RESEARCH AND REPAIR OF REINFORCEMENT BY OVERLAYING FLOOR SLAB METHOD IN EXPRESSWAY

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Abstract

NEXCO has been reinforcing floor slabs by overlaying for about 15 years as a measure against deterioration and increasing live load on steel bridges. However, re-deterioration has become noticeable on repaired bridges. This document is a summary of the measures taken to cope with the issue.

Introduction

In Japan, live load has raised, and the damage of floor slab has increased. The "Design and Construction Manual for Overlaying"[1)] was compiled as a guideline for reinforcing floor slabs and has been applied from 1995 on more than 400 bridges. But, recently, damages have been found in short periods after reinforcement and the number has been escalating as well. The following gives an outline of the overlay method, description of the deterioration factors, study results on improving the durability of the method and the resin injection method used to repair re-deteriorated floor slabs.

Outline about the reinforcement of overlaying[1)2)]

A repair method is decided by the location and the degree of deterioration which are determined by examining the floor slab. The repair method is selected from the followings: slab waterproofing, partial slab exchange, overlaying floor slab from bottom face, overlaying floor slab and full slab exchange.

In the overlaying method, load bearing capacity is recovered or improved by casting steel fiber reinforcement concrete on the existing floor slab. (Fig.1).

Steel fiber reinforcement concrete is cast thinly after polishing and sweeping the milling face. Rapid hardening cement is often used to shorten the construction and accompanying traffic control period. Steel fiber reinforcing concrete is generally produced exclusively at a large-sized plant and is laid and tamped by a concrete finisher dedicated for that purpose. It is used to prevent cracks and control the size of cracks if cracks develop. The design strength is the same as the existing concrete. The slump is to be around 5cm to reduce dry shrinkage and correspond to longitudinal and cross slopes. Most steel fiber is 30mm in length and has an aspect ratio of 50-60, and a mixture rate of 1.27vol.% as standard.

At present, more than 400 bridges adopt this method as a repair method of deteriorated floor slab in expressway.

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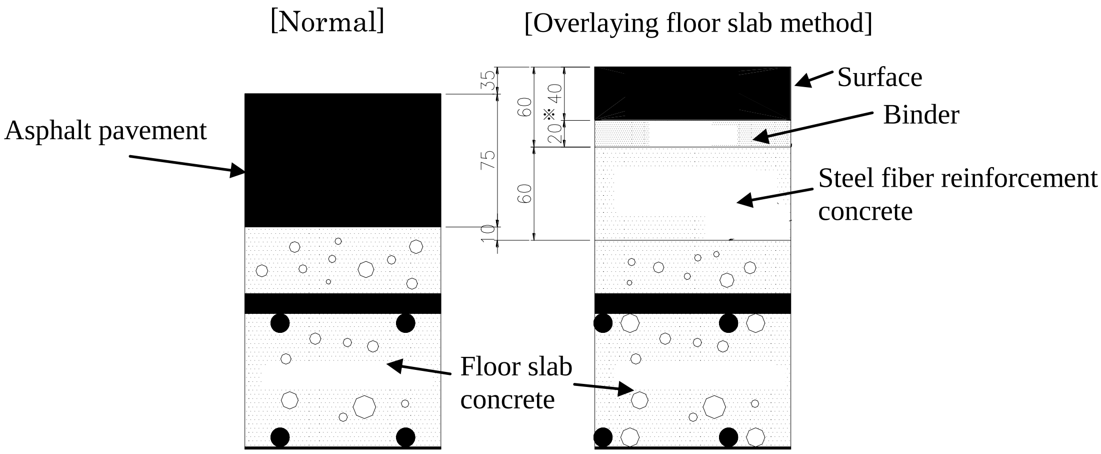

Fig.1 Cross section of overlaying floor slab method

Re-deterioration factor[3)]

Re-deterioration of floor slab has been reported from about 1998. The problem has become noticeable as potholes and cracks in the pavement.

We did a questionnaire survey, in 2006, for about 400 bridges repaired by overlaying. The survey showed that re-deterioration occurred in 12% of bridges. When we studied the record of damage and analyzed damage positions, we found that potholes occurred most at the construction joint between lanes (Fig.2) and tended to be near the shoulder next to running position of large-sized vehicles. Fig.3 shows the cross section of floor slab where many potholes were found. The damage state indicates infiltration of water from the construction joint and staying of slag at the boundary between existing floor slab and overlaying.

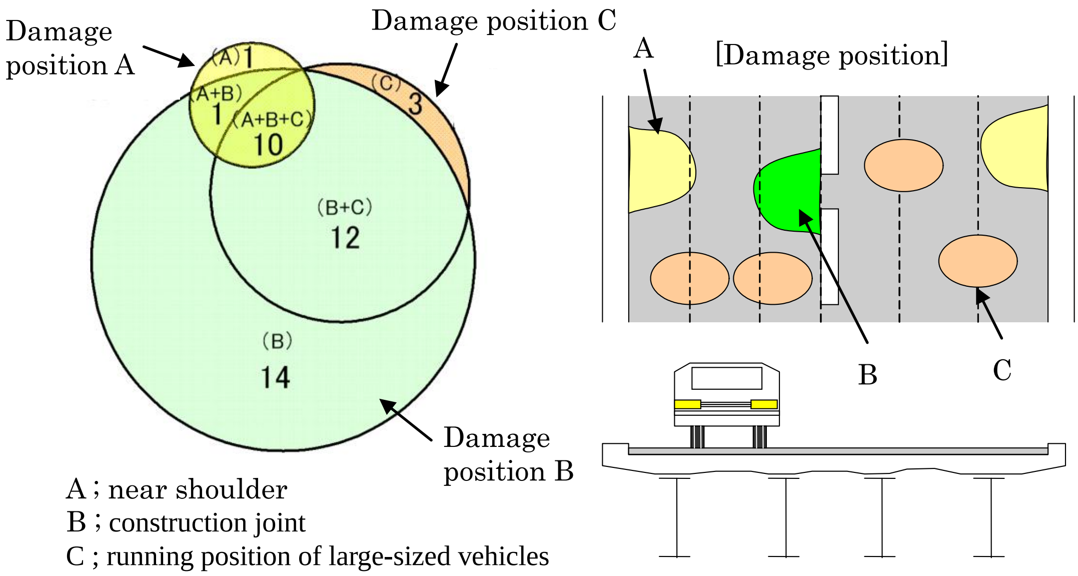

Fig.2 Damage position of overlaying floor slab

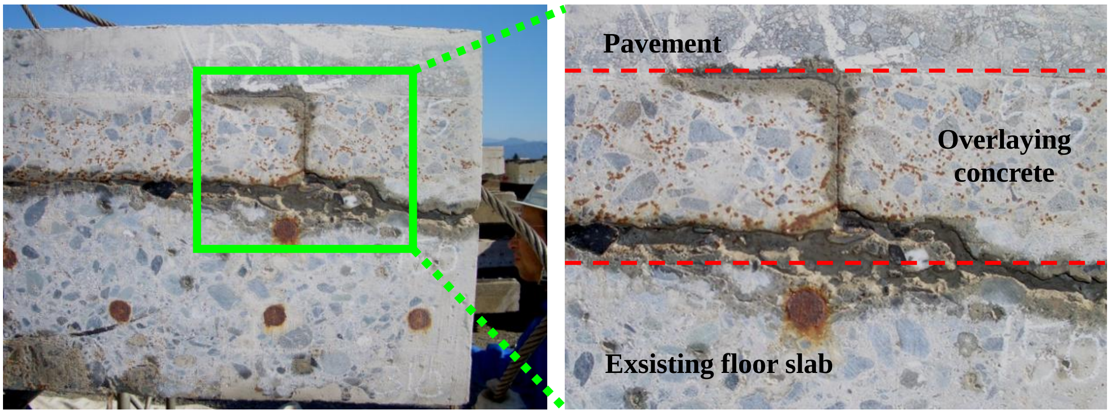

Fig.3 Section of floor slab with many potholes at construction joint

We analyzed the questionnaire survey statistically to find the causes for the re-deterioration. We roughly classified the re-deterioration factors as follows: structure factors, environmental factors, material factors, level of health and construction factors. Of the factors, those which we were able to find a tendency for occurrence are described below.

Structural factors: Steel bridges accounted for 70% of the bridges reinforced with the overlay method and re-deterioration was noticeable in plate girder bridges (Fig.4).In addition, much of the deterioration was found in bridges designed between 1971 and 1979 — design standards used for these bridges are not much different from the current standards.

Environmental factors: Re-deterioration tended to become noticeable when the cumulative quantity of anti-freezing agents used and the cumulative days of when minimum temperature is lower than zero degrees exceed a certain quantity (Fig.5, 6).

Construction factors: Milling machines and surface preparation may cause cracks in floor slabs. It was tested and confirmed on a test piece that minute cracks developed in existing floor slabs when floor slabs were cut or chipped with a milling machine or breaker.

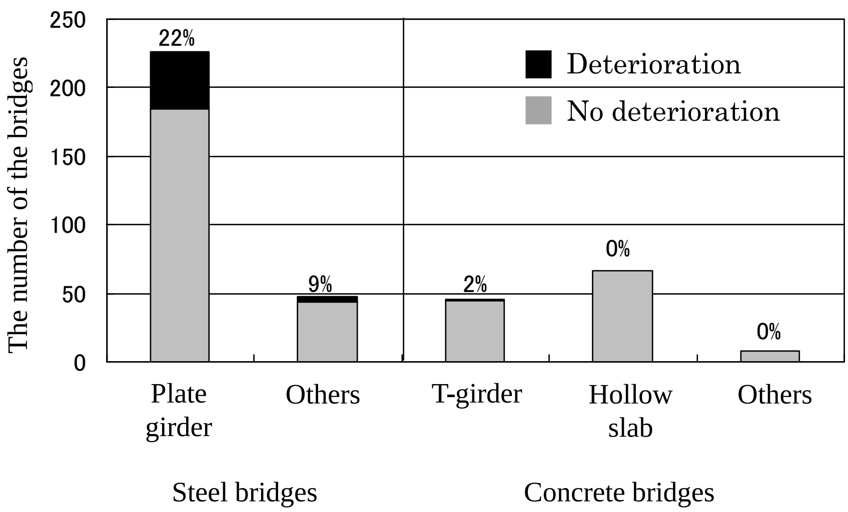

Fig.4 Relations of structure and deterioration

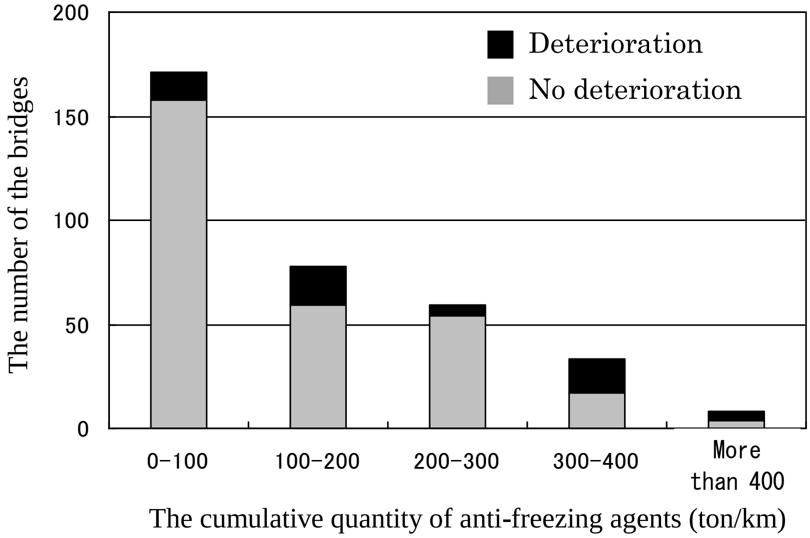

Fig.5 Number of deterioration caused by anti-freezing agents

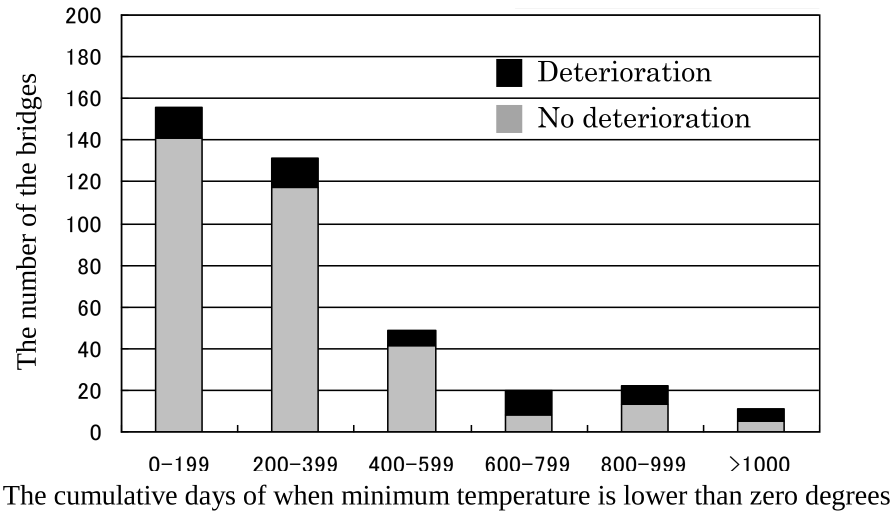

Fig.6 Number of deterioration caused by daily temperatures lower than zero degrees

We found that in many cases re-deterioration begins from the construction joint. A standard procedure in the overlay method is to polish and sweep the existing floor slab with a shot-blast machine after milling. Although the shot-blast machine is place along the construction joint, the area which is 150mm from the construction joint cannot be sufficiently polished and swept. We also found that although a sweeper cleans after milling, chips were not fully removed and tended to remain at the edge (Fig.7). Poor adhesion may occur when concrete is casted in this state. Therefore, vibrators are used for tamping by hand.

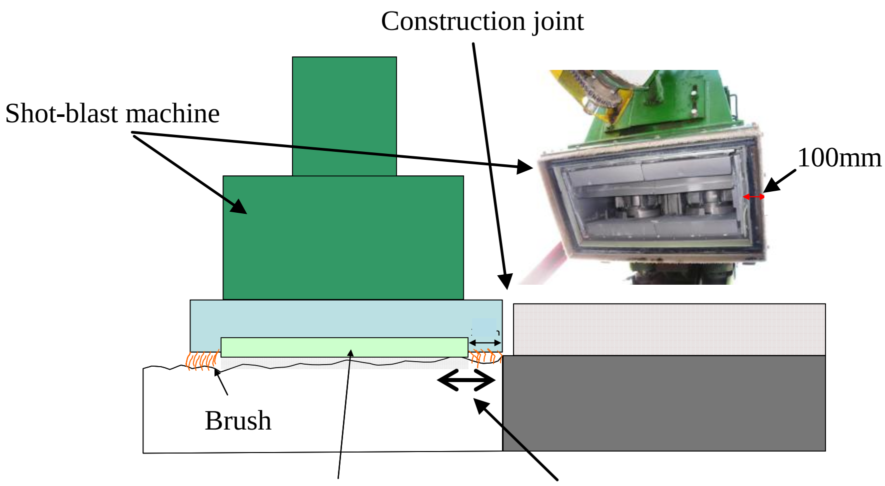

Fig.7 Position of a shot-blast machine at edge

Repair of re-deteriorated floor slab[4)]

In 2002, we repaired a re-deteriorated floor slab of a steel truss bridge which was reinforced by overlaying in 1990 (Fig.8). As some ten years had passed since the repair, potholes were often found in the pavement. Inspections showed that there was separation between the existing floor slab and overlaying concrete. It was assumed that this separation caused the damage to the pavement. Thereupon, we tried injecting resin in the interface of the re-deteriorated floor slab. This method was selected considering safety of road users and so that roadwork restrictions to control traffic are held down as much as possible as traffic on the bridge was more than 80,000 vehicles per day.

Fig.8 The bridge repaired by overlaying floor slab

Before the actual repair was carried out, a section of the re-deteriorated floor slab was cut out and resin was injected in the interface. Then a fatigue test using the accelerated load tester was conducted to confirm the effectiveness of the repair method. The result was compared with the fatigue test result of the section before injecting resin. Recovery of stiffness, improvement of durability and degree of separation were confirmed. The size of the section taken from floor slab of the actual steel truss bridge was 2.5m*5.0m.

Before injecting resin in the interface, approximately 2.5 liters of water was poured in from the injection holes at the center of the specimen. This was to wet the interface for the injection. Injection holes are placed at about 0.5m - 1.0m intervals. The qualities considered when selecting the resin for filling are filling characteristics, impregnation characteristics, the influence the mud on the boundary surface has on the resin, adhesiveness of the concrete and adhesiveness when surface is wet. Several hydrophilic materials were tested and an epoxy resin-based material with high filling performance was chosen.

The fatigue test showed that the number of loading (counting back and forth as one trip) before breakdown was 23,000 times for the test piece without resin injected. On the other hand, it was 139,000 times for the test piece with resin. This shows that durability is approximately 6 times more when resin is injected.

Fig.9 shows a section of the bridge actually repaired by injecting resin. After cutting the pavement, injection holes 100mm deep and with a diameter of 10mm were drilled, and the resin was injected. The resin was partly injected from the pavement surface as traffic control requirements restricted the work that can be carried out (Fig.10). In either case, the holes were cleaned by air (compressed air infusion) after drilling. But places where the concrete have turned to gravel were washed with water. Resin was injected every 1m in both longitudinal and perpendicular directions. Core sampling was performed after injection, and it was confirmed that filling was satisfactory in most of the repaired locations.

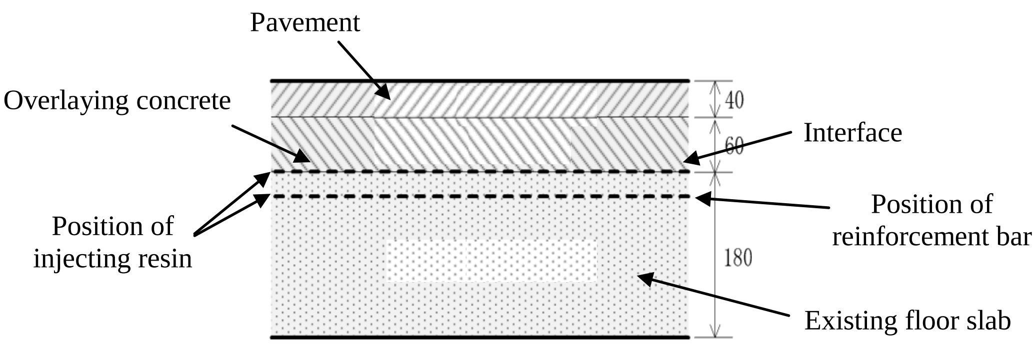

Fig.9 Section where resin was injected

Fig.10 Shows resin being injected

Examination results of reinforcement effect after repair[5)]

Repairs by injecting resin were carried out on a trial bases, and not many locations where the method was applied exist. Therefore, its effectiveness and the durability obtained were not verified. So to find out, we examined a re-deteriorated floor slab which had been repaired seven years ago.

Static loading test using load vehicle and frequency measurement using load of vehicles actually travelling on the bridge were conducted. In addition, separation of floor slab were tested by hammering for the upper part and visually from below for the bottom part of the floor slab.

To verify the effectiveness, the test results were compared with the results of the tests conducted in 2002 when the bridge was repaired by injecting resin. The tests were conducted under the same condition. Fig.11 shows the measurement position of the static loading test. Fig.12 shows the measurement position of deflection.

The results are as follows.

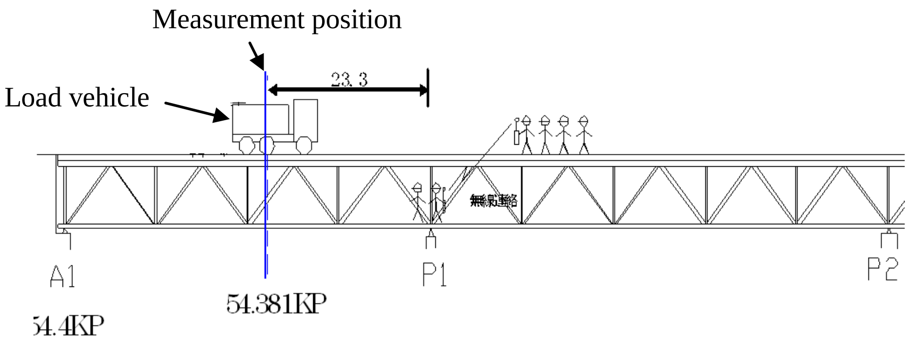

Fig.11 Measurement position of static load test

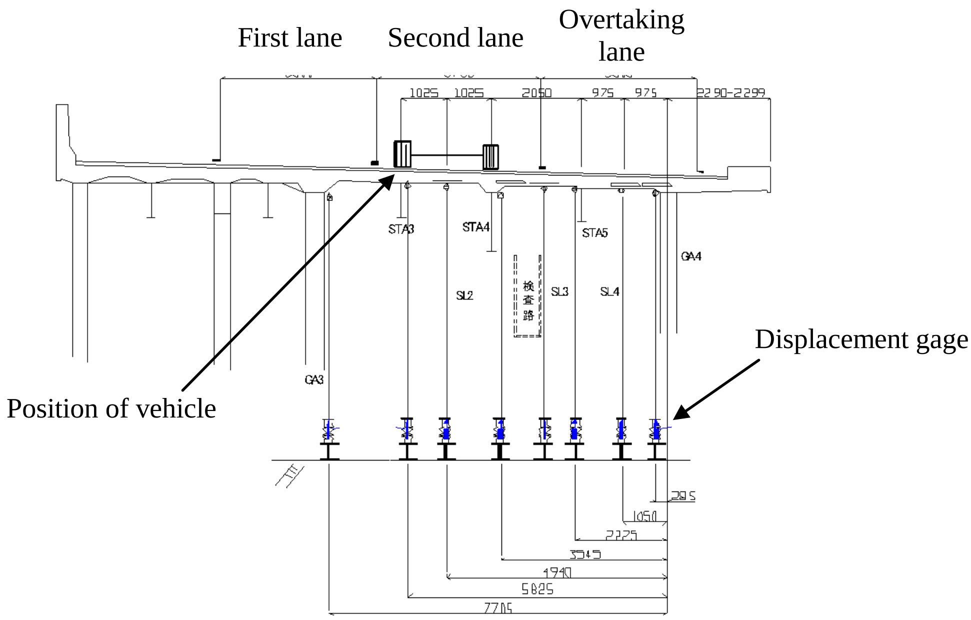

Fig.12 Measurement position of deflection

1. Static loading test

The results of the measurements of floor slab deflection, distortion of reinforcement bar and crack displacement are as follows.

The initial value was set on the assumption that there is no vehicle on the bridge and deflection was measured using a load vehicle. The "relative deflection" was compared. The value was relatively calculated, supposing that the position of an upper chord material of the main truss and the stringer were steady points.

Fig.13 shows the maximum measured deflection. The deflection decreased after repair. We found that the deflection measured “seven years after” repair is equal to the value measured immediately “after repair” and assumed that the load bearing capacity increased by the repair lasts.

The distortion of reinforcement bar was checked by measuring main reinforcement bar and distributing bar of floor slab. The measurements were compared in terms of stress, with the initial value set assuming that no vehicle is on the bridge. Though in some parts it seemed that the value for “seven years after” repair is larger than that for “before repair,” when the values for immediately “after repair” and “seven years after” repair are compared, they are about equal. Therefore we assume that increased load bearing capacity continues.

Crack displacement was also measured in the same way. The results of measurements are similar to the distortion. We concluded that the possibility of cracks progressing rapidly is low.

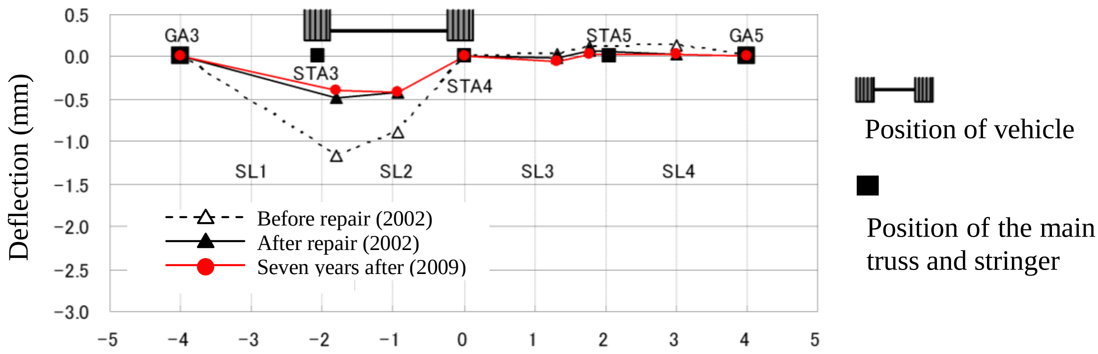

Fig.13 Distribution of relative deflection of floor slab

2. Frequency measurement using load of vehicles

Reinforcement bar distortion and crack displacement taken in the frequency measurement are as follows. The traffic density for 24 hours, the number of vehicles and the mix rate of large-size vehicles in the traffic on the day of measurement were the same as in 2002, when “after repair” confirmation tests were carried out.

Distortion was measured at main reinforcement bar and distributing bar at the bottom of floor slab. The distortion of main reinforcement bar of “seven years after” repair was the same value as immediately “after repair”. It was confirmed that the tendency was the same as the static loading test result. The distributing bar also had a similar tendency.

Crack displacement was measured for cracks in the longitudinal and perpendicular direction of the bridge axis. Fig.14 shows the measurement of a crack in the perpendicular direction. The crack displacement shows the range of crack displacement caused by vehicles travelling on the bridge. Though the displacement of “seven years after” repair is approximately 2 times that of immediately “after repair”, the displacement is low and is half that of “before repair”. Because the remaining crack width was between 0.10-0.20mm, we assumed that the crack did not tend to noticeably progress.

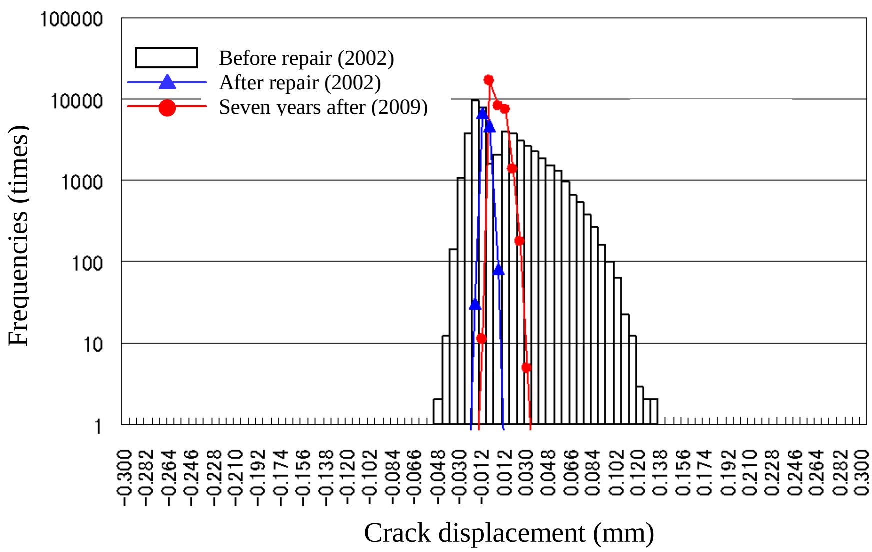

Fig.14 Frequency distribution of crack displacement

3. Examination of separation on the pavement

The area of separation was approximately 2% of the area inspected using a test hammer. (area : 6*6m). Little separation has developed after repair, and we can assume that the effectiveness of the repair is maintained.

4. Visual inspection of the floor slab bottom

A visual inspection of the floor slab bottom between A1 – P1 was performed. Though crack density progressed slightly after repair, deterioration of free lime and leakage water didn't occur. Therefore, we assume that the pace of deterioration is slow.

Conclusion

Most re-deterioration of floor slabs occurred at the construction joint between the lanes. Deterioration tended to be remarkable when large amounts of anti-freezing agents are used and when there are many days when the daily minimum temperature is below zero degrees. I would like to add that currently we apply an adhesive agent at the construction joint to improve adhesion.

Injecting resin has helped maintain floor slab condition for seven years after repair. Therefore, we can say that this method is effective as a repair method to prolong the life of the re-deterioration floor slab.

Reference

1) Express Highway Research Foundation of Japan: Design construction manual of overlaying floor slab method, 1995.7
2) NEXCO: Expressway Standard Specification by NEXCO for Bridge Maintenance Design, 2011.7
3) T.Nagatani, K.Wada, T.Ogata: Deterioration reproduction experiment of a part of construction joint on overlaying floor slab, Proceedings of the Japan Concrete Institute Vo1.32, No.2, 2010
4) S.Kubo, M.Fujii, Y.Miyasaka, M.Matsumoto, T.Itabashi: Consideration on repair method of deteriorated floor slab, Japan Society of Civil Engineers 2010 Annual Meeting, 2003.9
5)A.Goto, T.Nagatani, T.Ogata, M.Matsumoto: Examination of overlaying floor slab repaired by injecting resin, Proceedings of the Japan Concrete Institute Vo1.33, No.2, 2011