CHAPTER 5 BRIDGE MAINTENANCE PROCEDURE

5.1 General

Maintenance of bridges is a part of bridge management.

* Because of structural characteristics, the bridge is most sensitive to damage in the road system. Besides damage to the bridge tends to cause the most adverse effect on the road traffic. The bridge is a structure which needs maintenance and management most. On the other hand when compared with ordinary roads, the bridge requires higher technology and wider experiments.

* When the bridge is heavily damaged and must be replaced, the required construction period and cost becomes far beyond the case of ordinary road.

The most important purpose of bridge maintenance is to keep the bridge in a serviceable condition to contribute to public safety and economical activities.

Other purposes include;

- Neither damage nor loss to users of the bridge and the third party is preferable.

- Always offering the best condition for road traffic

- Conservation of the sound state because some bridges are historical heritage and represent the regional landscape.

In view of above purposes this guideline will define the bridge maintenance as "Action or work to prevent damage to bridges and also to prevent the defect from growing." Since this operation does not require costly substantial manpower, cost and time, bridge maintenance will be carried out by each provincial office of RDA under a guidance from RDA Head Office.

The bridge maintenance work includes;

- Cleaning
- Local repair of bridge surface
- Steel coating

These works will be executed as routine works by the provincial offices.

5.2 Classification by Bridge Type

Bridge types shown in a list of 206 bridges prepared by RDA are as follows.

Type of Superstructure

RCS	- Reinforced concrete slab
RCB	- Reinforced concrete beam
RC/BOX	- Reinforced concrete box culvert
PSC-PRE	- Prestressed pretensioned concrete beam
PSC-POS	- Prestressed posttensioned concrete beam
ARCH/BR	- Brick arch bridge
ARCH/CO	- Concrete arch bridge
ARCH/ST	- Stone arch bridge
STONE	- Stone bridge
TIMBER	- Timber bridge
ST.TR/T	- Steel through truss
ST.TR/D	- Steel deck truss
RSJ/RCS	- RC slab over rolled steel joist
RSJ/BUC	- Buckle plate over rolled steel joist
RSJ/COR	- Corrugate plate over rolled steel joist
RSJ/DEC	- Deck plate over rolled steel joist
RSJ/T	- Timber over rolled steel joist
STL.GRD.(SG)	- Steel girder
STL.TRS	- Steel truss
RCC	- Reinforced concrete
BAILEY	- Baily girder bridge
CAUSEWAY	- Causeway bridge

To clarify the target of maintenance the types of the selected 206 bridges in Sri Lanka shall be classified as shown is Table 5.1.

Table 5.1 Classification by Bridge Type (Superstructure)

	N.H.A	N.H.B	Total
ST. TR/	14	8	22
ST. TR/T	2	2	4
ST. TR/RCS	1	1	
ST. TR/H	-	3	3
ST. TR/COR	-	2	2
RSJ/RCS	13	16	29
RSJ/CON	-1	1	
RSJ/BUC	8	16	24
RSJ/COR	2	6	8
RSJ	12	16	28
RSJ/C	-	1	1
RSJ/T	3	7	10
ST. G.	1	-	1
BAILEY	2	13	15
ARCH/BR	1	1	2
ARCH/ST	5	2	7
ARCH/CON	-	1	1
ARCH/RSJ	1	-	1
RCS	12	7	19
RCB	1	1	2
RCB/RCS	2	1	3
PSC	2	2	4
PSC/PRE	1	3	4
CAUSEWAY	-	10	10
TIMBER	1	-	1
MASONRY	1	-	1
N/A	1	1	2
Total	86	120	206

In the bridge list prepared by RDA, 49 bridges whose completed year is described can be classified as follows.

Table 5.2 Classification of Bridges by Completed Year

Completed Year	Type of Bridge	Number
1860 - 1889	ST. TR/COR, ST. TR, ST. TR/DE, CAUSEWAY	4
1890 - 1899	ST. TR (2), ST. TR/H, ARCH/BR, ARCH/ST, RSJ/BUC	6
1900 - 1909	RSJ, RSJ/RCS, ARCH/BR, ST.TR,	4
1910 - 1919	ST. TR, RSJ/RCS, RSJ/BUC	3
1920 - 1929	ST. TR (4), RSJ. RCS (2), RSJ/C	8
1930 - 1939	ST. TR (3), ST. TR/H (2), RSJ (2), RSJ/RCS	8
1940 - 1949	ST. TR, RSJ/RCS, RSJ/BUC (2), PSC/PRE	5
1950 - 1959	NONE	0
1960 - 1969	RSJ (2), RSJ/RCS (4), RCS (2), ST. TR	9
1970 - 1979	RCS	1
1980 - 1989	NONE	0
1990 - Present	BAILEY	1
Total		49

Note: The numerical figure in parentheses under the column of "Type of Bridge" indicates the number of bridges of the type concerned. Type without numerical figure in parentheses - One bridge each

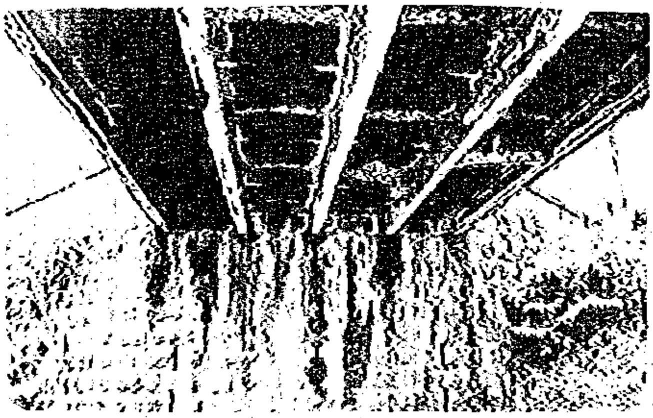
It may be known from this table;

(1) that among bridges constructed before 1899, 10 (about 20%) are still used. But the bridges constructed up to 1939 and still used at present account for extremely large ratio (i.e., 33 bridges or 67%).

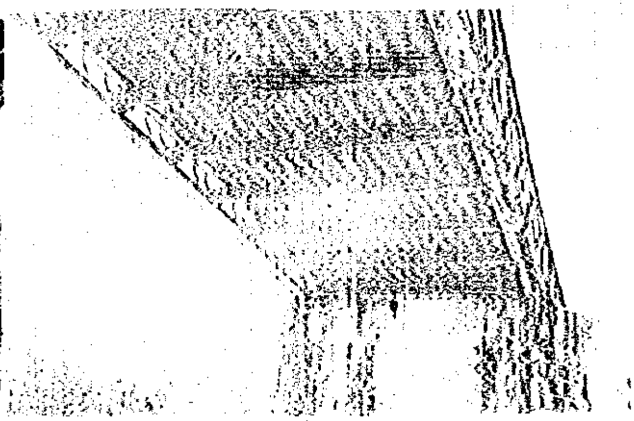
(2) The breakdown of 33 bridges constructed up to 1939 includes truss bridges (ST.TR, ST.TR/COR, ST.TR/DE, ST.TR/H) 17 (52%), steel beam bridges (RSJ, RSJ/BUC, RSJ/RCS, RSJ/COR) 10 (30%), arch bridges (ARCH/BR, ARCH/ST) 3 (9%) and others.

(3) Bridges constructed in and after 1940 include steel beam bridges, truss bridges and concrete bridges (PS/PE, PSC/POS, RCS).

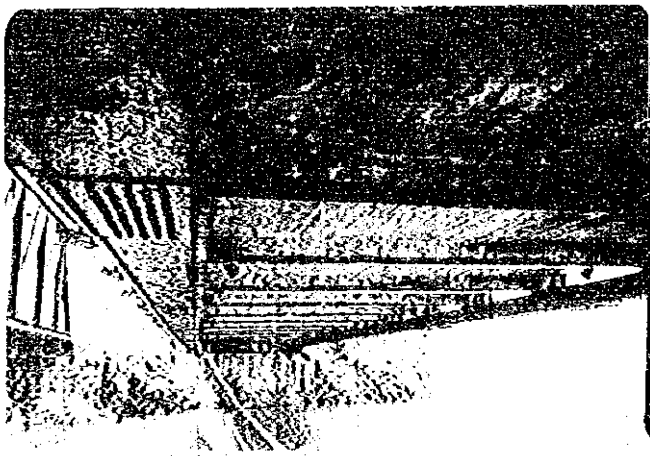
The sectional view or photos of typical bridges are shown in pages 5-5 to 5-8.



Steel beam w/buckle plate slab
(RSJ/BUC)

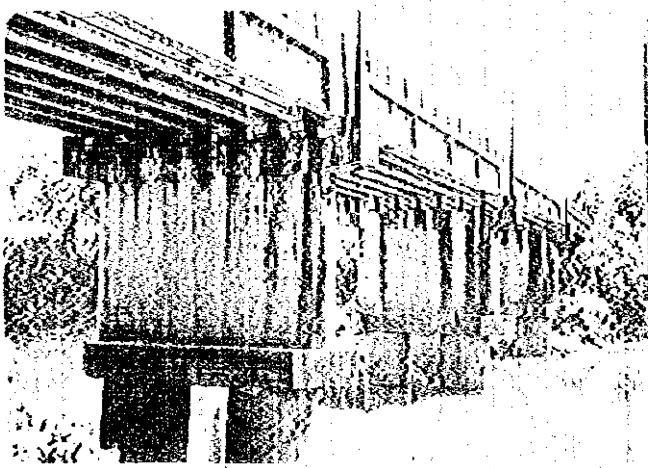


Steel beam w/corrugated plate slab
(RSJ/COR)

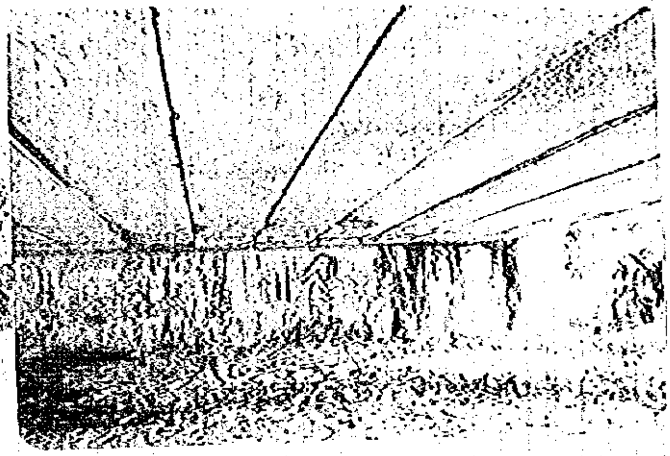


Steel beam w/reinforced concrete slab
(RSJ/RCS)

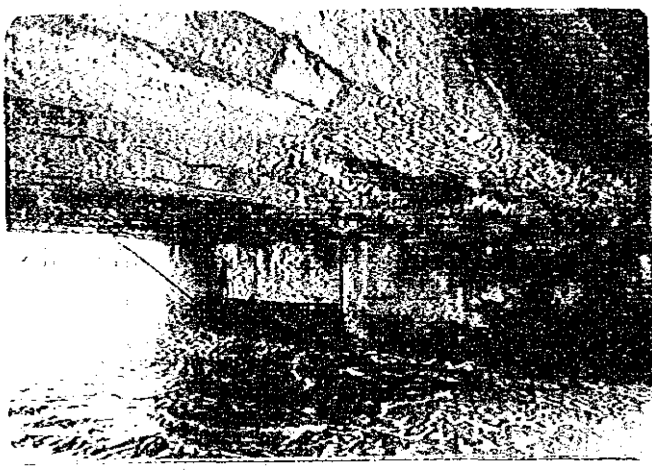
Steel truss (Through)
(ST.TR/TH)



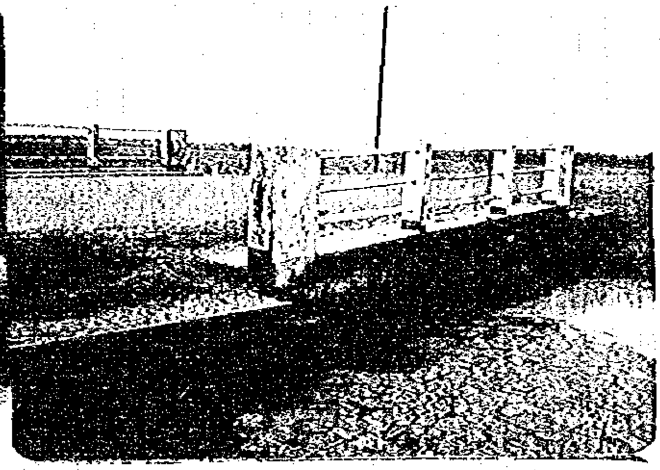
Prestressed posttensioned concrete beam
(PSC/POS)



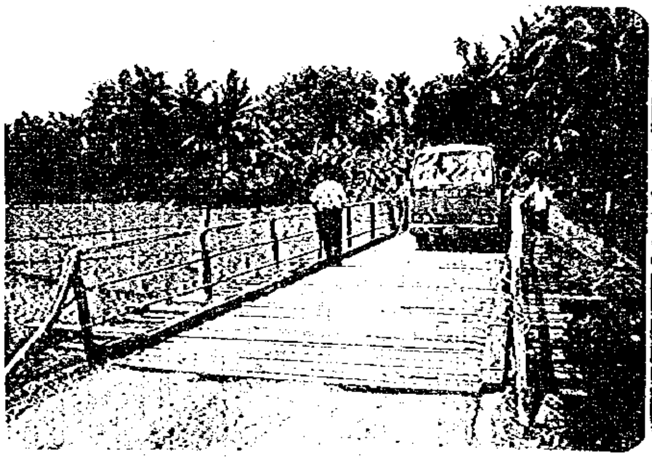
Prestressed pretensioned concrete beam
(PSC/PRE)



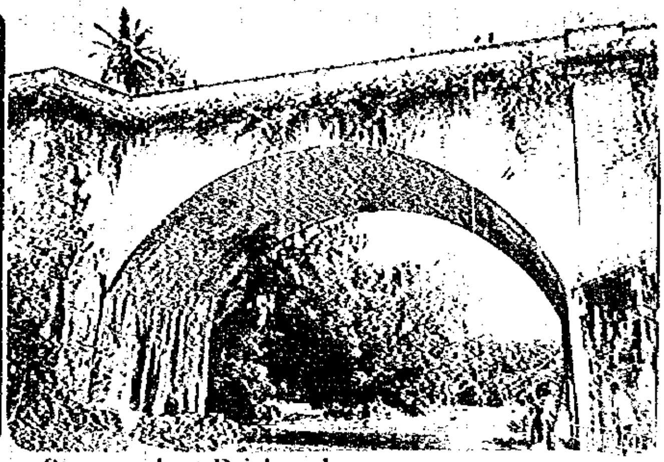
Reinforced concrete beam
(RCB)



Reinforced concrete slab
(RCS)



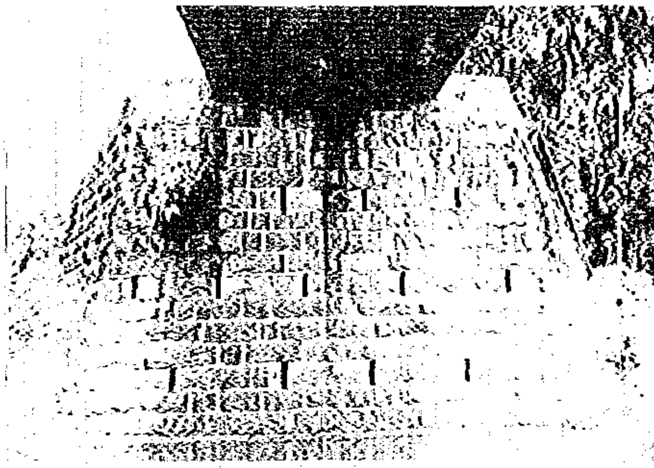
Timber deck

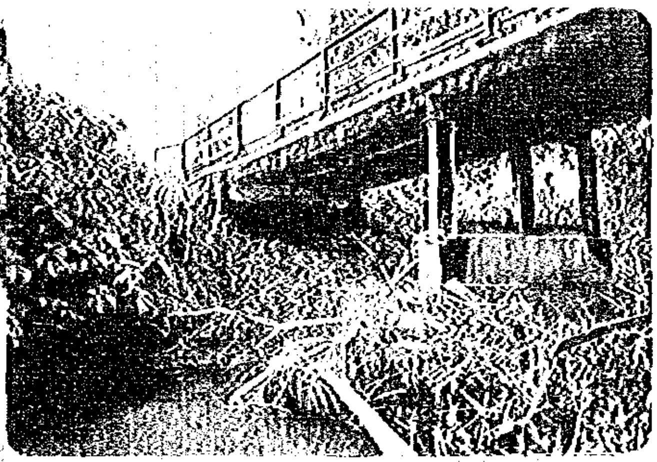


Stone arch or Brick arch
(ARCH/ST or ARCH/BR)

For the substructure typical types are as follows:

Abutment

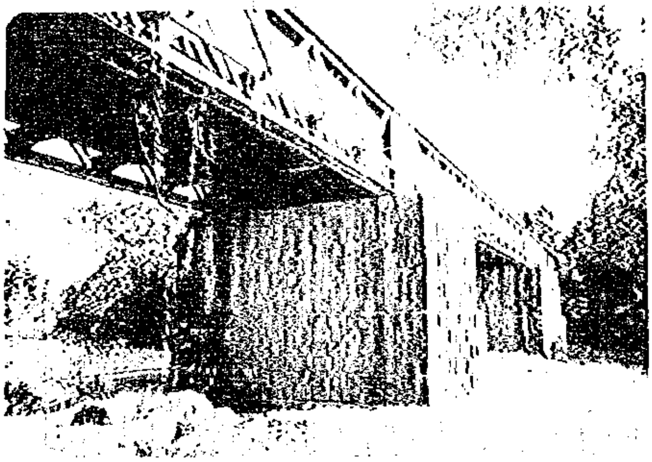




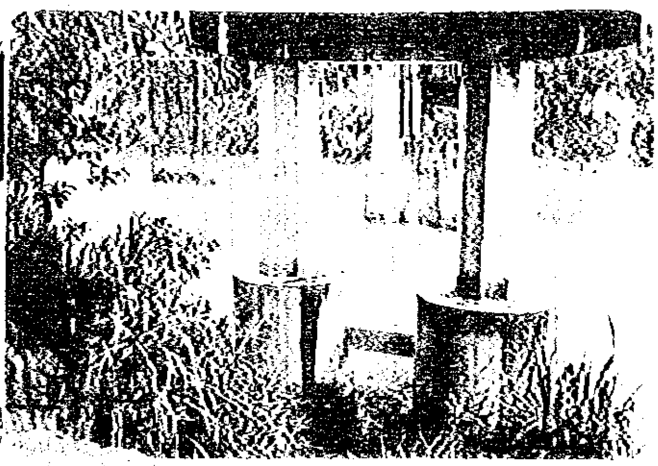
Stone abutment

Brick abutment

Piers

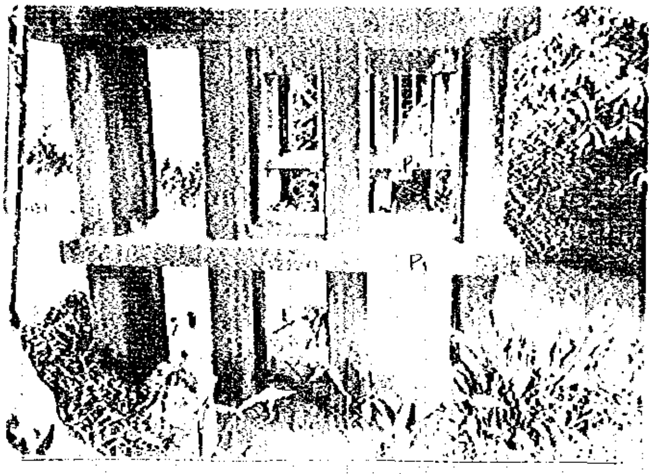


Stones Piers



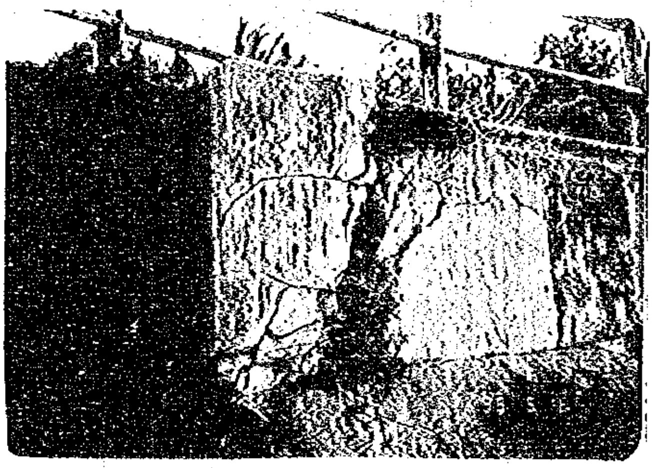
Steel piers (RSJ)

Caisson piers



Pile bent piers

Wing wall



Revetment

5.3 Bridge Maintenance Procedure

As described above the bridge maintenance will be carried out as a part of normal services of RDA's provincial offices. This work is classified as follows:

(1) Simple manual cleaning--- Removal of dust, sand and plants (weeds)

(2) Minor removal
and replacement --------- Removal and replacement of damaged members (deformed railings, expansion joint, etc.)

(3) Minor recovery ----------- Insertion of lost stones and bricks; recovery of traffic signs, railings and expansion joint

(4) Partial repair --------------- Repair of pot holes in pavement, repair of concrete scaling, flaking and spalling by patching

(5) Partial repainting ---------- Repainting to girders, chord, bearing and other steel and concrete

The maintenance work and technology are described below for each member.

5.3.1 Beam, Girder and Chord

H and I steels and built-up (plate girder) by welding are normally used for steel bridges, while the reinforced concrete and prestressed concrete are used for concrete bridges.

(1) Steel members

(a) Deposits on the lower flange

Mud and sand tend to deposit to the steel lower flange or the lower chord of a steel truss bridge, allowing growth of weeds and resulting in damage to the coating or steel itself. Visual inspection carried out during this master plan study detected many such examples.

(Maintenance)

Deposits must be removed by periodical cleaning. Use a mop when deposits are normally dry or use a brush or trowel when deposits are wet.

(b) Partial rusting

The most common damage to steel bridges is separation of coating and resultant rusting of steel. The steel surface is protected with coating or zinc plating which is damaged by air, water and droppings of birds

(Maintenance)

Touch-up coating is the most usual method. Before touch-up coating remove rust and impurities thoroughly and carry out coating in some layers.

(c) Partial deformation

The steel may be deformed when a passing vehicles collides or a drift wood knocks against it during flooding. Due attention must be paid to such deformation because, if left unattended, it may present threat to the stability of a bridge as a whole due to stress concentration depending on the location of such deformation.

(Maintenance)

When deformation is substantial, replacement of such member is necessary. But this replacement work is included in the repair. If deformation is small, it may be corrected by applying the heat or external force. Normally, however, it would be better to leave it to the repair work.

(2) Concrete members

(a) Partial damage

Partial damages to the concrete include honeycomb, scaling, and flaking. Honeycomb is holes or cavities arising from faulty compaction during placement.

Scaling is separation of cement paste due to the use of faulty material or faulty mixing design.

Separation or exposure of reinforcing steel bars is attributable to corrosion of steel bars due to insufficient concrete cover or faulty compaction.

Though partial, these damages will cause degradation of the load carrying capacity of concrete, if left unattended.

(Maintenance)

For these damages patching of mortar is made to prevent entry of air, water and moisture. The damaged portion or rust of steel bars (if these bars are exposed) must be completely removed beforehand, then carry out patching by applying epoxy resin.

5.3.2 Slabs

Slabs carry the live load (vehicle load) directly and distribute the load to beams and girders. Slabs are exposed directly to damages by the vehicle load, impact and wind, rain and miscellaneous materials.

Slabs are mainly made with reinforced concrete in Sri Lanka. In older bridges, however, slabs are mostly reinforced concrete placed over buckle plates or corrugated plates.

(1) Buckle plate or corrugated plate

(a) Partial corrosion

Most common damage to buckle plate or corrugated plate is deterioration of coating and resulting corrosion of steels. If left unattended, deterioration of coating and steel corrosion will proceed. Appropriate maintenance measures must be taken.

(Maintenance)

Repainting is made generally on damaged portions. Remove dirt and debris from damaged portions and clean these portions and surrounding area completely and carry out repainting according to the coating procedure. Since corrosion of these members is caused by water, it is necessary to clean the surface drainage pipe or to provide water-proofing to prevent entry of water and thus to prevent recurrence of corrosion.

(2) Concrete slabs

(a) Partial damage

Partial damages to concrete slabs include damages described in (2) Concrete members, that is honeycomb, cavity, separation and exposure of steel bars.

(Maintenance)

The method described for concrete members is applied. To prevent entry of rainwater, it is essential to clean the drainage or provide water-proofing.

5.3.3 Abutments and Piers

The abutments and piers are structures of the substructure, transmitting the load from the superstructure to the foundation.

The abutment is also a structure to retain and protect the embankment of access road. In Sri Lanka the wing wall is generally constructed with stone masonry or bricks and not joined with the abutment structure. Accordingly in many cases these wing walls tend to slide to be damaged under overload and earth pressure.

(a) Deposits around bearing seat

Water, mud, sand and dust entering from the superstructure causes corrosion of bearing or seat concrete. In extreme cases damaged portions were found to be covered with growing weeds.

(Maintenance)

The bearing seat and surrounding area must be cleaned periodically, with dirt and debris removed. To prevent entry of rainwater from the superstructure, the expansion joint must be kept in the sound condition.

(b) Partial damage

Damages to the abutments and piers include honeycomb, cavity, separation and exposure of reinforcement bars in the case of concrete and loose or lost stones in the case of stone masonry. These damages can be attributed to faulty construction materials and workmanship and erosion caused by flood.

(Maintenance)

Generally, mortar patching is used for damage to concrete and mortar filling is used for stone masonry.

(c) Blockage of the river by floating materials (driftwood, etc.):

Floating materials such as driftwood, aqueous plants and wastes are caught by abutments or piers, thereby reducing the sectional area of flowing water. As a result the flow velocity in this location increases, scouring the abutments and piers. If this is left unattended, blockage will grow further, causing water overflow, erosion and collapse of the embankment.

(Maintenance)

It is necessary to remove these floating or drifting materials.

(d) Vegetation

Dirt and debris, dust and mud deposits on the top or bearing seat of abutments allow plants to grow over a long time, causing crack or separation in the structure.

(Maintenance)

Any detected vegetation must be removed immediately and the area surrounding the bearing seat must be cleaned periodically.

(e) Local scour

Scouring of the abutments and piers occur, when the streambed material around the substructure is washed away by water channel flow, resulting in inclination of the abutments or piers or degradation of the bearing capacity of foundation piles.

(Maintenance)

Regardless of the scale, any detected scouring must be corrected immediately by providing gabions, filling the scoured portion with rock and by providing the concrete lining.

The bearing, whether it is made from steel or rubber, is an extremely important member of a bridge. This member transmits the load from the superstructure to the substructure while carrying the girder movement and rotation due to temperature change and thus should be kept in satisfactorily functional condition.

5.3.4 Bearings

As a result of visual inspection in Sri Lanka, it was found out that bearings of most of bridges could not be viewed, because they were covered with concrete, soil and dirt and debris.

(a) Suppression of function

If the bearings suffer deposition and adhesion of soil and mud, their movement and rotation are suppressed with unexpected stress acting on the superstructure, substructure and bearing seat to cause damage to the structure.

(Maintenance)

Cleaning of the bearing and surrounding area and removal of dirt and debris must be carried out periodically. In the case of steel slide and roller types lubrication is additionally necessary.

5.3.5 Deck Drainage Systems

Trapped or ponded water on a bridge pavement constitutes a traffic hazard and may contribute to deterioration of most of bridge structure members. Good deck drainage is therefore extremely important for bridges. Drainage of a bridge include drain holes (intake holes) and drain pipes.

(Maintenance)

Periodical cleaning of the bridge surface as well as cleaning of drain pipes and removal of dirt and debris is essential. In the case of bridges in Sri Lanka the drain pipes are mostly not installed vertically, but installed nearly horizontally under the sidewalk. Besides the diameter of drain holes and pipes is extremely small. In this context it is necessary to replace the existing drainage with a new one which has an appropriate diameter.

If the drain pipe is too short around the bearing, it will allow for water to splash over the bearing. Such pipes should be replaced with ones of required length.

5.3.6 Sidewalk and Curb

Damages to the sidewalk and curb include generally damage to the concrete and sidewalk precast concrete due to collision or override of vehicles.

(Maintenance)

Normal maintenance work is made for damage to concrete members. But any damaged precast concrete member must be replaced immediately.

During visual inspection, the wooden sidewalk plates provided on the outside of the through truss bridge were found to be left broken as shown in a photo in page 4-10 and 5-20.

5.3.7 Railings

Railings are barriers provided on the outside of carriageway and sidewalk, whose function is to prevent accidents and also to guide vehicles and pedestrians. In Sri Lanka railings are mostly made with steel and concrete.

(a) Concrete railings

(b) Steel railings

(Maintenance)
For both concrete or steel routine inspection and maintenance is essential, because it is very easy to inspect and maintain them. These members are replaced immediately, when the defect is found, because it affect directly to the safety of the the traffic.

5.3.8 Pavement

The pavement is provided over deck slabs for smooth running and walking while protecting slabs from wear and deterioration under vehicle load and impact.

In Sri Lanka pavement is generally asphalt concrete pavement. But stone laying and wooden pavements are also found.

(a) Pot hole

Pot holes occur because of faulty pavement work or under impact and other external forces. If left unattended, these pot holes may hamper traffic, resulting in accident and damageto slabs.

(Maintenance)

When pot holes are localized, remove the surface course down to the deck cutting square or rectangular with faces straight and vertical. Apply tack coat to the exposed deck and vertical faces. Patch asphalt concrete and compact with a tamper to the same elevation as the surrounding surface. If there are lots of pot holes or they are scattered over a wide area scarify the entire area and overlay with new asphalt concrete.

(b) Bridge approach

Bridge surface pavement immediately after abutment may often develop settlement due to consolidation of the embankment of the approach. If left unattended, such settlement may hamper vehicle traffic and the impact load may affect the structure adversely.

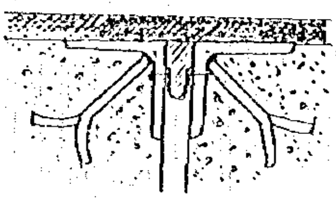
(Maintenance)

If the settlement is about 20 cm or less, asphalt concrete may be used for overlay. If the settlement exceeds 20 cm, the pavement and base course including the subgrade in certain cases must be removed and the repair must be made according to the correct method.

5.3.9 Expansion Joint

The expansion joint is provided in the gap of slabs to allow for longitudinal expansion/contraction of girders under fluctuating temperature. This joint also protects slabs and pavement edge while preventing fallingof dirt and debris.

The expansion joint used most generally in Sri Lanka is of a construction using angle materials as shown on the right. In many cases either the expansion joint is not installed in short-span bridges or covered with pavement.



(a) Crack normal to a bridge and water leakage

Most of expansion joint is covered with asphalt concrete and crack or wide gap were found frequently in the joint position.

(Maintenance)

When the expansion joint is covered with pavement, the pavement must first be removed to facilitate confirmation of the joint type. If the joint is of an open type without joint sealant, it must be replaced by a type with joint sealant. If left unattended, the open joint may allow rainwater, mud, dirt and debris to fall through the gap, depositing around the bearing and damaging the bearing and girders. If the slab concrete around the expansion joint is partially damaged, the damaged portion must be chipped and repaired with epoxy resin.

(b) Damage and abnormal sound of fingerplate or cover plate

Broken or loose anchor bolts of finger plate or cover plate may cause enlargement of the damage under impact of traffics, resulting in generation of abnormal sound. If this condition is left unattended, the loose joint member may damage a vehicle or cause traffic accident. In addition the damaged portion will much larger and the degree of damage much heavier.

(Maintenance)

The most effective method is to replace the damaged joint. If the damage is only partial, either anchor bolts must be replaced or re-fixed by welding.

5.3.10 Revetment

Except for viaduct all bridges cross over a river or channel and are always exposed to damage by flowing water. Damages include erosion of the revetment and scouring of the substructure.

(a) Damage to embankment revetment

This occurs when the revetment materials are washed away by flowing water or tidal current. Generally this kind of damage occurs when the channel is changed.

(b) Growing vegetation

When vegetation grows in the channel, it blocks the channel to affect the flow rate and flow velocity of a river at the bridge position. Growing vegetation also hampers bridge inspection.

(Maintenance)

Vegetation growing within about 10 m upstream and downstream of a bridge must be periodically removed.

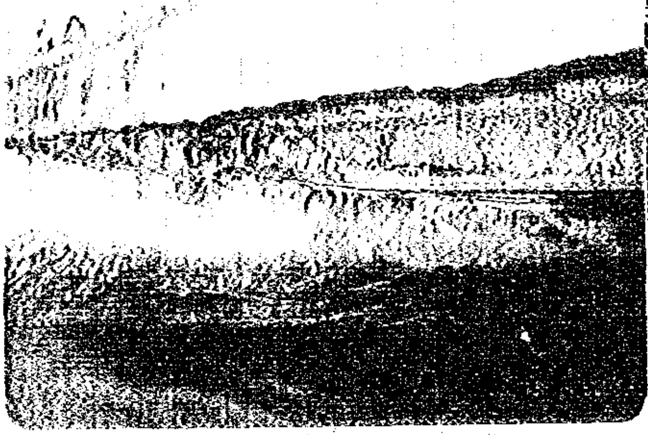
(c) Illegal waste dumping

Illegally dumped wastes, dirt and debris and surplus soil from construction will not only hamper water flow of a river but also cause degradation of environment.

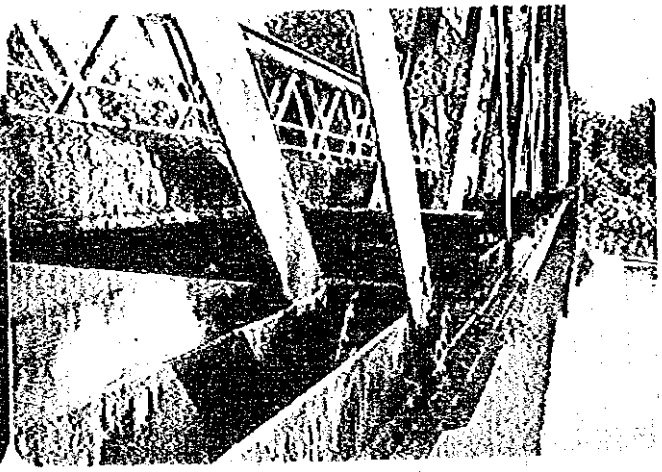
(Maintenance)

Dumped wastes, etc., shall be removed and warning signs and other appropriate measures shall be taken.

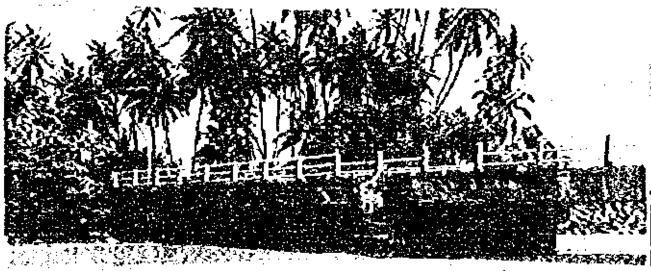
Bridge members requiring periodical maintenance and management are shown in photos in pages 5-8 to 5-22.



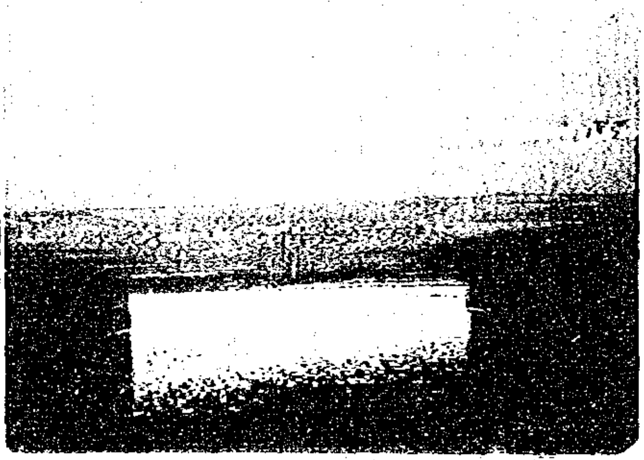
Steel beams, girders and chords



Steel chords



Concrete girders



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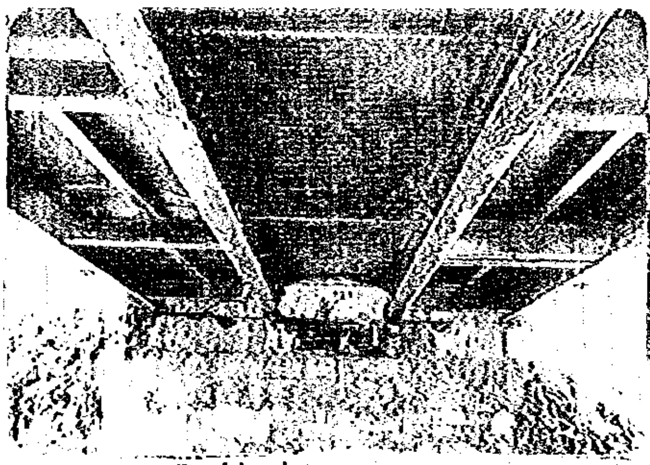
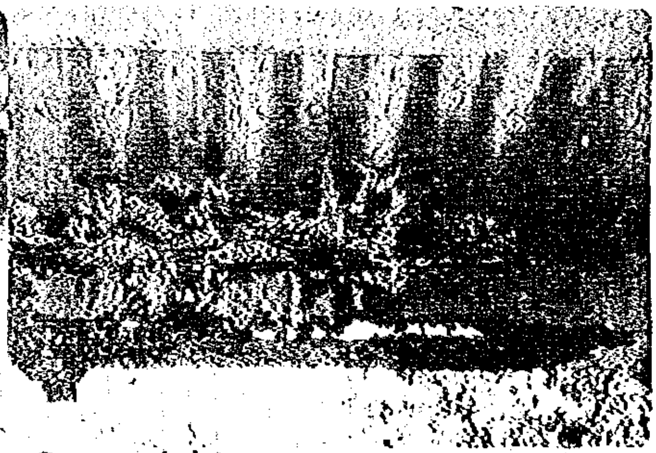
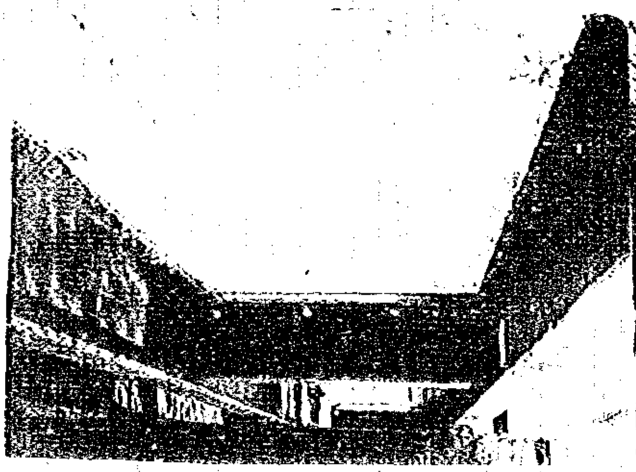


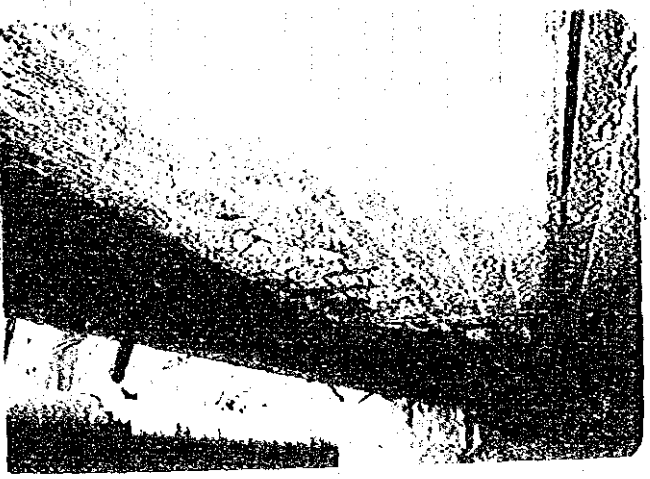
Buckle plates



Corrugated plates



Concrete slabs



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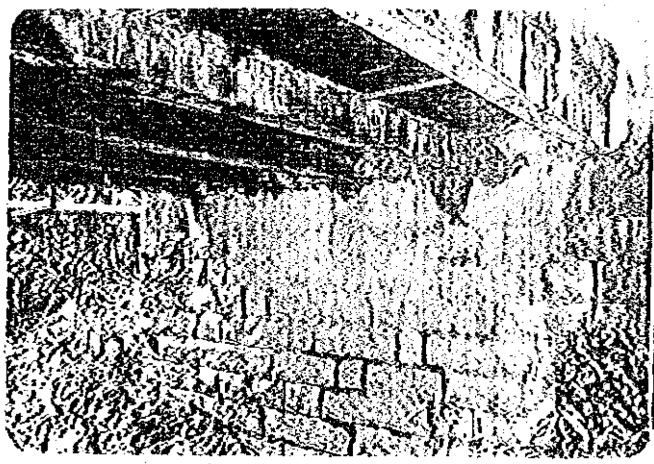
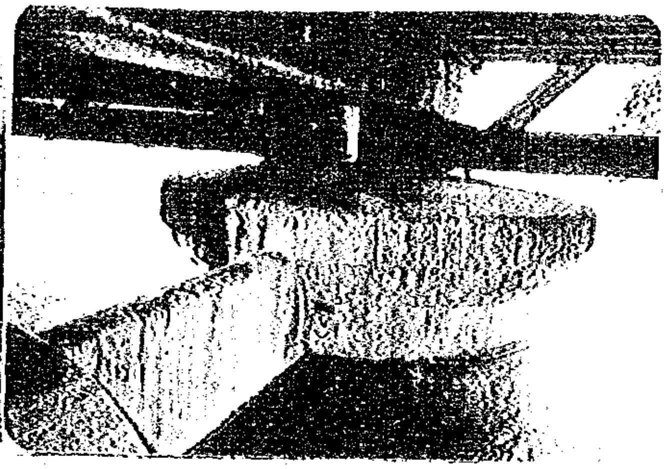
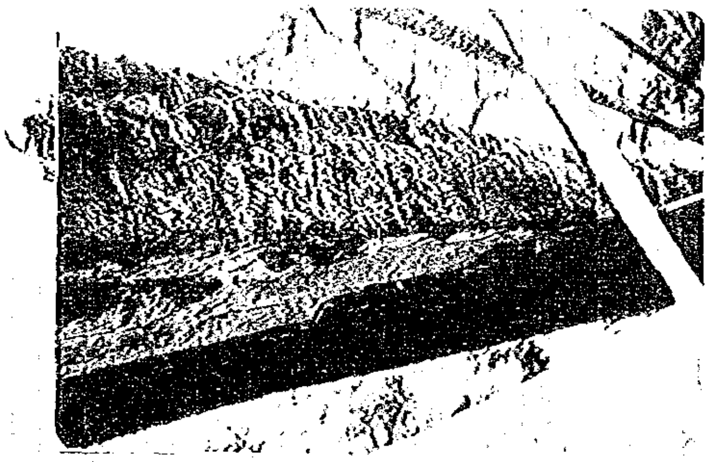


Area around bearing

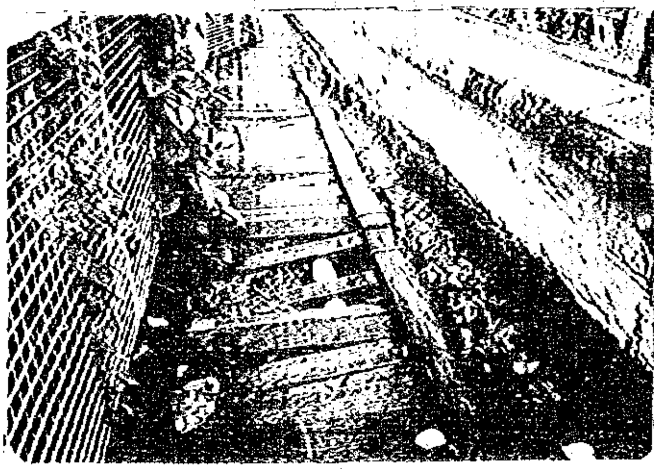


Bearing

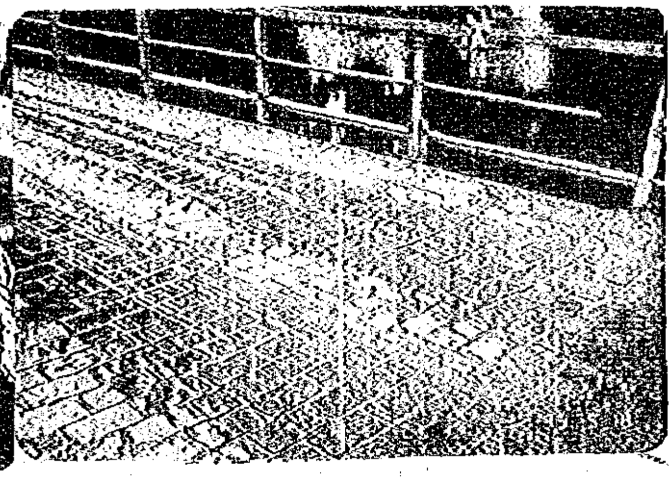
Blocked river



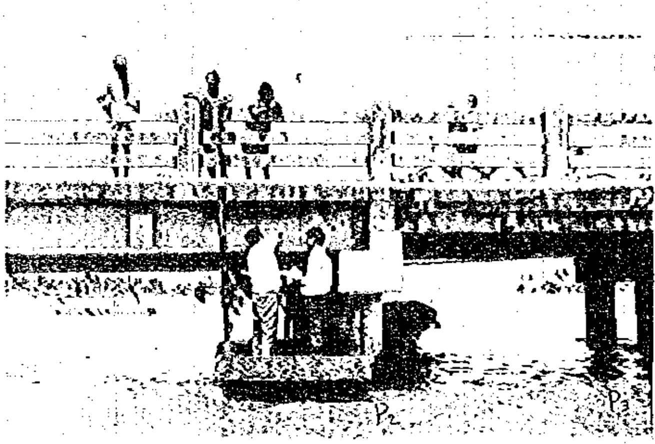
Vegetation



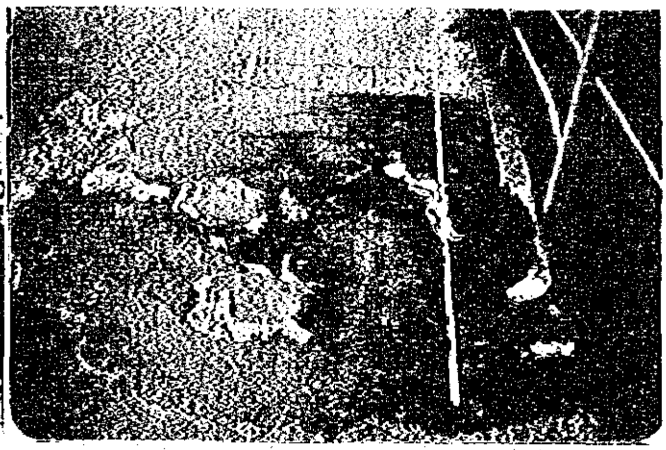
Sidewalk and curb



Pavement



Railing



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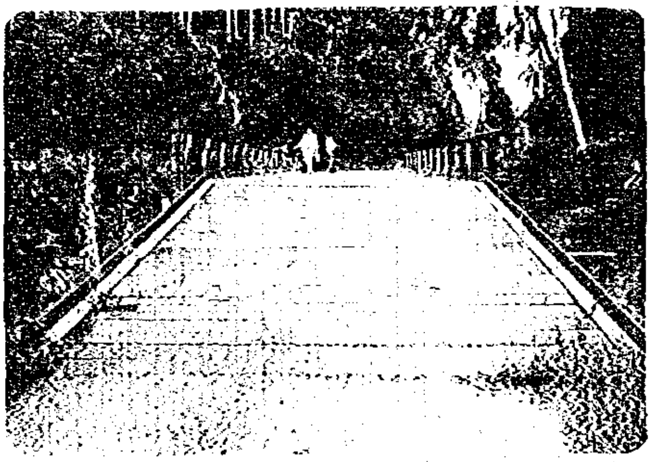
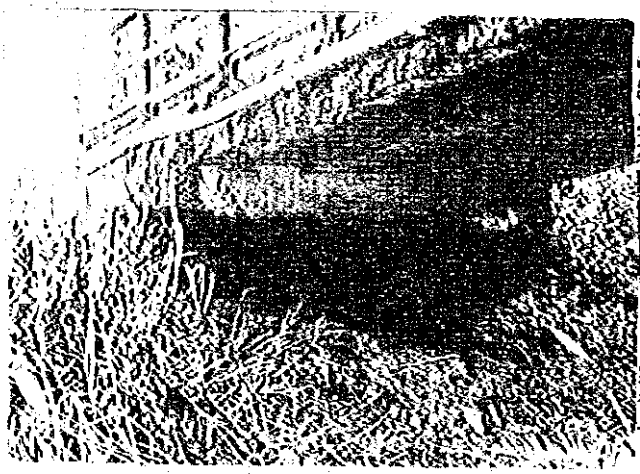
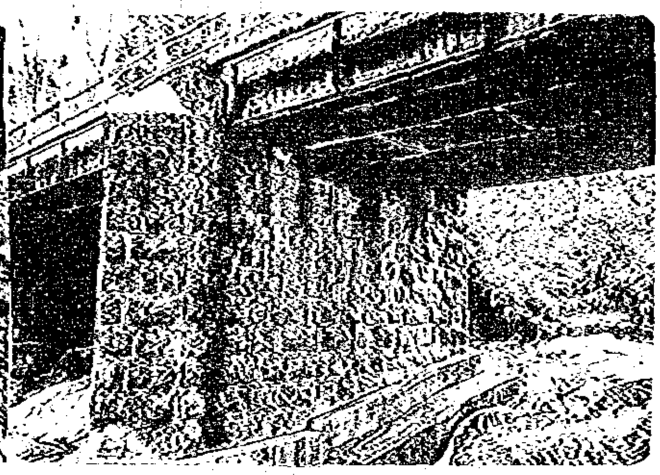


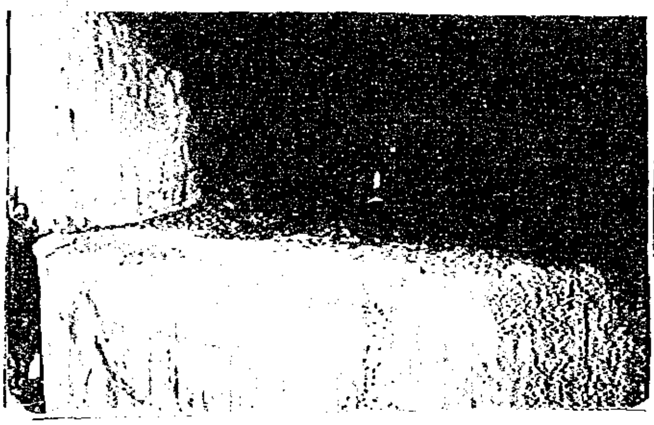
Bridge approach



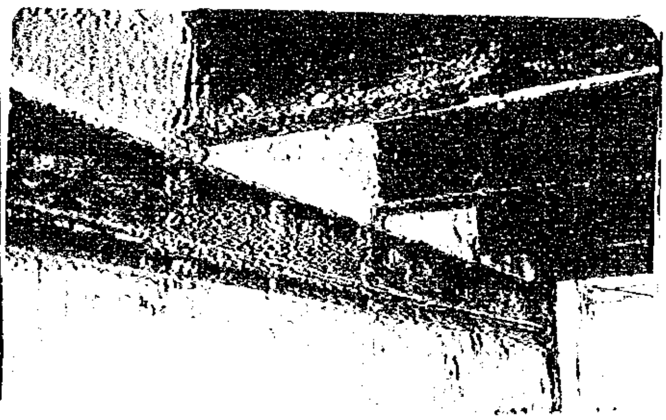
Scour



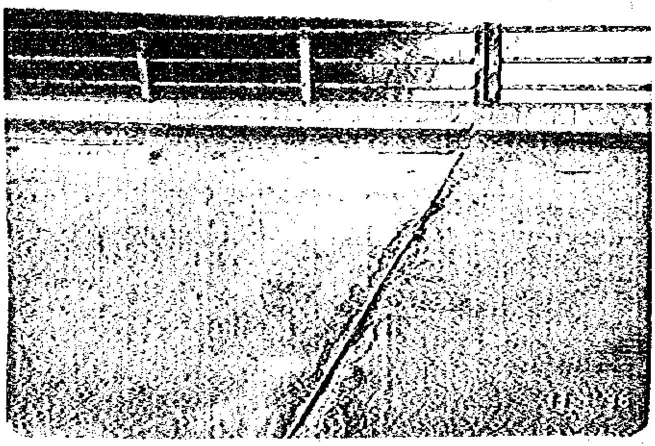
Same as left



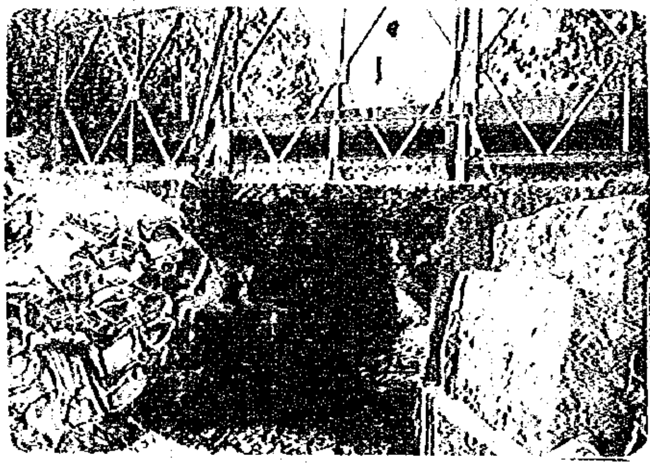
Abutment



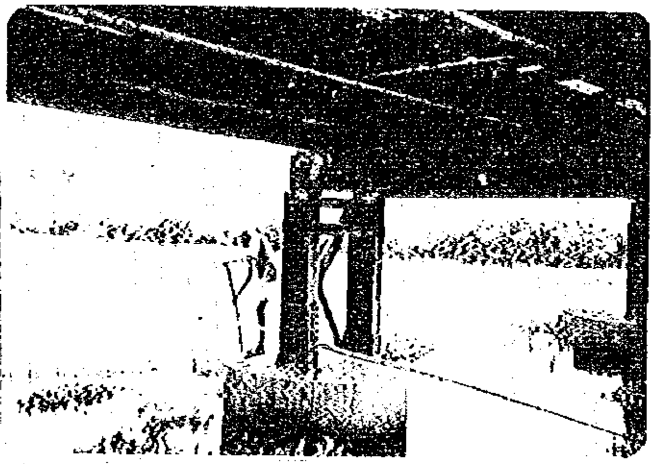
Bearing



Expansion joint



Revetment



Vegetation

CHAPTER6 BRIDGE REHABILITATION PROCEDURE

6.1 General

At present there are a total of about 4,700 bridges on national highways A and B under control of Sri Lanka RDA. Certain bridges are already 100 years old after construction and all bridges are getting older year by year. Besides increase in the traffic volume, growing axle load, contamination of rivers and scouring are making the bridge damage more and more severe every year.

Elements essential to extend the bridge life time as long as possible and to ensure the safety are periodical maintenance and management and execution of the repair and strengthening at right time.

Maintenance and inspection must be carried out periodically and without fail because insufficient maintenance makes inspection difficult or timely execution of repair and strengthening impossible, resulting in additional cost for bridge replacement.

Purposes of rehabilitation (repair, strengthening, etc.) of bridges are listed below:

- Protection of a bridge so that it can be used for the traffic and carry the load as long as possible
- Minimization of the hampering effect on the traffic
- Ensuring of the safety for road users
- Assuring of smooth traffic flow
- Reduction of present and future costs including the expenditure for bridge replacement.

6.2 Classification and Definition of Bridge Rehabilitation

Bridge rehabilitation is roughly classified as follows:

Repair
Strengthening
Functional improvement

Note: The replacement is out of scope of this guideline.

They are defined as follows:

Repair --------------------- Recovery of the original bridge service level intended at a time of construction (the protection included)

Strengthening-------------- Enhancing the service level above the original level expected at a time of construction

Functional improvement - Solving of problems, such as insufficient road width, lack of sidewalk, short bridge length, etc.

Figure 6.1 shows a flow chart to be followed when selecting the appropriate bridge rehabilitation method.

Note that this guideline does not cover the replacement of bridges.

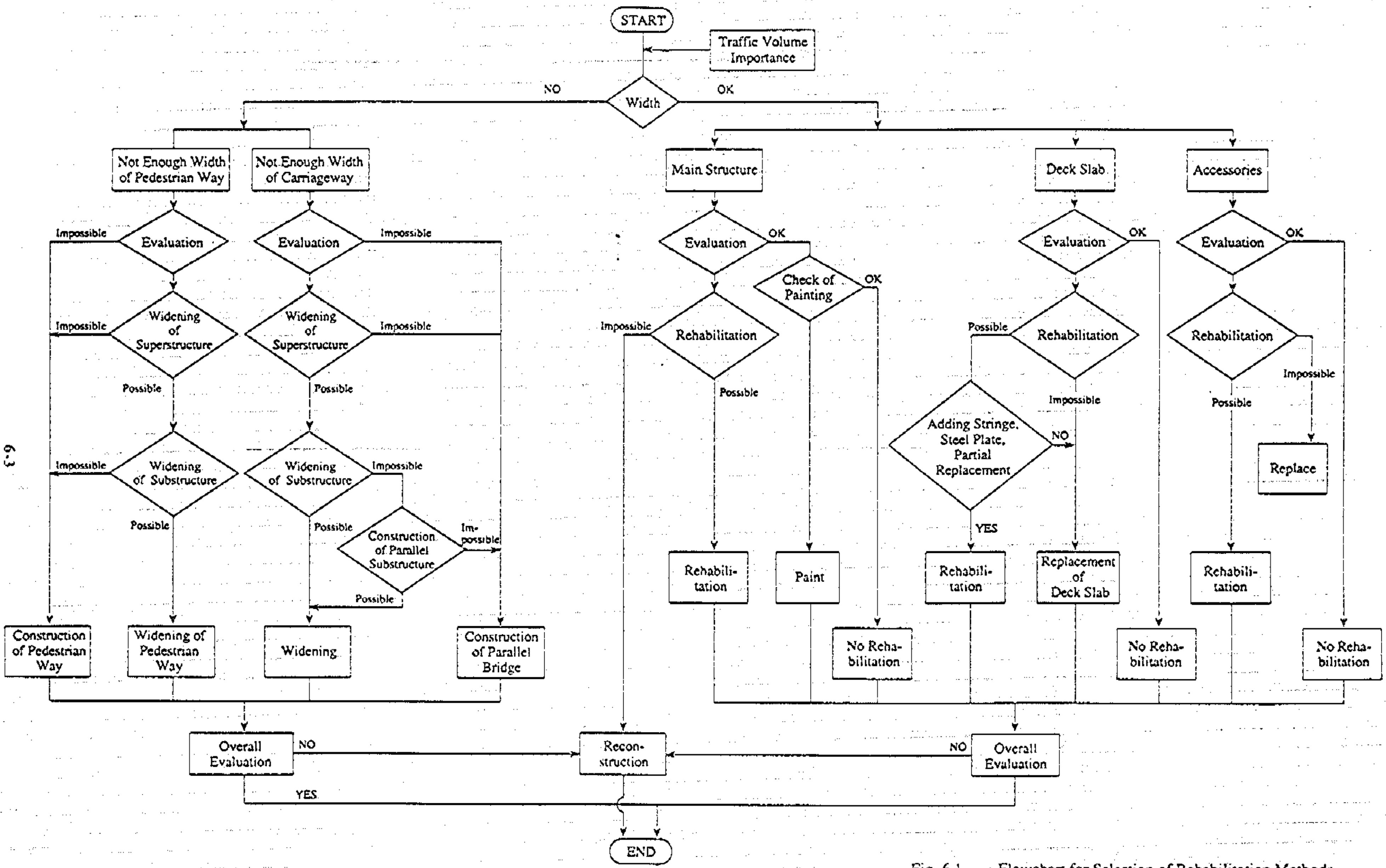


Fig. 6.1 Flowchart for Selection of Rehabilitation Methods (Reinforcement, Rehabilitation)

6.3 Rehabilitation Plan

According to the results of the preliminary inspection and detailed investigation bridges under control of Sri Lanka RDA have typical damages as shown below.

Structure	Defect
Concrete structure	Separation, flaking, and crack of concrete; exposure of reinforcing bar, free lime
Steel structure	Rusting, dislodgment of bolts, chips in section due to corrosion, excessive deflection due to insufficient sectional area
Substructure	Scour Crack in the retaining wall (stones, bricks), excessively large void, outflow of backfill soil
Bearing	No bearing, or bearing covered with concrete
Expansion joint	Crack of pavement Exposure of steel angle
Railings	Left in the damaged condition
Drain hole	Too small hole size

When selecting the appropriate rehabilitation method, two or three methods are chosen and compared, according to the results of detailed investigation on damages. It is necessary to consider not only the costs but also the effect on third parties (closing of the traffic, installation of scaffolding in the river, etc.).

Aspects	Items to be considered
Structural	* Type, degree, and scale of damage * Location of damaged member
Works	* Work space * Material and machinery required for repair or strengthening * Effects on the environment (noise, vibration and contamination)
Aesthetic aspect	* Repair result must not be readily visible.
Economical aspect	* Inexpensive (economical)