# Disaster prevention, mitigation, and risk management of road structures

## 1. Outline of Studies and Activities

NILIM has been conducting various surveys, tests, research, development, and technical guidance for disaster prevention, mitigation, and risk management of road structures with the goal of protecting the lives, bodies, and property of citizens from various disasters, such as earthquakes and torrential rains.

Table 1: History of Major Disasters and Disaster Prevention, Mitigation, and Risk Management Studies of Road Structures

| Major Disasters and the Organization of NILIM | Efforts focused on bridges, earthwork structures, etc. | Initiatives Focused on Earthquakes and Other Disasters |
|---|---|---|
| 1964 Niigata earthquake<br>1994 Off the east coast of Hokkaido earthquake<br>1995 Hyogo-ken Nanbu earthquake [Great Hanshin-Awaji Earthquake] | | 1950s [Earthquake] Start of strong-motion seismic observation<br>1988 [Earthquake] Published Handbook for Earthquake Disaster Countermeasures for roads |
| 2001 Establishment of the National Institute for Land and Infrastructure Management (NILIM) (Bridge and Structures Division of Road Department, Earthquake Disaster Prevention Division of Research Center for Disaster Management)<br>2003 Tokachi offshore earthquake<br>2004 Niigata Chuetsu earthquake<br>2005 Earthquake with epicenter off the west coast of Fukuoka Prefecture<br>2007 Noto Hanto earthquake<br>Niigata Chuetsu offshore earthquake<br>2009 Earthquake with epicenter in Suruga Bay<br>2011 Off the Pacific coast of Tohoku earthquake [ Great East Japan Earthquake ] | ○ [Liquefaction] Response to liquefaction and other ground deformation<br>2005–2007 [Bridge] Three-year program for seismic retrofitting of bridges on the emergency transportation routes<br>2009–2012 [Earthworks] Road Earthwork Guidelines Revised (Enhanced provisions for drainage etc.)<br>2012 [Bridge] Revision of Specifications for Highway bridges (Review of earthquake ground motion, verification of liquefaction determination method, etc.) | 2006 [Earthquake] Revision of Handbook for Earthquake Disaster Countermeasures for roads<br>2009 [Earthquake] Manual distribution of spectrum analysis information begins.<br>2010 [Earthquake] Revision of Handbook for Earthquake Disaster Countermeasures for roads |
| 2014 Establishment of Road Structures Department (Establishment of Research Center for Land and Construction Management, Disaster Prevention Division [Reorganized from Earthquake Disaster Prevention Division])<br>2016 Establishment and incorporation of Earthquake Disaster Management Division (Reorganized from Disaster Prevention Division)<br>2016 Kumamoto earthquake<br>2017 Establishment of Kumamoto Earthquake Recovery Division (Research Center for Infrastructure Management)<br>2017 Torrential rain in northern Kyushu<br>2018 Torrential rain in July, 2018<br>2018 Hokkaido Iburi East Earthquake<br>2019 East Japan typhoon<br>2020 Torrential rain in July 2020 | 2017 [Bridge] Revision of Highway bridges (Response to ground deformation and fault displacement, verification of earthquake ground motion, etc.)<br>○ [Bridge] Seismic Damper Initiatives<br>2020 [Earthwork and paving] Road infrastructure, completion of experimental facility | 2015 [Earthquake] Disaster preparedness study support, toolkit development<br>2016 [Disaster info.] Systematization of disaster information required for road managers<br>2017 [Earthquake] Automatic distribution of spectrum analysis information begins.<br>2019 [Disaster info.] Study of disaster information acquisition by automatic navigation UAV<br>2019– [Earthquake] Revision of *Handbook for Earthquake Disaster Countermeasures for roads* |

Table 1 shows the major disasters and the history of disaster prevention, mitigation, and risk management research on road structures from before the establishment of NILIM to the present. The research has been conducted by the Bridge and Structures Division of the Road Department and the Earthquake Disaster Prevention Division of the Research Center for Disaster Management since the establishment of NILIM. Subsequently, the Road Structures Department was established as a result of a reorganization and now in terms of individual structures,

Photo 1: Damage from the Kumamoto earthquake

such as bridges, earthworks, and tunnels, the Bridge and Structures Division, the Foundation, Tunnel, and Substructures Division, the Pavement and Earth Structures Division, and the Earthquake Disaster Prevention Division. The Earthquake Disaster Management Division is conducting research from the viewpoint of seismic motion. In addition, as a new initiative, the Kumamoto Earthquake Recovery Division (Research Center for Infrastructure Management) was established in April 2017 to accelerate recovery and reconstruction projects from the damage caused by the 2016 Kumamoto earthquake (Photo 1). Infrastructure Management was established in April 2017 to accelerate recovery and reconstruction projects from the damage caused by the Kumamoto earthquake (Photo 1) in 2016.

Table 2: Phases of Disaster Prevention for Road Structures and Corresponding Studies

| | | Earthquake | Torrential rain | Heavy thunder |
|---|---|---|---|---|
| Countermeasures in advance (Disaster prevention) | | ■Research on earthquake-resistant technology for road structures<br>■Research on improving the load-bearing capacity of road bridge foundations against earthquakes<br>■Research on risk assessment of functional deterioration of earthwork structures due to liquefaction; facilities and equipment<br>■Research on ground vibration characteristics and strong-motion observation surveys<br>■Research on disaster prevention training using the Disaster Countermeasures Study Toolkit<br>■Technical guidance and technology transfer (acceptance of human resources, research support, knowledge sharing) | ■Study of inspection methods for earthwork structures<br>■Research on functional restoration of existing earthwork structures<br>■Research on improving the load-bearing capacity of road structures against scouring caused by flooding etc.<br>■Technical guidance and technology transfer | ■Snow damage knowledge maintenance |
| Forecast | | | ■Research on new advance traffic control standards (use of radar rain gauges, study of new rainfall indicators) | ■Research on snow accumulation prediction considering road surface conditions |
| Occurrence of disaster | Initial response system | ■Analysis of seismic tremors and understanding and provision of information on the scale of damage<br>■Improvement of information analysis and decision support system for full-scale operation (distribution of spectral analysis information and list of CCTV cameras exposed to strong shaking)<br>■Immediate damage detection and strong-motion monitoring of civil engineering structures | | ■Utilization of road surface snow accumulation forecasts for snow removal activities |
| | Road opening | ■Survey on technology to determine if a road is passable or not (Various image centers, UAVs etc., and use of probe information)<br>■Research on estimation of damage to infrastructure caused by liquefaction etc. | | |
| | Emergency restoration | ■Research on improving the load-bearing capacity of road bridge foundations against earthquakes<br>■Research on inspection and diagnosis of cable-stayed bridge cables damaged by earthquake<br>■Utilization of new technologies in restoration (UAV, SAR, etc.)<br>■Field survey and technical guidance | ■Research on improving the load-bearing capacity of road structures against scouring caused by flooding, etc.<br>■Study of inspection methods for earthwork structures<br>■Use of new technologies in restoration (UAV, SAR, etc.)<br>■Technical guidance and technology transfer | |
| | Complete recovery (Relapse prevention) | ■Research on bridge repair and reinforcement design<br>■Research on verification methods for earthwork structures according to performance requirements<br>■Research on functional restoration of existing earthwork structures<br>■Research on data obtained from disaster restoration work and its utilization<br>■Field surveys, technical guidance, and participation in study committees | ■Research on improving the load-bearing capacity of road structures against scouring due to flooding etc.<br>■Research on bridge repair and reinforcement design<br>■Research on functional restoration of existing earthwork structures<br>■Field surveys, technical guidance, and participation in study committees | |

Disaster countermeasures for road structures vary from pre-disaster countermeasures to main restoration after the occurrence of a disaster, depending on the type of disaster, at each stage (Table 2). Since the scope of the studies is also diverse, these studies are conducted in cooperation and shared by the Public Works Research Institute(PWRI), the private sector, universities, and other research institutes.

The basic goal is to establish standards for the maintenance of facilities and maintenance management of bridges and other structures that make up the roadway against disasters that are linked to the level of service, such as "the road closure can be lifted within 0 days after a heavy rainfall that occurs once in XX years" (Figure 1).

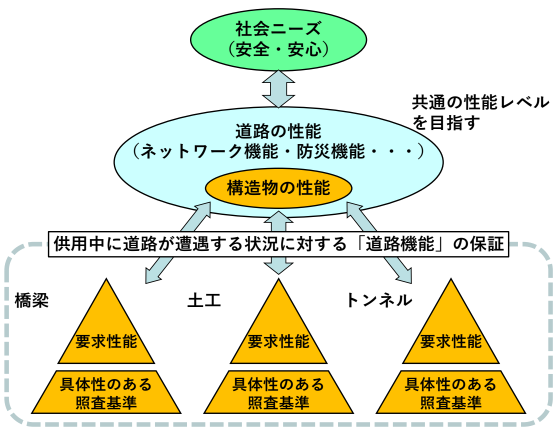

Figure 1: Concept of Standards Development for Road Structures

The Bridge and Structures Division is constantly revising the Specifications for Highway Bridges (hereinafter referred to as

"JSHB") based on the actual damage caused by the 2011 off the Pacific coast of Tohoku earthquake (hereinafter referred to as "Tohoku Earthquake"), such as bridge washouts due to tsunami and slope collapses during the Kumamoto earthquake, as well as the revision of the specifications for the emergency transportation routes as described below. In addition, we have been formulating and disseminating emergency measures, such as the Three-Year Program for Seismic Reinforcement of Bridges on Emergency Transportation Roads, which is described later in this report.

Similarly, for natural slopes and road earthwork structures, we have developed countermeasures based on damage to high embankments on catchment terrain in the 2004 Niigata Chuetsu earthquake (hereinafter referred to as the "Niigata Chuetsu Earthquake") and liquefaction in the Tohoku Region Pacific Ocean earthquake and reflected them in revisions of the Road Earthwork Guidelines and other guidelines.

On the other hand, we are also conducting research focused on disaster preparedness. Strong-motion seismic observations have been conducted since the 1950s as important information for clarifying earthquake damage and the behavior of structures during earthquakes. The *Handbook for Earthquake Disaster Countermeasures for Roads* was first published in 1988 as a guide to help reduce damage to road facilities in the event of a major earthquake and to contribute to road management after a disaster. Since then, it has been revised from time to time in response to the occurrence of earthquakes and changes in the needs of users. In addition, we are also studying spectral analysis of earthquake ground motion and its information distribution in order to enhance information on damage during the information vacuum period immediately after an earthquake. Recently, from the viewpoint of promptly identifying and responding to road damage, efforts have been made to systematize the information necessary for road administrators to respond to disasters and to develop technologies for acquiring such information.

## 2. Main Research Results

### (1) Initiatives for Disaster Prevention and Mitigation Focusing on Structures

#### ① Bridges

**1) Previous efforts**

NILIM has conducted damage surveys, provided technical support to road administrators, and analyzed damage cases, the results of which have been reflected in revisions of the JSHB and other technical standards.

**2) Response to various types of disasters**

**2)-1 Three-year program for seismic retrofitting of bridges on emergency transportation roads**

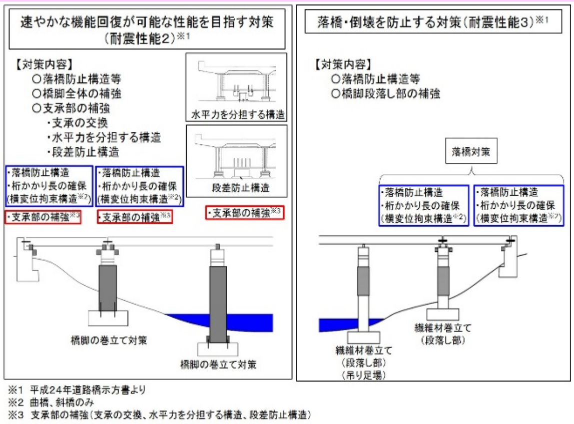


Figure 2: Overview of earthquake resistance measures (from MLIT website)

The Niigata Chuetsu Earthquake caused the most extensive damage to road structures since the 1995 Hyogo-ken Nanbu earthquake (hereinafter referred to as the "Hyogo-ken Nanbu Earthquake"). In response, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) established the Three-Year Program for Seismic Reinforcement of Bridges on the Emergency Transportation Routes and focused on seismic reinforcement of bridges on the emergency transportation routes, which play an important role in supporting restoration activities when damage occurs, during the three-year period from fiscal 2005 to 1995.

In this program, bridges that are subject to standards that are older than the 1980 revision of the JSHB and that need to be reinforced with special priority are reinforced with reinforced concrete piers, concrete filling of steel piers, installation of bridge fall prevention structures, etc. (Figure 2). NILIM supported the creation of a map of the expected progress of seismic reinforcement of bridges to provide easy-to-understand information on the progress of the program.

The Tohoku-Pacific Ocean earthquake carried out the operation "Teeth of a Comb," and thanks to the effect of this seismic reinforcement program, even road bridges to which old technical standards were applied were spared from catastrophic damage by the earthquake, contributing to the early opening of roads.

**2)-2 Revision of the Specifications for Highway Bridges in 2012 and 2017**

In the Tohoku-Pacific Ocean earthquake, damage to bridges caused by seismic motion was limited as described above, but the tsunami caused such damage as bridge washouts (Photo 2). In light of this, the 2012 revision of the JSHB stipulates that structural planning for bridges must take into account local disaster prevention plans and other factors related to tsunamis.

Photo 2: Damage to bridges damaged by the tsunami (Tohoku Earthquake out at Pacific Ocean)

Photo 3: Damage to a bridge that sustained ground deformation (Kumamoto Earthquake)

Photo 4: Damage to bridge with locking piers (Kumamoto Earthquake)

In addition, revisions were also made to the level 2 earthquake ground motions (type I) in consideration of plate boundary type large-scale earthquakes, such as the Tokai, Tonankai, and Nankai earthquakes, and to the application of high-strength steel bars (SD390 and SD490) to enable rationalization of reinforcement distribution in light of the situation where reinforcement distribution is overcrowded due to the advancement of earthquake-resistant design. The application of high-strength steel bars (SD390 and SD490) was revised to enable rationalization of reinforcement allocation.

The Kumamoto earthquake caused damage to bridges due to ground deformation, such as fault displacement and slope collapse (Photo 3). In addition, the superstructure supported by rocking piers suffered damage that resulted in the bridge falling (Photo 4). Based on the experience of these damages, the 2017 revision of the JSHB stipulates that the standard is to select bridge locations or bridge types that are not affected by large-scale ground deformation. It was also stipulated that the substructure must be stable and support the superstructure. In addition, although seismic motion exceeding the design spectrum was observed in some of the period bands of the Kumamoto earthquake, it was evaluated to be at the same level as the design spectrum established based on the seismic motion of the Hyogo-ken Nanbu Earthquake, and based on various engineering judgments, the characteristic values of Level 2 seismic motion considered in the previous specifications are to be retained.

**2)-3 Initiatives Related to Seismic Dampers for Road Bridges**

Seismic dampers are used as a technology to secure and improve the seismic performance of road bridges by reducing seismic shaking. However, in the Tohoku Pacific Offshore earthquake and the Kumamoto earthquake, the dampers were not effective as expected in the design because of damage to the damper attachment points (Photo 5). In order for dampers to behave stably in the event of an earthquake, it has been recognized once again that it is necessary to present the required performance of not only the dampers themselves but also their mounting parts in a unified manner, as well as the methods for checking such performance, and we are promoting these studies. Part of the results of this research is being used to establish performance evaluation items for the Vibration Control Damper Technology for Improving Seismic Resistance of Road Bridges (open call for applications in July 2020), which is a theme-based (public call for technology) project under the New Technology Utilization System.

Photo 5: Damper that did not function due to damage to the mounting (Kumamoto Earthquake)

**3) Future Initiatives**

In the torrential rains of July 2020, rising rivers caused damage to bridge superstructures. Immediately after the disaster, NRI analyzed the damage mechanism and developed a method to assess the risk of superstructure overflows on existing river bridges. We will continue our research to develop guidelines for planning so that road administrators can appropriately formulate long-life repair plans that take into account not only the existing disaster risk but also the aging of the bridge.

**② Earthwork structures (embankment and cut), natural slopes, pavements**

**1) Previous efforts**

Major earthquakes in the past have frequently caused significant damage to road earthwork structures, affecting roadway functionality. For this reason, the NILIM has revised the Road Earthworks Guidelines from time to time based on past damage. For example, the guidelines have been revised to reflect the damage to high embankments on catchment topography caused by the Niigata Chuetsu Earthquake, the 2007 Noto Peninsula earthquake, and the August 2009 Suruga Bay earthquake (hereinafter referred to as the “Suruga Bay Earthquake”), as well as liquefaction and other damage caused by the Tohoku District-off the Pacific Ocean earthquake.

**2) Response to various types of disasters**

**2)-1 Response to liquefaction and other ground deformation associated with earthquakes**

In the Tohoku Pacific offshore earthquake, liquefaction damage was also observed in the Kanto region. The NILIM collected liquefaction damage cases in various regions, organized and analyzed the relationship between various conditions, such as road structure, buried objects under the road, and ground conditions, and the damage situation. Based on the results, pavements with liquefaction countermeasures were constructed by local governments (Photo 6).

Photo 6: Liquefaction Countermeasure Pavement (Takaishi City, Osaka Prefecture)

In 2020, a road base structure experiment facility was constructed on the premises of the NILIM in order to reproduce ground deformations that may cause road bumps and sinking and to verify the passability of roads when deformations occur (Photo 7). This facility is designed to reproduce ground deformation during earthquakes by installing jacks on the experimental slab, constructing an embankment and pavement on top of the jacks, and inducing forced displacement of the embankment by the ups and downs of the jacks. In the same year, we conducted a confirmation test of the resistance of the pavement structure with geogrid inside to deformation caused by ground deformation (Figure 3).

Photo 7: Experimental facility for road base structure

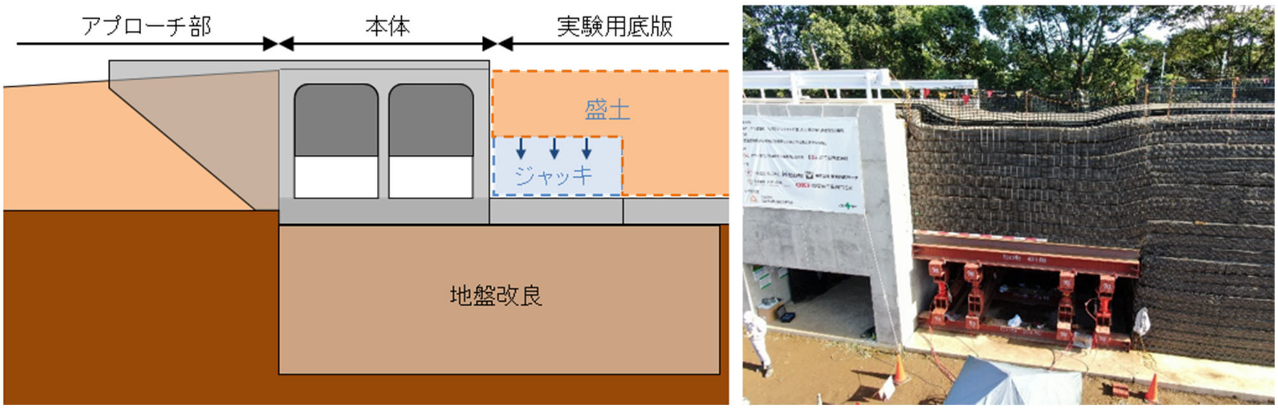


Figure 3: Test to confirm resistance of pavement structure with geogrid to deformation caused by ground deformation

**2)-2 Response to a series of typhoons and torrential rains**

In addition to the above, NILIM has also visited disaster-stricken sites of earthwork structures to accumulate knowledge and provide technical support. In recent years, NILIM has provided technical support to local governments on restoration policies for slope collapse in the Kumamoto earthquake and landslide and river flooding in the East Japan typhoon of 2019. Most recently, we conducted on-site surveys and provided advice on restoration methods after a landslide occurred on national and prefectural roads managed by Nagano Prefecture during the torrential rains in July 2020 (Photo 8).

Photo 8: Local assistance for damaged roads

**3) Future Initiatives**

We will continue to respond to requests for technical assistance from the field, and through the collection and compilation of recent damage situations and analysis of damage mechanisms, we will conduct research to understand and respond to the risks of natural slopes and road earthwork structures and study ways to ensure the unified performance of road networks.

**(2) Initiatives for disaster prevention and mitigation with a focus on earthquakes and other disasters**

**① Strong earthquake observation**

Strong-motion records obtained from actual earthquakes play an important role in the conversion from the seismic intensity method to the method of holding capacity during earthquakes and are closely related to the development of seismic resistance technology. The results of research on methods for estimating seismic motion characteristics based on ground vibration characteristics and earthquake location and on seismic behavior and performance verification of civil engineering structures have been reflected in seismic standards for roads, rivers, and other infrastructure facilities, as well as in the JSHB. In order to continue these studies, NILIM has been conducting the following strong-motion seismic observations.

**1) Strong-motion seismic observation for infrastructure facilities**

Strong-motion seismic observation of infrastructure facilities began in the 1950s during the period of the PWRI, and the observation system was expanded in 1960. Later, when the Niigata earthquake occurred in 1964, strong-motion earthquake records contributed greatly to the clarification of earthquake damage, which prompted the Ministry of Construction to formulate a plan for the deployment of strong-motion seismographs and to establish a system for the accumulation of strong-motion earthquake records at the PWRI.

As a result, the strong-motion earthquake observation network at regional construction bureaus and other related public corporations and local government infrastructure facilities was expanded, and the PWRI provided technical guidance for the installation of strong-motion seismographs.

NILIM has taken over this policy and is conducting strong-motion seismic observations at bridges and other road structures throughout Japan. Currently, NILIM conducts strong-motion seismic observations at a total of 75 locations, including 24 road structures and 51 river structures, and maintains and manages the equipment. In addition, we have developed a monitoring system (Figure 4) that can acquire data on the behavior of the entire system for road bridges etc. and are conducting observations.

**2) High-density strong-motion observation**

In addition to the above, high-density strong-motion seismic observations are being conducted at 76 sites in eight districts (Sagara, Yaizu, Numazu, Matsuzaki, Makuhari/Narashino, Tateyama, Odawara, and Kobe) where strong-motion seismographs are intensively placed in the ground and underground for the purpose of clarifying the mechanism of earthquake generation, propagation path, and the effects of local conditions on seismic characteristics in specific areas.

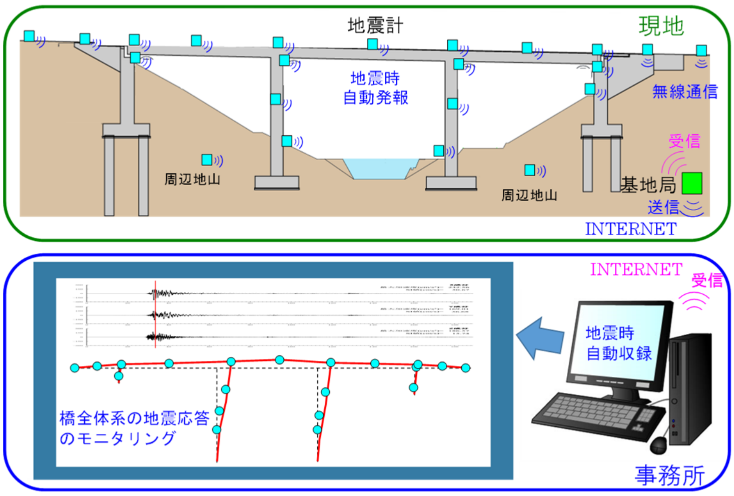

Figure 4: Monitoring system for whole system behavior

**②** ***Handbook for Earthquake Disaster Countermeasure for Roads***

The Handbook for Earthquake Disaster Countermeasure for Roads is published by the Japan Highway Association as a technical guide to help reduce damage to road facilities in the event of a major earthquake and to contribute to road management after the disaster.

The current edition includes the "Pre-earthquake Countermeasures" section, which describes the organizational structure to promote preventive measures against earthquakes, methods for determining the seismic performance of road facilities, and methods of seismic countermeasures, and plans to be established before the occurrence of an earthquake; the "Earthquake *Disaster* Restoration" section, which describes technical points and specific examples related to damage surveys, damage assessment, and restoration methods for rapid post-earthquake restoration; and the " Earthquake Disaster Risk Management" section, which describes the technical points and examples of restoration methods to be established immediately after the occurrence of an earthquake. The "Earthquake Crisis Management" section outlines the basic policies for road management and actions to be taken by road administrators during the initial response period immediately after an earthquake.

The Pre-earthquake Countermeasures and Earthquake Disaster Restoration were first published in 1988 and were revised in 2002, mainly by the NILIM based on the experiences of the 1993 Kushiro Offshore earthquake, the 1994 offshore earthquake off the east coast of Hokkaido, and the 1994 Southern Hyogo Prefecture earthquake. Subsequent revisions were made in 2006 and 2007 based on the experiences of the 2003 Tokachi offshore earthquake and the Niigata Chuetsu Earthquake.

The " Earthquake Crisis Management " was created as a basic policy guide for road administrators during the initial response period immediately after an earthquake in response to the recognition during the Hyogo-ken Nanbu Earthquake of the importance of establishing a post-quake road management system in advance, including the establishment of an emergency system immediately after an earthquake, information gathering, and coordination with related organizations, In 1996, it was published as the Earthquake Disaster Restoration. It was later revised in 2010 based on the experience of earthquake disasters after the Hyogo-ken Nanbu Earthquake.

Since this revision, the Tohoku Pacific offshore earthquake, the Kumamoto earthquake, and other earthquakes have occurred, and new lessons in both hardware and software have been accumulated. At the same time, new government laws and regulations have been enacted, the Central Disaster Management Council has compiled a series of damage estimates and guidelines for disaster countermeasures, and the MLIT has formulated various plans for disaster responses etc. Currently, *Handbook* for Earthquake Disaster Countermeasure for Roads is being revised to take into account these circumstances starting in 2019.

**③ Enhancement of road damage information during the information vacuum period immediately after the earthquake**

The MLIT immediately starts inspecting the facilities under its jurisdiction when a strong earthquake tremor is observed. However, during the information vacuum period immediately after an earthquake, only CCTV camera images and news reports are available, and the information available from these images is limited at night. Therefore, NILIM is implementing the following measures to improve the information available immediately after an earthquake.

### 1) Automatic distribution system for information on spectral analysis of earthquake ground motions etc.

NILIM has long compared the acceleration response spectra of strong-motion records observed during damaging earthquakes with those of past representative damaging earthquakes, such as the Hyogo-ken Nanbu Earthquake, and has reported the relationship between strong-motion and the scale of damage in emergency survey bulletins and other media. At the time of the Suruga Bay Earthquake, disaster response workers requested ways to understand the effects of seismic motions on road structures, so spectral analysis information was prepared at the time of an earthquake with a maximum intensity of 6 or lower and shared among relevant parties in the Ministry (Figure 5). In the Kumamoto earthquake, a major foreshock and main shock occurred during the night, and while the spectrum analysis information provided valuable information on the scale of damage, it took three to four hours after the event to analyze and chart the data, which meant that it could not be used during the information vacuum period immediately after the event. In order to improve this situation, a mechanism was established to automatically distribute spectral analysis information etc. utilizing the National Research Institute for Earth Science and Disaster Prevention (NIED)'s immediately available data, and the system has been distributed on a trial basis to the MLIT, regional development bureaus, and other related departments since 2017.

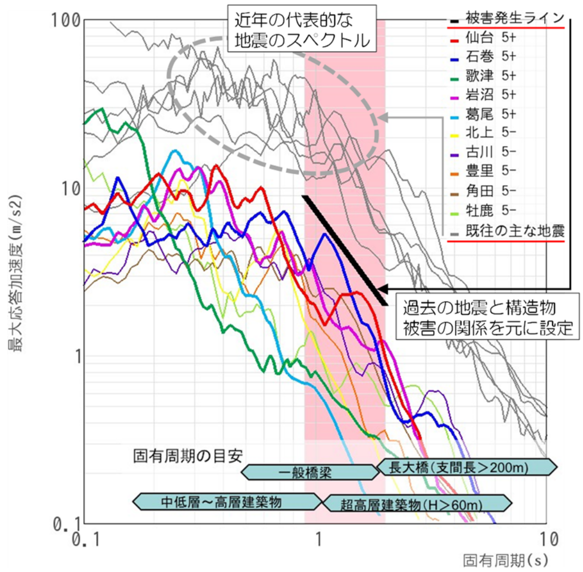


Figure 5: Spectral analysis information (excerpts))

### 2) Efficient acquisition of road damage information

Surveying road damage through visual inspections at the time of a disaster poses several challenges, including a shortage of personnel at the time of a disaster, the danger of inspecting damaged areas, and impediments to patrols due to road damage, traffic congestion, and other factors. Currently, road patrol cars and CCTV cameras are mainly used to assess the damage situation.

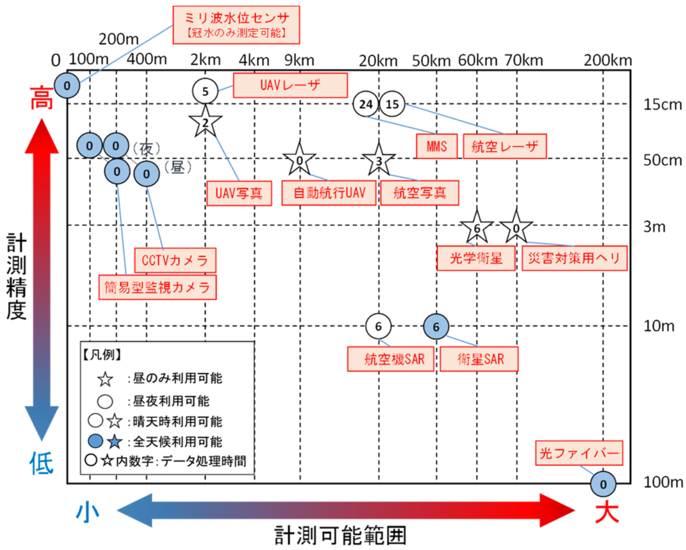


Figure 6: Applicable Conditions Chart

NILIM has been systematizing the information necessary for road administrators to respond to disasters since 2016 and has been working to clarify the technologies and their performance required for disaster awareness. This will enable us to further clarify the application scenarios and present the targets for technological development (Figure 6).

Photo 9: Experiment of information acquisition by an auto-navigating UAV

In the future, we will study the possibility of utilizing information collection by automatic navigation UAVs and satellites (Photo 9) and examine scenes in which road management technology can be used according to the disaster situation so that it can be used for road management not only in times of disaster but also in normal times.

**④Development and utilization of the Disaster Preparedness Study Support Toolkit**

The Tohoku-Pacific Ocean earthquake exceeded the scale of earthquakes and the aspect of disasters conventionally assumed, and it became clear that there are limits to what can be done with only existing empirical knowledge.

Various infrastructures managed by the MLIT are also taking both hardware and software measures, such as earthquake-proofing bridges and river embankments, conducting disaster drills, and stockpiling disaster recovery materials. NILIM has developed a Disaster Countermeasure Study Support Toolkit (Figure 7). This toolkit has not only functions as a method for studying disaster countermeasures but also as an effective method for disaster prevention education. The developed toolkit is being used on a trial basis at offices under the MLIT and at the National University of Land, Infrastructure, Transport and Tourism (NUMT).

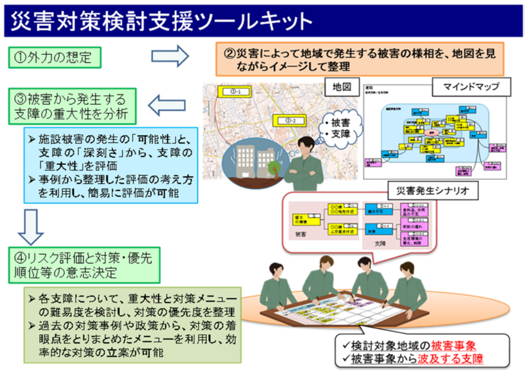


Figure 7: Disaster Preparedness Study Support Toolkit

## 3. List of related reports and technical documents


1) Research and Activities Policy of Road Structures Department, NILIM Home page
http://www.nilim.go.jp/japanese/organization/kouzou/houshin_dourokouzou.pdf

2) Technical standards for bridges, viaducts , etc. (Specifications for Highway Bridges（February 2012, July 2017）

3) Japan Highway Association, Handbook for *Earthquake Disaster Countermeasures for Roads* (Earthquake Disaster Risk Management) in July 2019, (Pre-Earthquake Countermeasures) in September 2006, (Earthquake Disaster Restoration) March 2007

4) *Journal of Disaster Research*, Dr14-2-9602, pp. 333-347, 2019.3. ”Development of Real-Time Collection, Integration, and Sharing Technology for Infrastructure Damage Information”
https://www.jstage.jst.go.jp/article/jdr/14/2/14_333/_article/-char/ja

5) “Strong Motion Records from the 2011 Off the Pacific Coast of Tohoku Earthquake,” Technical Note of NILIM No. 726
http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0726.htm

6) Strong-motion seismic observation of civil engineering structures at National Institute for Land and Infrastructure Management, Newsletter of the Seismological Society of Japan, No. 73 NL2, July 2020

7) "Automatic Distribution of Spectral Analysis Information on Earthquake Ground Motions and Its Improvements." *Civil Engineering Journal* 62-5 pp. 8-11

8) “Research on crisis management for excessive external forces and complex natural disasters,” Project Research Report of NILIM No. 64
http://www.nilim.go.jp/lab/bcg/siryou/kpr/prn0064.htm


## 4. Future Outlook

With the increasing frequency and severity of disasters, such as earthquakes, torrential rains, and heavy snowfalls, NILIM needs to make a concerted effort to study this field in cooperation with related organizations.

In the promotion of disaster prevention measures, it is necessary to evaluate the various disaster risks that roads currently face from a unified viewpoint by adding the latest knowledge available and to establish a management method for countermeasures based on the evaluation results. Based on the results of the evaluation, it is necessary to establish a management method for disaster prevention measures based on the latest knowledge.

In addition to earthquakes, road managers are required to further enhance disaster prevention education to widely disseminate the content of increasingly sophisticated countermeasures against disasters such as heavy rain and heavy snowfall.