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Health monitoring of RC decks with simplified impact test method

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ABSTRACT

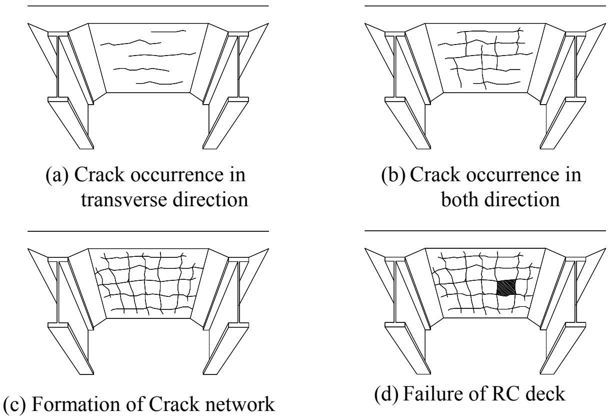
In Japan, the deterioration of bridge decks is one of the most important problems. According to past research works, the deterioration process of RC decks with the fatigue damages brought by live loads is almost figured out. In former investigations, some fracture types which can't detect with visual check is confirmed. To determine the health of RC decks, we must check the damages in RC decks. In the conventional method, we must use the real truck as the live load and also spend the much budget and efforts. Then the simplified testing method is required to inspect the RC bridge decks. The author focused on the FWD test. The FWD test is the one of the impact test methods and it is also the one of the systematized testing methods. Then the author carried out the trial experiment using FWD method.

Keywords. RC decks, health monitoring, FWD test

BACKGROUND OF THIS RESEARCH

In Japan, the one of the most important problem in maintenance of road bridges is the cracks of decks. The cracks checked on bottom surface of RC decks have been confirmed as the fatigue cracks in former research works[1]. The progress pattern of this type of cracks is explained with a set of illustrations shown in Fig.1. And the explanations of process of fatigue deterioration of RC decks are followings.

(a) At first, the cracks in the transverse direction will occur because of the smaller volume of distribution bars than it of main bars.



(a) Crack occurrence in transverse direction

(b) Crack occurrence in both direction

(c) Formation of Crack network

(d) Failure of RC deck

Fig.1 Crack progress by fatigue in RC decks [1), 2)]

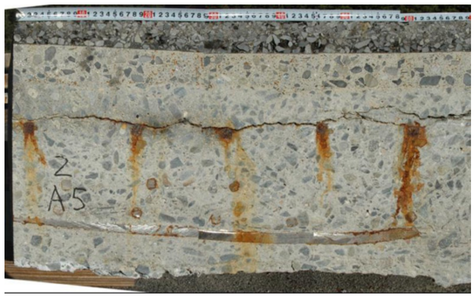


Fig.2 Horizontal crack in RC deck[2)]

(b) After the progress of transverse cracks, occurrences of cracks in longitudinal direction will be confirmed.
(c) The distance between cracks will be small and network of cracks will be formed.
(d) Failure of RC decks with punching shear failure.

With the RC decks made in the period from 1960's to 1970's, we can explain the failure of RC decks with fatigue by live loads. For this mechanism, we can check the state of RC decks with visual inspection.

Recently, there are different type of crack have been confirmed in RC decks (See Fig.2). This type of cracks are called "Horizontal crack" because of the direction of crack progress. The mechanism of occurrence and progress of this type of crack is uncertain. The influence of this cracks are quite large in the flexural rigidity of RC decks. It is thought that the durability of RC decks also influenced by this cracks. And it is growing the problem with this crack that we can't detect the Horizontal cracks with visual check. Then we must immediately develop the inspection method for checking the all influence of damages in RC decks.

OUTLINES OF FALLING WEIGHT DEFRECTOMETER (FWD)

Retrospective FWD method. The Falling Weight Defrectometer (FWD) is a testing method developed as the investigating method for asphalt pavement of roads. In this method, the testing impact load is given by falling weight in the testing system. And the deflection with the impact load will measured by displacement sensor involved in the system set in set positions. The image of this method is shown in Fig.3. In much of the existing FWD system, all devices of measuring system are mounted in a vehicle (See Fig.4 and Fig.5). The direction of distributing deflection sensors is fixed into the longitudinal direction of testing

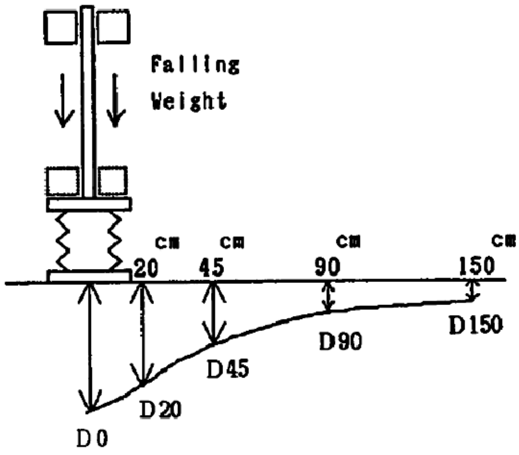


Fig.3 Image of FWD for asphalt pavement[3)]

Fig.4 An example of FWD testing vehicle[4)]

Fig.5 Displacement sensor mounted in FWD testing vehicle[4)]

vehicle. The impact of load will be set 49kN or larger. Because of the magnitude of impact load, the whole of bridge system will move in the test. And we can't measure the local displacement of RC decks because the direction of distribution of displacement sensors will match the longitudinal direction of bridge girder. Then we must confess the difficulties with the inspection with this method.

Improving FWD method. To solve the problems with FWD methods mentioned above, we tried to improve the FWD testing method. The points of improvement are followings.

(a) Magnitude of impact loads: We must search the smaller impact load than retrospective one because impact load of retrospective FWD is too large to inspect the bridge decks without influence of loading.
(b) Distribution of sensors: We must measure the local displacement of RC decks to investigate the status of RC decks. Then we must change the direction of distribution of displacement sensors.
(c) Speed of inspection: With testing vehicle, we must spend much time and efforts to carry

Fig.5 Small FWD testing system[5)]

out the inspection because of difficulties of position settings. Then the speed of retrospective FWD is not so high. To achieve the development of useful inspection method, we must solve this problem.

We picked out the small FWD system to solve these problems shown in Fig.5. This system is composed with three types of devices.

(a) Main device (Fig.6): This is set in the loading position to measure the impact load and displacement at the loading position.
(b) External displacement sensor (Fig.7): we use this device to measure the displacement in the arbitrary positions.
(c) Indicator (Fig.8): Use to indicate the displacement data and to log the measured data.

Fig.6 Main device

Fig.7 External sensor

Fig.8 Indicator

With this device, we can apply the smaller impact load than inspection vehicles and we can choose the reasonable direction of distribution of displacement sensors with each target bridges. It can be said that the sequence of positioning is quite simple.

Then we tried the FWD method with an old bridge to check the applicability of modification to the bridges.

(a) Appearance on the river (b) View from downward (north)

Fig.9 Investigated bridge

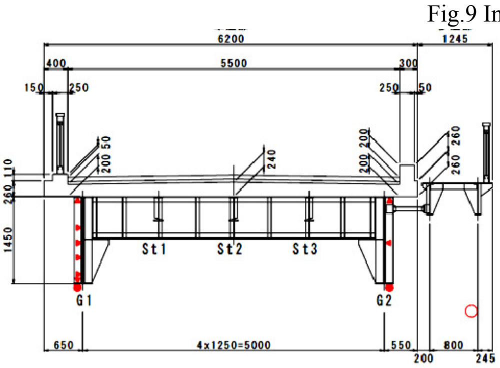


Fig.10 Cross section of investigated bridge

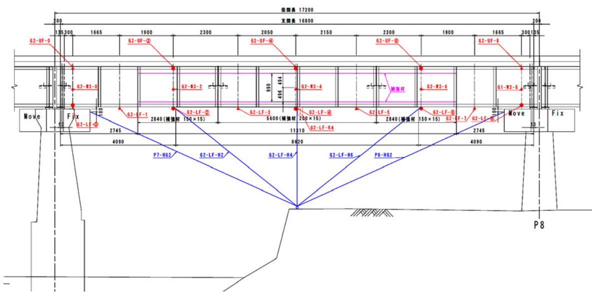


Fig.11 Side view of a span of investigated bridge

FIELD TEST

Outlines of investigated bridge. In this research, we used an old road bridge in Iwate prefecture (Fig.9). This bridge has 17 simple supported spans. In southern 9 spans, the plate girder with 2 main girders is used (Fig.10). On the other hand, the plate girder with 4 main girders is used in northern 8 spans. The southern part of this bridge was constructed in 1933 and the northern part was constructed in 1922. The width of this bridge is 6.2m for roadway and 1.25m for footbridge (Fig.10). The lengths of spans are about 16.8m (Fig.11) in southern part and 21.6m in northern part. In this paper, we show the obtained data in southern part of this bridge. The decks used in this part are RC decks with steel plate bonded with adhesive (Fig.9 (b)). Then we can’t carry out the investigations to determine the status of decks with visual check.

Investigating method. Past laboratory experiment as wheel load running test, we must check the distribution of deflections in both transverse and longitudinal directions. And we can easily obtain the relative deflection between tested decks and support girders. In former research works, it was cleared that the relative deflection is useful value to decide the deterioration of deck specimens. Then, in order to investigate the health of decks, we must

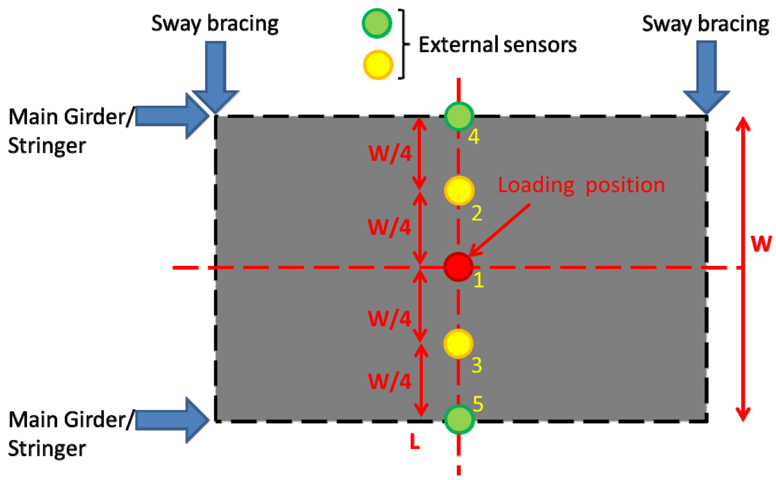


Fig.12 Basic layout of displacement sensor

obtain the relative deflection between decks and main girders in field. In ordinary FWD method for asphalt pavement, the layout of deflection sensor is fixed and we can't change. Then it isn't possible to measure the relative deflections of decks. With small FWD system, the layout of external sensor is free. Then we chose the basic layout shown in Fig.12 to measure the relative deflections between decks and main girders.

Results and discussions. An example of time history response obtained by small FWD test is shown in Fig.13. In this example, we can confirm small displacements in the positions above the main girders. The displacements on the main girders are almost 1/7 of it in center point of deck. And we also find out that the displacement in the center point is quite larger than the other points in this deck.

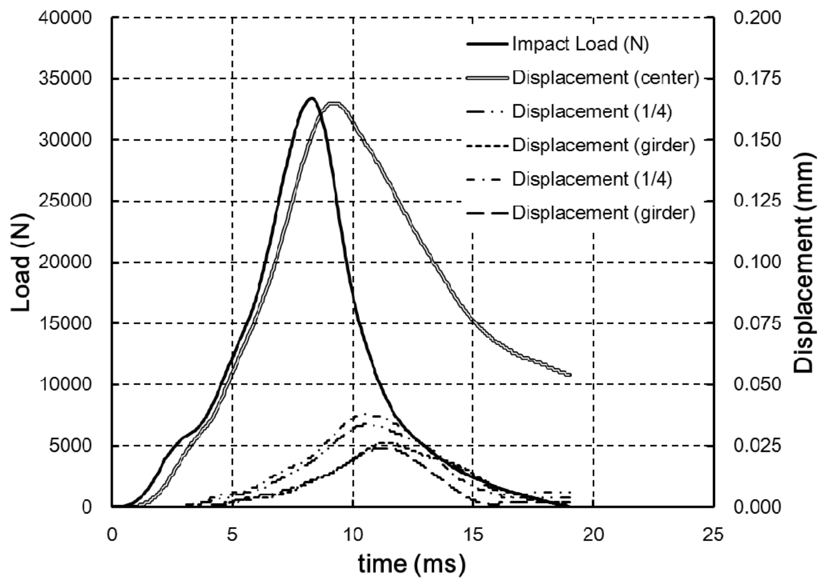
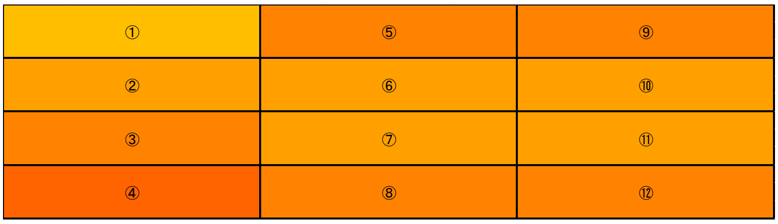
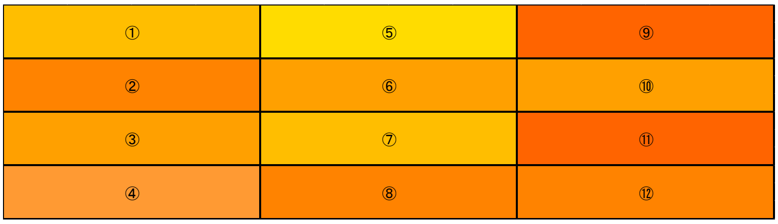


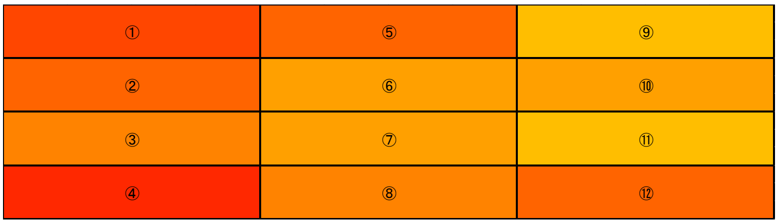
Fig.13 An example of obtained data by small FWD system



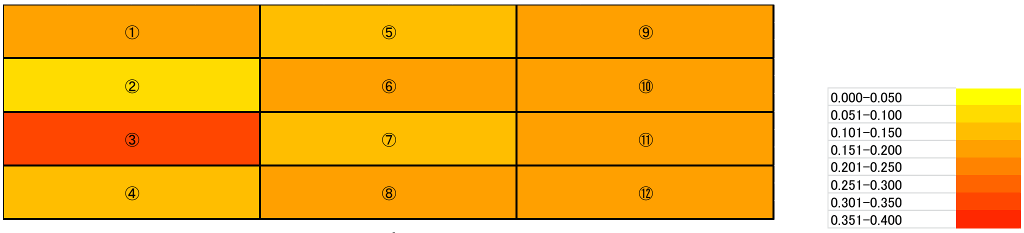
(a) 5th span



(b) 6th span



(c) 7th span



(d) 8th span

Fig.14 Maps of deflections measured by small FWD in the center of deck panel (unit: mm)

We tried to make the distribution maps of displacements in the center points of deck panels. The maps are shown in Fig.14. There are 12 deck panels in a span of investigated bridge. In these maps, we can see the distribution of deterioration of deck panels as the magnitude of displacement of decks. And we can also find out that there is deviation of distribution of displacements and large displacement concentrate in the end of each span. And we checked the distribution of the displacements in the deck panels. The examples of distributions are shown in Fig.15. In this example, shown distributions are obtained in panel 6-⑤ and 8-③. The state of panel of 6-⑤ is estimated as quite good and measured displacement of 6-⑤ is small. And state of panel of 8-③ is estimated as bad and measured displacement of 8-③ is the largest in this bridge. In the distribution of displacement in the panel 6-⑤, the distribution figure is quite smooth. And this figure of distribution in the panel 8-③ is sharply pointed. With the distribution figure obtained in panel 6-⑤, we can estimate that the

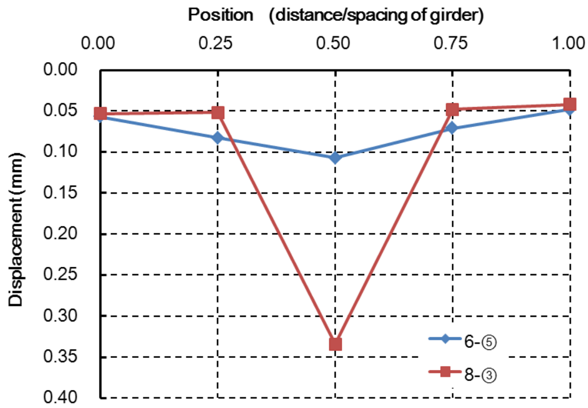


Fig.15 Distributions of displacement

flexural rigidity of deck remaining. We can also estimate that the deterioration of panel 8-③ is progressing and flexural rigidity of deck panel becomes small with the comparison between these data and past data given by laboratory experiments of RC decks.

CONCLUSION

In this paper, we obtained following things.

1) With small FWD testing system, we can carry out the suitable measurements for RC bridge decks.
2) To change the direction of distribution of external displacement sensors, we can obtain the relative displacement and we can also estimate the status of deck panels with comparisons to past experimental data.

ACKNOWLEDGEMENT

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