Support for maintenance and management of road structures

1. Outline of Studies and Activities

Social Background and Recommendations	Reflecting the movement and results of road administration	Activities of the NILIM (1) Establish maintenance cycles	(2) Initiatives to Support Planned Longevity	(3) Human resource development and technical assistance to road managers
		April 2001 Establishment of NILIM (Bridge and Structures of Division of Road Department)		
	○Mar. 2004 Notice of Draft Guidelines for Periodic Inspection of Bridges	・Drafting periodic bridge inspection guidelines and providing research results ・Damage Case Analysis	・Research on BMS and other planned management	・Technical consultation, Support for training activities ・Research on revisions of various standards
	○2010 Start of periodic inspection of signs and lighting posts (National highways under direct control)	Apr. 2005 Bridge and Structures Division of Road Department (Reorganization)		
		・Damage Data Analysis	・2007 Began supporting the development of a long-life repair plan. 【Guidelines for Collecting Basic Data on Road Bridges】	・Support for disaster-stricken areas as TEC-FORCE etc.
○Dec. 2, 2012 Sasago Tunnel falling ceiling panel accident	○Dec. 7, 2012 Conduct emergency inspections of road appendages, etc. in tunnels (jet fans, lighting, etc.)			
	○Feb. 2013– Conduct intensive inspection of road stock :Confirmation of safety from the perspective of preventing third-party damage	・Drafting inspection items and providing research results	・Research on deterioration characteristics and measures to	
○2013 MLIT First Year of Social Capital Maintenance	○Jun. 2013 Revision of the Road Law: Establishment of a system of direct diagnosis and national agency for repairs etc.			
	○Mar. 2014 Ministerial ordinance/notice concerning periodic inspection: Once every five years, inspection by close visual inspection	・Assistance in drafting ministerial ordinances and providing research results		
○Apr. 14, 2014 Recommendations for Full-Scale Implementation of Road Aging Countermeasures	○Apr. 2014– Road Maintenance Panels established. :Systematic support for local government initiatives	Apr. 2014 Establishment of Road Structures Department of NILIM (Bridge and Structures Division, Foundation, Tunnel and Substructures Division, Pavement and Earthworks Division)		
	○Jun. 25, 2014 Periodic Inspection Guidelines Notification:Present specific inspection methods etc. for smooth implementation of inspections.	・Drafting periodic inspection guidelines and providing research results	・Study of macro management measures etc. for structures nationwide	・Start of diagnosis, by the road maintenance specialist team
	○Jul. 1, 2014 Ministerial ordinance / notice on periodic inspections Enacted: Started inspections by close-up visual inspection once every five years.			・Creation of textbooks and dispatch of lecturers for practical training
	○Sep, 2018 Pavement Management Guideline based on Pavement Inspection Guideline		・Assistance in drafting pavement inspection guideline and providing necessary research results	
	○Feb. 28, 2019 Periodic Inspection Guidelines Notification :Streamlined implementation	・Draft revision of periodic inspection guidelines and provide research results		
	○Apr. 2019 Start of second round of periodic inspections			

Figure 1: Road Structure Maintenance Policies and NILIM Activities

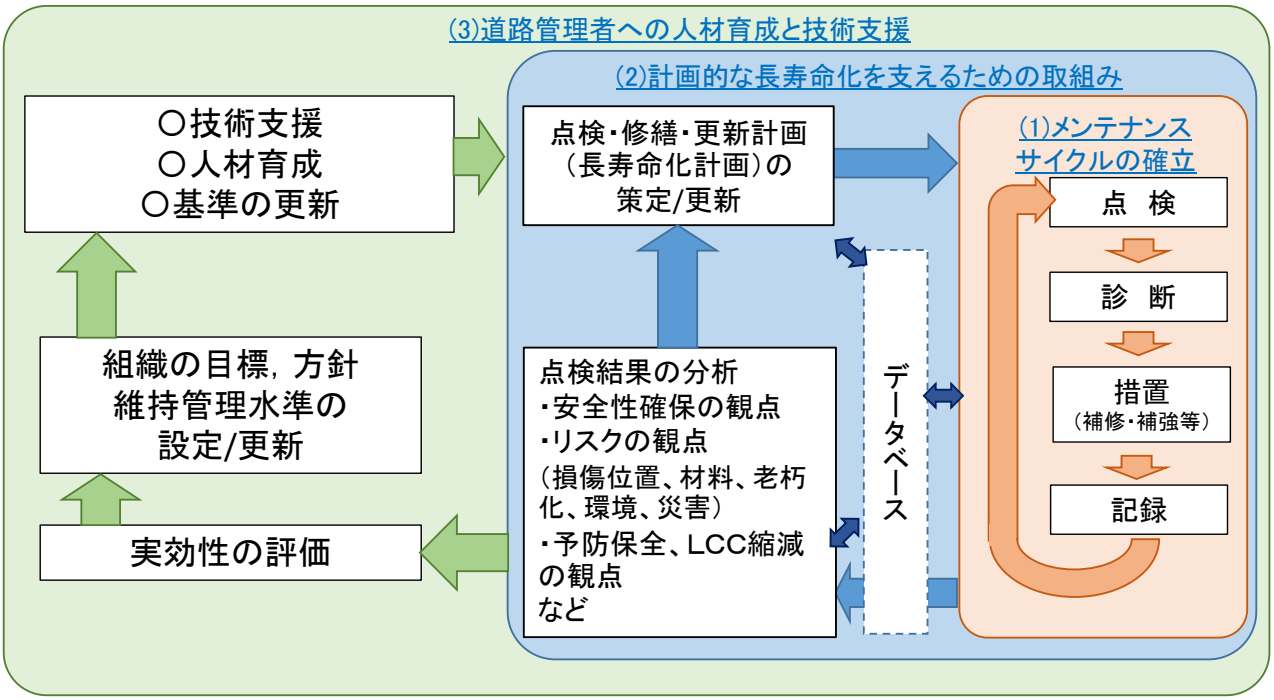

Figure 2: Image of maintenance system for road structures

In order to implement appropriate road management with periodic inspections at its core as a measure against aging road structures, NILIM has been conducting research on technical standards and reference drawing documents related to inspections and management as well as the training systems and technical support for road managers needed to properly implement these standards and documents.

In addition, with these studies as a backdrop, the committee has played a proactive role in activities, such as analysis of accident and damage cases ,legislation of periodic inspection and formulation of the guidelines, and survey and study

Figure 3: Maintenance of road structures

committee activities, formulation of periodic inspection legislation and technical advice (periodic inspection guidelines),

training for road administrators, and technical support as typified by direct supervision and diagnosis.

2. Main Research Results

(1) Establishment of maintenance cycles

① March 2004 Establishment of periodic inspection guideline (draft) for road bridges on national highways under direct control

The MLIT overall efforts to address aging roads are summarized on the Road Bureau's website.[1] At the time NILIM was established, discussions were just beginning on the need to shift to preventive maintenance management, to review the inspection system for this purpose, and to introduce asset management. Under these circumstances, the MLIT decided in 2004 to conduct periodic inspections of government-managed road bridges once every five years and revised its periodic inspection guidelines. The former guidelines, which were formulated by the Public Works Research Institute (PWRI) of the former Ministry of Construction in 1989, were revised to take into account as much as possible the knowledge on road bridge damage obtained during the 15 years the former guidelines were in use and to create an inspection system that would allow for appropriate preventive maintenance at the appropriate time. The revisions made at that time were important for the later enactment of legislation for periodic inspections of tunnels, bridges, and other structures on roads nationwide and for supporting the formulation of long-life repair plans. Details can be found in the Reference Material[2] on Periodic Inspection of Road Bridges, some of which are as follows.

(1) Salt-air damage (2) Alkali Aggregate Reaction

(3) Fatigue

Figure 4: Examples of Deterioration Damage of Road Structures

◯Frequency and Method: The old guidelines stipulate that periodic inspections should be conducted once every 10 years by close visual inspection and once every 2 years by distant visual inspection. Under the new guidelines, the frequency of periodic inspections is now every 5 years or less in light of the frequent cases of damage requiring repair within 10 years after periodic inspections and the increasing amount of damage due to fatigue and other deterioration of steel members. In addition, the inspection method is to be performed by close visual inspection to ensure that damage in areas that cannot be detected by long-range visual inspection can be detected and that necessary actions of percussion and palpation can be taken if necessary.

◯Diagnosis and data: The old guidelines mechanically classified the degree and extent of damage for each type of damage, but there was room for improvement in the usefulness of this information as a direct indication of the necessity and purpose of countermeasures, for example, the urgency of countermeasures varies depending on the cause and likelihood of progress even if the damage has the same degree of appearance. Therefore, under the new guidelines, engineers are required to perform two systems of evaluation: the act of diagnosis (determination of countermeasure classification) in which engineering considerations are made on the structure and cause of damage, leaving findings on the necessity and urgency of countermeasures against damage, and the evaluation of the degree of damage to obtain and record objective

and continuous data on the location, type, and extent of appearance of damage. The evaluation of the degree of damage was conducted in order to obtain and record objective and continuous data on the location, type, and extent of damage. While the judgment of countermeasure classification is information from a micro perspective as an engineering judgment specific to each bridge, the latter evaluation of the degree of damage is information from a national policy by evaluating and recording the same evaluation method and system for all road bridges nationwide, thereby accumulating high-quality data with continuity over time and conducting a macro evaluation of the condition of a group of bridges. The purpose is to accumulate basic data for the study of national policies and analysis of improvements to technical standards, including road bridge design, by evaluating the condition of bridges on a macro scale.

Subsequently, the occurrence of collapsed road signs and lighting poles, which were thought to be caused by deterioration, also became prominent, and the NILIM, in cooperation with the regional development bureaus etc., conducted research to facilitate smooth implementation of periodic inspections on national highways under direct control, including data analysis of damage.[3] Based on the results of this research, periodic inspections of signs and lighting poles have been conducted on national highways under direct control since 2010.

② A major turning point that led to the recognition of the need for mandatory maintenance management - the accident involving the falling of the tunnel ceiling panels -

In December 2012, a series of ceiling panels and bulkhead panels installed for tunnel ventilation fell for approximately 140 m in the Sasago Tunnel of the Chuo Expressway, resulting in deaths and injuries. The MLIT established the Committee for Investigation and Review of Accidents Involving Fallen Tunnel Ceiling Panels with the aim of understanding the cause of the fall and to study measures to prevent a recurrence of similar accidents from a professional standpoint. NILIM cooperated fully with the committee, conducting on-site surveys, verifying the effectiveness of inspection methods using close-up visual inspections, percussion, and palpation, and assisting with on-site investigations and an analysis of factors leading to the occurrence of accidents.

Figure 5: Accidental Fall of Tunnel Ceiling Panels

The above-mentioned investigation and review committee conducted on-site investigations etc. and compiled and published a report in June 2013.[4] The cause of the accident was analyzed as the cumulative effect of multiple factors at the design/construction stage, age-related

deterioration, and maintenance management. For example, in terms of maintenance management, the condition of the adhesive bolts used to suspend the ceiling plate at the top of the tunnel was not clearly verified, the visual inspection and sounding of the bolts in close proximity that had been scheduled by the manager was postponed because of changes in the inspection plan, and the history of confirmed deformation in previous inspections was not reflected in subsequent inspections and other maintenance management. The fact that the history of deformities identified in past inspections was not reflected in subsequent inspections and other maintenance activities was pointed out as a maintenance management issue. In response, momentum was generated for the need for minimum mandatory safety checks, preservation of maintenance records, and implementation of planned measures.

③ Total inspection of road stock, establishment of a statutory inspection system, and improvement of technical advice on periodic inspections

While the committee's investigation into the tunnel ceiling panels fall accident is underway, in February 2013, the MLIT requested that road administrators nationwide conduct a comprehensive inspection of road stock. This inspection was to cover bridges, pavements, road appendages (signs, lighting, information devices, pedestrian crossing bridges, etc.), and earthwork structures (slopes, embankments, retaining walls, etc.) in addition to tunnels for the purpose of preventing damage to road users and third parties and to check for the risk of falling members and concrete pieces from the structure itself and its appendages, potholes, under road surfaces, etc. The purpose of this project is to assess the degree of danger of falling members, concrete fragments, etc. from the structure itself or its appendages or sinking of potholes or cavities under the road surface and to take immediate damage prevention measures, such as implementing emergency measures as much as possible.

In the same year, the Road Law was revised to clarify that road structures should be inspected from the viewpoint of preventive maintenance in order to ensure safety and security, including appropriate responses to aging structures. In response, the relevant ministerial ordinances / notices were also revised with a government ordinance stating that it is the duty of the administrator to implement the maintenance cycle of inspection, diagnosis, measures, and recording, and a ministerial ordinance making it a statutory requirement that a knowledgeable and skilled person conduct a periodic inspection of bridges and tunnels once every five years, including a close visual inspection and soundness diagnosis. The ministerial ordinance also made periodic inspections of bridges, tunnels, and other structures once every five years by a knowledgeable and skilled person mandatory. This was an obligation imposed on all road administrators, including local governments, and was a reform that embodied the First Year of Social Capital Maintenance by the MLIT 2013.

Figure 6: Example of the subject of a general inspection

In June 2014, technical advice (periodic inspection guidelines) for conducting periodic inspections of tunnels, road bridges, sheds, large culverts, pedestrian crossing bridges, gantry-type signs, etc. was reported to all road managers. NILIM worked with the MLIT to draft the overall system and major parts of the revised laws and regulations and with the PWRI to draft the

periodic inspection guidelines. In addition, the NILIM reviewed the existing periodic inspection guidelines for national highways under direct control and developed new guidelines for some structures such as pedestrian crossing bridges.

Since the revision of the Road Law in 2013, the MLIT has been enhancing inspection guidelines for road managers nationwide in establishing road maintenance cycles, although specific inspection frequencies and methods are not specified by law, and in 2016 for pavements, and in 2017 for small appendages and earthwork structures excludiy sheds and large culverts.

In both of these formulations, the NILIM also prepared drafts and provided the research results necessary for the development of the guidelines. Then, in March 2019, the inspection guidelines were revised for the second round of statutory inspections of tunnels and road bridges, and technical reference materials were enhanced.

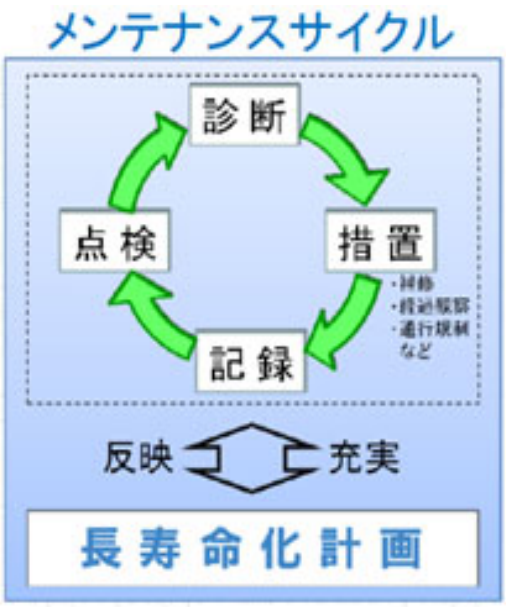

Figure 7 Maintenance Cycle Implementation

(2) Initiatives to Support Planned Longevity

① Establishment of guidelines for collecting basic data on road bridges

Asset management has also become a major pillar of subsequent research with research content even more extensive than in the past. In 2007, the MLIT began supporting the formulation of service life extension plans so that local governments could systematically repair road bridges. In order to formulate the plan, a method to promptly grasp the current status of managed road bridges was desired. Therefore, in the same year, NILIM presented a Draft Guideline for Collecting Basic Data on Road Bridges.[5]

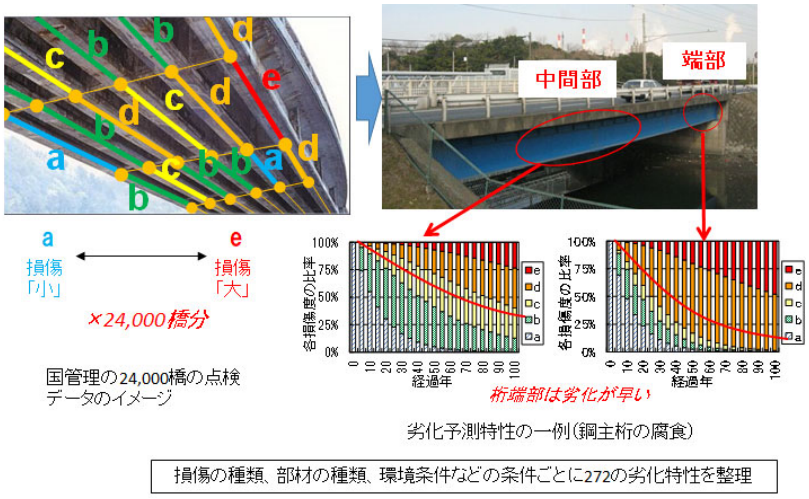

Figure 8: Example of analysis of degradation characteristics from inspection data

This was prepared because, while the safety and other aspects of individual bridges should be accurately managed, as the overall age of facilities increases, it is necessary to first obtain a minimum level of data on many bridges as quickly as possible in order to respond to the importance of developing management policies and plans for the overall facilities managed by each administrator and to promote the maintenance and management of the facilities as a whole. This technical document was prepared to respond to the importance of establishing management policies and plans for the entire facilities managed by each administrator and to promote maintenance and management. The data (degree of damage) collected in periodic inspections of road bridges on national highways under direct control from the viewpoint of upgrading management was utilized and analyzed, and it was found that it was possible to narrow down the items for which data was obtained etc. This was reflected in

the preparation of this document. It has been utilized by many road administrators and is still introduced in the appendix of the statutory inspection guidelines as a reference for collecting basic data for asset management in addition to statutory actions.

In the June 2014, notification of technical advice (periodic inspection guidelines) regarding the implementation of periodic inspections for tunnels, road bridges, sheds and large culverts, pedestrian crossing bridges, portal-type signs, etc., the company played a leading role in starting to accumulate objective information, including not only the diagnosis of the integrity of individual structures while considering their characteristics and the causes of damage but also the evaluation of damage levels as basic data for considering macro management measures etc. for structures nationwide.

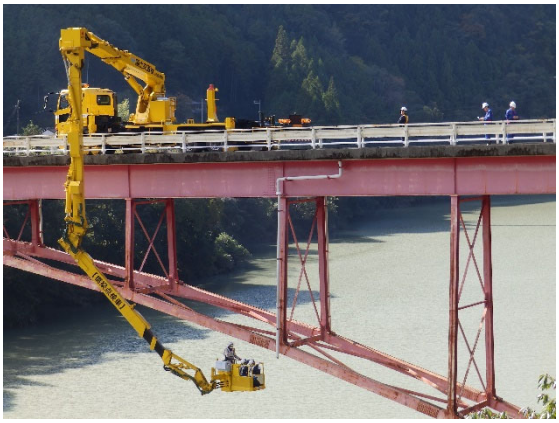

Figure 9: Diagnosis by the country

② Use of data to advance management for daily management, aging management, and disaster resilience

In developing the inspection procedures, NILIM provided knowledge based on the results of previous inspections and analysis of damage cases, and proposed drafts. In particular, in the development of inspection procedures for pavements, NILIM proposed the concept of efficient and effective inspections according to road classification and the reduction of early deteriorated sections by introducing a new concept of the *target service life* through an analysis of existing road surface condition survey data. In addition, we contributed to the publication of a technical book[6] that provides guidelines for establishing asset management of pavements based on the pavement inspection guideline, taking into account the results of studies on early deterioration mechanisms. In addition, for road bridges, we analyzed basic data on national highways under direct control that had been accumulated for more than 10 years, clarified statistical deterioration characteristics and created a collection of deterioration curves.[7]

On the other hand, in response to recent road disasters caused by heavy rains, there is growing demand for effective and efficient efforts to improve the performance of roads based on data from inspections and other sources in order to make them more disaster resistant, and discussions on risk assessment have begun in 2020 in the Road Technology Subcommittee of the MLIT.

(3) Human resource development and technical assistance to road managers

Periodic inspections and measures are judged from an engineering standpoint, reflecting the characteristics of individual structures and the causes of deformation, and it is feared that the formulation of a uniform decision flow may be dangerous and irrational. Therefore, it is necessary to combine various measures, such as training and qualification systems for the persons concerned to acquire appropriate technical skills, as well as to enhance the technical support system for road administrators, in order to properly implement these measures.

Therefore, in conjunction with the 2013 revision of the Road Law, the MLIT also began new attempts to provide training

for practitioners and direct diagnoses. For the training of practitioners, the Ministry has begun to provide training to acquire the minimum knowledge and skills required for the proper application of laws and regulations with a unified textbook and curriculum in cooperation with the local development bureaus and related organizations.

For road bridges, a test to confirm knowledge acquisition is now also being conducted. These series of efforts have shown that they can be referred to as examples of knowledge and skills required for periodic inspections in the current periodic inspection guidelines. The NILIM with advice from experts has also prepared official textbooks and published them as *Technical Note of NILIM* and continues to provide support to local development bureaus, which are responsible for conducting the training, by dispatching training instructors and preparing examination questions.[8]

The diagnosis by the road maintenance specialist team is a program to support local governments by providing technical advice on surveys and action policies for facilities that require urgent action and advanced technical capabilities upon request by the road maintenance specialist team consisting of staff from the Regional Development Bureau, NILIM, and PWRI. Since its inception in 2014, the program has provided continuous support every year. So far, a total of 16 structures have been covered for bridges, tunnels, and large sheds by FY 2020 (Table 1).

Table 1: List of Structures for which the Diagnosis by the Road Maintenance Specialist Team was Conducted

FY	Address	Bridge name	Contents of bridge
2014	Niyodogawa Town, Kochi Prefecture	Oodo Dam Bridge	Steel truss suspension bridge + simple composite plate girder bridge, bridge length: 444 m (year of construction: 1983)
2014	Mishima Town, Fukushima	Mishima Bridge	Steel arch bridge (trussed-ranger bridge), bridge length 131 m (year of construction: 1975)
2014	Tsumagoi Village, Gunma Prefecture	Oomae Bridge	Five-span simple RCT girder bridge, bridge length 73 m (year of construction: 1958)
2015	Karatsu City, Saga Prefecture	Yobuko Bridge	PC three-span continuous cable-stayed bridge + PC three-span and two-span continuous ramen box girder bridge, bridge length: 728 m (year of construction: 1989)
2015	Totsukawa Village, Nara Prefecture	Sarukai Bridge	Steel linger girder bridge + steel simple plate girder bridge, bridge length: 139 m (year of construction: 1974)
2015	Shimogo Town, Fukushima Prefecture	Numao Shed	Extension 189 m, width 5.0 m (year of construction: circa 1958)
2016	Yuzawa City, Akita Prefecture	Mangoku Bridge	Nine-span RCT gerber girder bridge, bridge length 171 m (year of construction: 1939)
2016	Kaminari-cho, Gunma Prefecture	Mikohoko Bridge	Five-span simple steel I-girder bridge, bridge length 46 m (year of construction: 1929)
2017	Kurobe City, Toyama Prefecture	Otozawa Bridge	Steel simple underpass truss bridge + steel simple composite plate girder bridge, bridge length 110 m (year of construction: 1971)
2017	Nakatsugawa City, Gifu Prefecture	Otohime Bridge	Two-span continuous truss bridge (upper road type) + simple steel curved box girder bridge, bridge length 317 m (year of construction: 1996)
2018	Satsumasendai City, Kagoshima Prefecture	Tentai Bridge	PC continuous posten box girder bridge + pletten hollow slab bridge + pletten T-girder bridge + posten T-girder bridge, bridge length 518 m (year of construction: 1984)
2018	Kure City, Hiroshima Prefecture	Nigatazuidou	Length: 262 m, width: 5.5 m (year of construction: 1938)
2019	Yoshida Town, Shizuoka Prefecture	Furukawa Bridge Chichibu Bridge	Three-span simple non-composite H-girder bridge, 55 m long (constructed in 1969)
2019	Chichibu City, Saitama Prefecture	Chichibu Bridge	Three-span continuous RC open arch bridge, 135 m in length (constructed in 1931)
2020	Shiraoi Town, Hokkaido	Shiraoi Bridge	Three-span continuous RC double-girder bridge + simple PC slab bridge, bridge length: 148 m (year of construction: 1953)
2020	Nara City, Nara Prefecture	Tsurumai Bridge	Eleven-span simple PC pretensioned slab bridge, bridge length: 98 m (year of construction: 1960)

3. List of related reports and technical documents

1) Website of Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism
https://www.mlit.go.jp/road/sisaku/yobohozen/yobohozen.html
2) Reference for periodic inspections on the highway bridges -Photographs of bridge damage-, *Technical Note of NILIM* No. 196, 2004.
http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0196.htm
3) Survey on Deterioration and Damage of Road Attachment Facilities, *Technical Note of NILIM* No. 685,2012.
http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0685.htm
4) Material Collection of the Committee for Investigation and Review of Accidental Falling of Tunnel Ceiling Plates, 2013.
https://www.mlit.go.jp/road/ir/ir-council/tunnel/index.html
5) Study on the basic survey of a highway bridge conditions -Basic data collection manual of a highway bridge conditions (draft)-, *Technical Note of NILIM* No. 381, 2007.
http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0381.htm
6) Japan Highway Association, Pavement Management Guideline based on Pavement Inspection Procedure, 2018.
7) Research on partial repainting for steel bridges -Partial repainting manual for steel bridges (draft)- *Technical Note of NILIM* No. 684, 2012.
http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0684.htm
Statistical data on the deterioration of road bridges based on the segmental damage extent recordings in bridge inspections, *Technical Note of NILIM* No. 985, 2017. http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0985.htm
Research on Reliability Improvement of Road Bridge Durability, *Technical Note of NILIM* No. 1121, 2020.
http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn1121.htm
8) Basic Textbook for Bridge Inspection, 2014 *Technical Note of NILIM* No. 829, 2015.
http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0829.htm

4. Future Initiatives and Outlook

Future Efforts and Prospects to improve the disaster resistance of roads and to increase the reliability and efficiency of inspection and management through advanced use of data, a developmental renewal of the current standards system and road management practice system with periodic inspection procedures as its core will be required. To this end, it is necessary to create a unified and quantitative reliability evaluation system that covers design, inspection/diagnosis, measures, and records in a single step, and a major research theme will be the utilization of various data in connection with a reliability evaluation.

As the MLIT began full-scale efforts to address aging roads, the Road Structures Department was established in April 2014 to formulate technical standards for the maintenance and management of road structures, analyze the results, and strengthen the system for providing technical support to road managers. In developing technical standards, NILIM has analyzed the results of periodic inspections nationwide and basic data collected on structures on national highways under direct control to provide knowledge for improving the reliability of periodic inspections and reducing the amount of labor required. This is an important role that NILIM will continue to play in the future.

On the other hand, in order to coordinate and efficiently implement management of aging and disaster resistance in addition to periodic diagnosis of soundness, efficient and effective acquisition of daily data and analysis and management of data using digital transformation are indispensable. NILIM has initiated research to establish a road structure management system that can utilize a variety of data and other information for reliability assessment, and to introduce a system for performance specification of technical standards for design, construction, etc. of structures and reliability assessment into management of safety and durability of existing structures as well as risk management.