

Deformation Measurement of the Bandai Bridge
by Close-range Photogrammetry

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1. Introduction

From 1984 to 1986, the deformation measurement of the Bandai Bridge was regularly carried out by means of close-range photogrammetry. The measurement was done in summer, 1987, and will be done in winter the same year and continued subsequently. The present paper gives the results of the measurement during the past 3 years as an interim report.

The Bandai Bridge is a noted bridge across the Shinano River. 58 years passed since it was built in 1929. It is a concrete arch bridge of 307m in length and 21.8m in width. Some parts of both ends were destroyed by the Great Niigata Earthquake in 1963 and they were reconstructed by concrete ramen structure, while other central 6 spans remained undamaged. The bridge is still important as the heart of transport in Niigata City and famous as a scenic spot throughout the country. Due to the Earthquake and ground subsidence, the bridge has been subsided about 2m since the time of its construction.

As a whole, many parts suffered displacements and cracks and in spite of repair works (resin plug and crack prevention repair work) the phenomena are still progressing. Since 1970, for the purpose of the bridge maintenance, the deformation has been observed by measuring the expansion and contraction between the marks (control points) settled on the bridge, the amount of subsidence and bending and the sea bottom depth. Since 1984, in order to grasp the conditions of the whole bridge and its superannuation, the deformation (displacement, crack and leakage of water) of the whole bridge and between adjacent piers have been obtained by applying close-range photogrammetry. Based on these basic data, the renewal of road surface and the repair of railings, underside and cracks on sidesurface have been executed since 3 years ago.

2. Outline of measurement

The plan of the Bandai Bridge is prepared by aerial photogrammetry at the very large scale of 1/100. Since 1984, the conditions of side and under surfaces have been observed annually by close-range photogrammetry. The actual conditions of the bridge (corner down, peeling off and falling off of concrete, isolation of lime, rusting, exposing of reinforcement, cracks, leakage of water, deterioration, corrosion, void, state of repair, and so on) have been obtained. By measuring the displacement of the marks on lower corner of arch-rib and railing, the structure deformation tables and map displacements and administration maps and tables and maps were reported.

The flow of measurement is shown in Fig.1.

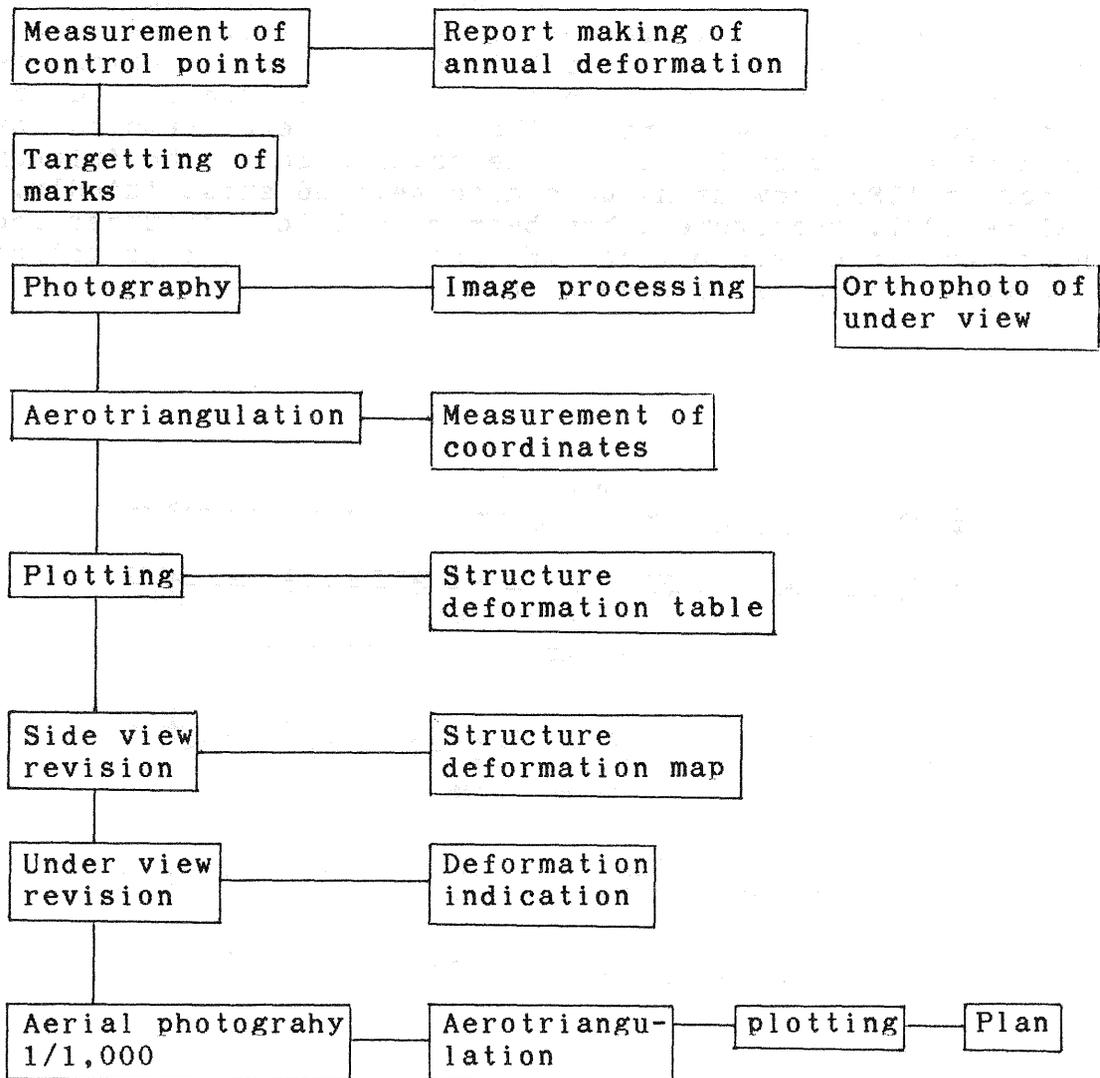


Fig.1 Flow of deformation measurement

3. Measurement of marks (control points)

Since marks were settled on the bridge in 1945 as shown in Fig.2, the expansion and contraction between them, the changes of elevation and the amount of bending have annually been observed. In 1984, plan, side and under views were prepared for the bridge maintenance to superannuation, and new marks shown in Fig.3 were settled to grasp the conditions of the whole bridge.

By ground subsidence, the elevation of national bench mark No.4423 has been varied so much that it was useless as the control point for observing the deformation of the bridge. Therefore, 4 marks were settled on both levees (2 marks on the upper stream and 2 on the downstream). By regarding them as fixed, the coordinates and elevation of each mark have been observed since 1984. The coordinate system was the optional one where y-axis was along the line connecting mark A2 and A14 on the upper stream.

As some marks were removed because of the renewal of roadway and sidewalk surface from 1985 to 1986, new marks were replaced so that the variations of data, which is obtained since 1986, from the past were acquired by adding to correction values. When other marks were removed by reason of setting up lights on the upper side of the fulcrum of pier in 1985, new marks were also settled substitutedly.

Since 1987, measurement has been made twice in summer and winter, and the deformation incidental to the fluctuation of temperature has also been observed.

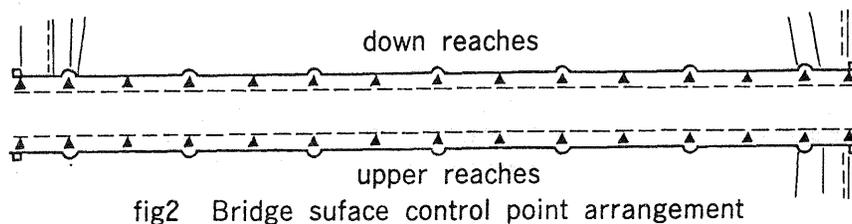


fig2 Bridge surface control point arrangement

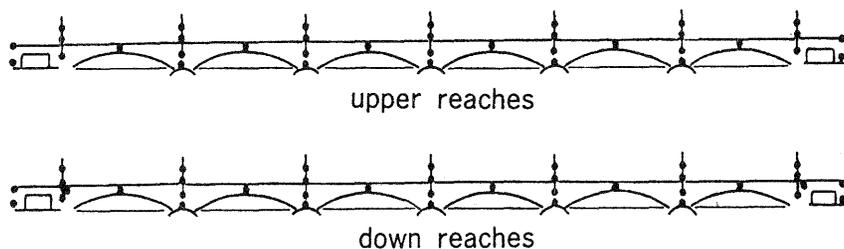


fig3 Bridge side control point arrangement

4. Photography

4.1 Photography of side surfaces of the bridge

Photographs of side surfaces of the bridge were taken with a metric camera P32, with the following attentions;

- 1) To photograph marks on both ends of one span in a frame.
- 2) To allow to take stereo measurement.
- 3) To configure a camera, in principle, not in convergent arrangement but in normal one.
- 4) To make the position of the boat quickly fixed against the rapid stream because the position of camera for spans between No.2 and No.7 were on the river.
- 5) To make the scale of photographs as similar as possible by the similarity of base length.
- 6) To eliminate the influence of boat vibration.

As it took many time to fix the boat when a barge and a tugboat were used, photographs were taken by using the tugboat (F11) for the open sea. The position of the camera was observed with transits on both levees and on the bridge. Photographs were taken with the special attentions below;

- a) To avoid the shade by reason of backlight.
- b) To stable the accuracy of annual data against the model deformation.
- c) To take the photographs so that annual data can be compared.
- d) To do works on the days when it was not so windy, rainy, snowy or sleety and the river was not so rough.
- e) To be care of the photographing time on the clear days because of the high possibility of backlight on the downstream.
- f) To pay attention to the passing of fisher-boats, sight-seeing boats, etc., and to take care not to cause an accident.
- g) To complete works in the time authorized by Maritime Safety Agency and to obey the laws.

4.2 Photography of underside of the bridge

The surveys of superannuation of the underside of the bridge was formerly carried out by visual observation. On the basis of the results, repair works (resin plug, repair of concrete, supplementation of corner down and hole, etc.) had partially been executed, whereas superannuation of each span were progressing year by year. To grasp these conditions, whole underside were covered in 8 photographs with a super-wide-angle (non-metric) camera and parts with great change like cracking were brought into a close-up. Scaling could be done with a photograph but interpretation of the condition could not be done because of blur of images. Therefore, standard targets were located in 2.5m grid instead of former 5.0m grid to catch 4 targets in each photograph and to determine the geometric relation of photographs.

A trial to photograph the underside with a panorama camera showed that it was unsuitable for interpretation by reason of the impossibility of scale correction. A camera which has view angle less than 90 degrees were unable to photograph this area, so the targets should be located in 1.0 m grid in case of using this camera.

5. Trends of displacements

5.1 Trends of displacement of the bridge by measurement of the marks

As the results of measurements of expansion and contraction between the marks on the upper and lower stream of the bridge, the distance between the marks were expanded about 20mm on the upper side and 30 to 40mm on the other side from 1970. But the comparison of annual data showed that data had similar values and trends and varied slightly for the past 2 or 3 years, and the fulcrum of piers were also changed little bit for the last 3 years.

Annual data of elevation of the middle mark varied with seasons and years, but they have varied little since 1982. According to the former measurement standardized by the national bench mark No.4423, amount of subsidence was -154mm on the bench mark and -130mm on the mark on the bridge. The measurements, therefore, was carried out by regarding the marks on both levees as fixed, and enabled to grasp the deformation of the bridge and to obtain stable results. It is supposed that subsidence is not so progressing nowadays.

5.2 Trends of displacements of the bridge by close-range photogrammetry

Owing to preparing plans, side views, under views and profiles at the scale of 1/100 by close-range photogrammetry, the conditions of the bridge became clear and the basic data for many kinds of repair works were acquired. The deformation such as the displacement of side surfaces and adjacent piers, cracks, and so on will hereafter be grasped by adopting stereo measurement by close-range photogrammetry when the charts will be revised and the distances between the marks and the elevation of them will be measured.

By reason of the difference of the condition like the renewal of marks, annual displacements were difficult to compare for the past 3 years, while stable data will be acquired from now on because of the uniformity of the conditions.

It is supposed that the errors of measurement is about 10 mm as the sum of the error of marks itself and that of photogrammetry. The standard of annual displacement is 15mm on the safety administration of a bridge, so it will be necessary to investigate the bridge in case of the displacement more than 25mm.

At present, instead of going into details about the change

3rd span Lower reaches

of data, it is necessary to store many data. It seems that the number of new cracks is small and deterioration has hardly progressed for one year.

By measurement of under surface, the location and size of cracks, peeling off, deterioration of surface, isolation of lime, exposing of reinforcement, corrosion, change of color, leakage of water, and so on can be expressed almost exactly, and the mutual relation of them can be grasped. It is useful for the project on repair work of under surface in 1987.

6. Deterioration of the bridge

Under and side views were prepared for judgement data of under and side surfaces of the bridge. Fig.4 shows the state of deterioration of an under surface. According to the standard on cracks of concrete slab, most of spans seem to need repair works. Especially span No.2 and No.7 are desired to be repaired urgently.

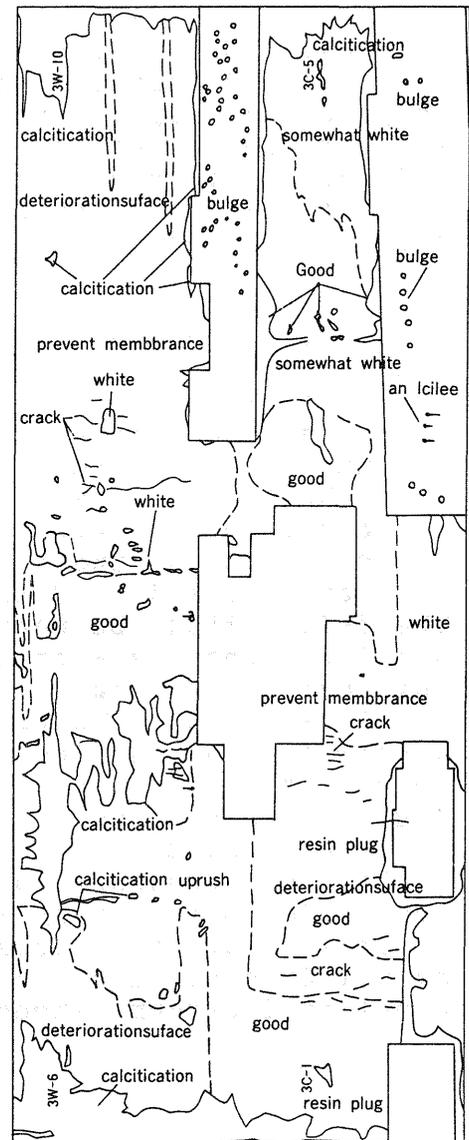
The partial changes like scratches by boats were seen, but there was no great change on span surfaces from 1985 to 1986. It seems that leakage of water decreased after the repair of road surface.

The repair work of under surface is scheduled to be completed in 2 or 3 years. The progress of deterioration after that will be observed by photogrammetry.

7. Conclusion

The repeated measurement of the Bandai Bridge mainly by close-range photogrammetry has been made for the last three years and is consequently made in 1987. The results settled many problems and was useful as the basic data for repair works.

The repair works of the bridge such as renewal of whole pavement of roadway and sidewalks, resin plug into cracks on



Upper reaches

fig4 under view

under surface, removal of strains on surfaces, repair of concrete have been executed and will be completed in 1 or 2 years. In November 1986, one month later from the repair work of road surfaces, 3 cracks were found out, so it is necessary to make repeated measurement for observing the bridge.

Close-range photogrammetry enables rapid data of uniform quality and measurement of the places difficult to measure by ground survey. Aerotriangulation has the accuracy of the standard deviation of about 3um on a film and produces the data of stable accuracy in many measurement. The values of data vary with surveyors. But the variance is attributed to only the difference of surveyors, the data indicate the same trend.

The factors of deformation of bridges (live load, vibration, fluctuation of temperature, wind, ground subsidence, etc.) are so complicated that it is very hard to measure them separately. Trends of changes can be understood by regarding the differences of data on one point as the values of changes of the year. The example is shown in Fig.5. Fig. 5-1 shows the state of deterioration of upper and side surfaces, and Fig.5-2 shows the deformation of arch bottom corner points on under surface.

Span No.1 and No.8 based on the land had hardly deformed. The deformation between span No.2 and No.7 indicated the similar trend between the upper stream and the downstream, but that of each span is different respectively.

Close-range photogrammetry is able to measure exactly the deformation of surfaces, the superannuation and the state of deterioration of a bridge. In case of the discovery of unusual data, the diagnosis of the bridge will be made by detailed inspection.

It is necessary to execute the repeated inspection and repair for maintaining the Bandai Bridge permanently.

It is important to keep the data about a bridge as long as it exists, and to hand down them, including the data about road circumstances, to the next generation.

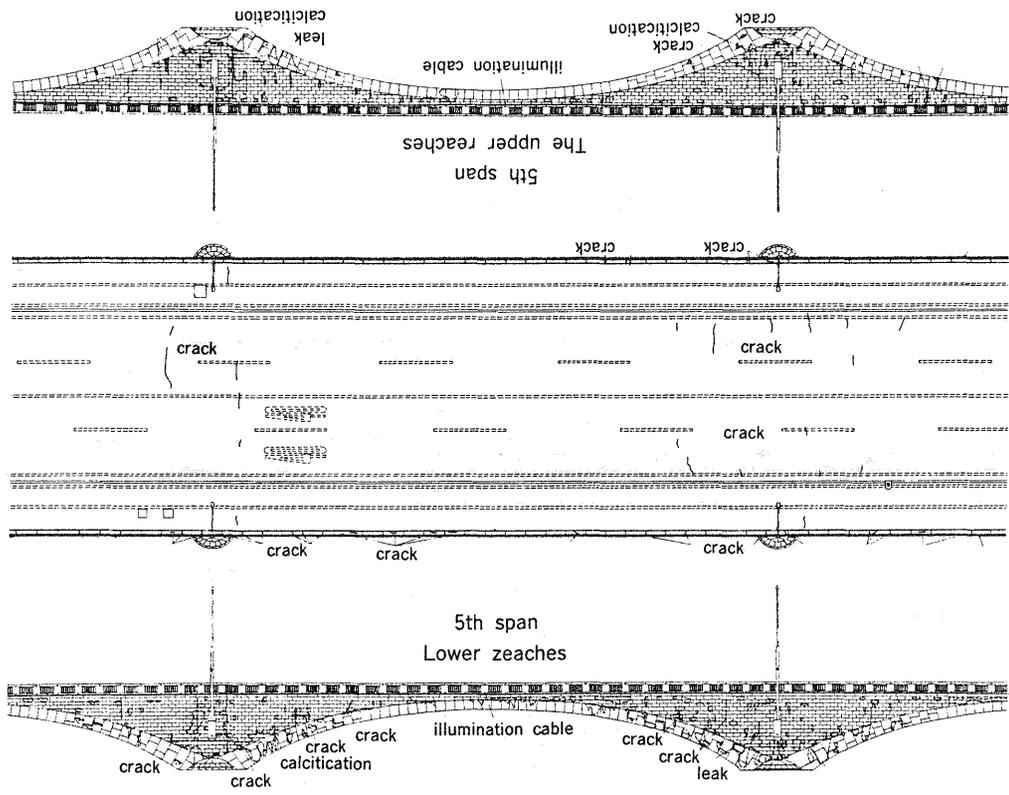


fig5 Plan side view

4th span arch bottom corner

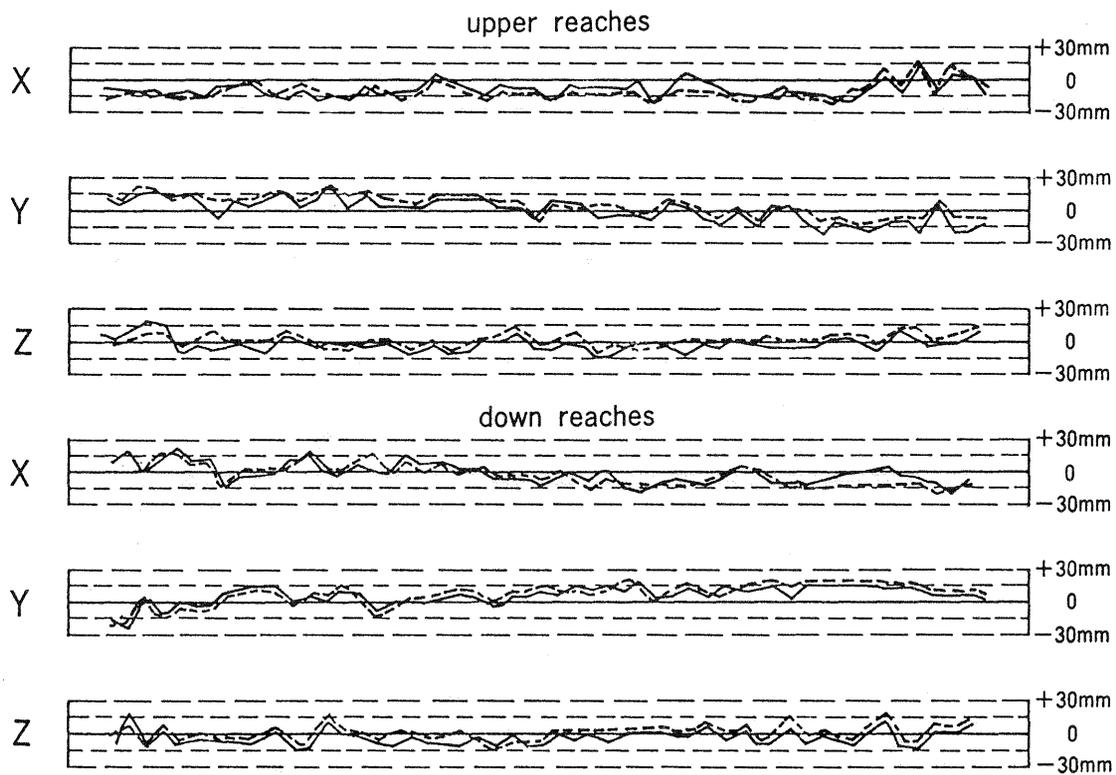


fig5 Bridge side arch bottom corner point deformation