Government of People's Republic of Bangladesh
Ministry of Road Transport and Bridges
Roads and Highways Department

Bridge Maintenance Management Standard

Final Draft

August 2018

PREFACE

It is a great pleasure to know that New Bridge Management System and its related technical manuals, namely Bridge Maintenance Management Standard, Bridge Inspection and Evaluation Manual, Bridge Rehabilitation and Strengthening Manuals consisting of two (2) volumes and BMS Manuals consisting of four (4) volumes have been created through Bridge Management Capacity Development Project (BMCDP) funded by Japan International Cooperation Agency (JICA).

These System and Manuals have been produced under the collaboration with Core Members selected from among RHD staff and their original works. In New BMS, there is no black box, therefore it can be revised and modified at any time by RHD itself if necessary.

New Bridge Management System is not a only database system but has been created with intention of becoming asset management system in future. After the accumulation of enough data, it would be possible to add several new functions required for asset management to the current functions.

All the manuals are related to the New Bridge Maintenance System. Bridge Maintenance Management Standard is mainly handling common items such as staff deployment (organization), procedure, budgeting, maintenance planning and human resources capacity development.

These Standard and Manuals would serve as a reference book for the decision/policy makers of RHD in this area and also the RHD field staff responsible for direct maintenance or maintenance by contract.

Finally, we would like to take this opportunity to thank the experts of JICA Consultant Team for their efforts in preparing these Standard and Manuals.

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Bridge Maintenance Management Standard (Final Draft)

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1 General

1-1 Background

The number of bridges and culverts under Roads and Highways Department of Ministry of Road Transport and Bridges (hereinafter referred to RHD) was 1,112 before the Liberation War in 1971 but since then the number of bridges and culverts has rapidly increased and it reached 11,879 in 2000, 14,712 in 2005 and 18,258 as of December, 2015. As mentioned above, the budget for bridges has been intensively invested for new bridge construction for the past forty years after the independence; on the contrary the maintenance of bridges has continued to be neglected relatively. However, from these years, the significance of road and bridge maintenance has become strongly prioritized due to continuous bridge collapse and tremendously poor condition of roads. As a result, the special 'Act for Road Fund' was agreed in July, 2013 in Bangladesh Parliament (Bangladesh National Assembly). Consequently, an active and specialized unit for bridge maintenance has been set up in RHD. However, RHD at present is faced with some acute problems related to bridge maintenance as mentioned below:

Firstly, due to lack of proper or necessary maintenance work, early deterioration of bridges or pre-mature bridge collapse takes place well ahead of the expiry of the design life. This sort of early deterioration or collapse is also attributable to excessive or uncontrolled over-loading. But the number of professional bridge engineers who can build high quality bridges and at the same time maintain them properly is remarkably insufficient in Bangladesh market. Among total 18,258 bridges and culverts, approximately 1000 fall under category of Portable Steel Bridges (PSB) which are used as emergency bridges and but surprisingly almost all collapsed bridges under RHD fall under this category. These Portable Steel Bridges (PSB) need to be replaced by more sustainable bridges. Till now, many bridges, from small to medium length, have been constructed by RHD utilizing available resources but the construction of large length bridges as river-crossing ferry replacements is yet to be undertaken in full. In addition to the above the required technical know-how for planning, designing, constructing and maintaining them is almost inadequate in RHD in comparison to the present requirements. To fulfill the above mentioned demands, specialized and advanced training for Bridge Engineers of RHD is necessary or in other words it's a dire need for RHD to build professional Bridge Engineers to meet its current demand.

Secondly, RHD has to perform effective and rational maintenance of 18,258 bridges and culverts and the number of which is increasing day by day. Under the present context, RHD has to emphasize on preventive maintenance rather than symptomatic maintenance of the bridges. The newly created bridge maintenance management

system (BMMS) unit under RHD has become a key unit for bridge related all activities but this unit has to be modified/re-organized and trained in a more sustainable and advanced way to cope with his present requirements moving parallel to today's advanced world. The BMMS unit has existence in RHD with limited capacity/capability. The potential resources for the unit are persons and tools, whereas persons are professional Bridge Engineers, Bridge Inspectors and System Engineers and on the other hand, tools are Bridge Maintenance Management System (hereinafter referred to BMMS) and so on. Present BMMS is an outdated or obsolete database and cannot be extended or modified to a more sophisticated system for preventive maintenance. There is no doubt that BMMS has to be created by RHD itself with continuous operation and maintenance to make the system effective, useful and sustainable. Moreover, it is very difficult to find professional Bridge Inspectors in Bangladesh because of its poor marketability. On the other hand RHD has to inspect its bridges and culverts every year based on Bridge Condition Survey Manual (May 2014) and outdated available tools. In view of the fact, as stated above, the Technical Cooperation was requested to JICA to train Bridge Engineers, System Engineers and so on to introduce professionalism in their services and also create new advanced BMMS and professional Bridge Inspectors having the capacity/capability to inspect its 18,258 bridges and culverts throughout the entire road network of RHD in Bangladesh. This Standard is one of the outputs developed by the Technical Cooperation Project, namely Bridge Management Capacity Development Project (BMCDP).

1-2 Purpose

In order to conduct bridge maintenance effectively and to prolong bridge service life, it is necessary to establish systematic bridge management cycle which is composed of Bridge Inspection, Set-up of Bridge Maintenance Plan, Execution of Plan and Recording of Execution. This Standard has been prepared so that all the personnel who are in charge of bridge maintenance could understand bridge management cycle and could certainly accomplish it using this standard together with other technical manuals developed through BMCDP.

1-3 Scope of the Standard

This Standard is applied to the maintenance and management of all bridges and culverts under RHD jurisdiction.

1-4 The Manuals related to the Standard

Following the introduction of new Bridge Maintenance Management System based on preventive maintenance, the Manuals developed through East Bangladesh Bridge

Improvement Project (EBBIP) were revised, renewed or upgraded through Bridge Maintenance Capacity Development Project (BMCDP). The Manuals related to the Standard are as follows:

- Bridge Inspection and Evaluation Manual
- Bridge Rehabilitation and Strengthening Manual
- Bridge Management System (BMS) Manual for Public Users
- Bridge Management System (BMS) Manual for Inspector and Evaluator
- Bridge Management System (BMS) Manual for Bridge Management Wing
- Bridge Management System (BMS) Manual for System Administrator

2 Current Situations of the Bridges and Culverts under RHD Jurisdiction

2-1 RHD Road Network

The road network in Bangladesh is composed of National Highways, Regional Highways, Zila Roads, Upazila Roads, Union Roads and Village Roads. Among them, National Highways, Regional Highways and Zila Roads are under RHD jurisdiction. Other roads are under the jurisdiction of LGED (Local Government Engineering Department), Ministry of Local Government, Rural Development & Cooperative. Table 2-1 shows the details of roads in Bangladesh compared to roads in Japan.

Table 2-1 Comparison of Roads in Bangladesh with Roads in Japan

Road Classification		Actual Length (km)		Pavement Ratio (%)		Road Density (km/1000km2	
Bangladesh	Japan	Bangladesh	Japan	Bangladesh	Japan	Bangladesh	Japan
Expressway	Expressway	—	7,431.20	—	100	—	20
National Highway	National Highway (Specified Section)	3,812.78	22,591.60	92.8	100	26	60
Regional Highway	Nationa Highway (Non-specified Section *)	4.246.97	31,938.80		98.9	29	85
Zila Road	Provincial Road	13,242.33	129,328.90		96.3	90	342
Upazila, Union and Village (UUV) Road	City, Town and Village (CTV) Road	304,379.31	1,009,599.40	27.4	76.2	2,067	2,671
TOTAL		325,681.39	1,200,889.90	31.7	79.6	2,207	3,178

* Not administrated by Ministry of Land Infrastructure ar Source: Japan: Annual Road Statistics in Japan, 2008
Trasport, but by Provincial Government Bangladesh: RHD Home Page, LGED Home Paga 2015

The land area of Japan is 377,944 km2 while that of Bangladesh is 147,570 km2. The proportion of the both is 1:0.39. From Table 2-1, it is known that in case of Bangladesh the pavement ratio of municipal roads is extremely low and the road density of main roads (roads and highways under RHD jurisdiction) is considerably low compared to those of Japan while there is topographical difference between the both. Anyway it could be said that the total length of roads and highways is still insufficient in Bangladesh.

Figure 2-1 shows the road network (as of 2009, Map from Road Master Plan) under RHD jurisdiction. Six long-distance and important national highways, namely National Highway No.1, No.2, No.3, No.4, No.5 and No.8, are stretching radially from Dhaka. Among them National Highway No.1 connecting Dhaka with Chittagong Port is most important and most overcrowded in traffic and consequently the condition of road pavements and bridges is seriously damaged. It could be said totally that the maintenance of roads and bridges doesn't catch up with the deterioration of roads and bridges at all.

Figure 2-1 RHD Road Network (as of 2009)

2-2 Bridges and Culverts

The number of bridges and culverts presented on the first page of RHD home page (November 3rd, 2015) is 4,507 bridges and 13,751 culverts respectively and the grand total is 18,258. On the other hand, the grand total of each type of bridge presented on the same HP is as shown in Table 2-2. The grand total of the both is not coincident at all, therefore the data lacks reliability. All the bridge data including bridge condition data which are now inputted in current BMMS database should be checked and renewed through all RHD bridge inspection as soon as possible.

Table 2-2 Breakdown of Bridge Types (RHD HP)

Type No.	Bridge/Culvert Type	Nos.
1	Box Culvert	3852
2	Slab Culvert	2270
	Sub-Total	6122
3	Unknown	3
4	Arch Masonry	378
5	RCC Bridge	1381
6	RCC Girder Bridge	1238
7	PC Girder Bridge	93
8	Steel Beam with RCC Slab	284
9	Truss with Steel Deck	153
10	Truss with RCC Slab	42
11	Bailey with Steel Deck	1005
12	Bailey with Timber Deck	82
	Sub-Total	4659
	Grand-Total	10781

Table 2-3 shows the results of inspection conducted as a part of East Bangladesh Bridge Improvement Project (EBBIP).
RCC is the abbreviation of Reinforced Cement Concrete and it is commonly RC. Bailey bridge is a kind of truss bridges but it is already used as a general name. Seeing the percentage classified by material, RC bridges account for near 60%. On the other hand, the percentages of PC bridges and steel bridges are small. More types of bridges which are more sustainable are should be introduced from now on.

Furthermore, it is a serious problem that Baily bridges which are used as temporary bridges are left without replacing for a long time. The number of Baily bridges was 997 bridges (22% of the whole bridges) at the time of EBBIP survey. Bailey bridges should be replaced according to well-planned replacement program.

Table 2-3 Bridge Types Surveyed by EBBIP

Type No.	Bridge/Culvert Type	Nos.	Percentage(%)	
1	RCC Bridge	245	RCC	58.4
2	RCC Girder Bridge	2393		
3	PC Girder Bridge	406	PC	9.1
4	PC Box Girder Bridge	5		
5	Steel Girder Bridge	230	Steel	10.4
6	Truss with Steel Deck	205		
7	Truss with RCC Slab	30		
8	Truss with Timber Deck	6		
9	Bailey with Steel Deck	974	Bailey	22.1
10	Bailey with Timber Deck	23		
	Total	4517	Total	100.0

2-3 Completion Year and Deterioration of Bridges and Culverts

Table 2-4 and Figure 2-2 shows the numbers of bridges and culverts constructed during each decade. By 2000 fiscal year, 12,991 bridges and culverts were constructed. Especially the construction of bridges and culverts from 1981 until 2000 is conspicuous.

Table 2-4 Numbers of Completed Bridges and Culverts per Decade

Decade	Number of Completed Bridges	Bridge Age as of 2015
before 1960	192	older than 55
1961–1970	920	45 to 55
1971–1980	1605	35 to 45
1981–1990	4343	25 to 35
1991–2000	5931	15 to 25

Source: Road Master Plan

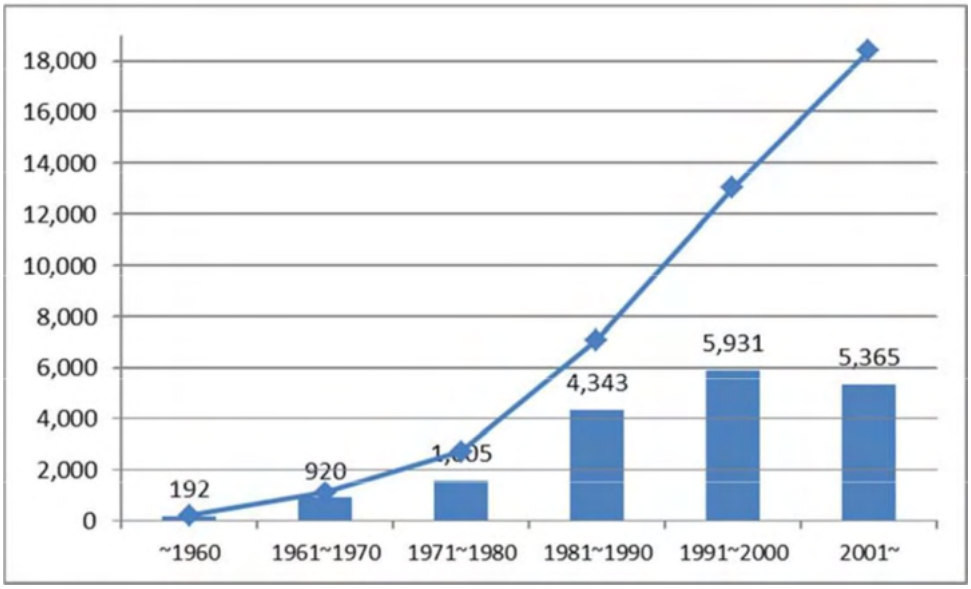


Figure 2-2 Numbers of Completed Bridges and Culverts per Decade

Table 2-5 shows the transition of bridge age. This table is made based on the data of 2004 year. Some of these bridges might be already replaced but in any case it is doubtless that bridge deterioration with aging would rapidly proceed.

Table 2-5 Transition of Bridge and Culvert Age

Year	2015	2020	2030	2040	2050
Bridge nos. over 50 years of age	192	1112	2717	7060	12991
Ratio(%)	1.05	6.06	14.80	38.46	70.78

Note: The numbers of all bridges and culverts are 18,355 based on RHD Home Page.

2-4 Damage Condition of the Bridges and Culverts

Table 2-6 shows the conditions of the bridges surveyed by EBBIP.

Table 2-6 Numbers of Bridges by Bridge Condition Category and Road Classification

Damage	A				B				C				D				Number of bridge in Zone			
Zone	N	R	Z	Σ	N	R	Z	Σ	N	R	Z	Σ	N	R	Z	Σ	N	R	Z	Σ
Barisal	28	15	212	255	9	4	28	41	10	6	46	62	4	0	16	20	51	25	302	378
Chittagong	71	53	211	335	52	25	41	118	67	56	119	242	6	11	41	58	196	145	412	753
Comilla	24	11	197	232	18	24	94	136	15	45	144	204	2	9	65	76	59	89	500	648
Dhaka	83	47	198	328	56	36	107	199	60	122	143	325	7	34	61	102	206	239	509	954
Gopalganj	35	22	102	159	8	12	27	47	22	2	42	66	6	2	15	23	71	38	186	295
Khulna	22	61	100	183	9	9	27	45	9	20	49	78	0	2	27	29	40	92	203	335
Rajshahi	47	20	110	177	10	6	44	60	12	11	45	68	4	12	14	30	73	49	213	335
Rangpur	37	15	192	244	11	3	40	54	11	7	38	56	4	4	25	33	63	29	295	387
Sylhet	71	63	97	231	21	32	28	81	16	45	36	97	2	4	17	23	110	144	178	432
Total	418	307	1,419	2,144	194	151	436	781	222	314	662	1,198	35	78	281	394	869	850	2,798	4,517

NB) N: National Highway, R: Regional Highway, Z: Zila Road

The culverts were not surveyed in EBBIP. The number of D category bridges is 394 but among them 281 bridges exist on Zila roads. The ratio of D category bridges, 8.7% is not a low figure at all. Above all the number of D category bridges on Zila roads is conspicuous.

Table 2-7 shows bridge condition category classified by bridge type. And the ratio of each condition category is shown by bridge type in Figure 2-3. The ratio of category D is high in Arch Masonry, RC Girder and Steel Girder excluding the ratio of Truss (TD) and Baily (TD) of which numbers are extremely small. On the other hand, Box Culvert and PC Girder are far much sound compared to other bridge types. The ratio of category D in Baily (SD) is lower than the one imagined although they are not permanent bridges.

Table 2-7 Bridge Condition Category by Bridge Type

	A		B		C		D		
	Nos.	Rate(%)	Nos.	Rate(%)	Nos.	Rate(%)	Nos.	Rate(%)	Sub-total
Box Culvert	7554	79.6	1016	10.7	794	8.4	131	1.4	9495
Slab Culvert	2554	63.7	494	12.3	755	18.8	207	5.2	4010
Arch Masonry	149	44.7	61	18.3	87	26.1	36	10.8	333
Sub-total	10257	74.1	1571	11.4	1636	11.8	374	2.7	13838
RC Slab	127	51.8	34	13.9	68	27.8	16	6.5	245
RC Girder	904	37.8	500	20.9	725	30.3	264	11.0	2393
PC Girder	282	69.5	61	15.0	52	12.8	11	2.7	406
PC Box	2	40.0	0	0	3	60.0	0	0	5
Sub-total	1315	43.1	595	19.5	848	27.8	291	9.5	3049
Steel Girder	76	33.0	35	15.2	89	38.7	30	13.0	230
Truss (SD)	152	74.1	13	6.3	32	15.6	8	3.9	205
Truss (RCD)	17	56.7	4	13.3	8	26.7	1	3.3	30
Truss (TD)	3	50.0	0	0	2	33.3	1	16.7	6
Sub-total	248	52.7	52	11.0	131	27.8	40	8.5	471
Baily (SD)	570	58.5	132	13.6	213	21.9	59	6.1	974
Baily (TD)	11	47.8	2	8.7	6	26.1	4	17.4	23
Sub-total	581	58.3	134	13.4	219	22.0	63	6.3	997
Grand-total	12401	67.6	2352	12.8	2834	15.4	768	4.2	18355

NB: (SD)=(Steel Deck), (RCD)=(RC Deck), (TD)=(Timber Deck)
Source: Box Culvert, Slab Culvert, Arch Masonry=BMMS
Other Types of Bridges=EBBIP Survey Results

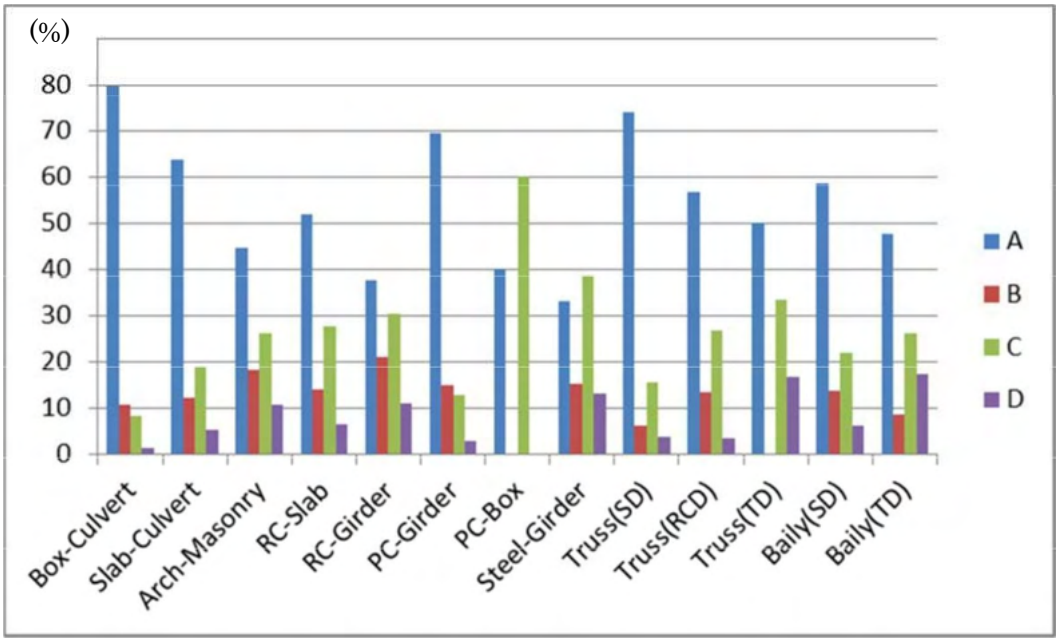


Figure 2-3 Ratio of Each Condition Category by Bridge Type

Table 2-8 shows the difference of bridge numbers between BMMS database and EBBIP survey results. The difference between the both is 3238 bridges. This is because the numbers of bridges are counted double as 2004 bridge survey results and 2013 survey results are written together in BMMS database.

Table 2-8 Bridge Numbers by BMMS Database and by EBBIP Survey

	BMMS	EBBIP	Difference
RC-Slab	326	245	81
RC-Girder	4098	2393	1705
PC-Girder	897	406	491
PC-Box	9	5	4
Steel-Girder	335	230	105
Truss(SD)	539	205	334
Truss(RCD)	68	30	38
Truss(TD)	8	6	2
Baily(SD)	1439	974	465
Baily(TD)	36	23	13
Total	7755	4517	3238

Figure 2-4 to Figure 2-7 show the transition of bridge condition category distribution with bridge age. These figures are made based on the data from BMMS database.

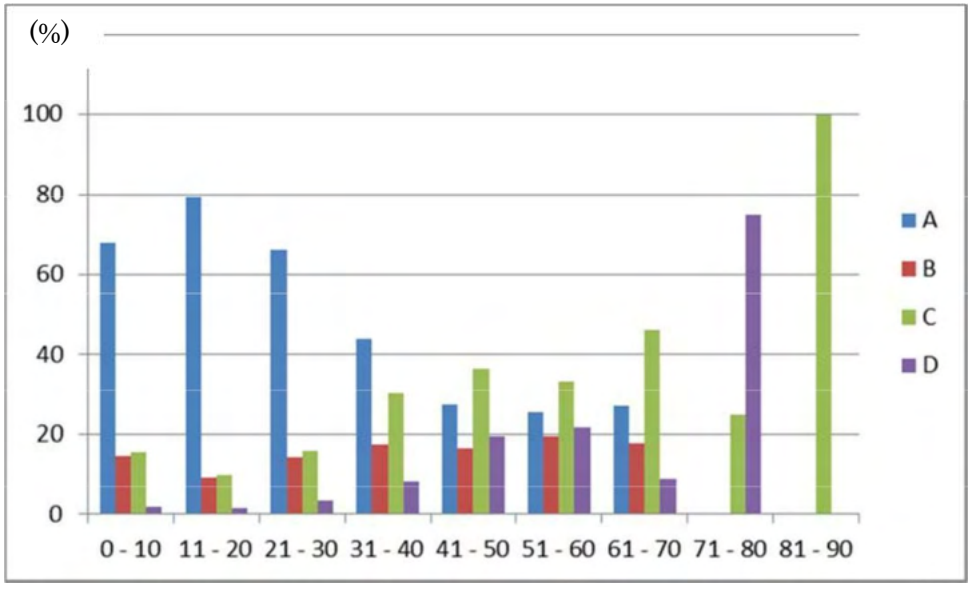


Figure 2-4 Condition Category Distribution (%) by Age Group (Whole Bridges)

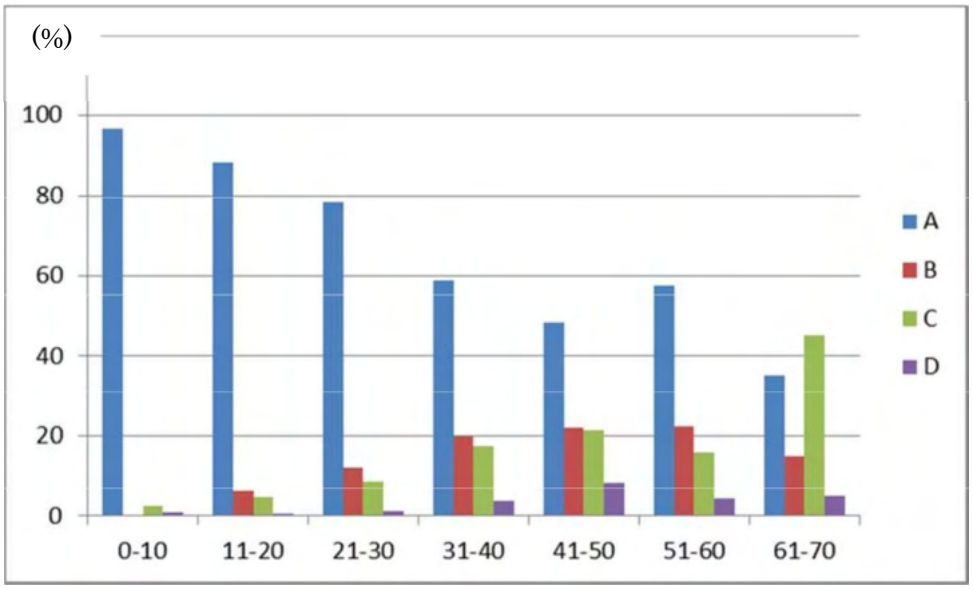


Figure 2-5 Condition Category Distribution (%) by Age Group (Box-Culvert)

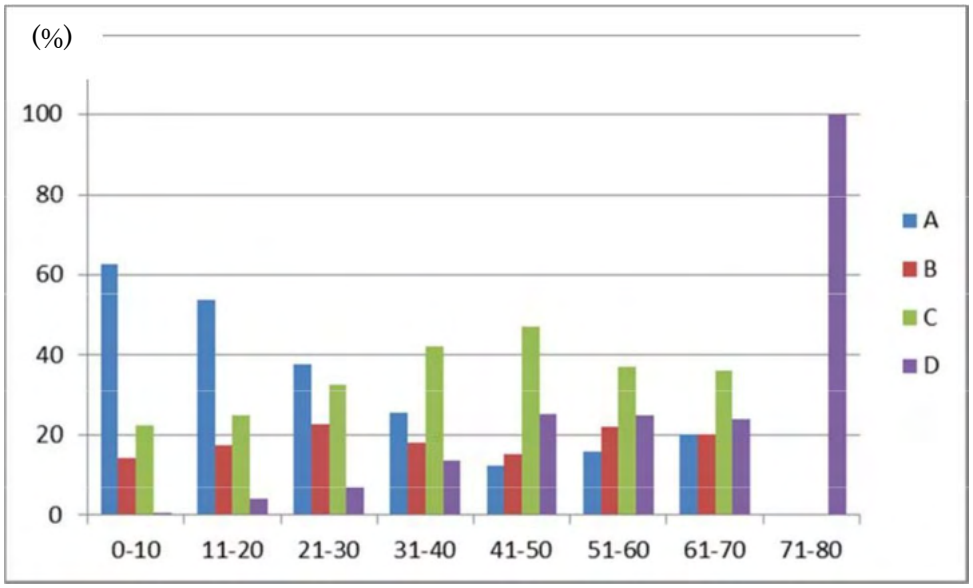


Figure 2-6 Condition Category Distribution (%) by Age Group (RC-Girder)

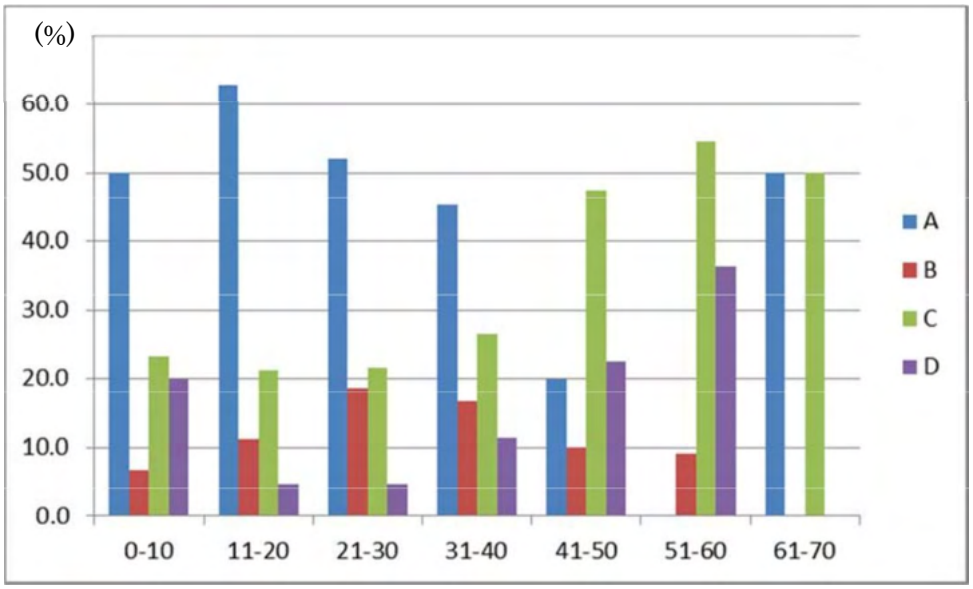


Figure 2-7 Condition Category Distribution (%) by Age Group (Baily(SD))

Seeing Figure 2-5 (Box-Culvert), Transition of bridge deterioration with aging is very clear. The transition is almost linear. On the other hand, the ratio of category C or category D of RC Girder and Baily (SD) within 10 years in age is abnormally high. This means that these types of bridges should be constructed with careful attention so as not to produce initial defects or that the defects should be treated before ten years have passed to prolong the service life of bridges. It might be possible to draw deterioration curve by classifying EBBIP survey data based on age group.

2-5 Transition of Road and Bridge Maintenance Budget

Table 2-9 shows the transition of road maintenance budget from 2004 fiscal year until 2013 fiscal year. Since 2012 fiscal year the maintenance budget has rapidly increased.

Table 2-9 Transition of Road Maintenance Budget

(Million Taka)

Fiscal Year	Routine Maintenance	PMP & Emergency	Total Maintenance	GOB	JDCF	DFID
1	2	3	4	5	6	7
2004-2005	186.20	7529.90	7716.10	3871.50	2000.00	1844.60
2005-2006	50.00	7280.00	7330.00	4370.00	2000.00	960.00
2006-2007	22.20	4147.40	4169.60	2919.60	1050.00	200.00
2007-2008	392.80	7183.40	7576.20	5276.20	2000.00	300.00
2008-2009	295.60	6217.60	6513.20	4513.20	2000.00	
2009-2010	300.00	5800.00	6100.00	4600.00	1500.00	
2010-2011	350.00	6328.00	6678.80	5328.00	1350.00	
2011-2012	500.00	6549.00	7049.00	7049.00		
2012-2013	530.00	10826.13	11356.13	11356.13		
2013-2014	530.00	11844.41	12374.41	12374.41		

PMP: Periodic Maintenance Program
JDCF: Japan Debt Cancellation Fund
DFID: Department for International Development

Table 2-10 shows the breakdown of road maintenance budget. The budgets for routine maintenance and PMP minor are extremely important to realize preventive maintenance. By introducing the concept of preventive maintenance, the expenses for PMP major would be leveled and decrease at life cycle cost.

Table 2-10 Breakdown of Road Maintenance Budget

(Million Taka)

Budget Item	Fiscal Year			
	2014	2015	2016	2017
Routine Maintenance	750	800	950	1,000
PMP Minor (Road & Bridge)	2,996	4,307	3,285	3,739
PMP Major (Road)	8,103	8,080	8,850	10,600
PMP Major (Bridge)	1,200	1,350	1,600	1,500
Emergency Maintenance (Road & Bridge)	100	100	100	100
Total	13,149	14,637	14,785	16,939

2-6 Organization and Staff Deployment

2-6-1 Outline

The Roads and Highways Department (RHD) was created in 1962 when the old 'Communication & Building (C & B) organization was split into two separate bodies (the other being Public Works Department). RHD is responsible for communication and maintenance of the major road and bridge network of Bangladesh.

2-6-2 Organization

As shown in Figure 2-8 and Table 2-11, current organization consists of 5 wings and 10 zones and the number of personnel is 2,450. The engineers in each zone are employed by RHD headquarter and are treated equal to the engineers of headquarter. Chief Engineer (CE) integrates RHD and under CE, five (5) tops of wings and ten (10) tops of zones are deployed as Additional Chief Engineers (ACE). Furthermore, 10 zones are composed of 21 circles, 65 divisions and 161 sub-divisions hierarchically as shown in Table 2-12 (Details are attached in **Appendix-1**).

There exist 9,377 posts but the number of personnel who is actually deployed is only 26 % of the number of posts. Especially the number of Class Ⅲ and Class Ⅳ personnel who are in charge of bridge maintenance works at the site is inadequate. As its reason, it seems that the number of personnel doesn't reach the fixed number due to lack of budget. In order of resolve this issue, the clarification and continuous security of required budget are needed.

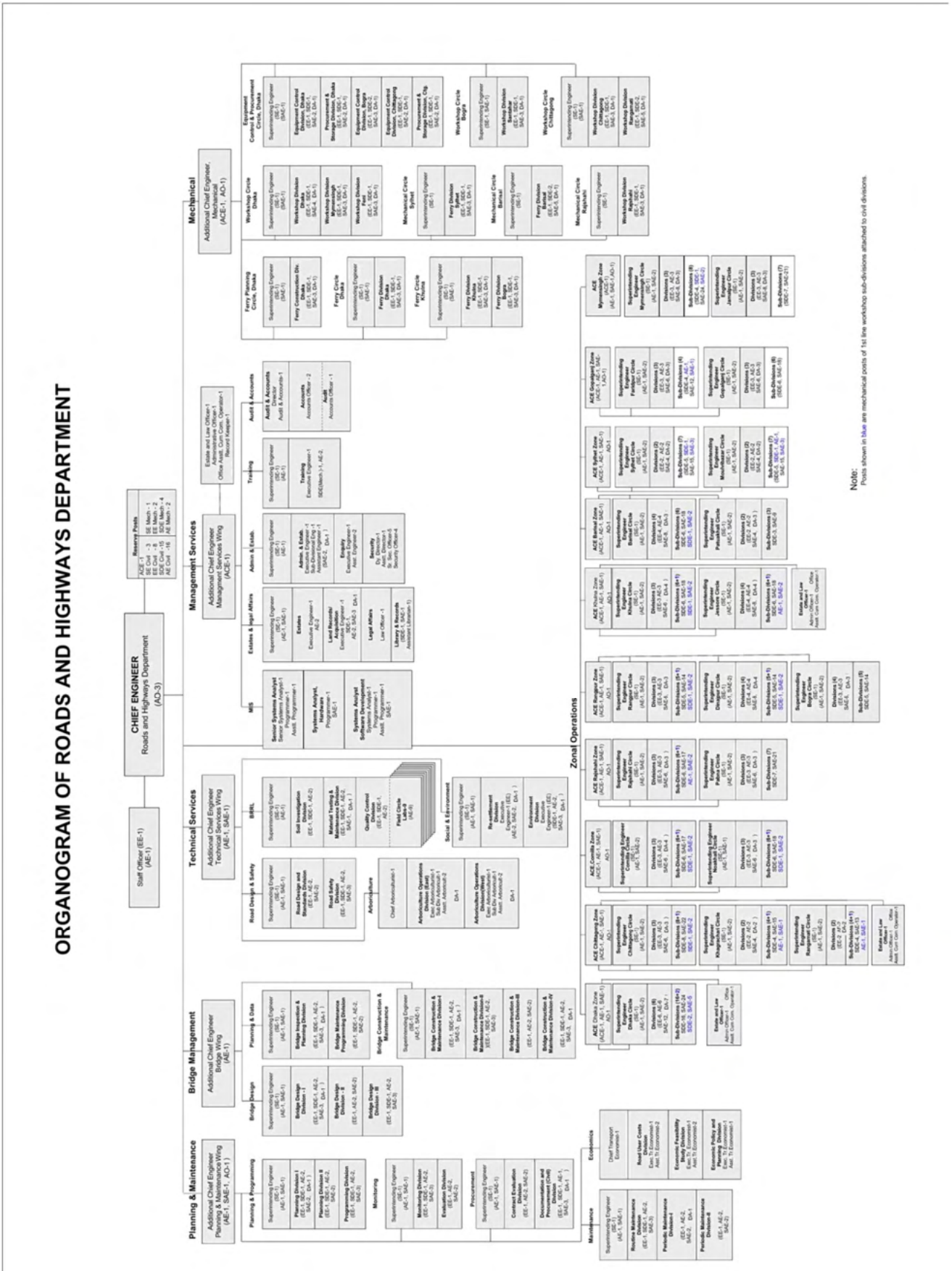


Figure 2-8 Organogram of RHD

Table 2-11 Staff Deployment

Post Name	Number of Posts	Number of Staff	Remarks
Chief Engineer	1	1	
Additional Chief Engineer (Civil)	14	14	
Additional Chief Engineer (Reserved) (Civil)	1	0	
Superintending Engineer Director (SE) (Civil)	35	35	
Superintending Engineer Director (Reserved) (Civil)	3	1	
Executive Engineer (Civil)	99	99	
Executive Engineer (Reserved) (Civil)	8	8	
Sub-Divisional Engineer (Civil)	153	130	
Sub-Divisional Engineer (Reserved) (civil)	15	0	
Assistant Engineer (Civil)	174	137	
Assistant Engineer (Reserved) (Civil)	16	0	
Class Ⅰ Civil Engineers	519	425	Subtotal A
Class Ⅰ Mechanical Engineers	97	55	B
Other Class Ⅰ Specialists	33	16	C
Total Class Ⅰ Posts	649	496	D=A+B+C
Total Class Ⅱ Posts	883	768	E
Total Class Ⅲ Posts	4,540	842	F
Total Class Ⅳ Posts	3,305	344	G
Total	9,377	2,450	Total D+E+F+G

Table 2-12 Local Organization of RHD

Zone Number	Zone Name	number of circles	number of divisions	number of sub-divisions
1	Dhaka	1	6	18(16)
2	Chittagong	3	6	19(16)
3	Comilla	2	6	15(12)
4	Rajshahi	2	6	17(13)
5	Rangpur	3	10	18(15)
6	Kluna	2	10	21(14)
7	Barisal	2	6	11(10)
8	Sylhet	2	4	15(11)
9	Gopalganj	2	5	10(9)
10	Mymensingh	2	6	17(17)
Total		21	65	161(133)

2-6-3 BMMS Division

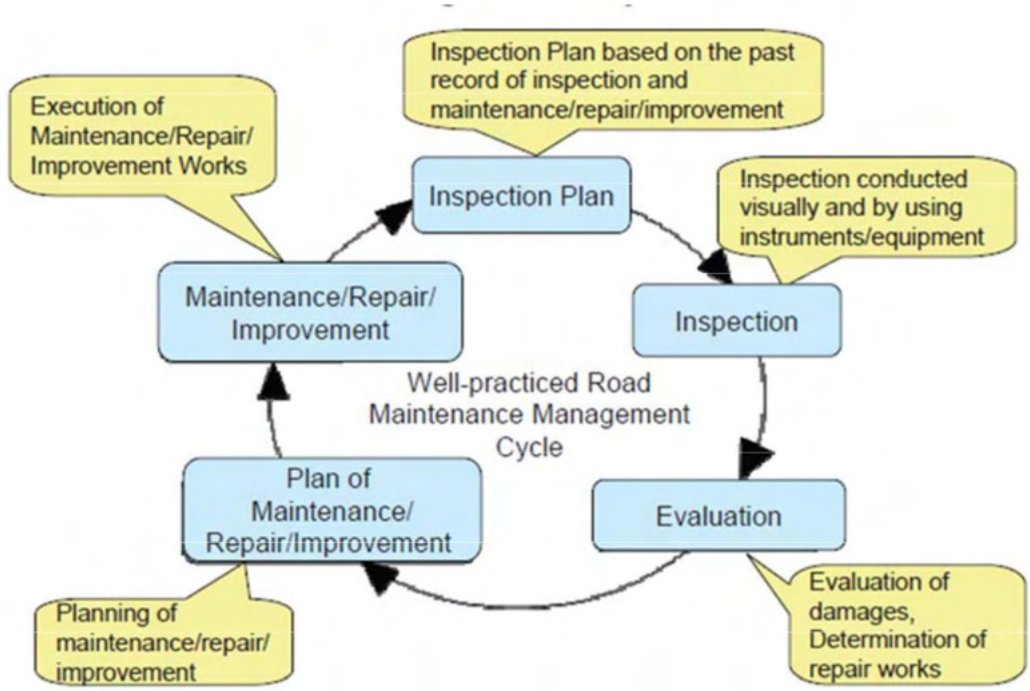
BMMS Division has been established by renaming 'Bridge Inspection & Planning Division to be Bridge Maintenance Management System (BMMS) Division in April of 2014. At the same time BMMS Sub-Division has been formed under BMMS Division.

It is expected that BMMS Division and Sub-Division would play a cardinal role for bridge maintenance management.

3. Establishment of Bridge Maintenance Management Cycle (BMMC)

3-1 Basic Concept of BMMC

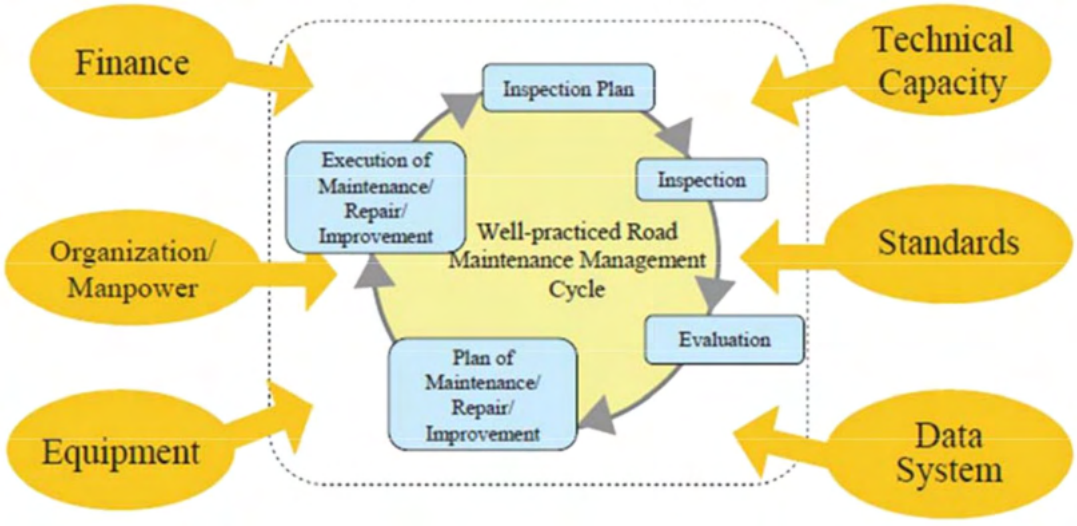
General road and bridge maintenance management cycle can be presented as Figure 3-1.



(Source: Economic Infrastructure Department, JICA)

Figure 3-1 Example of Road and Bridge Maintenance Management Cycle

In order to realize a well-practiced maintenance management cycle, the inputs as shown in Figure 3-2 are required.



(Source: Economic Infrastructure Department, JICA)

Figure 3-2 Inputs for Well-Practiced Maintenance Management Cycle

According to the answers to the questionnaire related to the baseline survey, the road maintenance management cycle of RHD is as follows.

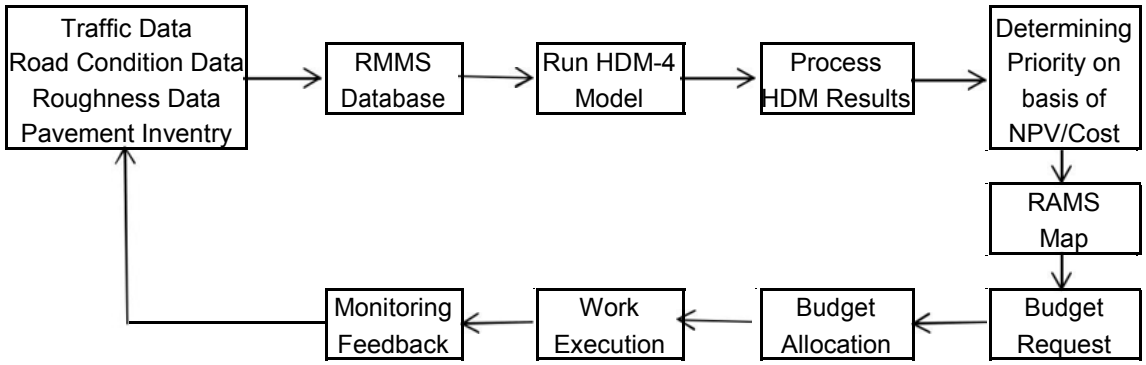


Figure 3-3 RHD Road Management Cycle

In case of road maintenance, "Maintenance Needs Report" is edited every year and the repair works of next year are to be selected from among the projects listed in "Maintenance Needs Report" in order of priority.

On the other hand, in case of bridge maintenance, the bridge condition survey hadn't been conducted for about 10 years since 2004 fiscal year in spite of the provision of Bridge Condition Survey Manual of RHD. In 2013 fiscal year, the condition survey of 4517 bridges excluding culverts were carried out as a part of EBBIP(East Bangladesh Bridge Improvement Project). The condition survey of over 13,000 culverts has not been carried out yet more than 10 years. Bridge

inspection should be carried out with clear purpose. Next step should be followed as road roughness survey. If applying bridge maintenance to Figure 3-3, it will be as follows.

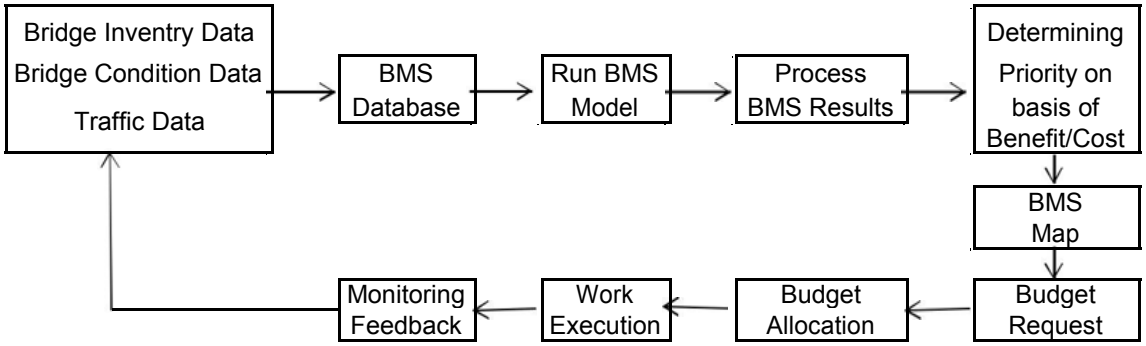


Figure 3-4 Conceivable RHD Bridge Maintenance Cycle

In order to establish well-practiced bridge maintenance management, the inputs such as technical capacity, standards, data system, equipment, organization/manpower and finance should be proper. In case of RHD bridge maintenance cycle, it hasn't started yet as bridge inspection was conducted by EBBIP consultant but hadn't been followed by next step. Consequently, all the inputs have been still inadequate. If bridge maintenance cycle starts moving, the situation of all the inputs would also be improved gradually.
Figure 3-5 shows practical Bridge Maintenance Management Cycle of RHD.

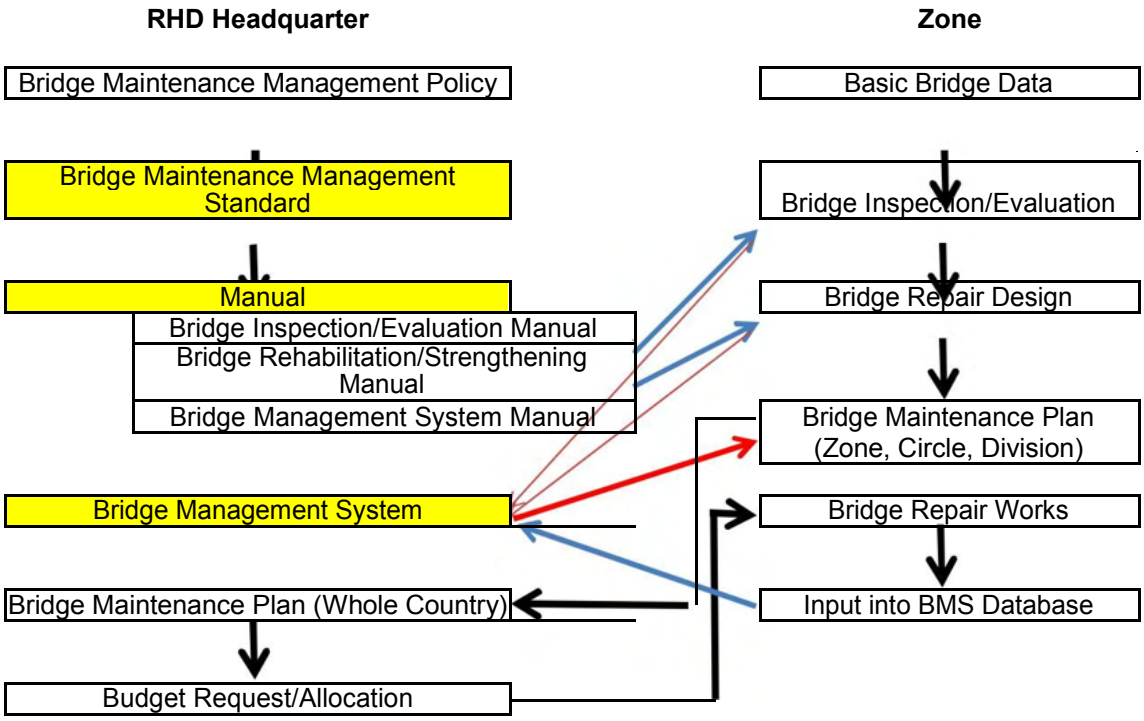


Figure 3-5 Practical Bridge Maintenance Cycle of RHD

3-2 Bridge Inspection

Bridge inspection is conducted to find damages and to know the extent of their damages. As the real conditions and the future damage progress of bridges and culverts are judged based on the results of bridge inspection, bridge inspection should be as exact as possible.

When developing Bridge Inspection Manual, the items to be considered are as follows.

(1) Types of Inspection

The followings are general.

- Routine Inspection/Patrol

  This is a road patrol executed daily or at least once a week on foot or by using a car.

- Periodic Inspection

  This is an inspection executed every year (BCS Manual 2014) or once per three years (Bridge Inspection Manual 2012) visually with a close-up range or with a distant view. In Japan, it is obligated that the initial inspection should be executed within two years after bridge completion.

- Emergency Inspection

  This is carried out after natural disasters such as earthquake, typhoon, heavy rainfall, flood, or large accident such as collision by car or ship.

  Detailed Investigation

  This is executed when necessary. In case of Japan, this is carried out in order to investigate the cause of damages and generally non-destructive tests are carried out at the same time.

(2) Method

There are two kinds of methods, namely a close-up visual inspection and a distant-view visual inspection. Generally speaking, a close-up visual inspection method is applied to Periodic Inspection.

(3) Types of Damages

According to BCS Manual, the types of damages are following eight kinds.

a) Scouring b) Leaning/Tilting c) Settlement d) Obstruction
e) Cracks f) Concrete Spalling g) Damaged or Missing Sections
h) Missing Bolts

In case of Bridge Inspection Manual for the National Highway Bridges in Japan, 26 types of damages are categorized. These numbers are variable in response to the numbers of applied bridge types and structural components.

Concerning the extents of damages, in case of RHD they are two grades, namely

minor and major. In case of Japan, damages are classified as five grades, namely “a” to “e”.

(4) Targets for Inspection

All the bridges and culverts under RHD jurisdiction are to be targeted.

(5) Composition of Inspection Team and Qualification of

Inspector General team composition is as follows.

- Senior Inspector: 1 person
- Inspector: 1 person
- Assistant Inspector: 2 persons
- Driver: 1 person
- Traffic Security Guard: numbers required

Qualification of a team leader and an inspector is established as requirement in the contract of bridge inspection work in USA, European countries and Japan.

(6) Inspection Tools

General inspection tools are as follows.

Table 3-1 General Inspection Tools

No.	Inspection Tools	Recordind Tools	Auxiliary
1	binocular	camera	light fixtures
2	inspection hammer	video camera	flash light (head lamp)
3	tape measure	blackboard chalk/marker	cleaning utensils
4	pole	blackboard/whiteboard	traffic control tools (red flag, arrow version, color corn, traffic wand)
5	vernier caliper	permanent marker	safe rope
6	clack gauge with magnifying glass	ruler	packing tape
7	leveling line	recording paper	step ladder
8	GPS	binder	dust-proof glasses/mask
9	GPS logger	pencil (black, red)	backet/watering pot
10	mirror	field notebook	roval spray for zinc plating repair
11	steel tape measure	personal computer	road map
12	laser range finder		helmet, safety belt, safety best, safety boots
13			brush
14			ratchet type monkey wrench
15			wire-brush
16			screwdriver
17			hammer & chisel
18			tool-storing belt

(7) Safety During Inspection

Prior to the inspection a suitable and sufficient assessment of the risks for the particular situation and inspection techniques needs are to be carried out. The assessment should cover the risks to the workforces and public, with particular attention to vehicular traffic passengers and pedestrians.

3-3 Evaluation of Bridge Condition

The evaluation of bridge condition is carried out in order to judge the necessity and priority of countermeasures and the time of commencement of countermeasures from the viewpoint of satisfaction of required performance based on inspection results.

The judgement on the necessity of countermeasures and the time of countermeasures greatly affects to subsequent bridge life. Therefore, when evaluating bridge condition, structural safety, causes of damages, progress of deterioration and so on are to be considered comprehensively. The evaluation of bridge condition requires advanced professionality and technology.

The evaluation of condition is conducted element by element. General description of condition category is given as Table 3-2.

Table 3-2 Element Condition Category

Condition Category	Description	Evaluation Point*)
At	No damage or slight damage	0
Bt	Damade is noticeable but there is no need of immediate repair.	33
Ct	Damage is substantial. There is a need of repair at an early stage.	67
Dt	Damage is serious. There is a need of urgent countermeasures.	100

*) Adopted by the local government of Japan

NB) Small "e" at the right side of condition category A to D meams "e" of element or "e" of evaluation.

The evaluation criteria used for the judgement of category A to category D is shown in Appendix-7 of Bridge Inspection and Evaluation Manual. Evaluation point is used when damage degree of entire bridge is calculated.

Target elements for evaluation are shown in Table 3-3.

Table 3-3 Target Elements for Evaluation

	Superstructure	Substructure	Bearing	Others
Element	Deck Main Girder Truss (including Bailey) Arch Rigid Frame Bridge Cable-stayed Bridge Cross Beam Stringer Sway Bracing Lateral Bracing	Abutment Pier Foundation	Bearing Bearing Seat	Pavement Expansion Joints Railing/Curb Drainage System Inspection Facility Lighting Facility Road Sign Facility Other Facilities

Evaluation of entire bridge is conducted by using evaluation points of all elements except sway bracing and lateral bracing of superstructure, all elements of substructure and all elements of bearing in Table 3-3.

Damage degree of entire bridge is calculating by using Damage Point, Impact Level, Evaluation Point, Weight coefficient of the element and Weight coefficient of the defect. Details are described in Bridge Inspection and Evaluation Manual. Bridge Conditions are categorized by Damage Degree as Table 3-4.

Table 3-4 Condition Category of Entire Bridge

Condition Category	Damage Degree	Urgency of Repair
A	0 ～ 20	No need of repair
B	20 ～ 60	Depending on situation
C	60 ～ 80	In its early stage
D	80 ～ 100	Emergency

The priority of repair works is determined considering both damage degree of each bridge and importance degree which is calculated taking account of the importance of route concerned, traffic volume, existence of detour, the situation under the bridge and so on.
In case that the damage of the bridge concerned is extremely severe, the replacement of the bridge concerned is to be examined. The judgement about replacement or repair is to be made considering economic efficiency, functionality and the extent of aging and so on. In principle, comparing repair cost/service life of repair method and replacement cost/life span of the bridge concerned, the countermeasure which gives cheaper unit cost is applied. The results of evaluation are to be inputted into BMS database.

3-4 Development of Short-Term and Medium-Term Maintenance Plan

3-4-1 Introduction of Preventive Maintenance and Asset Management

Preventive bridge maintenance is variously defined by various organizations but the contents are almost the same. The following is AASHTO definition on Preventive Maintenance.

> Preventive bridge maintenance avoids large scale work in stream environments, and thus makes sense from the standpoint of stewardship of both natural and financial resources. Preventive maintenance is defined as a planned strategy of cost-effective treatments applied at the proper time to preserve and extend the useful life of a bridge.
>
> - Cleaning activities, including annual water flush of all decks, drains, bearings, joints, pier caps, abutment seats, concrete rails, parapet each spring.
> - Preventive maintenance activities such as painting, coating and sealant applications and for routine, minor deck patching and railing repairs.
> - Technical and specialized repairs, including jacking up the structures, crack repairs, epoxy injection, repairing or adjusting bearing systems, repair and sealing of expansion joints, repair or reinforcement of main structural members to include stringers, beams, piers, and major applications of coatings and sealants.
> - Stream channel maintenance including debris removal, stabilizing banks and correcting erosion problems.

Preventive maintenance is one of approaches to reduce total maintenance cost (life cycle cost) by coping with damages in their early stage together with asset management approach. On the other hand, asset management is the whole of approaches conducted in order to optimize the investment related to bridge maintenance. In order to apply asset management approaches, deterioration curve, minimum Life Cycle Cost (hereinafter refers to LCC), optimum investment period and project priority are to be assumed. Preventive maintenance and asset management are utilized in many countries as effective approaches to maximize investment efficiency within limited budget.

In order to assume deterioration curve, various data such as unit prices of remedial measures, service life of each remedial measure, economic indexes like NPV (net present value), EIRR (economic internal rate of return) and B/C (cost benefit ratio) are to be accumulated. These data will be accumulated through new BMS database in future, but at present there are not enough data to apply the above planning approaches. Therefore,

in this standard and the manuals related, the approach using prioritization scores has been introduced to decide the priority of each maintenance works. This is one of approaches of asset management.

Bridge Inspection and Evaluation Manual 2018 has given the following table as the evaluation of entire bridge.

Table 3-4 Condition Category of Entire Bridge

Condition Category	Bridge Damage Degree	Expected Countermeasures
A	0 – 20	Sound condition
B	20 – 60	Depending on situation
C	60 – 80	In its early stage
D	80 – 100	Emergency

The urgency of remedial works is 1st: Category D bridges and 2nd: Category C bridges. For the remedial works of Category D and Category C bridges, Periodic Maintenance Program (hereinafter refers to PMP) (Bridge) Budget is to be appropriated. On the other hand, the remedial works for Category B bridges are preventive maintenance works and Routine Maintenance and PMP Minor Budget is to be appropriated for them.

3-4-2 Estimation of Work Volume based on Current BMMS Database

According to RHD Homepage as of January 3, 2016 the number of bridges/culverts classified by condition category is as shown in Table 3-5.

Table 3-5 Nos. of Bridges/Culverts per Condition Category (RHD HP)

Condition Category	Nos. of Bridges	Description
A	12,331	No damage
B	2,341	Minor damage
C	2,821	Major elemental damage
D	765	Major structural damage

As the number of bridges per condition category which were inspected at EBBIP survey is known, the number of culverts per condition category can be estimated by subtracting the number of bridges inspected by EBBIP from the number of bridges shown in Table 3-5. The inspection of culverts hadn't been conducted by EBBIP. The results of calculation are presented in Table 3-6.

Table 3-6 Nos. of Bridges/Culverts per Condition Category (EBBIP & RHD HP)

Condition Category	Total nos. of bridges & culverts (RHD Homepage)	Nos. of bridges (EBBIP)	Nos. of culverts
A	12331 (67.5%)	2144 (47.5%)	10187 (74.1%)
B	2341 (12.8%)	781 (17.3%)	1560 (11.4%)
C	2821 (15.5%)	1198 (26.5%)	1623 (11.8%)
D	765 (4.2%)	394 (8.7%)	371 (2.7%)
Total	18258 (100%)	4517 (100%)	13741 (100%)

All the bridges which fall in Category D are not always the targets of replacement. In reality, 82 bridges out of 394 bridges which fell in Category D as the results of EBBIP survey were judged as replacement. 20.8% of Category D bridges are the targets of replacement. Concerning culverts, by applying the same replacement ratio as bridges the total work volume could be calculated as shown in Table 3-8.

The average bridge length and unit price of repair/replacement are assumed as Table 3-7 based on Road Master Plan 2009.
The results of calculation are shown in Table 3-8.

Table 3-7 Average Length and Unit Price

	Average Length (m)		Unit Price (lac/m)		
	Category A & B	Category C	Minor Repairs	Major Repairs	Replacement
Road Master Plan	10.56	15.35	0.165	2.3	6.0
This Paper	10.56	15.35	0.33	4.6	12.0

Table 3-8 Estimated Work Volume

	Repair Type	Nos. of Bridges and Culverts			Length (m)	Unit Cost (lac)/m	Work Volume (crore)
		Bridges	Culverts	Total			
Category B	Minor Repairs	781	1560	2341	24,721	0.33	81.6
Category C	Major Repairs	1198	1623	3427	52,604	4.6	2419.8
Category D	Major Repairs	312	294	606	9,302	4.6	427.9
	Replacement	82	77	159	2,441	12.0	292.9
Total		2373	3554	5927	89,068		3222.2

NB: The average lengeh of bridges with Category D is supposed to be same average bridge length as the bridges with Category C.

The breakdown of maintenance budget in 2015 fiscal year is shown in Table 2-10. The periods needed to recover from Category D to Category A and from Category C to Category A are calculated as follows.

From Category D to Category A : (427.9+292.9)/150=4.8 years
From Category C to Category A : 2419.8/150 =16.1 years

On the other hand, if 25% of routine maintenance and PMP Minor budget are to be appropriated for Category B bridges, the maintenance works will finish within one year as show in the following.

From Category B to Category A : (75+300.7)x0.25=93.9 ＞ 81.6 crore

Full-fledged approaches of preventive maintenance and asset management come to be introduced in order after the maintenance works of Category D bridges and Category C bridges finish.

3-4-3 Development of Short-Term and Medium-Term Maintenance Plan

Considering the actual conditions of bridges/culverts of RHD, the basic policies of bridge maintenance plan are to be the followings.

(1) Policy 1

Remedial measures for the bridges/culverts with condition category D should be prioritized firstly.

Planning period is around five years based on 3-4-2.

(2) Policy 2

Remedial measures for the bridges/culverts with condition category C comes second after remedial works of category D bridges/culverts.

Planning period is around 15 years based on 3-4-2. However, this period should be shortened.

(3) Policy 3

Preventive maintenance is to be applied to the bridges/culverts with condition category B in order to reduce expenditure in future. A part of routine maintenance and PMP minor budget is to be appropriated for this preventive maintenance works.

(4) Policy 4

After the completion of remedial works of bridged/culverts with condition category D and C, full-scale preventive maintenance and asset management approaches are to be applied to make bridge maintenance plan.

The definition of condition category and the contents of preventive maintenance works are as follows.

Table 3-4 Condition Category of Entire Bridge/Culvert

Condition Category	Bridge Damage Degree	Expected Countermeasures
A	0 - 20	Sound condition
B	20 - 60	Depending on situation
C	60 - 80	In its early stage
D	80 - 100	Emergency

Table 3-9 Contents of Preventive Maintenance Works

Budget Classification	Contents of Works
Routine Maintenance Budget	Cleaning of decks, drains, bearings, joints, pier caps, abutment seats, rails, parapets
PMP Minor Budget	painting, coating and sealant applications minor deck patching and railing repairs crack repairs, epoxy injection, repairing or adjusting bearing systems, repair and sealing of expantion joints debris removal, stabilizing banks and correcting erosion problems

The process of maintenance plan setup is as follows.

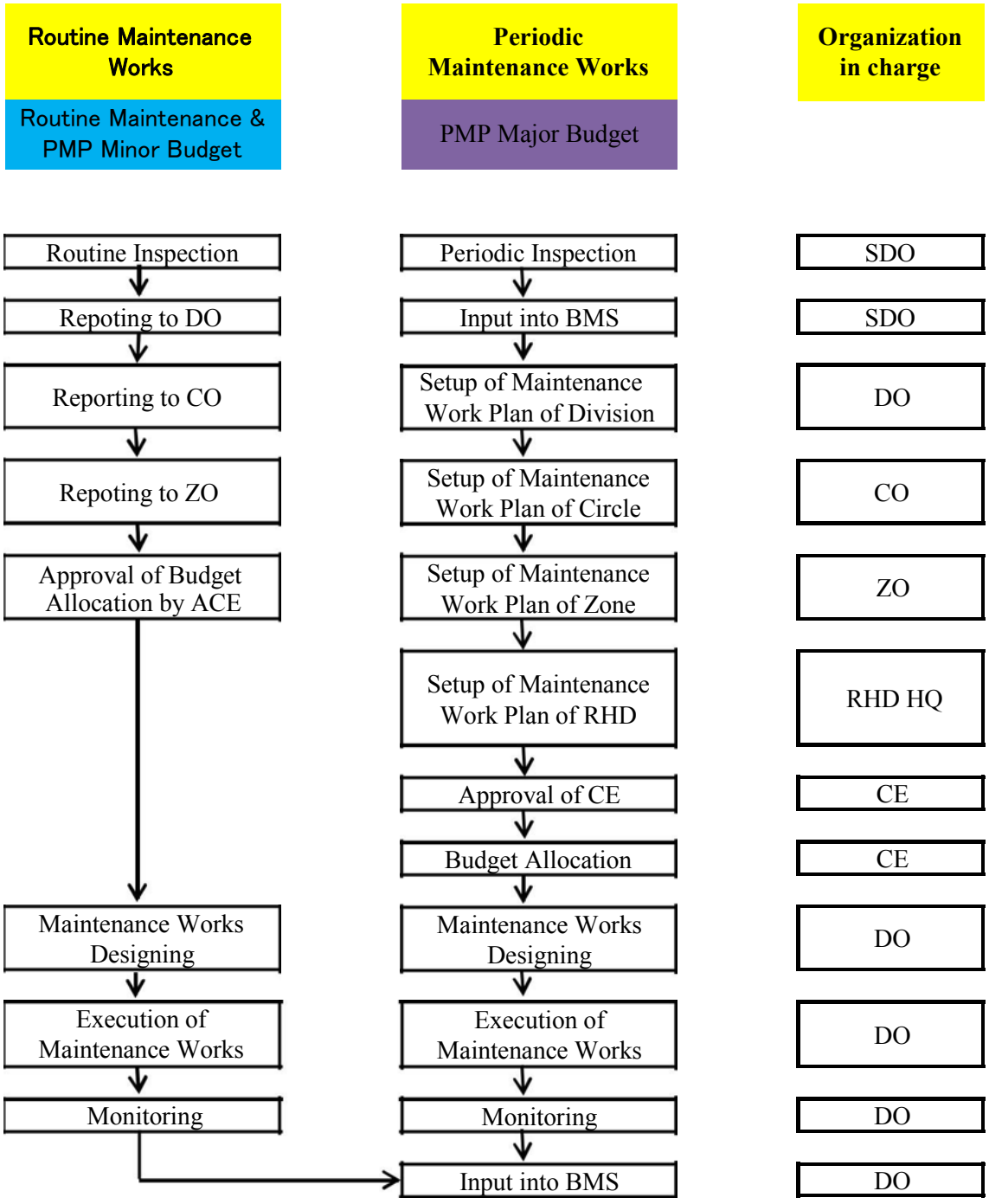
(1) Bridge inspection team conducts bridge/culvert inspection.
(2) Senior inspector evaluates the condition of each bridge/culvert element.
(3) Appraisal committee discusses and re-evaluates about the elements which were categorized into D.
(4) Inspection team inputs inventory data, inspection results and evaluation results into BMS.
(5) Inspection team inputs quantity of works.
(6) Inspection team input traffic volume of the road concerned.
(7) Damage degree, important degree, priority of bridges/culverts and the cost of repair works are automatically calculated and are arranged in designated order.
(8) Given the yearly budget limit, bridge/culvert lists of multiple fiscal years to be repaired or replaced are outputted automatically by BMS.
(9) In case that the remedial works of one bridge/culvert are divided into several fiscal years, the budget of each fiscal year has to be allocated manually.

An example of bridge/culvert maintenance work lists is shown in Table 3-10.

Table 3-10 Example of Maintenance Work List

Bridge Name	LRP Name	Zone	Circle	Division	Damage Degree	Importance Degree	Priority Scores	2019		2020			
								Works	Cost	Works	Cost	Works	Cost

Figure 3-6 shows the procedure of maintenance work plan setup. The left side of the figure is the flow of routine maintenance works.



NB) SDO: Sub-Division Office, DO: Division Office, CO: Circle Office, ZO: Zone Office
RHD HQ: RHD Head Quarter

Figure 3-6 Procedure of Maintenance Plan Setup

3-5 Development of Long-Term Maintenance Plan

3-5-1 Flow of Long-Term Maintenance Plan

The process of general maintenance plan setup is as follows.

(1) Periodic bridge inspection is carried out by each inspection team of Dub-Divisional Office.
(2) Results of inspection and evaluation of each element of bridges/culverts are inputted into BMS database.
(3) Prediction of deterioration of each element is conducted by the support system of BMS automatically.
(4) By setting up control level (maintenance target) of each bridge/culvert, Life Cycle Cost (LCC) of each bridge/culvert is calculated by the support system of BMS.
(5) Considering budget limitation, project priority and leveling of budget, bridge maintenance plan is drafted.

Figure 3-7 shows the general flow of maintenance plan setup.

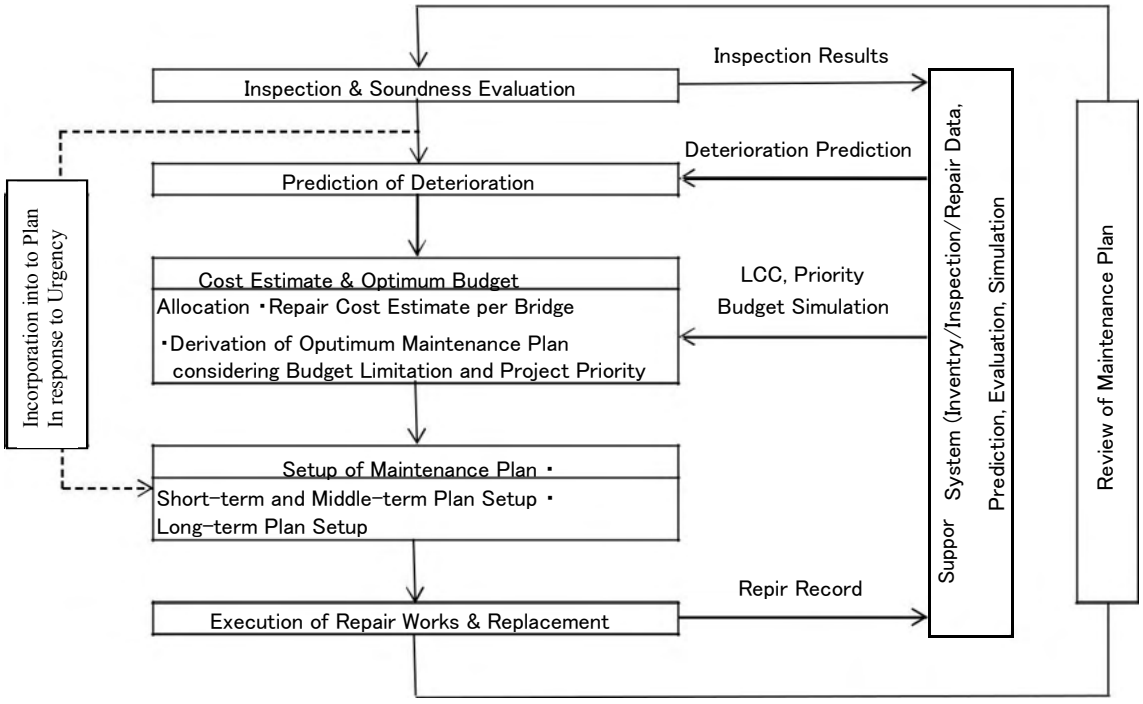


Figure 3-7 Flow of Maintenance Plan Setup

3-5-2 Control Level

When focusing on the total cost of maintenance, application of preventive maintenance to all bridges/culverts enables substantial cost saving by elongating the service life of bridges/culverts. However, as the construction of bridges/culverts had been executed from 1980 until 2000 intensively, the time of renewal of bridges/culverts is only put off and the concentration of renewal cost can't be avoided. By setting up control level/maintenance target of every bridge/culvert, the concentration of renewal cost could be mitigated.

Table 3-11 is an example of control levels.

Table 3-11 Example of Control Level

Control Level	Name	Description	Application
Ⅰ	Preventive Maintenance Level	Maintenance limit is bridge condition category B.	Impotant bridges of which replacement is very difficult
Ⅱ	Breakdown Maintenance Level	Maintenance limit is bridge condition category C.	Bridges/culverts other than the above

3-5-3 Prediction of Deterioration

Prediction of deterioration is carried out in order to grasp the transition of damage degree/soundness degree in future by predicting the deterioration progress of bridge element. It is utilized for the decision of remedial time and measures through LCC analysis, estimation of total budget, setting up of control level, making of inspection plan, evaluation of project priority and so on.

The methods of deterioration prediction are as follows.

Table 3-12 Methods of Deterioration Prediction

Methods	Contents
Statistical analysis of inspection data	Relation between element condition and element age is estimated by using regression analysis.
Theoretical equation	Rusting of steel girder, fatigue cracks of concrete slab and rebar rusting by chloride ion penetration are theoretically studied.
Service life of countermeasures	Countermeasure/renewal period is decided by using countermeasure records and engineering knowledge.

3-6 Rehabilitation and Strengthening Works

Bridge maintenance works are classified as Figure 3-8 based on budget items.

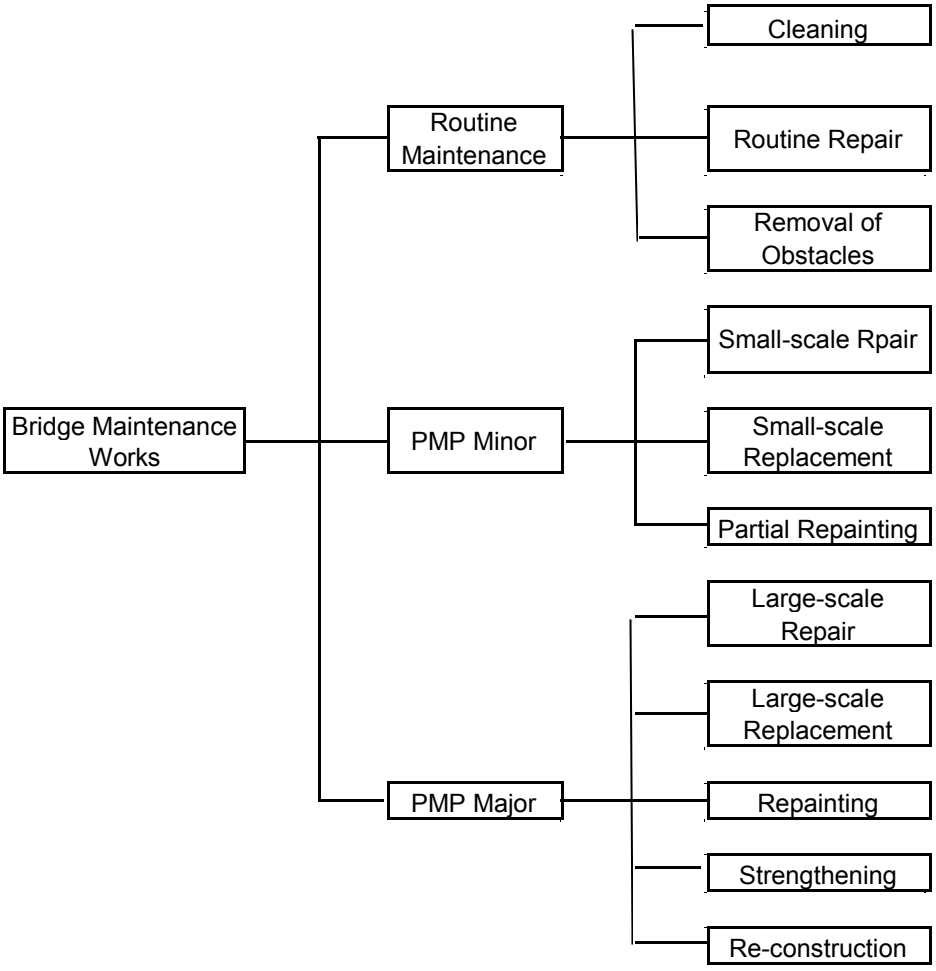


Figure 3-8 Classification of Bridge Maintenance Works

The name, description and purpose of each maintenance works are shown in Table 3-13.

Table 3-13 Description of Maintenance Works

Budget Item	Name of Works	Description of Works	Purpose of Works
Routine Maintenance	Cleaning	Cleaning works of bridges	To remove dust, soil, rubbish from bridge parts to avoid deterioration.
	Rutine repair	Repairing small scale of defects	To restrain further damages, the works such as adding bolts are carried out concurrently with inspection and cleaning works.
	Removal of obstacles	Removing obstacles which create risk of damage in bridge structures such as pier and abutment.	To maintain bridges stable and avoid flooding caused by the obstacles reducing channel width.
PMP Minor	Small-scale repair	Repairing small-scale defects of bridges	To rectify defects so as to avoid further escalation and ensure expected bridge life span and safety of traffic.
	Small-scale replacement	Replacing small elements/parts of bridges.	To replace damaged elements/parts so as to avoid further escalation and ensure expected bridge life span and safety of traffic.
	Partial repainting	Repainting steel elements partially.	To repaint steel elements partially to avoid the development and spreading of rusted areas.
PMP Major	Large-scale repair	Repairing large-scale defects of bridges.	To rectify defects so as to avoid further escalation and ensure expected bridge life span and safety of traffic.
	Large-scale replacement	Replacing large-scale elements or parts.	To replace large-scale elements or parts so as to avoid further escalation and ensure expected bridge life span and safety of traffic.
	Repainting	Repainting whole or particular elements of steel bridges	To repaint whole or particular elements of steel bridges to avoid the development and spreading of rusted areas.
	Strengthening	Increasing capacity of bridges to support higher traffic loading.	To enhance bridge strength in order to increase capacity to support higher traffic loading on the bridge.
	Reconstruction	Removing existing bridges and constructing new bridges.	To construct a new bridge to save excess cost likely to incur when maintenance/major repairs are repeated.

PMP is abbreviation of Periodic Maintenance Program. Routine maintenance works and PMP minor maintenance works are categorized into preventive maintenance works and in many cases they are executed under the direct management.

PMP major maintenance works are generally outsourced to private construction companies. In case of outsourcing the tendering process is as follows.

(1) Detailed investigation for repair design is carried out.
(2) The results of detailed investigation are inputted into BMS database.
(3) Repair design is carried out and tender documents are prepared. .
(4) A tender is opened and contract documents are signed.
(5) Repair works are executed and the progress of works is monitored.
(6) The results of repair works are inputted into BMS database.

3-7 Recording

The information on repair and strengthening is to be accumulated for the purpose of prediction of deterioration, optimization of rehabilitation and strengthening measures, basic data for the setup of maintenance plan and so on. Recording is very important in order to execute bridge maintenance management systematically and smoothly based on bridge maintenance cycle, namely “Bridge Inspection”, “Bridge Evaluation”, “Setup of Maintenance Plan”, “Rehabilitation Design”, “Execution of Rehabilitation Works”, “Recording” and “Ex-post Evaluation”. The followings are examples of information utilization.

(1) When inspecting bridges
By conducting inspection after the confirmation of rehabilitation work records, check points can be understood and the accuracy of inspection enhances.

(2) When evaluating bridge soundness and doing rehabilitation work design
The approach of rehabilitation works is greatly affected by whether the current damages produced after rehabilitation works or had already existed before rehabilitation works.

(3) When conducting the prediction of deterioration
By considering rehabilitation work records into the prediction of deterioration, the accuracy of prediction enhances.

(4) When doing ex-post evaluation
By knowing the level of recovery of repaired elements and the trend of re-deterioration, the rehabilitation and strengthening methods applied can be confirmed and optimized.

(5) Verification of new technologies and new materials
New technologies and new materials applied can be verified by rehabilitation work records.

4. Improvement of Bridge Maintenance Institutional Framework

4-1 Bridge Maintenance Institutional Framework and Staff Deployment

4-1-1 Institutionalization of Bridge Inspection

Bridge inspection is a starting point of bridge maintenance management cycle and without exact bridge inspection, systematic and effective bridge maintenance would be impossible. Continuous periodic bridge inspection is a must.

RHD conducted bridge inspection for all the bridges and culverts under RHD jurisdiction in 2004 fiscal year. Since then for around ten years, synthetic bridge inspection hadn't been conducted but in 2013 fiscal year, the bridge inspection for all the bridges except box culverts, slab culverts and arch masonries was finally carried out as a part of East Bangladesh Bridge Improvement Project (hereinafter refers to EBBIP) funded by JICA. The rest, around 13,500 culverts and 300 arch masonries haven't been surveyed yet. Even only from this fact, it is difficult to say that RHD is making much of bridge inspection.

In order to conduct bridge inspection periodically, the institutionalization or legalization of bridge inspection would be required. Arranging in the order of authority, it is a law/act, a government ordinance, a ministerial ordinance and notification/notice.

In case of USA, it is a law and in case of Japan it is based on Road Law. The thing which was first undertaken in order to stem the "Deteriorating America" was the legalization of bridge inspection. The existence of rule/regulation/standard/manual is not same as the execution of them. Legalization or institutionalization of bridge inspection is also a must.

4-1-2 Permanent Standing of Bridge Inspection Team

RHD manages 18,355 bridges and culverts and has to inspect them continuously. For the continuous inspection, the fixation of inspection team is required. Although for the time being a bridge inspection team is formed in a sub division office and will conducts bridge inspection, it is desirable that a bridge inspection team should be fixed as an organization and the inspectors should always be grasping the real condition of bridges and culverts under their jurisdiction. The member of team may change due to personnel transfer but it is important an inspection team exists as an permanent standing organization.

4-1-3 Increase of Local Organizations

According to current organogram of RHD, one assistant engineer (hereinafter refers to AE) is posted under executive engineer (hereinafter refers to EE) but there are some cases that the post of AE has been vacant after personnel transfer. In order to proceed

with all the tasks in a division office, at least two AEs are to be posted.

Furthermore the road length and the number of bridges and culverts which one sub-division office manages are lacking balance. It is recommended that the road length and the number of bridges and culverts to be managed by one sub-division should be leveled by increasing the number of sub-divisions.

4-2 Security of Maintenance Fund

4-2-1 Cost Saving due to Preventive Maintenance

Economic effect on preventive maintenance is written in Road Master Plan 2009. In this trial, it is assumed that the service life of a bridge is 30 years in case of "without maintenance" and 50 years in case of "with maintenance". Unit prices used for calculation are as follows.

○1	Routine maintenance (annual)	Tk	500 per m
○2	Periodic maintenance (5 yearly)	Tk	10,000 per m
○3	Minor repairs to B class bridges	Tk	16,500 per m
○4	Major repairs to C class bridges	Tk	230,000 per m
○5	Replacement	Tk	600,000 per m

Calculation period is 30 years (2007 to 2036).

When applying preventive maintenance to class A bridges and B bridges, it was calculated that EIRR is 22.18% and net benefit is 25341 mil Tk per 30 years.

In case of applying it to class C bridges, it was calculated that EIRR is 42.96% and net benefit is 8520 mil Tk per 30 years.

Totaling class A, B and C bridges and dividing by 30 years, annual benefit becomes 1128.7 mil Tk per year.

As this is an estimation as of 2005 fiscal year, the annual benefit or cost saving would become more than double considering the escalation of commodity price, namely 2257.4 mil Tk (225.74 crore Tk). This surpasses the budget of PMP major (Bridge), 150 crore as of 2015 fiscal year.

It is recommended that preventive maintenance should be introduced as early as possible.

4-2-2 Road Fund

Road fund is extremely effective for road and bridge maintenance. Table 4-1 shows the road funds of several countries. The data of JICA and World Bank are both the data of 2008 year. Although Bangladesh has also Road Fund (the Road Maintenance Fund Board Act) since July 2013, its operation is not clear yet.
It is recommended that Road Fund should be mobilized as early as possible.

Table 4-1 Road Funds of Several Countries

Country		Road Fund Source	Kind of Financial Resources
1	Tanzania	1, 2, 6	Specified
2	Kenya	1, 2	Specified
3	Bolivia	1, 2	Specified
4	Costa Rica	1, 2, 3	Specified
5	Philipines	1, 2	Specified
6	Kyrgys	2, 3, 5	General
7	Chile	4, 6	
8	Afghanistan		General
9	Timor Leste		General
10	India	2	Specified
11	Pakistan	1	Specified
12	Nepal	1,2	Specified
13	Sri Lanka		
14	Bangladesh		General
15	Bhutan		
16	Japan	2, 3, 4	Specified→General

Road Fund Sources: 1.Tolls 2.Fuel cess 3.Vehicle registration cess
4.Weight cess 5.Road development cess
6.Overloaded vehicle fine
Data Source: Country 1 to 9 JICA, Country 10 to 15 World Bank

The following is an extract from Home Page of Ministry of Land, Infrastructure and Tourism of Japan regarding Road Fund.

1) Arrival of the Motorization Age

Automobiles proliferated quickly as the Japanese economy recovered from defeat and the standard of living improved. Only 130,000 vehicles were registered at the end of World War II, but the number increased rapidly, reaching 500,000 vehicles by 1951, then doubling to one million in 1953, and doubling again to two million in 1957. The Age of Motorization had arrived in Japan.
However, the road system remained insufficient to support the rapid motorization. Ralph J. Watkins, an economist invited by the Japanese government to conduct research on the Meishin Expressway wrote in his 1956 report, "The roads of Japan are incredibly bad. No other industrial nation has so completely neglected its highway system".
Japan's road system in those days was indeed terrible. Only 23% of the first-class arterial national highway system was paved. Only two-thirds of the total national Highway Route 1, supposedly the major arterial highway connecting Tokyo with Osaka, was paved. The Japanese Government at that time accepted Mr. Watkins' proposals and immediately put them into practice. Thus, road improvement in Japan moved into high gear, propelling the nation into the high economic growth era of later years.

2) The Five-Year Road Development Program, Toll Road System, and Tax Revenue System with Earmarks for Roads

Without a history of horse-drawn carriages, Japan had only poor roads in those days. What is worse, road development was inevitably slow, because the development of the railway system was given priority over the development of roads. Under these circumstances, the Five-Year Road Development Program was launched so that road development would be fully accelerated.
Because the public works budget under the general revenue scheme was not sufficient to meet ever-increasing road traffic demand, two financing systems were introduced so that a significant number of road projects could be undertaken in a short period: the toll road system and the tax revenue system with earmarks for roads.
The former "Act on Special Measures concerning Road Construction and Improvement", enacted in 1952, enabled the introduction of the toll road system where the national and municipal governments could borrow sufficient money to develop roads and the borrowed money would be repaid with toll revenue from the new roads.
The toll road system was applied primarily for national expressway projects. In 1956, the Japan Highway Public Corporation (JH) was founded, so that expressways would be operated efficiently and financial resources from the private sector could be widely utilized.

With the founding of JH, toll road development was led by JH instead of by the National Government. Although the mechanism of the toll road system was similar to that of current PPP projects, the former included an ingenious system that enabled them to carry out unprofitable road projects if the road was recognized as necessary from an economic vantage point. The National Government reduced the business risk, of unprofitable road projects, by guaranteeing the loan and by paying a fixed rate of interest. In addition, the Government utilized the pool system, in which revenues and expenditures were balanced for the integral road network as opposed to a collection of individual roads. This system enabled them to develop not only profitable urban roads but also unprofitable regional roads across the country.

In 1953, the "Act on State's Tentative Financial Measures for Road Construction Projects" was enacted, which introduced a new tax revenue system with earmarks for roads. This system earmarked the revenues from gasoline tax and other automobile-related taxes for road projects based on the beneficiary payment principle. This measure secured stable f inancial resources for long- term development of roads, including the 1st to 12th Five-Year Road Development Programs.

The toll road system and the tax revenue system with earmarks for roads supported the development of the nationwide road network for more than 50 years. During those years, all major roads were paved and more than 10,000 km of expressways were developed all across the country.

However, there were increasing calls for a change in both of the financial revenue systems, since the road networks were developed to a certain level. There were various criticisms and opinions arguing that the roads were developed one after another by spending a large amount of both borrowed money and the national budget with a unilateral approach. At the same time, the repayment and management costs were not sufficiently saved due to the high-cost structure of JH's toll road system.

As a result, JH was privatized and reorganized into the Japan Expressway and Debt Repayment Agency (JEDRA) and 6 other Expressway Companies. The main purpose of this change was to ensure the full repayment of the massive debt reaching 40 trillion yen, to streamline the administrative authority, and to provide various services for road users by utilizing experience in the private sector.

There was also increasing criticism of the tax revenue system with earmarks for roads. Critics argued that fixed expenditures from the abundant financial resources resulted in a number of unnecessary road developments. In 2009, the tax revenue system with earmarks for roads was abandoned and the Government decided to cover road expenditures with general revenue.

4-2-3 Budget Separation of Routine Maintenance and PMP Minor

There are many cases that the pot holes on approach roads and on the pavement of deck, debris around expansion joints and bearings, obstacles in cannels, failure of embankment around abutment, mal-function of drainage and so forth have been left without any remedial action. These maintenance works are categorized into preventive maintenance works and whether these maintenance works are properly executed greatly affects subsequent bridge life. The budgets for the above maintenance works are appropriated from routine maintenance budget and PMP minor maintenance budget, current budget is total budget of roads and bridges. Considering actual condition of routine maintenance, it is difficult to say that these budgets are utilized properly for bridge maintenance.

Therefore, it is recommended that the budget for routine maintenance and PMP minor for bridges and culverts should be separated from the budget for road and these separated budgets should be appropriated clearly only for bridge and culvert maintenance.

Total budget of Routine Maintenance and PMP Minor is 37.57 crore taka as of 2015 fiscal year. If 25% of this budget is appropriated for bridge maintenance, all the bridges and culverts with condition category B would be able to be repaired in one year. The number of bridges and culverts which will recover from with category C or category D to category A will increase year by year with the completion of repair works. This budget is effectively utilized for these bridges and culverts. According to rough estimation based on current BMMS database, all the bridges and culverts will shift from current symptomatic maintenance to preventive maintenance after around twenty years.

4.3 Enhancement of Technical Ability

4.3.1 Significance of Enhancement of Technical Ability

The Enhancement of Technical Ability is one of the important inputs as well as Standard/Manuals, Data System, Equipment, Organization/Manpower and Finance in order to preserve well-practiced Bridge Maintenance Management Cycle.

The Enhancement of Technical Ability is not an issue that can be solved in a short time, continuous education, trainings, seminars and self-improvement will be required.

Through Bridge Maintenance Capacity Development Project funded by JICA, Bridge Maintenance Management Standard 2018, Bridge Inspection and Evaluation Manual 2018, Bridge Rehabilitation and Strengthening Manual 2018, BMS Manual for Public Users, BMS Manual for Inspector and Evaluator, BMS Manual for Bridge Management Wing and BMS Manual for System Administrator have been created. This is an input in terms of Standard/Manuals.

These three (3) manuals and a Standard have been created by ten (10) and more Core Members who have been selected from among RHD Head Quarter and several Zones under the cooperation of JICA Experts.

The three Manuals and a Standard were explained at the On-the-Job-Training (hereinafter refers to OJT) and based on them Bridge Inspection and Evaluation, Set-up of Annual and Short-Term Bridge Maintenance Plan by utilizing BMS and Set-up of Rehabilitation/Strengthening Work Plan and Cost Estimates of the Works were exercised during OJT.

The OJT was conducted in RHD Training Center and Model Area (Manikganj Division). The number of Master Trainers (hereinafter refers to MTs) including CMs is seventy five (75) and the training was conducted grouping MTs into three. The total training period was around two weeks. This OJT is the training for creating bridge maintenance trainers, therefore enough time was provided for the training.

To evaluate the condition of bridges and culverts exactly, the evaluators should have comprehensive knowledge on bridges and culverts. Master trainers should be excellent evaluators as well as excellent trainers. A Master Trainer should play an important role like Bridge Master/Meister/Maestro in each Division and should be a technical core of each division.

Although this OJT was conducted by external lecturers (JICA Experts), such trainings are to be conducted by internal lecturers (Master Trainers) for their successors continuously to keep bridge maintenance technology at required level.

4.3.2 Methodology of Enhancement of Technical Ability

(1) Internal Activities

Bridge maintenance engineers should have integrated and comprehensive knowledges required for bridge maintenance such as on bridge design, remedial measures, materials, equipment, chemistries, environmental and economic appraisal. It is difficult to obtain these knowledges in a day. Bridge maintenance technology is a kind of experience engineering and demands affluent experiences in terms of both desk works and field works. These situations should be considered in terms of personnel transfer.

To enhance technical ability, various seminars, workshops and on-the-job-trainings are to be planned and executed considering hierarchy, technology level and specialty.

The Activities for Enhancement of Technical Ability in RHD are exemplified in Table 4.2.

Table 4-2 Activities for Enhancement of Technical Ability (1/2)

Type	Name	Target	Lecturerer	Purpose	Contents	Nos. of Participants	Frequency
Seminar	Bridge maintenance new technology	ACE, SAE, EE, AE of RHD	Man of Learning & Experience	To obtain latest information on bridge maintenance	New Policy, Theory, System, Methodology, Material,	As many as possible	once a year
OJT	OJT for Bridge Inspection	AE, SAE, WS, WA of RHD and Consultants	EE of BMMSD	To enhance ability of RHD staff on bridge inspection and evaluation	OJT for Bridge Inspection	4 trainees/team x 5 trainees/time =20 trainees/time	twice a year
	OJT for Repair and Cost Estimate	ditto	EE of BMPD	To enhance ability of RHD staff on repair and cost estimate	OJT for bridge repair method and cost estimate	ditto	ditto
	OJT for BMS operation (1)	SE, EE, AE, SAE of RHD	EE of BMMSD	To enhance ability of BMS operation for data analysis	OJT for BMS operation for data analysis such as Annual Bridge Maintenance Needs Report	20 staff/time	once a year
	OJT for BMS operation (2)	EE, AE, SAE of RHD	EE of BMMSD	To inhance ability of BMS operation for data input and preparation of data analysis	To enhance ability of BMS operation data input and preparation of data analysis	20 staff/time	twice a year

Table 4.x.x Activities for Enhancement of Technical Activities (2/2)

Type	Name	Target	Lecturerer	Purpose	Contents	Nos. of Participants	Frequency
Briefing Workshop	Explanation of Bridge Maintenance Management Standard (1)	SE, EE of RHD	SE of P&DC	To make RHD staff well versed in the manual particularly in fundamental matters	Explanation of Bridge Maintenance Management Standard mainly regarding fundamental matters	10 staff/time	once a year
	Explanation of Bridge Maintenance Management Standaed (2)	EE, AE,SAE, WS, WA of RHD	EE of BMPD	To make RHD staff well versed in the manual particulary in practical matters	Explanation of Bridge Maintenance Management Standard mainly regarding practical matters	20 staff/time	once a year
	Explanation of Bridge Inspection/Evaluation Manual	EE, AE,SAE, WS, WA of RHD	EE of BMMSD	To make RHD staff well versed in the manual	Explanation of Bridge Inspection/Evaluation Manual with the same contents of the explanation to MTs by JICA Experts	20 staff/time	once a year
	Explanation of Bridge Rehabilitation/Strengthening Manual	EE, AE,SAE, WS, WA of RHD	EE of BMPD	To make RHD staff well versed in the manual	Explanation of Bridge Rehabilitation/Strengthening Manual	20 staff/time	once a year
	Explanation of BMS Users' Manual (1)	SE, EE of RHD	SE of P&DC	To make RHD staff well versed in data analysis by BMS	Explanation of BMS Users' Manual with the same contents of the explanation to MTs by JICA Experts	10 staff/time	once a year
	Explanation of BMS Users' Manual (2)	EE,AE, SAE, WS of RHD	EE of BMMSD	To make RHD staff well versed in data input and preparation of data analysis	Explanation of BMS Users' Manual with the same contents of the explanation to MTs by JICA Experts	20 staff/time	once a year
	Explanation of BMS Administrators' Manual	EE, AE, SAE of RHD	EE of BMMSD	To make RHD staff well versed in maintenance of BMS	Explanation of BMS Adminstrators' Manual with the same contents of the explanation to MTs by JICA Experts	20 staff/time	once a year

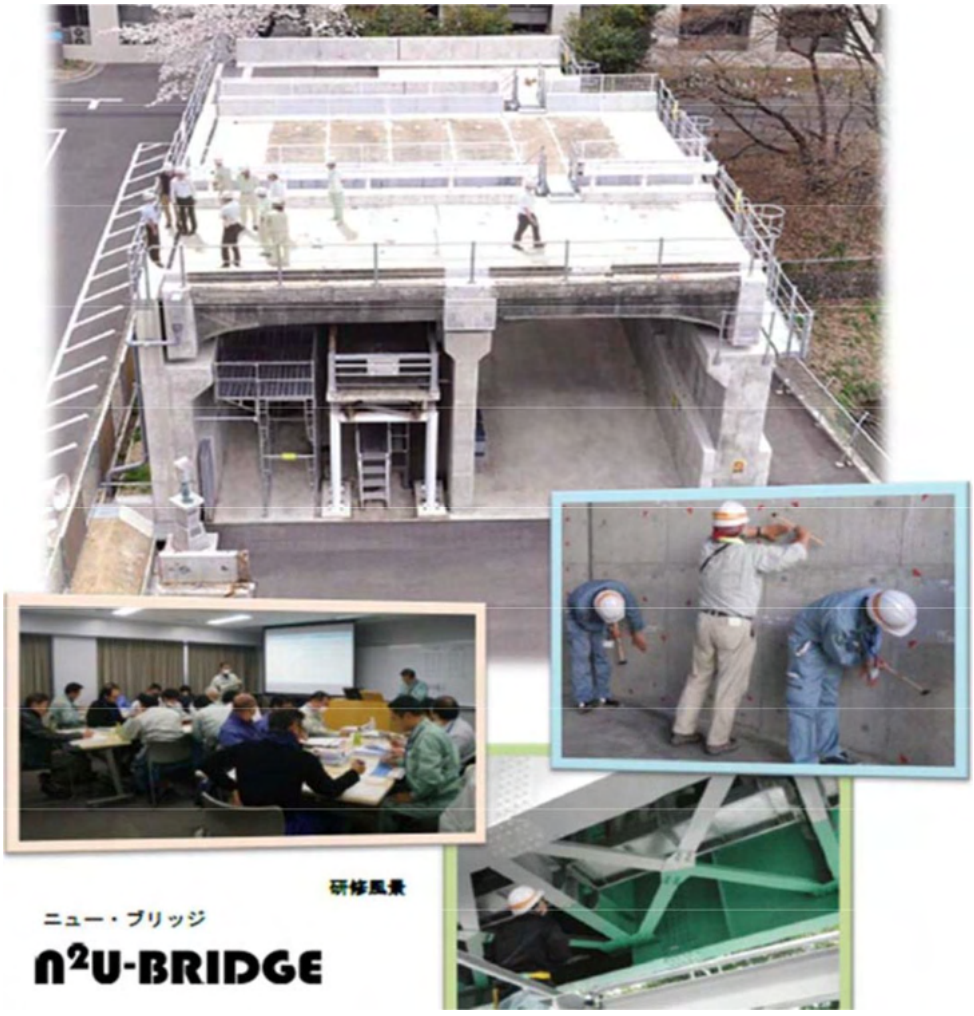
(2) Other Activities

To enhance technical ability in individual level, it would be desirable to participate in various external activities such as the followings.

(a) To participate in the seminars, workshops and lectures which public or academic bodies provide.
(b) To study and research about new material and new repair methods which are effective for bridge maintenance in cooperation with universities and public bodies.
(c) To open seminars inviting excellent engineers or professors from inside or outside of the country.
(d) To dispatch lecturers to the seminars, meetings and conferences within or outside the country.
(e) To dispatch lecturers to universities.

The following is one of bridge maintenance training courses which an university in Japan is providing.

Picture 4-1 Model Bridge for Bridge Inspection



Nagoya University in Japan is providing unique bridge inspection training course under the cooperation of NEXCO (Nippon Expressway Corporation, former Japan Highway Public Corporation) Central.

Model bridge (N2U Bridge) consists of 4 parts of removed old bridges (Steel Girder Bridge, PC Hollow Bridge, RC-T Girder Bridge and Pedestrian Bridge) and specially built sub-structures with various initial defects artificially introduced.

Nagoya University is providing three training courses, namely basic course, inspection course and evaluation course utilizing Model Bridge.

Appendix-1

Zonal Organization of RHD

Zone Number	Zone Name	Circle Name	Division Name	Sub-Division Name
1	Dhaka	Dhaka	Dhaka	1st Line Workshop Sub-Division
				Dhaka Sub-Division-1
				Dhaka Sub-Division-2
				Kallayanpur
			Gazipur	Gazipur
				Joydepur-1
				Tongi
			Manikganj	Manikganj
				Nayarhat
			Munshiganj	1-Line Workshop Sub-Division, Munshiganj
				Keraniganj
				Munshiganj
				Sreenagar
			Narayanganj	Narayanganj-1
				Narayanganj-2
				Vitikandi
			Narsingdi	Narsingdi
				Shibpur
2	Chittagong	Chittagong	Chittagong	1st Line Workshop Sub-Division, Chittagong
				Chittagong
				Fatikchari
				Sitakunda
			Cox's Bazar	Chakoria
				Cox's Bazar-1
				Cox's Bazar-2
			Dohazari	Dohazari
				Patiya
		Khagrachari	Khagrachari	1st Line Workshop Sub-Division, AE,
				Dighinara
				Khagrachari-1
				Manikchari
				Ramghar
		Rangamati	Bandarban	Bandarban-1
				Bandarban-2
			Rangamati	1st Line Workshop Sub-Division, Rangamati
				Rangamati-1
				Rangamati-2

Zone Number	Zone Name	Circle Name	Division Name	Sub-Division Name
3	Comilla	Comilla	Brahmanbaria	1st Line Workshop Sub-Division, Brahmanbaria
				Bancharampur
				Brahmanbaria
			Chandupur	Chandupur
				Hajigonj
			Comilla	1st Line Workshop Sub-Division, Comilla
				Comilla
				Gouripur
		Noakhari	Feni	Feni-1
				Feni-2
			Laxmipur	Laxmipur
				Ramgonj
			Noakhari	1st Line Workshop Sub-Division, Noakhari
				Chatkhil
				Noakhari
4	Rajshahi	Pabna	Natore	Natre-1
				Natore-2
			Pabna	1st Line Workshop Sub-Division, Pabna
				Pabna-1
				Pabna-2
			Sirajganj	1st Line Workshop, AE, Sirajganj
				Sirajganj-1
				Sirajganj-2
				Ullapara
		Rajshahi	Naogaon	1st Line Workshop Sub-Division, Naogaon
				Naogaon
				Patnitala
			Nawabganj	Nawabganj
				Shibgonj
			Rajshahi	1st Line Workshop, AE, Rajshahi
				Rajshahi-1
				Rajshahi-2

Zone Number	Zone Name	Ciecle Name	Division Name	Sub-Division Name
5	Rangpur	Bogra	Bogra	1st Line Workshop Sub-Division, Bogra
				Bogra
				Sherpur
			Gaibanda	Gaibanda
				Palashbari
			Joypurhat	Joypurhat
		Dinajpur	Dinajpur	1st Line Worhshop Sub-Division, Dinjpur
				Dinajpur
				Phulbari
			Nilphamari	Nilphamari
			Panchgarh	Panchgarh
			Thakurgaon	Thakurgaon
		Rangpur	Kurigram	Kurigram-1
				Kurigram-2
			Lalmonirhat	Larmonirhat
			Rangpur	1st Line Workshop Sub-Division, Rangpur
				Rangpur-1
				Rangpur-2
6	Kulna	Jessore	Chuadanga	Chuadanga
			Jessore	1st Line Workshop Sub-Division, Jessore
				Jessore-1
				Jessore-2
				Mechanical Sub-Division,Jessore
			Jhenaidah	1st Line Workshop, AE, Jhenaidah
				Jhenaidah
			Kushtia	Kushtia
				Mechanical Sub-Division, Kushtia
			Magura	Magura
			Meherpur	Meherpur
			Narail	Narail
		Kulna	Bagerhat	1st Line Worshop, SAE, Bagerhat
				Bagerhat-1
				Bagerhat-2
			Khulna	1st Line Workshop, AE, Khulna
				Khulna-1
				Khulna- 2
			Satkhira	1st Line Worshop Sub-Division, Satkhira
				Satkhira-1
				Satkhira-2

Zone Number	Zone Name	Circle Name	Division Name	Sub-Division Name
7	Barisal	Barisal	Barisal	1st Line Workshop Sub-Division, Barisal
				Barisal-1
				Barisal-2
			Bhola	Bhola
				Charfession
			Jhalokati	Jhalokati
		Patuakhali	Barguna	Barguna
			Patuakhali	Kuakata
				Patuakali
			Pirojpur	Kawkhali
				Pirojpur
8	Sylhet	Moulavi Bazar	Habiganj	1st Line Workshop Sub-Division, Habiganj
				Habiganj
				Shaistagonj
			Moulavi Baza	1st Line Workshop Sub-Division, Moulavi Bazar
				Kulaula
				Moulavi Bazar
				Sreemongal
		Sylhet	Sunamganj	1st Line Workshop Sub-Division, Sunamganj
				Chattak
				Sunamganj
			Sylhet	1st Line Workshop Sub-Division, Sylhet
				Biswanath
				Chandraghona
				Golapganj
				Sylhet

Zone Number	Zone Name	Circle Name	Division Name	Sub-Division Name
9	Gopalganj	Faridpur	Faridpur	1st Line Workshop Sub-Division, Faridpur
				Faridpur-1
				Faridpur-2
			Rajbari	Rajbari
		Gopalganj	Gopalganj	Bhatipara
				Gopalganj
				Kotalipara
			Madaripur	Bhanga
				Madaripur
			Sariatpur	Sariatpur
10	Mymensingh	Jamalpur	Jamalpur	Jamalpur-1
				Jamalpur-2
			Sherpur	Sherpur-1
				Sherpur-2
			Tangail	Madhupur
				Mirzapur
				Tangail
		Mymensingh	Kishoreganj	Bhairab
				Kishoreganj
				Nandail
			Mymensingh	1st Line Workshop Sub-Division, Mymensingh
				Bhaluka
				Mymensingh
				Phulpur
			Netyrokona	1st Line Workshop, AE, Netrokona
				Kendua
				Netrokona

Zone Number	Zone Name	number of circles	number of divisions	number of sub-divisions
1	Dhaka	1	6	18(16)
2	Chittagong	3	6	19(16)
3	Comilla	2	6	15(12)
4	Rajshahi	2	6	17(13)
5	Rangpur	3	10	18(15)
6	Kluna	2	10	21(14)
7	Barisal	2	6	11(10)
8	Sylhet	2	4	15(11)
9	Gopalganj	2	5	10(9)
10	Mymensingh	2	6	17(17)
Total		21	65	161(133)

NB: The number inside ( ) shows the number of sub-divisions excluding worksh

Appendix-2

Items to be Considered in Planning and Designing Stage

1. Planning

A bridge is designed with adequate design conditions and methods, constructed with adequate and quality materials in accordance with the construction specifications/standards/guidelines. In spite of such facts a bridge may fail to fulfill its expected life due to lack of durability caused by poor consideration on maintenance of the structure.

Planning of a bridge has a great contribution and affects the durability of the completed bridge. Therefore, it is important to carry out bridge planning carefully to produce appropriate design and construct a durable bridge.

Items to be considered for planning of a bridge are as follows.

1-1. Location of the Bridge

In order to avoid any damage caused by river water flow including flood, the highest water level and flooding area shall be taken into account for a bridge plan with particular attention to general and local scouring.

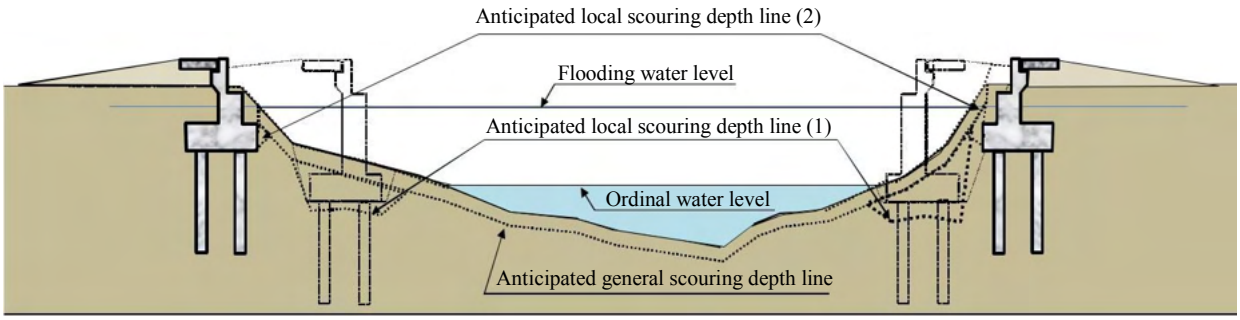


Figure-1 Avoiding the abutment within flood area

In order to avoid erosion of bank and scouring of foundations, it is better to select lower water velocity area and a straight channel area of the river alignment. In case the bridge is constructed at the straight and wider width section of the river, the longer bridge length in comparison to the bridge length at a curved or narrow section of the river will be offset by the lower life cycle cost of the bridge due to the enhanced durability and lower collapse risk.

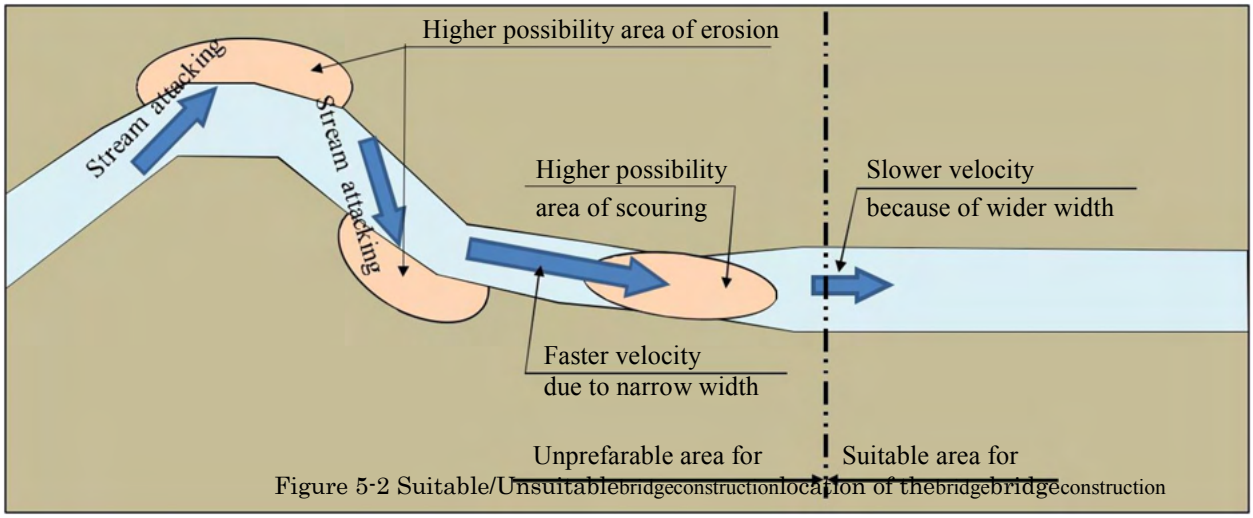


Figure 5-2 Suitable/Unsuitablebridgeconstructionlocation of thebridgebridgeconstruction

Figure-2 Planning of straight bridges

1-2. Span Arrangement

In order to avoid any damage caused by river water flow including floods, reduction of number of substructure components and length of embankment in water shall be considered at the bridge planning stage.

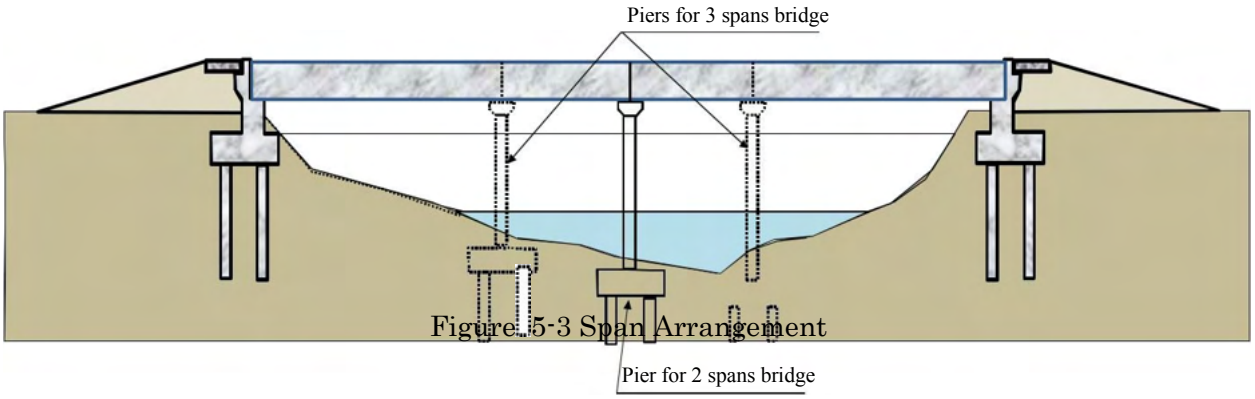


Figure 5-3 Span Arrangement

Figure-3 Reducing the number of piers within river

1-3. Superstructure Type

A RC girder has higher possibility of cracking than a PC girder. Concrete cracks will cause rebar rusting/corrosion and finally shortening of bridge serviceable life span. PC girders allow design of longer span bridges with reduction of number of piers in the river.

Hence, PC girder bridge construction is recommendable in lieu of a RC girder bridge regardless of design conditions such as necessary span length that would allow use of RC girders.

2. Designing

In order to design durable bridges, following points are to be paid attention.

2-1. Design Live Load

Many accidents like bridge collapse have been reported due to heavy traffic generated by robust economic activities.

Many bridges designed with small live load such as 5ton with no consideration of additional structural strengthening due to overloading were constructed on rural roads. Demand of heavy traffic will increase on any category of roads year by year.

⇒It is recommended that in order to avoid an accident like bridge collapse, it is imperative to design bridges with full live load.

2-2 Concrete Cover

Purpose of concrete cover is to protect rebar from corrosion caused by water, salt and other chemical contents in the air and neutralization of concrete. Thickness of concrete cover is decided based on environmental condition of surrounding area of concrete structures.

Sometimes concrete structures have rusted rebar due to lack of concrete cover. It is difficult to construct concrete structures with accurate concrete cover thickness due to inaccurate rebar erection works and impact caused by concrete casting works. In addition to the above, change of environment also affects rebar rusting. The time it takes for penetrating salts and other harmful substances to reach rebar depends on thickness of concrete cover.

⇒It is recommended to design concrete cover thickness with consideration of structure shape and construction method, labor skill level, environmental conditions of surrounding area and neutralization speed.

2-3 Matters Pertaining to Water and Drainage

Existence of water on any part of the bridge structures will affect durability of the bridge.

Ponding water: Ponding water on the deck slab will bring negative effects such as deck slab rebar rusting caused by water penetrating through cracks, car accidents due to skidding caused by reduction of friction ratio between tyres and pavement due to water on the deck surface.

⇒It is recommended to consider some slope with a minimum gradient of 0.4% on the vertical alignment to prevent ponding of water on the deck slab including the flat

sections.

Waterproofing: Cracks on the concrete deck caused by shrinkage are unavoidable yet water penetrating through the cracks will cause rebar rusting.

⇒It is thus recommended that Waterproofing layer be applied on the concrete slab.

Drainage pipe: Water on deck slab drained through drainage pipe will splash to girders/beams and cause rust of steel members.

⇒It is recommended that the length of the drainage pipes be extended such that their outlets are lower than the bottom of girder/beam.

2-4 Counter Measures against Salt Attack

Salt will penetrate into concrete and cause re bar-rusting/corrosion.

Salt penetration: Penetrating depth of salty particles included into water and air such as electrons and neutrons reach re bar depth, it cause re bar rust/corrosion seriously.

⇒It is recommended to consider enough thickness of concrete cover for re bar of the bridge members which locating in salty water area and in salty air area.

2-5 Counter Measures against the Neutralization of Concrete

Concrete will lose its protection ability of re bar from rusting due to change of its property year by year.

Neutralization: Concrete will change its property from alkali to neutral and lose its re bar protection ability from rusting.

⇒It is recommended to consider enough thickness of concrete cover for re bar or to consider cut off painting on the surface of the concrete which constructed in the bad air environment which highly containing harmful chemical particles.

2-6 Counter Measures against Scouring

Scouring of foundation such as piles and pile caps is one of the most serious defects on bridges. Bridges will lose its stability particularly at earthquake due to change of its supporting condition.

Scouring: River bed soil around a structure constructed in water flow will be scoured due to the causes such as Karman vortex. Scouring depth is depending on depth, velocity and direction of water and size of soil. Stability of structure will be affected by scouring because of change of design condition due to disappearance of sounding soil.

⇒It is recommended to consider following counter measures for scouring:

+ Protection of river bed soil from scouring by such as laying sand bags around the structure.

+ To consider enough soil cover for foundation taking anticipated scouring depth into account.

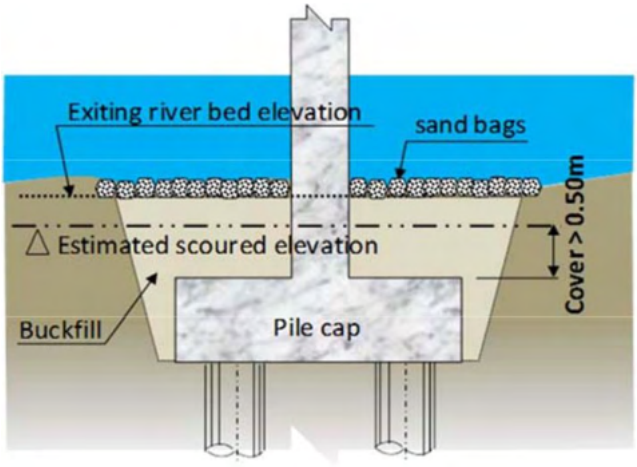


Figure-4 Countermeasures for Scouring

2-7 Counter Measures against Settlement of Backfill

Backfill soil occur settlement caused by difficulty of compaction works due to narrow space by existence of a stem wall and wing walls of the abutment.
Settlement of backfill affects traffic safety and durability of the abutment due to impact caused by unevenness of the road surface.

⇒It is recommended to consider construction of an Approach Slab at the back of the parapet to keep the road surface flat even if backfill settlement occurs.

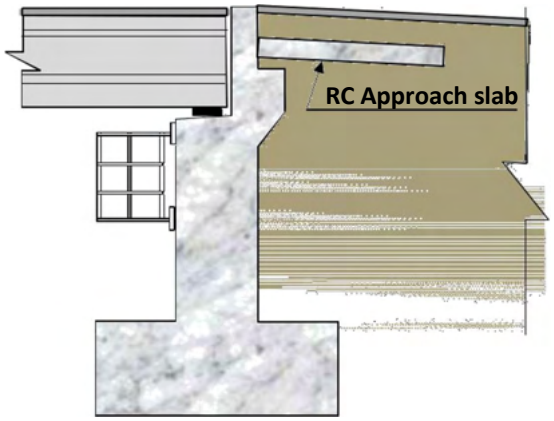


Figure-5 Counter Measure for Settlement of Backfill

2-8 Maintenance Facilities

Sufficient maintenance facilities will facilitate the easiness of maintenance works such

as Inspection, Minor repair and sometimes Major repair.

Accessibility to all bridge members affects Inspection, Routing maintenance works, and Minor maintenance works.

⇒It is recommended to consider provision of some accessing facilities such as:

+ Inspection stage with stair

+ Stepladder (temporally stage, stairs)

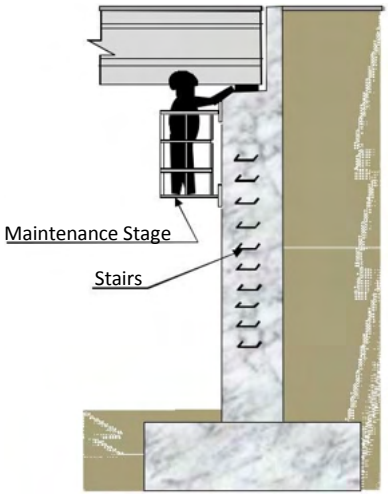


Figure-6 Inspection stage
(for a higher structure)

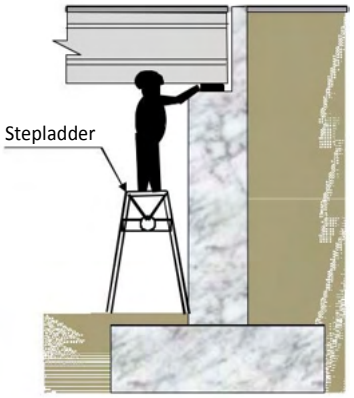


Figure-7 Stepladder
(for a lower structure)

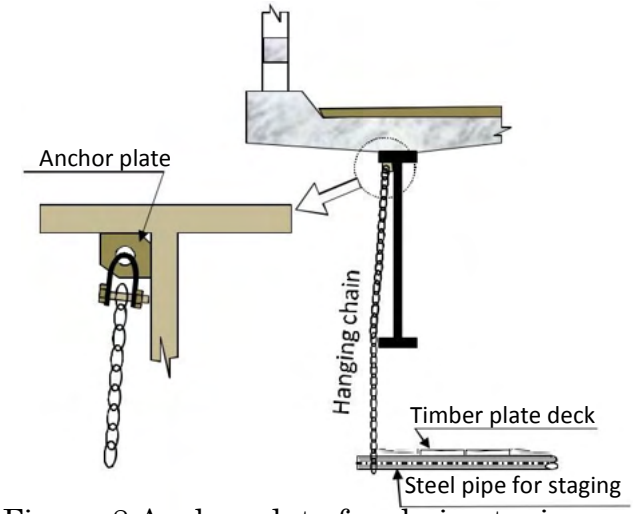


Figure-8 Anchor plate for chain staging

Figure-9 Inspection Vehicle

2-9 Prevention from Honey Comb

Many of bridges which have honey comb defects on deck slabs, girders and piers are confirmed through Bridge Condition Survey by EBBIP. Many of honey comb defects were very serious.

Deck slab (1) Deck slab (2) Girder

Figure-10 Example of honey comb

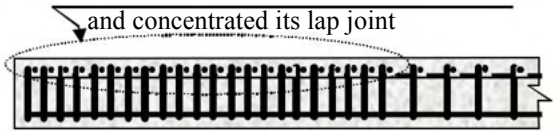
Cause of honey comb: Main cause of honey comb is lack of compaction of concrete and narrow space for concrete pouring work due to high density of re bar particularly at a girder end area where density of rebar is high due to small spacing of stirrup and its lapping.

⇒It is necessary to reduce re bar density by such as mutual lapping of stirrup re bar.

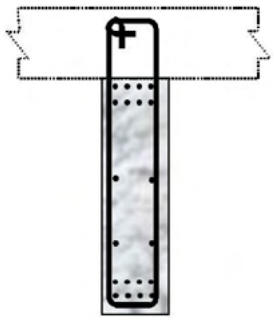
Re-bar density is too high due to
stirrups and concentrated its lap joints

Plan

high density area by stirrup
and concentrated its lap joint



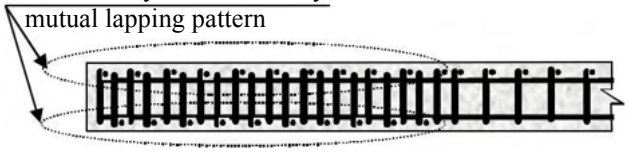
Cross section
(one side lap joint)



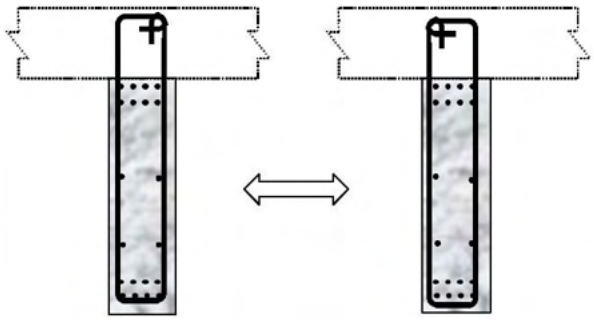
Re-bar density is reduced by mutual lap
joint location of stirrup

Plan

re bar desity is decreased by
mutual lapping pattern



Cross section
(mutual lap joint)



Repeating mutually

Figure-11 Stirrup lap location at the end area of a girder

Existence of honey comb will be confirmed easily at the time when form works removed. Remedial works of honey comb also can be carried out easily because temporary facilities for construction such as staging, stairs may be still on site.

⇒It is important to construct a durable bridge that when existence of honey comb find just after removing form works, the honey comb shall be repaired carefully and immediately.

Appendix-3

Numbers of Bridges and Culverts (as of June 2017)

Zone	Division	Nos of Culverts	Length of Culverts (m)	Nos of Bridges	Length of Bridges (m)
Dhaka	Dhaka	45	775	39	4399
	Manikganj	100	1368	115	5623
	Gazipur	179	837	81	4180
	Narsingdi	277	1306	65	4308
	Narayanganj	100	637	152	11628
	Munshiganj	57	436	136	6102
Mymensingh	Kishoreganj	391	1629	36	2113
	Netrokona	241	1524	47	2929
	Sherpur	351	1370	93	5603
	Mymensingh	466	1623	63	4218
	Tangail	176	1367	146	6843
	Jamalpur	97	351	45	2703
Chittagong	Rangamati	35	151	27	1011
	Dohazari	305	1812	63	3206
	Bandarban	160	528	183	5382
	Khagrachari	137	823	89	3186
	Cox's Bazar	553	2352	282	8960
	Chittagong	559	2981	157	5196
Sylhet	Moulvibazar	388	2165	78	2727
	Habiganj	370	1941	82	4038
	Sunamganj	158	1255	86	5220
	Sylhet	519	2475	161	9014
Comilla	Chandpur	199	1097	39	1860
	Lakshmipur	170	713	38	972
	Feni	333	977	55	2525
	Noakhali	237	868	50	906
	Comilla	425	2563	157	4572
	Brahmanbaria	123	783	174	5537
Rajshahi	Sirajganj	254	2120	131	7975
	Rajshahi	435	1519	50	1407
	Pabna	220	1404	30	3927
	Nawabgonj	207	710	17	1533
	Natore	209	649	45	2435
	Naogaon	389	1485	85	2761

Numbers of Bridges and Culverts (as of June 2017) 2/2

Zone	Division	Nos of Culverts	Length of Culverts (m)	Nos of Bridges	Length of Bridges (m)
Rangpur	Nilphamari	149	610	48	2017
	Bogra	422	1794	72	3745
	Gaibandha	141	825	38	2029
	Lalmonirhat	89	366	24	1847
	Kurigram	115	713	27	1918
	Panchagarh	134	580	19	1772
	Thakurgaon	173	715	5	157
	Joypurhat	250	741	25	795
	Rangpur	250	989	78	2372
	Dinajpur	461	1825	45	2982
Gopalganj	Shariatpur	123	916	46	1746
	Rajbari	58	463	7	274
	Faridpur	140	950	81	4038
	Madaripur	107	839	57	3609
	Gopalganj	188	1093	80	3878
Barisal	Patuakhali	144	663	43	3603
	Barisal	201	1061	75	4540
	Bhola	106	642	17	572
	Pirohjpur	195	920	170	5667
	Jhalokathi	381	1687	75	3502
	Barguna	136	483	33	1006
Khulna	Satkhira	232	631	36	1971
	Meherpur	68	212	7	342
	Chuadanga	83	259	15	739
	Khulna	286	1487	16	2898
	Narail	180	558	15	679
	Magura	165	737	19	794
	Kushtia	169	516	27	1503
	Jessor	284	637	24	884
	Bagerhat	148	787	47	2250
	Jhenaidah	371	1247	36	1201
	Total Nos. & Length	**14814**	**70537**	**4404**	**210329**

Summary of Bridges and Culverts per Type (as of June 2017)

Item	Bridge Category	Number	Length (m)	Average Length (m)
1	RC Girder Bridge	1,772	56,838.88	32.1
2	PC Girder Bridge	1,036	85,787.59	82.8
3	PC Box Girder Bridge	7	10,396.60	1485.2
4	RC Box Girder Bridge	6	1,026.74	171.1
5	RC Bridge	414	11,278.68	27.2
6	Arch Masonry Bridge	66	535.06	8.1
7	Steel Truss Bridge with RC Slab	36	4,070.04	113.1
8	Steel Truss Bridge with Steel Deck	107	6,240.74	58.3
9	Steel Truss Bridge with Timber Deck	3	48.00	16.0
10	Bailey Bridge with Steel Deck	855	31,806.74	37.2
11	Bailey Bridge with Timber Deck	1	24.39	24.4
12	Bridge with Steel Beam & RC Deck	101	2,275.25	22.5
Sub-total		4,404	210,328.71	47.8

Item	Culvert Category	Number	Length (m)	Average Length (m)
1	Box Culvert	12,366	61,447.59	5.0
2	Slab Culvert	2,376	8,849.38	3.7
3	Brick Masonry Culvert	72	240.32	3.3
Sub-total		14,814	70,537	4.8

Grand Total	19,218	280,865.71	14.6

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