CHAPTER 13 DETERMINATION OF APPLICABLE LIVE LOAD

13.1 General

The following design live loads were taken in this Study through examination and assessment on the existing traffic and loading condition in Sri Lanka.

(1) Live Load for Simple Repair Works

Specific live load was not determined for simple repair works such as re-painting, mortar injection to cracks, etc. The repair shall assumed only to remain existing loading capacity.

(2) Live Load for Rehabilitation

Since the design data to determine loading capacity of bridges are not existed, the Japanese Bridge Design Specification is adopted with some modification of intensity of the live load, TL20, considering the present condition obtained from the results of Axle Load Survey carried out by RDA.

In order to plan the optimum rehabilitation method, determination of proper design live load and allowable stress are principle factors..

(3) Live Load for Reconstruction

Present standard of live load in Sri Lanka is adopted in this Study.

13.2 Determination of Applicable Live Load for Rehabilitation Plan

This section presents the results and procedure for determination of the applicable design live load and allowable stress for rehabilitation plan.

13.2.1 Stress Check Applying Initial Live Load, TL20

The stress check, carried out on existing bridges applying TL20 live loading on some RSJ and ST.TR, revealed that there were many steel bridges which had excessive stress compared with allowable stress.

There are not so many heavy vehicles on most of the roads subjected to the Study except in the area of Colombo Port and its surroundings. Therefore, the latest Axle Load Survey carried out by RDA was reviewed for the live load to be used for the Rehabilitation Plan.

13.2.2 Determination of Basic Live Load

The basic design axle weight of 12 ton which is to be applied on bridges located on A-class roads is taken for the Study based on the consideration as follows:-

- 98% of vehicles is in the category of "axle load of under 12 ton" according to the axle load survey carried out on A-class roads. (see Table 13.1)

- Total vehicle weight of 12 tons is a standard size for national buses (SLTB BUS) in Sri Lanka.

- The number of bridges of which construction year are known is only 34 (46.6%) out of 73 of all steel bridges. Most of them were constructed in the period of British dominion (1796 to 1945). During the period, the Industrial Revolution has been taken place, therefore, introduction of vehicles is assumed to be in those days in Sri Lanka. Actually, steam paving machine is on display, which is assumed to be used in those days. However, weight of those vehicles can not be so heavy considering motorization surroundings at that time, and is assumed to be about 12 to 13 tons, and axle load is assumed to be 9.0 to 10.4 tons.

13.2.3 Determination of the Live Load to be Applied for Stress Check for Heavy Vehicles which Exceeds the Basic Live Load

The live load to be applied for stress check for the Rehabilitation Plan is determined as 18 tons for bridges on A-class roads based on the consideration as follows:-

- Vehicle weight of 18 tons covers 99.5% of all vehicles for short spanned bridge according to the axle load survey carried out on A-class roads (see Table 13.2).

- Where increase rate for allowable stress is set at 1.5, live load for stress check will be 18 tons.

On the other hand, vehicle weight of 16 tons is judged to be applied for bridges on B-class roads based on the consideration as follows:-

- Axle load survey has not been carried out for B-class roads, however, the importance of B-class roads is assumed to be lower than that of A-class roads.

- The limit of total vehicle weight for B-class roads in law is 15.275 tons for 2-axle truck.

- Vehicle weight of 16 tons covers 99.9% of all vehicles on AA012 road (Although it is under A-class road, it is more like B-class road. In fact, traffic volume is not so heavy), and maximum weight of vehicle is 18.6 tons.

These live load is set based on the present condition of traffic in Sri Lanka, therefore, the live load shall be re-set if any condition changes, such as an increase

Table 13.1 Results of Axle Load Survey (Axle Load)

No	1	2	3	4	5	6	Total Volume	% Volume Total	Sum %
Road	AA008	AA006	AA005	AA010	AA002	AA012			
Location	31km	57km	19km	6km	109km	54km			
Axle Renge tf	Ingiriya	Gokerella	Gampola	Werellagama	Boossa	Nochchiyagama			
0 - 1	1	0	0	2	13	2	18	0.3	0.30
1.1 - 2	38	55	165	108	356	79	801	13.3	13.60
2.1 - 3	63	137	255	190	566	122	1333	22.1	35.70
3.1 - 4	75	197	172	155	483	103	1185	19.6	55.30
4.1 - 5	46	200	158	129	299	49	881	14.6	69.90
5.1 - 6	33	110	69	89	200	22	523	8.7	78.60
6.1 - 7	11	63	41	63	123	5	306	5.1	83.70
7.1 - 8	8	49	23	18	77	4	179	3.0	86.70
8.1 - 9	12	29	30	7	49	10	137	2.3	88.90
9.1 - 10	4	47	34	15	30	5	135	2.2	91.20
10.1 - 11	7	116	33	34	42	2	234	3.9	95.00
11.1 - 12	7	71	34	38	45	0	195	3.2	98.30
12.1 - 13	11	19	15	10	17	1	73	1.2	99.50
13.1 - 14	2	4	9	1	2	1	19	0.3	99.80
14.1 - 15	0	5	0	2	2	0	9	0.14	99.95
15.1 - 16	1	0	0	0	0	0	1	0.02	99.97
16.1 - 17	0	1	0	0	0	0	1	0.02	99.98
17.1 - 18	0	0	0	0	0	0	0	0.0	99.98
18.1 - 19	0	0	0	0	1	0	1	0.02	100.00
19.1 - 20	0	0	0	0	0	0	0	0.0	100.00
Total	319	1103	1038	861	2305	405	6031	100.0	100.00

Table 13.2 Results of Axle Load Survey (Total Vehicle Weight) < 14t note) Applicable for Short Span

No.	Road Location	Date ADT hour	Volume % (Volume/Total) SUM %	Motor CY	Cars	Type of Vehicle 1~6, 11	Type of Vehicle 7~10 < 14t	< 16t	< 18t	< 20t	< 22t	< 24t	< 26t	Total	Remark	Max Vehicle Total Weight
1	AA008 Panadura -Nambapana -Ratnapura Rd 31st Km Ingiriya	95.08.30	Volume	551	281	819	(48) 92	(12) 23	(13) 25	(2) 4		-	(1) 2	(76/145) 1797	Max 25.88t	32.02t
		24 hour	%	30.7	15.6	45.6	5.1	1.3	1.4	0.2			0.1	100.0		
			SUM %	30.7	46.3	91.9	97.0	98.3	99.7	99.9			100.0	100.0		
2	AA006 Ambepussa -Kurunegala -Trinco Rd 57th Km Gokerella	95.08.03	Volume	787	499	1993	(205) 359	(141) 247	(70) 122	(13) 23	(6) 10	(2) 4	(2) 3	(439/768) 4047	Max 25.72t	40.78t
		24 hour	%	19.4	12.3	49.2	8.9	6.1	3.0	0.6	0.3	0.1	0.1	100.0		
			SUM %	19.4	31.8	81.0	89.9	96.0	99.0	99.6	99.8	99.9	100.0	100.0		
3	AA005 Peradeniya -Badulla -Chenkalady Rd 19th Km Gampola	95.11.14	Volume	490	737	2679	(208) 297	(55) 78	(37) 53	(5) 7				(305/435) 4341	Max 18.45t	18.45t
		24 hour	%	11.3	17.0	61.7	6.8	1.8	1.2	0.2				100.0		
			SUM %	11.3	28.3	90.0	96.8	98.6	99.8	100.0				100.0		
4	AA010 Katugastota -Kurunegola -Puttalam Rd 6th Km Werellagama	95.11.21	Volume	654	469	*1 1958	(73) 132	(36) 65	(18) 32	(5) 9	(9) 16	(5) 9		(146/263) 3344	Max 23.21t	29.26t
		24 hour	%	19.6	14.0	58.6	3.9	1.9	1.0	0.3	0.4	0.3		100.0	SLTB BUS Max 14.26t	
			SUM %	19.6	33.6	92.2	96.1	98.0	99.0	99.3	99.7	100.0		100.0		
5	AA002 Colombo-Galle -Hambantota -Wellawaya Rd 109 Km Boossa	95.12.15	Volume	915	1438	*2 3283	(315) 600	(62) 118	(42) 80	(10) 19	(2) 4	(1) 2	(1) 2	(433/825) 6461	Max 24.79t	38.23t
		24 hour	%	14.2	22.3	50.8	9.3	1.8	1.2	0.3	0.1	0.03	0.03	100.1		
			SUM %	14.2	36.4	87.2	96.5	98.3	99.6	99.88	99.93	99.97	100.0	100.0		
6	AA012 Puttalam -Anuradhapura -Trinco Rd 54 Km Nochchiyagama	93.04.28	Volume	467	114	424	(62) 91	(2) 3	-	(1) 1				(65/95) 1100	Max 18.64t	18.64t
		12 hour	%	42.5	10.4	38.5	8.3	0.3	-	0.1				100.1		
			SUM %	42.5	52.8	91.4	99.6	99.9	99.9	100.0				100.0		
	Total		Volume	3864	3538	11156	1571	534	312	63	30	15	7	21090	25.88t	40.78t
			%	18.3	16.8	52.9	7.4	2.5	1.5	0.3	0.1	0.07	0.03	99.9		
			SUM %	18.3	35.1	88.0	95.4	98.0	99.5	99.8	99.9	99.97	100.0	100.0		

*1 14t over 1volume Max 14.26t *2 14t over 6volume Max 17.14t of traffic volume and a number of heavy vehicles.

13.2.4 The Concept of Design Vehicle Weight in Japan

The concept of design vehicle weight reviewed recently in Japan is as follows:-

- According to the recent specification, TL25 consists one front axle load of 5 tons and two rear axle loads of 10 tons each, stipulated by law. Design axle load is considered to take the total of rear axle loads of 20 tons for T loading.

- On the other hand, total weight of special vehicles area allowed by 36 tons provided by law as shown in Appendix M. The difference of actual load and design load are allowed to a certain extent by some kinds of restrictions.

In addition, Road Bridge Rehabilitation Guideline (Japan Road Association) tells that "coefficient of load condition which is a factor to determine applicable design live load for the bridges to be rehabilitated shall be judged on the consideration of the loading of the bridges under normal traffic conditions."

On the other hand, the limits of total vehicle weight in Sri Lanka are 15.275 tons for 2-axle truck, 20 or 21 tons for 3-axle truck and 27.5 tons for 4-axle truck.

13.2.5 Allowable Stress for Steel Material

(1) Allowable Tensile Stress

Steel material used for steel bridges in Sri Lanka can be roughly classified into two kinds as stated in the Chapter 12: Strength Tests of Steel Samples. They are:

- Allowable tensile stress for steel produced before 1930 is assumed to be around 80% of allowable tensile stress for rolled steel (for normal structure) SS400. This can be applied for wrought iron and low quality mild steel.

- Allowable tensile stress for steel produced after 1930 is assumed to be almost the same as allowable tensile stress for rolled steel (for normal structure) SS400. This can be applied for mild steel.

(Allowable tensile stress for rolled steel (for normal structure) SS400 specified in the Japanese Bridge Design Specification is 1400kgf/cm2 which is obtained from dividing yield stress (2400kgf/cm2) by security factor (1.71).)

(2) Increase Rate for the Allowable Tensile Stress

Although the allowable tensile stress could be specified as the above, an increase rate for the allowable tensile stress should be confirmed in the Study considering present traffic condition in Sri Lanka.

The increase rate of allowable stress is set at 1.5. This value is less than 1.71 which is ratio between allowable stress and yield stress.

According to the axle load survey, only 2% of total numbers of axle load exceed 12 tons which is adopted as basic design axle weight. It can be considered that the above axle weight is very rare. So an occasion of the increase rate for allowable stress (1.5) is applicable for axle weight of 12.2 tons through 20 tons.

13.2.6 Applicable Live Load for Rehabilitation Plan

Based on the results of the analysis of the axle load survey and consideration on the difference of traffic volume between Japan and Sri Lanka, the live load and increase rate of allowable stress to be used for the Rehabilitation Plan was set in this Study as follows:-

- AA, AB-class roads : 18 tons
  (increase rate for allowable stress shall be 1.5.)
- B-class roads : 16 tons
  (increase rate for allowable stress shall be 1.5)

However, these live load, allowable stress and increase rate are based on the results from the axle load survey in the Study, so these shall be reconsidered in case any condition changes are arisen, such as increase of traffic volume, increase of percentage of heavy vehicles, etc.

On the other hand, if a rehabilitation method which is rather durable is used, such as covering RSJ with reinforced concrete, increase rate for allowable stress for steel shall be 1.2. This value is based on the Japanese Bridge Rehabilitation Manual which says that "allowable stress can be increased up to 20% in compressive side and 30% in tensile" side and is also based on a consideration which loss part of cross section due to corrosion was seen presently.

13.3 Determination of Applicable Live Load for Reconstruction Plan

This section presents the standard live load applied in Sri Lanka. In the Study, this live load is applied in the reconstruction plan only.

13.3.1 Design Standard in Sri Lanka

It is known that the most of bridges in Sri Lanka are built or designed using British Standard though design data and information at the time of construction is not existed.

In 1978, new bridge loading and a design standard known as BS 5400 (1978) was introduced to incorporate the application of ultimate limit state design philosophy in U.K. In 1982, the BS 5400 was introduced to Sri Lanka and has used so far.

13.3.2 Present Standard Live Load in Sri Lanka

RDA has established its own design live load based on the BS 5400 as follows:-

Loading

- All bridges in Sri Lanka to be designed to satisfy the more severe effects of either HA or HB Loading as stipulated in the Code of Practice BS 5400. The design HB loading is to be taken as 30 units, for the above exercise, for both A & B class roads.

- In areas of special significance or industrial towns, 45 units of HB Vehicle is to be checked, for the adequacy of the strength of the structures.

- For design purposes, in calculating load effects, the HB Vehicle may be considered as straddling two notional lanes as defined in the Code of Practice BS 5400.

13.3.3 Applicable Live Load for Reconstruction Plan

The HB vehicle has 4 axles, thus, the total weight of one vehicle reaches 1,200kN (120 ton).

According to the results of the Axle Load Survey, the heaviest vehicle of its total weight of about 41 tons and heaviest axle load of about 18 tons were observed on Gokkerella, 57th km of A-6 (Ambepussa - Kurunegala - Trincomalee) Road and Boosa, 109km of A-2 (Colombo - Galle - Hambantota) Road respectively, which are one of main corridors. Therefore, the weight of the HB vehicle seems to be conservative loading.

Taking into the consideration on RDA practice and their request, their Live Loading Standard of RDA was adopted in the reconstruction plan in this Study.

CHAPTER 14 PRELIMINARY REHABILITATION DESIGN

14.1 General

The main purposes of preliminary rehabilitation design covering the 10 bridges are to prepare standard rehabilitation design, to estimate the work quantities of each bridge. The preliminary design was carried out based on the output from the preceding detailed survey, bridge loading test as well as determination of applicable live load.

The design flow chart is illustrated in Figure 14.1 which also shows the interrelationship of above work items.

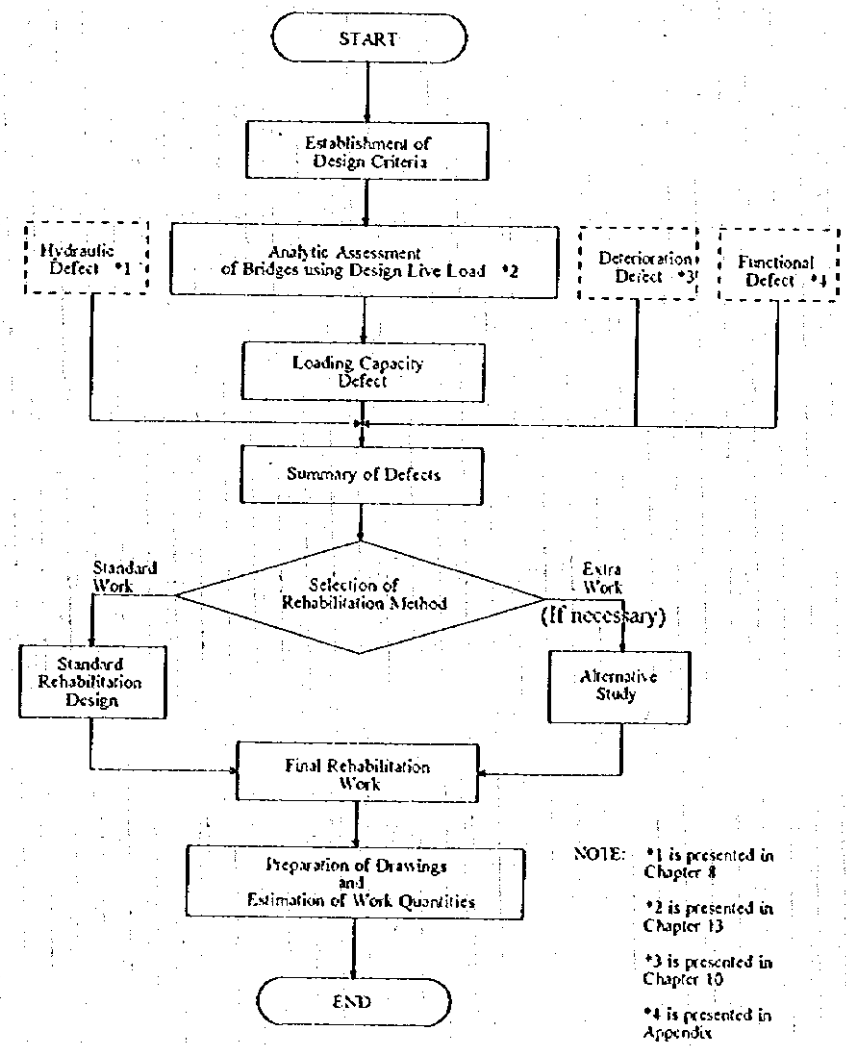

Figure 14.1 Flow Chart of Preliminary Design

Although preliminary rehabilitation designs for the 10 bridges were in various ways from repair to reconstruction in this chapter, the above ten rehabilitation methods were not enough to estimate rehabilitation costs for other 90 bridges. Therefore, preliminary design on reconstruction plan for each bridge was also carried out.

As for the other 90 bridges, it is necessary to establish some judgment criteria so as to decide a suitable rehabilitation plan for each bridge based on the bridge inventory. These criteria are described in Appendix-J and the Guideline for Maintenance and Management.

14.2 Establishment of Assessment Criteria

The structural assessment criteria to be applied in the Study is in principle based on Appendix - L except where the specification is not clear then the Bridge Design Specification in Japan applied. The assessment criteria covers the following items:

- Geometric design condition
- Bridge width
- Bridge loading
- Material and allowable stress
- Assessment method applied
- Superstructure design
- Substructure design
- Applicable design standard

This section presents an abstract of the above items and the details are enclosed in Appendix - L.

(1) Geometric Design Standard

The geometric design standard applied is in accordance with the RDA's standard. However, this is for highway design and it was used for approach road design in the case of reconstruction of bridge.

(2) Bridge Width

Bridge width applied in the case of reconstruction is in accordance with RDA standard, while bridge width applied in the case of rehabilitation is based on the sub-standard described in Appendix - L.

(3) Free Board

The free board requirement is not clearly in RDA standard, thus the recommendation given in River Design Standard in Japan is adopted after some modifications were made considering Sri Lanka river condition.

(4) Bridge Loading

For preliminary design in the case of reconstruction, the load to be considered are as follows:

- Dead loads
- Live loads (HA, HB loading)
- Footway load
- Breaking force
- Force due to earth pressure

Above design criteria are basically in accordance with RDA Standard. The other hand, live load for rehabilitation (reinforcement and repair) is T - Loading applied based on the results in Chapter 13.

(5) Assessment Method Applied

The assessment of the existing bridges and the design of rehabilitation work on the existing bridges were carried out in accordance with elastic design method (allowable stress design method), while for adding a footway which is not attached to the existing bridge or a new bridge for total replacement, the design was carried out using limit state design method.

The reasons for adopting these two different design methods in the preliminary rehabilitation design are:

- For assessment of the load carrying capacity, bridge history (year constructed, materials used, specification adopted), and design data and information are essential, while many bridges studies have not information and some of them were constructed in colonial times and are over 50 to 100 years old. These bridges were designed to various specifications which follows the elastic design principle.

- Quality of materials used in the studies bridges are also various. (That is strength variation is very wide.)

Thus, it is safe to apply elastic design method for the assessment and rehabilitation work. Contrarily, quality of material and accuracy of design for a new independent structure can be controlled properly within a very low tolerance. Accordingly, it is rational to apply limit state design methods only for an independent structure which will not be attached to the existing bridge.

The elastic design method was based on the Bridge Design Specification in Japan, while for limit state design the provisions prescribed in BS 5400 was applied.

(6) Material and Allowable Stress

1) Allowable stress design

Allowable stress for reinforced concrete and steel member shall be specified in Chapter 13.

2) Limit state design

The design strength of materials for limit state shall be as specified in BS 5400.

(7) Applicable Design Standard

In establishment of the assessment criteria, the Japanese Bridge Design Specification and the Rehabilitation Manual for Road Bridge published by the Japan Road Association.

(8) Assessment Criteria for the other 90 bridges

As for the rehabilitation plan for the other 90 bridges, each plan was decided based on the following criteria:

- The width of bridge for repair and reinforcement shall be determined in accordance with the substandard shown in Table L-3 in Appendix - L.
- In case of RSJ bridges, rehabilitation method shall be decided based on the assessment result described in Chapter 13.
- Since widening is remarkably difficult in case of truss bridge, the rehabilitation plan is limited to repair and/or redecking.
- Selection of rehabilitation method for each bridge shall be based on the judgment criteria shown in section 14.6 and the Guideline for Maintenance and Management.

14.3 Assessment of the Bridges

14.3.1 General

The contents of rehabilitation work for 10 bridges selected were divided into three main methods: Repair - for concrete and steel member, Widening - for footway and deck, Reconstruction - for super and substructure. The summary of Rehabilitation Plan is shown in Table 14.1

Furthermore, preliminary designs of additional reconstruction plan for the 7 bridges (SER No. 53, 59, 20, 70, 7, 211, 212) were carried out in order to assist the cost

Table 14.1 Summary of Rehabilitation Plan

SER No.	TYPE OF BRIDGE	Structural Defects (Rating)		Existing Width		Proposed Width		Bridge Length (m)	Treatment	
		Super-structure	Sub-structure	Carriage-way	Overall	Carriage-way	Overall		Superstructure	Substructure
85	ARCH/BR	2.0	2.0	6.30	7.50	7.4	9.8	68.90	Additional Footway	Widening
77	ST.TR/T/RCS +RSJ/BUC	3.0	2.0	5.36	5.66	6.8	9.2	39.22 79.66	Reconstruction by PSC/PRE & PSC/POS	Reconstruction 4@10+2@20+4@10=120m
53	ST.TR/T/RCS	2.0	1.0	3.37	3.65	-	-	39.95	Repair of Main Frame	-----
33	ST.TR/T/RCS RSJ/RCS	4.0	2.0	3.30	3.64	7.4	9.8	51.00 17.85	Reconstruction by PSC/PRE & S/BOX	Reconstruction 16+50+10=76m
59	RSJ/BUC	2.0	2.0	3.20	3.56	4.0	5.0	51.00	Redeck and Widen	Widening
20	RSJ/COR	4.0	2.0	3.97	4.29	6.0	7.0	14.35	Redeck and Widen	Widening
70	RSJ/RCS	2.0	3.0	5.46	5.93	6.5	7.5	43.23	Redeck and Widen	Widening
7	PSC/PRE +RCB	4.0	3.0	5.85	6.85	-	-	139.18	Repair of RCB	Repair
211	RSJ/RCS	2.0	2.0	3.55	3.83	6.0	7.0	23.60	Redeck and Widen	Widening
212	PSC/PRE	4.0	3.0	10.40	11.90	-	-	62.48	Repair	Repair

estimation on the other 90 bridges.

Table 14.2 shows the abstract of reconstruction plan for the above 8 bridges.

Table 14.2 Summary of Reconstruction Plan for 8 Bridges

SER No.	Proposed Width		Bridge Length (m)	Contents of Reconstruction
	Carriageway	Overall		
53	6.80	9.20	46.36	2 @ 23.14m L = 46.32m PSC/POS Abut: 2 nos. Pier: 1 no.
59	6.80	9.20	45.10	3 @ 15.00m PSC/PRE Abut: 2 nos. Pier: 2 nos.
20	6.80	9.20	18.08	2 @ 9.0m PSC/PRE Abut: 2 nos. Pier: 1 no.
70	7.40	11.00	43.60	3 @ 14.50m PSC/PRE Abut: 2 nos. Pier: 2 nos.
7	6.80	9.20	146.32	9 @ 16.23m PSC/PRE Abut: 2 nos. Pier: 8 nos.
211	7.40	9.80	23.28	2 @ 11.60m PSC/PRE Abut: 2 nos. Pier: 1 no.
212	7.40	9.80	48.79	3 @ 16.23m PSC/PRE Abut: 2nos. Pier: 2 nos.

14.3.2 Assessment of 10 Bridges

(1) SER No. 85

This bridge is proposed to be reconstructed in near future by Kuwait Fund. Although the existing width of this bridge is 6.3m without footway, the load carrying capacity is still enough as a structural member. Therefore, it was judged that it is possible to make good use of this bridge by widening with additional footway at both sides.

As a widening method, the existing curb at both sides shall be removed and then additional pretension slab beams shall be erected after construction of additional pier on the existing arch springing. The additional piers shall be anchored beside and on the existing arch.

1) Quantities

ITEM	UNIT	QUANITY
Demolish of existing curb	m^3	99.2
Additional concree for body	m^3	150.3
PSC/PRE (L = 16.23m)	nos.	16.0
Insitu concrete	L.S.	1.0
Curb and handrail	m	137.8

2) Work Schedule

ITEM	UNIT	QUANTITY	DURATION
Preparation	L.S.	1.0	30 days
Scaffolding	L.S.	1.0	30 days
Demolish of existing curb	m^3	99.2	30 days
Additional substructure	m^3	150.3	90 days
Additional superstructure	L.S.	1.0	90 days
Curb and handrail	m	137.8	30 days
Removal of Scaffolding	L.S.	1.0	30 days
Demobilization	L.S.	1.0	30 days
			12 months

(2) SER No. 77

This bridge consists of ST.TR/T/COR and RSJ/BUC. Functional defect of truss bridge is a narrow width and difficulty of widening, while structural defect is corrosion of steel member (corrugate plate and main frame). The reason for corrosion of lower chord is due to structural problem such as no drip check at lower chord member.

On the other hand, structural defect of RSJ/BUC is corrosion of steel member (buckle plate & main girder) and this type can be widened adopting additional main girders and redecked slab.

The possible rehabilitation work for truss bridge could be repainting and spricing with cover plate.

Main reason of defects of RSJ/BUC are structural problems such as inadequate length of drainage pipe, no curb or no cantilever slab. In addition to the above problems, it is easy to cause corrosion of the steel plate especially at the joints between buckle plates and girders in this type of slab.

Possible rehabilitation work for corroded steel buckle plate is repainting as a short term rehabilitation plan or replacement of the slab by appropriate type such as R.C. slab to cope with the structural problem as a long term.

As a fundamental solution, it was judged that reconstruction is a best way for this multi type bridge which consists of trussed beam and RSJ/BUC.

1) Outline for Reconstruction

Outline of reconstruction plan on this bridge is as follows:

Type of Superstructure : PSC/PRE, PSC/POS

Bridge Length	:	120.00m
Span Length	:	4 x 10.0 + 2 x 20.0 + 4 x 10.0m
Carriageway Width	:	7.40m
Overall Width	:	9.80m
Type of Substructure	:	Wall Type (Spread)

2) Quantities for Rehabilitation Plan

In this clause, quantities required for rehabilitation of truss bridge were calculated in order to assist cost estimation of the other 90 bridges.

■ Painted Area

(A1) Upper chord = 37.44 m²
(A2) Lower chard = 41.82 m²
(A3) End post = 13.81 m²
(A4) Lateral member = 31.51 m²
(A5) Main member = 249.16 m²
(A5 = (A1 + A2 + A3 + A4) x 2)
(A6) Cross beam = 115.63 m²

Total area = 365 m²

■ Amount of Cover Plate, H.T. Bolt

Plate (t = 9mm) for Web = 1.335 m² (94kg)
Plate (t = 12mm) for others = 0.148 m² (14kg)
H.T. Bolt (M22×70) = 84 nos. (47kg)
Weap hole (20) = 8 nos.

■ Amount of Slab

Demolition of slab concrete = 20.8m³

Replacing of slab concrete

d = k1 x d0 = 1.20 x 19.8 = 23.8 = 24 cm
d0=5L +11 = 5 x 1.757 + 11 = 19.8
L = 1.832 - 0.15/2 = 1.757 m
k1 = 1.20
V = 27.4m³

Rebar (φ19 ctc 125 for longitudinal)
(φ16 ctc 125 for transverse)
φ19 : W = 3,572 kg
φ16 : W = 2,558 kg

ϕ 13 : W = 245 kg
Total : 6.4 t (234 kg/m³)

3) Work Schedule (for Reconstruction)

ITEM	UNIT	QUANTITY	DURATION
Preparation	L.S.	1.0	30 days
Temporary Jetty	m^2	720.0	90 days
Substructure	L.S.	1.0	350 days
Superstructure	L.S.	1.0	250 days
Curb and handrail	m	240.0	90 days
Pavement	m^2	888.0	30 days
Demobilization	L.S.	1.0	60 days
			30 months

(3) SER No. 53

The type of this bridge is ST.TR/T/RCS which has simple span (L=39.95m) and main defect is corrosion of upper and lower chord member. The reasons for the defects are due to not only improper maintenance such as lack of repainting but also in some cases, structural problem such as no drip check at lower chord member.

The possible rehabilitation work could be repainting and spricing with cover plate.

1) Quantities

The Calculation results on repainting area and cover plate amount are as follows:

■ Painted Area

(A1) Upper chord = 95.39 m^2
(A2) Lower chard = 94.60 m^2
(A3) End post = 35.04 m^2
(A4) Lateral member = 115.23 m^2
(A5) Main member = 680.52 m^2
(A5 = (A1 + A2 + A3 + A4) x 2)
(A6) Cross beam = 79.82 m^2
(A7) Stringer = 56.12 m^2
(A8) Footway = 27.06 m^2
(A9) do = 56.12 m^2

Total area = 899.64 m^2
= 900.00 m^2

A5 + A6	= 760.34 m²	
	= 760 m²	
A7+ A8+ A9	= 139.5 m²	
	= 140 m²	

■ Amount of Cover Plate, H.T. Bolt

Plate (t = 9mm) for Web	=	1.800 m²
Plate (t = 9mm) for S.T.	=	0.432 m²
	=	2.232 m²
		(158kg)
Plate (t = 12mm) for others	=	0.022 m²
		(2kg)
H.T. Bolt (M22×70)	=	110 nos.
		(61kg)
Weap hole (20)	=	12 nos.

■ Amount of Slab

Demolition of slab concrete	= 31.8m³
Replacing of slab concrete	= 26.2 m³
Rebar	= 6.3 t
New S.T.	= 8.42 t

Note: The above mount on slab is calculated in order to assist cost estimation of the other 90 bridges.

2) Work Schedule

Item	Unit	Quantity	Duration
Preparation	L.S.	1.0	20 days
Scaffolding	L.S.	1.0	6 days
Removal of Existing Paint	m²	900	32 days
Repainting	m²	900	6 days
Spricing	kg	221	5 days
Removal of Scaffolding	L.S.	1.0	6 days
Demobilization	L.S.	1.0	20 days
			3.5 months

(4) SER No. 33

This bridge consists of ST.TR/T/RCS and RSJ/RCS, and precast reinforced concrete slab is adopted in both types.

The defect of truss bridge, especially vibration and deflection of main frame was remarkable and some of precast slabs of truss bridge have severe damages.

Considering difficulties to amend this deflection of main frame and to widen toe width of truss bridge, reconstruction could be a suitable rehabilitation method.

1) Outline for Reconstruction

The principles of preliminary design for reconstruction are two fold:-

- To use the standard design bridge (PSC/PRE, PSC/POS) as well as possible,
- To avoid increasing number of pier compared with the existing bridge.

After considering the principle above mentioned, intermediate span length (51m) could not be changed and it is necessary to adopt a steel box girder in simple span. Thus the composition of new bridge is as follows:

Type of Superstructure	:	PSC/PRE+Steel Box Girder+PSC/PRE
Bridge Length	:	76.00m
Span Length	:	16.0 + 50.0 + 10.0m
Carriageway Width	:	6.80m
Overall Width	:	9.20m
Type of Substructure	:	Wall Type (Caisson)

2) Work Schedule

ITEM	UNIT	QUANTITY	DURATION
Preparation	L.S.	1.0	30 days
Temporary Jetty	m²	456.0	90 days
Substructure	L.S.	1.0	280 days
Superstructure	L.S.	1.0	270 days
Curb and handrail	m	152.0	80 days
Pavement	m²	516.8	30 days
Demobilization	L.S.	1.0	60 days
			28 months

(5) SER No. 59

This bridge was one of the three bridges where loading test was carried out and it was confirmed that the loading capacity of the bridge still enough for the design load in rehabilitation study. The possible rehabilitation method is redecking and widening with R.C. slab and this plan includes repainting of existing main girders.

1) Outline of Rehabilitation Design

The principles of preliminary design for rehabilitation are three fold:-

- Thickness of slab shall be decided in accordance with the theory described in Chapter 13.

- Total width after widening shall be decided in accordance with the sub-standard described in Appendix - .

- In order to rehabilitate the defect which causes corrosion of steel members, slab on a buckle plate or corrugate plate shall be redecked with R.C. slab.

Thus the composition of new bridge is as follows:-

Type of Superstructure	:	RSJ/RCS
Bridge Length	:	45.10 m
Span Length	:	9.91 + 8.56 + 8.55 + 9.57 + 8.57 m
Carriageway Width	:	5.00 m
Overall Width	:	6.00 m
Type of Substructure	:	dia. 750mm concrete cylinder and steel frame
Additional main girder	:	5 nos.

2) Quantities

ITEM	UNIT	QUANTITY
Demolish of existing deck	m^2	181.6
Additional main girder	kg	4886
Redecking	m^2	255.0
Widening of substructure	L.S.	1.0

3) Work Schedule

ITEM	UNIT	QUANTITY	DURATION
Preparation	L.S.	1.0	20 days
Temporary Jetty	m^2	306	30 days
Scaffolding	L.S.	1.0	30 days
Demolish of existing slab	m^2	181.0	20 days
Additional substructure	L.S.	1.0	50 days
Redecking	m^2	255.0	50 days
Curb and handrail	m	102.0	20 days

Pavement	m^2	204.0	5 days
Repainting	m^2	342.4	15 days
Removal of Scaffolding	L.S.	1.0	10 days
Demobilization	L.S.	1.0	20 days
			9 months

(6) SER No. 20

This bridge consists of 2 nos. of simple beam (RSJ/COR), and it was found that some of main girders and corrugate plate have severe corrosion due to rain water penetrating into slab. According to the results of assessment on the applicable live loading described in Chapter 13, this bridge which conceits of H beam (300 x 155) 7.2 meters length does not necessity to be covered with reinforced concrete in order to keep the loading capacity of the bridge. Therefore it is required to replace some of main girders and to redeck and widen with R.C. slab.

1) Outline of Rehabilitation Design

The principle of preliminary design for rehabilitation are three fold:-

- Thickness of slab shall be decided in accordance with the theory described in Chapter 13.

- Total width after widening shall be decided in accordance with the sub-standard described in Appendix - .

- In order to rehabilitate the defect which causes corrosion of steel members, slab on a buckle plate or corrugate plate shall be redecked with R.C. slab.

Thus, the composition of new bridge is as follows:-

Type of superstructure	:	RSJ/RCS
Bridge length	:	14.35 m
Span length	:	7.07 + 7.28 m
Carriageway width	:	6.00 m
Overall width	:	7.0 m
Type of substructure	:	Wall Type (Spread)

2) Quantities

ITEM	UNIT	QUANTITY
Demolish of existing deck	m^2	61.6
Additional main girder	kg	3110
Redecking	m^3	100.5
Widening of substructure	L.S.	1.0

3) Work Schedule

ITEM	UNIT	QUANTITY	DURATION
Preparation	L.S.	1.0	30 days
Temporary jetty	m^2	86.1	30 days
Scaffolding	L.S.	1.0	5 days
Demolish of existing deck	m^2	61.6	20 days
Additional substructure	L.S.	1.0	80 days
Redecking	m^2	100.5	30 days
Curb and handrail	m	28.7	15 days
Pavement	m^2	86.1	15 days
Repainting	m^2	70.3	15 days
Removal of scaffolding	L.S.	1.0	5 days
Demobilization	L.S.	1.0	25 days
			9 months

(7) SER No. 70

This bridge consists of 5 nos. of simple beam (RSJ/RCS) and it was found that the superstructure is generally in fair condition, and suffer only little corrosion of steel frame of substructure and crack at A1 abutment. According to the results of assessment on the applicable live loading described in Chapter 13, this bridge which consists of H-beam (400x150) 9.5 metres length does not have necessity to be covered with reinforced concrete in order to keep the loading capacity of the bridge. Consequently the main rehabilitation is to widen superstructure and substructure.

1) Outline of Rehabilitation Design

The principle of preliminary design for rehabilitation are three fold:-

- Thickness of additional slab shall be decided in accordance with the theory described in Chapter 13.
- Total width after widening shall be decided in accordance with the sub-standard described in Appendix -
- Widening of substructure shall be carried out by using bracket-

type frame on the existing sylinder without any additional sylinder.

Thus, the composition of new bridge is as follows:-

Type of superstructure	:	RSJ/RCS
Bridge length	:	42.50 m
Span length	:	7.59+9.21+9.05+9.43+7.22 m
Carriageway width	:	6.50 m
Overall width	:	7.50 m
Type of substructure	:	Steel frame & concrete sylinder

2) Quantities

ITEM	UNIT	QUANTITY
Additional main girder	kg	4072
Redecking	m²	68.0
Additional substructure	kg	3679

3) Work Schedule

ITEM	UNIT	QUANTITY	DURATION
Preparation	L.S.	1.0	30 days
Temporary jetty	m²	255.0	30 days
Scaffolding	L.S.	1.0	20 days
Demolish of existing curb & handrail	m	85.0	20 days
Additional substructure	kg	3679	50 days
Decking	m²	68.0	50 days
Curb and handrail	m	85.0	30 days
Pavement	m²	68.0	10 days
Repainting	m²	265.6	20 days
Remoal of scaffolding	L.S.	1.0	10 days
Demobilization	L.S.	1.0	30 days
			10 months

(8) SER No. 7

This bridge consists of PSC/PRE, RC T-beam and RC-beam and the defects of the bridge could be found only in RC T-beam and RC-beam especially at both outside beams.

Main defects of R.C. bridge are remarkable rebar exposure and extents of them are up to half depth of web. And there are some columns which have severe damage. This bridge located in Negombo Lagoon and it is considered that chloride attack accelerates the deterioration of R.C. bridges.

It was not observed during the visual inspection stage that any vibration or deflection occurs, therefore the loading capacity of R.C. beams are adequate for existing traffic load.

1) Outline of Rehabilitation Design

The principles of preliminary design for rehabilitation are two fold:-

- This bridge has not footway and the carriageway 5.8 meters wide is not enough for full two-lane traffic. Therefore almost of traffic loading is not concentrated to outside beams but to inside beams. This is the reason why any remarkable vibration or deflection could not be observed in the RC-beams.

- Considering the above situation on traffic flow, it is considered that the defects of outside RC-beams can not prove fatal to the bridges. Therefore, the possible rehabilitation work for rebar exposure which has more than 10 centimeters depth could be prepacked concrete with reinforcement bars.

In the calculation on the inside beam, T-20 loading which consists of 4-ton and 16-ton axle weight is adopted and stresses of concrete and rebar calculated are as follows:

Loading case	:	D	σc = 21.3 kg/cm²
			σs = 414 kg/ cm²
Loading case	:	D+L	σc = 95.1 kg/cm²
			σs = 1,854 kg/ cm²

The axle weight investigation described in Chapter 13 indicates that 16 tons axle weight is observed rarely, consequently it can be considered that the overstress above mentioned would not be a big problem for the durability of the bridge.

2) Quantities

ITEM	UNIT	QUANTITY
Removal of loose weak material	m³	10.95
Sealant for crack injection	m	332.6
Crack injection	m	332.6
Re-bar	kg	112
Form	m²	14,598
Prepacked concrete	m³	10.95
Scaffolding	L.S.	1.0

3) Work Schedule

ITEM	UNIT	QUANTITY	DURATION
Preparation	L.S.	1.0	20 days
Scaffolding	L.S.	1.0	20 days
Removal of loose weak material	m^3	10.95	10 days
Sealant for crack injection	m	332.6	10 days
Crack injection	m	332.6	10 days
Setting of rebar	kg	112	15 days
Formwork	m^2	14,598	10 days
Placing of prepacked concrete	m^3	10.95	40 days
Removal of form	m^2	14,598	5 days
Removal of scaffolding	L.S.	1.0	20 days
Demobilization	L.S.	1.0	20 days
			6 months

(9) SER No. 211

This bridge was one of the three bridges where loading test was carried out and it was confirmed that the loading capacity of the bridge is adequate for the design load in the rehabilitation study. This bridge consists of 2 nos. of simple beam (RSJ/RCS) and substructures are abutments and 2 nos. of pile bent type pier. In the detailed structural survey, it was observed that there was not any remarkable damage. Therefore, the possible rehabilitation work could be widening of bridge.

1) Outline of Rehabilitation Design

The principles of preliminary design for rehabilitation are three fold:-

- Thickness of additional slab shall be decided in accordance with the theory described in Chapter 13.
- Total width after widening shall be decided in accordance with the sub-standard described in Appendix - .
- Widening of substructure shall be carried out with additional pile-bent type piers.

Thus the composition of new bridge is as follows:-

Type of superstructure	:	RSJ/RCS
Bridge length	:	23.19 m
Span length	:	7.71+7.79+7.69 m
Carriageway width	:	6.00 m

Overall width : 7.00 m
Type of substructure : Pile bent

ITEM	UNIT	QUANTITY
Additional main girder	kg	12,461
Widening of slab	m²	74.8
Widening of substructure	L.S.	1.0

3) Work Schedule

ITEM	UNIT	QUANTITY	DURATION
Preparation	L.S.	1.0	30 days
Temporary jetty	m²	141.6	30 days
Scaffolding	L.S.	1.0	5 days
Demolish of existing curb	m	47.2	10 days
Additional substructure	L.S.	1.0	85 days
Additional decking	m²	74.8	30 days
Curb and handrail	m	47.2	15 days
Pavement	m²	63.0	15 days
Repainting	m²	200.1	15 days
Remoal of scaffolding	L.S.	1.0	5 days
Demobilization	L.S.	1.0	30 days
			9 months

(10) SER No. 212

This bridge is located along sea shore and, it was designed and constructed about 20 years ago based on the Sri Lankan standard design which followed BS code.

Therefore the loading capacity of existing bridge is sufficient for design load. In fact, the result of loading test shows that this bridge has adequate rigidity and it was confirmed that the defect of the bridge could be repaired with patching with epoxy mortar or crack injection. As for a chloride attack, any damage could not be found in spite of the above location.

1) Outline of Rehabilitation Design

The principles of preliminary design for rehabilitation are two fold:-

- The main defects of superstructure are P.C. tendon and rebar exposure at the soffit of PSC beam and locations of these defects are near support. Consequently they don't give any severe effect to a durability of superstructure.

- The depth of flaking and P.C. tendons exposure is less than 50mm and the possible rehabilitation work will require some protection of soffit of beams against a further exposure.

2) Quantities

ITEM	UNIT	QUANTITY
Removal of loose weak material	m^3	0.77
Sealant for crack injection	m	3.9
Crack injection	m	3.5
Bond for damaged surface	m^2	14.5
Repair mortar	m^3	0.77

3) Work Schedule

ITEM	UNIT	QUANTITY	DURATION
Preparation	L.S.	1.0	5 days
Removal of loose weak material	m^3	0.77	10 days
Sealant for crack injection	m	3.9	5 days
Crack injection	m	3.5	5 days
Bond for damaged surface	m^2	14.5	5 days
Repair mortar	m^3	0.77	10 days
Demobilization	L.S.	1.0	5 days
			1.5 months

14.4 Preliminary Design for Reconstruction

14.4.1 General

This section presents the results of preliminary design for reconstruction as 9 bridges out of the 10 bridges to assist cost estimations on other 90 bridges.

At first, bridge planning was carried out based on the results of defailed survey consisted of topographic survey, geological investigation and hydraulic study.

The foundations of substructure vary with parameters such as reactions by superstructure, soil condition, its height and so on. Therefore, calculation of stability check was carried out on all 9 bridges in order to obtain certain accuracy for cost estimate.

14.4.2 Selection of Structural Type

(1) Superstructure

RDA has prepared its own PC concrete standard beams and they are being used for construction of bridges.

According to the RDA design practice, bridge span is determined by using these standard concrete beams. The dimensions of these are attached in Appendix .

The strength of existing concrete bridge in which one of the standard beams, (PSC/PRE) were used based on the results of the full scale loading test carried out in this Study.

Considering the present situation mentioned above, it can be judged that the standard beams are reliable to be adopted in this Study except for the center span of the bridge SER No. 33. Steel box girder is recommended in order to span 50 meters length. Since the steel box girder is very common type of superstructure in Japan, there are a lot of useful design data. Therefore, calculation was omitted by utilize of these data to determine the dimensions and steel weight of this steel bridge.

(2) Substructure

The type of foundation applied in this Study was determined considering current design practices in Sri Lanka and they are as follows:-

- Spread foundation
- Piled foundation (RDA standard - R.C. square piles 355 X 355)
- Caisson foundation (open caisson)

In the case of SER No. 212, two alternatives are prepared assuming the construction condition at site as follows:-

- Alternative 1
  Existing foundation can be used for new bridges

- Alternative 2
  New foundation can be constructed in the same place of existing foundation.

14.4.3 Results of Reconstruction Design

The preliminary design of reconstruction work in the Study was carried out in accordance with exercise mentioned in section 14.2 and 14.4.2. This section presents the summary of the stability check results and the corresponding work quantities, while the drawings prepared for all the reconstruction plans are attached in Volume IV Drawings.

(1) Summary of Stability Check

The stability check of foundation were carried out by applying HA and HB loading (30 units) which meet RDA design practice. The results are summarized and shown in Table 14.3 to Table 14.5.

(2) Summary of Work Quantities

The work quantities for 9 bridges, 2 bridges for the purpose of actual rehabilitation and 7 bridges for the purpose of cost estimate, were computed based on the preliminary design drawings attached in Volume IV.

<u>SER No. 212 (Alternative 1)</u>

1) Outline for Reconstruction

Type of Superstructure	:	PSC/PRE
Bridge Length	:	48.790 m
Span Length	:	3 x 16.23 m
Carriageway Width	:	7.4 m
Overall Width	:	9.8 m
Type of Foundation	:	Existing Caisson

2) Quantities for Reconstruction

Superstructure		:	478.00 m²
Substructure	Abutment	:	2 Nos.
	Pier	:	2 Nos.
Foundation	Caisson	:	Existed

Table 14.3 Summary of Stability Check (Spread Foundation)

SER No.		77	20			Remark
Width (m)		9.8	9.2			
Case 1	Structure No.	A1, A2	A1			
	Height of Abutment (m)	10.0	7.0			
	Fix or Mov	F	F			
	Breadth of Footing (m)	5.5	4.0			
	Bearing Qmax (t/m2)	29.4	26.3			
	Bearing Qa (t/m2)	30.0	30.0			
Case 2	Structure No.		A2			
	Height of Abutment (m)		7.0			
	Fix or Mov		M			
	Breadth of Footing (m)		3.5			
	Bearing Qmax (t/m2)		23.1			
	Bearing Qa (t/m2)		30.0			
Case 3	Structure No.	P3	P1			
	Height of Pier (m)	12.5	7.0			
	Fix or Mov	M+F	M+F			
	Breadth of Footing (m)	4.5	3.5			
	Bearing Qmax (t/m2)	29.2	27.4			
	Bearing Qa (t/m2)	30.0	30.0			
Case 4	Structure No.	P4				
	Height of Pier (m)	12.5				
	Fix or Mov	M+F				
	Breadth of Footing (m)	5.5				
	Bearing Qmax (t/m2)	27.9				
	Bearing Qa (t/m2)	30.0				
Case 5	Structure No.	P5				
	Height of Pier (m)	12.0				
	Fix or Mov	M+M				
	Breadth of Footing (m)	5.5				
	Bearing Qmax (t/m2)	21.1				
	Bearing Qa (t/m2)	30.0				

Table 14.4 Summary of Stability Check (Piled Foundation)

SER No.			212	211	59	7	Remark
Width (m)			9.8	9.8	9.2	9.2	
Case 1	Structure No.		A1	A1	A1	A1	
	Height of Abutment	(m)	4.8	5.0	4.5	5.5	
	Fix or Mov		F	F	F	F	
	Breadth of Pile Cap	(m)	3.0	3.0	3.0	3.5	
	Nos. of Piles	(Nos.)	3*10=30	3*10=30	3*10=30	3*11=33	
	Bearing per Pile	(t)	28.6	29.8	27.5	27.7	
	Bearing Qa per Pile	(t)	30.0	30.0	30.0	30.0	
Case 2	Structure No.		A2	A2	A2	A2	
	Height of Abutment	(m)	4.8	5.0	4.5	5.5	
	Fix or Mov		M	M	M	M	
	Breadth of Pile Cap	(m)	3.0	3.0	3.0	3.5	
	Nos. of Piles	(Nos.)	3*8=24	3*8=24	3*8=24	3*8=24	
	Bearing per Pile	(t)	28.2	25.1	26.8	29.3	
	Bearing Qa per Pile	(t)	30.0	30.0	30.0	30.0	
Case 3	Structure No.		P1	P1	P1	P1	
	Height of Pier	(m)	4.0	7.0	7.5	8.5	
	Fix or Mov		F+M	M+F	M+F	M+F	
	Breadth of Pile Cap	(m)	3.0	3.5	3.5	4.0	
	Nos. of Piles	(Nos.)	3*10=30	3*11=33	3*12=36	3*12=36	
	Bearing per Pile	(t)	28.2	29.1	28.8	29.4	
	Bearing Qa per Pile	(t)	30.0	30.0	30.0	30.0	

Table 14.5 Summary of Stability Check (Caisson Foundation)

SER No.			53	33	70		Remark
Width (m)			9.2	9.2	11.0		
Case 1	Structure No.		A1	A1	A1		
	Height of Abutment	(m)	9.0	7.0	5.0		
	Fix or Mov		F	F	F		
	Breadth of Footing	(m)	4.0	3.5	3.5		
	Size of Caisson	(m)	4.0*3.0	3.5*3.0	3.5*3.0		
	Nos. pf Caisson	(Nos.)	3	3	3		
	Bearing Qmax	(t/m2)	48.3	58.7	42.0		
	Bearing Qa	(t/m2)	60.0	60.0	60.0		
Case 2	Structure No.		A2	A2	A2		
	Height of Abutment	(m)	9.0	7.0	7.5		
	Fix or Mov		M	M	M		
	Breadth of Footing	(m)	4.0	3.5	3.5		
	Size of Caisson	(m)	4.0*3.0	3.5*3.0	3.5*3.0		
	Nos. pf Caisson	(Nos.)	3	3	3		
	Bearing Qmax	(t/m2)	46.3	53.5	48.9		
	Bearing Qa	(t/m2)	60.0	60.0	60.0		
Case 3	Structure No.		P1	P1	P1		
	Height of Pier	(m)	10.0	10.5	7.5		
	Fix or Mov		M+F	M+F	M+F		
	Breadth of Footing	(m)	4.0	5.0	3.5		
	Size of Caisson	(m)	4.0*3.0	5.0*3.0	3.0*3.0		
	Nos. pf Caisson	(Nos.)	3	3	3		
	Bearing Qmax	(t/m2)	40.8	50.0	48.4		
	Bearing Qa	(t/m2)	60.0	60.0	60.0		

Approach Road	:	30.00 m
Masonry	:	134.00 m^2
Temporary Jetty (w = 6.0 m)	:	293.00 m^2

3) Construction Period

21.0 months

SER No. 212 (Alternative 2)

1) Outline for Reconstruction

Type of Superstructure	:	PSC/PRE
Bridge Length	:	48.790 m
Span Length	:	3 x 16.23 m
Carriageway Width	:	7.4 m
Overall Width	:	9.8 m
Type of Foundation	:	Piled

2) Quantities for Reconstruction

Superstructure		:	478.00 m^2
Substructure	Abutment	:	2 Nos.
	Pier	:	2 Nos.
Foundation	R.C. Piles 355 x 355	:	690.00 m
Approach Road		:	30.00 m
Masonry		:	134.00 m^2
Temporary Jetty (w = 6.0 m)		:	293.00 m^2

3) Construction Period

25.0 months

SER No. 77

1) Outline for Reconstruction

Type of Superstructure	:	PSC/POS + PSC/PRE
Bridge Length	:	120.000 m
Span Length	:	2 x 20.0 m + 2 x 4 x 10.0 m
Carriageway Width	:	7.4 m
Overall Width	:	9.8 m
Type of Foundation	:	Spread

2) Quantities for Reconstruction

Superstructure	:	1176.00 m^2

Substructure	Abutment	:	2 Nos.
	Pier	:	9 Nos.
Concrete Wall (H ave.=3.0 m)		:	14.00 m
Approach Road		:	30.00 m
Temporary Jetty (w = 6.0 m)		:	720.00 m²

3) Construction Period

30.0 months

SER No. 53

1) Outline for Reconstruction

Type of Superstructure	:	PSC/POS
Bridge Length	:	46.355 m
Span Length	:	2 x 23.14 m
Carriageway Width	:	6.8 m
Overall Width	:	9.2 m
Type of Foundation	:	Caisson

2) Quantities for Reconstruction

Superstructure		:	426.00 m²
Substructure	Abutment	:	2 Nos.
	Pier	:	1 No.
Foundation	Caisson	:	1,026.00 m³
Approach Road		:	60.00 m
Masonry		:	335.00 m²
Temporary Jetty (w = 6.0 m)		:	278.00 m²

3) Construction Period

20.0 months

SER No. 211

1) Outline for Reconstruction

Type of Superstructure	:	PSC/PRE
Bridge Length	:	23.275 m
Span Length	:	2 x 11.6 m
Carriageway Width	:	7.4 m
Overall Width	:	9.8 m
Type of Foundation	:	Piled

2) Quantities for Reconstruction

Superstructure		:	228.00 m^2
Substructure	Abutment	:	2 Nos.
	Pier	:	1 No.
Foundation	Piles 355x355	:	505.50 m
Approach Road		:	40.00 m
Masonry		:	179.00 m^2
Mat Babion		:	150 Nos.
Temporary Jetty (w = 6.0 m)		:	140.00 m^2

3) Construction Period

17.0 months

SER No. 33

1) Outline for Reconstruction

Type of Superstructure	:	Stl. Box + PSC/PRE
Bridge Length	:	76.000 m
Span Length	:	50.0 m + 16.0 m + 10.0 m
Carriageway Width	:	6.8 m
Overall Width	:	9.2 m
Type of Foundation	:	Caisson

2) Quantities for Reconstruction

Superstructure		:	699.00 m^2
Substructure	Abutment	:	2 Nos.
	Pier	:	2 Nos.
Foundation	Caisson	:	1,251.00 m^3
Approach Road		:	135.00 m
Masonry		:	335.00 m^2
Temporary Jetty (w = 6.0 m)		:	456.00 m^2

3) Construction Period

28.0 months

SER No. 59

1) Outline for Reconstruction

Type of Superstructure	:	PSC/PRE
Bridge Length	:	45.100 m
Span Length	:	3 x 15.00 m

Carriageway Width	:	6.8 m
Overall Width	:	9.2 m
Type of Foundation	:	Piled

2) Quantities for Reconstruction

Superstructure		:	415.00 m²
Substructure	Abutment	:	2 Nos.
	Pier	:	2 Nos.
Foundation	R.C. Piles 355 x 355	:	756.00 m
Approach Road		:	30.00 m
Masonry		:	112.00 m²
Temporary Jetty (w = 6.0 m)		:	271.00 m²

3) Construction Period

23.0 months

SER No. 20

1) Outline for Reconstruction

Type of Superstructure	:	PSC/PRE
Bridge Length	:	18.075 m
Span Length	:	2 x 9.0 m
Carriageway Width	:	6.8 m
Overall Width	:	9.2 m
Type of Foundation	:	Spread

2) Quantities for Reconstruction

Superstructure		:	166.00 m²
Substructure	Abutment	:	2 Nos.
	Pier	:	1 No.
Approach Road		:	105.00 m
Masonry		:	224.00 m²
Temporary Jetty (w = 6.0 m)		:	108.00 m²

3) Construction Period

14.0 months

SER No. 70

1) Outline for Reconstruction

Type of Superstructure	:	PSC/PRE

Bridge Length	:	43.600 m
Span Length	:	3 x 14.5 m
Carriageway Width	:	7.4 m
Overall Width	:	11.0 m
Type of Foundation	:	Caisson

2) Quantities for Reconstruction

Superstructure		:	480.00 m²
Substructure	Abutment	:	2 Nos.
	Pier	:	2 Nos.
Foundation	Caisson	:	1,001.25 m³
Approach Road		:	30.00 m
Masonry		:	179.00 m²
Mat Gabion		:	150 Nos.
Temporary Jetty (w = 6.0 m)		:	262.00 m²

3) Construction Period

21.0 months

SER No. 7

1) Outline for Reconstruction

Type of Superstructure	:	PSC/PRE
Bridge Length	:	146.320 m
Span Length	:	9 x 16.23 m
Carriageway Width	:	6.8 m
Overall Width	:	9.2 m
Type of Foundation	:	Piled

2) Quantities for Reconstruction

Superstructure		:	1,346.00 m²
Substructure	Abutment	:	2 Nos.
	Pier	:	8 Nos.
Foundation	R.C. Piles 355 x 355	:	3,924 m
Approach Road		:	30.00 m
Masonry		:	201.00 m²
Mat Gabion		:	150 Nos.
Temporary Jetty (w = 6.0 m)		:	878.00 m²

3) Construction Period

36.0 months

(3) Specification

An applicable specification for reconstruction work is in principal based on RDA Standard Specifications for Construction and Maintenance of Roads and Bridges, 1989 and briefly described in the drawings.

14.5 Preliminary Design for Steel Bridges

This section presents the results of stress check carried out on RSJ and ST.TR.

14.5.1 Stress-check on RSJ

RSJ Bridges have been constructed for short spans, 3.7m to 10.5m. Slab type of BUC, COR, DEC and timber should be redecked with RCS according to Section 14.6. Since design standards for deck slab to determine slab thickness and arrangement of reinforcement has not yet been established in Sri Lanka, the standards have been prepared in this section. In addition, the study of load distribution expected by deck slab only was carried out. The study of composite action on existing non-composite beam bridges was also carried out. The stress check was carried out based on the results of above studies.

This section presents the results of the studies as follows:-

(1) Design standard for deck slab regarding slab thickness and arrangement of reinforcement

(2) Load distribution by deck slab only

(3) Composite action of non-composite beams

(4) Results of stress check for RSJ bridges

The stress check was extended on all RSJ bridges, 54 nos., which the preliminary inspection was carried out.

The results are attached in Appendix M-8.

The summary of the stress check is tabulated together with the corresponding rehabilitation plans in Table 14.6.

(1) Design standard for deck slab regarding slab thickness and arrangement of reinforcement

Slab thickness and arrangement of reinforcement were determined in accordance with the Japan Bridge Design Specification. The standards used for them are abstracted from Division 6 Deck Slab, Part II :steel bridges, specification for Highway Bridges, March 1987 and 1994 issued by Japan Road Association, and attached in Appendix-L.

(2) Load Distribution Ratio by Deck Slab

Generally, most of RSJ Bridges now in operating have no cross beam in Sri Lanka.

Table 14.6 Summary of Stress Check and Rehabilitation Plan for all RSJ Bridges

SER No.	Stress check		Reconstruction needed by		Rehabilitation Plan
	Without Concrete Cover	With Concrete Cover	Calculation	Damage	
44	Excessive stress	Excessive stress	O		Reconstruction by PSC/PRE
89	Excessive stress	OK			Covering of main beam with RC
2	Excessive stress	OK			Covering of main beam with RC
36	Excessive stress	Excessive stress	O		Reconstruction by PSC/PRE
102	OK	-			-
65	OK	-			-
52	Excessive stress	Excessive stress	O		Reconstruction by PSC/PRE
77	-	-		O	Reconstruction by PSC/PRE
106	OK	OK			-
108	Excessive stress	OK			Covering of main beam with RC
119	Excessive stress	Excessive stress	O		Reconstruction by PSC/PRE
175	-	-		O	Reconstruction by RCB
120	OK	-			-
30	OK	-			-
55	Excessive stress	OK			Covering of main beam with RC
56	OK	-			-
127	OK	-			-
31	-	-		O	Reconstruction by PSC/PRE
57	OK	-			-
131	OK	-			-
209	OK	-			-
210	OK	-			-
211	OK	-			-
33	-	-		O	Reconstruction by PSC/PRE
58	OK	-			-
59	OK	-			-
67	OK	-			-
18	-	-		O	Reconstruction by PSC/PRE
68	OK	-			-
133	OK	-			-
78	OK	-			-
135	OK	-			-
20	Excessive stress	OK			Covering of main beam with RC
38	-	-		O	Reconstruction by PSC/PRE
136	Excessive stress	OK			Covering of main beam with RC
195	OK	-			-
70	OK	-			-
138	OK	-			-
173	OK	-			-
39	OK	-			-
144	-	-		O	Reconstruction by RCB
147	OK	-			-
148	Excessive stress	Excessive stress	O		Reconstruction by PSC/PRE
21	OK	OK			-
40	OK	-			-
37	Excessive stress	OK			-
32	-	-		O	Reconstruction by PSC/PRE
150	OK	-			-
151	OK	-			-
154	OK	-			-
24	Excessive stress	OK			Covering of main beam with RC
25	Excessive stress	Excessive stress	O		Reconstruction by PSC/PRE
35	-	-		O	Reconstruction by PSC/PRE
74	OK	-			-

It was assumed that load distribution was not considered or was considered with deck slab only at the time of construction in old days.

Accordingly, comparison of reaction force from superstructure was carried out for load distribution. These data were obtained from the 1-0 method and FEM analysis of SER No. 59 and 211.

The results of the comparison of the load distribution ratio is summarized and shown in Table 14.7 below.

Table 14.7 Load Distribution Ratio by Deck Slab

	SER No. 59				SER No. 211			
	Dead Load		Live Load		Dead Load		Live Load	
	1-0 method	FEM	1-0 method	FEM	1-0 method	FEM	1-0 method	FEM
Outside Girder	0.400	(1.03) 0.413	0.27	(1.19) 0.32	0.419	(1.00) 0.419	0.267	(1.33) 0.356
Inside Girder	0.600	(0.98) 0.587	0.73	(0.93) 0.68	0.581	(1.00) 0.581	0.733	(0.88) 0.644

Note: ( ) is obtained from dividing reaction force of 1-0 method by reaction force of FEM.

Since the load distribution ratio derived from 1-0 method and FEM analysis are almost equal, the dead load is not distributed by deck slab.

12% of live load distribution ratio is reduced on inner beam of SER No. 211 which has thicker slab concrete slab thickness (t=27cm) and 7% for SER No. 59 which has thinner thickness (t=23cm: RCS+BUC was converted to RC slab). This reduction rates mean that 10% of live load on inner beam is distributed by deck slab only.

(3) Composite action on non-composite beams

Tables 14.8 and 14.9 show the comparison of actual value and design value of deflection of beam. The actual value was obtained from full scale loading test for SER No. 59 and 211 and the design value was calculated by FEM analysis.

Table 14.8 Deflection of Beam (SER No. 59)

Loading Test Cases		Outside Girder				Inside Girder			
		L/4		L/2		L/4		L/2	
Def.(mm)		Def.	F/A	Def.	F/A	Def.	F/A	Def.	F/A
Case-1	Actual	0.49	-	0.59	-	0.51	-	0.69	-
	FEM Analysis 1	0.438	0.894	0.608	1.031	0.484	0.949	0.698	1.012
Case-2	Actual	0.55	-	0.67	-	0.60	-	0.74	-
	FEM Analysis 1	0.522	0.949	0.659	0.984	0.598	0.997	0.756	1.022
Case-3	Actual	0.54	-	0.65	-	0.59	-	0.71	-
	FEM Analysis 1	0.506	0.937	0.626	0.963	0.578	0.980	0.702	0.989
Average	Actual	0.527	-	0.637	-	0.567	-	0.713	-
	FEM Analysis 1	0.489	0.928	0.631	0.991	0.553	0.975	0.719	1.008

Note: The amount of deflection above derived from FEM analysis are compensated.

Table 14.9 Deflection of Beam (SER No.211)

Loading Test Cases		Outside Girder				Inside Girder			
		L/4		L/2		L/4		L/2	
Def.(mm)		Def.	F/A	Def.	F/A	Def.	F/A	Def.	F/A
Case-1	Actual	0.160	-	0.240	-	0.200	-	0.270	-
	FEM Analysis 1	0.103	0.644	0.169	0.704	0.117	0.585	0.201	0.744
	FEM Analysis 2	0.350	2.188	0.575	2.396	0.364	1.820	0.611	2.263
Case-2	Actual	0.195	-	0.245	-	0.260	-	0.300	-
	FEM Analysis 1	0.106	0.544	0.153	0.624	0.126	0.485	0.176	0.587
	FEM Analysis 2	0.350	1.795	0.520	2.122	0.379	1.458	0.544	1.813
Case-3	Actual	0.200	-	0.245	-	0.270	-	0.300	-
	FEM Analysis 1	0.100	0.500	0.144	0.588	0.120	0.444	0.164	0.547
	FEM Analysis 2	0.331	1.655	0.490	2.000	0.360	1.333	0.510	1.700
Average	Actual	0.185	-	0.243	-	0.243	-	0.290	-
	FEM Analysis 1	0.103	0.557	0.154	0.634	0.121	0.496	0.180	0.621
	FEM Analysis 2	0.344	1.859	0.528	2.173	0.368	1.514	0.555	1.914

FEM Analysis 1 : Composite FEM Analysis 2 : Non-composite

Since the ratio of FEM/Actual of deflection of beam is nearly 1.0, it can be said that the beams behave like composite beam, in case of SER No.59 as shown in Table 14.8.

Since the average ratio of FEM/Actual of deflection of beam is 1.5, it can be said that the beam behave middle position of composite beam and non-composite beam, in case of SER No.211 as shown in Table 14.9.

Therefore, half composite action can be expected although the RSJ bridges are composed of non-composite beams. 10% of live load distribution is taken for the stress check of RSJ bridges.

(4) Results of Stress Check

This section presents the results of stress check for main beams, I-305mm and I-400mm. Calculation procedure and samples are attached in Appendix - M.

(a) Stress check of main beam on the assumption of non-composite beam

Table 14.10 Results of Stress Check of Main Beam I-305 assuming Non-composite Beam

Span Length L (m)	7.5	7.0	6.5	6.0	5.5	5.0
Md (tf.m)	4.521	3.938	3.396	2.894	2.431	2.009
Coefficient of impact	0.348	0.351	0.354	0.357	0.360	0.364
M1+i(T20)(tf.m)	25.275	23.643	22.003	20.355	18.700	17.050
ΣM (T20)(tf.m)	27.269	25.217	23.199	21.214	19.261	17.354
T20 σ (kgf/cm2)	3150	2913	2680	2451	2225	2005
T18 σ (kgf/cm2)	2888	2667	2451	2239	2030	1828
T16 σ (kgf/cm2)	2625	2422	2223	2028	1836	1650

Table 14.11 Results of Stress Check of Main Beam I-400 assuming Non-composite Beam

Span Length L (m)	10.5	10.0	9.5	9.0	8.5	8.0	7.5	7.0
Md (tf.m)	9.440	8.563	7.728	6.936	6.186	5.480	4.816	4.196
Coefficient of impact	0.331	0.333	0.336	0.339	0.342	0.345	0.348	0.351
Ml+i(T20)(tf.m)	34.939	33.325	31.730	30.128	28.518	26.900	25.275	23.643
ΣM (T20)(tf.m)	40.885	38.556	36.285	34.051	31.852	29.690	27.564	25.475
T20 σ (kgf/cm2)	2791	2632	2477	2324	2174	2027	1881	1739
T18 σ (kgf/cm2)	2576	2427	2282	2139	1999	1861	1726	1594
T16 σ (kgf/cm2)	2362	2222	2087	1954	1824	1696	1571	1448

Where; Span length of slab : l = 1.07m for I-305, l = 1.10m for I-400
Slab thickness : d = 17cm
Coefficient of load distribution rate by slab : d = 0.90
Coefficient of impact : i = 20/(50+L)
Md : Bending moment due to dead load
Ml+i : Bending moment due to live load
P : Knife edge load per beam taken P = 10tf/beam for T20
P = 9tf/beam for T18
P = 8tf/beam for T16

(b) Stress check of main beam on the assumption of composite beam

I-305; Since the neutral axis of composite beam is in the slab concrete even if the height of haunch is increased up to 10cm, many cracks will occur on the bottom surface of slab concrete. Because lower part of slab becomes tensional area. Therefore, this beam can not be composite beam.

I-400 : The neutral axis is in the slab. The height of 3cm haunch is considered to shift the neutral axis. Considering the difficulty of setting haunches, thickness of slab concrete is to be increased. The inertia of the additional concrete is ignored but the dead load is considered.

Span length	L = 9.0m,	Span length of Slab	l = 1.1m,
Slab thickness	d = 20.0cm (including the haunch 3cm height)		
Live load	T20: P = 10tf/beam		

Flexural compressive stress in slab concrete

σ c = 63.2kgf/cm2 < σ ca = 260/3.5 = 74.3kgf/cm2
Grade 30N/mm2 (Cubic Strength) → (Sylynder Strength)

Flexural tensile stress in extreme beam

σ s = 1477kgf/cm2 < σ sa = 1400 × 1.5 = 2100kgf/cm2 : Mild Steel
< σ sa = 1120 × 1.5 = 1680kgf/cm2 : Wrought Iron, Low Quality Mild Steel
(1400 × 0.8 = 1120)

(c) Strengthening by covering of main beam with reinforced concrete

I-305 : Span length of slab l = 1.1m

T-20 can be loaded on maximum span of 7.2m where the material is Mild Steel.

T-20 can be loaded on maximum span of 6.4m where the material is Wrought Iron and/or Low Quality Mild Steel.

I-400 : Span length of slab l = 1.1m

T-20 can be loaded on maximum span of 9.6m where the material is Mild Steel.

T-20 can be loaded on maximum span of 8.5m where the material is Wrought Iron and/or Low Quality Mild Steel.

(d) Preparation of figure for applicable beam depth and span length for non-composite beam and beams strengthened by covering of main beam with reinforced concrete.

In order to visualize the effectiveness of the rehabilitation method of strengthening of beam, a figure is prepared. The figure shows relation between applicable beam depth and span length with reinforced concrete, and attached in Figure 14.2.

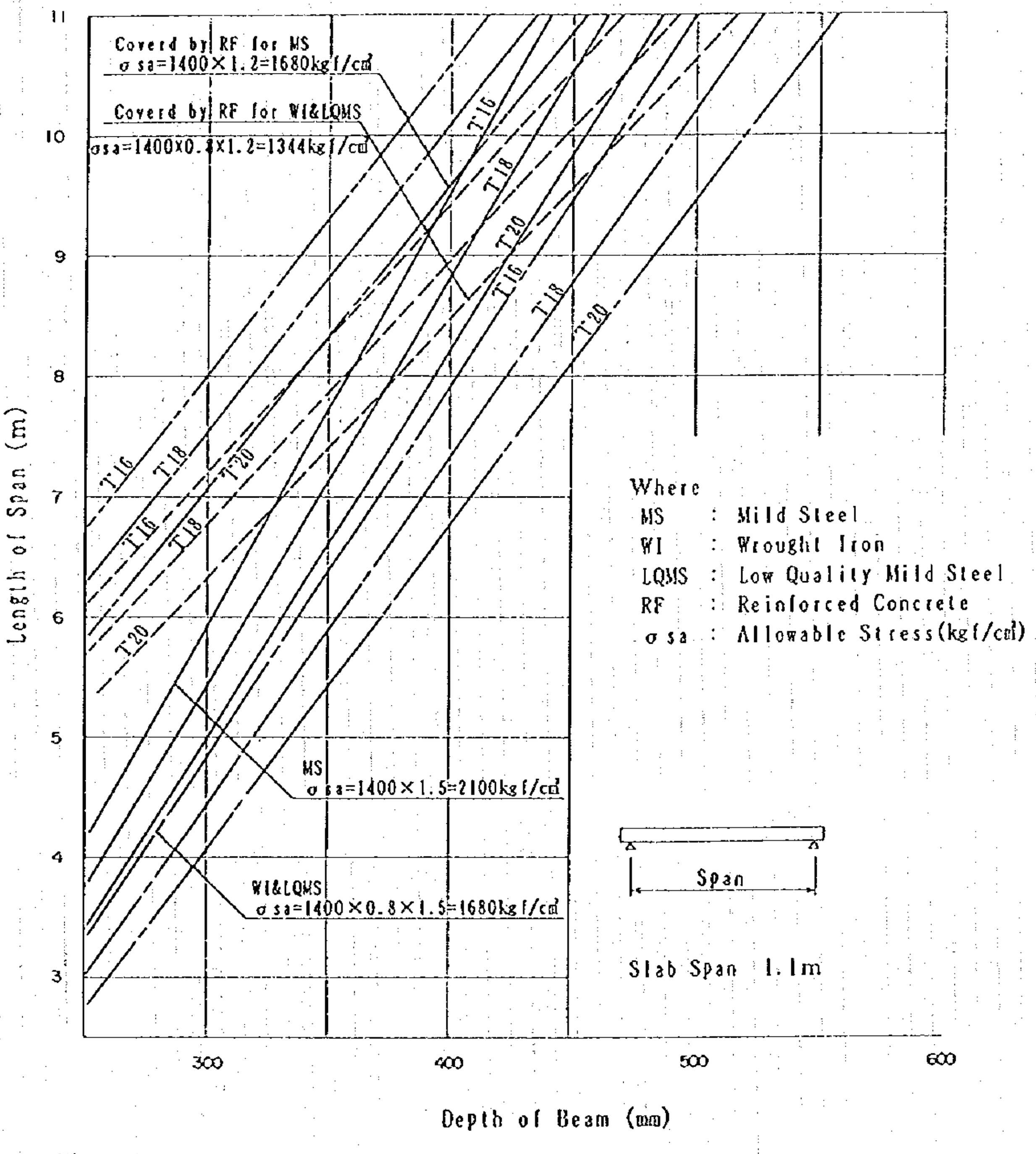

Figure 14.2

Applicable beam depth and span length for non-composite beams and beams strengthned by covering of main beam with reinforced concrete

14.5.2 Stress Check on Truss Bridges

Truss bridges have been constructed with its span range of small to medium, 10.9 to 51.0m. Many of the bridges have about 20m spans. Therefore, SER No.77 (L = 19.7m) was selected as a representative bridge to be checked the stress of its main frame. Calculation procedure and sample are attached in Appendix-M.

Results of Stress Check

Live Load	Members	Increased Allowable Stress	Stress
T-20	Upper & Lower Cord	Taken 1.5 of increase rate of allowable stress	Excessive stress of 3~4%
L-18	Upper & Lower Cord	Taken 1.5 of increase rate of allowable stress	Excessive stress of 12~14%
T-16	Upper & Lower Cord	Taken 1.5 of increase rate of allowable stress	No excessive stress

According to the above results, it can be assumed that other truss bridges are in some excessive stress in case of T-20 or L-20 live load is applied as the same as SER No.77.

14.6 Standard Rehabilitation Method

This section presents selected standard rehabilitation methods which are applicable in the Study in order to decide rehabilitation plan for each bridge in not only 10 bridges for detailed survey but also the other 90 bridges.

14.6.1 Study of Rehabilitation for RSJ

Nine options mentioned below ((1) to (9)) could be considered for repair and reinforcement for RSJ bridge. Merit/demerit and applicability of each option are studied considering various conditions of Sri Lanka.

(1) Painting

Thick-painting with tar paint and painting with epoxy paint are common in Sri Lanka for maintenance measure of steel bridges. Compared with the former and the latter, tar-thick-painting and epoxy-painting, if was observed that the former could prevent corrosion better than the latter. Besides, tar-thick-painting is more economical than the other, therefore, tar-thick-painting shall be adopted for painting.

(2) Reinforcement of Deck Slab

Reinforcement of deck slab is generally adopted, as rehabilitation measure, for bridges which do not have enough load carrying capacity and/or have heavy damage, but it shall be limited to the case that main structure such as main beam of bridge is not damaged in their function.

54 nos. of RSJ bridges out of the 101 bridges which have been investigated in the Study can be classified into types of deck slab as follows:

Buckle plate type (43%), Corrugated plate type (28%), Deck plate type (2%), Timber deck type (4%), Reinforced concrete slab type (26%)

RSJ bridges each for buckle plate type, corrugated plate type and deck plate type, which have been reconstructing or abandoned during the investigation, have been observed and found that loading carrying capacity of the deck slab for the bridges are tremendously poor. Because some of them have low mixed plain concrete slabs (generally dense reinforced concrete slabs are used nowadays) with subbase course material over steel plate, and others have block stone on plain concrete slabs.

Two-direction cracks of pavement and severe corrosion under steel plate due to high water permeability of the plain concrete slab also have been found. Deck slab with heavier corrosion caused some fallings of slab concrete. These deck slabs need to be rehabilitated so as to recover their loading carrying capacity by a replacement with reinforced concrete deck slab which is rather durable. Some rehabilitation measures to increase the loading carrying capacity such as adding stringer to shorten span of slab or placing cross-frame under steel plate should be considered as temporary measures until the time when a redecking or reconstruction would be carried out. In the Study, it has been observed that five bridges have rehabilitated by the above kinds of make-shift measures. However, these method are not basic solution, and they shall not be adopted except for the specially required cases.

On the other hand, RSJ bridges with reinforced concrete slabs have been less defects compared to the bridges above mentioned. In this type, five measures could be considered for repair/reinforcement for reinforced concrete slabs. These are; 1) Adding stringer, 2) Increasing thickness of top of deck slab, 3) Increasing thickness of bottom of deck slab, 4) Covering with steel plates, 5) Partly redecking, and 6) Epoxy injection. Applicability of each method is as follows:

1) Adding stringer

This method is quite difficult to be carried out in Sri Lanka because almost all the spaces between main beams are about 1.1m and this space is not enough fr the workability.

2) Increasing thickness of top of deck slab

This method needs special works which are cutting of asphalt surface, cutting of concrete surface, chipping/finishing of concrete surface and reinforcing with steel fiber concrete, and these works use also special machinaries.

3) Increasing thickness of bottom of deck slab

As every reinforced concrete slab has no haunch, this method is not only practical but also economical.

4) Covering with steel plates

This method is not practical either in Sri Lanka because this method requires wide extent of cover plate and high cost. Furthermore, there are almost no fly over bridge above road or railway, which shall prevent from falling of concrete-pieces from damaged deck slab.

5) Partly redecking

This method can be adopted for rehabilitation of bridges which have partly damaged deck slab and need minor redecking. This method is often adopted in Japan.

6) Epoxy injection

This method is quite practical for rehabilitation of bridges which have deck slab with minor crack and free lime. Although epoxy and machinaries to be used can not be procured in Sri Lanka, works do not influence upon traffic flow so much because the actual work is carried out from bottom side of deck slab. The method is often adopted in Japan due to its reliability.

Considering these mentioned above, 1) to 4) are judged not to be practical in Sri Lanka. 5) &6) have much more applicability.

(3) Redecking

Replacing damaged deck slab with reinforced concrete slab is common method for maintenance in Sri Lanka. However, thickness of the reinforced concrete slab is not assumed to be standardized. First of all, any design standards for determining thickness of deck slab and quantity of reinforcing bars have to be established for adopting this method. Although it needs some works before actual implementation is commenced, this method is practical and desirable for bridge rehabilitation considering its durability and reliability.

(4) Adding main beam between existing main beams

This method is generally adopted for rehabilitation of deck slab which has some problem in its durability and rigidity. However, actual implementation is rather difficult and impractical because of narrow space between main beams as mentioned under (2).

(5) Covering main beam with reinforced concrete

Covering by plain concrete is commonly adopted as a rehabilitation method for main beam in Sri Lanka for purposes of anti-corrosion for main beam and increasing of its rigidity. However, this method often causes pealing-off of the cover concrete because reinforcing bars are not placed in the concrete, and consideration is not given to any bond between main beam and the concrete. Therefore, reinforced concrete shall be used instead of plain concrete in this method.

Rehabilitation by the reinforced concrete have other efficiency for other than anti-corrosion for main beam and increasing of its rigidity, which is to decrease a stress of main beam by placing reinforcing bars at the bottom flange of main beam for axial direction. Considering these aspects, this method is very useful.

(6) Reinforcement of main beam

In case inertia of main beam is found to be inadequate for the design loading by the results of calculation, it is considered that increasing of inertia can be done by steel cover plates at any corresponding parts.

It is general that steel plates, inverted T-beam, I-beam and H-beam are placed at the bottom of lower flange by welding or using high tensional bolts.

Structural steel commonly used in Sri Lanka is assumed to be produced before 1930s. (Although nine bridges (17%) out of the 54 bridges studied in the Preliminary Visual Inspection are judged that they were constructed after 1930, other 83% are judged that they have been constructed before then by some data such as corrosion state and type of deck slab used. And it is confirmed that the materials used for these bridges are wrought iron, which is impossible to be welded, and mild steel of which quality is poor according to the material strength tests carried out in the Study.

Furthermore, it was observed that surface of the bottom lower flange of I-beam is uneven by its manufacturing conditions. Therefore welding is almost impossible because of its poor quality.

In the case high tensional bolt would be used, new steel beam and old one even can not be firmly welded because of the unsmooth surface of existing plates. In this case its structural action is expected as a non-composite beam. And the space between the new and the old causes corrosion because this space even can not be filled with paint.

Moreover, since width of flange of I-beam is narrow comparing to its thickness of about 20mm, the cross section of flange is reduced by 30 to 40% because of holes for bolts. And this reducing of flange area causes increasing of stress of main beam..

From these demerits above mentioned, reinforcement by using of steel cover plate shall not be adopted for reinforcement of existing main beams.

(7) Additional main beam (widening)

Widening by additional main beam on one side or both sides is a effective method for rehabilitation of bridges which do not have enough width. In case of this method is adopted, some considerations have to be given. They are; to confirm continuity between new members and existing members, to avoid rigidity differences between the new and the existing ones. As stated in aforesaid section (2), bridges of which deck slab has poor load carrying capacity, such as buckle plate type, corrugated plate type, and deck plate type, need to be widened basically along with redecking by using reinforced concrete deck slab which are highly durable and reliable.

(8) Placing sway brace and cross beam

Almost no bridge using I-beam has sway brace nor cross beam on I-beam in Sri Lanka. Therefore, most of bridges have features that the end of beam is embedded into concrete or bricks on its abutment and pier as to prevent from falling down for transverse direction and to increase stability of bridge for transverse direction. Placing of round bar at intervals of 3m between spans is also found on many bridges for countermeasures against these problem.

Purposes of placing sway brace and cross beam are as follows:

- To prevent excessive concentration of loading on each main beam by grid consisting of main beam, sway brace, and cross beam. This grid structure produces good results such as a decrease of relative deflections between main beams and an additional bending stress of deck slab by uneven deflections of main beams.

- To prevent from reducing allowable bending compressive stress which is decided by lateral buckling condition and can be increased by shortening the panel distance at compressive side of plate girder.

Since the width of flange of I-beam generally used in Sri Lanka is very narrow (125 to 155mm), sway brace and cross beam shall be placed at intervals of 3.5m to 4.0m at least in order to comply with the Japanese Bridge Design Standards.

If there are 2,200 nos. of plate girder bridges out of 4,720 bridges in Sri Lanka, which is assumed by the proportion (53%) of the plate girder bridges out of the 101 bridges studied in Preliminary Investigation, placing sway brace and cross beam to each bridge is indeed a visionary plan from the quantitative view point.

According to the results of other studies, in which a loading test by using 20tf truck was carried out, it was confirmed that the structural states of the tested bridge was similar to a perfectly composite girder although it was non-composite girder. In fact, the loading weight by 99.7% of traffic which cross bridges with span of under 10.8m on A-class roads in Sri Lanka are included within this category (20tf). Considering that the loading on plate girder in Sri Lanka is almost same with the loading described in the report of other studies, in can be judged that there is no necessity to reduce an allowable bending compressive stress at a compressive side of plate girder.

Most of plate girder bridges are simple beam and shall be redecked with reinforced concrete deck slab. Girders of many bridges are embedded into abutment and/or pier as mentioned, and tie-bar connected with each main beam is adopted for many bridges. Considering these matters along with remarks under this section, this method, which is visionary from the quantitative view point, shall not be adopted.

(9) Construction of additional pier

It is also considerable to construct new piers between existing substructures of a bridge which has too much stress on main beam because of unbalanced state between its main beam and the length of span.

This method was adopted in 4 bridges out of the 101 bridges in the Study. Actually, in Sri Lanka, shape steel is used for new piers of these 4 bridges to prevent from occurring excessive deflection of the bridge. However, severe corrosion has been found in the piers because any countermeasures for anti-corrosion has not been taken, so the new piers have lost some of their function. This method should be considered as a temporary repair, but is not permanent method.

Maximum span length of plate girder bridge in the Study is 10.8m, and it is not so long. Considering durability, reliability and economical aspect, it is more reasonable to replace this type of damaged plate girder bridge with PSC bridge than to construct new pier by using shape steel.

The followings are the summary for all above mentioned (1) to (9). They are classified into their practicabilities considering the various conditions in Sri Lanka.

Practicable Ideas for Repair and Reinforcement

(1) Painting
- Tar painting

(2) Reinforcement of deck slab
- Partly-redecking of RCS
- Injection of epoxy into cracks

(3) Redecking
- Redecking of BUC, COR, and DEC to RCS deck slab

(5) Covering main beam with reinforced concrete
- Reinforcement of main bean by covering of reinforced concrete

(7) Additional main beam (widening)
- Widening after redecking to RCS deck slab

Impractical Ideas for Repair and Reinforcement

(2) Reinforcement of deck slab
- BUC, COR, and DEC deck slabs do not use reinforcing bar, of

which loading carrying capacity is quite low and poor, so this method shall be considered as temporary method.

(4) Additional main beam between existing main beams

- It is impossible because of the narrow space between existing main beams of about 1.1m.

(6) Reinforcement of main beam

- This method is not effective because of the condition of steel used. Some of them are wrought iron which can not be welded, and other of them are mild steel of which surface is not smooth

(8) Placing sway brace and cross beam

- This method is visionary from the quantitative view point.

(9) Construction of new pier

- This method shall be considered as temporary because its durability can not be expected.

As mentioned above, practical methods shall be adopted for rehabilitation of RSJ bridges considering various conditions in Sri Lanka. They are: painting with tar-paint, redecking, partly redecking of RCS deck slab, injection of epoxy into crack of RCS deck slab, covering main beam with reinforced concrete, and widening.

Figures 14.3 to 14.6 show a summary of the references.

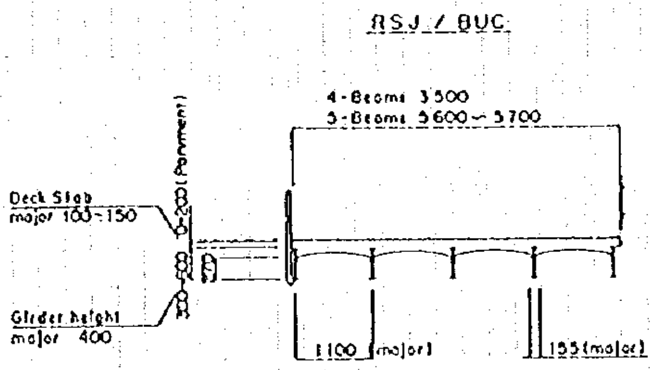

Figure 14.3 Cross Section of RSJ/BUC

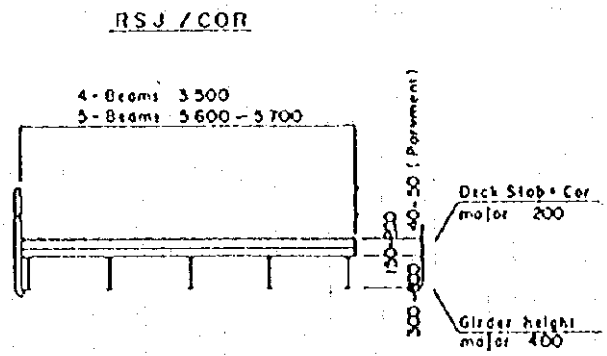

Figure 14.4 Cross Section of RSJ/COR

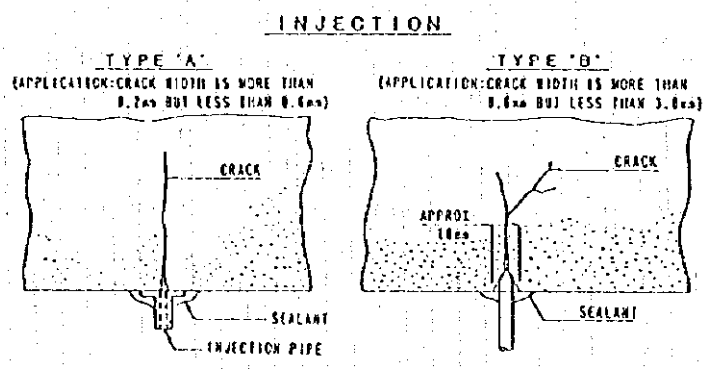

Figure 14.5 Injection of Epoxy

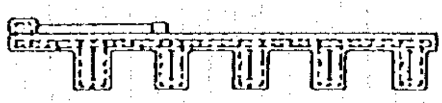

Figure 14.6 Covering Main Beam with R/F Concrete

14.6.2 Study of Rehabilitation for Truss Bridge

Nine options mentioned below ((1) to (9)) could be considered for repair and reinforcement for truss bridges. Merit/demerit and applicability of each option are studied considering various conditions of Sri Lanka.

(1) Painting

Thick-painting with tar paint and painting with epoxy paint are common in Sri Lanka for maintenance measure of steel bridges. Compared with the former and the latter, tar-thick-painting and the epoxy-painting, it was observed that the former could prevent corrosion better than the latter. Besides, tar-thick-painting is more economical than the other, therefore, tar-thick-painting shall be adopted for painting.

(2) Reinforcement of Deck Slab

Reinforcement of deck slab is generally adopted, as rehabilitation measure, for bridges which do not have enough load carrying capacity and/or have heavy damage, but it shall be limited to the case that main structure such as main beam of bridge is not damaged in their function.

22 nos. of truss bridges out of the 101 bridges which have been investigated in the Study can be classified into types of deck slab as follows:

Corrugated plate type (59%), Buckle plate type (4.5%), Deck plate type (4.5%), Reinforced concrete slab type (32%).

It is assumed that most of those reinforced concrete slabs have replaced buckle plates or corrugated plates, which have been falling down due to substantial damages.

Truss bridges each for buckle plate type, corrugated plate type and deck plate type, which have been reconstructing or abandoned, have been observed and found that loading carrying capacity of the deck slab for the bridges are tremendously poor. Because some of them have low mixed plain concrete slabs (generally dense reinforced concrete slabs are used nowadays) with subbase course material over steel plate, and others have block stone on plain concrete slabs.

Two-direction cracks of pavement and severe corrosion under steel plate due to high water permeability of the plain concrete slab also have been found. Deck slab and/or cross beam which supported the deck slab both/either with heavier corrosion caused some fallings of slab concrete. These deck slabs need to be rehabilitated so as to recover their loading carrying capacity by a replacement with reinforced concrete deck slab which is rather durable or replacement with deck steel plate slab under reinforced concrete with high rigidity.

On the other hand, truss bridges with reinforced concrete slabs have less defects such as two-direction cracks and/or two-direction free lime at the bottom of slab. It is because these bridges have been constructed more recent than the bridges above mentioned. In this type, certain measures could be considered for repair/reinforcement of reinforced concrete slabs. These are; 1) Epoxy injection into cracks and 2) Partly redecking. Other than them, there are also 3) Increasing thickness of top of deck slab, 4) Increasing thickness of bottom of deck slab, and 5) Covering with steel plate, as general rehabilitation measures. However, these measures, 3) to 5), are not assumed to be suitable considering various conditions of Sri Lanka as mentioned at the section of 'Study of Rehabilitation for RSJ'. Therefore, measures against reinforcement of RCS deck slab, which is not damaged severely, shall be limited to epoxy injection and partly redecking.

(3) Redecking

Replacing damaged deck slab with reinforced concrete slab is common method for maintenance in Sri Lanka for truss bridges as the same as the case of RSJ bridges. However, thickness of the reinforced concrete slab is not assumed to be standardized. First of all, any design standards for determining thickness of deck slab and quantity of reinforcing bars have to be established for adopting this method.

Deck slab of truss bridges in Sri Lanka is generally supported by cross beams, therefore, the design span of deck slab is parallel to traffic. In case the space between cross beams is too long, several stringers shall be added to shorten the design slab span and then to reduce the dead load due to reduce of thickness of deck slab. This design span is then perpendicular to traffic.

If these considerations are given, redecking with reinforced concrete slab is quite effective method for rehabilitation, which is rather durable and reliable.

It is assumed that low mixed plain concrete slabs are used for COR, BUC, and DEC, therefore, these shall be replaced with reinforced concrete slab.

Deck plate slab with reinforced concrete could be considered as a rehabilitation method other than the above, however, it is less economical.

(4) Covering main structure with reinforced concrete

Covering main structure with law mixed plain concrete is commonly adopted for anti-corrosion and increasing rigidity for RSJ bridges. However, if the same method is adopted for truss bridges, it will cause tremendous increase of dead load and excessive stress by tension member. Therefore, this method shall not be adopted.

(5) Reinforcement of main structure

In case inertia of main structure is found to be inadequate for the design loading by the results of calculation, it is considered that increasing of inertia can be done by using steel cover plates at any corresponding part.

It is general that steel plates, inverted T-beam, I-beam and H-beam are placed at the corresponding area.

Structural steel commonly used in Sri Lanka is assumed to be produced before 1930s. (Only one bridge (5%) out of 22 truss bridges studied in the Preliminary Visual Inspection is judged that it was constructed after 1930. There are 5 bridges of which year constructed is not known, and there is 1 bridge which is a re-used bridge. However, these 6 bridges are also assumed to be constructed before 1930 from their corrosion state and type of deck slabs used. Therefore, 21 bridges (95%) are assumed to be constructed before 1930.) It is confirmed that the materials used for these bridges are wrought iron, which is impossible to be welded, and mild steel of which quality is poor according to the material strength tests carried out in the Study.

Although materials used for these bridges are various depending on the year of bridge constructed, structure type is mostly pony-truss which uses pins or rivets as in the respects of its component of upper and lower code and connection method of members. Short span has T section for both upper and lower code, and long span has π section for both the same. Some combined members such as flat plate, angle and channel are welded to main structure by rivet. However, reinforcement against reduction of section area is not considered, which is caused by pin or rivet holes for connection.

According to the results of the stress check using 20tf truck loading for SER No. 77, upper and lower codes which are the most essential members (generally for bridges) have excessive stress. However, 18tf loading can make them in the allowable range. It is assumed that this result can be adopted all the truss bridges in Sri Lanka.

It is almost impossible to reinforce through truss bridges which can not be widened even though their width is not enough. Reconstructing RSC bridge instead of the through truss bridge is more realistic and economical considering any conditions such as damage degree and traffic aspect.

Therefore, rehabilitation of steel members shall be implemented for substantially damaged members. Basic rehabilitation method shall be to weld steel plates and shape steels or to place them by using high tensional bolts. Either can be determined depending on the material characteristics used in the existing members.

(6) Weapholes

Section reduce has occurred on lower code, of which shape is π , due to severe corrosion caused by the water stagnation. Therefore, weapholes of 20 to 25mm diameters shall be made on the bottom flange of the lower code for drainage purpose.

(7) Additional main structure (widening)

Additional main structure, in short, 'widening', on one side is one of the bridge reinforcement methods. However, in this case, stress on central main structure becomes about 2 times. Considering the fact that excessive stress on main structure by normal vehicle loading in Sri Lanka already has being occurred, this method is not desirable at all.

(8) Placement or addition of knee brace

Most of truss bridges in Sri Lanka are pony truss through bridges. Half of bridges subjected to the Study have knee brace to prevent lateral buckling, however, the other half don't have it at all or don't have enough knee brace. It is observed that main structure of truss is swaying laterally when vehicles passing. For these bridges which do not have appropriate knee brace shall be reinforced by placing or adding knee brace.

(9) Adding of footway

Footways have already been added outside of main structure for some truss bridges which have heavy traffic volume and/or heavy pedestrian volume, and which are located near school and/or other public facilities.

If necessity of extra footway is found for other bridges, which presently do not have, because of increasing traffic and/or pedestrian volume, footway shall be added considering the corresponding 'Bridge Rehabilitation Plan'.

The followings are the summary for all above mentioned (1) to (9). They are classified into their practicabilities considering various conditions of Sri Lanka.

<u>Practicable Ideas for Repair and Reinforcement</u>

(1) Painting
- Tar painting

(2) Reinforcement of deck slab
- Partly-redecking of RCS
- Injection of epoxy into cracks

(3) Redecking
- Redecking of BUC, COR, and DEC to RCS deck slab

(5) Reinforcement of main structure
- It shall be adopted only for substantially damaged members.

(6) Weapholes
- Weapholes shall be made on the bottom flange of the lower code (π) for drainage purpose.

(8) Placement or addition of knee brace
- Knee brace shall be placed for bridges which do not have it, and it causes swinging of main structure.

(9) Adding of footway
- Footway shall be added outside of main structure of bridges if necessary.

Impractical Ideas for Repair and Reinforcement

(2) Reinforcement of deck slab
- BUC, COR, and DEC deck slabs do not use reinforcing bar, of which loading carrying capacity is quite low and poor, so this method shall be considered as temporary method.

(4) Covering main structure with reinforced concrete
- This method causes tremendous increase of dead load and excessive stress by tensile members.

(5) Reinforcement of main structure
- It is quite difficult to reinforce the through truss bridges which do not have enough width but cannot be widened, and which have excessive stress even for 20tf loading.

(7) Additional main structure (widening)
- At present, even normal vehicle loading has caused excessive stress.

As mentioned above, practical methods shall be adopted for rehabilitation of truss bridges considering various conditions of Sri Lanka. They are: painting with tar-paint, redecking, partly redecking of RCS deck slab, injection of epoxy into crack of RCS deck slab, reinforcement of main structure which is severely damaged only, making weaphole at the bottom flange of lower code, placement or addition of knee brace against lateral buckling, and adding of footway.

14.6.3 Concrete Member

The standard rehabilitation methods are broadly divided into the following two categories:-

(1) Protection work to concrete
(2) Reinforcement work to concrete

(1) Protection Work to Concrete

In general, this types of protection work is applicable to defects which are not active.

1) Epoxy Injection

Condition for Application

- Cracks are not active and its surface width is more than 0.2mm, but less than 3.0mm.
- No water leak and no liquid rust.
- If surface crack width is more than 3.0mm, apply cement mortar injection.

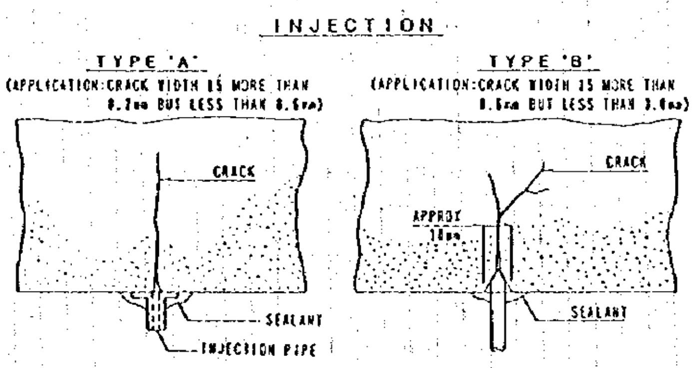

Figure 14.7 Epoxy Injection

2) Patching

Condition for Application

- Damage such as honeycomb, flaking, and cavity that are not active.
- Reason of these damages are mainly due to inferior concrete or poor workmanship.

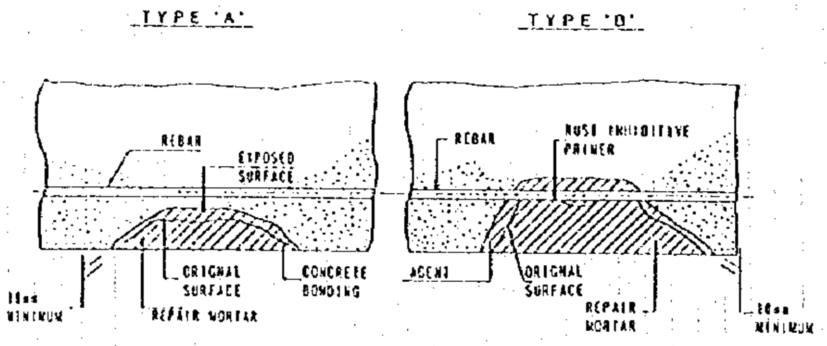

Figure 14.8 Patching

(2) Reinforcement Work to Concrete

This type of reinforcement works is in principle applicable to a bridge member which has inadequate load carrying capacity or has active defects such as bending or shear crack or two way cracks, etc.

1) Prepacked Concrete Lining with Additional Rebar

<u>Conditions for Application</u>

- Inadequate loading capacity
- Various active cracks due to bending moment or shear force
- Inadequate concrete cover
- Soffit of member where it is difficult to pour concrete.

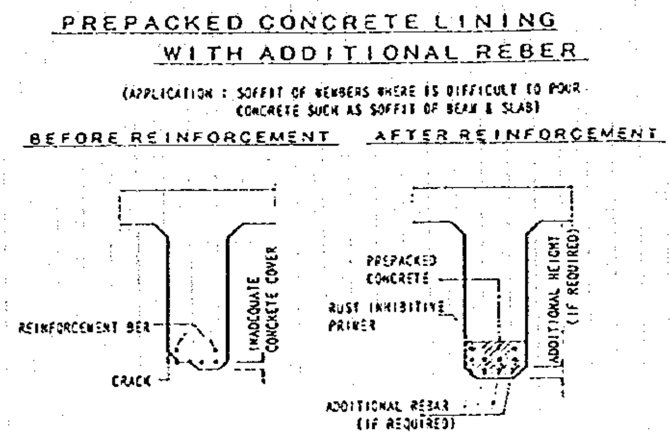

Figure 14.9 Prepacked Concrete

14.6.4 River Training Works

River training work consists of slope protection, foot protection, river bed protection and river alignment depending on where protection work is provided.

(1) Slope Protection

This type of work is applicable to river banks around abutment where erosion is observed.

1) Stone Masonry

<u>Condition for Application</u>

- Slope : 1:0.5 to 1:15.
- Height : Less than 5m
- Application : Small to medium scale river

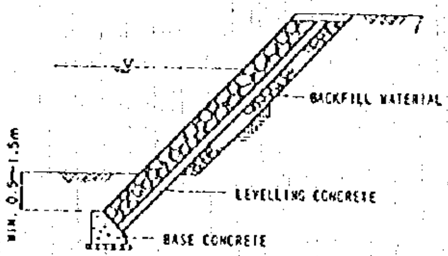

Figure 14.10 Stone Masonry

2) Concrete Block Masonry

<u>Conditions for Application</u>

- Slope : 1:0.3 to 1:10
- Height : Less than 3m
- Application : Rapid stream and small to medium scale river

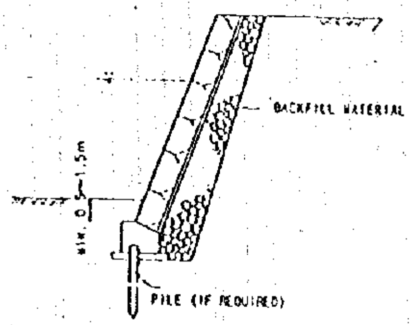

Figure 14.11 Concrete Block Masonry

(2) Foot Protection

This type of work is applicable to footings for slope protection in order to prevent slope failure caused by scouring action on the river bed.

1) Dumped Stone

Conditions for Application

- Small to medium scale river and foundation ground is relatively solid.

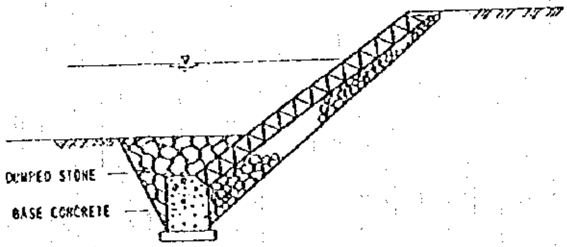

Figure 14.12 Dumped Stone

2) Wire Mesh Gabion

Conditions for Application

- Small scale river and foundation ground is soft.

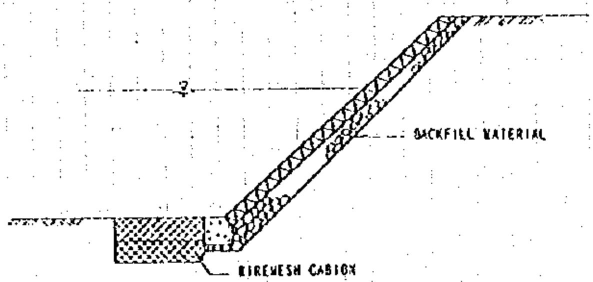

Figure 14.13 Wire Mesh Gabion

3) Concrete Block Mattress

Conditions for Application

- Medium to large scale river or rapid flow velocity.

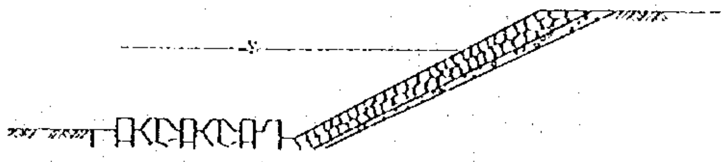

Figure 14.14 Concrete Block Mattress

(3) River Bed Protection

This type of work is applicable around river piers where local scouring or river bed lowering is observed.

1) Wire Mesh Gabion

<u>Conditions for Application</u>

- Foundation protection

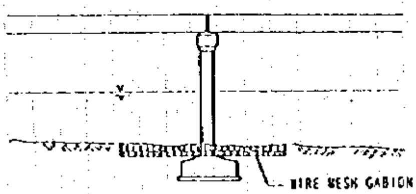

Figure 14.15 Wire Mesh Gabion

2) Dumped Stone and Wire Mesh Gabion

<u>Conditions for Application</u>

- Local scouring

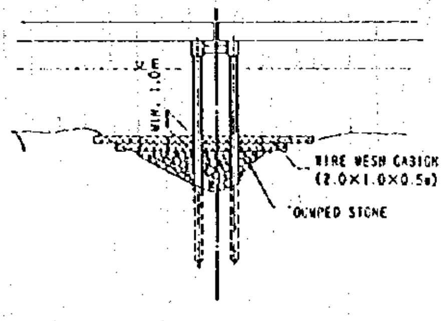

Figure 14.16 Dumped Stone and Wire Mesh Gabion

(4) River Realignment

This type of work is applicable to extremely eroded banks of a meandering river located upstream of a bridge.

1) Spur dike by Stone Masonry

<u>Condition for Application</u>

- Large scale river

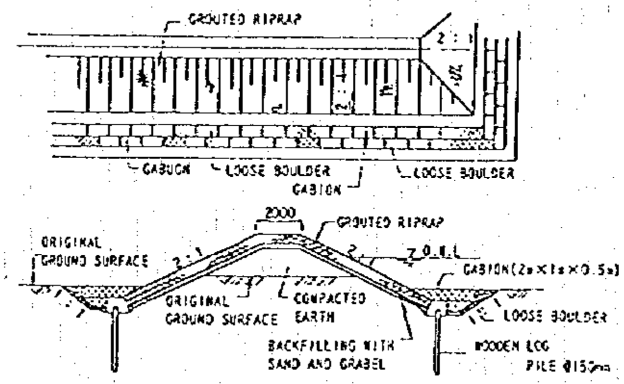

Figure 14.17 Spur Dike by Stone Masonry

CHAPTER 15 MAINTENANCE AND REHABILITATION PROGRAMME FOR 100 BRIDGES

15.1 General

Planning of maintenance and rehabilitation works covering all the study bridges (100 bridges) was carried out based on the preliminary inspection results and the results of preliminary rehabilitation design.

15.2 Setting Up of Bridge Rehabilitation Priority

The priority of bridge rehabilitation plan shall be decided considering the importance of route and urgency of rehabilitation of bridge.

The connection between function of roads and damage degree of 101 bridges are shown in Table 15.1.

Table 15.1 Connection between Function of Roads and Damage Degree of Bridge

Function of Road		Damage Degree of Bridges				
Roads by Priority	Traffic Volume	4.0	3.2	3.0	2.4 to 2.0	under 2.0
1 st	Over 5,000 veh/day	1, 175	–	27,66,70,75, 108,120,197	76,79,84, 85,99,195, 201	–
2 nd	more than 3,000 veh/day	32,86,202, 212	119	17,47,93, 102,123, 151,154	36	46,106
3 rd	more than 2,000 veh/day	91	78,80	52,65,77,89, 147,148, 173,209	138,211,216	–
4 th	more than 1,000 veh/day	7,18,20,33, 129,150	34,40,42, 44,87,178	19,26,30,39, 57,131, 135,136	2,43,45,58, 59,103,130	–
5 th	less than 1,000 veh/day	31,35,38,61, 62,63,68,72 122,128,144, 208	21,24,55,56, 74,127,133	25,41,67, 69	53,60	22,71,73
Undergoing or planned		139				
Sub- Total		25	16	34	20	5

For the Table 15.1, where road function is given the first item to be considered and damage of bridges is considered next the priority for the bridge rehabilitation is determined. The relationship between them is shown in Table 15.2.