Current Status of Bridge Management in Japan

Takashi Tamakoshi[1], Keita Nakasu[2]

Abstract

Road bureau of the Ministry of Land, Infrastructure and Transport (MLIT) is promoting scientific bridge management to preserve the enormous number of bridges in Japan effectively. National Institute for land and Infrastructure Management (NILIM) is carrying out research and development on inspection and database systems, soundness evaluation, deterioration prediction and durability improving methods to establish new bridge management system with the cooperation of the related organizations. In this paper, the current policy trend of bridge management in Japan and our effort for scientific bridge management are reported.

1． Introduction

The number of highway bridges over 15m in Japan is more than 140,000 as illustrated in figure 1. An enormous number of bridges were constructed during the period of rapid economic growth that started in the middle of 1950's. Therefore it is expected that rehabilitation or renewal costs of highway bridges will rapidly increase in the future.

On the other hand, serious damage which influence the loading capacity of bridges is reported recently in Japan. Photos 1-4 show examples of typical damage such as fatigue cracks of concrete slab, fatigue cracks on steel members, salt damage or alkali-silica-reaction (ASR) of concrete members.

In these circumstances, a strategic and efficient bridge management system is required to reduce life-cycle-cost (LCC) of highway bridges and keep the highway network in good condition for the future.

In this paper, current status of bridge management in Japan and the latest research and development for the scientific bridge management are reported.

[1]Head of the Bridge Division, National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Transport

[2]Researcher of the Bridge Division, National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Transport

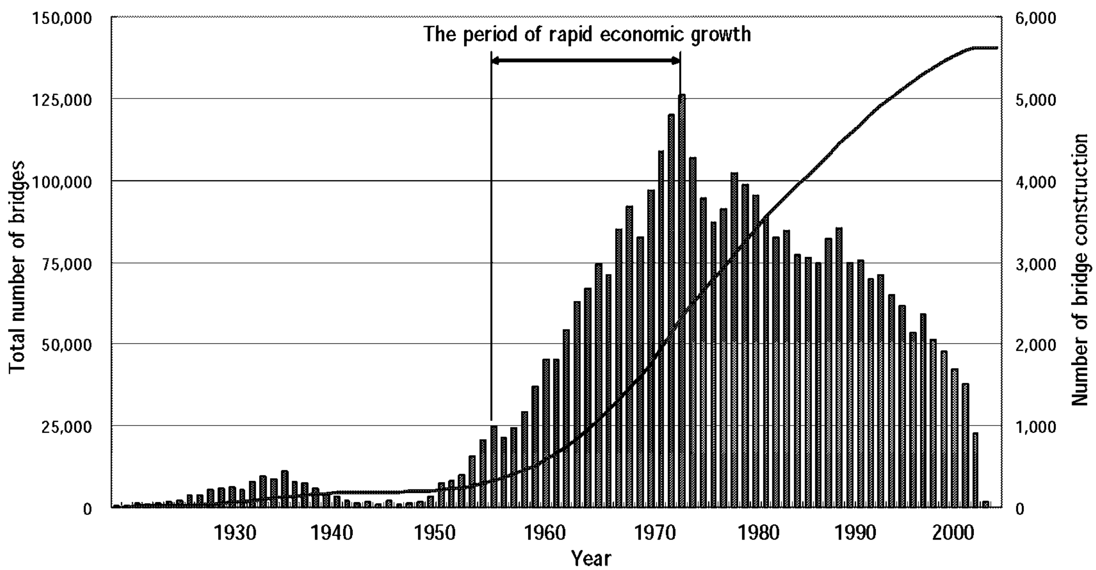


Figure 1 Total number of bridges and annual bridge construction in Japan

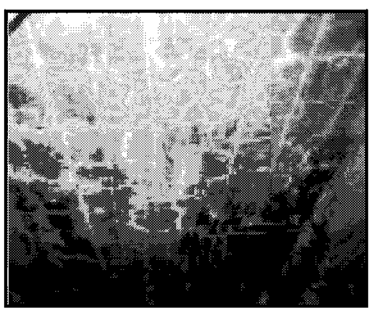


Photo 1 Fatigue cracks on concrete slab

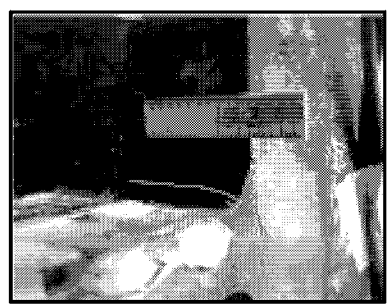


Photo 2 A fatigue crack on steel member

Photo 3 Salt damage of concrete members

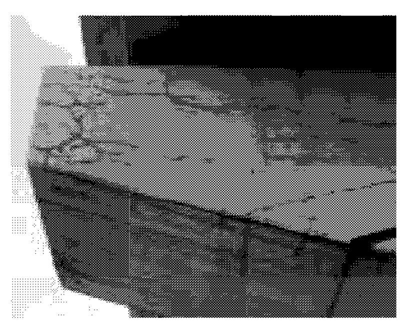


Photo 4 ASR of a concrete member

2 . The need for scientific bridge management

2.1 Current situation of highway bridges in Japan

The number of highway bridges in Japan is more than 140,000 and an enormous number of bridges were constructed during the period of rapid economic growth that started in 1950's and ended in 1970's.

In general, the life span of highway bridges is considered to be about 50 years in Japan. However, according to the latest analysis conducted by NILIM based on the statistics on the reasons for bridge replacement, it is pointed out that the life span of highway bridges is different depending on the period of construction. Figure 2 shows the general relationship between constructed year and the life span of bridges. The average life span of bridges which were constructed until the 1950's is about 30 or 40 years. After the 1950's the life span of bridges is getting longer because of the experiences of damage and the revisions of the related specifications. It is estimated from the NILIM's trial calculation that the life span of bridges constructed in recent decades reach about 100 years or more.

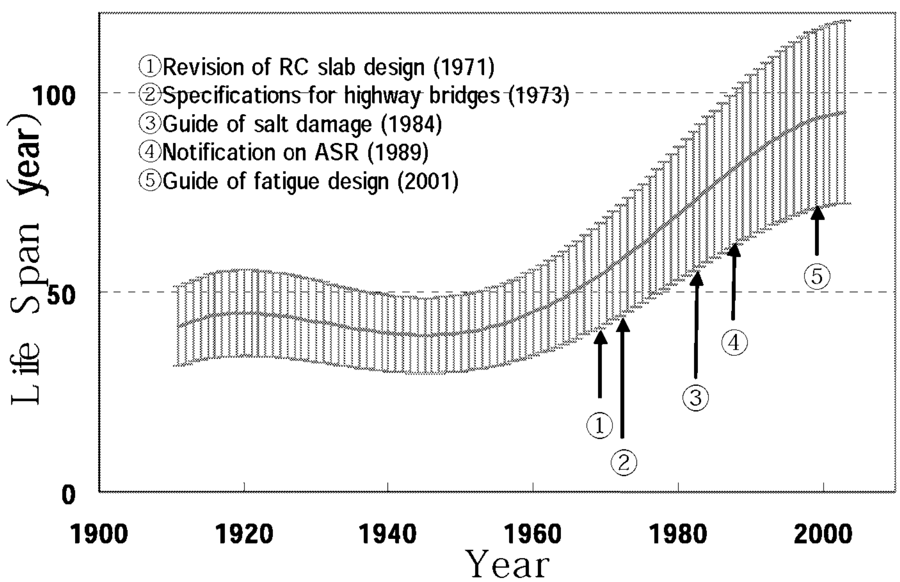
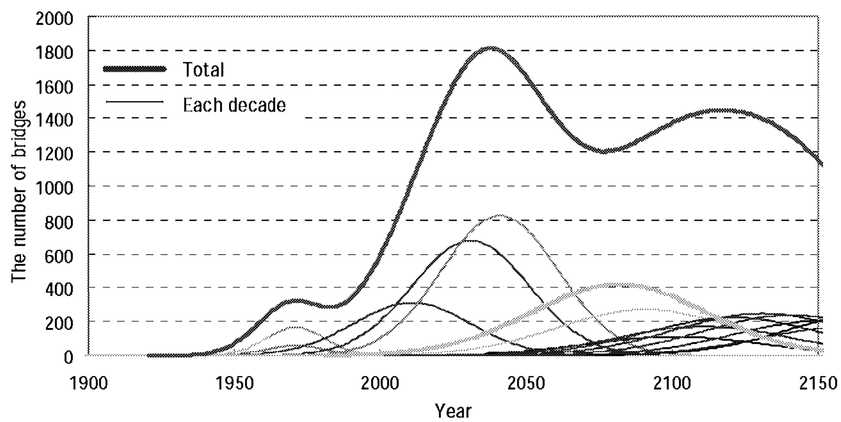


Figure 2 General relationship between life span and constructed year of highway bridges

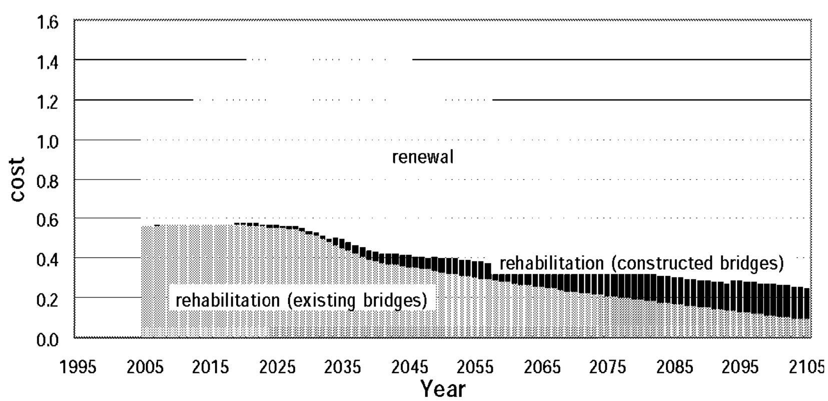
2.2 Future estimation of maintenance cost

Figure 3 shows the estimated number of bridge replacement and costs of bridge maintenance in Japan. These estimations were carried out from the average bridge life span calculated by NILIM for each decade using the data of the result of bridge replacement and construction. According to the result of trial calculation, the peak of maintenance costs will appear during 2020 to 2040, and cost in 2030 is approximately 1.5 times higher than the value of 2004.

In order to ease the rapid increase of maintenance costs in the future, it is necessary to reduce the number of bridge replacements by promoting preventive management or durability improvement. Figure 4 shows the estimated number of replacement and maintenance costs of highway bridges if the life span of each bridge were 1.5 times longer than the case of figure 3. It is understandable that the peak of maintenance costs will be reduced by conducting preventive management.

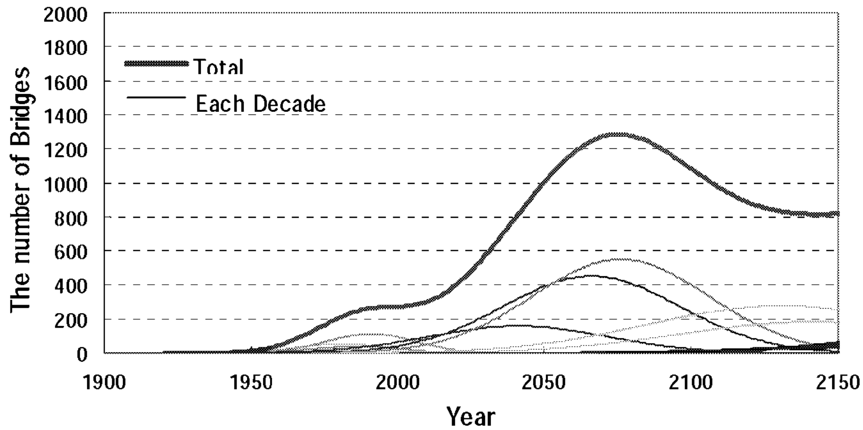


(a) The number of bridge replacement

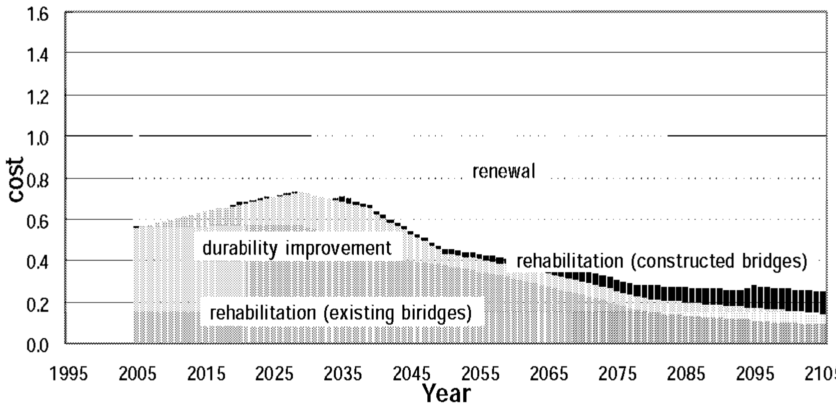


(b) Costs for rehabilitation or renewal (value of 2004 = 1.0)

Figure 3 Future estimation based on historical data



(a) The number of bridge replacement



(b) Costs for rehabilitation or renewal (value of 2004 = 1.0)

Figure 4 Future estimation in case life span is 1.5 times longer

3. The Bridge management system in Japan

3.1 A concept of bridge management

As shown in Figure 5 there are mainly two types of approaches to reduce LCC in the strategy of bridge management. The first approach is conducting preventive management and the second approach is extending bridge life span.

In order to illustrate the effectiveness of preventive management, retrofitting methods for concrete slab in various levels of damage are shown in table 1. Although the frequency of maintenance works will increase by conducting preventive measures in the early stage, the costs for recovering the performance of a damaged bridge decrease drastically. On the other hand, it is possible to reduce the frequency of replacement by extending the bridge life span. Therefore preventive management and extension of the bridge life span are efficient to reduce LCC of bridge.

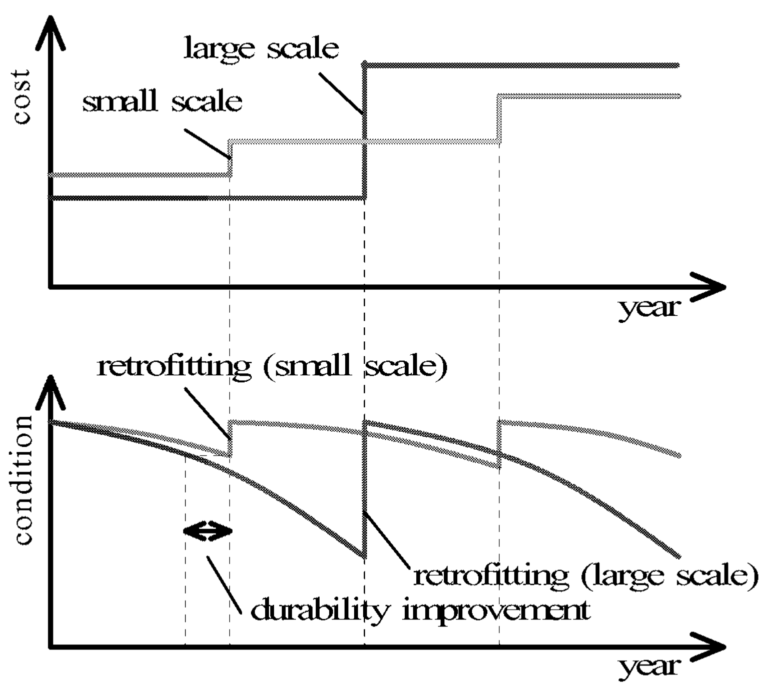
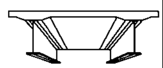
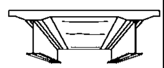
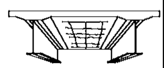
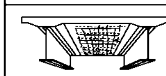
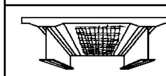
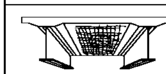


Figure 5 Concept of bridge management that reduce LCC

Table 1 Retrofitting methods for concrete slab

Figure	Stage of damage	Measures
	no damage	no need
	drying shrinkage crack	reinforcement against bending CFRP attachment
	grid style crack	reinforcement against bending steel plate attachment
	progressing of grid style crack	reinforcement against bending and shearing steel plate attachment, thickness increasing
	surface scratching in crack	reinforcement against bending and shearing thickness increasing, replacement
	dropping off of concrete	replacement

3.2 The bridge management system in Japan

The techniques of bridge management are different corresponding to the role of administrative organization. Therefore the information used for the decision making in bridge management is also different corresponding to that. For example, as shown in figure 6, higher organizations of highway administration mainly discuss policy issues such as preservation level or investment scale for group of bridges (macro management). On the other hand, regional offices which manage local bridges judge more practical issues such as methods or priority of rehabilitation for individual bridges. Bridge management system should be developed in consideration of the kind of administrative organizations. NILIM is developing an integrated bridge management system that is available for various purposes of bridge management.

Figure 7 shows the framework of bridge management system and related technologies. The bridge management system contains various parts such as inspection and database systems, soundness evaluation, deterioration prediction and investment planning. Therefore, in order to establish the integrated management system, it is important to develop related technologies from various aspects.

NILIM is now trying to use the system for macro management, because a perfect database or accurate deterioration predicting methods are not always required at this level of management. In the long run, we will update and improve the system so that it can be useful for various purposes by collecting data or introducing new related technologies.

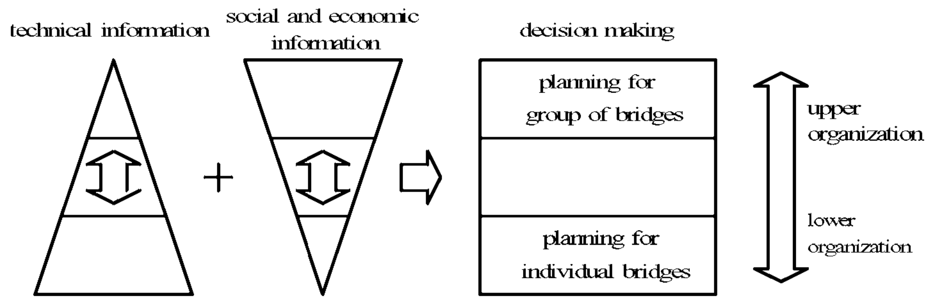


Figure 6 Decision making level and needed information

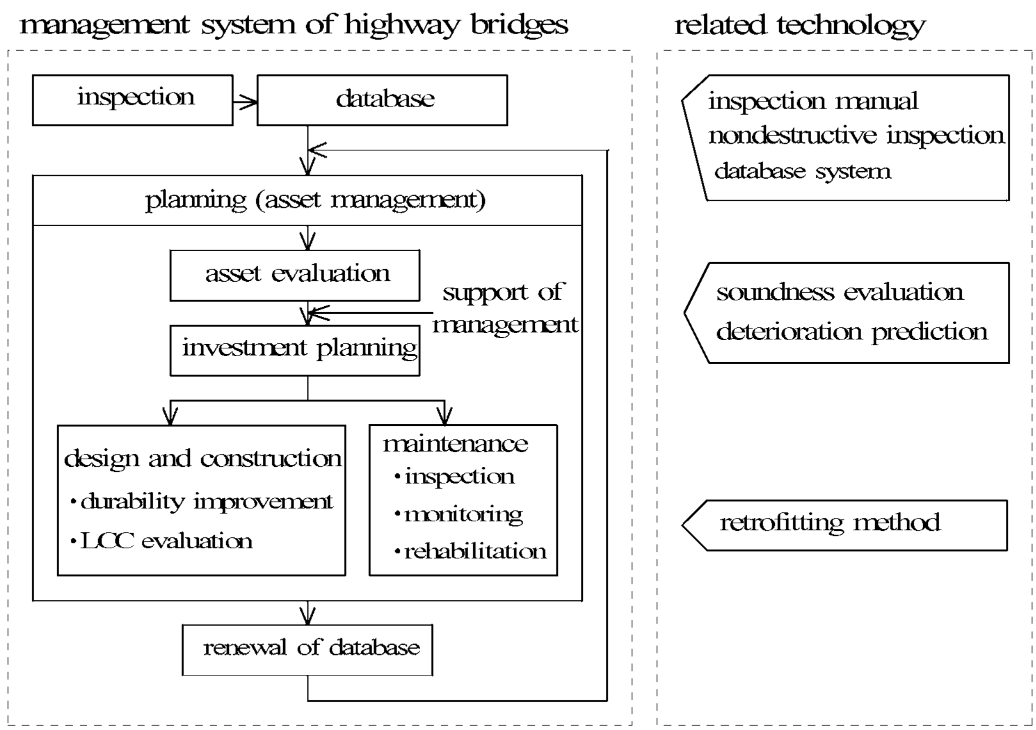


Figure 7 Framework of the bridge management

4. Research and development on serious damage

4.1 Fatigue of concrete slabs

Because of the experiences of dropping off damage of concrete slabs, structural details such as minimum thickness of slabs or quantity of reinforcing bars had been reconsidered repeatedly since the late 1960's. Later, the wheel running tests for slabs were carried out, and the relative durability evaluation with calibrated slabs under the increased loading conditions is becoming possible.

However, as the absolute durability evaluating method for concrete slabs has not been developed yet, accurate deteriorating prediction is still difficult. Therefore it is impossible to decide a suitable timing for retrofitting or to prove the performance of new types of slabs based on the damaging mechanism.

NILIM is carrying out studies on an absolute durability evaluation method of concrete slabs based on the failing mechanism by analyzing existing data of the wheel running tests.

4.2 Fatigue of steel member

Fatigue design for steel members was introduced with the revision of the specifications for highway bridges in Dec 2001. The guideline of fatigue design for steel bridges was published as an example of a practical design method in March 2002. However, current fatigue design methods have problems that it is difficult to apply to the complex parts such as corner area of steel piers or steel decks.

NILIM is carrying out studies on structural details that improve the durability of steel pier's corners, or steel decks, based on the analysis of actual damage patterns.

4.3 Salt damage of concrete member

Specifications against salt damage were reconsidered with the revision of the specifications for highway bridges in Dec 2001. According to the current specifications, proper measures should be taken as well as increasing the thickness of covering if the bridges are constructed in a severe salt environment. In this circumstance, many kinds of measures such as painted bar or concrete painting have been tried to use. However, as the evaluating methods for these measures have not been developed yet, there is a problem that these measures have not adopted effectively.

NILIM is carrying out investigations on the required performance or performance evaluating methods for the measures against salt damage in consideration of the actual conditions in constructing works or operation.

4.4 ASR of concrete member

As the serious ASR damage that causes breakages of reinforcing bars in concrete members is reported recently in Japan, it is necessary for us to establish the evaluating method for loading capacity and rehabilitation methods for the concrete members damaged by ASR.

NILIM is carrying out investigations on the fundamental characters such as material property or bond strength of the reinforced concrete member which is damaged by ASR with the cooperation of related organizations.

5. Accountability of bridge management level

In order to promote preventive bridge management, it is important to conduct an adequate scale of investment at the best timing. However, in the case of highway bridges, it is difficult to recognize or quantify the soundness of bridges for both bridge user and bridge administrator. Therefore, in order to conduct the preventive investment for aging bridges, user accountability using proper and understandable management indexes is important in the process of decision making.

NILIM is trying to develop management indexes that express the condition of bridges in consideration of the scale or place of damage, type of bridge structure or the importance of the route.

6. Conclusion

MLIT is promoting scientific and strategic bridge management to avoid a rapid increase of costs for bridge management in the future. In order to reduce bridge LCC, it is important to conduct preventive management and improving durability of highway bridges. NILIM is conducting research and development on a bridge management system and related technologies.

As the effort for the scientific and strategic bridge management have just started, the management system has not been sophisticated yet. NILIM will try to improve and establish integrated bridge management from the knowledge through the actual use for macro management and newly developed technologies.

Reference

1) Nakatani, S., Tamakoshi, T., Nakasu, K. “A Management System for Highway Bridges in Japan” Annual Report of NILIM, 2004.
2) Nakasu. K., Tamakoshi, T., Ishio, M., Takeda, T., “Current Policy Trend and Challenges on Bridge Management in Japan” Civil Engineering Journal, 2004.11 (in Japanese).