APPENDIX 8.

PAVEMENT DESIGN

AASHTO Pavement Design (Asphalt Pavemment)
Kanchpur, Meghna, Gumti

$$\log_{10}W_{18}=Z_R*S_0+9.36*\log_{10}(SN+1)-0.20+\log_{10}(\Delta PSI/(4.2-1.5))/((0.40+1094/(SN+1)^{5.19})+2.32*\log_{10}M_R-8.07$$

*Effective Resilient Modulus of Subgrade (psi)	M_R=	1,500*CBR
*Reliability: (middle range of Interstate/Rural)		90 %
*Standard Deviation:	Z_R =	-1.282
		0.45
*Initial Pavement Serviceability Index for the Asphalt Pavement:	Po=	4.2
*Terminal Serviceability Index:	Pt=	2.5
*Δ PSI = Po -Pt =		1.7
*Cumulative traffic (ESAL)		

ESAL for 20 years = 229,000,000

Input Data for SN

W_{18}	$\log_{10}W_{18}$	Z_R	S_0	Z_R*S_0	Δ PSI	C=$\log_{10}$(Δ PSI /(4.2-1.5))	CBR	M_R	$\log_{10}M_R$
2.29E+08	**8.360**	-1.282	0.45	-0.577	1.7	-0.201	5	7,500	3.875

$$Y=Z_R*S_0+9.36*\log_{10}(SN+1)-0.20+\log_{10}(\Delta PSI/(4.2-1.5))/((0.40+1094/(SN+1)^{5.19})+2.32*\log_{10}M_R-8.07$$

Computed SN

CBR= 5

SN	A=Z_R*S_o	B=9.36*$\log_{10}$(SN+1)-0.2	C	D=0.40+1094/$(SN+1)^{5.19}$	E=C/D	F=2.32*$\log_{10}M_R$-8.07	Y
7.500	-0.577	8.499	-0.201	0.416	-0.482	0.920	8.360
7.510	-0.577	8.504	-0.201	0.416	-0.483	0.920	8.365
7.520	-0.577	8.509	-0.201	0.416	-0.483	0.920	8.369

Proposed Pavement Structure (20 Years)

Pavement Layer	a	m	CBR= 5		
			Thickness (inch)		SN
			inch	cm	
Asphalt Concrete Surface Course	0.44	1.00	1.98	**5.00**	0.87
Asphalt Concrete Binder Course	0.36	1.00	7.90	**20.00**	2.84
Base Course	0.14	1.05	13.80	**35.00**	2.03
Sub base	0.11	1.05	15.75	**40.00**	1.82
Total	-		**39.43**	**100.00**	7.56

> **7.510** **OK**

AASHTO Pavement Design (Asphalt Pavemment)
Kanchpur, Meghna, Gumti

$$\log_{10}W_{18}=Z_R*S_0+9.36*\log_{10}(SN+1)-0.20+\log_{10}(\Delta PSI/(4.2-1.5))/((0.40+1094/(SN+1)^{5.19})+2.32*\log_{10}M_R-8.07$$

*Effective Resilient Modulus of Subgrade (psi)	M_R=	1,500*CBR
*Reliability: (middle range of Interstate/Rural)		95 %
*Standard Deviation:	Z_R =	-1.645
		0.45
*Initial Pavement Serviceability Index for the Asphalt Pavement:	Po=	4.2
*Terminal Serviceability Index:	Pt=	2.5
*Δ PSI = Po -Pt =		1.7
*Cumulative traffic (ESAL)		

ESAL for 10 years = 102,000,000

Input Data for SN

W_{18}	$\log_{10}W_{18}$	Z_R	S_0	Z_R*S_0	Δ PSI	C=$\log_{10}$(Δ PSI /(4.2-1.5))	CBR	M_R	$\log_{10}M_R$
1.02E+08	**8.009**	-1.645	0.45	-0.740	1.7	-0.201	5	7,500	3.875

$$Y=Z_R*S_0+9.36*\log_{10}(SN+1)-0.20+\log_{10}(\Delta PSI/(4.2-1.5))/((0.40+1094/(SN+1)^{5.19})+2.32*\log_{10}M_R-8.07$$

Computed SN

CBR= 5

SN	A=Z_R*S_o	B=9.36*$\log_{10}$(SN+1)-0.2	C	D=0.40+1094/$(SN+1)^{5.19}$	E=C/D	F=2.32*$\log_{10}M_R$-8.07	Y
7.100	-0.740	8.303	-0.201	0.421	-0.477	0.920	8.006
7.110	-0.740	8.308	-0.201	0.421	-0.477	0.920	**8.011**
7.120	-0.740	8.313	-0.201	0.421	-0.477	0.920	8.016

Proposed Pavement Structure (10 Years)

Pavement Layer	a	m	CBR= 5		
			Thickness (inch)		SN
			inch	cm	
Bituminous Wearing Course	0.44	1.00	1.98	**5.00**	0.87
Bituminous Binder Course	0.36	1.00	7.50	**19.00**	2.70
Base Course	0.14	1.05	11.85	**30.00**	1.74
Sub base	0.11	1.05	15.75	**40.00**	1.82
Total	-		**37.08**	**94.00**	7.13

> **7.110** **OK**

Estimation of Construction Cost of Pavement for 20 years

No	item Name	ence of	Unit	Area	thickness	Qty.	Adopted Unit Rate in yen (2012)	Amount (in Yen)	Amount (in BDT)
(A)	Pavement								
1	Wearing Course		cu.m	1m2	5	0.05	16,000	800	833
2	Binder Course		cu.m		20	0.20	17,000	3,400	3,542
3	Base Course		cu.m		35	0.35	9,000	3,150	3,281
4	Sub-Base		cu.m		40	0.40	4,100	1,640	1,708
5	Sub-Grade		cu.m		100	1.00	1,100	1,100	1,146
6	Bituminous prime coat		qu.m			1.00	110	110	115
7	Bituminous tack coat		qu.m			1.00	30	30	31
	Sub-total							10,230	10,656
(B)	overlay(Wearing+Binder) for 75 years		time			2.75	4,340	11,935	12,432
	cut for 75 years		time			2.75	5,500	15,125	15,755
	Sub-total							27,060	28,188
	Total							37,290	38,844

Estimation of Construction Cost of Pavement for 10 years

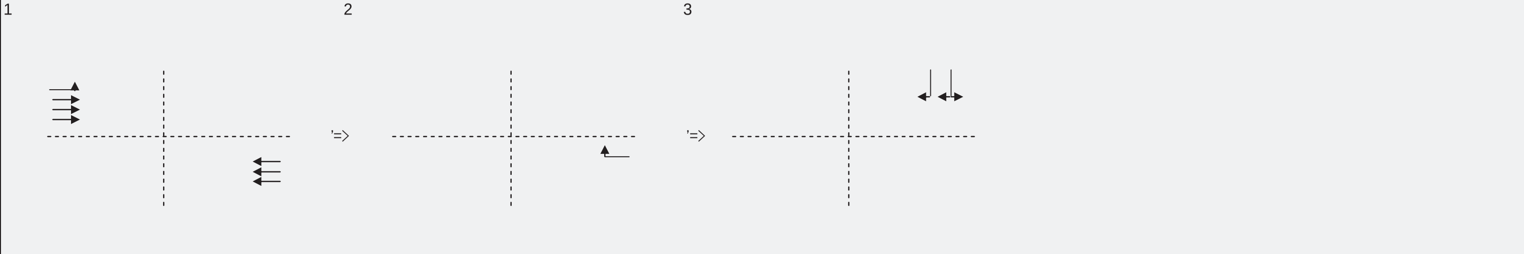
No	item Name	ence of	Unit	Area	thickness	Qty.	Adopted Unit Rate in yen (2012)	Amount (in Yen)	Amount (in BDT)
(A)	Pavement								
1	Wearing Course		cu.m	1m2	5	0.05	16,000	800	833
2	Binder Course		cu.m		19	0.19	17,000	3,230	3,365
3	Base Course		cu.m		30	0.30	9,000	2,700	2,813
4	Sub-Base		cu.m		40	0.40	4,100	1,640	1,708
5	Sub-Grade		cu.m		100	1.00	1,100	1,100	1,146
6	Bituminous prime coat		qu.m			1.00	110	110	115
7	Bituminous tack coat		qu.m			1.00	30	30	31
	Sub-total							9,610	10,010
(B)	overlay(Wearing+Binder) for 75 years		time			6.5	4,170	27,105	28,234
	cut for 75 years		time			6.5	5,500	35,750	37,240
	Sub-total							62,855	65,474
	Total							72,465	75,484

APPENDIX 9.

RESULT OF INTERSECTION ANALYSIS

Kanchpur Intersection (Year 2022) - Option-1

Traffic Volume

	East Bound			South Bound			West Bound		
	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn
Flow Rate (pcu/h)	685	1,197		546		755		1,974	505
Lane Group	LT	TH	RT	LT	TH	RT	LT	TH	RT
Phase Number	1/2/3	1		3		3		1	2
Phasing									
Flow Rate in Lane Group (v) (veh/h)	685	1,197		546		755		1,974	505

Saturation Flow

	EB LT	EB TH	EB RT	SB LT	SB TH	SB RT	WB LT	WB TH	WB RT
S_o: Base Sturation Flow	1,900	1,900		1,900		1,900		1,900	1,900
N: Number of Lanes	1	3		1		1		3	1
f_w: Lane Width Adjustment Factor	1.000	1.000		1.000		1.000		1.000	1.000
f_{HV}: Heavy-vehicle Adjustment Factor	0.651	0.676		0.840		0.666		0.652	0.750
f_G: Grade Adjustment Factor	1.000	1.000		1.000		1.000		1.000	1.000
f_P: Parking Adjustment Factor	1.000	1.000		1.000		1.000		1.000	1.000
f_{BB}: Bus Blockage Adjustment Factor	1.000	1.000		1.000		1.000		1.000	1.000
f_A: Area Type Adjustment Factor	1.000	1.000		1.000		1.000		1.000	1.000
f_{LU}: Lane Utilization Adjustment Factor	1.000	0.908		1.000		1.000		0.908	1.000
f_{LT}: Left-turn Adjustment Factor	1.000	1.000		1.000		0.950		1.000	0.950
f_{RT}: Right-turn Adjustment Factor	0.850	1.000		0.850		1.000		1.000	1.000
f_{Lpb}: Left-turn Ped/Bike Adjustment Factor	1.000	1.000		1.000		1.000		1.000	1.000
f_{Rpb}: Right-turn Ped/Bike Adjustment Factor	1.000	1.000		1.000		1.000		1.000	1.000
Adjusted Saturation Flow (pcu/h)	**1,051**	**3,499**		**1,357**		**1,202**		**3,374**	**1,354**

Capacity Analysis

	EB LT	EB TH	EB RT	SB LT	SB TH	SB RT	WB LT	WB TH	WB RT
Cycle Length (s)	150	150		150		150		150	150
Effective Green Time (s)	150	66		46		46		66	26
Los Time (s)	4	4		4		4		4	4
Green Ratio	1.000	0.440		0.307		0.307		0.440	0.173
Lane Group Capacity (c) (pcu/h)	1,051	1,540		416		369		1,485	235
v/c Ratio for Lane Group	**0.651**	**0.777**		**1.312**		**2.049**		**1.330**	**2.152**

	EB LT	EB TH	EB RT	SB LT	SB TH	SB RT	WB LT	WB TH	WB RT
Flow Ratio	0.651	0.342		0.402		0.628		0.585	0.373
Critical Lane Group/Phase						*		*	*
Sum of Critical Flow Ratios	1.586								
v/c Ratio for Intersection	**1.724**								

Kanchpur Intersection (Year 2022)- Option-2

Traffic Volume

	East Bound			South Bound			West Bound		
	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn
Flow Rate (pcu/h)	685	1,197		546		755		1,974	505
Lane Group	LT	TH	RT	LT	TH	RT	LT	TH	RT
Phase Number	1/2	1		2		2		1	
Phasing	1		2						
Flow Rate in Lane Group (v) (veh/h)	685	1,197		546		755		1,974	

Saturation Flow

	EB LT	EB TH	EB RT	SB LT	SB TH	SB RT	WB LT	WB TH	WB RT
S_o: Base Sturation Flow	1,900	1,900		1,900		1,900		1,900	
N: Number of Lanes	1	3		1		1		3	
f_w: Lane Width Adjustment Factor	1.000	1.000		1.000		1.000		1.000	
f_{HV}: Heavy-vehicle Adjustment Factor	0.651	0.676		0.840		0.666		0.652	
f_G: Grade Adjustment Factor	1.000	1.000		1.000		1.000		1.000	
f_P: Parking Adjustment Factor	1.000	1.000		1.000		1.000		1.000	
f_{BB}: Bus Blockage Adjustment Factor	1.000	1.000		1.000		1.000		1.000	
f_A: Area Type Adjustment Factor	1.000	1.000		1.000		1.000		1.000	
f_{LU}: Lane Utilization Adjustment Factor	1.000	0.908		1.000		1.000		0.908	
f_{LT}: Left-turn Adjustment Factor	1.000	1.000		1.000		0.950		1.000	
f_{RT}: Right-turn Adjustment Factor	0.850	1.000		0.850		1.000		1.000	
f_{Lpb}: Left-turn Ped/Bike Adjustment Factor	1.000	1.000		1.000		1.000		1.000	
f_{Rpb}: Right-turn Ped/Bike Adjustment Factor	1.000	1.000		1.000		1.000		1.000	
Adjusted Saturation Flow (pcu/h)	**1,051**	**3,499**		**1,357**		**1,202**		**3,374**	

Capacity Analysis

	EB LT	EB TH	EB RT	SB LT	SB TH	SB RT	WB LT	WB TH	WB RT
Cycle Length (s)	150	150		150		150		150	
Effective Green Time (s)	150	80		62		62		80	
Los Time (s)	4	4		4		4		4	
Green Ratio	1.000	0.533		0.413		0.413		0.533	
Lane Group Capacity (c) (pcu/h)	1,051	1,866		561		497		1,799	
v/c Ratio for Lane Group	**0.651**	**0.641**		**0.973**		**1.520**		**1.097**	

	EB LT	EB TH	EB RT	SB LT	SB TH	SB RT	WB LT	WB TH	WB RT
Flow Ratio	0.651	0.342		0.402		0.628		0.585	
Critical Lane Group/Phase						*		*	
Sum of Critical Flow Ratios	1.213								
v/c Ratio for Intersection	**1.282**								

Kanchpur Intersection (Year 2022)- Option-2 (Improved)

Traffic Volume

	East Bound			South Bound			West Bound		
	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn
Flow Rate (pcu/h)	685	1,197				755		1,974	505
Lane Group	LT	TH	RT	LT	TH	RT	LT	TH	RT
Phase Number	1/2	1				2		1	
Phasing	1 		2						
Flow Rate in Lane Group (v) (veh/h)	685	1,197				755		1,974	

Saturation Flow

S_o: Base Sturation Flow	1,900	1,900				1,900		1,900	
N: Number of Lanes	1	3				2		3	
f_w: Lane Width Adjustment Factor	1.000	1.000				1.000		1.000	
f_{HV}: Heavy-vehicle Adjustment Factor	0.651	0.676				0.666		0.652	
f_G: Grade Adjustment Factor	1.000	1.000				1.000		1.000	
f_P: Parking Adjustment Factor	1.000	1.000				1.000		1.000	
f_{BB}: Bus Blockage Adjustment Factor	1.000	1.000				1.000		1.000	
f_A: Area Type Adjustment Factor	1.000	1.000				1.000		1.000	
f_{LU}: Lane Utilization Adjustment Factor	1.000	0.908				1.000		0.908	
f_{LT}: Left-turn Adjustment Factor	1.000	1.000				0.950		1.000	
f_{RT}: Right-turn Adjustment Factor	0.850	1.000				1.000		1.000	
f_{Lpb}: Left-turn Ped/Bike Adjustment Factor	1.000	1.000				1.000		1.000	
f_{Rpb}: Right-turn Ped/Bike Adjustment Factor	1.000	1.000				1.000		1.000	
Adjusted Saturation Flow (pcu/h)	**1,051**	**3,499**				**2,403**		**3,374**	

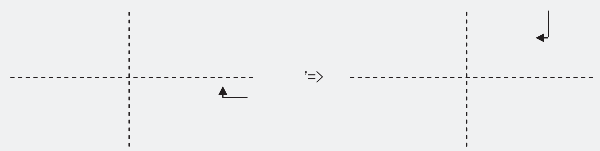
Capacity Analysis

Cycle Length (s)	150	150				150		150	
Effective Green Time (s)	150	90				52		90	
Los Time (s)	4	4				4		4	
Green Ratio	1.000	0.600				0.347		0.600	
Lane Group Capacity (c) (pcu/h)	1,051	2,100				833		2,024	
v/c Ratio for Lane Group	**0.651**	**0.570**				**0.906**		**0.975**	

Flow Ratio	0.651	0.342				0.314		0.585	
Critical Lane Group/Phase						*		*	
Sum of Critical Flow Ratios	0.899								
v/c Ratio for Intersection	**0.950**								

Kanchpur Intersection (Year 2022)- Option-4,5,6

Traffic Volume

	East Bound			South Bound			West Bound		
	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn
Flow Rate (pcu/h)	685	1,197		546		755		1,974	505
Lane Group	LT	TH	RT	LT	TH	RT	LT	TH	RT
Phase Number						2			1
Phasing	1 		2						
Flow Rate in Lane Group (v) (veh/h)						755			505

Saturation Flow

S_o: Base Sturation Flow						1,900			1,900
N: Number of Lanes						1			1
f_w: Lane Width Adjustment Factor						1.000			1.000
f_{HV}: Heavy-vehicle Adjustment Factor						0.666			0.750
f_G: Grade Adjustment Factor						1.000			1.000
f_P: Parking Adjustment Factor						1.000			1.000
f_{BB}: Bus Blockage Adjustment Factor						1.000			1.000
f_A: Area Type Adjustment Factor						1.000			1.000
f_{LU}: Lane Utilization Adjustment Factor						1.000			1.000
f_{LT}: Left-turn Adjustment Factor						0.950			0.950
f_{RT}: Right-turn Adjustment Factor						1.000			1.000
f_{Lpb}: Left-turn Ped/Bike Adjustment Factor						1.000			1.000
f_{Rpb}: Right-turn Ped/Bike Adjustment Factor						1.000			1.000
Adjusted Saturation Flow (pcu/h)						**1,202**			**1,354**

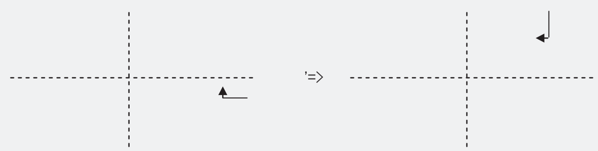
Capacity Analysis

Cycle Length (s)						150			150
Effective Green Time (s)						90			52
Los Time (s)						4			4
Green Ratio						0.600			0.347
Lane Group Capacity (c) (pcu/h)						721			469
v/c Ratio for Lane Group						**1.047**			**1.076**

Flow Ratio						0.628			0.373
Critical Lane Group/Phase						*			*
Sum of Critical Flow Ratios	1.001								
v/c Ratio for Intersection	**1.058**								

Kanchpur Intersection (Year 2022)- Option-4,5,6(Improved)

Traffic Volume

	East Bound			South Bound			West Bound		
	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn
Flow Rate (pcu/h)	685	1,197		546		755		1,974	505
Lane Group	LT	TH	RT	LT	TH	RT	LT	TH	RT
Phase Number						2			1
Phasing	1		2 						
Flow Rate in Lane Group (v) (veh/h)						755			505

Saturation Flow

S_o: Base Sturation Flow						1,900			1,900
N: Number of Lanes						1			2
f_w: Lane Width Adjustment Factor						1.000			1.000
f_{HV}: Heavy-vehicle Adjustment Factor						0.666			0.750
f_G: Grade Adjustment Factor						1.000			1.000
f_P: Parking Adjustment Factor						1.000			1.000
f_{BB}: Bus Blockage Adjustment Factor						1.000			1.000
f_A: Area Type Adjustment Factor						1.000			1.000
f_{LU}: Lane Utilization Adjustment Factor						1.000			0.971
f_{LT}: Left-turn Adjustment Factor						0.950			0.950
f_{RT}: Right-turn Adjustment Factor						1.000			1.000
f_{Lpb}: Left-turn Ped/Bike Adjustment Factor						1.000			1.000
f_{Rpb}: Right-turn Ped/Bike Adjustment Factor						1.000			1.000
Adjusted Saturation Flow (pcu/h)						**1,202**			**2,630**

Capacity Analysis

Cycle Length (s)						150			150
Effective Green Time (s)						100			42
Los Time (s)						4			4
Green Ratio						0.667			0.280
Lane Group Capacity (c) (pcu/h)						801			736
v/c Ratio for Lane Group						**0.942**			**0.686**

Flow Ratio						0.628			0.192
Critical Lane Group/Phase						*			*
Sum of Critical Flow Ratios					0.820				
v/c Ratio for Intersection					**0.867**				

Kanchpur Intersection (Year 2024)- Option-2(Improved)

Traffic Volume

	East Bound			South Bound			West Bound		
	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn
Flow Rate (pcu/h)	766	1,338				844		2,206	564
Lane Group	LT	TH	RT	LT	TH	RT	LT	TH	RT
Phase Number	1/2	1				2		1	
Phasing	1 	2							
Flow Rate in Lane Group (v) (veh/h)	766	1,338				844		2,206	

Saturation Flow

S_o: Base Sturation Flow	1,900	1,900				1,900		1,900	
N: Number of Lanes	1	3				2		3	
f_w: Lane Width Adjustment Factor	1.000	1.000				1.000		1.000	
f_{HV}: Heavy-vehicle Adjustment Factor	0.651	0.676				0.666		0.652	
f_G: Grade Adjustment Factor	1.000	1.000				1.000		1.000	
f_P: Parking Adjustment Factor	1.000	1.000				1.000		1.000	
f_{BB}: Bus Blockage Adjustment Factor	1.000	1.000				1.000		1.000	
f_A: Area Type Adjustment Factor	1.000	1.000				1.000		1.000	
f_{LU}: Lane Utilization Adjustment Factor	1.000	0.908				1.000		0.908	
f_{LT}: Left-turn Adjustment Factor	1.000	1.000				0.950		1.000	
f_{RT}: Right-turn Adjustment Factor	0.850	1.000				1.000		1.000	
f_{Lpb}: Left-turn Ped/Bike Adjustment Factor	1.000	1.000				1.000		1.000	
f_{Rpb}: Right-turn Ped/Bike Adjustment Factor	1.000	1.000				1.000		1.000	
Adjusted Saturation Flow (pcu/h)	**1,051**	**3,499**				**2,403**		**3,374**	

Capacity Analysis

Cycle Length (s)	150	150				150		150	
Effective Green Time (s)	150	90				52		90	
Los Time (s)	4	4				4		4	
Green Ratio	1.000	0.600				0.347		0.600	
Lane Group Capacity (c) (pcu/h)	1,051	2,100				833		2,024	
v/c Ratio for Lane Group	**0.729**	**0.637**				**1.013**		**1.090**	

Flow Ratio	0.729	0.382				0.351		0.654	
Critical Lane Group/Phase						*		*	
Sum of Critical Flow Ratios	1.005								
v/c Ratio for Intersection	**1.062**								

Kanchpur Intersection (Year 2022)- Option-4,5,6(Improved)

Traffic Volume

	East Bound			South Bound			West Bound		
	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn
Flow Rate (pcu/h)	766	1,338		610		844		2,206	564
Lane Group	LT	TH	RT	LT	TH	RT	LT	TH	RT
Phase Number						2			1
Phasing	1 		2						
Flow Rate in Lane Group (v) (veh/h)						844			564

Saturation Flow

S_o: Base Sturation Flow						1,900			1,900
N: Number of Lanes						1			2
f_w: Lane Width Adjustment Factor						1.000			1.000
f_{HV}: Heavy-vehicle Adjustment Factor						0.666			0.750
f_G: Grade Adjustment Factor						1.000			1.000
f_P: Parking Adjustment Factor						1.000			1.000
f_{BB}: Bus Blockage Adjustment Factor						1.000			1.000
f_A: Area Type Adjustment Factor						1.000			1.000
f_{LU}: Lane Utilization Adjustment Factor						1.000			0.971
f_{LT}: Left-turn Adjustment Factor						0.950			0.950
f_{RT}: Right-turn Adjustment Factor						1.000			1.000
f_{Lpb}: Left-turn Ped/Bike Adjustment Factor						1.000			1.000
f_{Rpb}: Right-turn Ped/Bike Adjustment Factor						1.000			1.000
Adjusted Saturation Flow (pcu/h)						**1,202**			**2,630**

Capacity Analysis

Cycle Length (s)						150			150
Effective Green Time (s)						106			36
Los Time (s)						4			4
Green Ratio						0.707			0.240
Lane Group Capacity (c) (pcu/h)						849			631
v/c Ratio for Lane Group						**0.994**			**0.894**

Flow Ratio						0.702			0.214
Critical Lane Group/Phase						*			*
Sum of Critical Flow Ratios	0.917								
v/c Ratio for Intersection	**0.968**								

APPENDIX 10.

AXLE LOAD SURVEY

Axle load survey results obtained from Gumti toll gate

Date	Axle no.	Max load (tf)	Min load (tf)
26.02.2012	2	33.87	
	2		24.45
25.02.2012	3	37.91	
	2		2.59
25.02.2012	3	37.5	
	2		22.51
24.02.2012	3	50.86	
	2		21.93
24.02.2012	3	48.55	
	2		24.15
24.02.2012	3	45.91	
	2		2.583
23.02.2012	2	37.1	
	2		21.37
23.02.2012	3	48.76	
	2		22.6
23.02.2012	2	35.02	
	2		23.81
22.02.2012	3	46.34	
	2		22.8
22.02.2012	2	34.21	
	2		3.48
21.02.2012	2	35.05	
	2		2.6
20.02.2012	-	33.77	
	-		14.97
20.02.2012	-	30.69	
	-		24.17
19.02.2012	-	33.57	
	-		25.12
19.02.2012	-	33.72	
	-		2.583
19.02.2012	-	31.33	
	-		2.557
18.02.2012	3	31.82	
	2		20.83
17.02.2012	3	44.94	
	2		25.1
17.02.2012	3	53.08	
	2		24.29
17.02.2012	2	54.7	
	2		24.02
16.02.2012	2	47	
	2		24.03
16.02.2012	2	33.32	
	2		25.97
15.02.2012	2	49.98	
	2		25.16
15.02.2012	3	60.83	
	2		2.538
14.02.2012	2	30.64	
	2		24.55
14.02.2012	3	45.25	
	2		23.18
14.02.2012	3	56.2	
	2		25.06
13.02.2012	2	42.15	
	2		24.38
14.02.2012	2	34.18	
	2		21.5

APPENDIX 11.

APPLICABILITY OF WEATHERING STEEL IN BANGLADESH

A11. APPLICABILITY OF WEATHERING STEEL IN BANGLADESH

11.1 Track Record of Weathering Steel

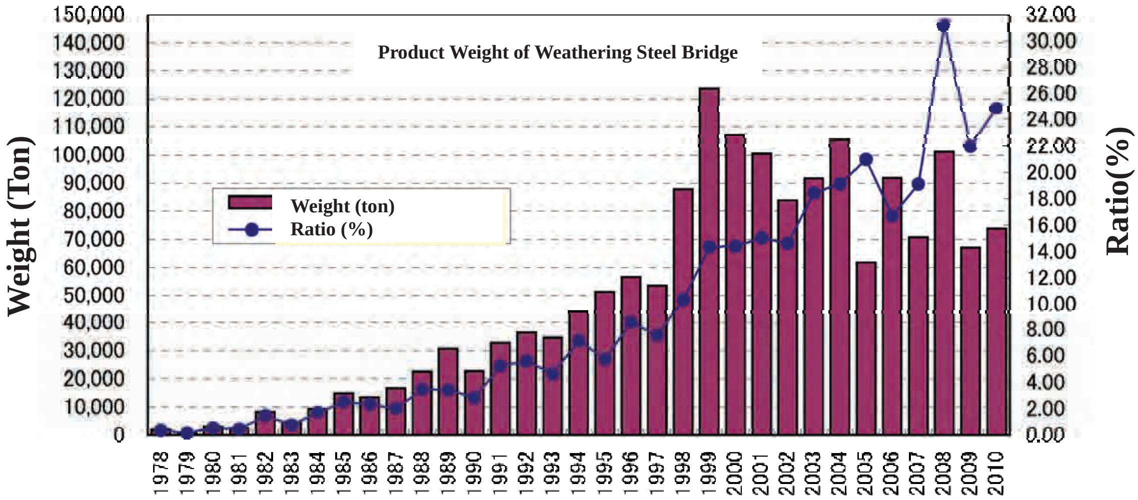
The introduction of high-performance and high-strength Weathering Steel (WS) that does not require panting, has drastically increased the number of steel bridges being built through the world. In order to get an idea on their track record in the world, some records of usages in USA and Japan are summarized in Table A11.1.1. These records are taken as reference to find out their increasing application trend. In USA, the weathering steel was launched to sale in 1933 and started to apply as weathering steel bridge in 1964. Consequently, their record of construction as of 2000 ranges 40%~50% of total bridge construction.

In Japan, the weathering steel was launched to sale in 1957 and started to apply as weathering steel bridge in 1968. Afterwards, several joint researches were conducted to set up design criteria and prepare construction manual. Based on available data as of FY 2010 (Figure A.11.1.1), the used ratio of weathering steels to total steel bridges has increased rapidly in Japan and reached more than 30%.

Table A11.1.1 History of weathering steel bridge

Year	USA	Year	Japan
1933	Launch the sale of weathering steel		
		1957	Launch the sale of weathering Steel
1964	Starting to apply weathering steel to Bridges		
		1968	Starting to apply weathering steel to Bridges Established in JIS
		1980	Construction record（0.6%）
		1981	Undertake joint research (investigation of effect of windborne salt accumulation)
		1993	Report of joint Research (≦0.05mdd)（Design and Construction Manual（(draft revisions)）
2000	Construction record（40～50%:300,000～400,000 Ton）		
		2010	Construction record（25%:70,000 Ton）

Source: Japan Association of Steel Bridge Construction



Researched by Japan Bridge Association

Figure A11.1.1 Product weight of weathering steel bridges in Japan

11.2 Merit of Weathering Steel Application

If the bridge superstructure is planned to fabricate with steel material, then a question will arise what type of steel material is applicable with respect to site environment. In order to clarify this issue, a cost comparison between ordinary steel and weathering steel is shown in Table A11.2.1 in accordance with their construction cost, maintenance cost and life cycle cost. If the cost is precisely examined, it can be seen that the maintenance cost to be incurred for weathering steel differs significantly from that of ordinary steel, even though their construction cost seems to be same in initial stage. This is because the weathering steel requires least frequency of maintenance works.

Furthermore, based on a trial cost simulation in Japan, a life cycle cost comparison between ordinary steel and weathering steel is schematically shown in Figure A11.2.1. It represents that the life cycle cost index of ordinary steel is 14.6 whereas that of weathering steel is 3.4. Therefore, the weathering steel can reduce the life cycle cost mostly. Consequently, if some key issues such as protection of steel surface from aggressive corrosive action due to airborne salt adhesion, avoidance of repainting troublesome works and minimizing life cycle cost are taken into consideration, the selection of weathering steel as a material of superstructure will provide better advantages over ordinary steel.

Table A11.2.1 Cost comparison of bridge superstructure with steel material

<table>
<tr><th colspan="4">Item</th><th>Ordinary Steel (OS)</th><th>Weathering Steel (WS)</th><th>Remarks</th></tr>
<tr><td rowspan="11">Construction cost</td><td rowspan="5">Cost in Plant</td><td rowspan="2">Fabrication</td><td>Material</td><td>29.2</td><td>35.8</td><td></td></tr>
<tr><td>Fabrication</td><td>20.3</td><td>20.3</td><td></td></tr>
<tr><td colspan="2">Painting</td><td>6.4</td><td>2.9</td><td>OS: out & inside
WS: outside ends & inside</td></tr>
<tr><td colspan="2">Subtotal</td><td>55.9</td><td>59.0</td><td></td></tr>
<tr><td colspan="3">Transportation cost</td><td>8.1</td><td>6.0</td><td></td></tr>
<tr><td rowspan="4">Cost in site</td><td colspan="2">Erection</td><td>35.0</td><td>35.0</td><td></td></tr>
<tr><td colspan="2">Painting of splice</td><td>0.8</td><td>0.0</td><td></td></tr>
<tr><td colspan="2">Touch up</td><td>0.1</td><td>0.0</td><td></td></tr>
<tr><td colspan="2">Subtotal</td><td>35.9</td><td>35.0</td><td></td></tr>
<tr><td colspan="3">Total</td><td>99.9</td><td>100.0</td><td></td></tr>
<tr><td colspan="4">Maintenance cost</td><td>21.0</td><td>0.5</td><td>OS: 3 times
WS: 1 time</td></tr>
<tr><td colspan="4">Life cycle cost</td><td>120.9</td><td>100.5</td><td></td></tr>
</table>

Note; construction cost with weathering steel is set as the base (100.0)

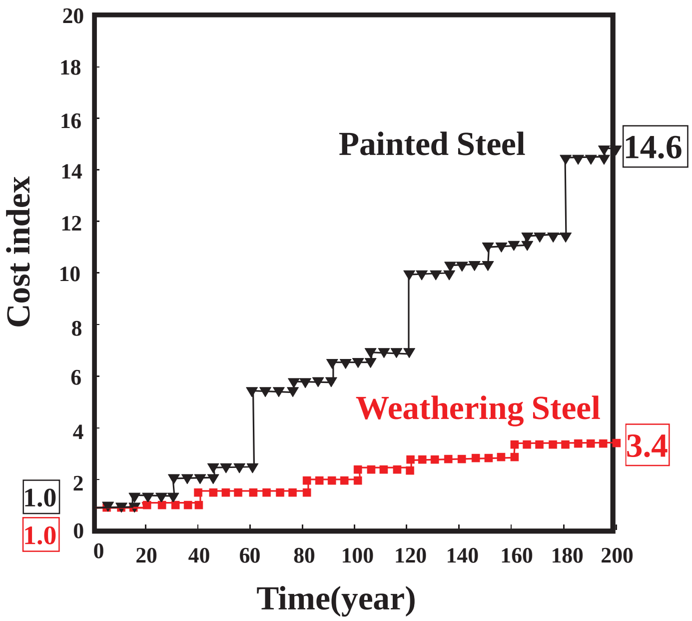


Figure A11.2.1 Life cycle cost comparison between steel materials

(A trial cost simulation in Japan)

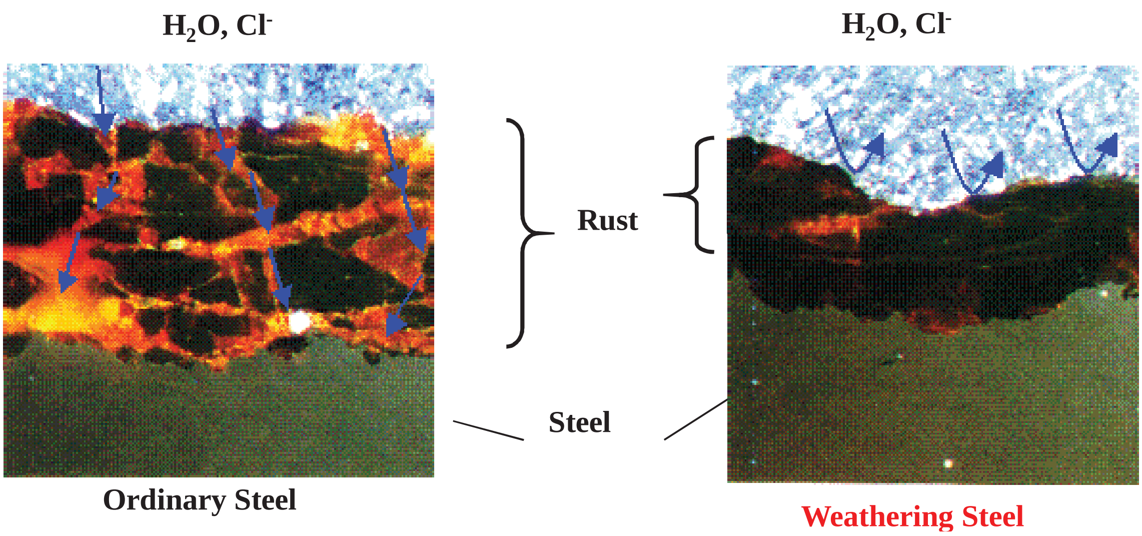
11.3 Corrosion Restraint Mechanism by Weathering Steel

In order to explain the corrosion restraint mechanism, at first the chemical composition of weathering steel is examined and compared to that of ordinary steel. The mass distribution of the chemical constituents in weathering steel is shown in Table A11.3.1 in which copper (Cu), nickel (Ni) and chromium (Cr) are added to activate the corrosion resistance mechanism. This is the basic difference in a sense that the ordinary steel does not contain such corrosion resistant elements.

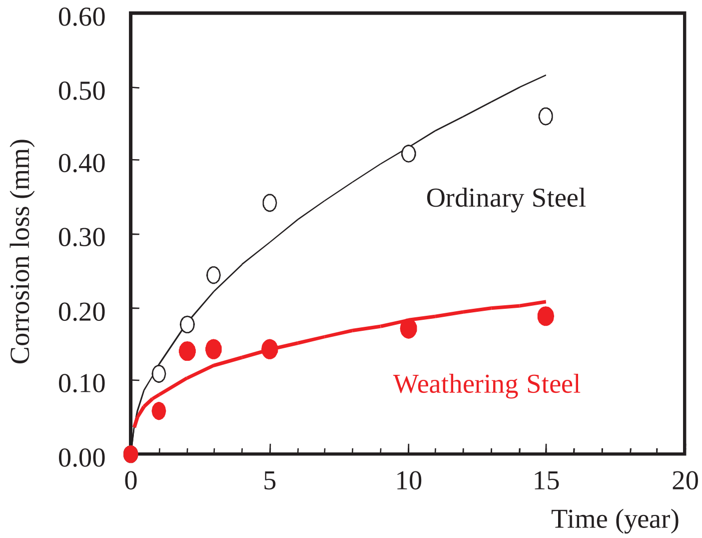
Table A11.3.1 Chemical composition of weathering steel

C	Si	Mn	Cu	Ni	Cr
0.12	0.40	0.90	0.35	0.20	0.50

Unit: mass%



(a) Mechanism of corrosion resistance



(b) Corrosion loss

Figure A11.3.1 Corrosion resistance mechanism and corrosion loss in weathering steel

Ordinary steel material will oxidize when exposed to oxygen, atmospheric moisture (H_2O) and chloride ion (Cl^-). Due to the chemical reaction in steel surface in presence of oxygen, some of the steel metal is corroded and ferric oxide (red rust) is formed on the surface. The red rust formed is generally scaly and loose, easily falls away exposing more and more basis material to the environment.

However, weathering steel (ordinary steel added with Cu, Ni and Cr) oxidizes in a similar way in the initial stage. The difference is that the copper, nickel and chromium oxides formed are a more uniform and tenacious oxide layer that protect the underlying material by "protecting rust surface" from further oxidation once formed. Therefore, the protective rust surface acts as an insulator of steel surface from H_2O and Cl^-.

The effect due to the formation of dense and well-adhering protective layer on steel surface is examined in Figure A11.3.1. It can be seen that the corrosion loss in weathering steel decreases significantly and remains in almost constant value over long time, whereas the corrosion loss in ordinary steel increases with time increment.

11.4 Weathering Steel: Exposure Test in Japan

(1) Locations of exposure tests

Extensive joint research works have been conducted by Ministry of Land, Infrastructure, Transport and Tourism, Japan Bridge Association, and Japan Iron and Steel Federation in order to understand the behavior of weathering steel. Since 1981-1993, several exposure tests on 41 bridges all over Japan were executed. The locations of exposure test already executed in Japan are marked in Figure A11.4.1.

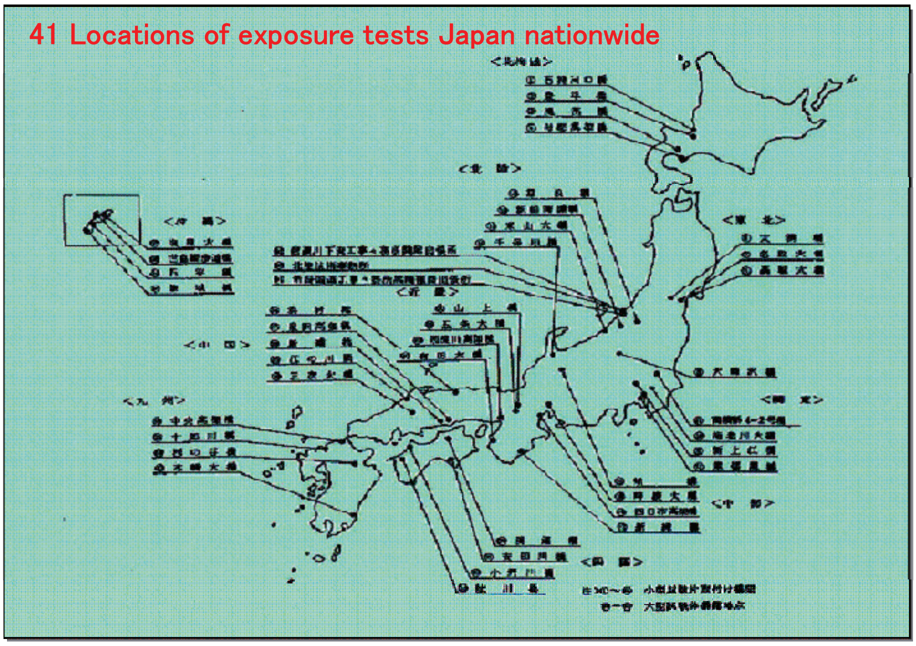


Figure A11.4.1 Locations of exposure test conducted in Japan

(2) Results and application conditions

- Results

Based on the exposure tests executed in several areas in Japan, some considerations on corrosion rate acceptable for the use of unpainted weathering steel are coded as application condition of JIS weathering steel. The design considerations shown in Figure A11.4.2 are expressed by the relationship between airborne salt adhesion and plate thickness reduction. By using these results, the tolerable limit of airborne salt adhesion is set at 0.05mdd and the corresponding thickness reduction over 50 years shall be below 0.3mm.

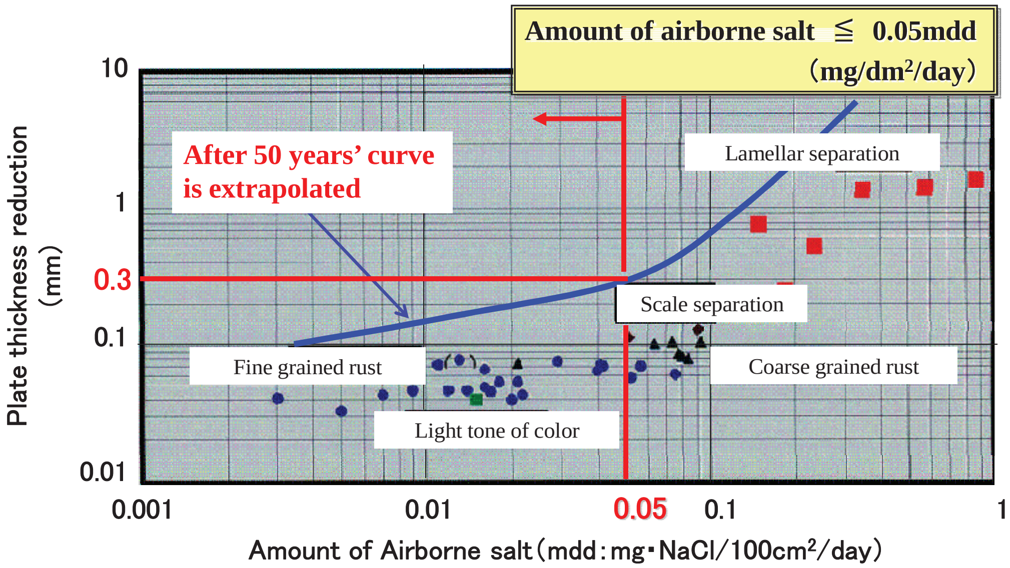


Figure A11.4.2 Application condition of JIS weathering steel

- Example of visual appearance

Based on the visual appearance of proto-type bridge observation after 9 years, the deteriorations in steel plate due to corrosive action are graded into five categories.

(a) Grade 5: Very good

(b) Grade 4: Good

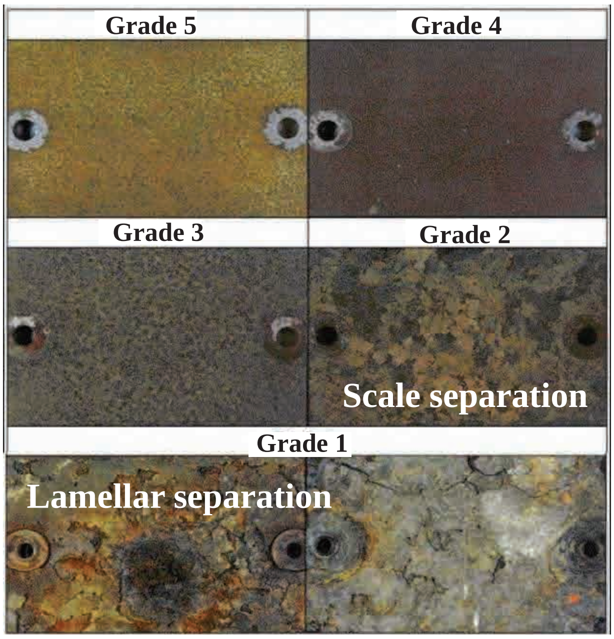
(c) Grade 3: Not bad

(d) Grade 2: Bad

(e) Grade 1: Too bad

The definition of each grade of deterioration and the visual appearance corresponding to each deterioration level is shown in Figure A11.4.3. If appearance grade after 9 years is evaluated between 3 and 5, the thickness reduction after 100 years is found to be less than 0.5mm. ⇒**Applicability of weathering steel to the bridge shall be remarked as good.**

Grade	Visual appearance
5	**Very good. thin rust, not so corroded**
4	**Good. Rust grain below 1mm. Uniformly corroded**
3	**Not bad. Rust grain 1～5mm**
2	**Bad. Scale separation observed**
1	**Too bad. Lamellar separation observed**



Specimen dimension 150mm×100mm After 9 years appearance

Figure A11.4.3 Visual appearance of proto-type bridge observation

- General trend of corrosion loss over years

Based on the observation results shown in Figure A11.3.1 and Figure A11.4.2 , a general trend of corrosion loss over time is formulated by an exponential relationship.

$$Y=AX^{B}$$

where, A= one year corrosion loss and B=power index for curve slope obtained by observed data, X= period in year, Y= corrosion loss (plate thickness reduction)

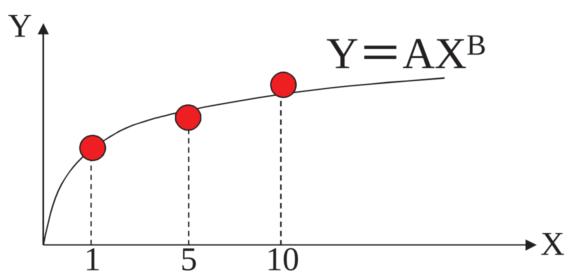


Figure 11.4.4 General trend of corrosion loss over year

11.5 Applicable Areas of Weathering Steel: Areas in Japan as an Example

To explain the areas where the weathering steel can be applied to bridges without any painting, some areas in Japan are taken into consideration as a reference. Based on the research findings explained in Sec 11.4, the areas in Japan marked in Figure A11.5.1) are categorized into five.

1) Coastal area along the Pacific Sea, more than 2km distant from coast

2) Coastal area along the Setouchi Sea, more than 1km distant from coast

3) Coastal area along the Japan Sea, more than 20km distant from coast

   (Observation data: airborne salt is less than 0.05 mdd)

4) Coastal area along the Japan Sea, more than 5km distant from coast

   (Without any observation data of airborne salt)

5) Okinawa (not applicable)

The boundary line shown in Figure A11.5.1 represents that the areas, more than 20km distant from coast and the airborne salt found to be less than 0.05 mdd, are recommended to be suitable for weathering steel application.

The project 2nd bridges planning to construct are located at 200 km distant from Bay of Bengal. Therefore, in accordance with above boundaries, the project areas can be recommended to be safe for weathering steel application.

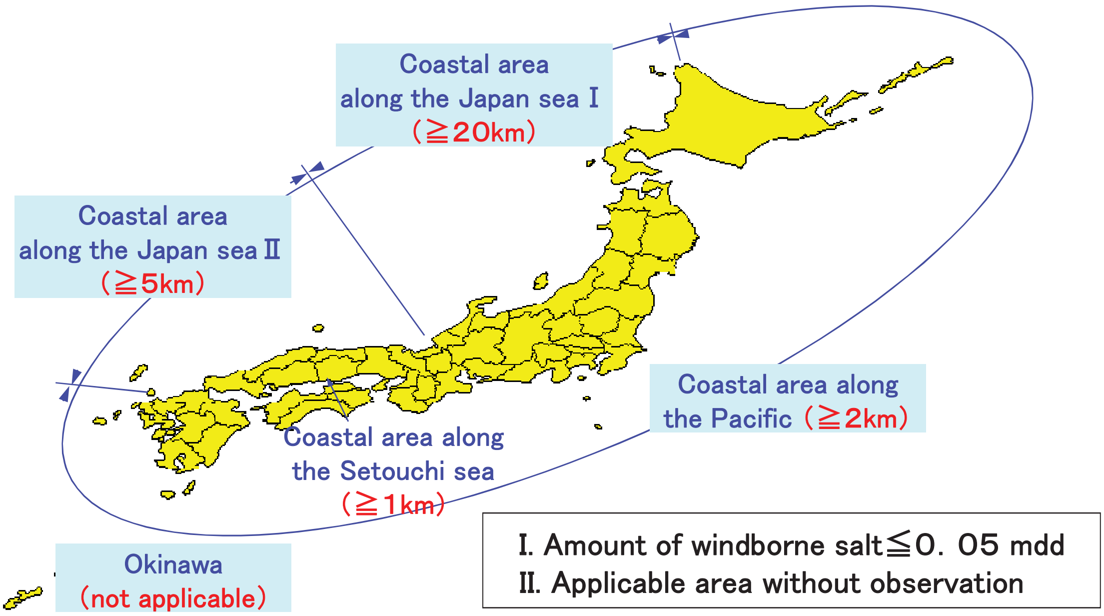


Figure A11.5.1 Selected areas in Japan for weathering steel application

11.6 Planning of Weathering Steel Bridges

If the bridge superstructure is planned to fabricate with weathering steel, some design considerations must be ensured in their plan and detailed design. These considerations for respective member components are mainly important so that the floor slab system will behave like a waterproof structure. The anticipated components of floor slab system are schematically shown in Figure A11.6.1 and the necessary considerations for their detailed design are summarized in Table A11.6.1.

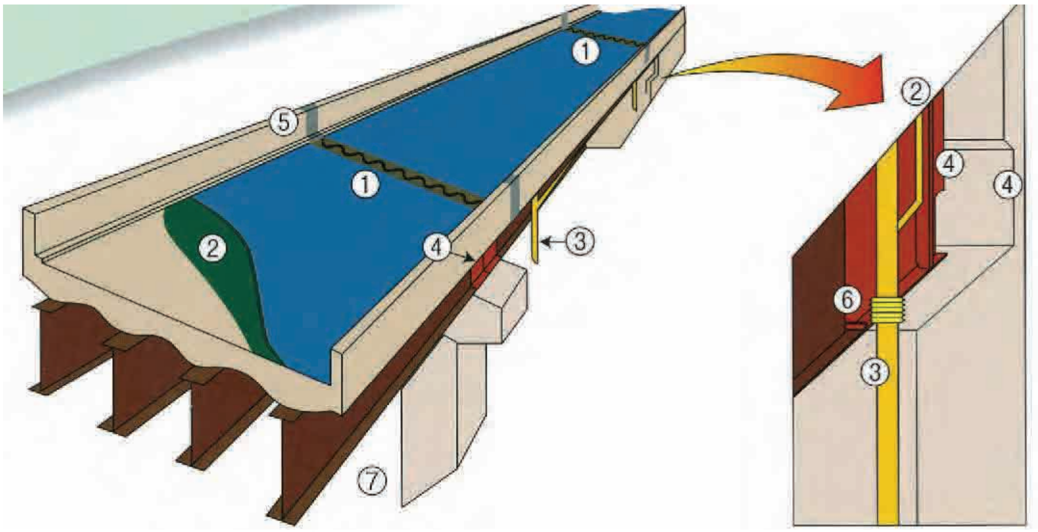


Figure A11.6.1 Components of floor slab system need special consideration

Table A11.6.1 Considerations for application of weathering steel

Structural components	Planning and design consideration
(1) Expansion Joint	Select un-drained type expansion joint
(2) Slab Deck)	Install reliable waterproof layer and slab drain
(3) Drainage	Extend drain pipe end down to underneath of girders
(4) Girder End	Paint girder end and cut out girder web and parapet (For water leak, humidity and maintenance)
(5) Concrete Barrier	Install waterproof structure
(6) Structural Detail	Detailed design of water stopper

11.7 Application of Weathering Steel in Bangladesh

(1) Airborne salt adhesion

- Salinity data

In order to verify the applicability of weathering steel in Bangladesh, the salinity data has been collected from Bangladesh Water Development Board (BWDB) for the respective bridge sites. The salinity data has been collected at four stations (ID 115, 277, 278, and 279) marked in Figure A11.7.1. Among the four stations, the station ID 115 is located at Gumti Bridge site, while the station ID 277 is near Meghna Bridge site. But, the salinity data at the station near Kanchpur Bridge site is not available. But, it is assumed that the salinity level at Kanchpur site will be lower than that at other two bridge sites. This is because the Kanchpur Bridge is located at upstream of Meghna and Gumti Bridges.

Figure A11.7.1 Locations of Salinity Stations (BWDB)

Table A11.7.1 Salinity Data

Station ID	Max chloride concentration (ppm)		NaCl concentration (%)	
	High tidal	Low tidal	High tidal	Low tidal
115*	190	-	**0.031**	-
277**	505	322	**0.083**	0.053
278***	1570	456	0.259	0.075
279****	1280	1070	0.211	0.176

* data available at BWDB from 2006 to 2009
**data available at BWDB from 1996 to 2009
***data available at BWDB from 2000 to 2008
****data available at BWDB from 2000 to 2008

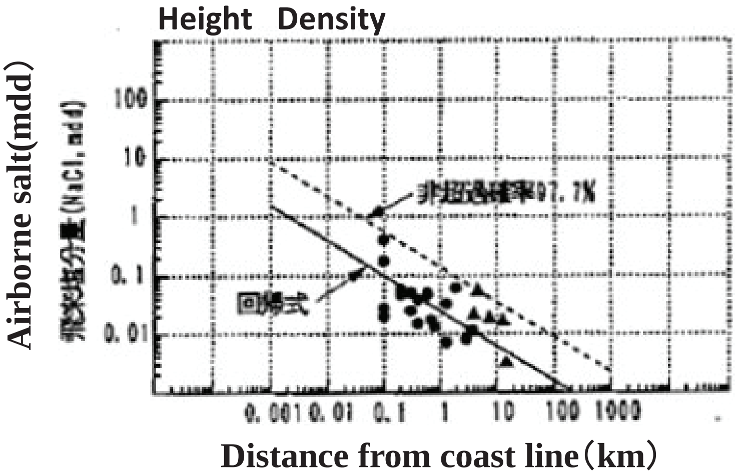


Figure A11.7.2 Measured Airborne Salt near Coast of Setouchi Sea

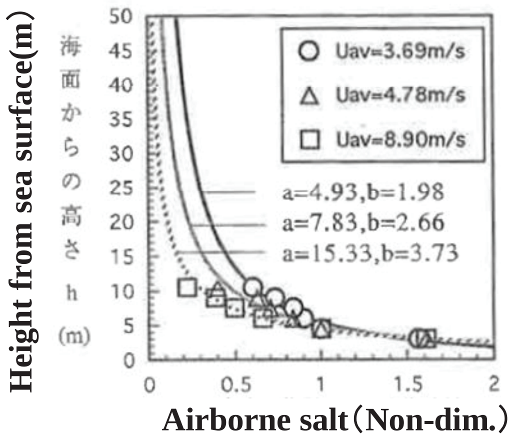


Figure A11.7.3 Vertical Distribution of Airborne Salt near Coast Line

- Computation of airborne salt

In order to measure the airborne salt at Meghna and Gumti Bridge sites, Figure A11.7.2 and Figure A11.7.3 are used, which show the relationship between airborne salt concentrations and the height from sea surface. Salt concentration in sea water is more than 3%, whereas from Figure A11.7.2, the airborne salt near the sea at the height of 1.5m is 1mdd (1mg/dm2/day). On the other hand, the airborne salt at 10m height is 1/3 of that at 1.5m height (Figure A11.7.3).

< Airborne salt at Meghna Bridge site >

The NaCl concentration in Meghna River water is found to be 0.083%. So, the airborne salt at 10m height from the river surface is

1mdd× (1/3) × (0.083/3) = **0.009mdd ＜ 0.05mdd** (Specification practice in Japan for plates without painting)

< Airborne salt at Gumti Bridge site>

The NaCl concentration in Gumti River water (station ID 115) is found to be 0.031%. So, the airborne salt at 10m height from the river surface is

1mdd× (1/3) × (0.031/3) = **0.003mdd ＜ 0.05mdd** (Specification practice in Japan for plates without painting)

- Evaluation

From the above calculations, it can be concluded that the airborne salt concentration at the 2nd bridge sites is much lower than tolerable limit. Therefore, the application of weathering steel as a material for bridge superstructure is expected to be safe from any aggressive corrosive action.

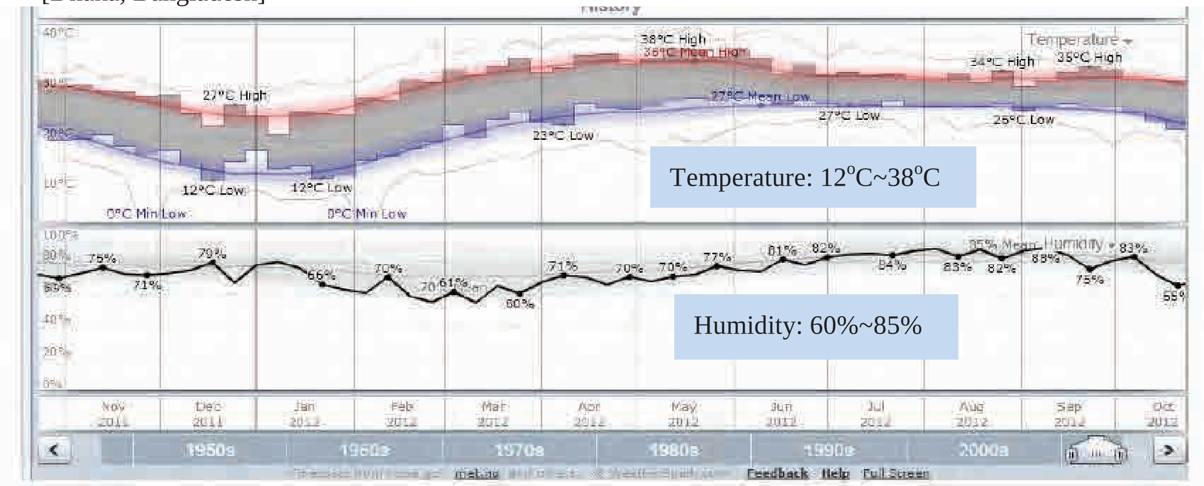
(2) Anti-freezing admixture

As is shown in Chapter 6, the minimum temperature at Dhaka side is found to be 12^{o}C which is not the favorable condition for snowfall. Therefore, the possibility of anti-freezing admixture adhesion on bridge exposed area can be easily ignored.

(3) Temperature and humidity in Bangladesh and Japan

The trend in temperature and humidity change over last one year in Bangladesh and Japan are shown in Figure A11.7.4.

[Dhaka, Bangladesh]



[Tokyo, Japan]

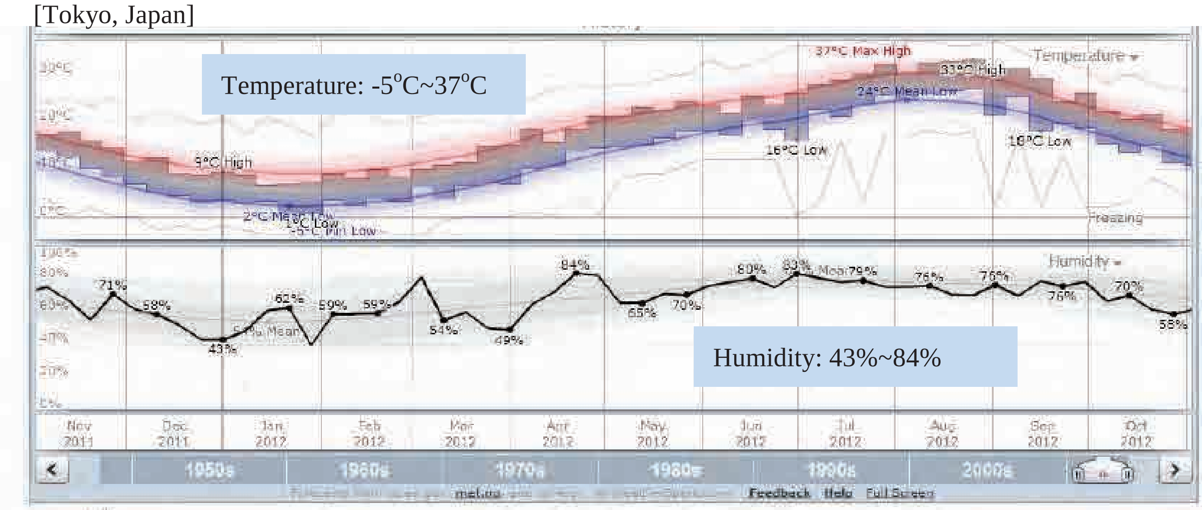
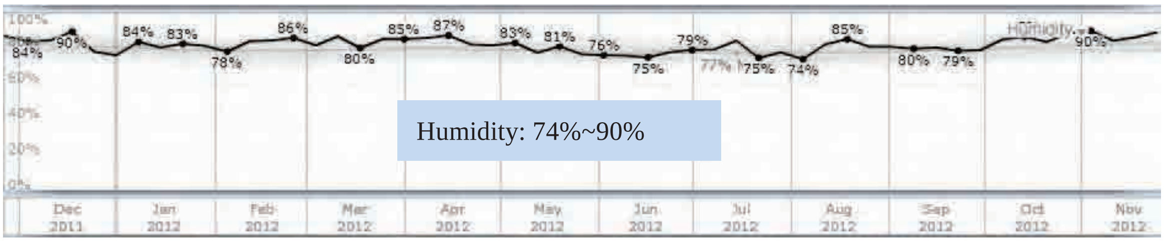
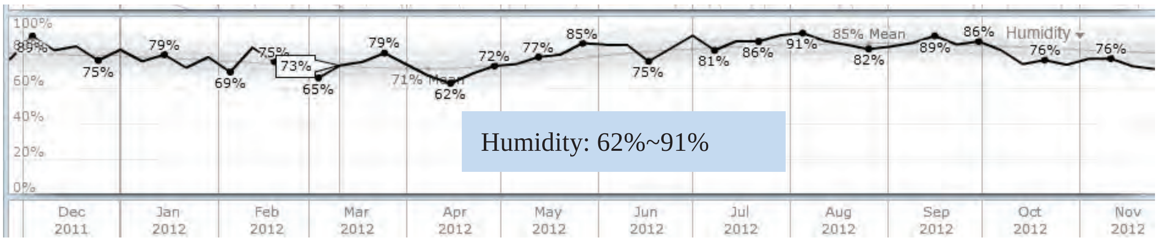


Figure A11.7.4 Temperature and humidity in Bangladesh and Japan

(4) Humidity in southern-east Asia



(i) Kuala lumpur (Sultan Abdul Aziz Shah Airport)-Malaysia



(ii) Manila (Ninoy Aquino International Airport) – Philippine

Figure A11.7.5 Humidity in South-East Asia

(5) Example of weathering steel bridges (Malaysia, Philippine)

Two weathering steel bridges which were constructed in South-East Asia (Malaysia and Philippine) are taken as example. The performance of these bridges after several years prior to construction is found to be satisfactory.

(a) Kepong Interchange (Malaysia)

Type: Plate and box girder

Bridge length: 412.6m

Completion: 1986

(b) Gumain Bridge (Philippine)

Type: weathering steel bridge (7-weathering steel bridges on Subic-Clark expressway)

Bridge length: (70.25+3x80.0+70.25=380.5m)

Completion: 2007

(a) Kepong Interchange (Malaysia)

(b) Gumain Bridge (Philippine)

Figure A11.7.6 Example of weathering steel bridges in South-East Asia

11.8 Proposal of Exposure Test

An exposure test procedure for weathering steel generally followed in Japan is described step wise below. This exposure test procedure is also recommended to follow in Bangladesh.

(1) Evaluate the applicability

In order to evaluate the applicability of weathering steel, the corrosion loss due to reduction of plate thickness shall be examined in accordance with its tolerable limit over exposed time. In accordance with exposure test results conducted in Japan, the corrosion loss should be less than 0.03mm in first year. Moreover, some tolerable values recommended for corrosion loss over time to be elapsed are set at

Corrosion loss ≤ 0.03 mm (in 1 year)

≤ 0.30 mm (in 50 years)

≤ 0.50 mm (in 100 years)

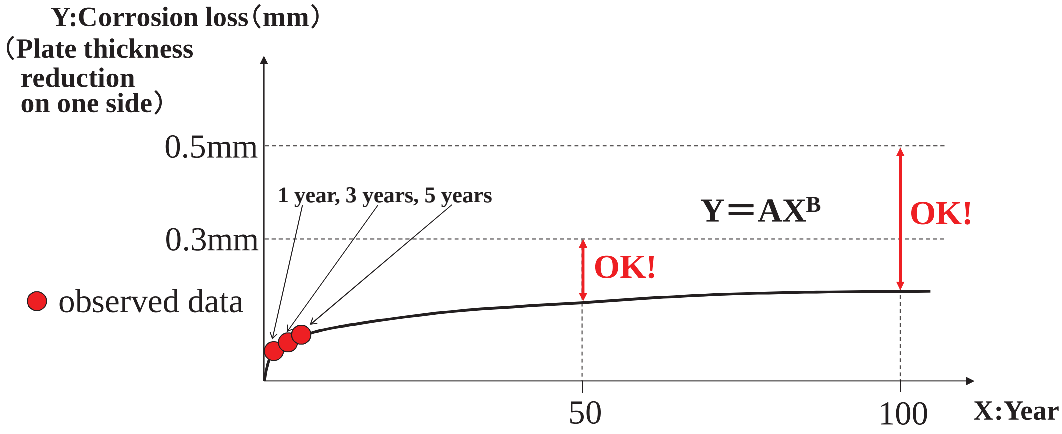


Figure A11.8.1 Evaluation the applicability of weathering steel

(2) General method of exposure test

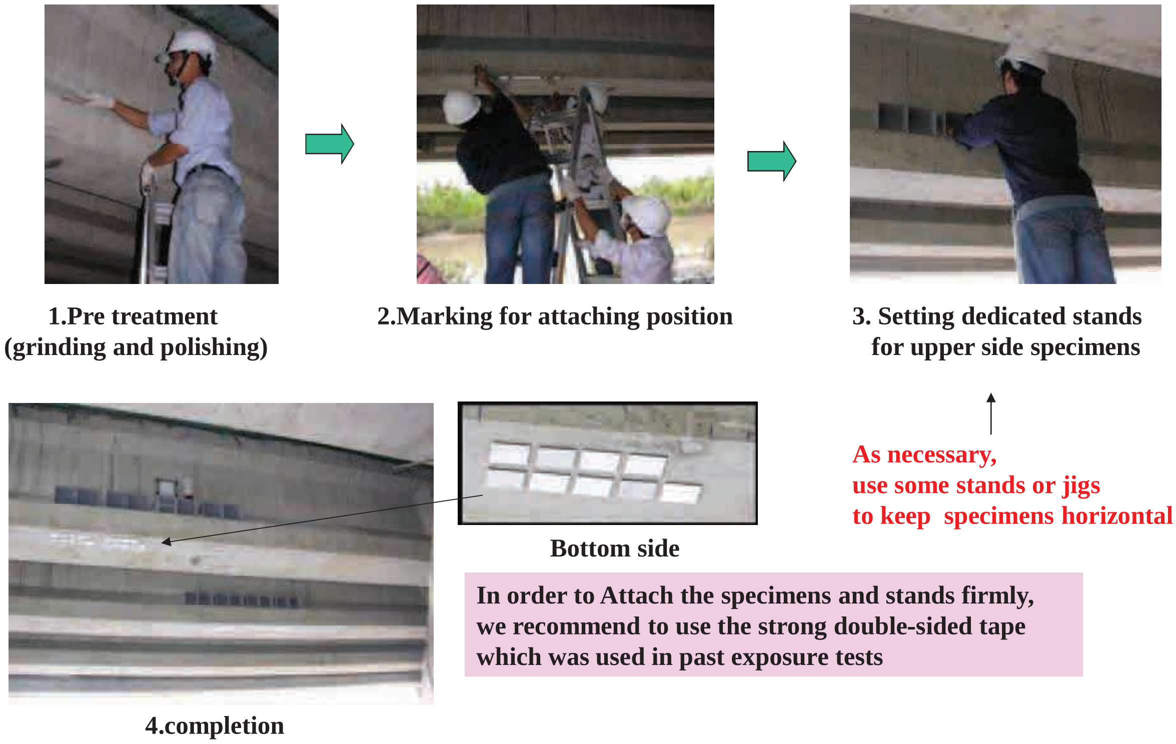
A general method to install specimen on concrete girder is described in Figure A11.8.2. The sequences how to attach test specimens on the concrete girder are as follows:

(a) Pre-treatment by grinding and polishing

(b) Marking for attaching position

(c) Setting dedicated stands for upper side specimen

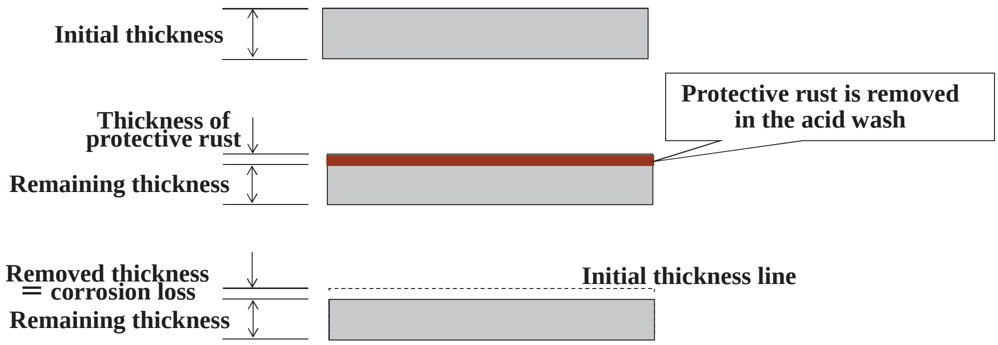
(d) Completion



(a) Test piece attachment to the concrete girder

For analysing the corrosion loss of the specimen, following key point shall be taken into consideration.

- Reduction of plate thickness due to corrosion is determined by measuring weight after removing rust



(b) Corrosion loss analysis

Figure A11.8.2 Exposure test procedure for weathering steel

(3) Remarks

Based on the test procedure described above, some remarks are recommended below

(a) Test specimens are to be set to the lower side of the girder.

(b) If test specimens are set to the open air space, it should be evaluated with rainfall wash condition.

(c) Test specimens are never to be touched by sweaty hands. It should always be touched by hands with new gloves.

11.9 Exposure Test Plan recommended

The exposure test of the weathering steel is expected to conduct in the real weather condition for confirming the rust growth rate. The test pieces will be installed on the exposed area of girder end of three existing bridges.

(1) Location of test pieces to be installed

The numbers of exposure test pieces are planning to be 3 pieces for 1st year result and another 3 pieces will be tested in 2nd year. Therefore, the number of test pieces amounts to 6 for each location. The target test locations are shown as follows:

(i) Middle of girder (humidity concentrated area) (Kanchpur Bridge)

(ii) Side and lower side of girder (Meghna Bridge)

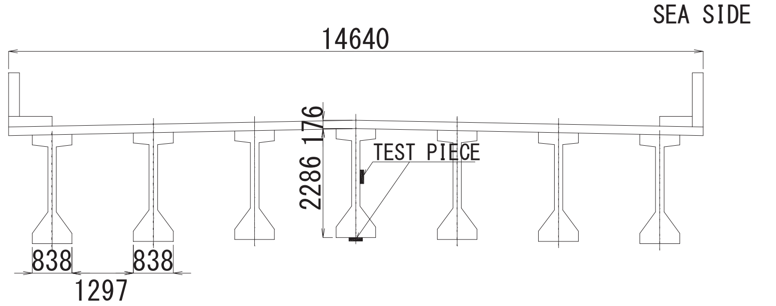
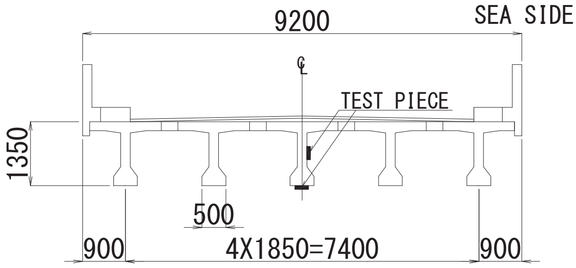
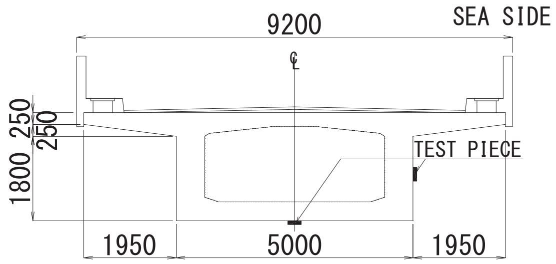
(iii) Inner of the girder (Gumti Bridge)

All together 6 locations times 6 pieces equals 36 pieces. A schematic view of test piece locations is shown in Table A11.9.1.

Test piece size: 50mm×50mm×2mm

It should be noted that the test specimens must be kept clean and touched by hands covered with new gloves just avoidance of influence from sweaty human body.

Table A11.9.1 Proposed test piece location for exposure tests

<table>
<tr><th>Bridge name</th><th>Girder end</th><th>Test piece</th></tr>
<tr><td rowspan="2">Kanchpur</td><td>
</td><td rowspan="2">12</td></tr>
<tr><td>(3+3)x2=12</td></tr>
<tr><td rowspan="2">Meghna</td><td>
</td><td rowspan="2">12</td></tr>
<tr><td>(3+3)x2=12</td></tr>
<tr><td rowspan="2">Gumti</td><td>
</td><td rowspan="2">12</td></tr>
<tr><td>(3+3)x2=12</td></tr>
<tr><td>Spare test pieces</td><td></td><td>14</td></tr>
<tr><td>Total test pieces</td><td></td><td>50</td></tr>
</table>

(2) Open air test period and evaluation timing

The test piece must be installed and kept at least one year. This is because the progress of protective rust formation must require at least 1 year from installation. After one year, half of the specimens shall be examined. Judgement on the applicability of WS shall be made based on the results obtained after 1^{st} year. And remaining half of the test pieces will be examined in 2^{nd} year in order to evaluate the 1^{st} year test results. The tentative schedule of exposure test is shown in Table A11.9.2.

Table A11.9.2 Schedule of exposure test proposed

Timing	What to do
Start of exposure test	Install specimen
1^{st} year	Specimen collection (1^{st} year) Evaluation of 1^{st} year results Judgment on applicability of WS
2^{nd} Year	Specimen collection (1^{st} year) Evaluation of 1^{st} year judgment

(3) Evaluation

After one year, the exposure test pieces shall be examined and the obtained results shall be evaluated accordingly. The evaluation methods are as follows:

- Measure the initial weight of test specimens

  After 1^{st} and 2^{nd} years
- Wash away by using acid
- Measure weight of specimen after removing rust
- Calculate corrosion loss by thickness reduction.

APPENDIX 12.

OPERATION AND MAINTENANCE ADMINISTRATION

Japanese experience on road improvement

Financing Road Improvement

1. The Source of Revenue for Road Projects

Unlike the administrative categories stipulated by “Road Law”, road projects in Japan are broken down into three types from the perspective of who oversees the project and the financing source.

General road projects are financed by national funds (costs paid by the state) and local funds (costs paid by local public body), and are broken down into directly administrated road projects conducted by the national government (the Ministry of Construction) and subsidized projects conducted by a local public body. Toll road projects are financed by mainly loans (such as treasury investments and loans) procedure by 4 public corporation (Japan Highway Public Corporation, Metropolitan Expressway Public Corporation, Hanshin Expressway Public Corporation and Honshu-Shikoku Bridge Authority), and repaid by toll revenue after completion. Subsidies are provided from national and local investments and loans. In addition there is local independent financing by local public bodies.

In this form of financing, road projects in Japan are financed mainly by national and local funds and treasury investment and loans.

1) National funds

National funding sources consist of gasoline tax, LPG tax, motor vehicle tonnage tax and other taxes, government construction bonds, and NTT funds. They are used for the cost of executing directly administered projects, for subsidies to subsidized projects, and for investments and loans for toll road projects.

2) Local funds

Local fund sources consist of diesel fuel transaction tax, motor vehicle purchase tax, tax revenue transferred from the central government (local road tax, LPG tax and motor vehicle tonnage tax, are transferred from the government respectively), other taxes, local subsidies and local bonds. They are used for the shared cost of work directly administered by central government, cost of executing subsidized project and local independent work, as well as for, investments and loans for toll road projects.

3) Treasury investments and loans

Sources of this category of funds including treasurer investments and loans, and connection bonds, and they are used to fund the construction of toll roads.

Earmarked Funds for Road Improvement

1. Earmarked funds and general funds

Funds for road works from national and local tax revenues fall into two categories: fund "earmarked" exclusively for road works and "general account" funds, which are raised without any specification about its use.

National government "earmarked" funds for roads are raised through the levying of the gasoline tax, LPG tax, and motor vehicle tonnage tax. Local "earmarked " funds are raised from transfer taxes collected by central government and transferred to the local government (transferred taxes on local roads, LPG and motor vehicle tonnage), and local taxes collected by the local public bodies to be used for toad improvement (diesel fuel transaction tax, motor vehicle purchase tax).

Funds earmarked for roads account for 50% to 60% of the total national and local funds.

2. Outline of Earmarked Tax Revenues for Road Works

A special funding source system for road works was initiated in 1954 when the revenue from the gasoline tax was set aside as a funding source for the implementation of the 5-year Road Improvement Program. This decision was based on the enactment of the "Temporary Measure Act Relating to the Financial Sources of Road Improvement Costs" (Today's "Emergency Measure Act for Roads Improvement") in the same year, in order to urgently implement planned improvement of the poor road conditions in Japan which lagging far behind those in other advanced nations. Since then, in order to carry out road improvement projects which address needs arising from increasing motor vehicle traffic volume, and the diversifying user needs, efforts have been made to establish a more comprehensive earmarked fund by levying new taxes and raising tax rates.

The special earmarked fund for road works is based on the idea that beneficiaries must bear the burden, or the people who are the origin of the causes must bear the burden. Therefore, the users of motor vehicle are called upon to bear the cost of road improvement through their consumption of fuel, purchase and possession of motor vehicles. The shouldering of the costs by beneficiaries is a system by which "the users of motor vehicles bear the burden of being the special funding source for road works which will be used for road improvements. Road improvements will result in the reduction of driving time and enhancement of safety, which in turn will benefit the road users." This system has the advantage of providing a stable source of funds without being influenced by the financial situation at a particular moment. Thus, it plays a primary role in the steady execution of road improvement projects based on the long-term road improvement programs, mainly the 5-year Programs.

Table　Overviews of "Earmarked Taxes for Road Financing"

<table>
<tr><td></td><td>Fuel consumption</td><td>Purchase of Motor vehicles</td><td>Ownership of motor vehicles</td></tr>
<tr><td>Gasoline vehicles</td><td>Gasoline tax
Gasoline tax (national revenue source)
Local road tax (local revenue source)</td><td rowspan="3">Motor vehicle purchase tax
(local revenue source)</td><td rowspan="3">Motor vehicle tonnage tax
(national/local revenue source)</td></tr>
<tr><td>Diesel Fuel vehicles</td><td>Diesel Fuel transition tax (local revenue source)</td></tr>
<tr><td>LPG vehicles</td><td>LPG tax (national /local revenue source)</td></tr>
</table>

:

This description is taken from the Brochure "Mich Roads in Japan 2002" , which is edited with the cooperation of the Road Bureau, Ministry of Land, Infrastructure and Transport.

PRINCIPAL BRIDGE INSPECTION REPORT

LRP name: 24a.
Zone: Dhaka; Circle: Dhaka; Division: Munshigonj.

Road No.: N-1
Road Name: Dhaka-Comilla-Chittagong Technaf Road Road

1. **Summary**
   1.1 The principal bridge inspection of this **Meghna Bridge** was carried out by SARM – DUL Consortium on the 13th Sept. 2004.
   1.2 This was constructed in 1989.
   1.3 The structure is in fair condition but some repair works are needed.

2. **General Information**
   2.1 The bridge is located at chainage 24.393 Km of Dhaka-Comilla-Chittagong, Road (N-1). This is a 900m.long P.C. I girder and P.C. Box girder bridge (Progressive Cantilever) having 13 spans. Length of individual spans are 24.25m, 24.25m, 48.3m., 9 spans @ 87m. each and 1 8.2m. The width and carriage way of the bridge is respectively 9.2m. and 7.2m.

3. **Results of inspection**

3.1 Foundation

The foundations are supported on RCC caissons and piles. Piled foundation of abutments are buried and therefore could not be visually inspected. A visual inspection conducted at the foot of the abutments revealed no cracks. RCC caissons that are used as foundation under the piers are also buried that’s why it was not possible to assess their condition. However, there is no sign of movement of piers.

3.2 Abutment

Both abutments are RCC, solid type and condition is good.

3.3 Pier

Piers are R.C.C solid type. They are in fair condition but pier no. 8 and 9 shows concrete spalling.

3.4 Wing Walls

All the wing walls are of R.CC which are fixed with abutments and have no weep holes. They are in good condition.

3.5 Bearings

2 span where girders are P.C. simply supported I section have neoprene bearings. Other progressive cantilever 11 spans have no bearings.

3.6 P.C. I Girder, P.C Box Girder

2 span out of 13 have 5 no. P.C. girder at each span and the other 11 span have P.C. box girder. Condition of these girders are good. There is no sign of crack or excessive deflection in these girders.

3.7 Railing

Railing type is of R.C.C post & steel rail.
The overall condition of the railing is fair, though minor damage is observed. It has 0.80m. wide foot path at both sides.

3.8 Deck Slab

The condition of RCC deck slab is in quite good condition. But minor quantity of concrete spalling has been observed.

3.9 Wearing Course

The wearing course is of bitumen type, it needs repair work.

3.10 Expansion Joint

Expansion joints are partially damaged. 4 number of expansion joints need replacement and another 2 number need repair.

3.11 Approach Protection and Drainage

Abutment approach protection and drainage is in good condition though minor damage is observed. The bridge has drainage facility.

3.12 Navigability

It is navigable during all season. Most of the river traffics are big boats including country boat, engine boat, small ships etc. Their height are mostly 10m.

3.13 Recommendation

The condition of the bridge is good.
But:
8sqm over 8 & 9 no. pier need repair for concrete spalling
12m length of railing at left side need repair
2sqm deck need repir, 12sqm approach road at side of the bridge need repair
2sqm slope protection need repair, 8sqm side walk at right side need repair
6m. expansion joint, 2m. railing need repair and 4 m. railing need replacement.

Top View of Bridge

Side View of Bridge

Approach Road Bridge

Another Top View of the Bridge

APPENDIX 13.

TERMS OF REFERENCE FOR EXTERNAL MONITORING AGENCY

DHAKA-CHITTAGONG NATIONAL HIGHWAY NO.1 BRIDGE CONSTRUCTION AND REHABILITATION PROJECT

Terms of Reference for External Monitoring Agency (EMA)

A. Project Background

The Government of Bangladesh (GoB) has undertaken a project to construct three Bridges on National Highway No.1 (NH-1) i.e. Kanchpur, Meghna and Gumti Bridge including rehabilitation of the existing bridges through the Roads and Highways Department (RHD) under the Ministry of Communications (MOC) with financial assistance from the Japan International Cooperation Agency (JICA). The project involves construction of new bridges parallel to the existing bridges with approach road. The length of the bridges including viaduct are Kanchpur 400 m, Meghna 930 m and Gumti 1,410 m respectively. The overall objective of the Project is to mitigate the increasing traffic demand of NH-1, which can be made by;

i. Construction of new 2nd Kanchpur Bridge, 2nd Meghna Bridge and 2nd Gumti Bridge together with approach road respectively.

ii. Rehabilitation of existing Kanchpur Bridge, Meghna Bridge and Gumti Bridge

According to the Resettlement Action Plan (RAP) prepared by the RHD in 2012, a total of 306 households will be affected by the project. This includes 274 households to be displaced and 32 households experiencing indirect or secondary impacts.

RHD will mobilize RAP Implementing Agency (IA) to implement the RAP for the Project. The IA will implement the RAP as per the resettlement policy, ensure stakeholders participation as per the project need, and provide technical assistance for compensation and assistance to the APs. A monitoring mechanism has also been framed and adopted in the RAP involving the RHD, the IA, Resettlement Expert of the consultants and JICA.

The RHD seeks to engage an independent External Monitoring Agency (EMA) to review the internal monitoring and undertake third party monitoring and evaluation of the RAP implementation process for the Government of Bangladesh.

B. Key Objective of External Monitoring

Monitoring is an integral part of the resettlement process. As part of this Project, a three-tier monitoring system has been designed to monitor and evaluate the progress of the RAP implementation. These 3-levels comprise of: a) Internal monitoring involving the IA and RHD Project Implementation Unit (PIU) field offices; b) monitoring by Resettlement Expert (RE) of the project construction supervision consultant (CSC) and c) independent external monitoring. The primary objective for engaging an independent external monitor is to review the efficacy of internal monitoring, design and conduct periodic third party monitoring and feedback RHD and JICA on policy improvement and enhancement of implementation process. The External Monitoring Agency (EMA) will review implementation process as per set policies in the RAP and assess the achievement of resettlement objectives, the changes in living standards and livelihoods, restoration of the economic and social base of the affected people, the effectiveness, impact and sustainability of entitlements, the need for further mitigation measures if any, and to learn strategic lessons for future policy formulation and planning.

C. Scope of Work

The scope of work of the External Monitoring Agency (EMA) will include the following tasks:

(1) To develop specific monitoring indicators for undertaking monitoring for Resettlement Action Plans (RAP) and Income & Livelihood Restoration Plan (ILRP).

(2) To review and verify the progress in resettlement implementation of the Project.

(3) Identify the strengths and weaknesses of the resettlement objectives and approaches, and implementation strategies.

(4) Evaluate and assess the adequacy of compensation given to the APs and the livelihood opportunities and incomes as well as the quality of life of APs of project-induced changes.

(5) Identification of the categories of impacts and evaluation of the quality and timeliness of delivering entitlements (compensation and rehabilitation measures) for each category and how the entitlements were used and their impact and adequacy to meet the specified objectives of the Plans. The quality and timeliness of delivering entitlements, and the sufficiency of entitlements as per approved policy.

(6) To analyze the pre-and post-project socio-economic conditions of the affected people. In the absence of baseline socio-economic data on income and living standards, and given the difficulty of APs having accurate recollection of their pre-project income and living standards, develop some quality checks on the information to be obtained from the APs. Such quality checks could include verification by neighbors and local village leaders. The methodology for assessment should be very explicit, noting any qualifications.

(7) Review results of internal monitoring and verify claims through sampling check at the field level to assess whether land acquisition/resettlement objectives have been generally met. Involve the affected people and community groups in assessing the impact of land acquisition for monitoring and evaluation purposes.

(8) To monitor and assess the adequacy and effectiveness of the consultative process with affected APs, particularly those vulnerable, including the adequacy and effectiveness of grievance procedures and legal redress available to the affected parties, and dissemination of information about these.

(9) Identify, quantify, and qualify the types of conflicts and grievances reported and resolved and the consultation and participation procedures.

(10) Provide a summary of whether involuntary resettlement was implemented (a) in accordance with the RAPs, and (b) in accordance with the stated policy.

(11) To review the quality and suitability of the relocation sites from the perspective of the both affected and host communities.

(12) Verify expenditure & adequacy of budget for resettlement activities.

(13) Describe any outstanding actions that are required to bring the resettlement activities in line with the resettlement policy. Describe further mitigation measures needed to meet the needs of any affected person or families judged and/or perceiving themselves to be worse off as a result of the Project. Provide a timetable and define budget requirements for these supplementary mitigation measures.

(14) Describe any lessons learned that might be useful in developing the new national resettlement policy and legal/institutional framework for involuntary resettlement.

D. Methodology and Approach

The general approach to be used is to monitor activities and evaluate impacts ensuring participation of all stakeholders especially women and vulnerable groups. Monitoring tools should include both quantitative and qualitative methods. The external monitor should reach out to cover:

- 100% APs who had property, assets, incomes and activities severely affected by Project works and had to relocate or whose source of income was severely affected.
- 10% of persons who had property, assets, incomes and activities marginally affected by Project works and did not have to relocate;
- 10% of those affected by off-site project activities by contractors and sub-contractors, including employment, use of land for contractor's camps, pollution, public health etc.;

Supplemented by Focused Group Discussions (FGD) which would allow the monitors to consult a range of stakeholders (local government, resettlement field staff, NGOs, community leaders, and, most importantly, APs), community public meetings: Open public meetings at resettlement sites to elicit information about performance of various resettlement activities.

E. Other Stakeholders and Their Responsibility

1. Responsibility of RHD

Roads and Highways Department (RHD) through its Project Implementation Unit (PIU) will ensure timely supply of background references, data and project options to the independent monitor. It will ensure uninterrupted access to work sites, relevant offices of the GOB and RHD in particular. The independent external monitor will sit in quarterly coordination meetings with the RHD in presence of the Resettlement Expert of supervision consultant.

Recommendation based on the result of the monitoring should be offered to RHD to cover up the deficiencies identified by the external monitor. RHD will accept the recommendations of the external monitor if it is within the scope of work and there is nothing incorrect in the report.

2. Responsibility of Supervision Consultant

The supervision consultant will provide appropriate protocol at site or at its Project Office for the mission of the EMA. It will on behalf of RHD ensure free access to work sites, impact areas and the database on resettlement and civil works. The supervision consultant will ensure timely intimation of its civil works planning as and when made or updated during the construction period and keep the external monitoring and evaluation consultant informed.

3. Responsibility of the Implementing Agency (IA)

The RAP Implementing Agency (IA) will assist and cooperate the external monitor through providing free access to its database and the automated management information system (MIS). It will provide copies of the progress reports and other reports as requested by the external monitor. The IA may have to carry out surveys as well for fulfilment of the requirements of the external monitoring.

4. Japan International cooperation Agency (JICA)

The JICA will keep closer look into the activities of the external monitor in light of the social safeguard strategy and the involuntary resettlement guideline. It will ensure timely response from the RHD on queries and recommendations from the independent monitor.

F. Team Composition of the External Monitoring Agency

The EMA should focus on field based research on institutional arrangement, implementation strategy, policy objectives, and the targets. Data collection, processing and analysis to pin point problem areas and weaknesses, and to light on deserving measures to achieve the objectives on schedule are the special interest of the subject. Thus, there is a need for a dedicated monitoring team with adequate gender representation. Further, it is essential that the central team or field level coordinators responsible for monitoring, are skilled and trained in data base management, interview technique, and social and economic/finance. Keeping in mind these criteria, the team should ideally include:

Position/expertise	Qualification and experience
1. Team Leader/ Implementation Specialist	Masters in social science with 15 years working background in planning, implementation and monitoring of involuntary resettlement for infrastructure projects. Experience in institutional capacity analysis and implementation arrangement for preparation and implementation of resettlement plans, and knowledge in latest social safeguard policies of the international development financing institutions in Bangladesh are preferred.
2. Social Impact Specialist	Masters in social science with 10 years working experience in social impact assessment including census and socioeconomic surveys, stakeholders' consultation, and analyzing social impacts to identify mitigation measures in compliance with social safeguard policies of the international development financing institutions and national legislations. Experience of preparing resettlement framework and action plans and implementation of plans for externally financed projects is essential.
3. Gender Specialist	Masters in social science with 10 years working experience in relevant field; Thorough knowledge of gender issues and their implications in development projects; research and work experience relating to gender issues; and knowledge of techniques and their applications in mobilizing community participation in development programs.
4. Data Analyst	Graduate with working experience and knowledge of software, preferably relational, those are most commonly used in Bangladesh; demonstrated ability to design and implement automated MIS(s) for monitoring progress, comparing targets with achieved progress and the procedural steps.

G. Time Frame and Reporting

The EMA will be employed over a period of 6 years with intermittent inputs from the professional team to continue one year after completion of the RAP implementation.

Quarterly and annual monitoring reports should be submitted to the RHD with copies to the international co-financiers. An evaluation report at the end of the project should be submitted to the RHD and concerned parties with critical analysis of the achievement of the program and performance of RHD and IA

The external monitors will provide monitoring and evaluation report covering the following aspects:

- Whether the resettlement activities have been completed as planned and budgeted;
- The extent to which the specific objectives and the expected outcomes/results have been achieved and the factors affecting their achievement or non achievement;
- The extent to which the overall objective of the Resettlement Plan, pre project or improved social and economic status, livelihood status, have been achieved and the reasons for achievement / non achievement;
- Major areas of improvement and key risk factors;
- Major lessons learnt; and
- Recommendations.

Formats for collection and presentation of monitoring data will be designed in consultation with RHD, Resettlement Expert of the consultants and IA.

H. Qualification of the External Monitoring Agency

The EMA will have at least 10 years of experience in resettlement policy analysis and implementation of resettlement plans. Further, work experience and familiarity with all aspects of resettlement operations would be desirable. NGOs, Consulting Firms or University Departments (consultant organization) having requisite capacity and experience as follows can qualify for services of and external monitor for the project.

a. NGOs registered with the Social Welfare Department of the GOB, Consulting Firms registered with the Joint Stock Company or Departments of any recognized university.

b. The applicant should have prior experience in social surveys in land based infrastructure projects and preparation of resettlement plans (RP, RAP, LARP) as per guidelines on involuntary resettlement of any of the ADB, World Bank, JICA, DAC-OECD.

c. The applicant should have extensive experience in implementation and monitoring of resettlement plans, preparation of implementation tools, and development and operation of automated MIS for monitoring.

d. The applicant should be able to produce evidences of monitoring using structured instruments and computerized MIS with set criteria for measuring achievement.

e. The applicant should have adequate manpower with capacity and expertise in the field of planning, implementation and monitoring of involuntary resettlement projects as per donor's guidelines.

Interested agencies should submit proposal for the work with a brief statement of the approach, methodology, and relevant information concerning previous experience on monitoring of resettlement implementation and preparation of reports.

The profile of consultant agency, along with full CVs of the team to be engaged, must be submitted along with the proposal.

I. Budget and Logistics

The budget should include all expenses such as staff salary, office accommodation, training, computer/software, transport, field expenses and other logistics necessary for field activities, data collection, processing and analysis for monitoring and evaluation work. Additional expense claims whatsoever outside the proposed and negotiated budget will not be entertained. VAT, Income Tax and other charges admissible will be deducted at source as per GOB laws.

(Engr. -----------------------)
Project Coordinator
Project Implementation Unit (PIU)
Roads and Highways Department, Dhaka