Standard maintenance manual for short-span bridges managed by municipalities in the Hokuriku region (draft)

2022 December

1 General

1.1 Objective

This manual aims to contribute to the rationalization of road bridge maintenance and management in municipalities in the Hokuriku region and provides standard procedures and methods that can be used as references in a series of inspections, judgements, repairs, and renewals. It is desirable for municipalities to modify and utilize them to suit their actual circumstances, based on their individual natural and social environments.

[Commentary]

The Hokuriku region covered by this manual comprises four prefectures, as shown in Fig.1. Plenty of deicer is sprayed on highways during winter. In coastal areas, many chloride ions are blown by seasonal wind. Therefore, road bridges are prone to chloride attack. Furthermore, the alkali-silica reaction (hereinafter referred to as ASR), which is mainly caused by andesite, is occasionally observed. Some bridges have deteriorated in combination. These phenomena reduce the performance of road bridges at an early stage, which is faster than the progress of aging deterioration on a national average. Therefore, there is a demand for proposals for maintenance and management procedures and methods that respond to early deterioration in the Hokuriku region, which is different from the uniform road bridge management system that looks at the entire country from a macro perspective.

Fig.1 Regions covered by this manual

Based on this, from 2014 to 2022, "the Cross-ministerial Strategic Innovation Promotion Program (SIP)", Hokuriku Regional Development Association, and Japan Society of Civil Engineers for subsidized research have been implemented. Collaborating with industry, government, and academia, universities and technical colleges, as shown in Table 1, promoted the elucidation of the early deterioration mechanism of concrete bridges and the development of a management system that considers the performance related to material and structures.

Table 1 Participating Universities and Technical Colleges

Prefecture	Universities and Technical Colleges
Niigata	Nagaoka University of Technology (NUT), National Institute of Technology, Nagaoka College (NITNC)
Toyama	Toyama Prefectural University (TPU), University of Toyama (UT)
Ishikawa	Kanazawa University (KU), Kanazawa Institute of Technology (KIT), National Institute of Technology, Ishikawa College (NITIC)
Fukui	University of Fukui (UF), National Institute of Technology, Fukui College (NITFC)

The procedures and methods described in this manual are the results of these activities. In particular, from 2017 onwards, the professors listed in Table 2 visited the municipalities at Toyama prefecture, Ishikawa prefecture, Fukui prefecture, and the Jyouetsu area in the Niigata prefecture, shown in Table 3, and conduct interview surveys. Also they exchanged opinions with the Center for Structural Maintenance Research (CAESAR) at the Public Works Research Institute who is a national research corporations, and Japan Construction Consultants Association Hokuriku Branch. As shown in Fig. 2, the municipalities visited accounted for 94% of each prefecture. By doing so, we attempted to match the academic proposals of experts with the actual maintenance situation and management of road bridges in municipalities. As shown in Table 4, it became clear that many municipalities have common issues, and this manual describes standards based on these needs. However, the natural and social environments differ between individual municipalities, such as sea-side or inland locations and many or few bridges. Therefore, it is desirable to modify this standard procedure and method according to the actual situation in each municipality.

Table 2 Interviewing professors for municipalities

Name	Affiliation	Name	Affiliation
Ito Hajime	TPU	Tsuda Makoto	NITIC
Ibayashi Kou	NITNC	Terayama Kazuki	NITIC
Uchida Shinya	TPU	Hanaoka Daishin	KIT
Kubo Yoshimori	KU	Fukada Saiji	KU
Kurihashi Yusuke	KU	Maeda Kenji	NITIC
Kouno Tetsuya	UT	Miyazato Shinichi	KIT
Suzuki Keigo	UF	Miyashita Takeshi	NUT
Tachibana Junzo	TPU	Yanagida Ryohei	KU
Tanaka Yasushi	KIT	Minowa Keisuke	NITFC

Table 3 Interviewed municipalities

Prefecture	Municipality	Population	Area (km^2)	No. of bridges	Location
Niigata (Jyouetsu)	Joetsu C.	193,039	973.8	1,146	Sea-side
	Itoigawa C.	43,897	746.2	525	Sea-side
Toyama	Toyama C.	417,760	1,241.7	2,222	Sea-side
	Himi C.	48,671	230.6	360	Sea-side
	Asahi T.	11,936	227.4	122	Sea-side
	Takaoka C.	172,535	209.6	1,200	Sea-side
	Imizu C.	93,289	109.4	492	Sea-side
	Nanto C.	51,171	668.6	923	Inland
	Oyabe C.	30,162	134.1	449	Inland
	Nyuzen T.	24,894	71.6	450	Sea-side
	Uozu C.	40,253	200.6	239	Sea-side
	Namerikawa C.	33,023	54.6	293	Sea-side
	Kamiichi T.	19,429	236.7	199	Inland
	Tateyama T.	25,021	307.3	312	Inland
	Tonami C.	47,462	127.0	608	Inland
Ishikawa	Kanazawa C.	466,183	468.6	1,388	Sea-side
	Kahoku C.	34,293	64.4	90	Sea-side
	Wajima C.	26,312	426.3	446	Sea-side
	Nomi C.	48,934	84.1	252	Sea-side
	Hakusan C.	109,581	754.9	369	Sea-side
	Uchinada T.	26,943	20.3	7	Sea-side
	Hodatsushimizu T.	12,805	111.5	132	Sea-side
	Nonoichi C.	55,297	13.5	220	Inland
	Komatsu C.	106,905	371.0	473	Sea-side
	Tsubata T.	37,618	110.6	174	Inland
	Suzu C.	14,574	246.9	171	Sea-side
	Kaga C.	67,357	305.9	356	Sea-side

Table 3 Interviewed municipalities (Cont.)

Prefecture	Municipality	Population	Area (km^2)	No. of bridges	Location
Ishikawa	Nakanoto T.	18,102	89.5	244	Inland
	Noto T.	15,810	273.3	303	Sea-side
	Anamizu T.	7,623	183.2	92	Sea-side
	Nanao C.	49,645	318.3	455	Sea-side
	Shika T.	18,945	246.8	274	Sea-side
	Hakui C.	20,311	81.9	166	Sea-side
	Kawakita T.	6,144	14.6	36	Inland
Fukui	Fukui C.	264,344	536.4	1,771	Sea-side
	Echizen T.	21,021	153.2	225	Sea-side
	Sabae C.	68,397	84.6	399	Inland
	Obama C.	29,534	233.1	402	Sea-side
	Katsuyama C.	23,392	253.9	349	Inland
	Echizen C.	83,184	230.7	675	Inland
	Tsuruga C.	66,060	251.4	307	Sea-side
	Ikeda T.	2,604	194.7	99	Inland
	Mihama T.	9,609	152.4	130	Sea-side
	Sakai C.	89,648	209.7	599	Sea-side
	Eiheiji T.	18,105	94.4	162	Inland
	Ono C.	31,258	872.4	444	Inland
	Minamiechizen T.	9,960	343.7	268	Sea-side
	Ohi T.	8,007	212.2	329	Sea-side
	Wakasa T.	13,908	178.7	472	Sea-side
	Awara C.	29,933	117.0	135	Sea-side
	Takahama T.	9,865	72.4	139	Sea-side

(At the time of interview)

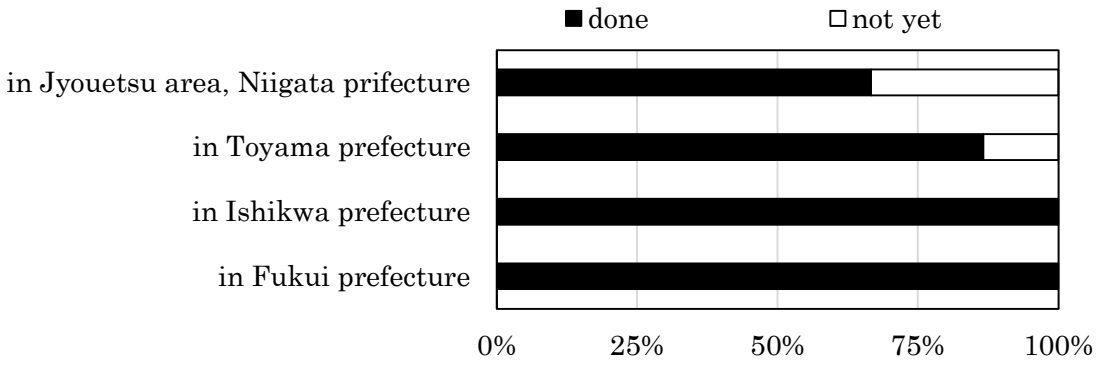

Fig. 2 Percentage of interviewed municipalities

Table 4 Common issues identified in interviews

Cause	No	Issue	%※	Section
Human resources	①	It is difficult to develop human resources in the workplace through on-the-job training (OJT) because there are few staff who are familiar with bridges, staff cannot concentrate on bridge maintenance, and they change every two or three years.	100	6
Support	②	Few opportunities to obtain information on the latest technology.	100	6
Budget	③	Even corrective maintenance is a problem, and a shift to preventive maintenance cannot be planned.	100	3
Deterio-ration	④	Deterioration due to chloride attack and ASR is progressing.	80	2
	⑤	Initial defect has existed and it makes deterioration progressing.	90	2
Inspection	⑥	For bridges that are easy to inspect, staff who are not confident in their technical capabilities want to inspect them without using machines.	80	4
	⑦	A series of inspection, judgment, and repair manual is desired.	100	3
Repair	⑧	Appropriate repair methods and their effects are unknown.	100	5
	⑨	The life of the bridge is extended without repairing, as much as possible, and if the safety and usability of the bridge cannot be satisfied, it will be renewed.	100	5

※ Percentage of issued municipalities out of all municipalities interviewed

This manual was arranged for the Hokuriku Region. However, streamlining the maintenance and management of road bridges in municipalities is a nationwide issue[1)], and we believe that this will serve as a reference for other regions as well.

1.2 Term definition

This manual defines terms as follows:

Short-span bridge: A bridge with a length of 2 m or more and less than 5 m. Includes culvert boxes and slab bridges with overburdens of less than 1 m.

Corrective maintenance: Although there is no problem with the function of the structure, early measures should be taken to delay the progress of deterioration.

Preventive maintenance: There is a possibility that the function of the structure will be hindered, and measures should be taken.

[Commentary]

Regarding short-span bridges, the Hokuriku region has a lot of irrigation water for agriculture, and there are many bridges of less than 5 m across it. In addition, in inspections by some municipalities, bridges with a length of less than 6 m were classified as bridges with short spans. In such cases, bridges with a length of less than 6 m may be considered short-span bridges if there is no problem in practical use.

Regarding corrective and preventive maintenance, consider a relatable situation to explain the concept; the medical act of going to the dentist after having a decayed tooth corresponds to corrective maintenance. In contrast, daily tooth brushing corresponds to preventive maintenance. Corrective maintenance involves pain for humans, and in the case of road bridges, the risk of collapse. In general, corrective maintenance requires a temporarily high treatment cost, whereas preventive maintenance flattens the treatment cost and can be reduced.

2 Application target

The procedures and methods described in this manual are applicable to short-span bridges managed by municipalities in the Hokuriku region, which are not emergency transportation roads or the overpasses of roads and railways, have no significant initial defects, and have low traffic volumes.

[Commentary]

According to the pavement inspection guidelines of the Road Bureau of the Ministry of Land, Infrastructure, Transport, and Tourism, as shown in Fig. 3, roads are classified into four categories according to their characteristics. Based on this, road bridges were classified into four groups, as listed in Table 5. Group C was the target for applying this manual. That is, it is a short bridge that does not overpass emergency transit roads, roads, or railroads, and has low traffic (e.g., less than 1000 vehicles/day). In addition, initial defects, such as insufficient cover, as shown in Fig. 4, lead to spalling of the superstructure concrete because the preconditions for the design are not ensured. Therefore, it cannot be said that the simple procedures and methods shown in this manual will ensure the safety of bridges with significant initial defects, even for a community road, hence, they are excluded from the application target.

In the Hokuriku region, some road bridges have ASR, as shown in Figs. 5 and 6. In addition, as shown in Fig. 7, after repairing the chloride attack, some parts deteriorated again because of macrocell corrosion. These are subject to application.

In addition, all construction years were covered. In other words, it has been

pointed out that the floor slabs before 1979 were thinner than the current standards, and that they could easily fall off due to fatigue, but the traffic volume of large vehicles on municipal roads in the Hokuriku region was small. In addition, in 1986, the Ministry of Construction issued a "temporary countermeasure against alkali-aggregate reactions" but in the Hokuriku region, ASR has progressed in some buildings even after that. Therefore, there is no particular classification by construction year.

Characteristic	Classification	Main road (image)
High-standard arterial roads (roads with high service standards that require high-speed driving)	A	Highway
Rapidly damaged roads (e.g. roads with a lot of heavy vehicle traffic)	B	Directly managed national road; Auxiliary national road, Prefectural road; General roads in ordinance-designated city
Slowly damaged roads (e.g. roads with little heavy vehicle traffic)	C	
Community road (Damage progresses extremely slowly, long life if there is no impact of occupation construction)	D	Municipal road

Note: The selection of roads for each classification was determined by each road administrator. (This is simply an image. For example, even if it is a municipal road, it is acceptable to classify it as Category B at the discretion of the road administrator.)

Fig. 3 Image of road classification indicated in pavement inspection procedure

Table 5 Classification of road bridge maintenance (draft)

Group	Subject
A	Emergency transport road bridges, Overpasses, Bridges with a length of 15 m or more
B	Other than the above, for example, bridges with a length of 5 to 15 m
C	Other than the above, for example, bridges with a length of less than 5 m and less traffic
D	Bridges with short design life and low traffic volume, Bridges in depopulated areas that may be removed in the future

Fig. 4 Short-span bridges where superstructure concrete has fallen due to initial defect

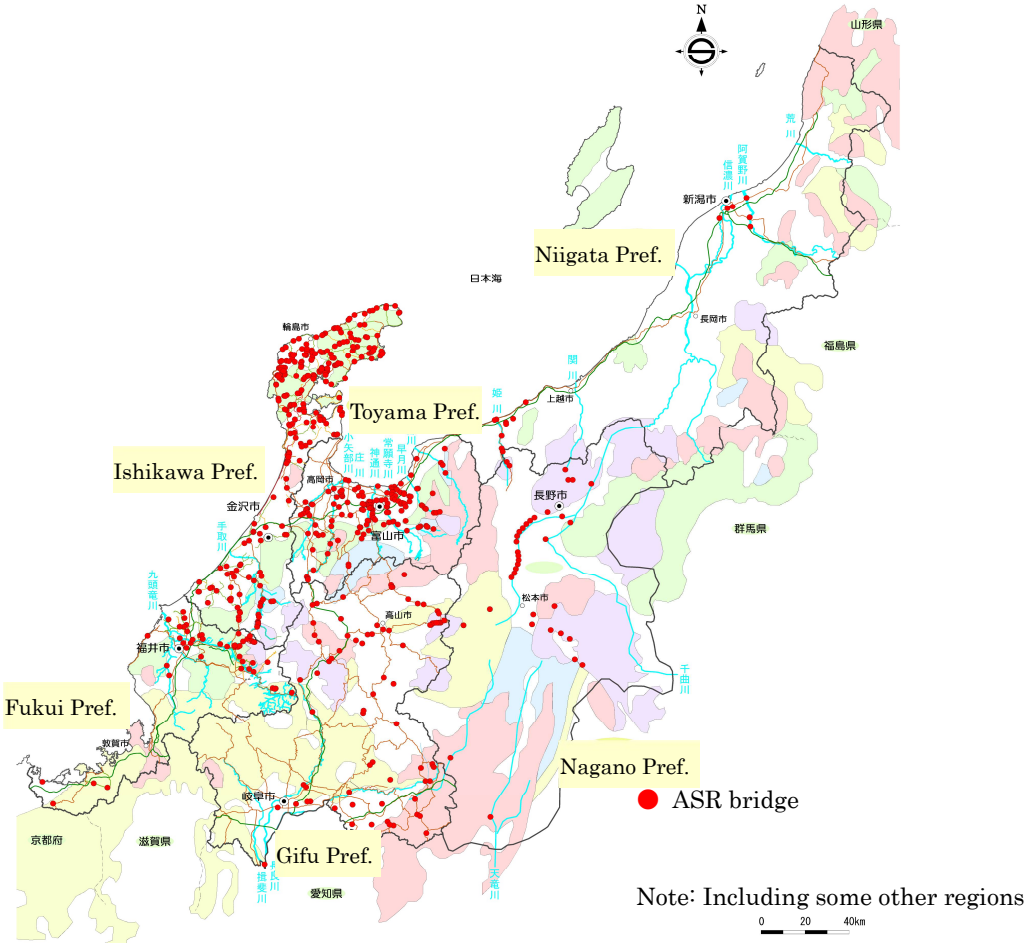

Fig. 5 Map of bridges where ASR occurred

Fig. 6 Example of a bridge deteriorated by ASR

Fig. 7 Example of re-deterioration due to macrocell corrosion after patch repair

It is desirable to maintain and manage long bridges and important bridges that are not applicable, using the same procedures and methods as national roads, expressways, and prefectural roads. If you want to identify the cause of deterioration, you can refer to the "Concrete Crack Investigation, Repair, and Reinforcement Guidelines -2022-" published by the Japan Concrete Institute. Furthermore, regarding the maintenance and management of bridges that are clearly degraded by salt damage and ASR, please refer to the CAESAR web page shown in Table 6; the "Chloride attacked bridge maintenance manual (draft)" of the Hokuriku Regional Development Bureau and "Guidelines for Repair and Reinforcement of Bridge Piers and Abutments of Road Bridges Degraded by Alkali-Aggregate Reaction (Draft)" by the Kinki Regional Development Bureau of the Ministry of Land, Infrastructure, Transport, and Tourism are helpful.

Table 6 Web page by CAESAR

Inspection	https://www.pwri.go.jp/caesar/technical-information/manual/check-and-research.html
Repair	https://www.pwri.go.jp/caesar/technical-information/manual/operation-and-maintenance.html

3 Maintenance procedures

The standard maintenance procedure for the superstructure and substructure of a concrete bridge is the flow of inspection, judgement, repair, and replacement shown in Fig. 8 and Table 7.

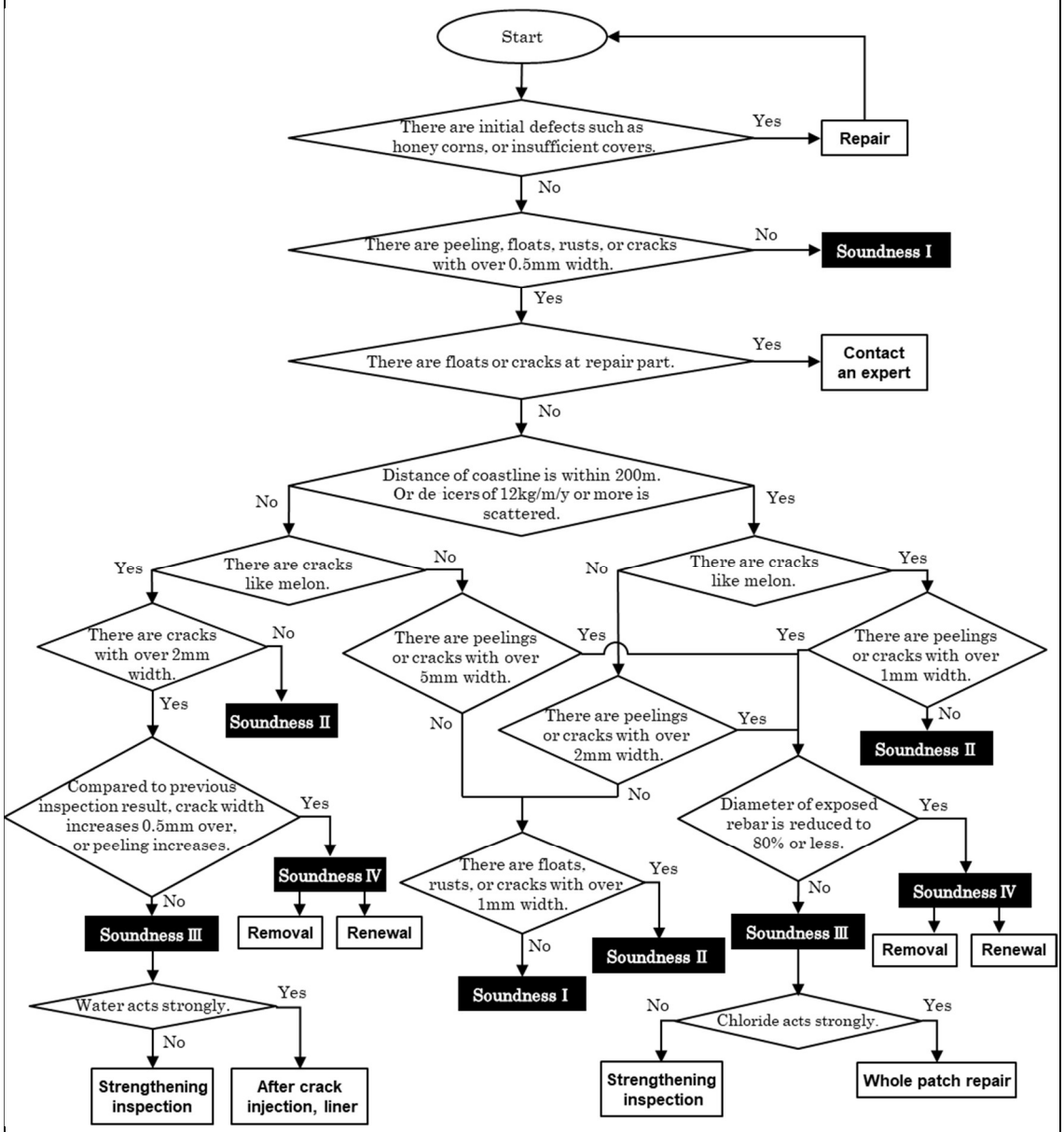

Fig.8 Standard maintenance flow for concrete bridge superstructure and substructure

Table 7 Classification of soundness[2)]

I	II	III	IV
Soundness	Preventive maintenance phase	Early action phase	Emergency phase

[Commentary]

According to the report by a subcommittee about "Maintenance Priority Research for Concrete Structures" in the Japan Society of Civil Engineers, if the level of maintenance and management is not set as high as for short-span bridges managed by municipalities in the Hokuriku region, and if third-party effects can be ignored because they cross agricultural irrigation water, the life cycle cost is the lowest in the scenario of decommissioning after usage to the limit of load-bearing capacity. In other words, it is most economical to avoid a strategy-less repair scenario. Therefore, in this flow, preventive maintenance is not performed, and corrective maintenance is performed only when repair effects can be expected. That is, for chloride attack, repairs are performed when there is no significant decrease in the yield strength, that is, when the weight loss of the reinforcing bars is small. In addition, the ASR is repaired when the progress rate of deterioration is slow, that is, when the increase in the crack width is small. In particular, according to Fig. 9, 80% of the cases in which the progress of ASR deterioration is stopped have minor cracks. Therefore, even if there is a possibility of an ASR, it is not necessary to judge the necessity of repair by just one inspection, but rather by the comparison with the previous inspection (here, a visual inspection five years ago is assumed). It was decided to remove an abandoned bridge or replace it only if the crack width was increased by 0.5 mm or more. If the crack width of the ASR is already large and in progress, it will be cheaper to replace the short-span bridge because repair will not slow the deterioration progress.

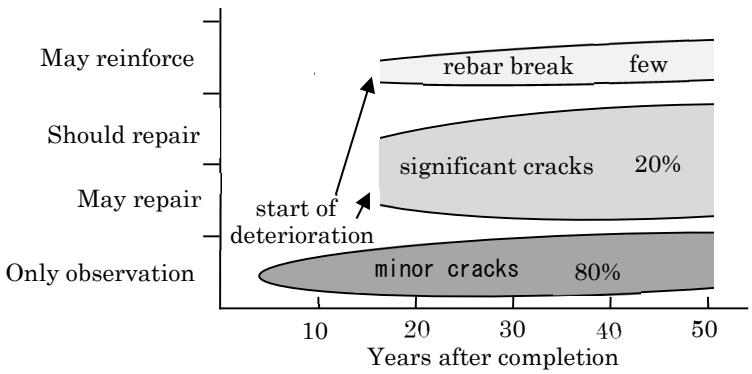

Fig.9 Degradation progress image of a concrete structure with ASR[3)]

The items to be inspected in this flow are the width and shape of the cracks, spalling, floating, and rust liquid. Here, cracks like melon, are the main feature of ASR deterioration and can be determined by non-experts without special equipment. In addition, in high-strength pretensioned PC girders, even if cracks due to corrosion do not

occur, rust juice may be generated, and the steel may break[4]. Therefore, not only the presence of cracks but also the presence of floats and rust juice should be considered.

Even in the Hokuriku region, where airborne chloride ions are high, according to PWRI data No. 3175 "National survey of airborne chloride (IV)" p.27, if the distance from the coastline exceeds 300 m for more than 100 years, it is estimated that the rebar will not corrode. Subsequently, according to the National Research Institute Material No. 55 "Chloride attack countermeasures for concrete bridges" p.60, it is estimated that if the distance from the coastline exceeds 700 m, the reinforcing bars will not corrode. Therefore, if maintenance is to be performed at a level that does not allow the corrosion of reinforcing bars, it is desirable to classify the effects of a chloride attack using a threshold of 700 m from the coastline. However, short-span bridges managed by municipalities should be maintained at a level that prevents collapse while allowing the corrosion of reinforcing bars. Here, the closer the coastline, the more the deterioration progresses[5], and it has been pointed out that repair is necessary as soon as the deterioration becomes apparent, especially within 200 m[6]. Therefore, this flow classifies the influence of chloride attacks at a threshold of 200 m from the shoreline.

In the Hokuriku region, anti-freezing agents are rarely sprayed onto municipal roads. However, chloride ions attached to vehicles on highways and national roads may affect the nearby municipal roads. Figure 10 shows the relationship between the amount of de-icer sprayed and the surface chloride ion concentration on the highway under the Central Nippon Expressway. In addition, for the above-mentioned coastal chloride attack, the threshold may be 200 m from the coastline. According to the Japan Society of Civil

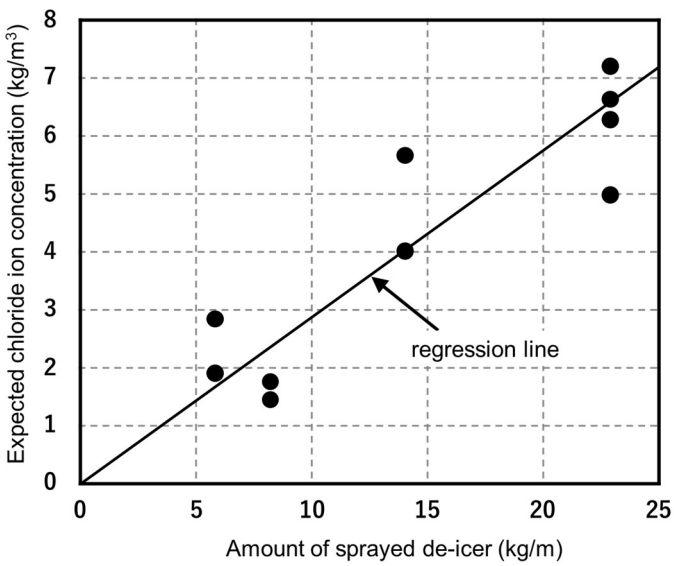

Fig.10 Relation between de-icer amount and surface chloride ion concentration[7]

Engineers 2018 Concrete Standard Specifications [Maintenance] p.143, the surface chloride ion content is equivalent to 3.0 – 4.5 kg/m^3. Therefore, when these two values were compared, the amount of the de-icer applied was equivalent to 11 – 17 kg/m/y. Therefore, the threshold for this flow classifies the effects of the chloride attack at a de-icer application rate of 12 kg/m/y.

It is thought that the cracks and floats in the repaired part were caused by re-deterioration. In this case, it is necessary to clarify which of the repair period, repair material, repair area, amongst others had an adverse effect and it will used to take measures against similar situations in the future. Therefore, inquiries were made to experts in the Hokuriku region, such as university and technical college teachers, and concrete consultants, as shown in Table 2.

The advantage of using this flow for municipalities is that 1) it is possible to select a measurement method without specifying the deterioration factor, 2) the basic inspection objects are only crack width, peeling, rust juice, float, and more, and 3) it can deal with corrective maintenance, which is an upcoming issue. In particular, for 3), ③ in Table 4 was considered. Regarding 1), if the inspector makes effective repairs immediately after inspection using temporary scaffolding, maintenance can be rationalized without ordering the individual design and its repair again. Thus, ⑦ can be solved in Table 4.

Here, priority is given to superstructures and substructures, which are the main members that affect the performance of road bridges, rather than to balustrades, ground guards, expansion devices, and bearings. In addition, according to the above-mentioned National Research Institute Material No. 55 "Chloride attack countermeasures for concrete bridges" p.75, the degree of damage to the superstructure and substructure tends to be the same. Therefore, a standard maintenance flow was formulated without distinguishing between the superstructure and the substructure.

In addition, many road bridges managed by municipalities in the Hokuriku region are made of concrete, with a few steel bridges. Therefore, this manual covers the procedures for the inspection, judgement, repair, and replacement of concrete bridges. For the flow of maintenance and management of steel bridges, refer to the "Steel structure series 18, Durability verification manual for corroded steel structures" edited by the Japan Society of Civil Engineers, Steel structures committee, Subcommittee about steel structures residual load-bearing performance evaluation and durability

Supplement: De-icer based on sodium chloride, potassium acetate, sodium acetate, potassium formate and sodium formate promote ASR. Therefore, they should not be used in the Hokuriku region.

improvement policy research" and more. will be helpful. According to this, for example, if the amount of the deicer sprayed is 1 kg/m^2/year or less, the effect on weathering steel girders is small. It is also known that weathering steel girders can be used in coastal areas where the amount of airborne chloride ions is 0.05 mdd or less. Referring to this information and the flow in Fig. 8, it is desirable to formulate procedures for inspections, evaluation judgments, repairs, and renewals specific to steel bridges. The methods described in the following sections can also be applied to steel bridges:

4 Inspection method

(1) If the soundness of the previous periodical inspection was I or II, it may be inspected with a simple method such as using a tablet or a simple check sheet.
(2) If the previous periodical inspection showed that the soundness was III and close visual inspection is possible without the need for a special scaffolding, it is desirable to have an inspection by an expert such as a consultant. In some cases, Comprehensive ordering may reduce outsourcing costs.
(3) In some cases, new technologies such as monitoring and AI can support inspections.

[Commentary]

Regarding (1), based on ⑥ in Table 4, if there is little risk of a bridge collapse, we recommend inspection by a simple method. Here, for some bridges managed not only by the Niigata City, Itoigawa City, Sanjo City, Tonami City, Shunan City, and Kyrgyzstan, Cambodia, inspections using tablets[8), 9), 10)] have been put into practical use, and the rational effect has been confirmed.

In addition, for some bridges managed by Kaga City, inspection using a simple sheet with limited items was implemented, and the effect of rationalization was confirmed.

(2) If the soundness of the previous periodic inspection is III, an expert should inspect with conventional close-up visual inspection to evaluate the possibility of collapse within five years. However, robotic technology, including drones and high-performance cameras, have been developed to obtain results equivalent to close-up visual inspections, including the SIP[11)] results.

In addition, although they are extremely rare in short bridge bridges, they may be inspected using temporary scaffolding, bridge inspection cars, or rope access. Inspection using a robot if the same or more accurate results can be obtained, is able to apply for the entire or part of these bridges. Alternatively, it is possible to combine

inspection using a robot and close-view inspection. It is expected that the degrees of freedom for the selection of the inspection time, reduction of inspection costs, and inspection time can be reduced.

(3) Even after 2018, at the end of the first SIP activities, new technologies have been developed for the inspection of road bridges. This includes the technology and methods that contribute to cost and operational reduction. For example, the Japan Society of Civil Engineering, Infrastructure Maintenance Committee, Subcommittee about New Technology Applicable Promotion published "Guidelines for Utilization of Monitoring Technology (Draft)" in July 2022, which provide effective use of monitoring technology in various situations. In addition, uploading photos of damage taken with smartphones and digital cameras and uploading simple information to the cloud determines the deterioration of AI immediately and distinguishes the healthy parts and deterioration parts such as chloride attacks, ASR, and freeze-thaw damage. Simultaneously, the system automatically outputs the inspection results to a chart. This reduces the variation in the results and reduces the maximum of 35% owing to labor savings. Furthermore, the Ministry of Land, Infrastructure, Transport, and Tourism presented the "Inspection Support Technology Catalog" and lists the performance confirmation sheets of image measurement technology, non-destructive inspection technology, measurement/monitoring technology, and data collection and communication technology.

5 Measure method

(1) When the soundness is III, if the inspection is enhanced without repairing, the visual inspection is performed within 5 years.

(2) When a concrete bridge has de-iciers or airborne chlorides, and its soundness was III, the whole surface of cracks, peeling, floating, and rust juice have been measured with a patch repair. The repair material and its area must be recorded.

(3) Under the environment without de-icers and airborne chlorides, the concrete bridge with a soundness of III has cracks like melon without growing, cracks are obstructed by the resin injection, to prevent the penetration of substances that induce corrosion into the internal rebar, and a silane type surface penetrant is applied. The repair material and its area must be recorded.

(4) When the concrete bridge with soundness of IV is updated, highly durable material should be used.

[Commentary]

Regarding (1), inspection strengthening is one such measure. Here, inspection enhancement increases the frequency of inspection or improves inspection accuracy[12]. In a short bridge, increasing inspection frequency is less expensive than improving inspection accuracy. In addition, installing a board on a road bridge, saying, "Please contact the city hall or town hall if you notice a variable," is also effective on busy roads.

In a severe environment, the cause of the soundness of III is likely to be exposure to the same harsh environment after repair, and the deterioration may progress. In addition, if the reason for the soundness of III is low-quality material, it is likely that the deterioration of the existing members will progress even after repair. In these cases, repairs are repeated every few years, and the cost is higher. Therefore, from a life cycle cost viewpoint, it is reasonable to update or remove when the soundness is IV, after continuing to use as much as possible without any repair.

(2) In a short-span a concrete bridge with rebar corrosion, regardless of cracking, peeling, floating, or rust juice, high-concentration chloride ions over the threshold value are often permeated on the entire surface of the member. As a result, it has been confirmed that the rebars will be corroded in other concrete when only the concrete in the place of remarkable corrosion is removed. Therefore, all members must be repaired.

In addition, even JR (Japan Railway Company) and NEXCO (Nippon Expressway Company), which are advanced in repairing, are continuously scrutinizing repair methods that are definitely effective. Therefore, it is important for municipalities to accumulate repair data including test construction. Based on the ⑧ of Table 4, the road bridge managed by municipalities in the Hokuriku region has been tested for short time, low cost, and simple repair works since 2019. The condition is to operate during the cold season, which is the non-agricultural season from November to March. In addition, it is also necessary to maintain the repair effect for at least five years. The final result will be revealed after 2024, but intermediate evaluation results will be helpful.

(3) Organic or inorganic injection methods can close ASR cracks. In addition, it has been reported that a silane type surface penetrant method can suppress water absorption for cracks with a width of 0.6 mm or less[13]. Furthermore, based on (8) in Table 4, similar to (2), road bridges managed by municipalities in the Hokuriku region were repaired in a short-term, low-cost, and simple trial. This study investigates the repair effects of the "crack injection method" and the "patch method for peeled areas", and the intermediate evaluation results will be helpful. It is also important to accumulate the repair data.

(4) High-quality and stable fly ash was distributed in the Hokuriku region. There is also a manual (http://www.rikuden.co.jp/ash/attach/14040301.pdf) for a mixture proportion design, manufacture, and construction of concrete mixed with concrete. It has been

clarified that the use of this fly ash can reduce the progress of chloride attack and ASR [for example 14), 15)], and can also reduce temperature cracks [16), 17)]. Practical applications are progressing in the Niigata Prefecture, Toyama Prefecture, Ishikawa Prefecture, and Fukui Prefecture, including the extension work of the Hokuriku Shinkansen. Therefore, in order to extend the service life of bridges that are subject to similar environmental effects after renewal, and to develop green infrastructure, it is recommended to use concrete with fly ash from 15% to 20% in cement.

As shown in Fig. 4, road bridges with significant initial defects exhibit extremely low durability. Therefore, during renewal, the structure must be constructed without defects. Therefore, it is desirable to use precast products, which generally reduce total construction costs, including material, construction, and traffic regulatory costs.

Furthermore, if the costs required for future maintenance of the bridge greatly exceed the convenience of the zone, it is desirable to consider excluding (removing) from the viewpoint of management. If the safety and usability of the bridge have already deteriorated, it would be better to prohibit the use of the bridge for a certain period of time and determine whether it should be removed (abandoned) based on the detour status of users.

6 Operation of manual

This manual will be improved by collaboration between professors of universities and technical colleges and staff of municipalities, and if necessary, professional engineers, concrete diagnosiser, centers in each prefecture, etc. in the Hokuriku region.

[Commentary]

Based on Table 4, Fig.11 shows the measures used to solve the issues faced by municipalities. In other words, it is necessary to continue "1) a system for providing technical information" and "2) a system for proceeding with rational maintenance". Here, the Ministry of Land, Infrastructure, Transport and Tourism, NEXCO, JR, prefectures, and more, set up a committee that included experts. In addition, the flow of inspection, judgement, and repair for structures such as highways, shinkansen, and harbors has been prepared as a manual. This is useful for (2). However, as shown in Table 8, the situation differs depending on the organization that manages road bridges. Therefore, it is difficult to transfer maintenance procedures and methods to national roads and highways for the maintenance of municipal roads.

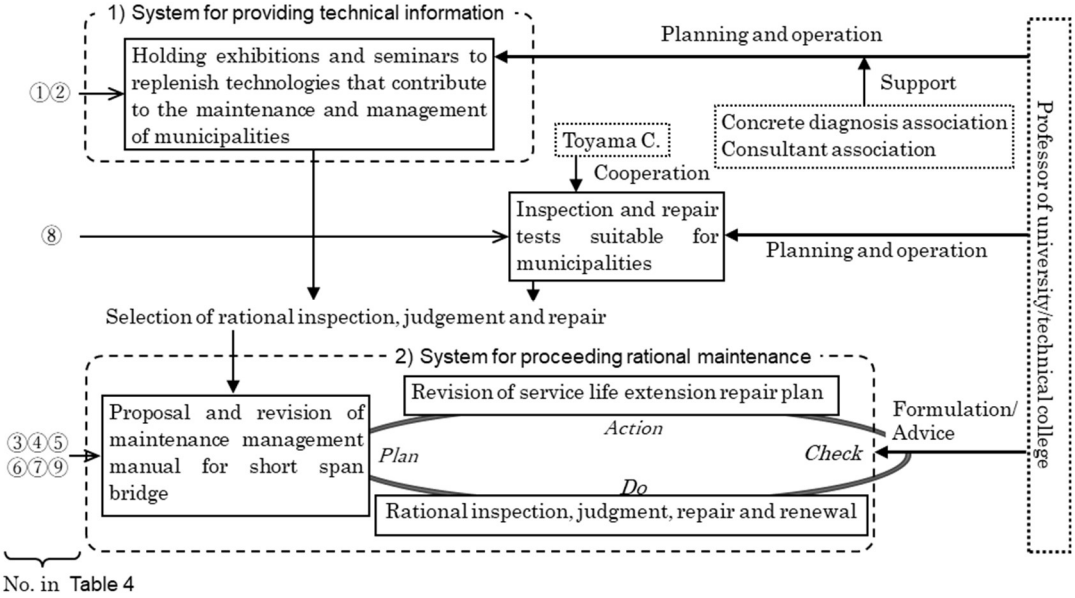

Fig. 11 Mechanisms for resolving municipal road issues

Table 8 Comparison of road bridge managers

Item	National road	Highway	Prefectural road	Municipality road
Staff	Many		⇔	Little
Bridge length	Long		⇔	Short
Budged	Ritch		⇔	Poor
Related organization	Public Works Research Institute	NEXCO Research Institute	Center, Public corporation	-

In addition, the inspection, judgment, and repair/renewal flow shown in Fig. 8 should be improved during the operation. Therefore, while going through the PDCA cycle shown in Fig. 11, it is desirable to update the standard version and customize it based on the natural and social environment of each municipality.

References

1) Nakamura Hitoshi, Taniguchi Nozomu, Onishi Hiroshi, Syo Sei, Saito Michio: Current situation analysis of road bridge maintenance based on questionnaire survey of local governments, Proceedings of Construction Steel, Vol.25, pp.566-570, 2017.

2) Road Bureau in Ministry of Land, Infrastructure, Transport and Tourism: Road bridge periodic inspection procedure, 2019.

3) Kawano Hirotaka: Study about deterioration progress and maintenance management of concrete structures with alkali-aggregate reaction, Doctoral thesis, Kyoto University, 2005.
4) Aasakura Keiji, Sato Makoto, Kondo Masanori, Yamazaki Michito: A study on rust juice from chloride attack to concrete bridges and sequence of occurrence of corrosion cracks, The 71st Japan Society of Civil Engineers Annual Meeting Proceedings, Vol.5, pp.1117-1118, 2016.
5) Takahashi Tsuyoshi, Tanaka Yasushi: Analysis of the actual state of deterioration of bridges due to chloride attack in coastal areas of Niigata Prefecture, Proceedings of the Japan Concrete Institute, Vol.35, No.1, pp.829-834, 2013.
6) Maeda Kei, Sato Takeshi, Yamaguchi Toshinobu, Takewaka Koji, Akira Yoshikazu: A study on assessment of environmental action on maintenance of bridges in Kagoshima prefecture, The 71st Japan Society of Civil Engineers Annual Meeting Proceedings, Vol.5, pp.899-900, 2016.
7) Sakai Hideaki: A study on predictive method of the chloride ion concentration of bridge protective barrier in region using the anti-freezing agent, Journal of Japan Society of Civil Engineers E, Vol.66, No.3, pp.268-275, 2010.
8) Ibayashi Kou, Hayashi Honoka, Minagawa Atsuya: Development and examination of bridge inspection system with smart phone by citizen participation, Proceedings of the Concrete Structure Scenarios, JSMS, Vol.17, No.1, pp.631-634, 2017.
9) Sasaki Yusuke, Tsuchida Hiroshi, Ibayashi Kou: Examination of effectiveness of bridge general inspection system using tablet by field survey, The 70th Japan Society of Civil Engineers Annual Meeting Proceedings, Vol.6, pp.665-666, 2015.
10) Maruyama Kyuichi, Tanaka Yasushi: Current status and issues of aging bridges in Hokuriku, 6th Infrastructure Maintenance Seminar, 2012.
11) Implementation Support Team for Maintenance, Renewal, and Management Technology in SIP Infrastructure: Regional implementation activity report of new technology in SIP infrastructure -For the future of regional infrastructure maintenance and management-, JSCE, 2019.
12) Japan Society of Civil Engineers, Concrete Committee, Subcommittee of structural performance research for degraded concrete structures: Structural performance of concrete structures with material deterioration, Concrete engineering series Vol.71, 2006.
13) Kubo Yoshimori, Abe Hanaka and Kikuchi Souta: Investigation of silane impregnation for crack on concrete surface, Proceedings of the Concrete Structure Scenarios, JSMS, Vol.16, pp.545-550, 2016.

14) Miyazato Shinichi, Torii Kazuyuki, Ito Hajime : Evaluation on effect of classifying flyash on improving anti-chloride permeability in concrete based on Hokuriku regional characteristics, Proceedings of the Japan Concrete Institute, Vol.35, No.1, pp.163-168, 2013.
15) Hirono Shinichi, Torii Kazuyuki: The alkali-silica reactivity of representative andesite aggregates produced in Hokuriku district and its mitigation mechanisms by flyashes, Cement Science and Concrete Technology, Vol.66, pp.499-506, 2013.
16) Ito Hajime, Ohno Hiroki, Hashimoto Toru, Miyazato Shinichi: Investigation of thermal crack suppression effect of concrete by mixing classified flyash, Proceedings of the Japan Concrete Institute, Vol.35, No.1, pp.1267-1272, 2013.
17) Ishikawa Taro, Inoue Shou, Kato Hiroyuki: Application and test construction of flyash concrete for Hokuriku Shinkansen, Proceedings of the Japan Concrete Institute, Vol.40, No.1, pp.123-128, 2018.