A Study for Early Restoration of the Road Bridge Damaged by the Earthquake

(Study period: FY2017-)

NISHIDA Hideaki, Head, MIYAHARA Fumi, Senior Researcher,
TANAKA Kenshiro, Researcher, SUZUKI Shinya, Guest Research Engineer,
Research Center for Infrastructure Management, Kumamoto Earthquake Recovery Division

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1. Introduction

Kumamoto Earthquake Recovery Division has been providing advanced technical support on the disaster sites for recovery from the damage by the Kumamoto Earthquake and striving for early recovery in close cooperation with the Kumamoto Reconstruction Project Office of Kyushu Regional Development Bureau, which is responsible for the restoration project.
In implementation of the road bridge restoration project, it is necessary to resume the service as early as possible by the bridge that secured both structural safety and smooth road function. In restoration, since the restoration work repairs the bridges that were partially damaged or deformed, it is necessary to demonstrate the effect of repair considering various uncertainties, which are not found in new bridges. Further, from the viewpoints of inspection and diagnosis in maintenance stage after the restoration work or acceleration and reliability improvement of the study in cause investigation when a problem occurs, it is important to collect and properly record / retain information in the process of restoration work for contribution to utilization in the following stage of maintenance.
In order to contribute to early recovery of road bridges damaged by earthquake, this paper reports, focused on the steel bridge damaged by the Kumamoto Earthquake, method of recovery work and verification of the effect of repair, as well as information that contributes to grasping the state of the bridge, etc. if a major earthquake occurs again during the bridge resumes service after recovery and the method of recording and retaining such information.

2. Repair of a steel bridge leaving the damaged spot and verification of repair effect with monitoring

As the damage to the Okirihata Bridge, a steel 5-span continuous non-composite curved plate girder bridge, 265 m in length, the top structure moved on the whole in the direction outside the curve and part of the main girder collapsed. It is particularly characteristic that the damage to the main girder occurred at points other than the supporting point. Above all, relatively major damage, including out-of-plane deformation, occurred to two main girders (G1 girder, G2 girder) outside the curve between P1 and P2.
As a measure to address major damage that occurred to the main girder at a point other than the supporting point, it is generally considered to remove or reconstruct the whole main girder or damaged part. In this paper, however, a main girder ("additional girder") cross-sectional rigidity enough to supplement the load bearing capacity of the main girder, which was lowered by the damage, was installed (Fig. 1), while strategically leaving the greatly damaged main girder, considering mainly that at least the load bearing capacity enough to support the weight of floor slab etc. is kept since no damage or deformation is increasing after the earthquake and that there is uncertainty in the extent of effect of the stress remaining in the component on other components when the main girder is removed.

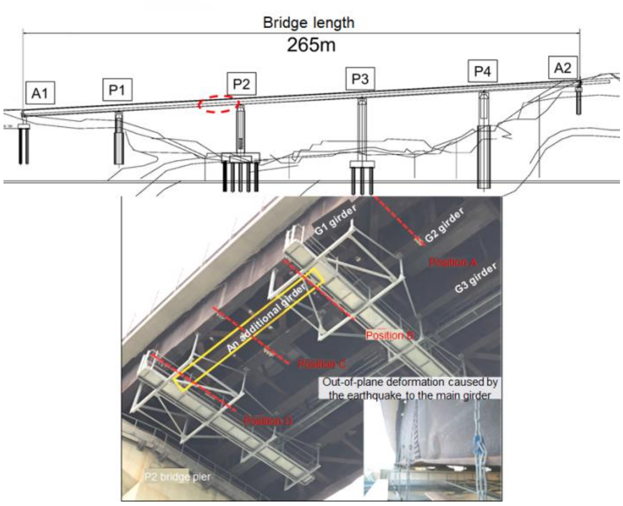

Fig. 1 Additional girder installed in restoration of the Okirihata Bridge

In such repair work where a girder is added leaving the damaged parts, there are some uncertainties that are not found in new construction, such as diagnosis of residual stress, and it is important to secure the reliability of diagnosis on the state of components. Then, in this study, we verified whether the additional girder shows the tendency of sharing load as expected in design by monitoring stress variations from changes in the strain during jack-down after the girder was added.
Considering that the actual state the damaged part is between the state of functioning as the state of not

functioning as a resistance cross section, we compared results of two analyses for monitoring results --- one is where the damaged part also functions as a resistance cross section (not damaged) and the other is where it does not function (damaged). As Fig. 2 shows, it was found from the results of comparison that the additional girder is functioning as a resistance cross section expected in the design since the measured values of stress variations were between the values of two analyses in an expected range.

3. Utilization of BIM/CIM models in maintenance

In the bridge of which restoration work was completed, there remain some uncertainties that are difficult to consider in the phase of repair design or construction for restoration, such as decline in load bearing capacity due to temporal variation of the repair effect. For such uncertainties, it is effective to properly identify the damage caused by the earthquake to components, repair method for the damage, and information to be needed in securing the durable performance of the relevant repair method from the information to be obtained in the restoration work and record and retain the obtained data so that mutual relationship of data is made clear.

Then, we studied, focused on the Okirihata Bridge, for which repair work was implemented as stated above, what information should be kept and in what form considering utilization in future maintenance, and then visualized data obtained by utilization of CIM in a three-dimensional form.

First, based on the existing two-dimensional structural general drawing, we created a three-dimensional model of the whole structure with detailed degree of 300 [1], which accurately represents the outer shape. Next, we created a model for additional components, including additional girder, additional cross frame, and remaining temporary cross girder, installed when supporting the bent (Fig. 3). Note that additional components are indicated with colors so that difference from existing components is easily recognized.

In contrast, for the spots where damage to the main girder is left behind, the positions of such spots were only marked and, as attribute information of such marking, a link was set to the photograph showing the state of damage. This is because we considered that it is reasonable to confirm the three-dimensional shape of damage with eyes and it is unnecessary to create a model. In addition, only positions were indicated for the joint of girders and a link was set for details to the PDF of the relevant drawing as attribute information. This is because we considered that it is effective to create a model for joint positions to grasp the state of components but it is unnecessary to create a model for bolt shapes.

Further, for the hollow P2 bridge pier with a perforated crack, we filled concrete into the base of the hollow part and added up the thickness and piles,

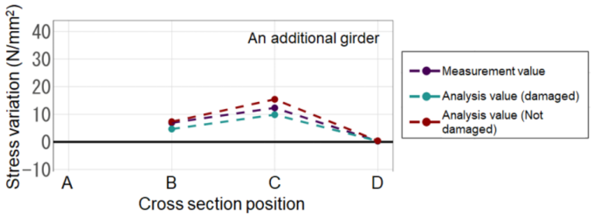

Fig. 2 Stress variation in jack-down of the additional girder

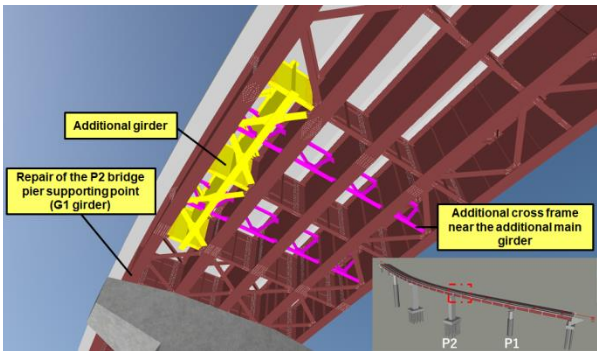

Fig. 3 Three-dimensional model of the Okirihata Bridge (near the additional girder)

and created a three-dimensional model for to visualize the positions where perforated cracks occurred and the range of filling concrete because they will be invisible upon completion of the restoration work. For the width, depth, etc. of cracks, the data was kept only as attribute information.

As stated, we are classifying information into those for which recording and retention after visualizing with a three-dimensional model considering utilization in future maintenance and into those for which recording and retention as attribute information are reasonable.

4. Future prospects

In fiscal 2019, the third year of agency under the State's direct authorization, the Tawarayama Tunnel route of the prefectural road was fully opened. [2] We continue to address the restoration of the Great Aso Bridge on National highway No. 325 and the existing road on National highway No. 57.

☞See the following for details.

1) Ministry of Land, Infrastructure, Transport and Tourism (MLIT): CIM Introduction Guideline (Draft), Part 5: Road Bridge, May 2019
http://www.mlit.go.jp/tec/it/pdf/guide05.pdf
2) Civil Engineering Journal, Vol. 61, No. 11, pp.48-49, 2019