EXPRESSWAY STANDARD SPECIFICATION BY NEXCO FOR BRIDGE MAINTENANCE DESIGN

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Abstract

NEXCO constructs and manages expressways in Japan, with a total network length of 8531km. NEXCO constructs and manages expressways both by its own expressway standard specification and by the national standard. Expressway standard specification by NEXCO has been regularly reviewed and updated in the 50 years since its first use on the Meishin expressway.

This text discusses the structure, contents and future direction of the Expressway standard specification by NEXCO.

Introduction

NEXCO group (East Nippon Expressway Co. Ltd., Central Nippon Expressway Co. Ltd. and West Nippon Expressway Co. Ltd.) constructs and manages expressways in Japan, with a total network length of 8531km (as of 2009). It began service between Ritto to Amagasaki with the Meishin expressway in 1963 (Table 1, Figure 1). The expressways managed by NEXCO are on average 20 years old (as of 2008) and it also includes the route that took 47 years to reach.

Table 1 Service length of NEXCO expressway network

Items	NEXCO group total
Service Length	8531km (as of 2009)
Bridge Length	1250km (as of 2004)
Bridges	13,500 (as of 2004)

The total bridge length is about 15% (1,250km) of the total length of about 13,500 bridges. About 40% are steel superstructure bridges and the remaining 60% are concrete. At the concrete bridges, approximately half are reinforced concrete (RC) and the other half are prestressed concrete (PC). Recently, new structural forms, such as corrugated steel-web bridges, have been developed and are frequently constructed. Most substructures are concrete. The construction time and the number of bridges of bridges of each bridge types are indicated in Figure 2.

NEXCO privatized away from the Japan Highway Public Corporation in 2005, which was established in 1956. NEXCO-RI (Nippon Expressway Research Institute Co. Ltd.), which was a part of the Japan Highway Public Corporation, was established by 3 NEXCO companies in 2007. NEXCO-RI concentrates on technology of NEXCO group and makes standard specification drafts, carries out research and development, provides

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technical support, intellectual property management, and training and publication services.

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This text discusses the structure, contents and future direction of the Expressway standard specification by NEXCO.

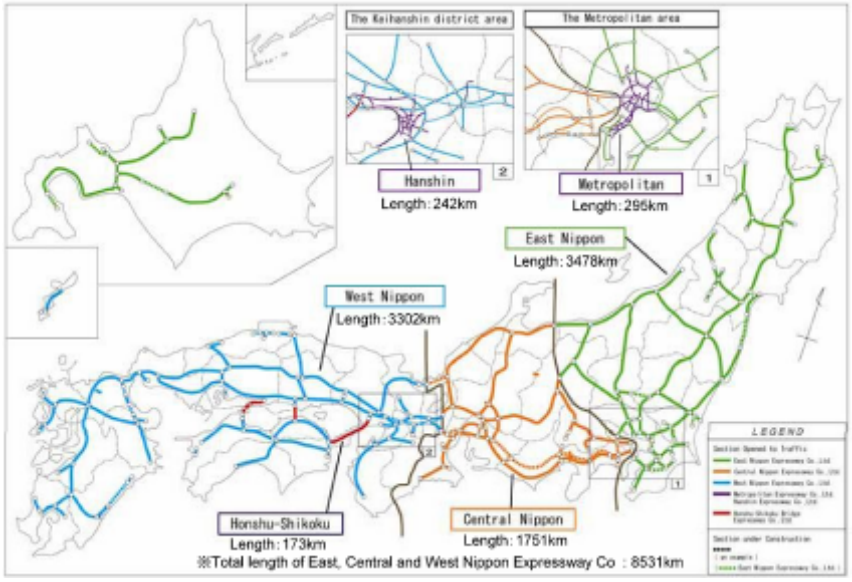


Fig.1 Expressway Network in Japan (2009.Apr) (1)

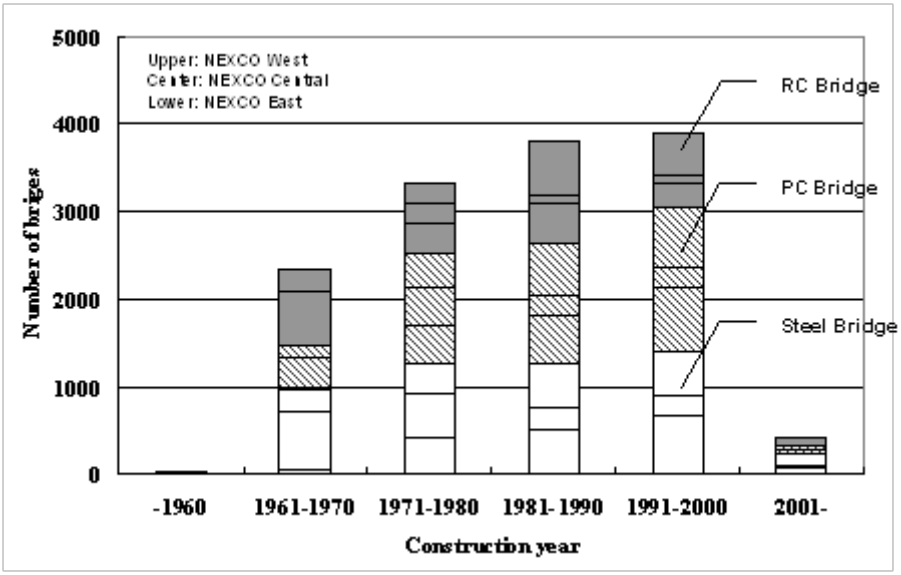


Fig.2 Relationship between number of bridges and construction year of bridge types (2003)

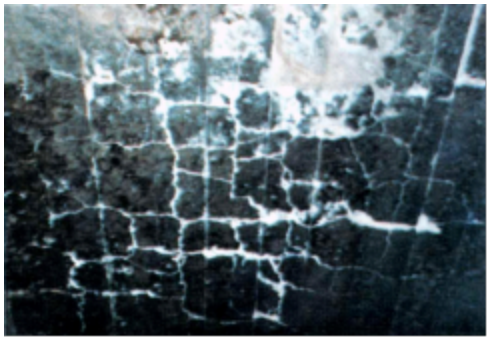
Maintenance Characteristics

Among NEXCO's expressways, there are many routes that pass through mountainous districts to traverse the Japanese islands, and that pass in the cold regions such as Hokkaido and Tohoku. Therefore, to prevent the road surface freezing in the winter, deicer is sprinkled. There are several examples of causing chloride attack via the sodium chloride (NaCl), the principal ingredient of deicer. NaCl is raised by passing vehicles and escapes from the expansion joint of the bridges.

The unexpected increase in the load of vehicles caused heavy traffic, thereby making it necessary to reinforce the decks. The reviewed seismic design code after the Hyogo-ken Nanbu Earthquake in 1995, is thereby making it necessary to reinforce the piers.

(a) Salt Damage

(b) Salt Damage (RC Deck)



(c) Fatigue (RC Deck)

(d) ASR

Fig.3 Examples of deterioration

Standard System

NEXCO group still continues to employ the same technical standard used after privatization. It is called the Expressway Standard Specification by NEXCO. Its composition is as shown in Table 2, and this standard is placed as shown in Figure 4.

NEXCO constructs and manages its bridges in accordance with the own specification, the "Specifications For Highway Bridges" (Japan Road Association) and the "Standard Specifications for Concrete Structures" (Japan Society of Civil Engineers). Expressway Standard Specification by NEXCO is regularly reviewed in light of new knowledge and experience. It is revised roughly every year.

Table 2 Composition of the Expressway Standard Specification by NEXCO

For Design	Earth Work	Earth Work, Drainage, Landscape Architecture
	Pavement	
	Structure	Bridge Construction, Bridge Maintenance, Retaining Wall, Culvert
	Tunnel	Tunnel Construction, Ventilation, Emergency Facility
	Geometric	Geometric for Through Lane, Geometric for Interchange, Geometric for Bus Stop, Geometric for Rest Area
	Safety Facility	
	Facility	Architecture, Electric/Machine, Telecommunication
For Construction		
For Test Method		Soil, Asphalt Pavement, Concrete, Structure, Foundation, Greening, Tunnel
For Maintenance		

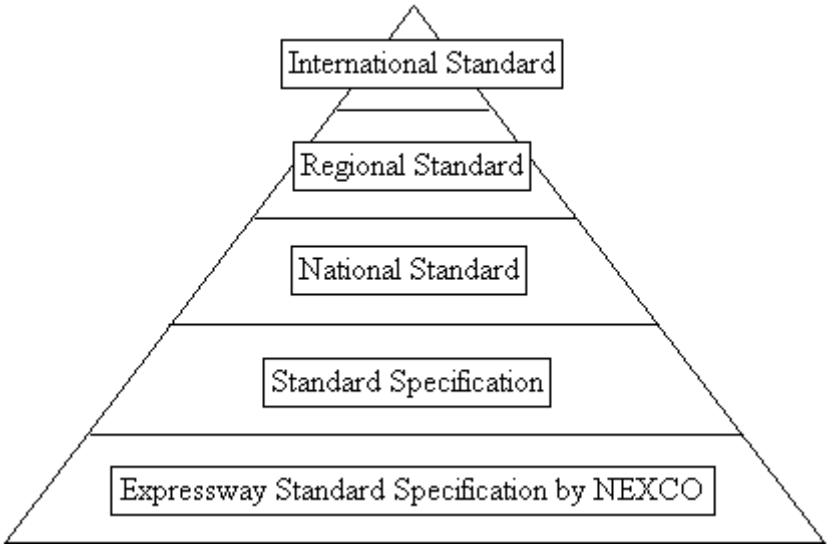


Fig.4 Hierarchy of Standard

Structure of Expressway Standard Specification for Bridge Maintenance Design

The Expressway Standard Specification for Bridge Maintenance Design was enacted as the Expressway Standard Specification for Deck Maintenance Design in June, 1978. Use of the Meishin Expressway in 1963 resulted in various cases where slabs had been damaged by fatigue in several years. In one case, significant damage had been done to a deck and reinforcing was added to it; this work was carried out in 1970.

The Expressway Standard Specification for Steel Bridge Coating Design was enacted in April, 1979; the Steel Bridge Weld Design, Concrete Wall Railing, Bearings, and Expansion Joints were enacted in May, 1983. It is in these specifications that the judgment of the degree of damages and the choice of repair method are detailed for damages that occur.

The large-scale reinforcement corresponding to the condition of the bridge, the increased vehicle loading, and the earthquake strengthening was performed after the Hyogo-ken Nanbu earthquake occurred, it was necessary to update the standard specification accordingly. It was then reorganized and renamed as The Bridge Maintenance Design in November, 1997.

The Present Expressway Standard Specification for Bridge Maintenance Design

The content of the July, in 2010 version are shown in Table 3. It introduces the chapters "Chapter 3: Concrete Structures" and "Chapter 4: Decks". These are discussed bellow.

Table 3 Content

Chapter 1	General Rules
Chapter 2	Steel Structures
Chapter 3	Concrete Structures
Chapter 4	Decks
Chapter 5	Bearing and Attachment
Chapter 6	Seismic Design

1. Chapter 3: Concrete Structures

(1) Selecting Method for Repair and Reinforcement

The process of the movement measures is shown Figure 5. After investigating and assessing the performance of structure, the structure which facilitates the movement is confirmed and the required repair and reinforcement measures are determined. It is important to plan the repair and reinforcement method from the viewpoint of the life cycle cost as per the maintenance policy, that is, to determine the most economical way to maintain, construct, and repair assets by predicting its deterioration. Therefore, it is necessary to individually examine each structure to be able to select the most appropriate measures.

A Bridge Management System (BMS) is used; when the examination is done, the deterioration is predicted and the life cycle costs are provisionally calculated.

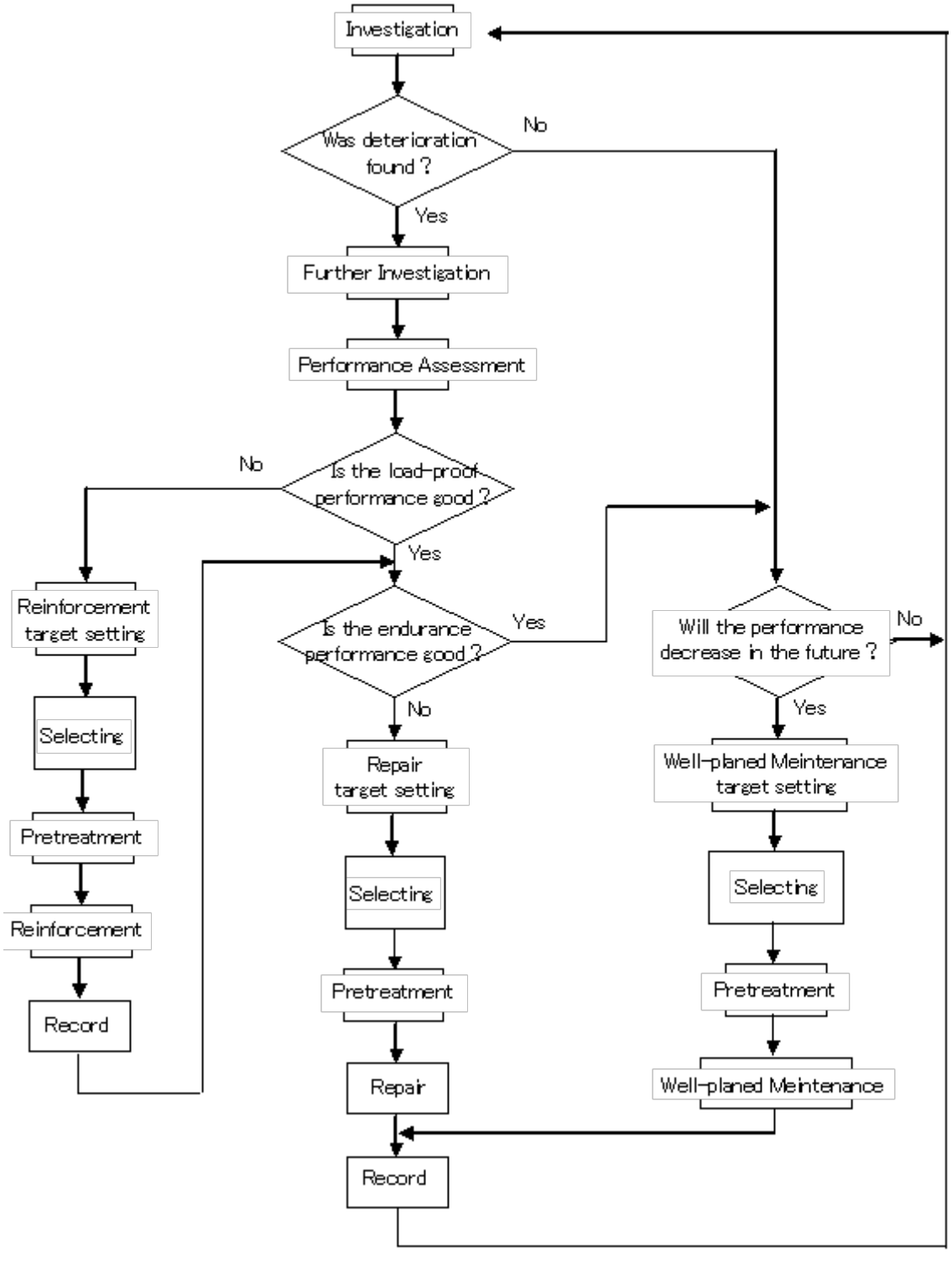


Fig.5 Process of the movement measures

(2)Pretreatment

As part of the repair and reinforcement of the concrete structure, the concrete member that binds the protective texture and reinforcement to the concrete surface is renewed and often augmented. A certain adhesion between the existing and the new material is required, and therefore an appropriate pretreatment is necessary. The specification includes a note about surface preparation and the chipping process. The standard chipping process is the hydrodemolition, and is used to avoid the generation of the micro-cracks. The chipping depth is assumed to be to the back of the reinforcement bar.

(3) Repair Method

The repair method includes description about the performance criteria, design, general planning, and notes about surface coating, crack injection, section repairs, electrical protection, concrete pieces fall protection, and chloride attack measures. The standards used for the repairing materials are described in the Expressway Standard Specification for Construction and for Test Method, and the repairing materials passed the examination are used.

(4) Reinforcement Method

The reinforcement method describes the design procedure, design method, and structural details for the overlay, steel plate bonding, prestress introduction, and continuous fiber sheet bonding methods.

2. Chapter 4: Decks

(1) Deterioration Type

There various kind of decks used for expressway bridges by NEXCO, which are used in various situations. However, there are several RC decks and many deterioration cases in NEXCO. Therefore, this chapter concerns repair and reinforcement of RC decks.

For NEXCO's expressways, most RC deck dererioration is the result of

1. Fatigue by traffic loading, or
2. Deterioration on the upper deck by the deicer.

A kind of fatigue deterioration by traffic loading has been the main problem for dererioration of the RC decks to date. This dererioration tended to be present for a comparatively long time, and frequently present in bridges constructed before 1970. However, flaking off of material from the deck and potholes has often occurred recently, not only on heavy traffic routes but also on routes sprinkling deicer. This dererioration might be different from the fatigue by traffic loading, and the deterioration might be limited on upper side of the deck.

The deterioration criteria from the lower side of RC decks is performed using the

method shown in Table 4~6. First, the dererioration grade of the deck (main girder × cross beam) is estimated according to the panel on the lower side by examining the efflorescence and the cracks, as shown in Table 4. The dererioration grade of the deck (span × width) is estimated according to the span and is based on Table 5, which uses the deterioration grade judgment result according to the panel. Moreover, the dererioration grade judged from deterioration other than efflorescence and cracking is estimated by using Table 6. On the other hand, for the deterioration of the upper surface of decks, there are many cases where deterioration progresses even when there is no efflorescence and cracking on the lower side. The dererioration grade for this kind of deterioration is estimated based on Table 7.

Table 4 Dererioration grade of the deck panel (the efflorescence and the cracks)

Dererioration Grade	Condition of Deck		Criteria
A	General part	The efflorescence is generated in two directions, both 50㎝ or less the interval. The efflorescence has discolored by muddy water and the rust fluid. Dererioration grade is "B" and the one with an early the progress.	Deterioration is remarkable. An urgent repair is necessary.
	Seam part	The efflorescence has discolored by muddy water and the rust fluid in the construction seam.	
B	General part	The efflorescence is generated in two directions, and the interval is both 50㎝ or less, and the one with white the color. Dererioration grade is "C" and the one with an early the progress.	Deterioration is large. An immediate repair is necessary.
	Seam part	The efflorescence is generated, and the one with white the color in the construction seam.	
C	The efflorescence is generated in two directions, and the interval in either of direction is 50㎝ or more. (No state of the tortoise shell it or nor the interval is large.) The crack not to accompany the efflorescence occurs in two directions, and the interval is both 50㎝ or less. Dererioration grade is "D" and the one with an early the progress.		Deterioration is growing. It is necessary to repair to the appropriate time.
D	The efflorescence has been generated in one direction. The crack not to accompany the efflorescence occurs in two directions.		Deterioration is small. A regular investigation is necessary.
E	The crack of the efflorescence and two directions do not occur.		

Table 5 Dererioration grade of the span (main girder × cross beam)

Dererioration Grade	Condition of Deck	Criteria
Ⅴ	There is deterioration in B or more in 40% or more of the deck panel.	Deterioration is remarkable. An urgent repair is necessary.
Ⅳ	There is deterioration in B or more in 30% or more of the deck panel.	Deterioration is large. An immediate repair is necessary.
Ⅲ	There is deterioration in D or more in 40% or more of the deck panel.	Deterioration is growing. It is necessary to repair to the appropriate time.
Ⅱ	There is deterioration in D or more in 30% or more of the deck panel.	Deterioration is small. It is necessary to repair to the appropriate time.
Ⅰ	There is deterioration in less than 30% of the deck panel or D or more.	Deterioration is small. A partial repair is necessary.

Table 6 Dererioration grade of the deck panel (expect the efflorescence and the cracks)

Dererioration Grade	Condition of Deck	Criteria
a	Peeling: The peeling is in the range of diameter 50cm or more. The exposure of the reinforcement bar: A main reinforcement bar has been exposed within the range of 50cm or more. The honeycomb and the cave: The honeycomb and the cave are in the range of the diameter 50cm or more.	Deterioration is remarkable. An urgent repair is necessary.
b	Peeling: The peeling is in the range of diameter 10-50cm. The exposure of the reinforcement bar: A main reinforcement bar has been exposed within the range of 50cm or less. The honeycomb and the cave: The honeycomb and the cave are in the range of the diameter 10-50cm.	Deterioration is large. An immediate repair is necessary.
c	Peeling: The peeling is in the range of diameter 10cm or less. The honeycomb and the cave: The honeycomb and the cave are in the range of the diameter 10cm or less.	Deterioration is small. It is necessary to repair to the appropriate time.

Table 7 Dererioration grade of the deck lower side

Dererioration Grade	Condition of Deck
Ⅳ	The pavement is frequently repaired. Concrete on the deck is crushed and it makes it to gravel. The reinforcement bar is corrodes, reduction of cross sections. Moreover, the efflorescence is often seen on the deck lower side.
Ⅲ	The pavement is frequently repaired. Concrete on the deck is crushed. The reinforcement bar is corrodes, but no reduction of cross sections.
Ⅱ	There are many healthy parts though deterioration in above-mentioned Ⅳ and Ⅲ are seen in a part when the pavement is removed.

(2) Selecting Method for Repair and Reinforcement

Figure6 shows the basis of selecting the repair and reinforcement method of RC decks. When the repair and reinforcement method for a deteriorated RC deck in selected, because of the influence of a traffic loading, it is necessary to select an appropriate method according to the level of deterioration of the deck. It is also necessary to consider the usage of the bridge and the period of any possible regulation of traffic.

(3) Repair and Reinforcement Method

The repair and reinforcement method describes the design procedure, design, and structural detail for waterproofing, the partial changing, overlay from under the deck, overlay method from over the deck, and overall changing.

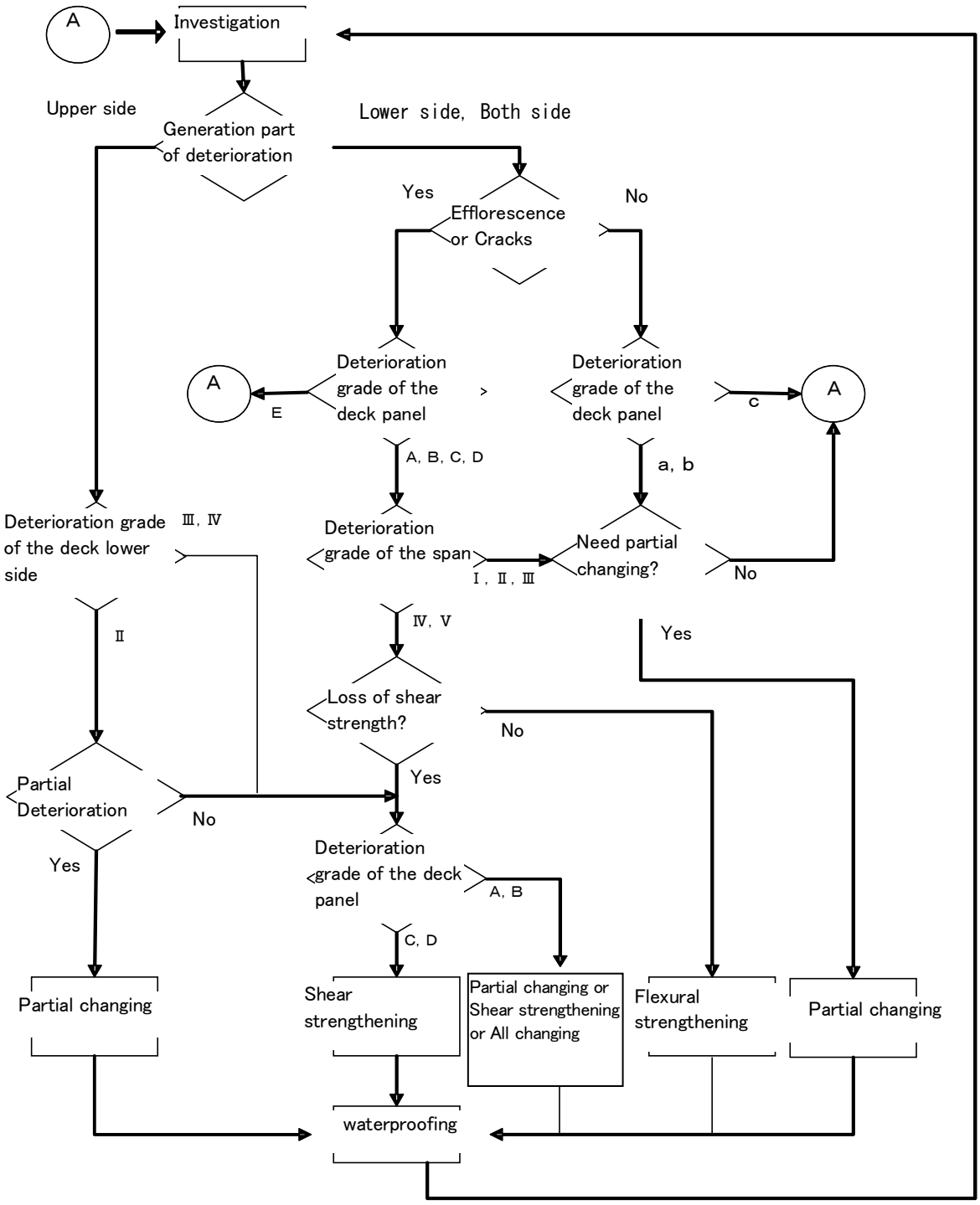


Fig.6 Process of selecting the movement measures

Future Direction

As already stated, the Expressway Standard Specification for Bridge Maintenance Design is organized and operated by NEXCO. However, the method of assessment used to select the repair and the reinforcement method might be weak, and an inappropriate method be selected at site, resulting in a re-deterioration.

Each individual structure is differentiated by its environmental surroundings, deterioration mechanism, deterioration level, and its importance in the network (impact and traffic), and it is difficult to organize an assessment method to apply it to all. However, it is hoped that a decision on grouping and priority levels can be made, and that a clearer description of the method of the assessment can be written.

An increase in the number of men performing maintenance tasks cannot be expected, even as infrastructure continues to age. Therefore, it is necessary to reduce the time taken to diagnose condition of bridges and to increase the efficiency at the assessment level.

Conclusion

Expressway standard specification by NEXCO has been regularly reviewed and updated in the 50 years since its first use. Expressway standard specification for Bridge Maintenance Design is rare specification. However, the method of assessment used to select the repair and the reinforcement method might be weak. An increase in the number of men performing maintenance tasks cannot be expected, even as infrastructure continues to age. Therefore, it is necessary to reduce the time taken to assess condition of bridges and to increase the efficiency at the assessment level.

If this text becomes reference of other road administrators who have similar problems, it is great.

References

(1) Japan Expressway Holding and Debt Repayment Agency, et al.: Recent Technologies and Services of Expressways in Japan

(2) NEXCO: Expressway Standard Specification by NEXCO for Bridge Maintenance Design, 2010.7