7.4 Bridges

7.4.1 Status of Damage to Bridges

Damaged bridges ranged so widely from Manila to the northern part of Luzon Island that a field survey on all of them in a limited period was hardly possible. Therefore, we decided on a survey policy which would cover as many sites as possible and check on bridges heavily damaged.

In fact, field surveys on a total of 30 bridges were made. We also checked nine damaged bridges on the Filipino-Japanese Friendship Highway by hearings as well as by photographs which had been taken by local cooperators in previous surveys.

According to the DPWH damage survey results, surveys have not yet been done on 25 bridges. However, these apparently do not include bridges with serious damage, such as bridge falls. Fig. 7.4.1 shows location of damaged bridges but added by the subsequent inspection.

Bridge damages extended to large area of Luzon Island, including many bridges particularly on the Filipino-Japanese Friendship Highway and the Manila-North Road. These are trunk roads linking the northern part of Luzon Island to Manila.

On the Manila-North Road linking Manila and San Fernando via Tarlac and on roads in its vicinities, the Carmen, Calvo and Tabora Bridges fell and the Aringay Bridge was seriously damaged.

In Dagupan City and its suburbs where heavy damage was caused by liquefaction, the Magsaysay Bridge fell and the Embarcadero and Rabon Bridges were heavily damaged.

On the Filipino-Japanese Friendship Highway, meanwhile, the Manicla Bridge fell while the Sicsican Bridge is in danger of falling. As for the Puncan II Bridge, no anomalies have yet been discovered in its body but it may be damaged hereafter by the large quantity of oncoming driftwood.

Photos 7.4.1 - 7.4.23 show the status of damage caused to different bridges.

7.4.2 Analysis of Damage to Bridges and Judgement on Damage Degrees

Table 7.4.1 shows data, status of damage and damage degrees concerning the 39 bridges that were covered by our surveys. Table 7.4.2 is a bridge summary table concerning levels of damage. As for Table 7.4.1, the interim report submitted to the DPWH (August 6, 1990) was partially amended, based on subsequent study (same with Table 7.4.3).

Damage characteristics include falls of the superstructure due to pier inclination caused by the liquefaction of ground, damage of the girder ends, shoes, and bridge seats caused by inertial force, damages of the abutment piles, footings, and girder ends caused by earth pressure and inertial force, damages of the pile heads in pile bent piers, settlement of piers, and settlement of approaches.

Of these damage types, damage by liquefaction, damage to pile bent abutments and piers and damage to shoes and bridge seats were especially heavy and common.

Mention must first be made of the fact that the horizontal bearing force of damaged bridges in general was small because their foundations generally had insufficient setting depth (presumed to be about 10 m, at most). The single-row pile form (one row in the direction at right angles to the bridge axis) was common (pile bent) and the commonly used piles were made of wood or RC piles. Their shoes were of relatively simple structure and did not have a sufficient number of anchor bolts. The bridge seat on which the shoe rested was narrow so that there was a danger of bridge fall or easy slip-out of the shoe in the event of a large displacement of the substructure. Also, shear fracture was liable to occur in the bearing edge at the pier top and in the girder end.

Damage degrees must be judged in order to carry out emergency rehabilitation. We decided upon damage degrees for individual bridges (Table 1) in accordance with Manual for Repair Methods of Civil Engineering Structures Damaged by Earthquakes (draft) (Ministry of Construction, March 1986). Damage degrees concerning bearing force were decided according to the following five ranks:

- A: No damage ..... There is no known anomaly concerning bearing force.
- B: Minor damage ..... There is no immediate decline of bearing force.
- C: Medium damage ..... The damage may affect the lowering of the bearing force, but if it does not worsen from aftershocks, live load, etc., the bridge can be used for the present.
- D: Major damage ..... The damage seriously affects the bearing force and may lead to critical consequences, such as a bridge fall.
- E: Bridge fall ..... The case of a fallen bridge

In deciding upon damage degrees concerning bearing force, it is most important to determine whether or not a bridge fall will eventually occur. Here, bridges with the possibilities of a fall due to live loads, aftershocks, etc. are classified as being in the D rank. As a whole, these bridges must be totally closed to traffic.

7.4.3 Recommendations on Rehabilitation of Heavily Damaged Bridges

These recommendations concern the 11 heavily damaged bridges placed in the D and E damage degree ranking in the preceding section plus the Puncan II Bridge. (The locations of these 12 bridges are shown in the enlarged map of Fig. 7.4.2.)

Also, the generally estimated rehabilitation costs for the above 11 heavily damaged bridges (13 million pesos for emergency rehabilitation and 117 million pesos for regular rehabilitation) are shown in a reference material table: Ref. 7.4.1.

Emergency rehabilitation measures (draft) and regular rehabilitation measures (draft) for each of these bridges are indicated in Table 7.4.3.

It seems that all these bridges must be rehabilitated with equal urgency. Yet, the importance of rehabilitation from the viewpoint of road networking and safety of traffic and from the point of view of rehabilitation requirements are as described below.

(1) Carmen Bridge

This bridge is 655 m long and six of its spans fell and its six piers were greatly inclined because of liquefaction. Also, a bearing is missing from one span. It is the largest bridge on the Manila-North Road and the effect of its rehabilitation is probably the greatest from the aspect of road traffic. However, to rehabilitate it properly, its tilted piers must be reconstructed. Since this will take considerable time, it is believed that constructing an emergency detour is positively necessary. A temporary wooden bridge using wooden piles is now being constructed about 200 m upstream but when the regular typhoon season comes, it may well become unusable or washed away. It is, therefore, deemed necessary to construct an emergency bridge that can be used in all seasons. In this case, it will be economical if the emergency bridge and the usable parts of the existing bridge section can be linked together.

(2) Calvo Bridge

This is a rather large bridge with a length of 200 m although it is situated off the trunk line of the Manila-North Road. So, its rehabilitation priority is felt to be high. Its pier greatly tilted through liquefaction and presumably cannot be reused but the superstructures of the two fallen spans can probably be used again if they are repaired. In this case, checking for the bearing force of these superstructures is necessary. The damage level of another slightly inclined pier (moved horizontally by an estimated 20 cm or so at the pier top) must probably be examined in detail.

(3) Magsaysay Bridge

The emergency rehabilitation of this bridge must be rushed because it is on a Dagupan main street. Its super- and sub-structures cannot probably be reused. A possible alternative is to construct an emergency bridge by the side of the fallen bridge. (A plan to construct an emergency bridge is ready.)

(4) Embarcadero Bridge

Its abutment piles and bridge seats on pier tops are damaged and the bridge is in danger of falling. Preventing the fall of the bridge and undertaking traffic regulation seem to be necessary as urgent emergency measures. Renewal should be included among the proposals of regular rehabilitation because the present bridge is old.

(5) Cupang Bridge

This is a rather small bridge (length: 30 m) on the Manila-North Road. The piles of an abutment were destroyed on one side but temporary supports have already been installed and the bridge is available for traffic.

This is sufficient for some time as an emergency measure but, when effecting regular rehabilitation, the abutments must be reconstructed. In this case, the use of pile bent piers will have to be avoided.

(6) Tabora Bridge

Two pile bent piers were destroyed and, as an emergency measure, temporary supports have already been installed. In making regular rehabilitation, it is probably advisable to avoid the use of pile bent piers and use more rigid substructures instead.

(7) Aringay Bridge

There are signs of violent hits between girder and abutment, between girder and pier and between girder and girder, thus causing heavy damage to the abutments, girder ends and substructures. In view of the possibilities of a future bridge fall, something must be hurriedly done to prevent a bridge fall. Renewal should be included among the proposals of regular rehabilitation because the present bridge is old.

(8) Caba Bridge

The damage to this bridge is similar to that of the Aringay Bridge (as concerns girders and substructures) and something must be done to prevent its fall. Renewal should be included among the proposals of regular rehabilitation because the present bridge is old.

(9) Rabon Bridge

It has four pile bent piers and the piles were greatly deformed horizontally (estimated ± 10 cm or so on the ground plane) in the earthquake. There are signs that the superstructure hit the abutment hard and the concrete at the heads of all piles were damaged. Furthermore, considering the fact that the superstructure shakes violently when a large truck passes, it seems that the bearing force of the substructure must be increased during regular rehabilitation.

(10) Manicla Bridge

This is a small one-span bridge on the Filipino-Japanese Friendship Highway. The fallen superstructure may be reusable but the abutments will have to be renewed.

(11) Sicsican Bridge

This is one of the important bridges on the Filipino-Japanese Friendship Highway. No earthquake damage, such as destruction of superstructure members, could be found but the shoe in the middle span was out of place and the girder barely stayed on the tip of the pier head. Also, the pier is slightly inclined. Closure to traffic and immediate measures to prevent bridge fall (girder connecting, for example) are necessary. In regular rehabilitation, measures including the widening of bridge seats are necessary.

(12) Puncan II Bridge

This is a bridge on the Filipino-Japanese Friendship Highway. Large quantities of sediments and driftwood crowded toward it. There is still no damage to the bridge proper but, in a heavy rainfall, these deposits may begin to move. Therefore, measures such as removing driftwood, are urgently necessary.

7.4.4 Recommendations Concerning Bridge Maintenance and Construction

Many bridges were damaged by the recent earthquake and an analysis of earthquake damage has revealed certain characteristics (7.4.2).

To reduce earthquake damage in the future, a number of improvements on the maintenance of existing bridges and the design and construction of proposed bridges may be possible with consideration for these characteristics. Hence, the following recommendations:

(1) To avoid a bridge fall, it is advisable to take such measures which provide girder connection by way of anti-earthquake reinforcement. Shift restricting equipment and assurance of sufficient bearing edge distance is also necessary.

(2) In an area where liquefaction is feared, it is advisable to increase the load bearing force of foundations by, among other things, assuring sufficient foundation settings and rigidity by way of preventing from damage by liquefaction.

(3) In view of frequent damage to pile bent piers and abutments, it is advisable to use foundation forms with large bearing forces. This can be done, for example, by arranging more than one row of piles in a direction at right angles to the bridge axis. The pile bent foundation had better be avoided especially if high-banking foundations are to be constructed on soft ground.

(4) It is advisable to change antiseismic standards so as to improve the earthquake resistance of bridges.

(5) It is advisable to have emergency bridges ready for use in contingencies.

Table 7.4.1 Bridges Damaged by Earthquake (1/5)

No.	Name of bridge	Location	Bridge type		Damage	Degree of damage	Remarks
			Superstructure	Substructure			
P-1	T. Sison (Carmen) Bridge	172k+500 Rosales Pangasinan	. Simple steel truss, 13 spans . Bridge length 655m (span 50m)	. P1 - P12 wall type piers . P11 rigid-frame pier (pile bent)	. Six spans fell (Tarlac side) . Six piers tilted or toppled . Bearing fell off (P11)	E	. Detour being constructed . Unavailable for traffic
P-2	Calvo Bridge	Bayambang Pangasinan	. 4-span simple steel truss . Bridge length 200m (span 50m)	. A1 and A2 pile bent abutment . P3 wall type pier . P1 pile bent foundation . P2 multispan	. Two spans fell . One pier tilted . One pier toppled	E	. Available for light-vehicle traffic . Detour bridge was constructed above old bridge
P-3	Magsaysay Bridge	Dagupan City Pangasinan	. 3-span simple RC girder bridge (span 14m) . Combination of 3-span simple plate girder and RC girder (span 20 m)	. A1 and A2 pile bent abutment . P1 - P6 wall type pier	. Four spans fell . Two piers collapsed . Three piers tilted or toppled	E	. Unavailable for traffic
P-4	Aloragat Bridge	194k+591 2nd District Pangasinan	. Multispan simple RC girder bridge	. A1 and A2 pile bent abutment . Wall type pier	. P-12 pier settled by about 30 cm	C	. Available for light-vehicle traffic
P-5	Embarcadero Bridge	Mangaldan Pangasinan	. 3-span simple plate girder (3x12.0m) . 3-span continuous RC girder (3x14.0m) . 6-span continuous RC girder (6x8.5m)	. A1 and A2 pile bent abutment . Wall type pier	. Shear fracture in pier top . Abutment approach settled by 50cm (A1) and 1m (A2) . Reinforcing bars of abutment pile bent became exposed	D	. Bridge fall countermeasures are necessary . Available for light-vehicle traffic
P-6	Mangguer-agday Bridge	On Dagupan-Bonoan-San Fabian Road, Dagupan City	. 2-span simple steel truss (span 50m)	. Rigid-frame pier . Pile bent abutment	. Approach settled by about 0.5 - 1.0m . Pile bent reinforcing bars became exposed and cracks developed in footing	C	
P-7	Uyong Bridge	On Pangasinan-Zambales Road, Pangasinan	. 4-span simple RC girder, bridge length 80m (span 20m)	. A1 and A2 pile bent abutment . Wall type pier (3)	. No damage	A	. No damage

Table 7.4.1 Bridges Damaged by Earthquake (2/5)

No.	Name of bridge	Location	Bridge type		Damage	Degree of damage	Remarks
			Superstructure	Substructure			
P-8	Gayaman Bridge	Binmaley Dagupan-Lingayen Road, Pangasinan	. Single span steel truss	. A1 and A2 pile bent abutment	. Approach on A2 abutment side settled	A	
P-9	Hector Mendo za	Alcala, Laoac, Pangasinan	. Wooden bridge	. Wooden	. Four spans collapsed	E	. Temporary bridge
P-10	Qintos Bridge	Dagupan City Pangasinan			. Slight cracks in A1 abutment	A	
P-11	Bolosan Bridge		. Single span steel plate girder	. A1 and A2 pile bent	. Banked parts of A1 and A2 settled and stone masonry in banked parts was destroyed	B	
P-12	Cayanga Bridge		. RC rigid-frame girder	. Pile bent	. Reinforcing bars in column capital became exposed . Pile tilting	C	. Requires repair
L-1	Luguit Bridge	On Naguilian Road, La Union	. 2-span simple bridge (2x16.0m)		. Banking in approach section collapsed . Reinforcing bars in RC pile bent became exposed	C	. Requires repair
L-2	Cupang Bridge	Sto. Tomas, La Union	. 2-span simple steel plate girder (2x15.0m)	. A1 and A2 pile bent abutment . Wall type pier	. Reinforcing bars in RC pile bent became exposed . Approach section settled . Abutment tilted	D	. Repaired by timber support
L-3	Tabora Bridge	240k+026 On MNR, La Union	. Simple RC girder with cantilever	. Pile bent pier	. RC pile bent was destroyed	E	. Repaired by timber support . Available for light-vehicle traffic
L-4	Aringay Bridge	244k+130 On MNR, La Union	. Multispan RC girder bridge . 23 spans, bridge length 253m	. A1 and A2 wall type abutment . Wall type pier	. Girder ends, pier tops, abutment bodies and piles were heavily damaged . Settlement of approach sections	D	. Being repaired . Available for light-vehicle traffic . Requires bridge fall countermeasures

Table 7.4.1 Bridges Damaged by Earthquake (3/5)

No.	Name of bridge	Location	Bridge type		Damage	Degree of damage	Remarks
			Superstructure	Substructure			
L-5	Caba Bridge	248k+512 On MNR, La Union	. RC girder bridge (8x12) (bridge length 96m)	. A1 and A2 wall type abutment . P1 - P7 wall type pier	. Shear fracture occurred at girder ends and pier tops	D	. Requires bridge fall countermeasures
L-6	Bauang I Bridge	258k+912 On MNR, La Union	. Steel truss	. A1 and A2 wall type abutment	. Approaches settled by 30cm (A1) and 15cm (A2)	A	
L-7	Bauang II Bridge	259k+402 On MNR, La Union	. Steel truss	. A1 and A2 wall type abutment	. Approach on A2 side settled by a length of 40m	A	
L-8	Pagdalagan Bridge	265k+373 On MNR, La Union	. 4-span RC girder bridge, bridge length 52.8m (4x13.2)		. No damage	A	
L-9	Bani North Bridge	405k+351 La Union	. 2-span simple RC girder bridge	. A1 and A2 pile bent abutment . Pile bent pier	. Approach on A1 side settled . Cracks in pile bent	B	. Approach is being repaired with timber
L-10	Principe Bridge	La Union 237K+360	. 3-span simple RC girder bridge	. A1 and A2 pile bent abutment . Wall type pier	. Reinforcing bars were exposed in all pile bents . Shearing cracks at girder ends . Approach settlement	C	. Requires repair
L-11	Rabon Bridge	233k+576 Pangasinan-La Union Inter-provincial Road, La Union	. 5-span rigid-frame RC slab bridge	. Pile bent	. Reinforcing bars were exposed at each pile top . Tilting of piles . Approach on A1 side settled for a length of 10m	D	. Bearing force of substructure is inadequate
N-1	Manicla Bridge	Northern part of San Jose, Nueva Ecija		. Pile bent	. Bridge fell . A1 abutment tilted	E	. Available for light-vehicle traffic . Temporary bridge has already been constructed on top of fallen bridge

Table 7.4.1 Bridges Damaged by Earthquake (4/5)

No.	Name of bridge	Location	Bridge type		Damage	Degree of damage	Remarks
			Superstructure	Substructure			
N-2	Sicsican Bridge	Nueva Ecija	. Steel through truss	. A1 and A2 wall type abutment	. Girder end of Span No. 2 slipped out of place, reducing bearing edge distance to only 20cm; thus, bridge may possibly fall.	D	. Requires bridge fall countermeasures
N-3	General Luna Bridge	119k+100	. 13-span PC girder bridge, bridge length 611.0m (span 47m)	. A1 and A2 wall type abutment	. Destroyed expansion joint (finger joint) Cracks in wing wall	B	
N-4	Tuntunin I Bridge	172k+400	. Steel plate girder	. A1 and A2 wall type abutment	. Foundation stone on A2 side collapsed. . Approach on A1 side settled . Destroyed expansion joint	B	. Photographic survey
N-5	Tuntunin II Bridge	173k+500	. RC girder bridge, bridge length 12.0m	. A1 and A2 wall type abutment	. Cantilever slabs on A1 side fell off. . Cracks developed diagonally in A1 and A2	C	. Photographic survey
N-6	Puncan II Bridge	176k+600	. 5-span steel RC girder bridge, bridge length 78.0m (span length 15.6m)		. No damage	A	. Driftwood and sediments blocked because of insufficient under-girder clearance. . Driftwood and sediments must be removed at once. . Photographic survey
N-7	Tactac Bridge	178k+600	. 2-span rigid structure, bridge length 12.0m		. Foundation stone partially collapsed	B	. Photographic survey
N-8	Bancay Bridge	180k+510	. Rigid structure, bridge length 7.2m	. A1 and A2 pile bent abutment	. Approach slightly settled	A	. Photographic survey
N-9	Digdig Bridge	181k+500	. RC slab (8.0x2) . Steel truss (50.0), bridge length 66.0m	. A1 and A2 pile bent abutment . P1 and P2 wall type pier	. Horizontal cracks on lower side of pier	C	. Photographic survey

Table 7.4.1 Bridges Damaged by Earthquake (5/5)

No.	Name of bridge	Location	Bridge type		Damage	Degree of damage	Remarks
			Superstructure	Substructure			
N-10	Minuli Bridge	201k+500	. Rigid structure, bridge length 7.5m	. A1 and A2 pile bent abutment	. Stream is greatly impeded by flow of fragments	B	. Fragments caused by earthquake . Photographic survey
N-11	Consuelo Bridge	216k+900	. RC girder (15.0m) . Steel plate girder (9.5x2), bridge length 34.0m	. A1 and A2 pile bent abutment	. Tilting of approach slab	A	. Photographic survey
N-12	Balining Bridge	219k+300	. RC girder bridge, bridge length 39.2m (12.0x2+15.2)		. Revetment on upstream side collapsed over 20m	A	. Photographic survey
T-1	San Isidro Bridge	149k+500 Paniqui, Tarlac	. 7-span RC girder bridge	. A1 and A2 pile bent abutment . Wall type pier	. Settlement of A1 abutment . Approach settled 2m for 250m . Shearing cracks at girder ends	B	. Requires bridge fall countermeasures
T-2	J. Cojuangco Bridge	Paniqui, Tarlac	. 6-span steel plate girder (6x30.0m)	. A1 and A2 pile bent abutment . P1 - P5 wall type pier	. Approach settled . Cracks in stringer board . Cracks in pile bent	C	
T-3	Bamban Bridge	Bamban, Tarlac	. Steel plate girder		. No damage	A	
Pan-1	Candaba Viaduct	Pampanga, Manila-North Highway	. RC girder bridge	. A1 and A2 wall type abutment . 2-post rigid frame pier	. Expansion joint slid for about 70cm in transverse direction . Expansion joint expanded over 20cm.	B	

Table 7.4.2 Summary of Damaged Bridges Under Survey

Degree of damage	Number of bridges
A: No damage (Relating to bearing force)	11
B: Minor damage (")	8
C: Medium damage (")	8
D: Major damage (There is a possibility of bridge fall.)	6
E: Bridge fall	6 (Including a temporary bridge)
Total number	39

(Note) Twenty-five other bridges not covered by the survey were also damaged (from the results of a DPWH survey). No details are available on the degrees of damage to these bridges but none apparently fell.

Table 7.4.3 Recommendations on the Rehabilitation of Bridges, Etc. That Were Seriously Damaged or Fell (1/4)

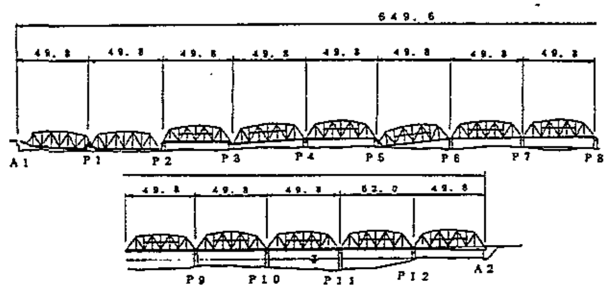
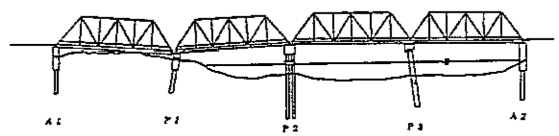
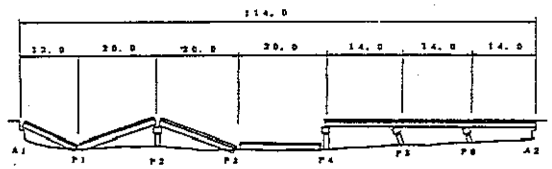
No.	Name of bridge	Temporary restoration	Permanent restoration	Sketch of damaged bridge	Remarks
P-1	Sison (Carmen) Bridge, (Pangasinan)	. A temporary wooden bridge is being constructed on the upstream side. . An emergency bridge should be constructed beside the damaged bridge.	. The piers (five) damaged by liquefaction should be reconstructed. In this case, liquefaction countermeasures must be incorporated. . It is difficult to reuse the fallen superstructures.		. When reusing the fallen superstructures, it is necessary to check for related bearing force.
P-2	Calvo Bridge, (Pangasinan)	. Temporary supports are necessary for the emergency bridge installed on the fallen spans. . The abovementioned emergency bridge alone is inadequate to handle traffic. Therefore a temporary bridge should be constructed beside the fallen bridge.	. The piers damaged by liquefaction should be reconstructed. . Pier liquefaction countermeasures are necessary. . The fallen superstructures can be reused.		. Same as above
P-3	Magsaysay Bridge, (Pangasinan)	. An emergency bridge should be constructed.	. A new bridge should be constructed. If this is done, liquefaction countermeasures are necessary.		

Table 7.4.3 Recommendations on the Rehabilitation of Bridges, Etc. That Were Seriously Damaged or Fell (2/4)

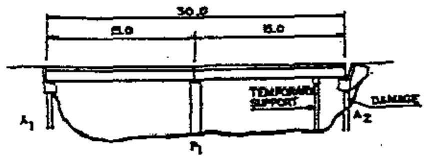
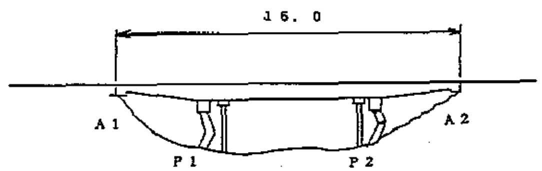
No.	Name of bridge	Temporary restoration	Permanent restoration	Sketch of damaged bridge	Remarks
P-5	Embarcadero Bridge, (Pangasinan)	. Bridge fall countermeasures and traffic regulation are urgently required.	. The repair of damaged parts, especially abutments, is necessary.		
L-2	Cupang Bridge, (La Union)	. A temporary support (one) is in place as an emergency message.	. The destroyed abutment must be reconstructed. If this is done, avoid using a pile bent type foundation.		
L-3	Tabora Bridge, (La Union)	. Two temporary supports (two) are in place as an emergency measure.	. The destroyed piers must be reconstructed. If this is done, avoid using a pile bent type foundation.		
L-4	Aringay Bridge, (La Union)	. Bridge fall countermeasures and traffic regulations are urgently required.	. The damaged parts should be repaired.		. It is necessary to check for related bearing force.

Table 7.4.3 Recommendations on the Rehabilitation of Bridges, Etc. That Were Seriously Damaged or Fell (3/4)

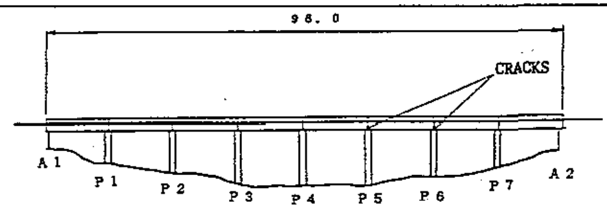
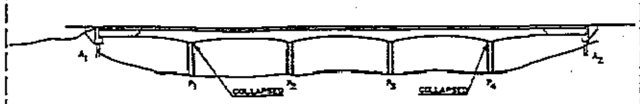
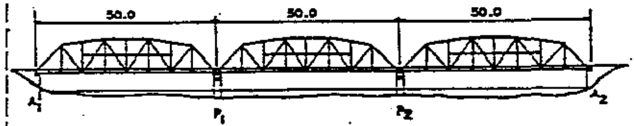
No.	Name of bridge	Temporary restoration	Permanent restoration	Sketch of damaged bridge	Remarks
L-5	Caba Bridge, (La Union)	. Bridge fall countermeasures are urgently necessary.	. Damaged parts should be repaired.		. It is necessary to check related bearing forces.
L-11	Rabon Bridge, (La Union)	. Traffic regulation is necessary.	. The bearing force of the substructures should be increased.		. It is necessary to check related bearing forces.
N-1	Manicla Bridge, (Nueva Ecija)	. An emergency bridge is in place.	. The abutments must be reconstructed.		
N-2	Sicsican Bridge, (Neuva Ecija)	. Bridge fall countermeasures are urgently necessary.	. Permanent bridge fall countermeasures are necessary.		

Table 7.4.3 Recommendations on the Rehabilitation of Bridges, Etc. That Were Seriously Damaged or Fell (4/4)

No.	Name of bridge	Temporary restoration	Permanent restoration	Sketch of damaged bridge	Remarks
N-6	Puncan II Bridge, (Nueva Ecija)	. It is urgently necessary to remove driftwood and sediments.			

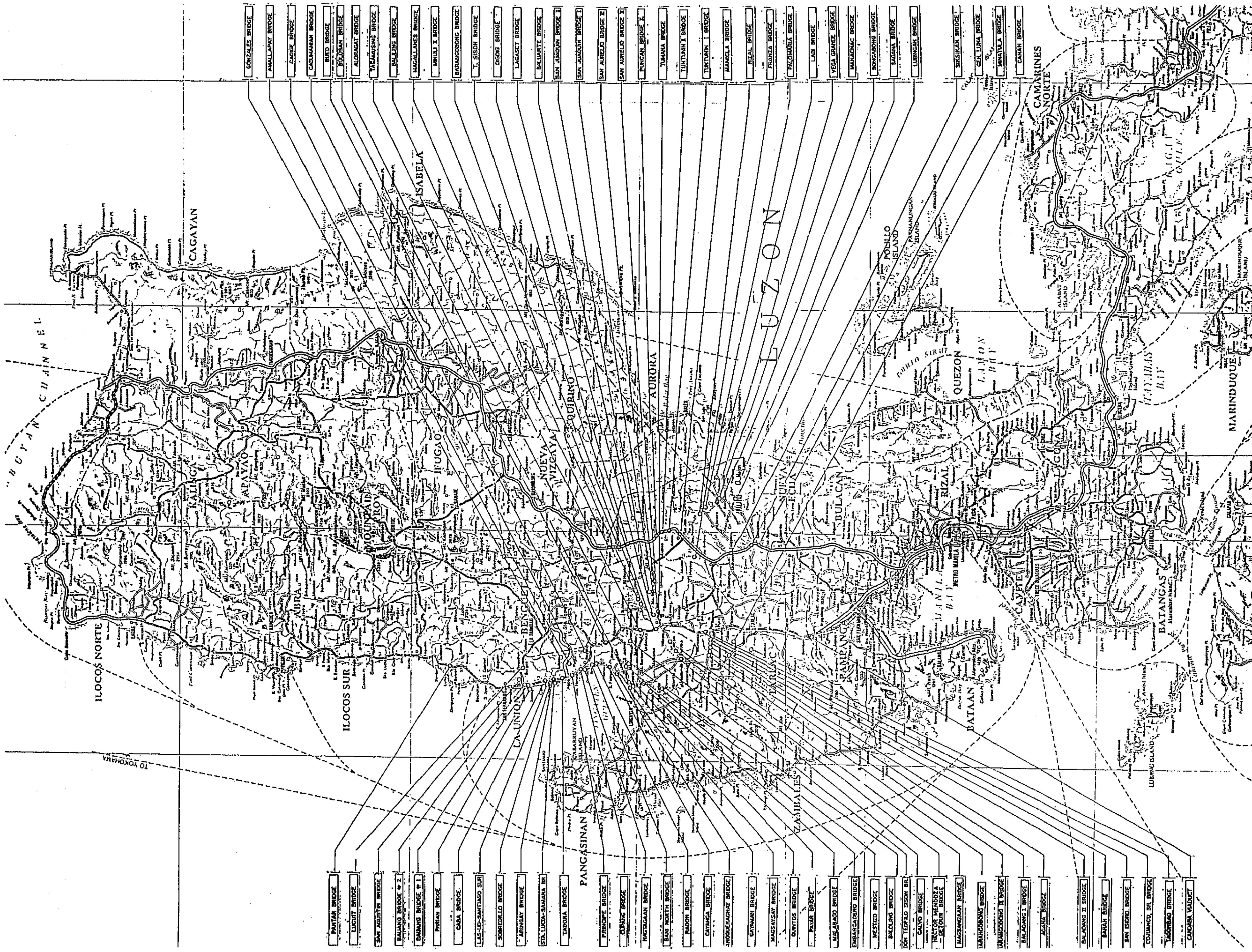


Figure 7.4.1 Location of damaged bridges

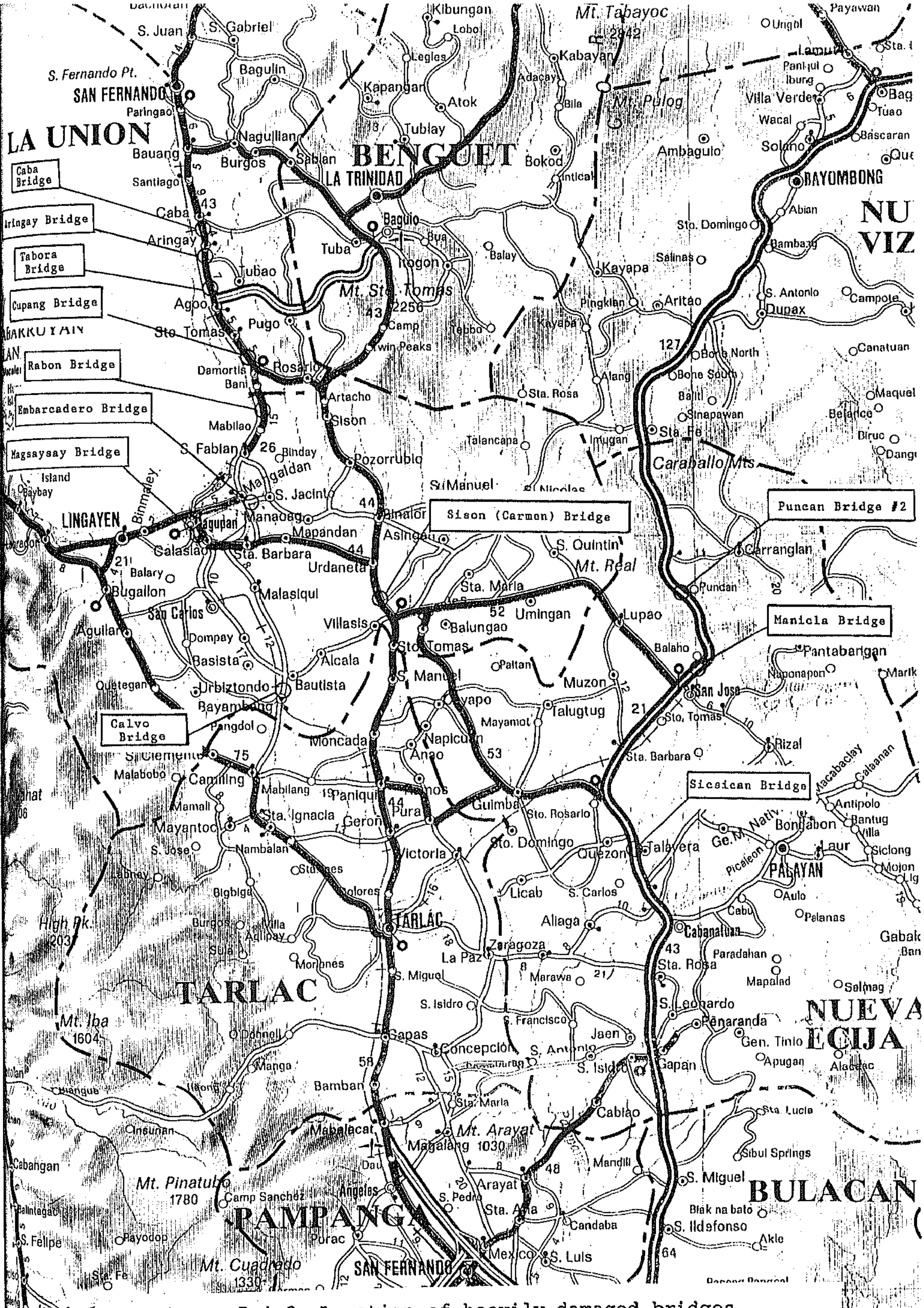
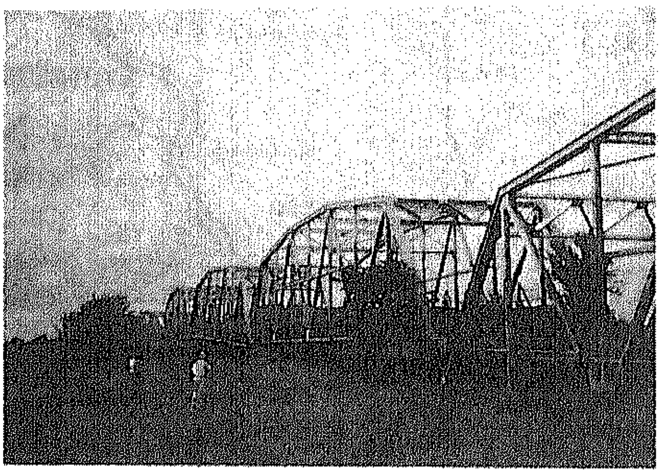
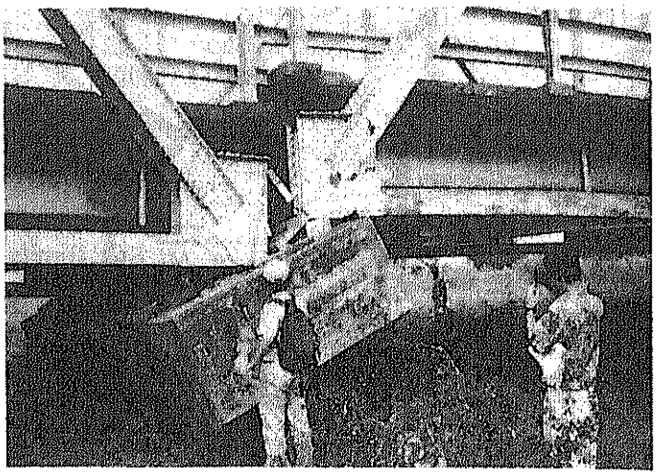


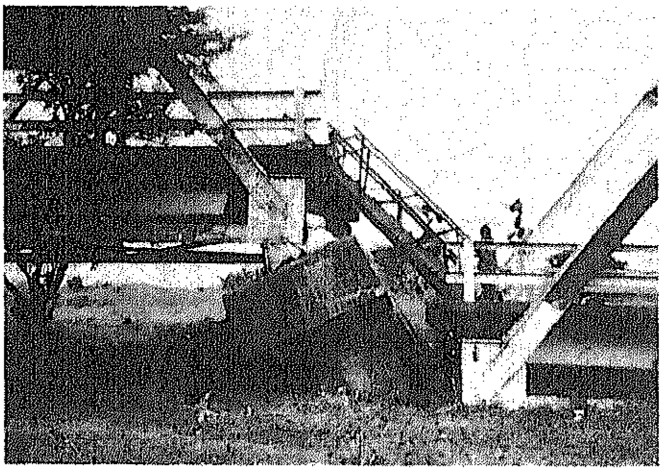
Figure 7.4.2 Location of heavily damaged bridges



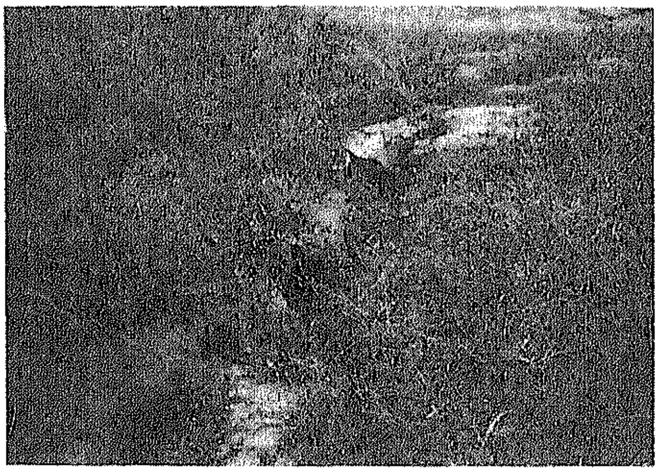
(1-a) Six spans fell.



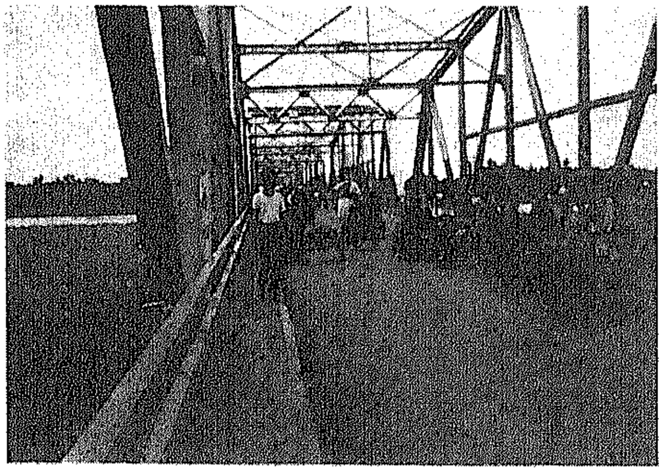
(1-b) Pier tilted and settled by liquefaction



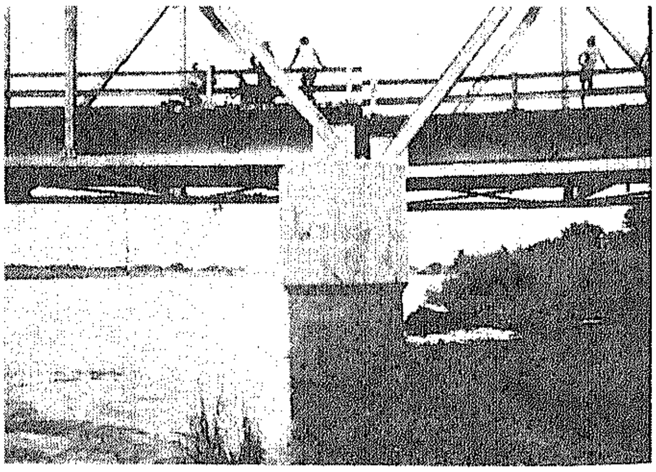
(1-c) Pier tilted and settled by liquefaction



(1-d) Hole caused by sand jetting



(1-e) Taxis assembled to pick up pedestrians caught by traffic disruption



(1-f) Pier (P11) newly constructed due to scour damage - Span on right hand fell from shoe.

Photo 7.4.1 Fallen Carmen Bridge (P-1) (1/2)

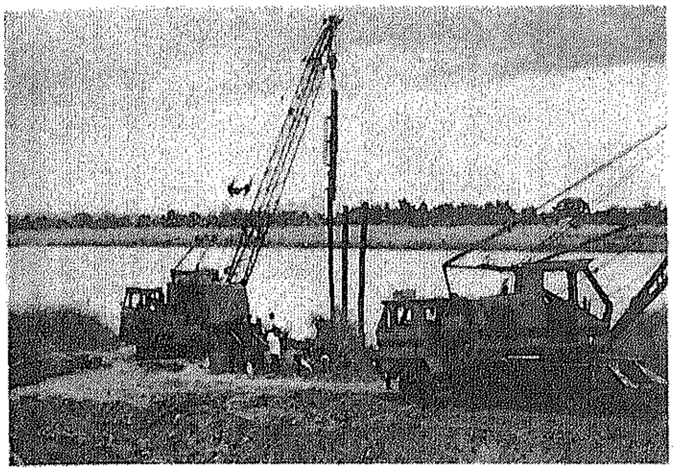
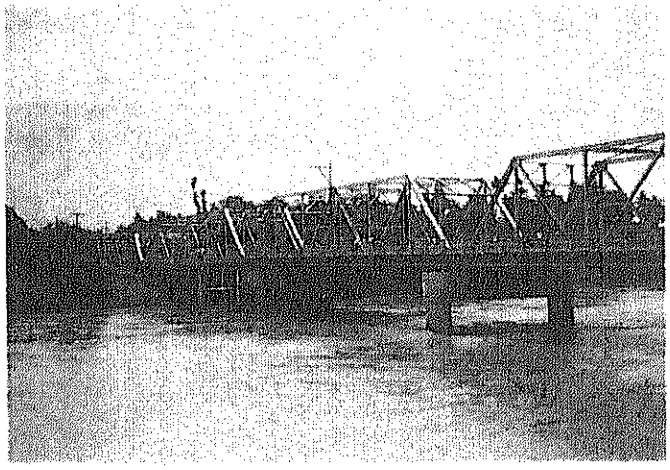
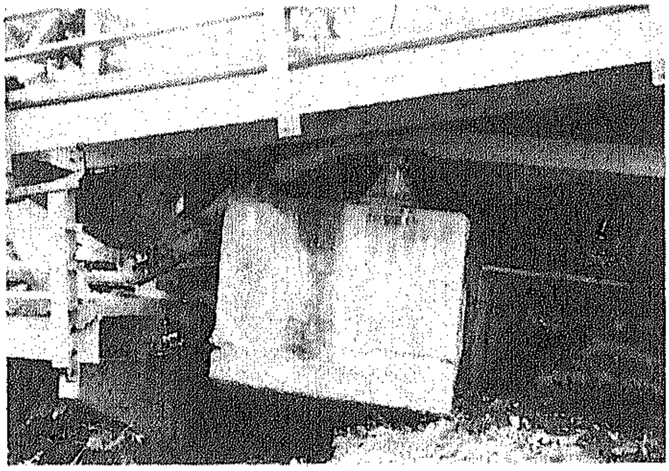


Photo 7.4.1 (2/2)

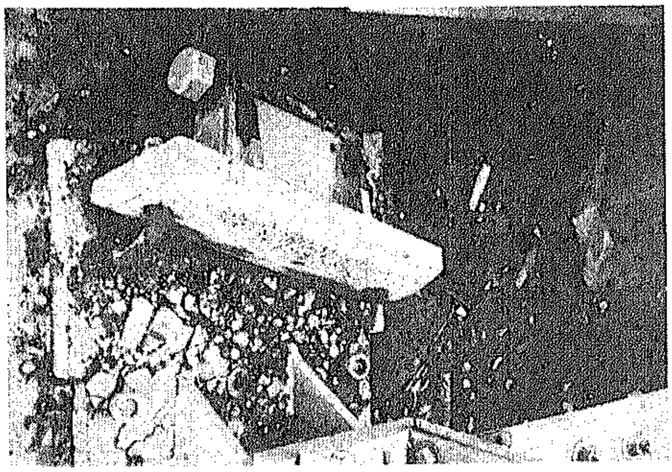
(1-g) Temporary bridge being constructed (about 200m on upstream side)



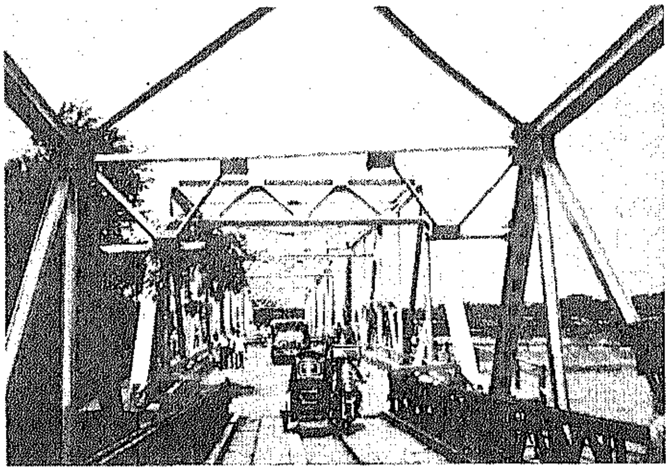
(2-a) Two spans fell. (Pier on this side was newly constructed but leans slightly.)



(2-b) Pier tilted and moved by liquefaction

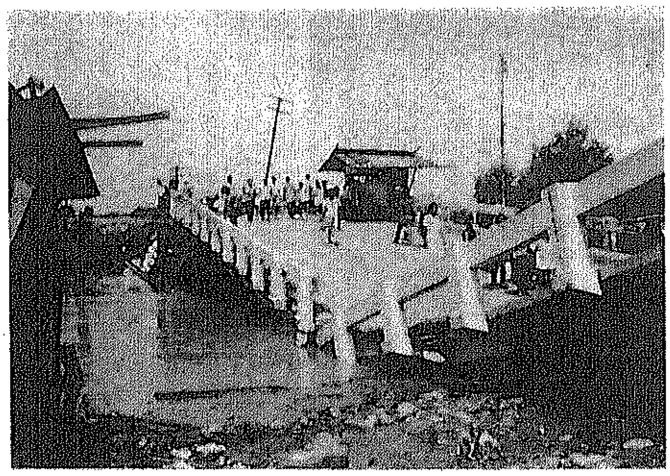


(2-c) Destroyed movable bearing

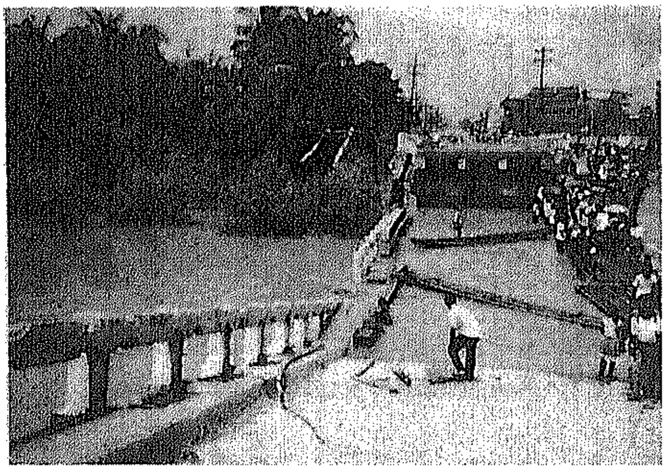


(2-d) Temporary bridge constructed on fallen spans

Photo 7.4.2 Fallen Calvo Bridge (P-2)



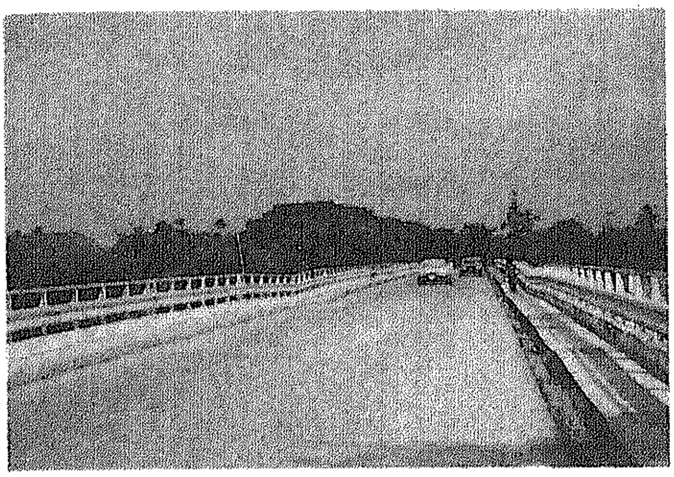
(3-a) Four spans fell



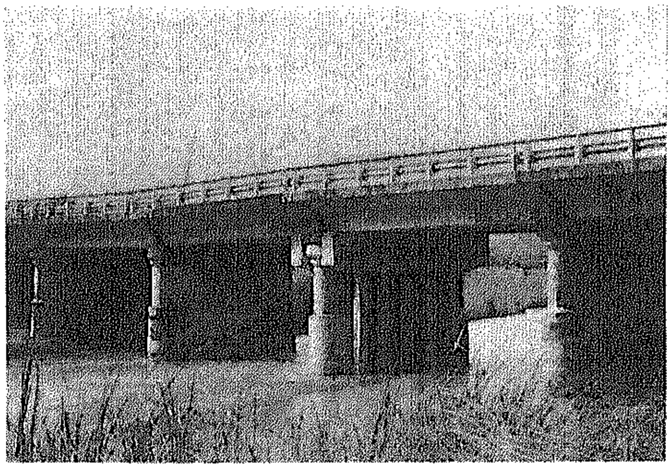
(3-b) Emergency bridge formed by linking boats

(3-c) Pier tilted by liquefaction

Photo 7.4.3 Fallen Magsaysay Bridge (P-3)



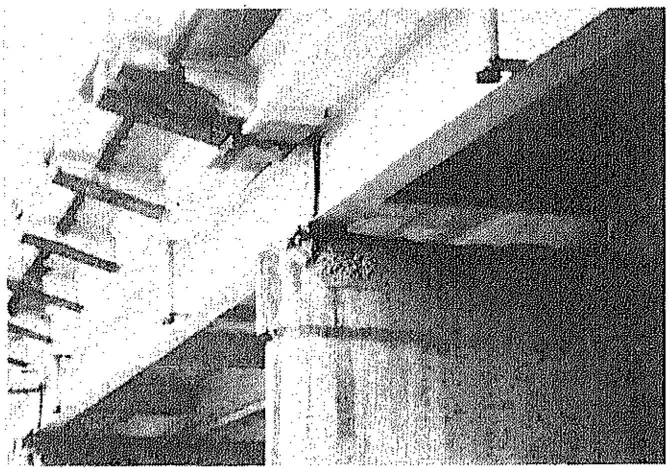
(4-a) Road surface settled by about 30cm



(4-b) Settled pier (Pier on right side was formerly reinforced after scour damage.)

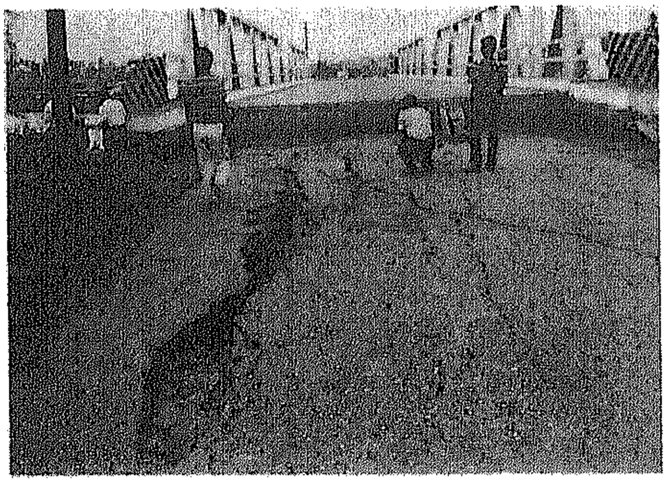
Photo 7.4.4 Aloragat Bridge (P-4)

(5-a) Abutment pile damaged by rupture in bending

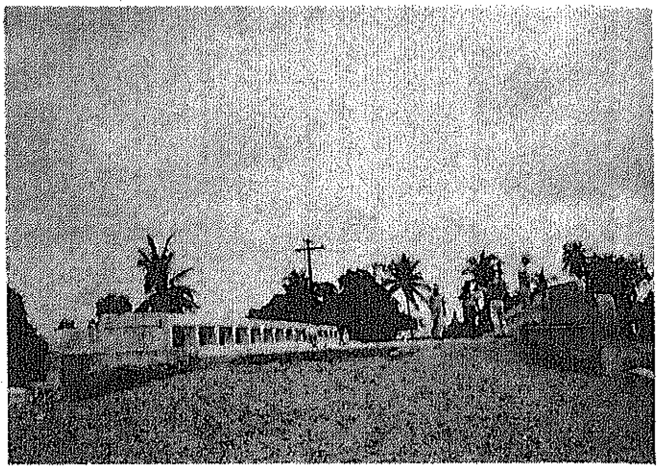


(5-b) Bearing edge damaged by shear fracture

Photo 7.4.5 Embarcadero Bridge in Danger of Fall (P-5)



(6-a) Settled approach

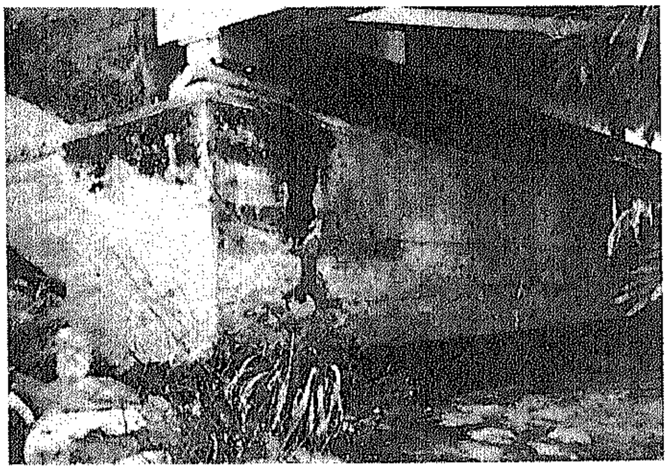


(7-a) Settled approach

(6-b) Banking in approach settled and moved sideways

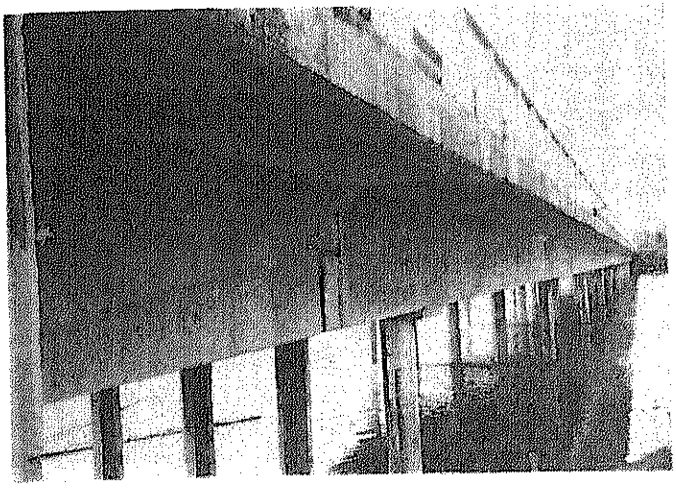
(7-b) Settled abutment banking

Photo 7.4.7 Bolosan Bridge (P-11)

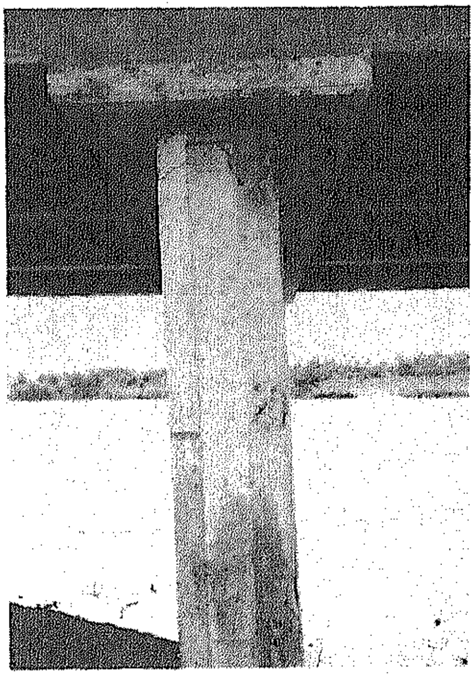


(6-c) Cracks in abutment footing and pile

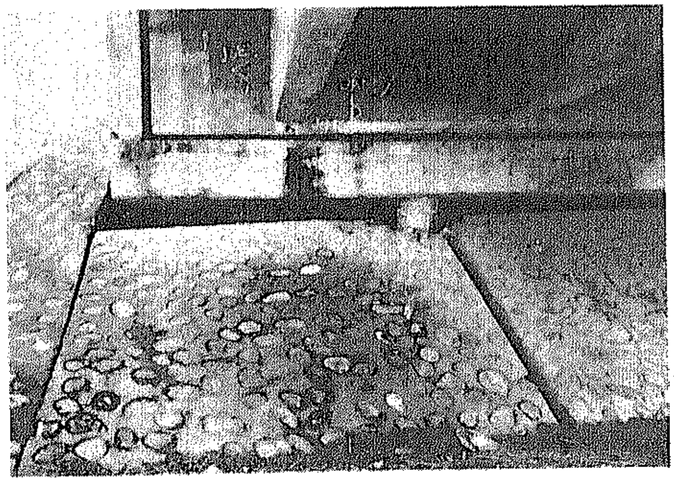
Photo 7.4.6 Manggueragday Bridge (P-6)



(8-a) Pile bent pier

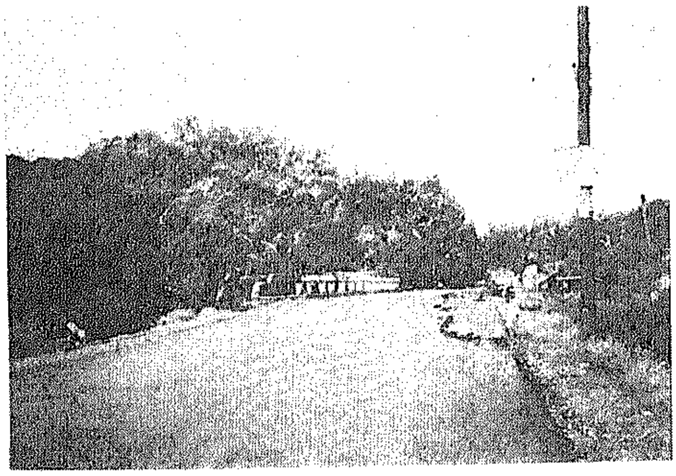


(8-c) Pile tilted and reinforcing bars at pile top became exposed



(8-b) Settled abutment banking (settled approach)

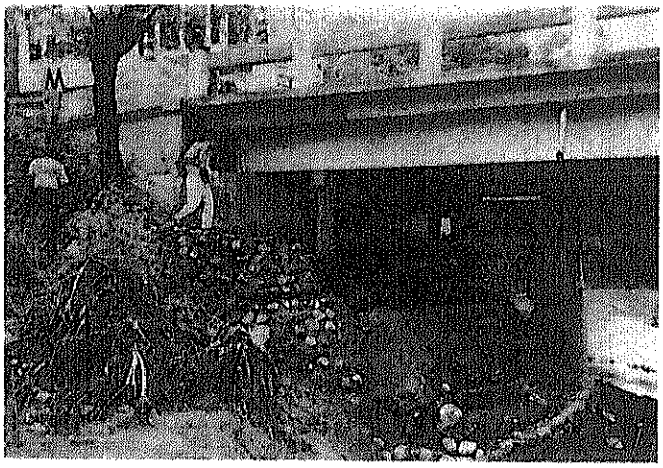
Photo 7.4.8 Cayanga Bridge (P-12)



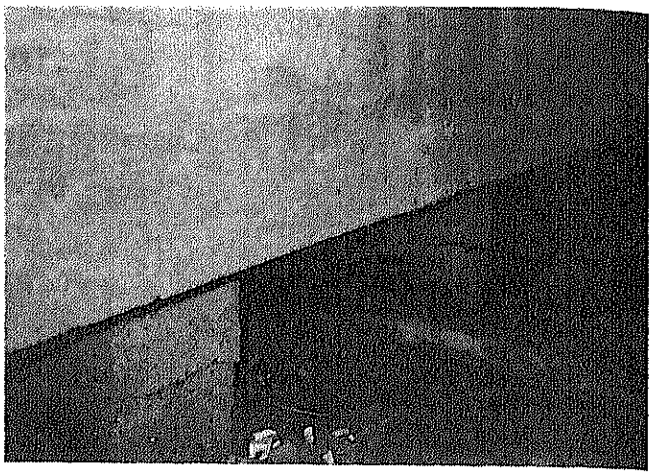
(9-a) Collapsed abutment baking

(9-b) Collapsed abutment banking

Photo 7.4.9 Luguit Bridge (L-1)

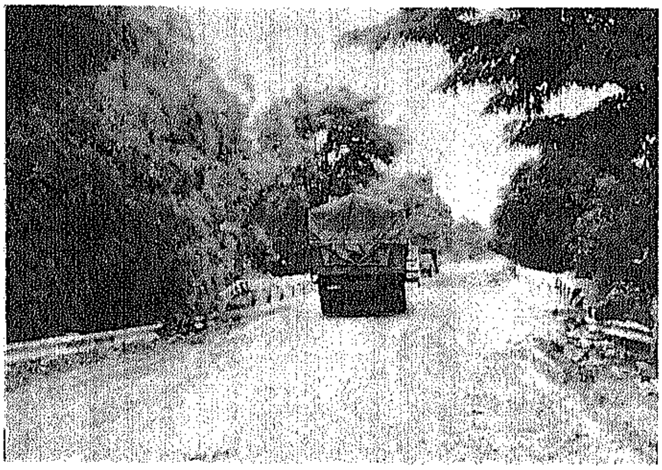


(10-a) Pier tilted to front and temporary support was installed. (Bridge behind is an old bridge.)

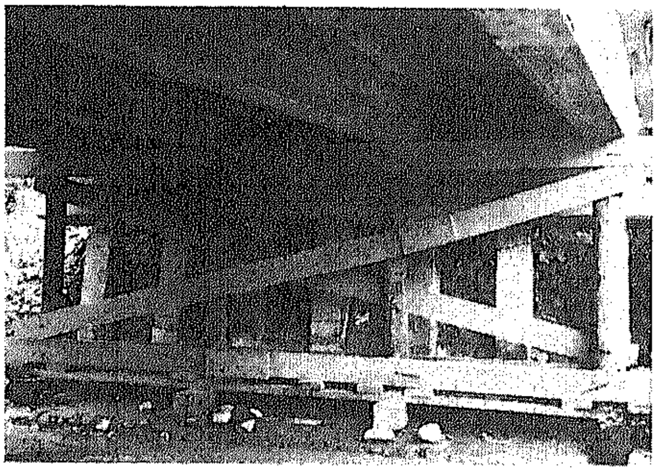


(10-b) Destroyed pile

Photo 7.4.10 Cupang Bridge (L-2)

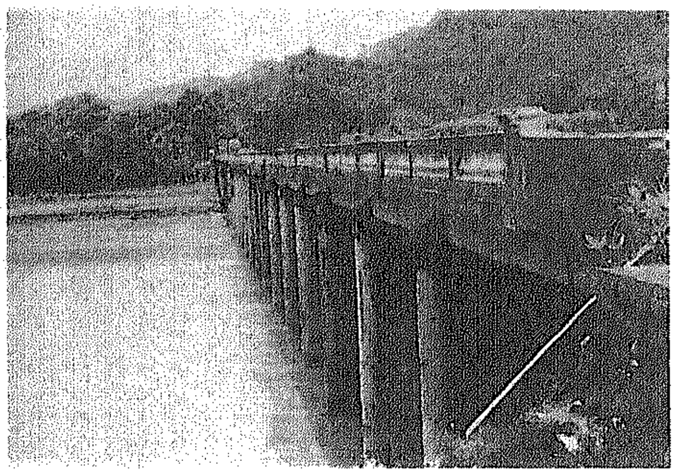


(11-a) Settled approach

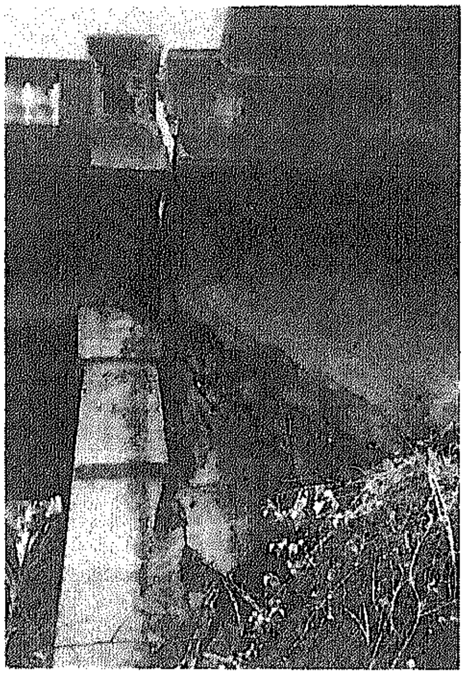


(11-b) Abutment pile was destroyed and temporary support was installed.

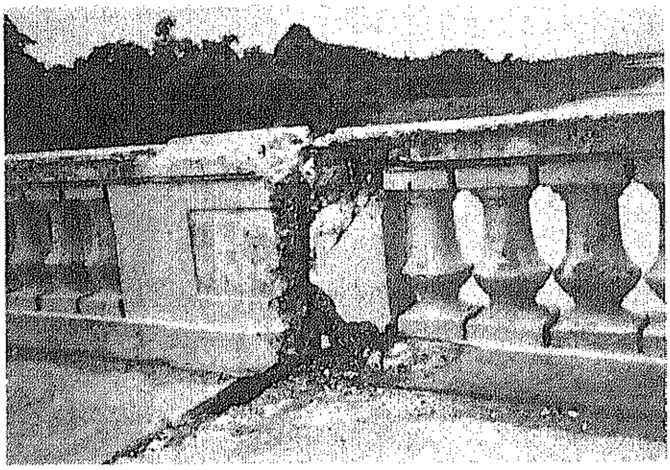
Photo 7.4.11 Tabora Bridge (L-3)



(12-a) It is an old RC bridge

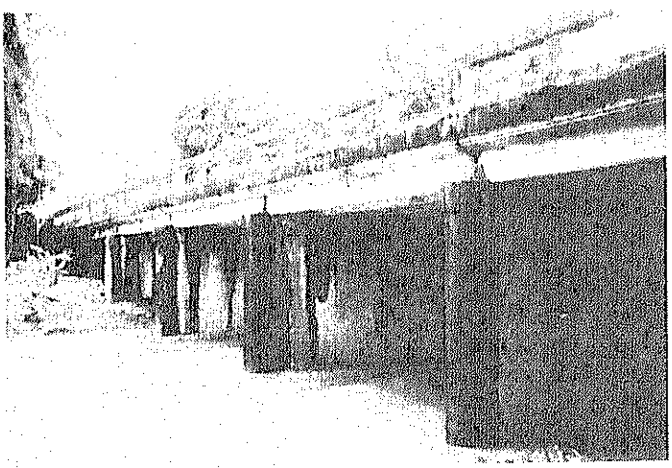


(12-c) Destroyed abutment body

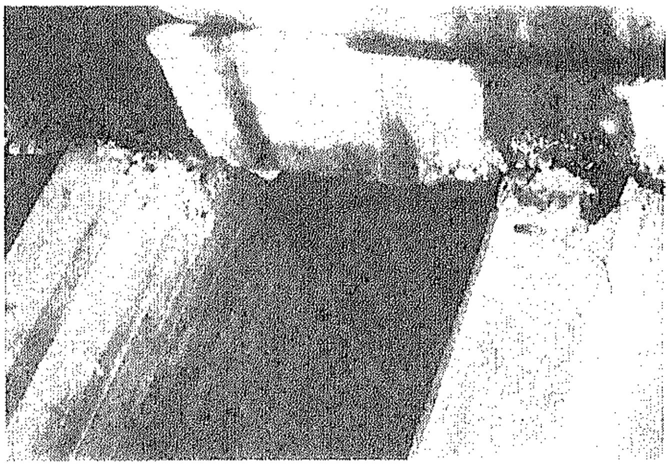


(12-b) Handrail was damaged by violent collision between girders

Photo 7.4.12 Aringay Bridge in Critical Condition (L-4)

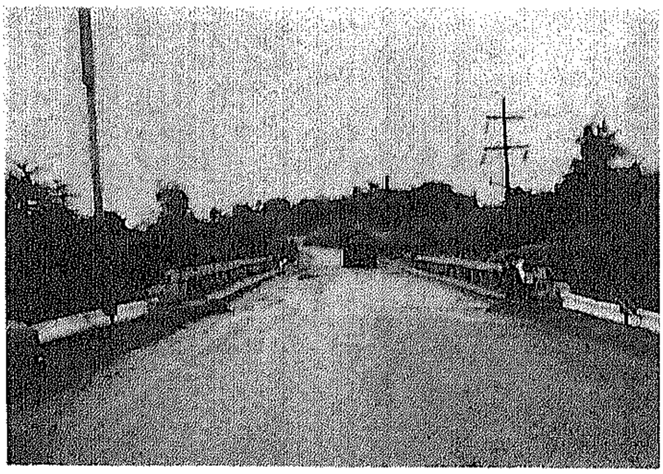


(13-a) Break-off of concrete in bearing edge



(13-b) Heavily damaged girder and substructure

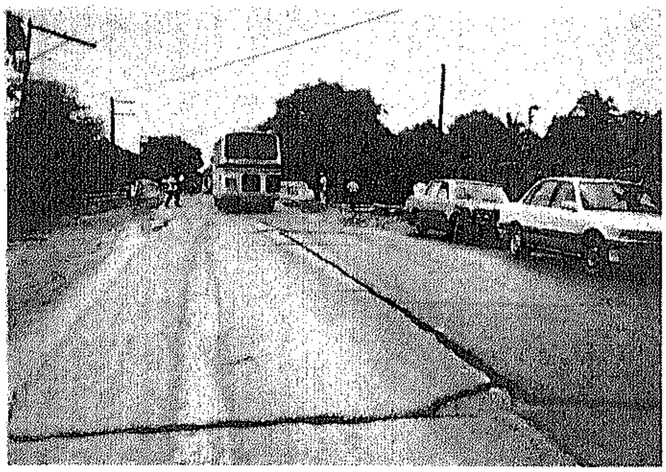
Photo 7.4.13 Caba Bridge in Danger of Fall (L-5)



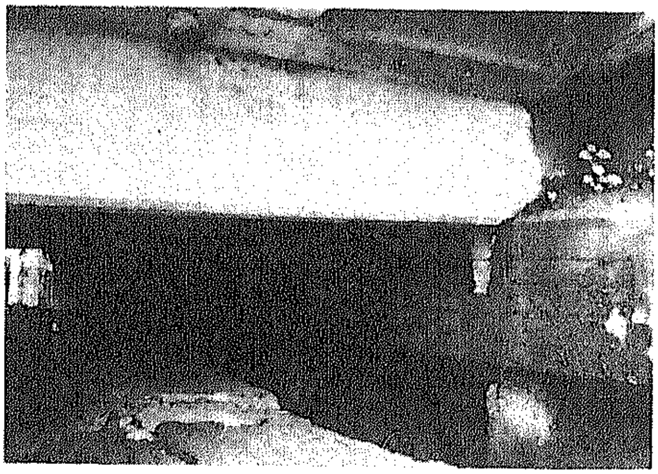
(14-a) Settled approach

(14-b) Collapsed abutment back-fill
(It underwent emergency repair.)

Photo 7.4.14 Bani North Bridge (L-9)



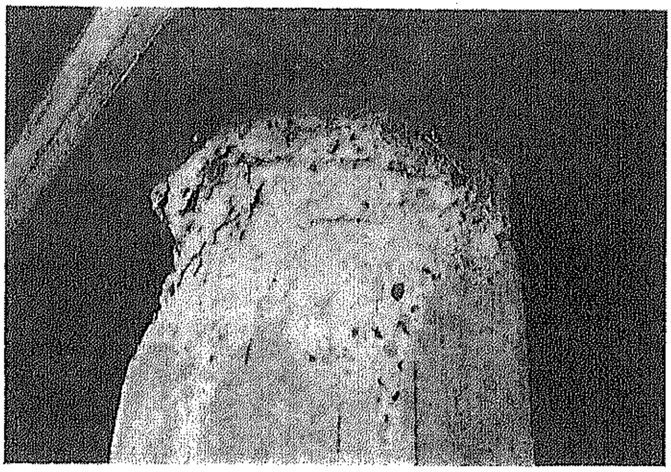
(15-a) Settled approach



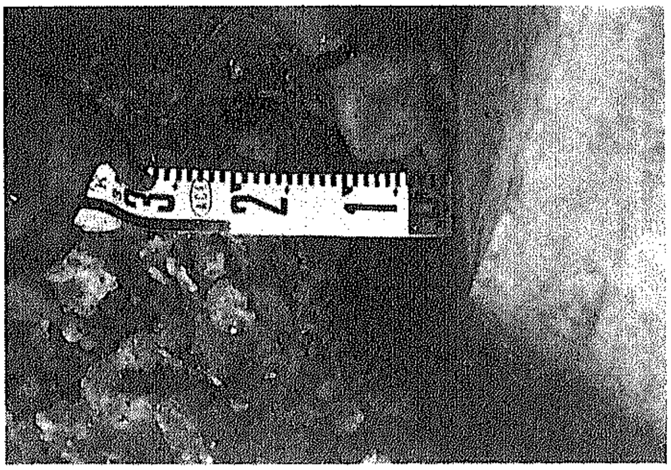
(15-b) Damaged pile

Photo 7.4.15 Principe Bridge (L-10)

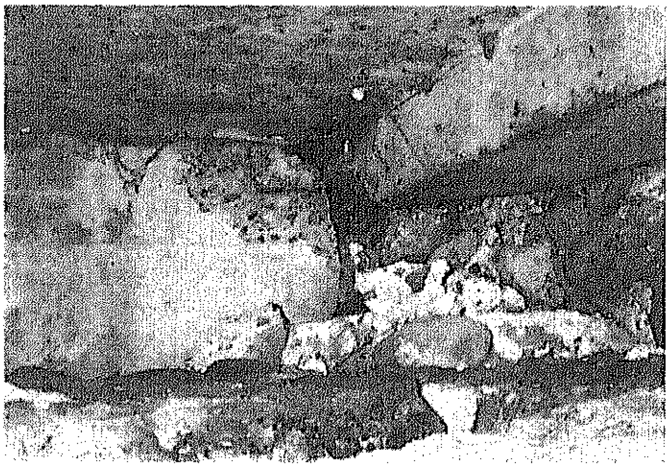
(16-a) Pile bent pier



(16-b) All pile tops were damaged

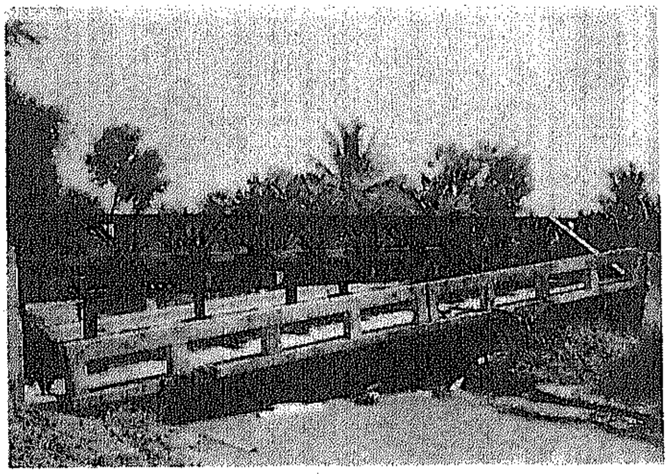


(16-c) Pile shock violently in horizontal direction

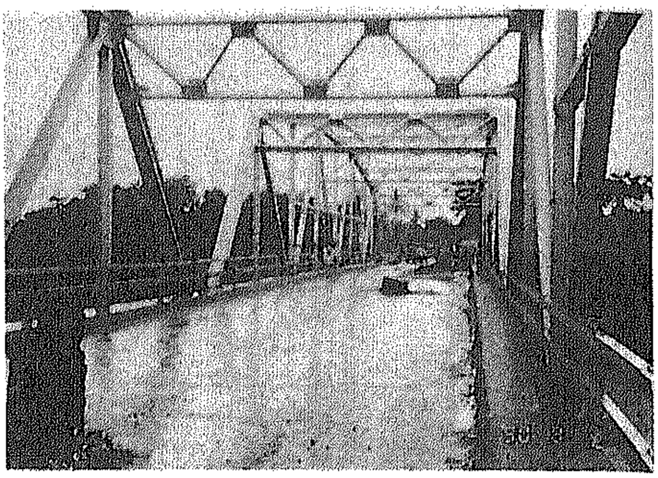


(16-d) Girder hit abutment

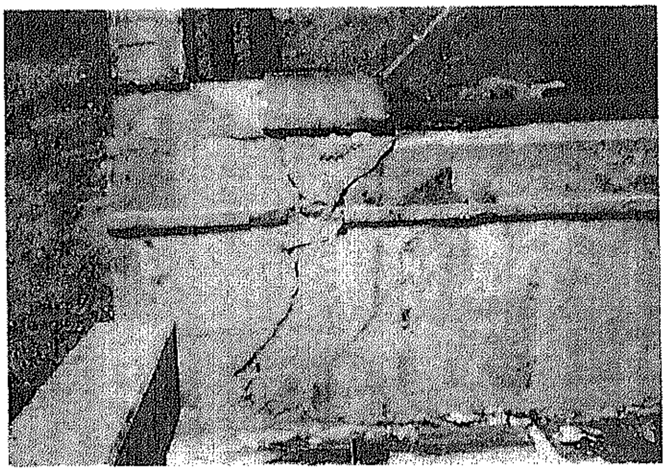
Photo 7.4.16 Rabon Bridge (L-11)



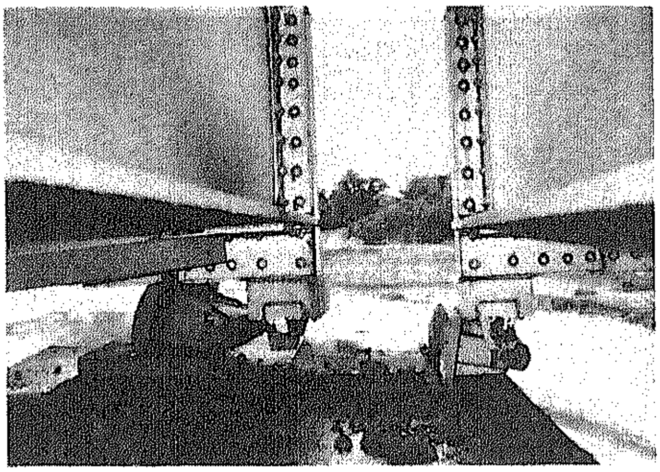
(17-a) Temporary bridge was constructed on fallen spans



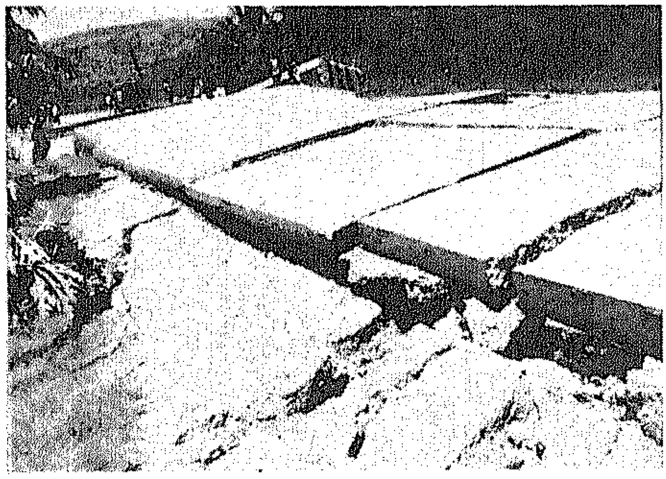
(18-a) Slabs being repaired



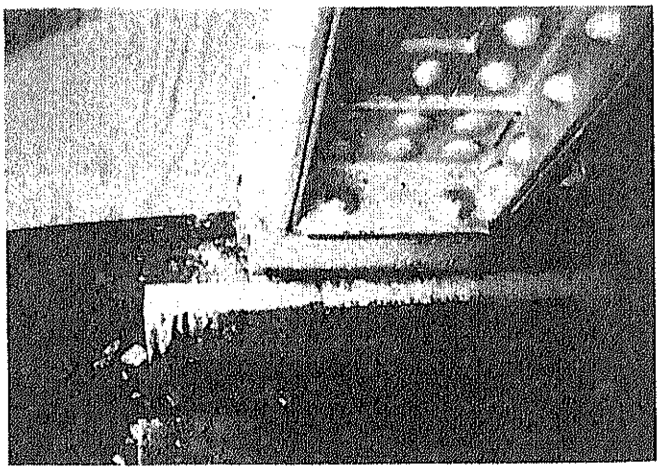
(17-b) Destroyed abutment body



(18-b) Movable shoe slipped out and is threatening to fall



(17-c) Destroyed approach pavement



(18-c) Another movable shoe in the same condition

Photo 7.4.17 Fallen Manicla Bridge (N-1)

Photo 7.4.18 Sicsican Bridge in Danger of Fall (N-2)

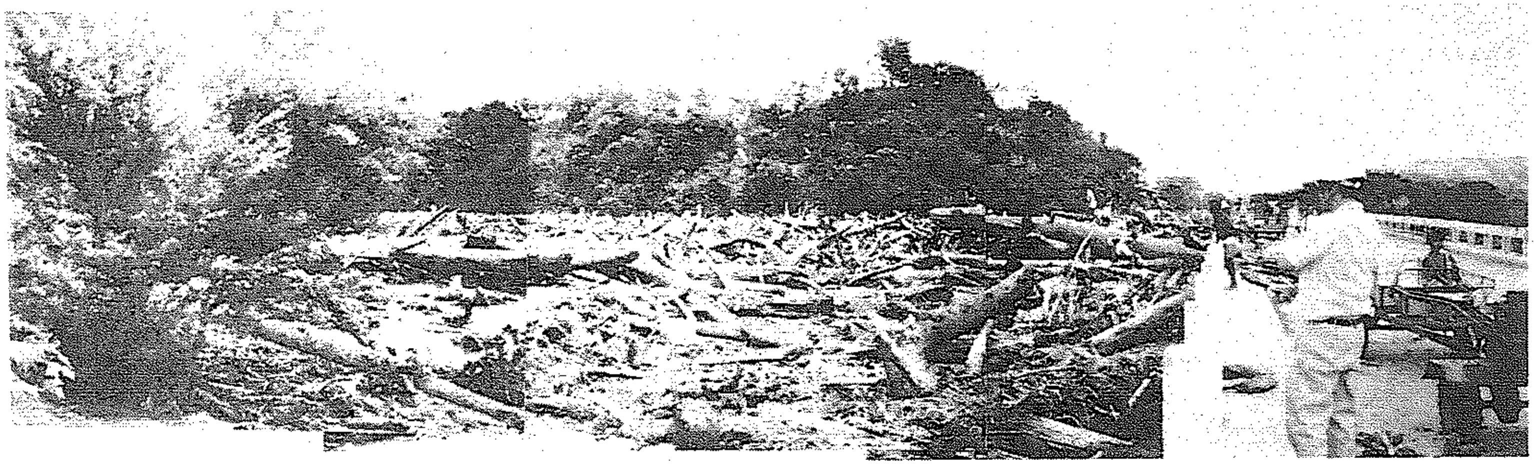
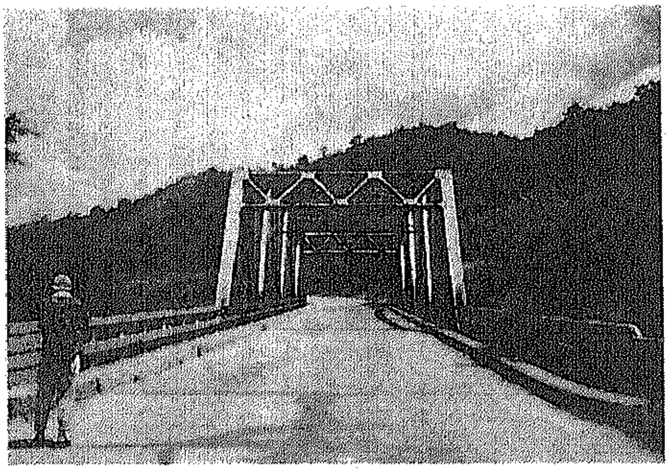
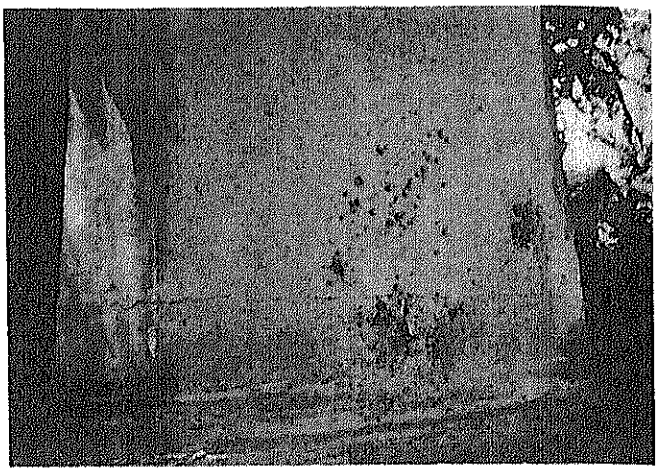


Photo 7.4.19 Puncan Bridge #2 with Large Quantities of Driftwood and Sediments (N-6)

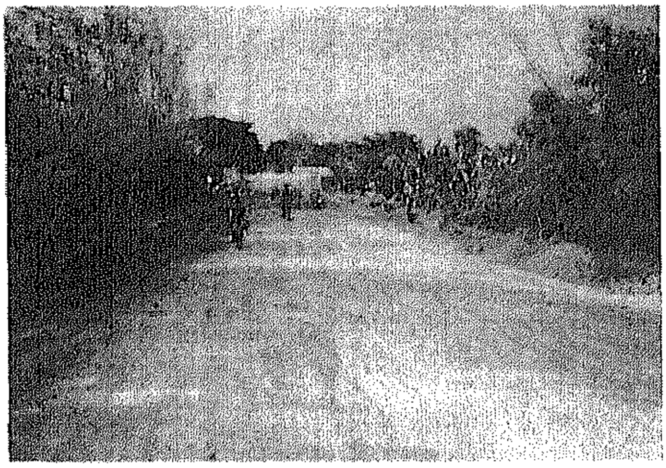


(20-a) Scarcely any damage to superstructure

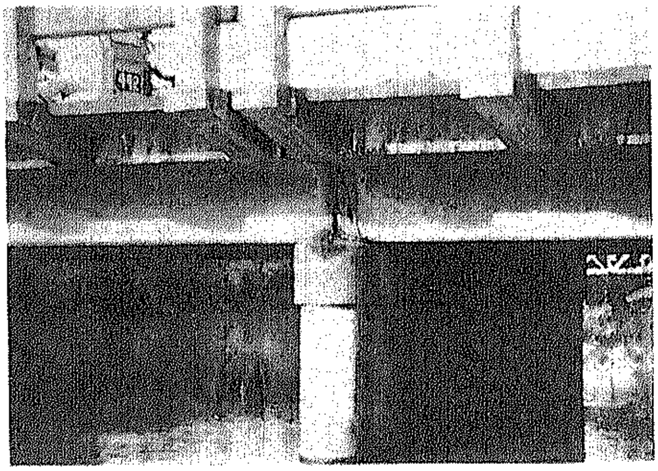


(20-b) Large cracks in pier

Photo 7.4.20 Digdig Bridge (N-9)



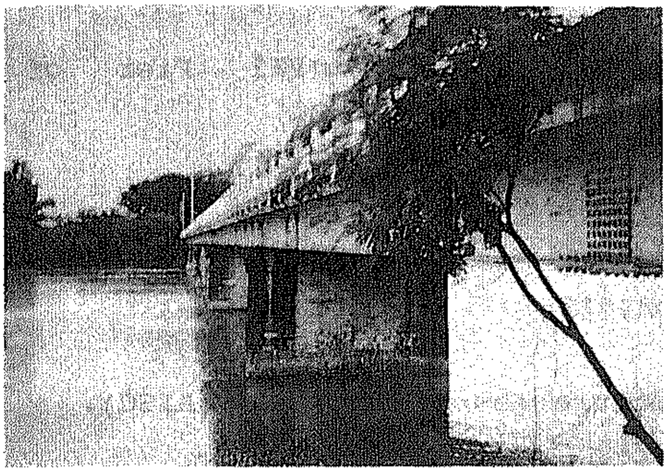
(21-a) Approach settled by about 2m



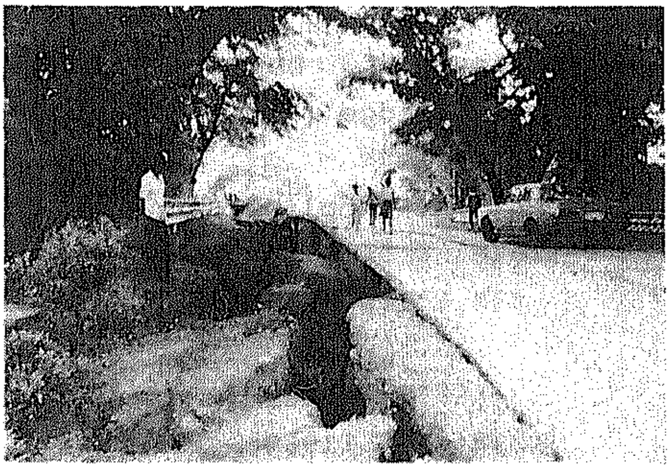
(21-b) Shear cracks at girder end

(21-c) Nearby buildings settled

Photo 7.4.21 San Isidro Bridge (T-1)

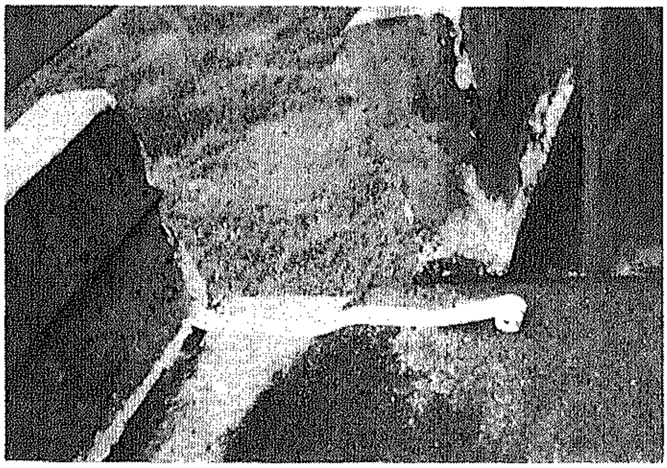


(22-a) Damage to girder ends due to collision between girders. Apparently no damage to piers.

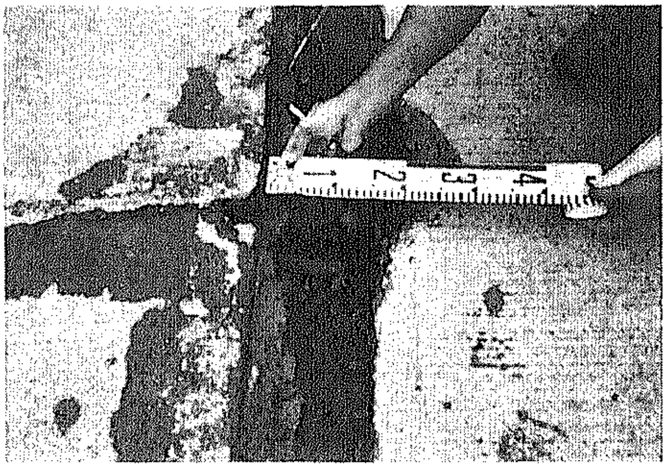


(22-b) Collapse of approach banking (both sides)

Photo 7.4.22 Cojuangco Bridge (T-2)



(23-a) Expansion joint slipped out of place by 90cm in direction of bridge axis.



(23-b) Expansion joint opened by 20cm

Photo 7.4.23 Candaba Viaduct (PAN-1)

Reference Material 7.4.1

Outline of Design Concerning Repair of P11 Pier of Carmen Bridge (By DPWH Design Documents)

A. Applied Standards

1. AASHTO, 12th edition, 1977

2. American Steel Structure Association INC (AISC), 1980

3. Government Standard Specifications Concerning Speedways and Bridges, revised edition, 1972

4. American Welding Society (AWS)

B. Design Loads

1. Dead load

a)	Concrete	23.6 kN/m^3
b)	Structural steel	77.0 kN/m^3
c)	After dead load	1.05 kPa

2. Live load
   M18 (H20-44) (using American automobile load)

3. Earthquake force
   10% (dead load+live load/2)

C. Materials and Design Unit Stress

1. Minimum critical compressive strength of concrete (28 days)
   - a) Footing and body (Class A) fc′ = 20.70 MPa
   - b) Slab and sideway (Class D) fc′ = 27.58 MPa
   - c) PC pile fc′ = 34.5 MPa
     Pre-stress time fc′ = 27.58 MPa

2. Structural steel (ASTM A-36 or AASHTO-077 M183)
   fy = 248.2 MPa, ft = 137.90 MPa

3. High-strength bolt (ASTM A-325)

4. Bar steel for reinforced concrete (ASTM A-61E grade 40)
   fy = 275.8 MPa, fs = 137.90 MPa

5. PC stranded wire (ASTM A-416, ϕ12.7 mm, grade 270)
   fy′ = 1862 MPa

6. Shop welding (electrode E 70XX) fu = 482.6 MPa

D. Foundation

1. Prestressed concrete pile
   400mm x 400mm, pile length 16m

2. Bearing power
   880 kN (90 tons) (Confirmed by test pile)

3. Work method
   Driving (with steel cap attached to pile top)

E. Joining Material

Joining is done by high-strength bolts (ASTM A-325). $\phi 7/8$ inch

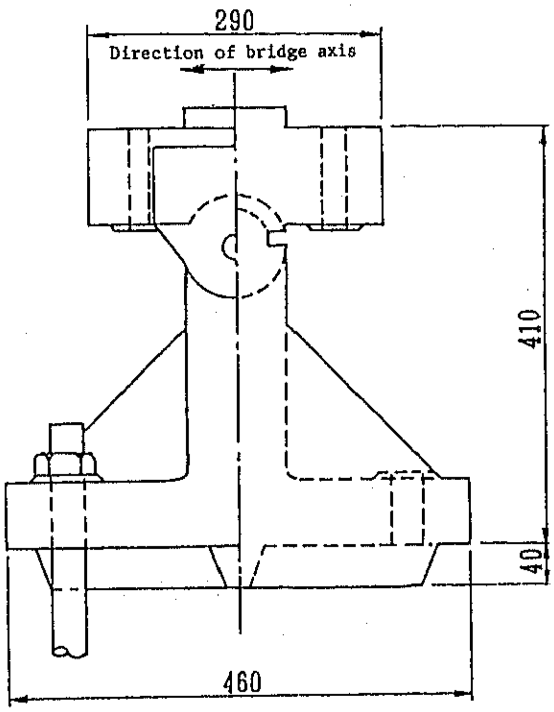
F. Painting

a) Shop painting : Red lead and tinted red lead

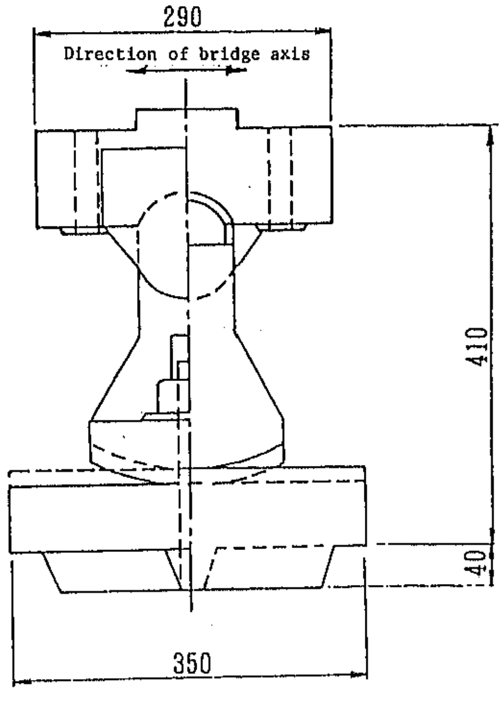
b) Field painting: Aluminum tint

However, steel-to-steel or steel-to-concrete joints are not painted.

G. Bearing Structure (Fig. Ref. 7.4.1)



Fixed shoe (4 anchor bolts)



Movable shoe (2 anchor bolts)

Fig. Ref. 7.4.1 Bearing Structure

Reference Material 7.4.2

Table Ref. 7.4.1 Summary of General Estimates of Construction Costs Necessary for Rehabilitation of Heavily Damaged Bridges (Draft)

Unit: (MP) million pesos

Restoration cost / Name of Bridge	Temporary restorations	Permanent restoration	Temporary restoration + permanent restoration	Remarks
P-1 Sison (Carmen) Bridge	7.3	57.4	64.7	
P-2 Calvo Bridge	2.6	7.1	9.7	
P-3 Magsaysay Bridge	1.4	23.8	25.2	
P-5 Embarcadero Bridge	0.9	(25.3) 6.7	(26.2) 7.6	( ) is cost of constructing entire bridge.
L-2 Cupang Bridge		1.7	1.7	
L-3 Tabora Bridge		4.9	4.9	
L-4 Aingay Bridge		(50.6) 7.7	(50.6) 7.7	( ) is cost of constructing entire bridge
L-5 Caba Bridge	0.6	(14.2) 2.0	(14.8) 2.6	( ) is cost of constructing entire bridge
L-11 Rabon Bridge		0.7	0.7	
N-1 Manicla Bridge		2.2	2.2	
N-2 Sicsican Bridge	(2.8) 0.2	2.8	(5.6) 3.0	( ) is cost of constructing temporary bridge.
Total	(15.6) 13.0	(190.7) 117.0	(206.3) 130.0	

Note 1) Conversion rate: 1 peso (P) = 6 yen (Aug. '90)

Note 2) Numerals in this table were worked out on the assumption that there would be considerable errors, such as exclusion of costs of temporary works for coffering, etc.

Table-Ref. 7.4.2 Details of Estimated Construction Costs

MP: million pesos

	Temporary Restoration	Permanent Restoration	Remarks
P-1 Sison (Carmen) Bridge	Temporary bridge (1=200m) 200m x 17,000 p/m = 3.4 MP Pile bent 5 x 180,000 P each = 0.9 MP Superstructure jack-up 10 shoes x 300,000 P/shoe= 3.0 MP 7.3 MP	Removing work 4.4 MP (6 spans superstructure and substructure) Superstructure 28.0 MP (8 spans, PC girder bridge) Substructure (1 abutment and 7 piers) 22.4 Temporary works 2.6 57.4 MP	. Cast in-place piles (φ2.0) will be used. . Trusses of existing bridge will be used for seven spans. . New PC girders (38.5m) will be used for eight spans. . 40 x 40 RC piles will be used for emergency bridge.
P-2 Calvo Bridge	Temporary bridge (1=150m) 150m x 17,000 P/m = 2.6 MP	Reconstruction of two piers 2 x 2,800,000 P each = 5.6 MP Superstructure jack-up and temporary support 5 shoes x 300,000 P/shoe = 1.5 MP 7.1 MP	. Cast in-place piles (φ2.0) will be used. . Piers will have footings. . Superstructure (turss) will be reused.
P-3 Magsaysay Bridge	Temporary bridge (1=80m) 80m x 17,000 p/m = 1.4 MP	Construction of a PC bridge of 4@30m=120m Superstructure 4 spans x 2,400,000 P/span = 9.6 MP Substructure: 2 abutments x 2,900,000 P each = 5.8 MP 3 piers x 2,800,000 P each = 8.4 MP = 23.8 MP	. Cast in-place piles (φ2.0) will be used. A PC bridge with 30m spans will be used for the superstructure. Both superstructure and substructure will be renewed.
P-5 Embarcadero Bridge	Temporary support 6 places x 150,000 P/place = 0.9 MP	Reinforcement of shoe seats 11 x 94,000 P each = 1.0 MP Pile for reinforcing 1,320m x 1,500 P/m = 2.0 MP Footings 7 x 188,000 P each = 1.3 MP Abutments 2 x 1,200,000 P each = 2.4 MP = 6.7 MP	. Shoe seats and footings will be reinforced for piers. . Reinforcement of shoe seats and piles and construction of new footings. . Inverse-T abutments will be constructed. . Cost of constructing new bridges: 25.3 MP

	Temporary Restoration	Permanent Restoration	Remarks
L-2 Cupang Bridge	A temporary support is already in place as an emergency measure.	Construction of abutment (A1) 1 x 1,400,000 P each - 1.4 MP Superstructure jack-up and temporary support - 0.3 MP - 1.7 MP	. Abutment will be of inverse-T type and 40 x 40 RC piles will be used. The whole thing will be renewed. Existing superstructure will be used by jack-up.
L-3 Tabore Bridge	A temporary support is already in place as an emergency measure.	Construction of piers, P1 and P2 2 x 925,000 P each - 1.9 MP Construction of abutments (A1 and A2) 2 x 1,200,000 P each - 2.4 MP Superstructure jack-up and temporary support - 0.6 MP - 4.9 MP	. Both piers and abutments will be renewed and 40 x 40 PC piles will be used. . Existing superstructures will be used by jack-up.
L-4 Aringay Bridge	A temporary support is now being constructed beside A1 abutment as an emergency measures.	Reinforcement of shoe seats 2 x 94,000 P each - 2.1 MP Piles for reinforcing 2,500m x 1,500 P/m - 3.8 MP Footing 2 x 188,000 P each - 0.4 MP Construction of abutment (A1) 1 x 1,400,000 P each - 1.4 MP - 7.7 MP	. 23 spans, bridge length 253.0 m . Reinforcement as in the remarks for P-5 . Cost of constructing new bridge: 50.6 MP
L-5 Caba Bridge	Temporary support 4 x 150,000 P/place - 0.6 MP	Reinforcing of shoe seats (4 + abutment) x 94,000 P each - 0.5 MP Piles for reinforcing 460m x 1,500 P/m - 0.7 MP Footing 4 x 188,000 P each - 0.8 MP 2.0 MP	. Reinforcement as in the remarks for P-5. . Bridge length 71.0m . Cost of construction new bridges: 14.2 MP
L-11 Rabon Bridge	Traffic regulation only	Reinforcing of pier tops (including temporary support) 2 x 200,000 P each - 0.4 MP Reinforcing of upper girder ends 2 places x 150,000 P/place - 0.3 MP - 0.7 MP	. Reinforcing of pier tops.

	Temporary Restoration	Permanent Restoration	Remarks
N-1 Manicla Bridge	An emergency bridge is already in place.	Removal of abutment (A1) and replacement 1 x 1,900,000 P each = 1.9 MP Superstructure jack-up and temporary support = 0.3 MP ——— = 2.2 MP	. Superstructure can be reused. . Abutment A1 will be removed and a new abutment using an earthquake-proof structure will be constructed at the same location.
N-2 Sicsican Bridge	Temporary support 1 place x 225,000 P/place= 0.2MP (Temporary bridge (l=150m) 150 x 17,000 P/m = 2.6 MP)	Bridge removal 1 x 400,000 = 0.4 MP Bridge construction 1 x 1,600,000 = 1.6 MP Jack-up 300,000 a set = 0.3 MP Reinforcing of truss members 500,000 a set = 0.5 MP ——— = 2.8 MP	. Substructure will be removed and renewed while superstructure is supported using temporary timbering. . Superstructure can be partially repaired. So, it will be reused after being reinforced.