

Investigation report on Kumamoto earthquake

Name of investigation team “Investigation concerning Higher Durability and Quality of Reconstructed Infrastructure after Kumamoto earthquake” (JSCE concrete committee)

Members :

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Duration of investigation (6th -7th May 2016)

1. Introduction

Two earthquakes struck the Kumamoto region of Japan in April 2016, one on the night of Thursday, April 14 and a second in the early hours of Saturday, April 16. Both registered 7 on the Japanese intensity scale and together they claimed 49 lives. It was the first time in Japan’s recorded history that two consecutive earthquakes with an intensity of 7 occurred in the same area. The main shock on April 16 caused particularly severe damage, including large-scale collapse of mountainsides in Aso City and other areas, destruction of central Mashiki Town and extensive damage to houses and the social infrastructure over a wide area from Kumamoto to Oita Prefectures.

The Japan Society of Civil Engineers (JSCE) dispatched an advance investigation team to inspect damage caused by these earthquakes and a preliminary reporting session to present the results was held on April 27 (Wednesday). This kind of early research is crucial because it allows inspection and recording of the situation before recovery efforts begin and helps to clarify the mechanism of the damage. An important mission for academics and the JSCE, and one that continues as time passes after an earthquake, is to examine the damage in detail and discuss possible courses of recovery and reconstruction through exchanges of opinions with government personnel in charge of the work on the ground.

After the Great East Japan Earthquake of 2011, the JSCE made various contributions toward reconstruction in the affected area. For instance, the society’s Concrete Committee set up the “Subcommittee on Ensuring the Quality of Concrete Structures” (chaired by Takahiro Tamura, professor of the National Institute of Technology, Tokuyama College and commonly known as Committee 350) to work on specific efforts to ensure the quality of rebuilt concrete structures. This fiscal year, through collaboration with other JSCE committees, this effort bore fruit as a priority issue in “Establishment and Practice of Management Systems for Ensuring Quality and Durability of Concrete Structures and for Human Resource Development”. Meanwhile, the Cabinet Office initiated the cross-ministerial Strategic Innovation Promotion Program (SIP) for “Infrastructure Maintenance, Renewal, and Management Technology” (directed by Yozo Fujino, professor of Yokohama National University). Under this program, members of the JSCE project “Comprehensive Study of Deployment and Application of Road

Infrastructure Management Cycle in Japan and Overseas” (led by Koichi Maekawa) worked to develop technology to improve the durability of concrete slabs and other concrete structures, and their findings were applied to the reconstruction of roads and reconstruction access routes in the Tohoku region.

Now, five years since the Great East Japan Earthquake, it is of great significance to make use of the knowledge and experience gained as a result of that disaster. The methods and techniques worked out in the response are now being applied to recovery and reconstruction work in Kumamoto. Applying these responses to the new situation requires study to decide which measures match the state of damage and the needs on the ground based on a full understanding of terrestrial and meteorological situations. To this end, under the heading “Investigation concerning Higher Durability and Quality of Reconstructed Infrastructure (based on Experience in the Great East Japan Earthquake)”, a research team comprising prominent JSCE members studying this priority issue and SIP program members was organized.

2. Investigation report

2.1 Interview with Yasuo Morita, Director of Kumamoto River and National Road Office

(Saturday, May 7, 2016 10:00-10:35)

The team interviewed Yasuo Morita, who was directing recovery efforts in the affected area, to obtain information concerning collaboration with prefectural government as restoration projects are implemented and the approach to restoring the road network needed for reconstruction in the region over the medium term. Additional information was also collected from released materials relating to the Naka Kyushu Odan Road (the planned expressway along the route of National Route 57), media reports, and other sources. Based on this information, the situation on the ground as of May 13, 2016 is summarized as follows.

The prefectural government is finding it difficult to implement disaster recovery projects without help. Although the collapsed Aso Bridge falls under the jurisdiction of the prefectural government, the upper slopes of the mountain on which the mudslide occurred are still in motion. Erosion control officials were dispatched from the central government to visit the site for an investigation on May 2. To restore access to National Route 57, temporary restoration work on alternative access via the prefecture-administered “Milk Road” has been carried out by the Kumamoto River and National Road Office of the Ministry of Land, Infrastructure, Transport and Tourism.

Under these circumstances, the national government on May 6 designated the Kumamoto earthquakes a “major disaster” under the Act on Reconstruction from Large-Scale Disasters, thus enabling central government to carry out projects on behalf of the prefectural government, including road rebuilding and work at landslide sites. The act was established in 2013 after the 2011 Great East Japan Earthquake and this is the first instance of it being applied. By designating an occurrence as a major disaster, central government can take over a wide range of work that is generally the responsibility of prefectural governments, such as work on roads, ports, fishing ports, and erosion control dams. In this case, a Cabinet meeting on May 10 approved the central government taking control.

One example where there is hope of early restoration work by central government is the Tawarayama Bypass. Although this is a prefecture-administered road, it is a vital part of the region’s road network. Several bridges collapsed and the Tawarayama Tunnel was also damaged.

高規格幹線道路は全国的に高速交通サービスを提供する幹線道路ネットワークを形成する道路です。

また、地域高規格道路は高規格幹線道路を補完し、地域相互の交流・連携の促進や地域の道路の混雑緩和を図るための道路です。

※H26年度末時点の整備率

- ・九州横断自動車道 延岡線 11%
- ・南九州西回り自動車道 56%

熊本県内では以下の4路線を事業中です。また、2路線について事業化に向けて概略ルート・構造の検討(計画段階評価を進めるための調査)を進めています。

■事業中の路線

- ・九州横断自動車道 延岡線 嘉島JCT～矢部
- ・中九州横断道路 国道57号 滝室坂道路
- ・熊本天草幹線道路 国道57号 熊本宇土道路
国道57号 宇土道路
- ・有明海沿岸道路 国道208号 大牟田～大川

■都市計画・環境アセスメントを進めるための調査

- ・有明海沿岸道路(Ⅱ期) 大牟田市～長洲町

■計画段階評価を進めるための調査

- ・中九州横断道路 熊本市～大津町
竹田～阿蘇
- ・九州横断自動車道 延岡線 蘇陽～高千穂



Figure 1 Arterial roads and regional arterial roads in Kyushu including Kumamoto Prefecture (extracted from “Rivers and Roads in Kumamoto 2015”)

Figure 1 is a route map of major roads in Kumamoto Prefecture and the other Kyushu prefectures, including those under planning. Reconstruction of Takimurozaka Road in the Takimurozaka area, which was damaged by the storm known as the North Kyushu Rainstorm in July 2012, was in planning and the new road is to form part of the Naka Kyushu Odan Road. The section of the expressway from Kumamoto City to Otsu Town has currently passed the planning evaluation stage. It is hoped that construction of these planned roads will be accelerated for the sake of regional recovery.

As described in the next section, the Naka-Kyushu Odan Road runs through cold areas with snow cover. National Route No. 57 experienced heavy snowfalls in the same area in fiscal year 2015 and was treated with large amounts of antifreeze agent. Any concrete structures to be newly constructed for the expressway must be designed with improved durability. In addition to the expressway, many other roads in the area require antifreezing measures in winter, so it is necessary to ensure that deterioration of concrete structures by antifreeze agents is properly controlled.

2.2 Environment for the planned Takimurozaka Road

Early in the morning of Saturday, May 7, 2016, environmental conditions and existing structures were investigated along the planned route of the Takimurozaka Road, which as noted above will form part of the Naka-Kyushu Odan Road.



Photo 1 Start of the Takimurozaka section of National Route No. 57

The Takimurozaka section of the current National Route No. 57 is 4 km long with an elevation difference of 220m, reaching an altitude of nearly 800m at its highest point. The road alignment is also quite irregular. The outer rim of the Mt. Aso caldera, which includes the Takimurozaka area, consists of shallow deposits of volcanic ash over welded tuff in many locations. Further, the mountainside is very steep, at about 30 degrees. As a consequence, the subsurface soil is vulnerable to heavy rainfalls.

During the North Kyushu Rainstorm of July 2012, mudslides closed the Takimurozaka section and service resumed only on August 20 after a temporary bridge was installed. Thereafter, protective work was carried out on the slopes near the road, using rock sheds, shotcrete, etc., and the road fully reopened a year and seven months later.



Photo 2 Rock shed and slope protection structures near to the beginning of the Takimurozaka section

As Fig. 2 shows, the planned Takimurozaka Road has an extension of 6.3 km. A construction project that includes a tunnel of about 4.6 km, was finalized in fiscal year 2013. Structures in the Takimurozaka area suffer freezing damage and roads require the application of antifreeze agents. Existing concrete structures show signs of deterioration due to freezing and the alkali-silica reaction (ASR).

The maintenance demands of the new Takimurozaka Road should ideally be minimal in order to reduce the future maintenance burden, so improved durability should be aimed for in the planned construction work. To secure such quality and durability improvements when building concrete structures, we consider it possible to make use of the approach used by the Tohoku Regional Bureau when reconstructing roads, developing reconstruction access routes and constructing new roads that will require application of large amounts of antifreeze agents.



Figure 2 Overview of Takimurozaka Road plan (extracted from “Rivers and Roads in Kumamoto 2015”; Kumamoto River and National Road Office)



Photo 3 Surface antifreeze agent storage container



Photo 4 Deterioration of retaining wall possibly due to ASR

Photo 3 shows an antifreeze agent container on the Takimurozaka section.

Photo 4 shows a roadside retaining wall exhibiting signs of deterioration of the liquid membrane applied in earlier repair work, possibly due to the ASR. Possible causes include the reactivity of the aggregates used in the concrete, sodium originating from the antifreeze agents, or the supply of alkalis from soil behind the wall. The need to curb the ASR is clear.



Photo 5 Deterioration of safety barrier due to freezing damage

Photo 5 shows the deterioration of a safety barrier along the Takimurozaka section, probably caused by freezing damage. There are reports that antifreeze agents promote

freezing damage to concrete. This deterioration of a safety barrier may also have been accelerated by the use of antifreeze agents.



Photo 6 Deterioration at entrance to rock shed, middle of Takimurozaka section

Photo 6 shows the deterioration at the entrance to a rock shed around the middle of the Takimurozaka section. Cracking has developed in the concrete in a horizontal direction, causing cement gel to leak from inside. A visual inspection indicates that the cause of the deterioration could be a combination of slight freezing damage and the ASR. Corrosion of steel members and high-strength bolts was also observed.

3. Conclusions

This onsite investigation of road structures and exchange of opinions with Yasuo Morita, Director of Kumamoto River and National Road Office, determined that the top priority in working for recovery of the area damaged by the Kumamoto earthquakes should be early restoration of arterial roads, including National Route No. 57 and the Tawarayama Bypass near the Aso Bridge. Moreover, in carrying out future reconstruction work, the early completion of roads providing east-west axes for the Kyushu region, such as the Naka-Kyushu Odan Road (including the Takimurozaka Road section) and the Nobeoka Route of the Trans-Kyushu Expressway is indispensable.

The situation in Kumamoto Prefecture is similar to that encountered in the region affected by the Great East Japan Earthquake in 2011. Since that earthquake, early commencement of planned construction was promoted so as to establish reconstruction access routes that would serve as east-west axes for the Tohoku region (the Trans Miyako-Morioka Road; the Trans Tohoku Expressway Kamaishi-Hanamaki Route; and the Tohoku Central Expressway Soma-Fukushima Route) as well as to reconstruct a damaged route (the Sanriku Coastal Road). The approach adopted by the Tohoku Regional Bureau can be used as a guide for the Kumamoto area. In collaboration with the JSCE and as part of the SIP project, the Tohoku Regional Bureau has made efforts to ensure that new road structures are of high quality and durability. The technology and expertise introduced for the work should be utilized in the reconstruction of Kumamoto.

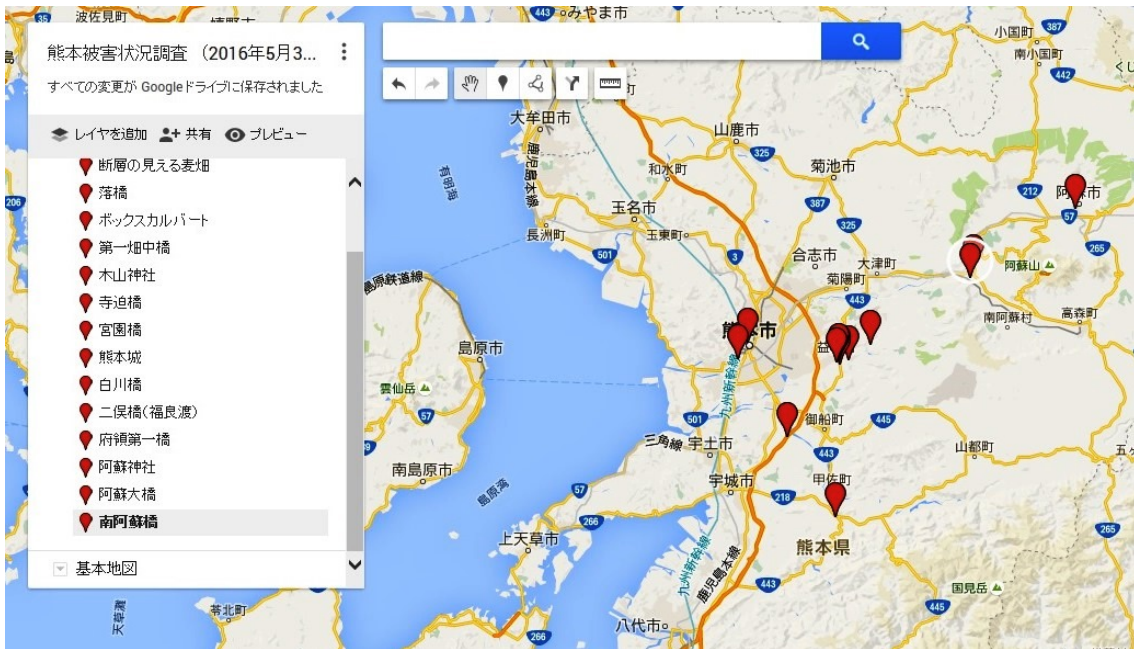
The accelerating deterioration of social infrastructure has recently been attracting a lot of attention. In new construction projects, it is essential to ensure that structures are highly durable and impose less of a maintenance burden based on a full understanding, during both design and construction phases, of the environment to which they will be exposed. This should apply equally to structures that contribute to recovery and reconstruction from disaster. By making the most of the achievements of the JSCE Committee 350's past work and SIP projects, it is fully possible to construct social infrastructure of high quality and durability while imposing a lower life cycle cost. The use of technology that features or complements materials procurable in the local area based on a full knowledge of the properties of those materials is one part of the approach. To that end, we will continue our efforts through coordination with the Kyushu Regional Development Bureau and other relevant organizations.

To conclude, we thank Yozo Fujino, SIP Program Director, and Koichi Maekawa, Concrete Committee Chairman and SIP Project Leader, for approving the dispatch of the investigation team and providing support. We express our gratitude to Yasuo Morita, Director of Kumamoto River and National Road Office, Kyushu Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism, who kindly agreed to the interview while schedule with restoration work on the ground. We also appreciate the cooperation of those concerned at JSCE and SIP.

Appendix: Report on Investigation of Bridge and Building Damage resulting from Kumamoto Earthquakes

Investigation sites

Civil structures and buildings to be investigated were selected with reference to the documents and materials presented at the preliminary session of the investigation into the damage caused by the 2016 Kumamoto Earthquake and other documents. The locations of these civil structures and buildings that were visited for on-site investigations on May 6 and 7, 2016 were plotted on Google Maps.



Inspections

Day 1 May 6

14:30 Aso Bridge (type: arch bridge with inverted-Langer girder deck truss; total length: 205.9m; main span: 132.2m; width: 8m; constructed in 1970).



Damaged state:

Total collapse, possibly due to widespread failure of mountainside (but possibly as a direct result of the earthquake). The fall prevention system was destroyed. National Route No. 57 over the bridge was cut off and the alternative “Milk Road” was serving as the road link from Kumamoto via Aso to Oita.

Aso Shrine



“Romon Gate”, which is designated by the government as an important cultural property, was completely destroyed. The shrine buildings also collapsed.

Day 2 May 7

11:00 Furyo-daiichi Bridge (type: prestressed concrete three-span continuous hollow floor slab bridge; total length: 61m; constructed in 1974). The bridge crosses the Kyushu Expressway near the Midorikawa parking area.



The bridge, with rocking piers, spans the Kyushu Expressway. The on-site evidence (including the way in which the horizontal restraining members and shoe seat surfaces had failed) indicates that the bridge collapsed to the left in the photo. The girder had been removed and the Kyushu Expressway resumed full operation on April 29 (15th day after the disaster).

12:00 Futamata-fukurawatashi Bridge (type: masonry arch bridge; total length: 27m; constructed in 1830).



The stones forming the wall toward the top of the arch crumbled in the earthquake. A twin bridge nearby, the Futamata Bridge, had no visible damage. The difference can be assumed to be due to the direction of the earthquake motion. The waterproof sheet visible in the photographs was installed by the bridge manager a few years ago to prevent the entry of storm water.

14:30 Bridge of unknown name (type: girder bridge total length: about 15m; construction year: unknown)



It can be assumed that failure of the plain concrete piers resulted in collapse of the bridge. The girder consisted of round-section steel. Demolition work was under way at the time of the inspection.

15:00 Daiichi Hatanaka Bridge (type: girder bridge; constructed in 1976)



Serious damage was concentrated at the top and bottom of the circular piers. It is possible that the amount of hoop reinforcement is small. No damage was observed to the girder. The road was closed to traffic.

15:30 Miyazono Bridge (type: girder bridge; total length: about 15m; constructed in 1977).



The rubber pads (used in place of shoes) bearing the girder were visible, which indicates that the bridge had shifted in the direction perpendicular to its axis due to the effect of the earthquake motion. The lower part of the parapet collapsed. The amount of main reinforcing steel is small. The road continues to be in service.

15:30 Terasako Bridge (type: girder bridge; total length: about 50m; construction year: unknown)



The girder had shifted horizontally in the direction of the bridge axis. Diagonal cracking had developed in the section of the abutment that carries the girder. A large vertical crack was observed in the middle of the vertical wall of the abutment.

16:00 Box culvert at Terasako Intersection



The retaining wall and the end of the box culvert collided during the earthquake, causing damage that resembles punching shear failure in the end of the box culvert. No other damage that could have been caused by earthquake motion was discovered in the box culvert.

16:30 Kiyama Shrine



As with the Aso Shrine, the shrine building collapsed. Stone monuments, garden lanterns, etc., also fell to the ground.

17:00 Kumamoto Castle



The stone castle walls had collapsed in numerous places in connection with embankment failures. Plaster-finished earth walls also collapsed. Some tiles had fallen from the castle tower, etc.

18:00 Shirakawa Bridge (type: Lohse bridge; total length: 69.6m; constructed in 1959)



Girder displacement, road subsidence, etc., were observed. The principal cause is collapse of the pin bearings (on the Kumamoto Station side). The bridge is located on Prefectural Route No. 22 that leads away from the east exit of the station. Thus, closure of the road has had a significant impact on local traffic.