ANALYSIS OF PERIODIC INSPECTION RESULTS OF HIGHWAY BRIDGES IN JAPAN

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Abstract

Analyses of initial inspection results, relationship between age and damage, progress of damage, and fatigue damage were conducted using periodic inspection results as a part of the research on rational periodic inspection method to grasp conditions of nationwide bridges from the uniform point of view efficiently.

Background

In Japan, under limited budget and stuff according to social and economical change that low fertility and aging are in progress, to maintain service level of its huge road network strategically and efficiently is required. For this, prevention maintenance that countermeasures are conducted at the early stage before the abnormalities become serious, not the countermeasures like symptomatic treatment for remarkable damages, is needed, and strategic and rational management that contributes on reducing life cycle cost for long time considering whole road asset is also needed. Furthermore, it comes important to maintain roads over the nation as network.

Under this background, paying attention to bridge inspection which is the most basic action to get information needed for bridge maintenance, analyses of periodic inspection results were conducted as a part of the research about the rational periodic inspection method to grasp conditions of nationwide bridges from an uniform point of view efficiently.

State of bridge inspection in Japan

Bridges operated by MILT are inspected with periodic inspection manual, which was revised on March 2004 from that edited on July 1988 to conduct inspection more efficiently with the new findings in maintenance and inspection results.

1) Frequency of inspection

For inspection frequency, initial inspection should be done within 2 years after the bridge is opened to the traffic, after that the bridge should be inspected every 5 years.

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Initial inspection is aimed to increase durability and to reduce life cycle cost by taking measure at early stage against initial defects which appear within several years after opening to the traffic. The initial inspection results are meaningful as the initial data for various maintenance works like repair and reinforce within the service life of the bridge.

2) Method of periodic inspection

The method of periodic inspection has basically followed the precedent: the method to evaluate every member considering every usual kinds of damage by close visual inspection.

This is the result of the judge that this inspection method is the most rational and indispensable considering economy at this point to detect partial damage and to grasp the progress of serious damage which develops extremely rapidly at some parts in the point of view of keeping structural safety of the bridges, preventing damage for a third person, realizing preventive maintenance by detecting the indication of damage at early stage. That is, considering the limit of stuff and budget, there are some places to examine to use distant view or to introduce advanced technical skills like non-destructive inspection methods, but many serious damages to affect the safety of bridges like short of sectional area in steel members by crack or corrosion are difficult to detect by distant view, and the rational methods to cover the risk of missing those damages have not been established.

3) Evaluation of inspection results

Two types of evaluation of inspection results were introduced when the periodic inspection manual was revised on 2004: "evaluation of degree of damage"- it is a record of facts of degree of damages, and "judgment of countermeasure"- it is a first diagnosis about function of bridge and structure by proper engineers.

Information which is grasped by inspection like damages and aging is not only indispensable to inferring cause and to evaluating performance, but also used for future estimation or trend analysis. Information should be objective data based on an uniform standard.

On the other hand, evaluation and diagnosis by engineer with technical knowledge accompanied with inspection are dispensable to various damages and their effects' being measured. It is very important for administrator to decision-make properly about need for traffic regulation and countermeasure like repair and rehabilitation gasping the performance of bridges from inspection. For this, it is important to get not only facts of kind of each damage and degree of their development, but also damage's effect to bridge's performance and view about response that should be done from the damage's effect. For example, some fatigue cracks of steel members develop rapidly to dangerous state of the bridge even if the crack is small when it is detected.

For "evaluation of degree of damage", every parts is evaluated in the divided unit of each member because the evaluation is the basic data for investigation for rationalization of future inspection. Damages detected at periodic inspection are evaluated at every element and at every degree of damage, and the classification means objective facts indicating the degree of damage. The classification of degree of damage is shown in Table.1. Damages are evaluated to the classification of "a", "b", "c", "d", and "e" by degree of damage, and "a" is the least serious and "e" is the most serious.

Table 1. Classification of degree of damage

Evaluation division	Degree of damage
a	Small
b	↓
c	
d	
e	Large

For "judgment of countermeasure", on the other hand, the unit of member with some sizes, like main girder or pier, is evaluated because "judgment of countermeasure" is qualitative evaluation which can be called an advice for administrator about countermeasure in relation to performance of the bridge. The classification of evaluation is shown in Table.2.

Table. 2 The classification of evaluation at judgment of countermeasure

Evaluation division	Content of evaluation
A	Damage is not confirmed or little, so repair is dispensable.
B	Repair is needed according to the situation.
C	Repair is needed immediately.
E 1	Emergency response is needed for structure safety.
E 2	Emergency response is needed for other reason.
M	Response through maintenance construction work is necessary.
S	Detailed investigation is necessary.

Analysis of periodic inspection results

Various kinds of analysis of the periodic inspection results were conducted for improvement of periodic inspection because one round of periodic inspection had almost finished.

1) Analysis of initial inspection results

Damages were detected in most of bridges in first inspection. The number of bridges as the objects of first inspection was 198, which were within 2 years after opening to the traffic and after construction completed, and damages were detected in 193 bridges (97%). The most detected damage was deterioration of rust-proof performance and corrosion in steel members and crack, leakage and isolated lime in concrete members. Abnormality of anchorage zone of PC member and abnormality of performance of bearing were detected as the serious damage to affect performance of bridge.

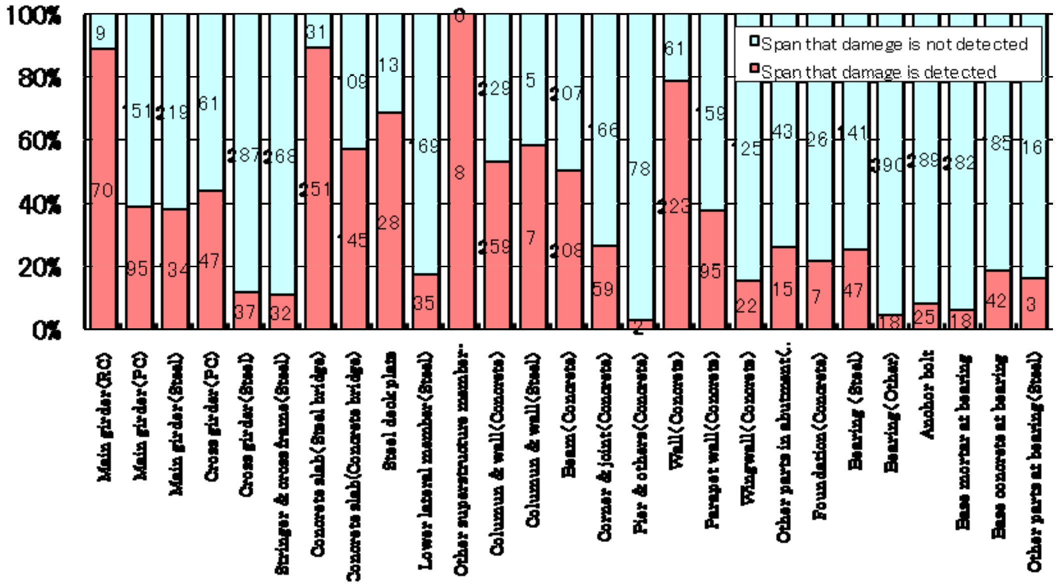


Fig.1 Initial inspection results (main members)

2) Relationship between age and damage

As a whole, the rate of abnormality seems to increases in accordance with age. Fig.2 shows states of damage in periodic inspection results at age after opening to the traffic. Bridges' deterioration characteristic has huge variation because it depends on bridge's structure and environment, and it can be inferred that degree of deterioration and damage of each bridge differ. However, as a whole, the trend that the rate of abnormality increases in accordance with age is notable.

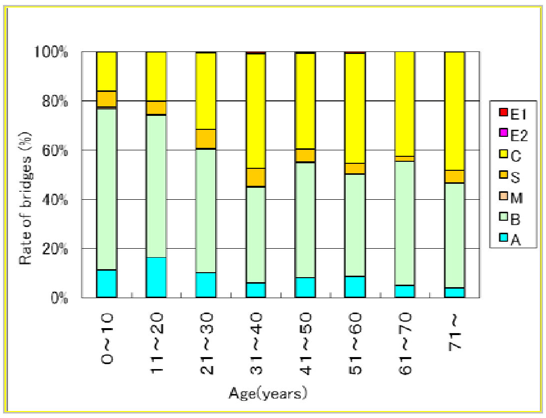


Fig.2 The rate of bridges in classification of measure

3) Analysis about progress of damages

① Crack at concrete members (part)

Among the relationships between age and degree of various kinds of damage, the example of crack at concrete main girder is shown in Fig.3, and the example of abutment is shown in Fig.4. The transitions of main girder and abutment are different. On the other hand, it can be inferred that when crack generated even at main girder, the crack certainly progresses within 5 years.

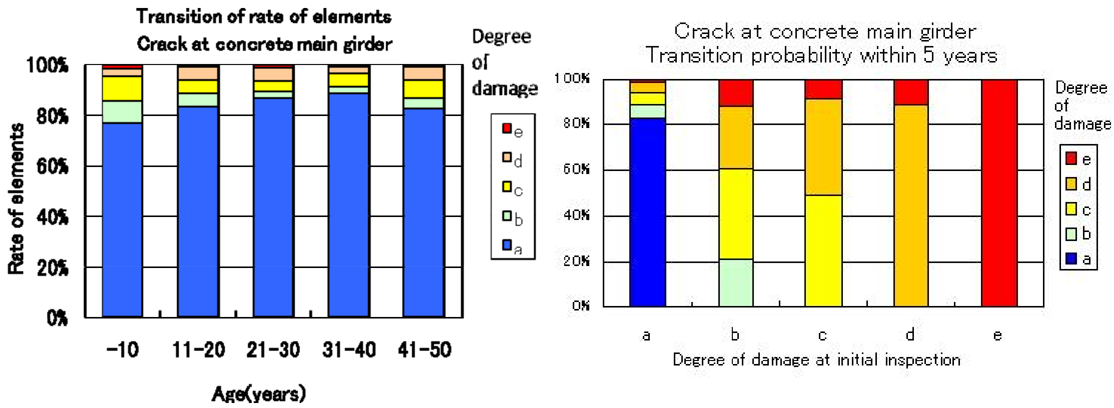


Fig.3 Relationship between age and degree of damage
(crack at concrete main girder)

② Crack at concrete members (environment)

The transition of two periodic inspection results was analyzed classifying chloride damage area and other area to grasp the effect of environment regardless age. The result is shown in Fig.5. Marcov transition probability based on Fig.5 is shown in Fig.6. It is recognized that the deterioration speed in is a little faster chloride damage area when degree of damage is light.

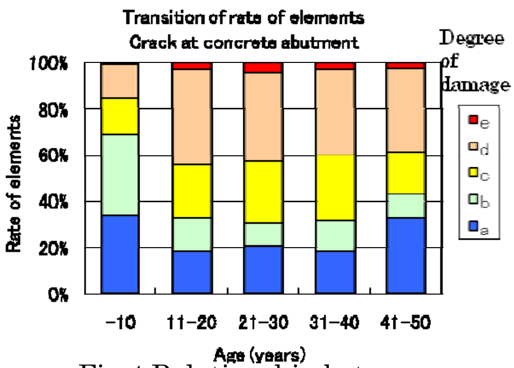


Fig.4 Relationship between
age and degree of damage
(crack at concrete abutment)

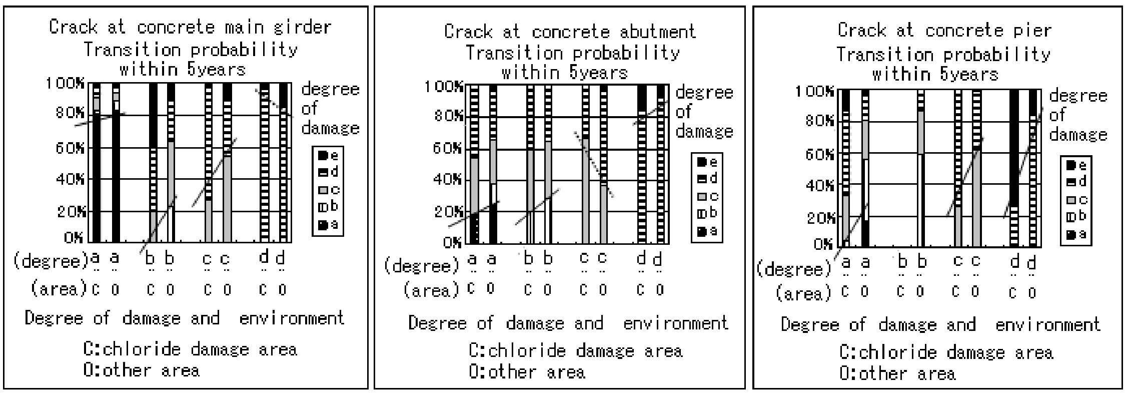
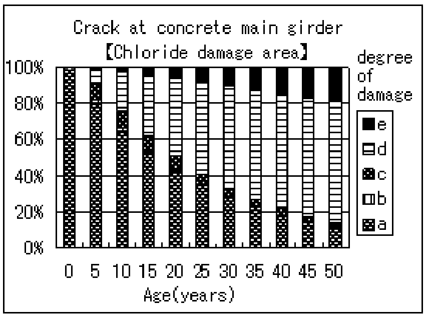


Fig. 5 Transition probability of generation of crack at concrete members



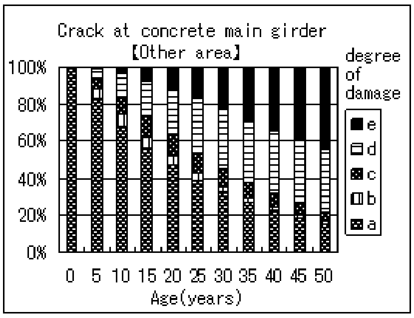


Fig.6 Marcov transition probability of crack at concrete main girders

③ Crack at concrete members(structural type, crack pattern)

Age and state of crack generation at PC post-tensioned hollow slab bridge and PC post-tensioned T section girder bridge are shown in Fig.7 and Fig.8.

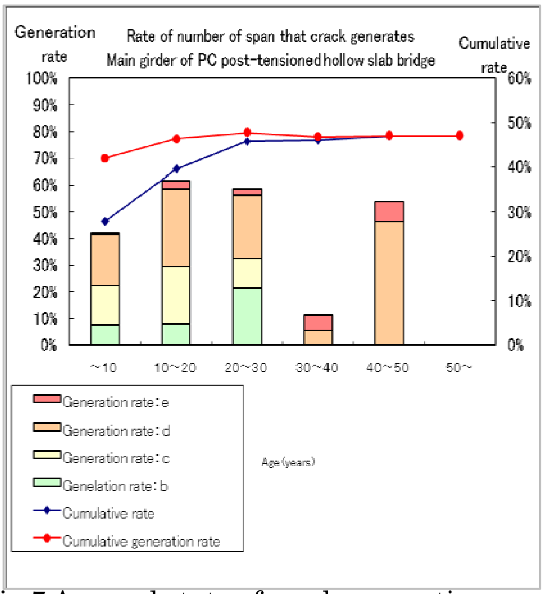


Fig.7 Age and state of crack generation
(PC post-tensioned hollow slab bridge)

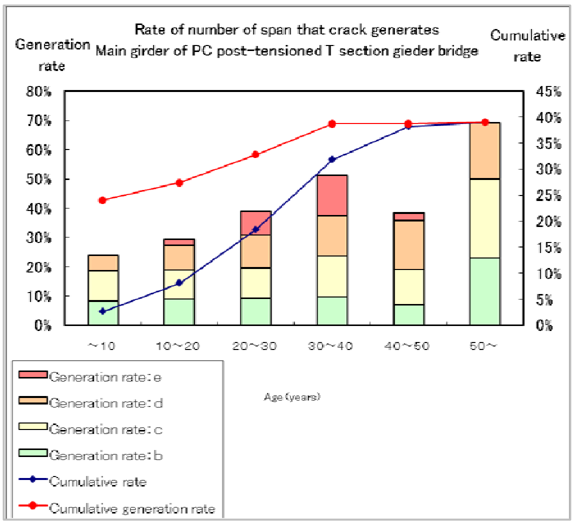
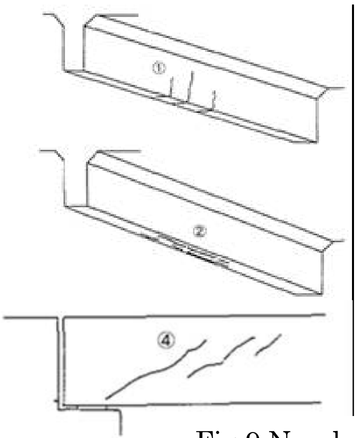


Fig.8 Age and state of crack generation
(PC post-tensioned T section girder bridge)

For PC post-tensioned T section girders, age and state of crack generation in each pattern whose generation rate is high is shown in from Fig.9 to Fig.12



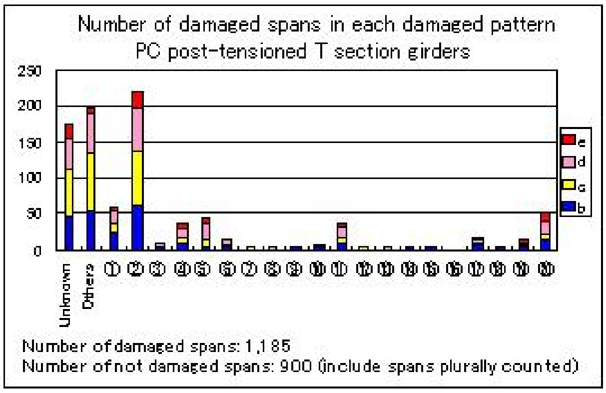


Fig.9 Number of damaged span in each damaged pattern
(PC post-tensioned T section girder bridge)

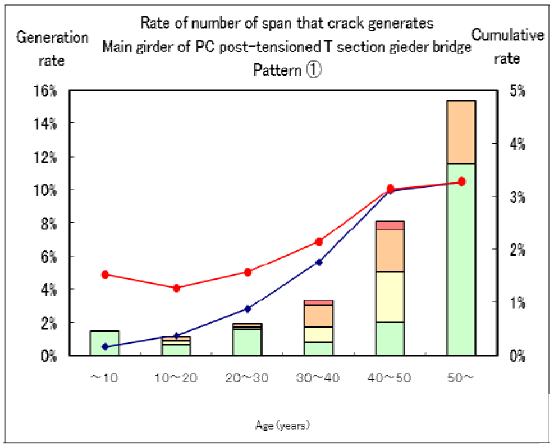


Fig.10 Age of PC post-tensioned T-section girder bridges and state of crack generation (Pattern①)

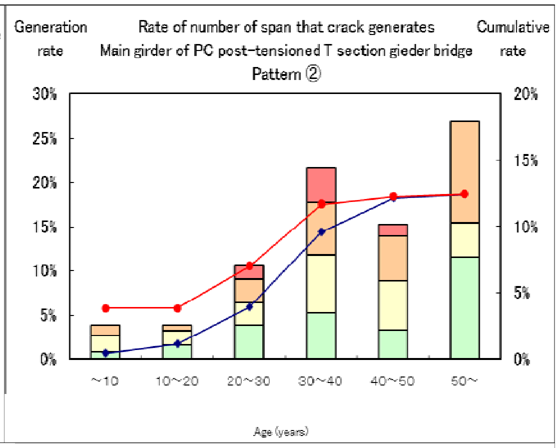
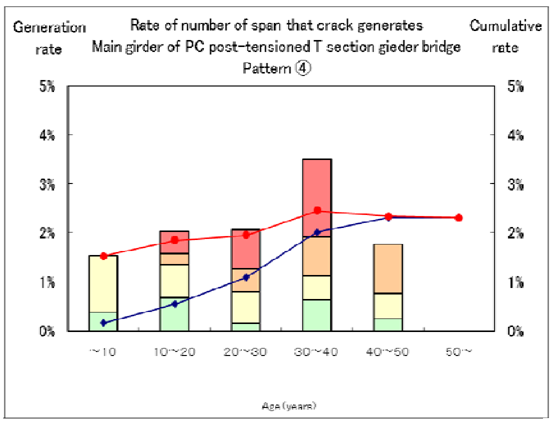


Fig.11 Age of PC post-tensioned T-section girder bridges and state of crack generation (Pattern②)



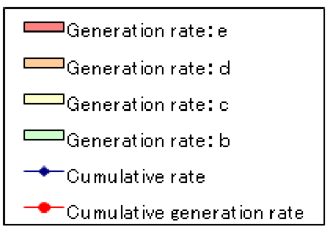


Fig.12 Age of PC post-tensioned T-section girder bridges and state of crack generation (Pattern④)

④ Corrosion at steel girder (difference of material)

Transition probability about corrosion at steel girder also calculated at general painting system and heavy-duty painting system. The result is shown in Fig.13.

The trend is that the speed of development at general painting system is quicker than that of heavy-duty painting system for small damage, but the difference is not notable for large damage.

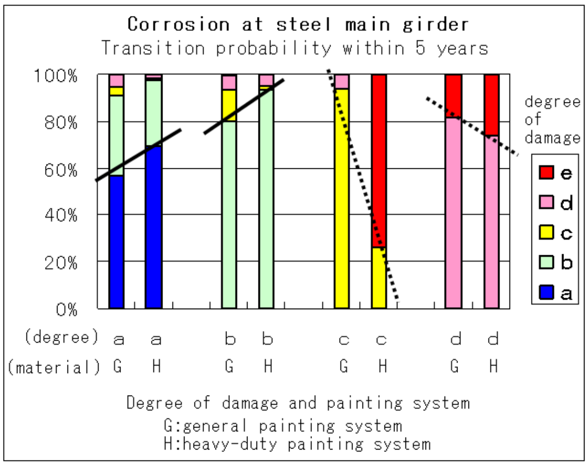


Fig.13 transition probability of corrosion at steel main girders

4) Analysis about fatigue

In the crack of steel member, the relationship of fatigue damage, age, and cumulative traffic volume was analyzed. The results of steel plate girder bridges and steel box girder bridges are shown in Fig.14, and the results of steel truss bridge are shown in Fig.15. The trend is recognized that the rate of generation of crack increases when the age gets more than 30 years, and cumulative large vehicle volume gets 250 thousand vehicles･year in steel plate girder bridges and steel box girder bridges, and that the rate of generation of crack increases when the age gets more than 30 years in steel truss bridges.

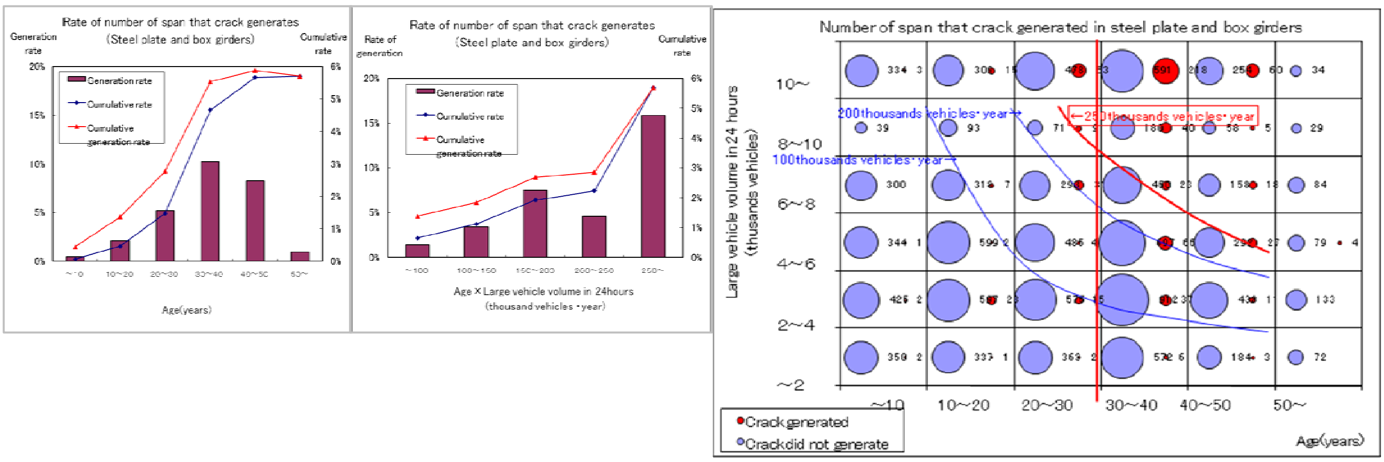


Fig.14 Rate of number of span that crack generates (Steel plate and box girder bridges)

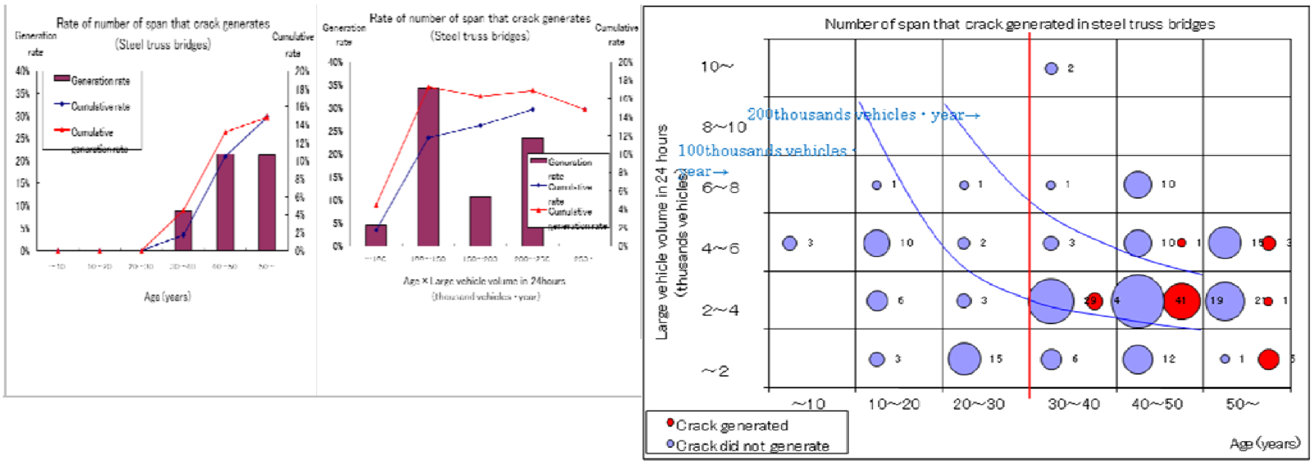


Fig.15 Rate of number of span that crack generates (Steel plate and box girder bridges)

The results about RC slab are shown in Fig.16. It could not be seen the damage's significant relationship with age and traffic volume. The damages might include the damage except for fatigue.

For fatigue damage of RC slab, damage progress patterns are being analyzed including states of leakage and isolated lime with crack. The result of analysis of crack patterns is shown in Fig.17

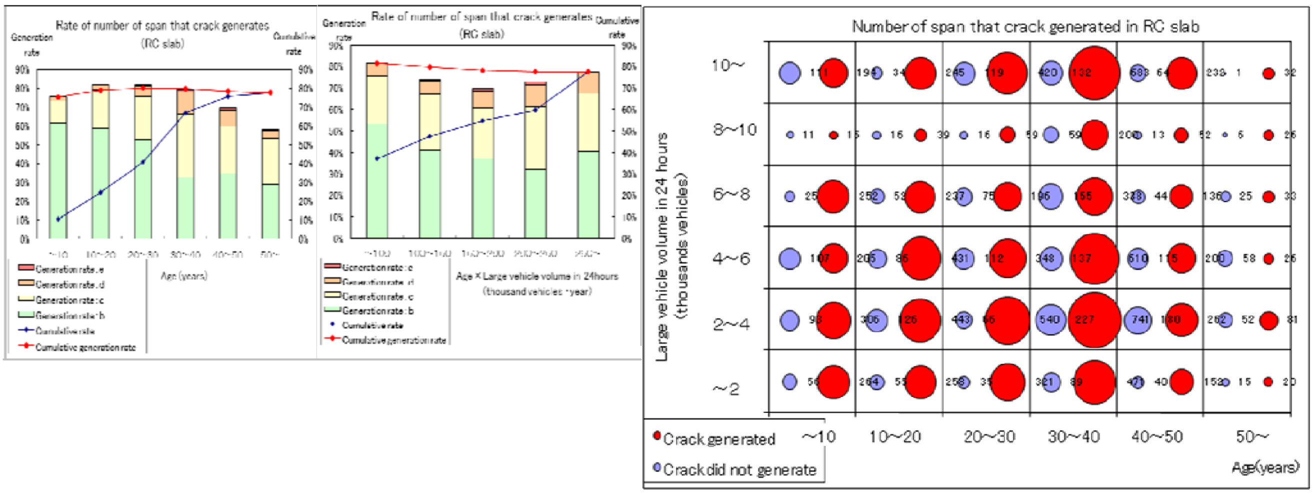


Fig.16 Rate of number of span that crack generates (RC slab)

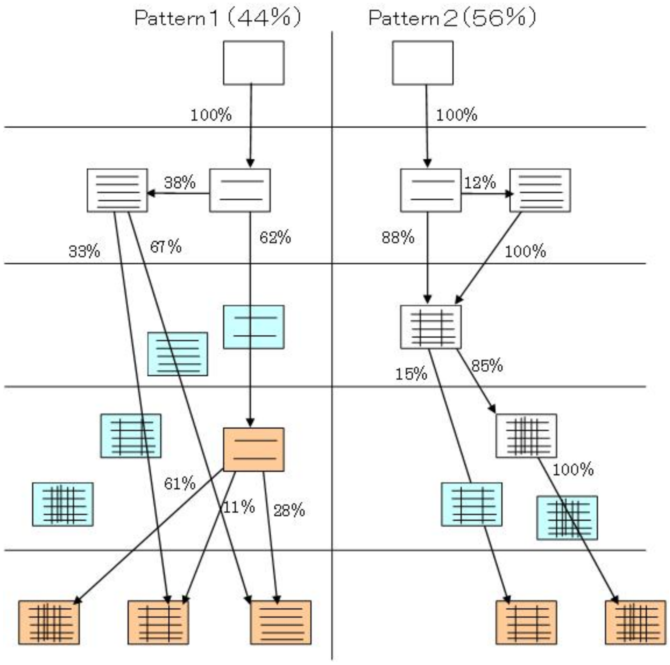


Fig.17 Analysis of crack patterns of RC slab

5) The relationship of degree of damage and classification of measure

The relationship of degree of damage and classification of measure in the case of crack at concrete main girder is shown in Fig.18. Both evaluations are not coincident. It can be inferred that engineers evaluate in classification of measure considering the bridge's unique condition like environment.

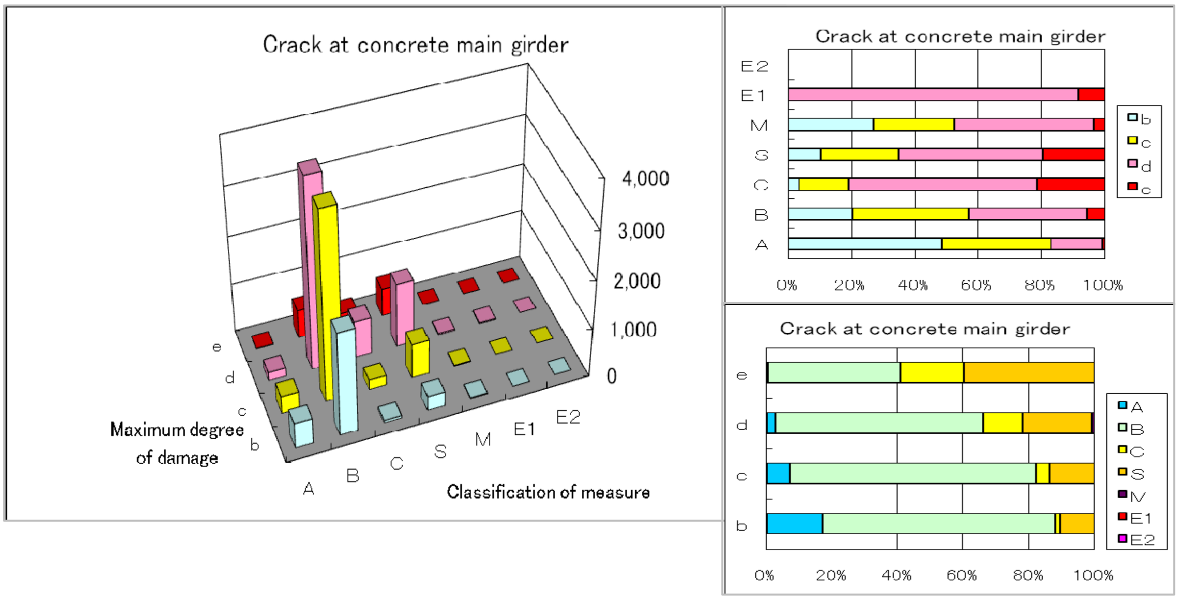


Fig.18 The relationship of degree of damage and classification of measure
(crack at concrete main girder)

Summary

Periodic inspect ion data has been analyzed to rationalize periodic inspection to get basic data in maintenance strategy and to grasp state of bridges for prevention of emergent accident and timely countermeasure like preventive maintenance.

The followings can be mentioned as findings from this analysis:

1) It is highly possible that there is a limitation to model deterioration characteristic because progress of deterioration is related to various factors such as construction environment, traffic condition, structural characteristic of whole bridge and every member.
2) Therefore, it can be referred that inspection method and frequency should be optimized according to not only common conditions such as structural characteristic and traffic but also individual part or member of the same bridge.
3) Degree of damage as “Objective fact” used for deterioration prediction and statistical analysis not always corresponds with evaluation based on performance of the bridge. Both of them are needed for maintenance.
4) Evaluation based on performance of the bridge should be considered each viewpoint of damage risk, emergency, preventive maintenance and so on for proper countermeasure.

Analyses of inspection results will be continued for an establishment of the rational bridge inspection system.