The Five-year History of the Kumamoto Earthquake Recovery Division and its Aim to Recover from the 2016 Kumamoto Earthquake

(Research period: FY2017–FY2021)

Kumamoto Earthquake Recovery Division, Research Center for Infrastructure Management

Head NISHIDA Hideaki Research officer NISHIMURA Kaichi

(Keywords) Kumamoto Earthquake, cables, three-dimensional point group data

1. Introduction

The Kumamoto Earthquake Recovery Division (the Division), which was established in 2017, was permanently stationed at the recovery site and worked on resolving issues that require advanced expertise, in order to speed up recovery and restoration after the 2016 Kumamoto Earthquake. In addition, the Division also engaged in research to gather the technical findings gained through the recovery project and reflect them in technical standards, etc. Table 1 outlines the main research topics and outcomes from our work over the past five years. This report briefly describes research case examples concerning new issues that we found based on on-site investigations.

2. Main research outcomes

(1) Research on assessments of cable load-bearing capacity and durability

Table 1. Main research topics and outcomes of the Kumamoto Earthquake Recovery Division

Research topic	Main outcomes
Minimizing effects of ground deformation on bridges	· Proposing damage control methods (failure modality and design methods) for fulcrum sections, contributing to reductions in bridge collapses and faster restoration of road functions · Proposing methods for rapidly gaining information on slope deformation along roads
Methods for checking repair effects on bridges restored after earthquakes	Proposing monitoring methods for checking the repair effects in earthquake recovery works, using ICT technology
Assessments of cable load-bearing capacity and durability	· Accumulating findings on cable load-bearing capacity · Proposing cable covering repair method and waterproofing testing method
Gathering state information on foundations, and the conditions for foundations less susceptible to damage	· Proposing methods for using high-frequency impact probing in foundation damage investigations · Accumulating findings on the impact of foundation structural forms and topographical conditions on foundation damage
Information that should be acquired in earthquake recovery works and is useful in maintenance, and its usage methods	Presenting methods of using information gained in earthquake recovery works in maintenance and recording and storage methods

The Kuwazuru Ōhashi, a cable-stayed bridge, suffered damage to the cable coating materials due to cable twisting and contact with the lighting poles by the earthquake. This disaster led to awareness of the issue of how to gain information on and diagnose the load-bearing capacity and durability of cables..

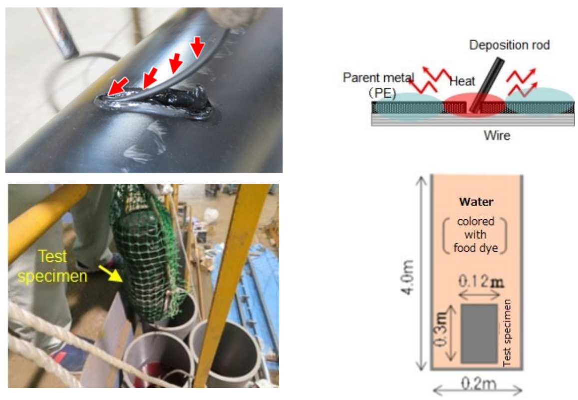

Fig. 1. Repair method (top) and waterproofing testing method (bottom)

Based on such a background, the research on assessing the load-bearing capacity and durability of cables coated with high-density polyethylene (PE) was conducted by using the cables removed from the bridge because of deformations observed in their external appearance.

In the investigation of the load-bearing capacity of the steel wires inside the cable, tension tests of the steel strands of the cable were conducted and it was found the trend between the state of rustproofing or external deformation and the tension strength. Furthermore, a method of checking for corrosion within the cable coating by drilling minute holes in the PE coating was proposed. In proposing the location and diameter of the holes, we took into account the ease of the checking work and repair methods to fill the holes, among other factors. For the coating repair method, we made use of the removed cables and devised a waterproofing testing method where the repaired test specimen is placed in colored water at high pressure to check suitable quality, Furthermore, it was suggested how to give the heat when the coating was repaired by welding method (fig. 1). The outcomes of the above were reflected in checks of the condition of the steel wires inside the remaining cables and the repairs of the sections drilled to check them.

(2) Examination of method for gaining information on slope deformation along roads using 3D point group data

The Kumamoto Earthquake caused damage that impeded road functionality due to the effects of ground deformation; some of these roads ran along steep slopes and took a long time to restore. In order to determine whether roads in such conditions are passable after an earthquake and how to restore them temporarily as quickly as possible, gathering information on the condition of slopes quickly and broadly was recognized as an important point. The Division conducted research on a method to gain information on deformations using three-dimensional point group data acquired by UAV laser surveying, as a method to quickly and broadly gain information on the state of slopes that are difficult to approach.

Laser surveying measures in a way that fulfills the required point density for original point group data based on the Public Survey Manual. However, when seeking to evaluate deformations across an entire slope from differences between data from two different periods at a similar accuracy, it also seems necessary to have a small dispersion in point density due to the angle of the subject slope and the degree of unevenness of the surface and to have similar measurement accuracy between the two periods. Therefore, the matters that should be required in order to evaluate deformation from the differences were considered.

Here we show the examination results relating to the flying altitude of the UAV as one such matter. For this examination, we acquired point group data at the same time under conditions with the UAV flying altitude kept constant and with it changing according to the slope (fig. 2).

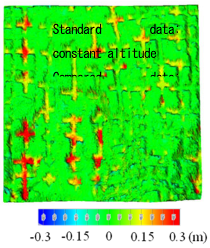

Fig. 3. Difference diagram

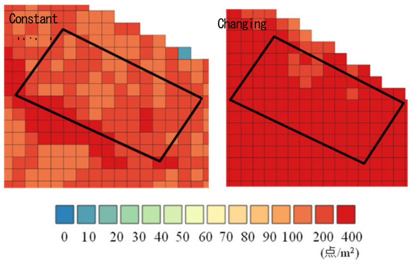

Fig. 4. Point density distribution diagram

To verify the accuracy, we created a three-dimensional model (TIN model) from three-dimensional point group data under constant flying altitude conditions and then evaluated the normal distance from the measured points acquired under changing altitude conditions to the surface formed by the TIN model as the difference.

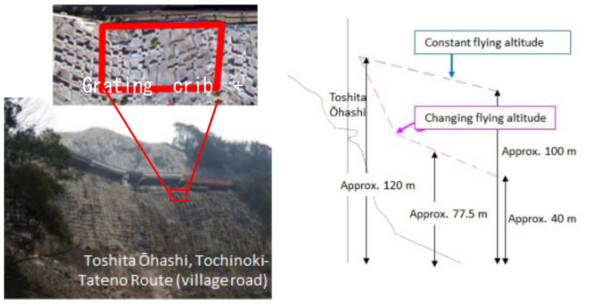

Fig. 2. Location for measurement

Figures 3 and 4 show a difference diagram and a point density distribution diagram at the locations where work for the grating crib wall and its anchors was performed (fig. 2). As the data was acquired at the same time in the same location, there should be no difference in the first place, but figure 3 shows significant differences around the pressure plates towards the bottom of the slope in particular. The point density is somewhat lower with constant flying altitude than with changing flying altitude. Figures 3 and 4 suggest that measurement at constant flying altitude may not fully capture the slope shape around the pressure plates due to the effects they exert.

As shown above, we confirmed that in order to gain information on deformation with similar accuracy across an entire slope, it is necessary to acquire point group data by shining lasers from various angles, such as by changing the flying altitude of the UAV, to enable data density to be secured near uneven sections on the slope in particular.

Based on this examination, we organized the main factors that influence the accuracy of information on deformation of the subject slope (table 2) and summarized the requirements regarding data acquisition, etc. in the case that three-dimensional point group data from UAV surveying is used to measure slope deformation.

3. Conclusion

In conducting the technical support and research relating to restoration, we received assistance in various forms from many people, including the MLIT Kyushu Regional Development Bureau, NILIM, the Public Works Research Institute, Kumamoto Prefecture and Minami-Aso Village, which were the road administrators, and various businesses involved with investigations, design, and construction. We express our gratitude to all of them.

Table 2. Main factors affecting the slope deformation evaluation accuracy when using point group data from UAV laser surveying

Item	Contents (main factors)
1. Method to acquire original point group data	○ Measurement method ○ Flying conditions (course (altitude, overlap), speed)
2. Method to process point group data	・Number and location of control points ○ Filtering method to remove effects of trees, etc. ○ 3D model creation methods
3. Method to evaluate deformation	○ Method to evaluate differences