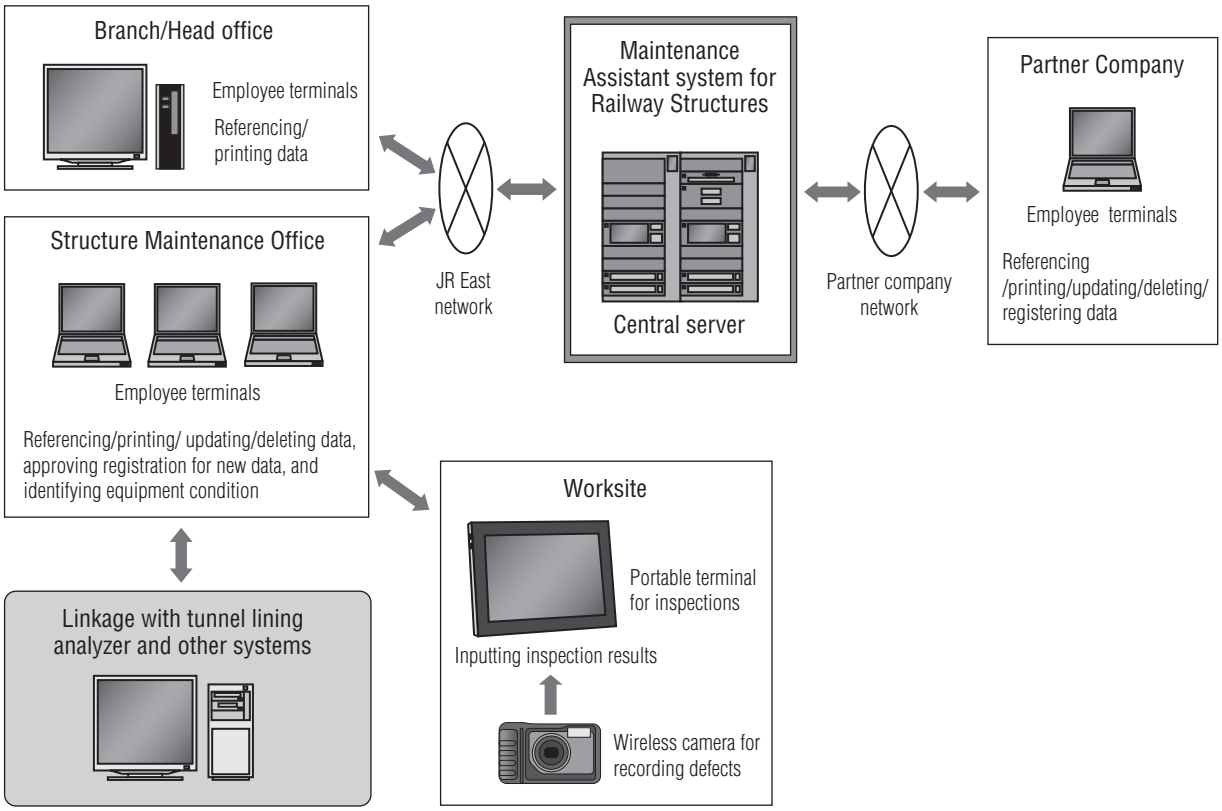
The results of inspections, including photographs and drawings of defects, are recorded and saved to the Maintenance Assistant system for Railway Structures (MARS) (Figure 2). In addition to inspection results, the system includes specifications and drawings of structures, histories

Figure 2 Maintenance Assistant System for Railway Structures

Concept



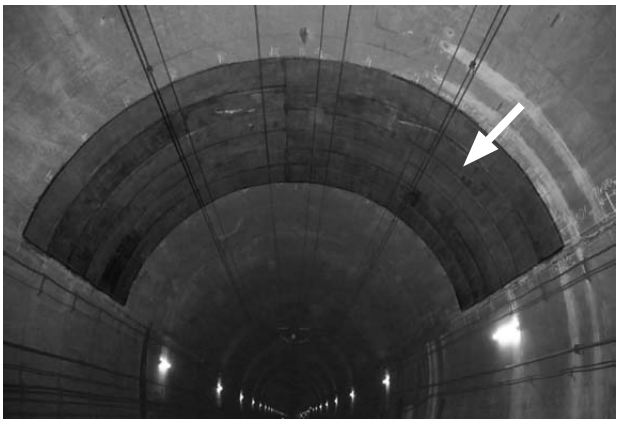
Network structure



Tunnel Lining Scanning Car (TuLIs) (JR East)

Concrete Lining Inspection Car (CLIC) (JR East)

Peeling and flaking on concrete viaduct (top) After repair work (bottom) (JR East)



Repaired concrete tunnel (JR East)

of defect repairs, and more. It has a function for formulating inspection and construction plans, and it implements consolidated management of information required for maintenance and management. JR East engineers can access the data server at any time over the intranet.

JR East has also developed and introduced inspection machinery to improve the precision of tunnel inspections instead of just conducting visual checks and hammering tests, which depend on the skill of evaluation personnel. Such machinery includes the Tunnel Lining Scanning Car (TuLIS), which captures video data on the surface condition of concrete linings, as well as the Concrete Lining Inspection Car (CLIC), which finds abnormalities such as cavities behind tunnel linings using radar. Furthermore, CLIC inspections can replace hammering inspections at special general inspections.

Case Examples of Measures Taken for Civil Engineering Structures

Measures are taken according to the results of inspections to secure safe train operations. They include repair,

Secondary lining improvement of Tokyo Tunnel (JR East)

Replacement of Tone River Bridge (JR East)

improvement, replacement, restriction of use, and monitoring. In order to maintain functionality, JR East takes measures, such as repair and improvement of defects to prevent defects developing further, as well as replacement of some or all structural members.

The company allocates an annual budget for maintenance. Basic repair expenses are mostly fixed, because the company manages a fixed number of structures. Priority is determined based on inspection results and line importance and repairs such as countermeasures to peeling and flaking on concrete viaducts and in tunnels and repainting of steel bridges are undertaken. When unusual

defects are discovered, special budgets are secured to take countermeasures.

When a defect is found to be fatal and sufficiently severe that it would be difficult to handle by repairs, large-scale renovation and replacement is done. In these cases, effects are verified by individual cost benefit analysis. A good example of large-scale renovation is the work on the secondary lining in the Sobu–Tokyo Tunnel. An example of replacement is the construction currently in progress to replace the Tone River Bridge (1040m) on the Joban Rapid Line.

Future Issues and Efforts

About 40% of JR East's personnel in charge of inspection work reach retirement age in the next 10 years. This rapid generation change is causing concern about a loss of or drop in inspection skills. Civil engineering structures in service are also getting older and new structures are being added as shinkansen lines are extended. In this situation, new technologies and methods are needed to maintain and increase levels of inspection skills and continue long-term use of the diverse mix of old and new civil engineering structures.

In maintenance and management to date, inspections are done by uniform inspection methods, regardless of the structures' age or usage environment. Looking at transport volume, however, there are major differences in usage and social importance as exemplified by urban lines where trains operate at peak headways of 2 or 3 minutes, contrasting with rural lines where only a few trains run each day.

In the future, using the same methods regardless of usage will not be efficient. JR East is studying introduction of inspections based on individualized maintenance scenarios in which focal points for inspection, possible defects and countermeasures are organized according to transport volume, train speed, natural environment, construction status, years used, and other factors.

To improve the quality of inspections, new technologies must be introduced supporting faster, more accurate, and more efficient identification of occurrence and development of defects as has been done with machinery for tunnel inspections. If defects can be detected at the very early stage by monitoring technologies using vibration and acceleration sensors, it may contribute greatly to increased life of civil engineering structures by facilitating earlier countermeasures.

Conclusion

Railways have many types of civil engineering structures as their foundation, so many management resources (human and financial) are needed for maintenance and management, making this an important issue in managing a railway company. By actively introducing new technologies and techniques to detect defects earlier and more reliably permitting earlier and more effective countermeasures, JR East hopes to achieve efficient maintenance and management of civil engineering structures to support safe railway transportation that passengers can use with peace of mind. ■

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