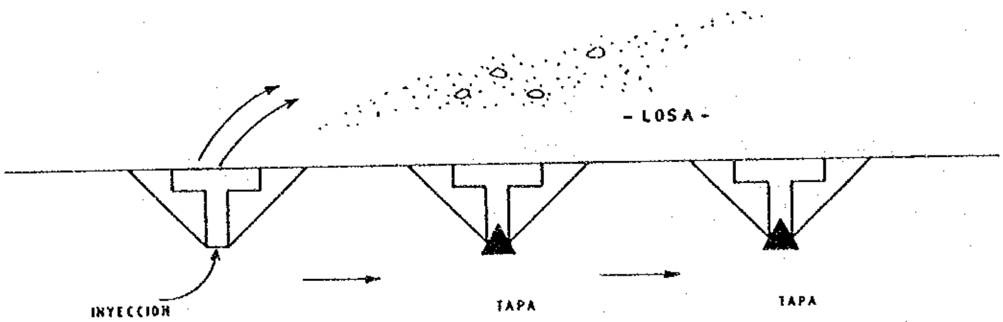


Figure 4-20 Injection of Mortar

(2) Steel Plate Attachment (Pullally Bridge)

In this method, steel plates are attached on the outside of the tensile edge of the concrete members in such a way as to ensure transmission of shear forces between the two, to integrate the steel plates with the existing member and thus add to the cross-sectional strength of the member with the steel plates acting as steel reinforcement. The steel plates normally used are 4.5 to 6 mm in thickness and epoxy resin is used as the adhesive. Bonding methods include that by compression and injection. The former method is described below.

For compression bonding, the adhesives are coated to a thickness of around 2 mm on both the faces to be attached and the steel plate is attached to the concrete face. The adhesive is made to harden while the steel plates are pressed against the concrete face with the anchor bolts inserted into the concrete. To ensure proper attachment, it is important that the face of the concrete slab is level and smooth, and it is important therefore to take care over the preparation of the concrete face. The face of the steel plate is blasted to remove any rust and is then dried to avoid any lowering of the bonding capacity. While the resin is hardening, the traffic of heavy vehicles at least should be suspended to prevent disturbance of the bonding faces. Care is also required in the application control of the resin and in curing, as the hardening speed of the resin shows a significant drop in cold weather. (Refer to Figure 4-21)

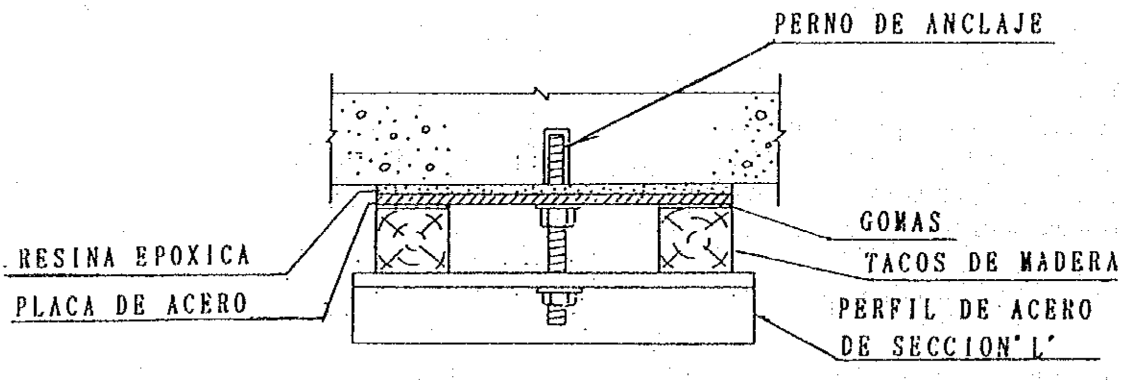


Figure 4-21 Adhesion with Compression for Steel Plate

(3) Floor System Reinforcement

New cross beams are inserted for the construction of new stringers and for their support. The stringers have to support the floor slabs directly. A gap is left between the upper flanges and the lower faces of the slabs and the outside of the gap is sealed as shown below. Epoxy resin is injected into this gap through injection holes. Restrictions should be placed on the passage of large vehicles and on the travel speed while injected resin is hardening. The cross beams and reinforcement steel are attached with high-strength bolts and welding is avoided. This is due to the fact that the dead load stress is already acting on the welds of existing members, and it is not possible to confirm the strengths of the welds on the existing members. Additionally, the welding work involves workers placed in dangerous positions. (Refer to Figure 4-22)

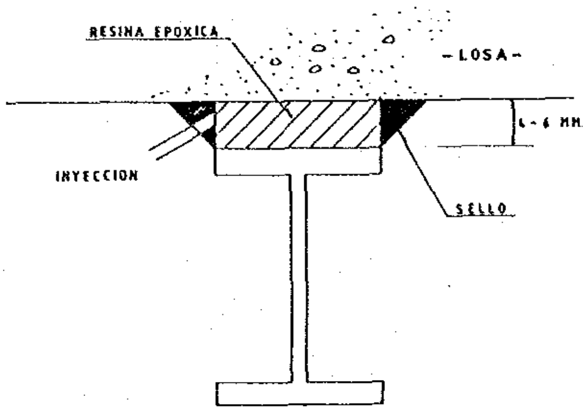


Figure 4-22 Reinforcement of Floor System

(4) Repair of Side Faces of Arches with Masonry Work (Claro Bridge)

The load acting on the side faces of the arches is indirectly dispersed through installation of new floor slabs and the side faces themselves are repaired by attaching stone panels to them for maintaining their aesthetic appearance. For the installation of the floor slabs, if they are to be cast in place, this will require tall scaffolding, while if precast concrete slabs are to be used, this will involve the use of heavy machinery such as truck cranes. The procedure for the masonry work will be as follows.

1) The scaffolding is constructed on the sides of the arches.
2) The old facing stone panels are removed and anchor bars are driven into the wall face.
3) A network of reinforcement bars is installed on the side faces and are connected to the anchor bars.
4) Stone panel walls are constructed and are connected to the reinforcement bar network and supported on the outside by timbering.
5) Mortar is injected and cured.

Because the injection thickness is small, utmost care is required in the mortar injection. The injection should desirably be implemented in several stages. A method has to be devised for connecting the stone panels with the reinforcement bar network. The drawing below shows one possibility. (Refer to Figure 4-23)

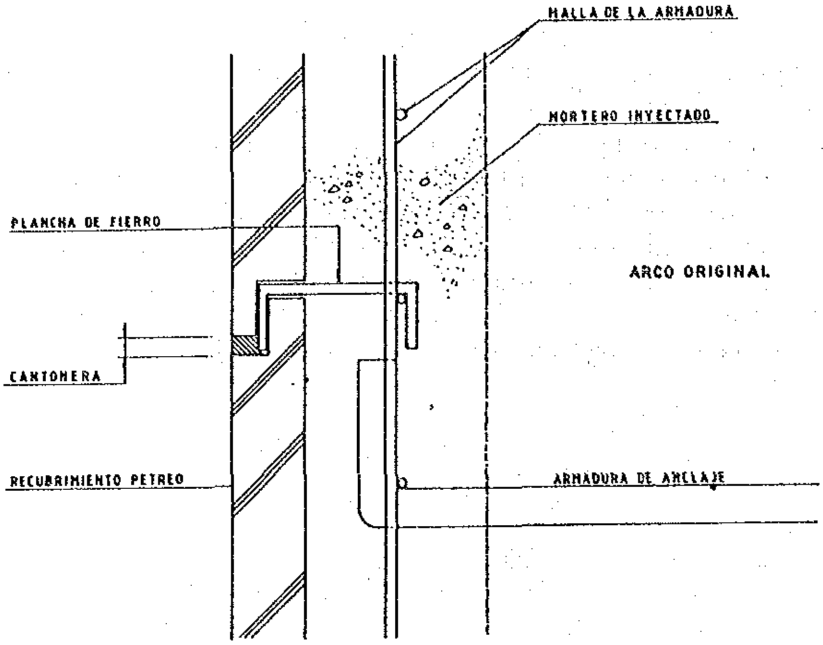


Figure 4-23 Repair by Masonry for Sidewall

(5) Repair of Underside of Arches with Reinforced Concrete Arches (Claro Bridge)

This work is aimed at the repair of the underside of the existing arches. The new reinforced concrete arches are not intended to directly support the dead and live loads of the arches themselves. The procedure will be as follows. (Refer to Figure 4-24)

1) The scaffolding is constructed.
2) Anchor bars are driven into the lower faces of the original arches.
3) A network of reinforcement bars is attached to the anchor bars.
4) Timbering is constructed and concrete forms are installed.
5) Fresh concrete is injected through pumps.
6) Steps 4) and 5) are repeated several times and the crown concrete is placed from the side in the final stage.
7) The forms and the timbering are removed after curing of concrete.

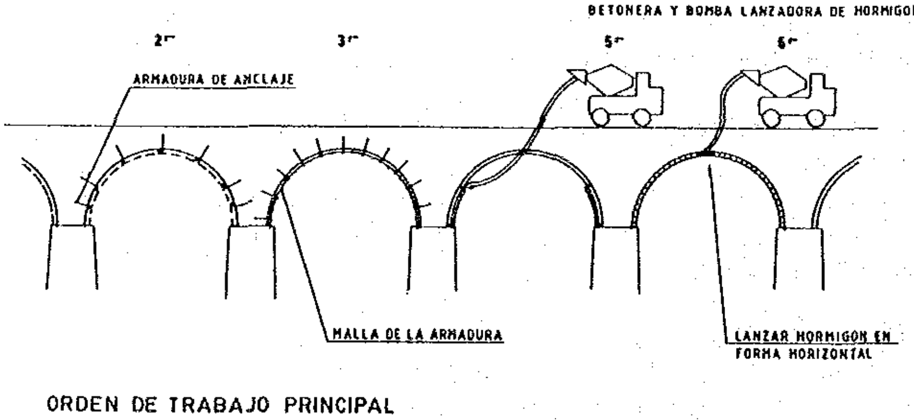


Figure 4-24 Repairing Method of Arch for Claro

(6) Fall-Off Prevention (Bio Bio Bridge)

Four types of fall-off prevention devices normally used were listed in Section 4-2-2 (7). Here, the connection of girders with chains is taken up. (See figure 4-25)

- The surfaces at the ends of the main girders are cleaned with grinders etc.
- Holes are drilled at the bolt positions with reamers. The use of gas-cutters should be avoided as the material quality of the webs is altered by heat.
- The steel plates are set in position and fastened with bolts.

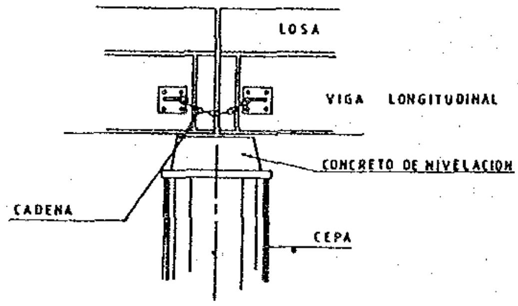


Figure 4-25 Counter Measure for Damage by Earthquake

(7) Repair of Gerber Section (Cayumapu Bridge)

The possibilities for the repair of the Gerber section include installation of additional reinforced concrete cross beams and shear reinforcement using steel plates. The latter method will be used under the present project. Reinforcement with steel plates is a method often used in Chile and there is no need to describe it here. Care, however, should be taken to ensure the safety of the scaffolding as the work will be taking place in a high place. Replacement of rusty shoes and repair work for prevention of leakage from the expansion joints should be implemented at the same time.

(8) Foundation Reinforcement by BH Method

Though limited, there are a number of pile drivers that can be used when there is little headroom below the bridge girders, as is the case in the construction of additional piles for reinforcement of the foundation at Ramadillas Bridge. As the work cannot take place under water, the drought season will have to be chosen and temporary roads for the transportation of the machinery, channels for diverting the river water and jetties will need to be constructed in the river channel. Where the riverbed is low around the piers, islands will be constructed and the pile drivers positioned on them. As the headroom below the girders is around 4 to 5 m, small reverse-circulation drills will be used for the pile drivers. As an example of such a pile driver, the TBM-LH is briefly discussed below. (Refer to figure 4-26)

This is a low-head, large-hole boring machine aimed at raising the efficiency of the BH method and has the following features.

1) The swivel head is low, allowing safe and speedy attachment and removal of the rods.

2) Long rods can be used even in positions with restrictions in the clearance.
3) Others

- Circulation method: direct circulation
- Dimensions during operation
  height: 3.3 to 4.8 m
  width: 1.2 m
  length: 3.0 m
- Weight: 3.2 t
- Borehole diameter
  normal soil: 0.2 to 1.5 m
  rocks: 0.2 to 0.5 m
- Borehole depth: 40 to 100 m
- Driving System
  rotation: 30 to 150 rpm
  torque: 0.6 tfm
  stroke: 500 mm
  thrust: 6.1 tf
- Motor: diesel engine, 18.5 kW (32 PS)

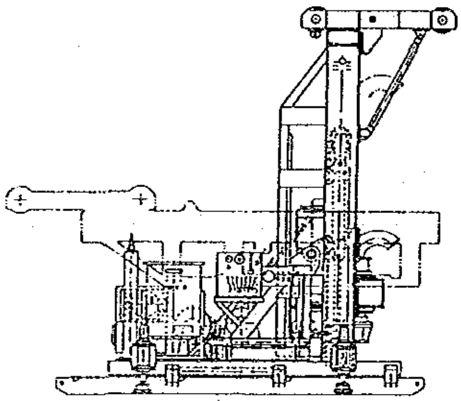


Figure 4-26 Large Hole Boring Machine

(9) Foundation Reinforcement with Cast-in-Place Piles (Loncomilla Bridge)

Since the river is deep, the work will take place during the drought season. The procedure of the work is outlined below. (Refer to Figure 4-27)

1) A jetty is constructed between Abutment E2 and Pier No. 5 using H-shaped steel and rail piles.
2) The pile driver is transported to Pier No. 5.
3) Parts obstructing the pile placement are removed as required.
4) The cast-in-place piles are placed.
5) The concrete on the edge of the old footing is removed to expose the reinforcement bars to be joined to the new footing .
6) The timbering, forms and reinforcement for the new bottom slabs are constructed and the concrete is placed. The foundation for the temporary supports are placed beforehand within the new bottom slabs.

7) The temporary supports are constructed and jacks are positioned at the top to support the bridge.
8) The tops of the pier caps of the original bridge piers are leveled, the cantilevers are repaired and the shoes are set in position.
9) The position of the superstructure is adjusted while loosening the jacks.
10) The temporary supports and the jetty are removed.

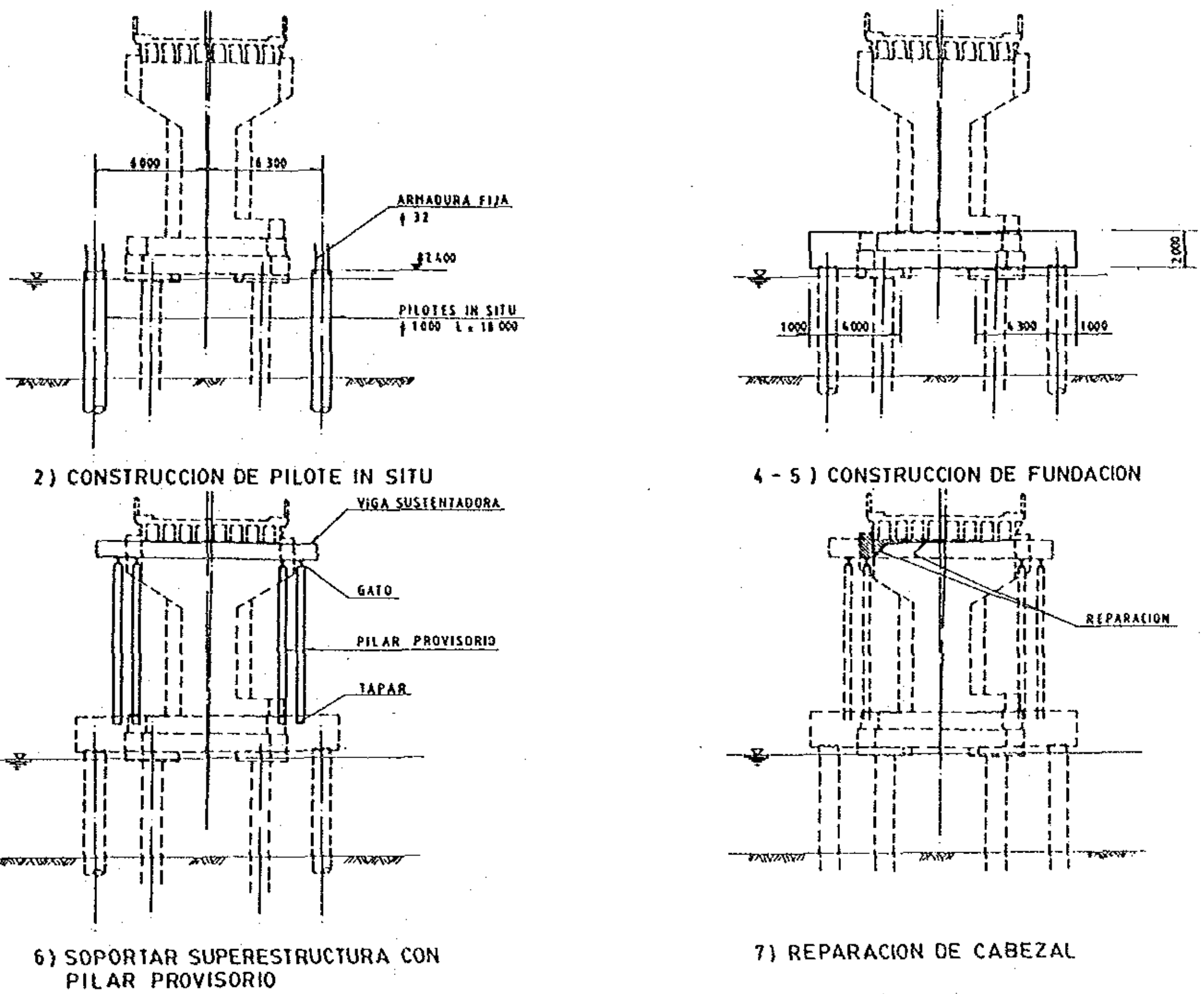


Figure 4-27 Reinforcement of Substructure by Cast-in-Place Pile

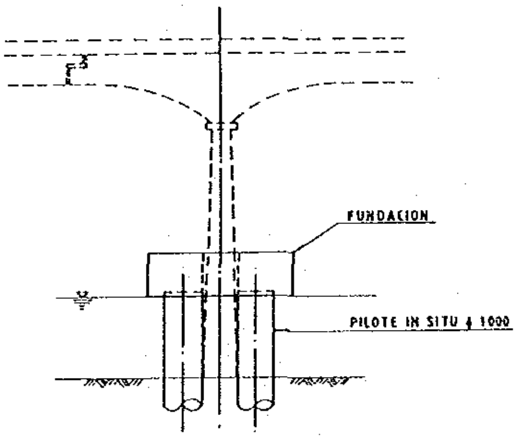
(10) Foundation Foot Protection Work (Claro Bridge)

Ripraps and gabions are to be used to prevent scouring of the riverbed and the existing foundations below the water surface are reinforced with prepacked concrete. For the placing the prepacked concrete, the riverbed is first leveled and the forms are installed under water. The aggregate is then placed in accordance with the mix design. This is followed by the injection of the cement mortar which is then allowed to harden.

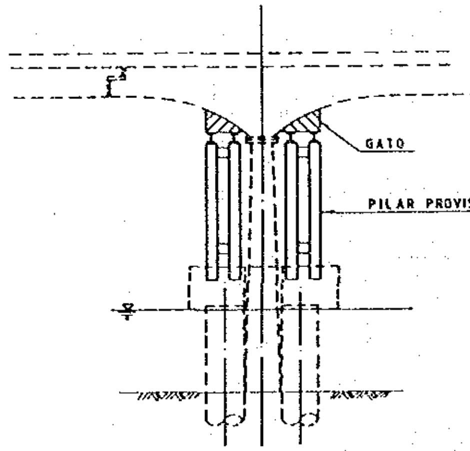
(11) Construction of New Pier (Cayumapu Bridge)

The procedure for the construction of the new pier, Pier No. 2, is described below. Refer to Figure 4-28.

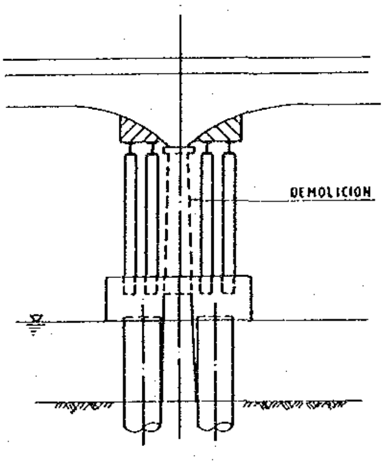
1) The temporary road and jetty for transportation of the pile-driving machinery are constructed within the river channel.
2) The cast-in-place piles are placed.
3) New bottom slabs are installed around the cast-in-place piles of the old pier, and the wall reinforcements are placed in position.
4) Temporary supports are constructed on these bottom slabs to support the original T-shaped girder. The foundations for the temporary supports will have been constructed within the bottom slabs and jacks placed on the top of the temporary supports for this purpose.
5) The walls of the original pier are removed.
6) The reinforcements, forms and timbering for the new pier walls are constructed.
7) Concrete is placed on the walls of the new pier and cured.
8) Shoes are placed on the top of the pier and the superstructure is lowered to the required position using jacks.
9) The temporary supports and the jetty are removed.



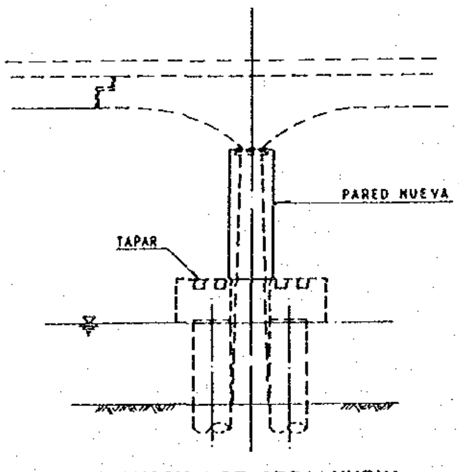
3) CONSTRUCCION DE PILOTE IN SITU Y FUNDACION



4) SOPORTE SUPERESTRUCTURA CON PILAR PROVISORIO



5) DEMOLICION DE PARED DE CEPA ORIGINAL



6) CONSTRUCCION DE CEPA NUEVA

Figure 4-28 Replacement Method of Pier

4-3-3 Materials Used and Quality and Construction Supervision

(1) Materials Used

The strengths of the principal materials used under the repair design are as follows.

Repair Method	Position	Material	Material Strength	Bridge
Flood slab replacement	Floor slabs	Concrete	fc = 240kg/cm^2	Claro
Steel plate attachment	Floor slabs	Steel plates	ft = 1400kg/cm^2	Pullally
Resin injection	Floor slabs			Amolanas, etc.
Patching	Floor slabs	Concrete	fc = 240kg/cm^2	Bio Bio
Arch repair	Lower faces of arches	Concrete	fc = 240kg/cm^2	Claro
Gerber repair	Gerber supports	Steel plates	ft = 1400kg/cm^2	Cayumapu
Shoe seat widening	Substructure crowns	Concrete	fc = 240kg/cm^2	Amolanas, etc.
Pier reinforcement	Piers	Concrete	fc = 240kg/cm^2	Amolanas
Pier repair	Piers	Concrete	fc = 240kg/cm^2	Ramadillas, etc.
Masonry work	Piers	Mortar	c = 500kg/m^2	Claro
Foundation repair	Pier foundations	Prepacked concrete	fc = 180kg/cm^2	Claro
Foundation reinforcement	Bottom slabs	Concrete	fc = 240kg/cm^2	Loncomilla, etc.
Additional piles	Foundations	Concrete	fc = 240kg/cm^2	Loncomilla
Additional piles	Foundations	Triple rail piles	ft = 1400kg/cm^2	Ramadillas, etc.
New piers	Piers	Steels	ft = 1400kg/cm^2	Malleco
Expansion joints	Joints			Maipo, etc.
Shoes	Shoe seats	Neoprene		Loncomilla, etc.
Fall-off prevention	Cross beams	PC steel bars	0.70fu = 12300kg/cm^2	Maipo
Fall-off prevention	Girder ends	Chains		Bio Bio, etc.
Painting	Steel girders			Pullally, etc.
Railing	Railing			Claro, etc.
Approach slabs	Approaches	Concrete	fc = 210kg/cm^2	Amolanas, etc.
Road pavement	Approaches	Asphalt		Amolanas, etc.
Scouring prevention	Riverbed	Gabions		Pullally, etc.
Scouring prevention	Riverbed	Ripraps	diameter: 30 cm or more	Loncomilla, etc.

Specifications for Principal Members

Material	Standard	Stress	Applicable Specifications
Reinforcement Steel	Grade 40	2800kg/cm^2 (Yield)	AASHOTO M31/ASTM A615
Steel Members		2800kg/cm^2 (Yield)	AASHOTO M183/ASTM A36
PC Steels	Grade 250	17,600kg/cm^2 (Ultimate)	AASHOTO M204/ASTM A416

(2) Quality and Construction Supervision

The repair work will be carried out in accordance with the design drawings and execution plans. As the quality of the work will have a direct effect on the stability of the structures, construction supervision will be of utmost importance. Points of particular note include the following.

1) Earth Work

The foundations for Amolanas and Malleco Bridges must penetrate down to the bedrock. Care needs to be taken in the scouring-prevention work at Maipo Bridge to avoid disturbing the ground around the foundations.

2) Concrete Work

The quality control will be implemented according to the following procedure.

- Determination of the properties required (e.g. compressive strength, slump) and the standard values (strengths and dimensions)
- Determination of inspection methods and control standards to be used in quality control
- Determination of the display methods for the data and of the criteria
- Quality control is implemented during the progress of the work and, when abnormalities are observed, their causes are sought and either the causes are removed or the work procedure is improved.

Concrete pumps will be used in the work on the piers at Amolanas Bridge and on the arches at Claro Bridge. Execution planning will be carried out in advance with detailed considerations for the equipment plan (layout of machinery, machines used and their capacities, piping), placement procedure and measures to be taken in case of breakdown.

3) Form Supports

Design work will be required for the concrete forms for the more important structures. Considerations will be made for the vertical loads of the forms, supports, concrete, reinforcement bars, workers and construction equipment, as well as horizontal loads, such as the lateral pressure of the concrete against the formwork. Settlement and lateral movement of the supports during concrete placement due, for example, to the lack of bearing capacity will result in a lowering of the accuracy in the finish. Appropriate types of supports must be selected on the basis of preliminary studies of the ground conditions.

4) Resin Injection

Materials: Epoxy and polyester resins are normally used. Polyester resins are subject to significant shrinkage and have low adhesion and durability, as well as being totally averse to water. They have the advantage, however, that they require lower curing temperatures than epoxy resins and the possibility of lowering their viscosity makes them suitable for use in small cracks.

Injection: Since the resins are sensitive to temperature variation, times at which the external temperature ranges between 10 and 30°C and the concrete surface temperature is 10°C or above, should be selected for their injection.

5) Steel Plate Attachment

Given below is an standard example for the specifications for epoxy resin to be used as the adhesive.

Specific gravity:	1.1 to 1.9 (permissible error: 5%)
Viscosity:	35,000 to 65,000 cP
Usable time:	60 minutes or more
Tensile strength:	200 kg/cm2 or more
Flexural strength:	400 kg/cm2 or more
Compressive strength:	(yield point) 700 kg/cm2 or more
Tensile shear strength:	150 kg/cm2 or more
Impact strength:	2.0 kg/cm2 or more
Tensile elastic modules:	10,000 kg/cm2 or more
Flexural elastic modules:	10,000 kg/cm2 or more
Compressive elastic modules:	10,000 kg/cm2 or more

The boring of the steel plates should be implemented at the factories and the hole diameters should be made 5 to 10 mm greater than the anchor bar diameters.

6) Pile Work

The ends of the piles must penetrate down to the bearing stratum. This is particularly important in Chile. When driven piles are used as friction piles, bearing capacity tests should desirably be carried out. Since the horizontal forces due to earthquakes and other causes tend to concentrate at the pile heads, the connection with the bottom slabs must be made firm. When the centre-lines of the piles are found to be out of position reinforcement will be required.

7) Steel Frame Pier

The points of note in the construction of this pier are listed below.

- Measurement of the positions of the foundations and bearing supports before and during execution are of importance. During the assembly of the members, measurements are taken at each panel point in the structures.
- The construction control is carried out taking account of the characteristics of steel frame structures, calculating the stresses and displacement at various stages of the construction and confirming the safety through measurements.
- Checks and inspections are made on the structures during construction. It is important to keep records of these inspections (ground bearing capacity, materials, joints, accuracy of assembly, displacement etc.).

4-3-4 Safety of Work and Environmental Measures

(1) Safety Control

Safety measures during construction include those to do with the safety of the workers, local residents and bridge users. Workers must not be made to undertake dangerous work, or work that may be hazardous to their health, and must be given thorough instructions concerning safety. Special supervisors will be appointed for maintenance of safety and will ensure communication and coordination between various items of work, as well as patrolling the sites and ensuring the safety of the equipment.

(2) Environmental Measures

The following measures should be taken with regard to the environmental problems that might arise from the construction work.

- When the temporary roads and storage space for materials and equipment pass through or occupy parts of houses or farmland, appropriate measures should be taken in advance to prevent difficulties.
- Measures, such as construction of new drainage channels, should be taken where water is drained from the construction site or where different drainage systems from that prior to the construction work are required.
- Hazardous materials, toxic chemicals and waste concrete blocks must be disposed of at designated sites.
- Test excavation should be carried out in advance to ensure that no damage is caused to the existing underground utilities such as water pipes and sewage pipes.
- Power transmission lines should be provided with protection or moved to other sites.

(3) Traffic Safety

Some of the work will involve reduction of traffic lanes and restrictions on types of passing vehicles. Detailed planning is required for such traffic restrictions with considerations for the construction methods and schedule. Road signs, construction signs, safety fences, safety cones, signal lights, lighting, traffic signals etc. will be required at the sites and it would be best to employ personnel for guiding the traffic. Since the bridges in question are located on trunk routes, the traffic restrictions should be advertised through newspapers and radio broadcasts.

4-4 Cost Estimation

4-4-1 Composition of Construction Costs

A brief summary is given below for the cost estimation methods for bridge repair work used by the MOP. Construction costs can be expressed by the following equation.

Precio = (intru + gastos general + utilcompania) + IVA
P = (I + G,G + UC) + IVA
where,

- P: construction costs (estimate for total construction costs or bid price)
- I: prime cost for construction (materials + labour + equipment + transportation + other expenses)
- GG: general expenses (expenses other than "I" - e.g. communication and clerical work)
- UC: company profit (net profit of firm undertaking the work)
- IVA: tax (government tax rate: 18%)

Of these, the prime construction costs (I) are calculated according to the "Plan nacional de puentes. Programa de rehabilitación y conservación vial." The general expenses (GG) and company profit (UC) varies from company to company, but examples of past projects show this to be around 30 to 40% of the prime construction costs. A 40% will be used in the preliminary design here. The tax rate at present in 18% of {T + (GG + UC)}. Materials used for reference in the cost estimation include the following.

- Plan nacional de puentes. Programa de rehabilitación y conservación vial (Especificaciones técnicas generales, mayo 1983)
- ONDAC. El manual de la construcción edición
- Normas de autopistas (No. 1 - No. 5)

4-4-2 Unit Costs of Construction Items

The conventional items of work are used together with the item numbers and unit costs as given in the estimation standards of MOP. For items of work newly added for the repair design, the directions given by MOP were followed and the standard costs were determined as shown in Table 4-10. Even for same items of work, where the erection methods etc. differ, the costs for these are calculated by increasing the standard unit costs.

Table 4-10 Standard Unit Costs

No.	Item of Work	Unit	Cost (P)	Remarks
201	Mechanical excavation	M3	1,500	Including refill
202	Ordinary manual excavation	M3	14,000	Including refill
203	Underwater excavation	M3	2,500	Including replacement of water
204	Rock (and boulder) excavation	M3	3,000	Including disposal of waste soil
241	Cast-in-place piles	M3	90,000	Materials and placement
244	Triple rail piles	M	40,000	Materials and placement
251	Form work	M2	6,000	
261	Reinforcement work	TON	275,000	
263	PC steel bars	NO	24,000	Maipo Bridge
275	Concrete ($240kg/cm^2$)	M3	56,000	Excluding forms
277	Prepacked concrete ($180kg/cm^2$)	M3	62,000	
279	Approach slabs	M3	83,000	per set
428	Masonry work	M3	40,000	per set
429	Stone panels	M2	41,300	Thickness: 4cm
430	Stone panel attachment (mortar injection)	M3	62,000	Construction costs
435	Concrete removal	M2	20,000	Equivalent to thickness of 30cm
511	Temporary bridge or detour route	GL	—	Differs from bridge to bridge
802	Precast concrete slabs	M3	120,000	per set
805	Drainage work	No	14,000	
815	Road pavement	M2	5,000	
830	Railing replacement	M	26,000	
835	Resin injection	M	2,500	
855	Expansion joints	M	33,000	
950	Slab patching	M2	51,000	per set
955	Scouring prevention	M3	26,000	
956	Ripraps	M3	9,500	
965	Rubber bearings	No	330,000	
970	Painting	M2	1,500	
975	Anchoring	No	4,400	
976	Shoe seat widening	No	29,000	Steel
977	Gerber repair	No	175,000	Steel (except shoes)
978	Fall-off prevention	No	42,000	Chains
979	Steel girder repair	TON	350,000	
980	Steel frame work	TON	800,000	Malleco Bridge
981	Steel plate attachment	M2	45,000	

4-4-3 Approximate Repairing Cost

(1) Summary of the Repair Cost

Table 4-11 Approximate Repairing Cost

	Name of Bridge	Principal Items of Repair	Estimated Cost	Remarks
1	Amolanas	Pier reinforcement, resin injection	81,853,000	
2	Pullally	Steel plate attachment, shoe seat widening	96,753,000	
3	Maipo	Fall-off prevention, scouring prevention	38,826,000	
4	Claro	Stone panel attachment, reinforced concrete arches	396,429,000	
5	Loncomilla	Foundation reinforcement, scouring prevention	428,299,000	
6	Bio Bio	Fall-off prevention, resin injection	148,800,000	
7	Ramadillas	Foundation reinforcement, shoe seat widening	352,703,000	
8	Malleco	Construction of trestle bridge	3,955,549,000	
9	Pichoy	Foundation reinforcement, fall-off prevention	170,960,000	
10	Cayumapu	Construction of new substructure, Gerber repair	103,347,000	
	Total			

(2) Repair Cost for Individual Bridges

1) Amolanas

No.	Item of Work	Unit	Quantity	Unit Cost (P)	Coefficient (%)	Cost (P1000)
202	Ordinary manual excavation	M3	50	14,000	1.00	700
251	Form work	M2	785	6,000	2.00	9,420
261	Reinforcement work	TON	13	275,000	2.00	7,150
275	Concrete (240 kg/cm²)	M3	130	56,000	2.00	14,560
279	Approach slabs	M3	36	83,000	1.00	2,988
815	Road pavement	M2	200	5,000	1.00	1,000
835	Resin injection	M	4,240	2,500	1.00	10,600
855	Expansion joints	M	68.5	33,000	1.00	2,260
976	Shoe seat widening	NO	2	29,000	15.00	870
	Subtotal					49,548
	Expenses (40%)					19,819
	Government Tax (18%)					12,486
	Total					81,853

2) Pullally Bridge

No.	Item of Work	Unit	Quantity	Unit Cost (P)	Coefficient (%)	Cost (P1000)
203	Underwater excavation	M3	175	2,500	1.00	438
835	Resin injection	M	3,060	2,500	1.00	7,650
855	Expansion joints	M	45	33,000	1.00	1,485
955	Scouring prevention	M3	250	26,000	1.00	6,500
970	Painting	M2	4,600	1,500	1.20	8,280
976	Shoe seat widening	NO	16	29,000	1.00	464
981	Steel plate attachment	M2	750	45,000	1.00	33,750
	Subtotal					58,567
	Expenses (40%)					23,427
	Government Tax (18%)					14,759
	Total					96,753

3) Maipo Bridge

No.	Item of Work	Unit	Quantity	Unit Cost (P)	Coefficient (%)	Cost (P1000)
201	Mechanical excavation	M3	600	1,500	1.00	900
203	Underwater excavation	M3	200	2,500	1.00	500
263	PC steel bars (fall-off prevention)	No	78	24,000	1.00	1,872
855	Expansion joints	M	300	33,000	1.00	8,900
955	Scouring prevention	M3	390	26,000	1.00	10,140
956	Ripraps	M3	20	9,500	1.00	190
	Subtotal					23,502
	Expenses (40%)					9,401
	Government Tax (18%)					5,923
	Total					38,826

4) Claro Bridge

No.	Item of Work	Unit	Quantity	Unit Cost (P)	Coefficient (%)	Cost (P1000)
202	Ordinary manual excavation	M3	10	14,000	1.00	140
203	Underwater excavation	M3	20	2,500	1.00	50
251	Form work	M2	1,090	6,000	1.50	9,810
261	Reinforcement work	TON	21	275,000	1.50	8,663
275	Concrete (240 kg/cm²)	M3	210	56,000	1.50	17,640
277	Prepacked concrete (180 kg/cm²)	M3	200	62,000	1.00	12,400
428	Masonry work	M3	300	40,000	1.00	12,000
429	Stone plate materials	M2	2,300	41,300	1.00	94,990
430	Stone plate attachment	M3	230	62,000	1.00	14,260
435	Concrete removal	M2	1,400	20,000	0.50	14,000
802	Precast concrete slabs	M3	280	120,000	1.00	33,600
805	Drainage work	No	24	14,000	1.00	336
815	Road pavement	M2	180	5,000	1.00	900
830	Railing replacement	M	236	26,000	1.00	6,136
855	Expansion joints	M	18	33,000	1.00	594
955	Scouring prevention	M3	400	26,000	1.00	10,400
956	Ripraps	M3	160	9,500	1.00	1,520
975	Anchoring work	No	1,150	4,400	0.50	2,530
	Subtotal					239,969
	Expenses (40%)					95,988
	Government Tax (18%)					60,472
	Total					396,429

5) Loncomilla Bridge

No.	Item of Work	Unit	Quantity	Unit Cost (P)	Coefficient (%)	Cost (P1000)
241	Cast-in-place piles	M3	288	90,000	1.20	31,104
251	Form work	M2	490	6,000	1.20	3,528
261	Reinforcement work	TON	240	275,000	1.20	66,000
275	Concrete (240 kg/cm²)	M3	295	56,000	1.20	19,824
435	Concrete removal	M2	96	20,000	1.20	2,304
511	Temporary Bridge or detour route	M	300	350,000	1.20	126,000
830	Railing replacement	M	20	26,000	1.00	520
855	Expansion joints	M	25	33,000	1.00	825
955	Scouring prevention	M3	30	26,000	1.20	936
956	Ripraps	M3	200	9,500	1.00	2,280
965	Rubber bearings	No	18	330,000	1.00	5,940
	Subtotal					259,261
	Expenses (40%)					103,704
	Government Tax (18%)					65,334
	Total					428,299

6) Bio Bio Bridge

No.	Item of Work	Unit	Quantity	Unit Cost (P)	Coefficient (%)	Cost (P1000)
835	Resin Injection	M	5,700	2,500	1.00	14,250
950	Slab patching	M2	115	51,000	1.00	5,865
970	Painting	M2	34,250	1,500	1.20	61,650
976	Shoe seat widening	No	20	29,000	1.00	580
978	Fall-off prevention	No	184	42,000	1.00	7,728
	Subtotal					90,073
	Expenses (40%)					36,029
	Government Tax (18%)					22,698
	Total					148,800

7) Ramadillas Bridge

No.	Item of Work	Unit	Quantity	Unit Cost (P)	Coefficient (%)	Cost (P1000)
201	Mechanical excavation	M3	200	1,500	1.00	300
203	Underwater excavation	M3	100	2,500	1.00	250
244	Triple rail piles	M	260	40,000	1.00	10,400
251	Form work	M2	1,420	6,000	1.00	8,520
261	Reinforcement work	TON	54	275,000	1.00	14,850
275	Concrete (240 kg/cm²)	M3	680	56,000	1.00	38,080
435	Concrete removal	M2	220	20,000	1.00	4,400
511	Temporary Bridge	M	120	350,000	1.00	42,000
	and detour route	M	240	150,000	1.00	36,000
855	Expansion joints	M	159	33,000	1.00	5,247
965	Rubber bearings	No	112	330,000	1.00	36,960
970	Painting	M2	6,615	1,500	1.20	11,907
975	Anchoring work	No	1,390	4,400	0.75	4,587
	Subtotal					213,501
	Expenses (40%)					85,400
	Government Tax (18%)					53,802
	Total					352,703

8) Malleco Bridge

No.	Item of Work	Unit	Quantity	Unit Cost (P)	Coefficient (%)	Cost (P1000)
201	Mechanical excavation	M3	37,700	1,500	1.00	56,550
251	Form work	M2	1,150	6,000	1.00	6,900
261	Reinforcement work	TON	150	275,000	1.00	41,250
275	Concrete (240 kg/cm²)	M3	2,450	56,000	1.00	137,200
511	Temporary Bridge or detour route	M	800	150,000	1.50	120,000
970	Painting	M2	26,000	1,500	1.00	39,000
979	Steel girder repair	TON	140	350,000	1.50	73,500
980	Steel frame work	TON	2,400	800,000	1.00	1,920,000
	Subtotal					2,394,400
	Expenses (40%)					957,760
	Government Tax (18%)					603,389
	Total					3,955,549

9) Pichoy Bridge

No.	Item of Work	Unit	Quantity	Unit Cost (P)	Coefficient (%)	Cost (P1000)
201	Mechanical excavation	M3	40	1,500	1.00	60
244	Triple rail piles	M	784	40,000	1.00	31,360
251	Form work	M2	160	6,000	1.00	960
261	Reinforcement work	TON	7	275,000	1.00	1,925
275	Concrete (240 kg/cm2)	M3	90	56,000	1.00	5,040
279	Approach slabs	M3	36	83,000	1.00	2,988
435	Concrete removal	M2	90	20,000	1.00	1,800
815	Road pavement	M2	400	5,000	1.00	2,000
855	Expansion joints	M	58	33,000	1.00	1,914
965	Rubber bearings	No	25	330,000	1.00	8,250
970	Painting	M2	1,960	1,500	1.20	3,528
976	Shoe seat widening	No	1	29,000	10.00	290
978	Fall-off prevention	No	6	42,000	1.00	252
	Subtotal					60,367
	Expenses (40%)					84,514
	Government Tax (18%)					26,079
	Total					170,960

10) Cayumapu Bridge

No.	Item of Work	Unit	Quantity	Unit Cost (P)	Coefficient (%)	Cost (P1000)
201	Mechanical excavation	M3	40	1,500	1.00	60
241	Cast-in-place piles	M3	108	90,000	1.10	10,692
251	Form work	M2	135	6,000	1.10	891
261	Reinforcement work	TON	9	275,000	1.10	2,723
275	Concrete (240 kg/cm2)	M3	105	56,000	1.10	6,468
279	Approach slabs	M3	36	83,000	1.00	2,988
435	Concrete removal	M2	70	20,000	1.10	1,540
511	Temporary bridge or detour route	M	80	350,000	1.10	30,800
815	Road pavement	M2	400	5,000	1.00	2,000
955	Scouring prevention	M3	40	26,000	1.00	1,040
965	Rubber bearings	No	6	330,000	1.10	2,178
976	Shoe seat widening	No	1	29,000	10.00	290
977	Gerber repair	No	6	175,000	1.00	1,050
	Subtotal					62,720
	Expenses (40%)					25,088
	Government Tax (18%)					15,805
	Total					103,613

Chapter 5 Bridge Rehabilitation Planning

5-1 Principle for the Planning of Bridge Rehabilitation

5-1-1 Present Situation of Bridge Rehabilitation Practice in Chile

One of the main objectives of this Study is to work out an optimum methodology which will contribute to the effective maintenance of bridges on the National Route 5 which is the most important trunk road in Chile, aiming to secure safe and smooth flow of traffic, from the engineering and socioeconomic standpoints, and then, to formulate a bridge rehabilitation plan. Through a series of bridge inspections carried out in the first and second phases of the Study, it was identified that there were many bridges which were in the latter stage of senility in their life cycles and had severe defects among those on this route.

A bridge is one of the components of a road network system, and therefore, when the function of a bridge is once lost, it will give a great adverse effect to the society and economy not only in the area where the road is running, but also of the whole country. Furthermore, because of the reason that the National Route 5 is the most important artery of this country whose traffic volume has been rapidly increasing in line with the development of economy, the loss of national benefits and interests will be unaccountable by the suspension or loss of bridge function. Therefore, implementation of the proper maintenance and rehabilitation activities to bridges on the National Route 5 is considered to be of great importance and urgent necessity in this country.

In parallel with the Study, the Government of Chile, with its own discretion and financial resources, has also been planning and implementing new construction, rehabilitation and replacement of those bridges which immediately require such measures, in order to comply with the rapid increase of traffic volumes. In particular, in Regions VI and VII, implementation of the large-scale highway improvement programs are underway, including construction of grade-separated intersections and widening of carriage ways. In line with the programs, Maule Bridge and Piduco Bridge which were identified to be of high priority for proposed replacement in this Study are now in the process of actual replacement works.

Under the present circumstances in Chile, although there are many bridges which require immediate rehabilitation, it will need a huge amount of cost in spite of a very limited available fund, which necessitates the road administrators to implement the maintenance and rehabilitation works with the best possible cost performance. To this end, it is indispensable to utilize a system which can compile, assemble and retrieve the data and information related to bridge engineering, in order to execute scientifically and rationally the bridge rehabilitation plan which includes many bridges and work loads in quantity and quality. During the process of the Study, a system which can rationally determine the rehabilitation priority and related cost was developed.

5-1-2 Bridge Rehabilitation Planning

Determination of the bridge rehabilitation priority consists of many factors and elements. The priority shall preferably be determined by the comprehensive evaluation based on the engineering and structural factors such as the degree of bridge defect and functional characteristics, as well as the political and socioeconomic factors like traffic volume, regional development plan and national development policy. However, formulation of a bridge rehabilitation plan in the Study was attempted with application of the Bridge Maintenance Management System developed for this Study, due to the following reasons. The process of plan formulation can be roughly described as the evaluation of bridge defective degree based on the results of periodic inspection as the first step, and then, the determination whether the inspected bridges require rehabilitation or not as the second step, which is followed as the final step by determination of the bridge rehabilitation priority and estimation of rehabilitation cost.

1. There exists no comprehensive regional development plans covering all the areas where all the road sections of National Route 5 are stretching for which the bridge rehabilitation plan is to be intended.

2. The Government of Chile has already politically decided road sections, for which bridge rehabilitation and replacement have been implementing.

3. The Government of Chile is seeking a rational system which can logically determine bridge rehabilitation priority for formulation of the future bridge improvement plans.

As a part of plan formulation, prioritization of bridge rehabilitation for all the inspected bridges on National Route 5 was worked out by the following conditions and methods.

1. All the inspected bridges on National Route 5 are to be compared with the same conditions, regardless of bridge status whether included in the existing rehabilitation plans with budget allocations or on-going rehabilitation works being undertaken.

2. Rehabilitation priority shall be determined from the viewpoint of engineering criteria such as degree of defect, function and type of the bridge.

3. The standard rehabilitation method and its cost for each bridge component shall be determined for those bridges which are rated as the defective degrees 4 and 5.

4. With an assumption that all the bridges rated as above on National Route 5 shall be rehabilitated with the aforesaid standard methods, calculation of each bridge rehabilitation cost will be made.

5. As the indicators for evaluation of rehabilitation priority, estimation of cost for bridge rehabilitation work and applicable traffic volume are to be worked out.

6. Above indicators shall be properly tabulated so that the bridge rehabilitation priority determined in item 2 can be evaluated.

5-1-3 Indicators for Determination of Rehabilitation Priority

The priority of a project is normally determined by the criteria or indicators such as benefit/cost ratio (B/C), internal rate of return (IRR). However, adoption of these criteria to all the bridges on National Route 5 for this purpose is considered to be almost impossible, because there would be no benefit to be yielded from bridge rehabilitation and the basis of benefit and cost estimation can not be clarified nor accurate, which leads to meaningless result. Therefore, the following indicators are adopted for determination of bridge rehabilitation priority. Tables 5-3(1) through 5-3(8) show the examples of determined priority of each bridge for rehabilitation, by application of the integrated evaluation indicators (TE) for rehabilitation /replacement priority.

(1) Integrated Determination Indicators for Bridge Rehabilitation/Replacement Priority (TE)

"TE" is to be expressed as an integrated indicator for determination of bridge rehabilitation/replacement priority, mainly judged by the level of functional and engineering requirement factors of the bridge, such as degree of defect, load bearing and functional fulfillment or service level. Among above factors, the deficiency rate of bridge is regarded as the most important, and the calculation method of the rate is explained in Section 8-3 of Chapter 8 and the concept on the "TE" is described in Section 8-4 of the same chapter.

(2) Rehabilitation Cost (COST)

The Government of Chile is adopting its own standard bridge rehabilitation methods as shown in Table 8-4. For plan formulation, the Study applied this standard method for determination of the rehabilitation methods of the bridges inspected, and estimation of the rehabilitation cost is worked out by the following procedure.

1. Based on the results of inspection, deficiency rate of the bridge component is determined by the evaluation criteria shown in Tables 8-5 and 8-6.

2. Standard rehabilitation method of bridge component is determined for those bridges with the deficiency rate of 4 and 5, which is referred to Tables 8-7 and 8-8.

3. Quantity calculation by size and dimension of the bridge is carried out in accordance with the formulae shown in Tables 8-9 and 8-10.

4. Estimation of the cost of bridge rehabilitation work is made with application of standard unit cost of adopted standard method and the calculated quantity.

(3) Average Daily Traffic Volume (ADT)

The Government of Chile has been conducting nation-wise traffic surveys. Based on the traffic volume count surveys for 1988 and 1990, projection of the traffic volumes for 1992, 2002 and 2012 are attempted. Figures 5-1 through 5-6 indicate the estimated average daily traffic volumes on the road sections on the National Route 5.

(4) Bridge Rehabilitation Cost/Average Daily Traffic Volume (COST/ADT)

The main beneficiary of the bridge is the vehicle traffic using that bridge. Because of the reason that the time saving benefit and the saving benefit of vehicle operating costs such as fuel and oil consumption and others are mostly in direct proportion to the traffic volume, value of benefit/cost ratio commonly used for project evaluation is proportional to the size of traffic volume when the cost is constant. Therefore, as an economic indicator to determine the bridge rehabilitation priority, the Study applied the rehabilitation cost/average daily traffic volume (COST/ADT). In this case, the smaller the value is, the greater the cost efficiency becomes.

(5) Rehabilitation Cost/Average Daily Traffic Volume/Bridge Area (COST/ADT/BA)

The COST/ADT indicator as described in the preceding paragraph (para. 4) is inclined to show high priority where the size of a bridge is small which can be rehabilitated with a low cost, when the traffic volume is constant on the same road section. In order to avoid such discrepancy, this indicator (COST/ADT) is divided by the area of a bridge surface (BA). This revised indicator shows the value of cost performance factor per unit bridge area, in which case the smaller the value is, the greater the cost performance is.

5-2 Evaluation of Bridge Deficiency Rate

The evaluation of bridge deficiency rate was attempted based on the results of preliminary or periodic inspection carried out to 246 bridges on the National Route 5. The concept of bridge deficiency rate evaluation is described as follows. The bridge deficiency rate is evaluated relatively by the weighted criteria or extent how much three components of bridge (super-structure, sub-structure and accessories) will affect to the total structural function of the bridge. The evaluated value of each bridge is obtained by the layer analysis method in which the weighted value of the bridge deficiency is overlapped with the deficiency rate of each component of the bridge.

The detail of the evaluation method of bridge deficiency rate is described in Section 8-3 of Chapter 8, and the relative evaluation values and weights are shown in Table 8-3 in that section. For determination of the priority of bridge rehabilitation, the deficiency rate are converted to five-rank ratings by the statistical approach, and applied as the evaluation criteria to the structural deficiency of the bridge.

5-3 Determination of Rehabilitation or Replacement

There are following three major cases which would necessitate bridge replacement.

1. When the traffic demand exceeds the traffic capacity of the bridge

2. When the bridge is obliged to be replaced by the requirements attributable to river conditions and shortage of clearance under the girder, etc.

3. When the bridge comes to have too much senility in its life cycle or too great defect so that replacement can attain better cost performance than rehabilitation.

In this Study, discussions are not extended to above-mentioned Case I and Case 2 in the planning of bridge rehabilitation. There would be two measures to solve the problem of traffic capacity shortage as described below.

1) Construction of an additional new bridge in parallel with the existing bridge in use

2) Construction of a new bridge which has enough traffic capacity, as the replacement of the existing bridge

At present the Ministry of Public Works of the Government of Chile is adopting the former measure for the widening of carriage ways to increase the traffic capacity. Because of the reason that this Study aims at the planning of bridge rehabilitation intended for rehabilitation or replacement of the existing bridges, discussion on the additional bridge or the wider bridge to be newly constructed is considered to be of another plan and is regarded as out of scope.

It is a general understanding that there is no established method nor means to determine exactly how long the life span of a bridge will be prolonged by implementation of rehabilitation. There have normally been many cases that when the rehabilitation works on an old bridge have been executed, many other additional defects have been found at other structural parts. Furthermore, prolonged life span of a bridge can be variable depending not only on the method and scale of rehabilitation, but also on the kind of structural components of bridge to be rehabilitated.

Assuming that the replacement of a bridge is implemented after 10 years and its cost is now US $100, this cost at present value after 10 years would be US $56 with a discount rate of 6 % per annum disregarding the price escalation. This will lead to a consideration that if the cost of rehabilitation to be implemented now would be less than 44 % of the cost of replacement, this rehabilitation can be regarded as economically more advantageous, even if the replacement is executed after 10 years. In this case, the higher the discount rate is, the more advantageous the rehabilitation becomes, and it can be done with less cost.

5-4 Engineering Evaluation for Determination of Priority

For determination of priority of a bridge for rehabilitation or replacement, its evaluation criteria will differ according to the characteristics of area, administrative organization structure and objective of bridge maintenance, etc., and eventually, weight of the criteria would be adjusted accordingly. In addition to the result of bridge defect evaluation, evaluation criteria for determination of priority of a bridge for rehabilitation or replacement would be the engineering and structural factors like the engineering characteristics of the bridge, its site and surrounding geography, as well as the socioeconomic factors like national development plan, projected traffic demand and available source of fund, etc. In this section, examination was tried to the engineering evaluation criteria for priority determination and the weight of each criterion.

There are several ideas as to the engineering evaluation criteria and the prioritization methods. In this Study, the independent factors which will mutually influence to prioritization are set as the criteria at the first level layer, and the factors which will minutely evaluate at the first level are set as the criteria at the second level. Then, by application of layer analysis method which will review the weight of each level, prioritization of the bridges subjected for rehabilitation on the National Route 5 are sought from engineering standpoint. The weight list of each criterion classified by each layer level is shown in Table 8-16.

5-5 Evaluation by Socioeconomic Factors for Prioritization

5-5-1 Basic Approach to Socioeconomic Evaluation

A general approach to socioeconomic evaluation for feasibility study is the quantitative calculation and comparison of the influential factors accrued by implementation of a certain project. However, because of the reason that clarification of such influences is very complicated and difficult, so that the traditional method of economic viability has been evaluated by comparison of just the benefit and cost directly related to project implementation, which are tangible and quantitative, and can be expressed in monetary values.

For instance, in case of a road project, the evaluation elements are limited to the construction and maintenance costs and the benefits as savings in monetary terms of the vehicle running cost and travel time which are directly related to the road users and can fairly accurately be accountable.

A bridge has a certain life span as is everything, and its function will be lost sometime unless a certain measure like rehabilitation is taken for prolonging the life span, which will cause suspension of the traffic flow. Loss of a bridge function on the existing road, especially on the very important trunk road would cause an enormous damage, and clear quantification of such a damage would be almost impossible. Suspension of the traffic flow due to bridge collapse will not only give a great adverse effect to the road users directly, but also cause unmeasurable influence to the society. Apart from this influence, there would be no new benefit yielded by just the implementation of bridge rehabilitation. In other words, bridge rehabilitation can improve the level of traffic safety, but will not increase the traffic capacity, and therefore, there will basically be no change of traffic benefit before and after its implementation. Consequently, it will be meaningless to adopt a traditional method for economic evaluation of the rehabilitation of existing bridge by comparison of the investment cost and the very limited or nil benefit.

Therefore, socioeconomic evaluation for the rehabilitation plan of the existing bridges on the National Route 5, to be formulated in the Study, was mainly intended and applied to the determination of rehabilitation priority. To this end, evaluation elements were confined to those indicators which were derived from analytical works on the collected data and information, and were useful for determination of the priority of rehabilitation or replacement.

5-5-2 Evaluation Elements

The following were conceived as the evaluation elements selected from various socioeconomic indicators. They are adaptable for determination of rehabilitation priority of the existing bridges, in the process of formulating the bridge rehabilitation plan in the Study.

1. Comprehensive development plans

2. Important development areas

3. Population

4. Traffic volume and heavy vehicle composition rate

In addition to above, scale of budget, restrictive conditions on source of fund, and rehabilitation cost will be regarded as the financial types of evaluation elements. Among those listed above, as there had not been sufficient data on the various development plans, traffic volume and rehabilitation cost were adopted as the socioeconomic evaluation elements, for priority rating of rehabilitation. Traffic volume can be regarded as the reflection of economic activity of the area where the bridges are located.

5-6 Bridge Rehabilitation Plan for the National Route 5

The priority of bridge rehabilitation decided by the integrated determination indicators (TE) is performed in the Study. The high priority bridges for the rehabilitation which have the bridge deficiency rate 5 for the super- and sub-structure and have high value of TE are shown in Table 5-3, in which 37 bridges are listed in high order of TE indicator. In Table 5-3, the following bridges which have special situations are included;

- MAULE Bridge is now under construction for replacement.
- CLARO Bridge is necessary for preservation as historical monument.
- PIDUCO Bridge fell to the river for scouring of abutment during the Study period.

The bridges which are necessary urgent repair are shown in Table 5-1, the bridges which are desirable early repair are shown in Table 5-2. The bridges with the following conditions are not included in the Tables.

1. Bridges which already have plans for rehabilitation/replacement.
2. Bridges which are not the bridge deficiency rate 5 for the super- and sub-structure, though the TE indicator is higher
3. Bridges which are necessary to construct new bridge (replacement) due to severe damage occurred by problems of basic structure and of conditions for the bridge location.

Table 5-1 Bridges Necessary Urgent Repair

NO	NO	NOMBRE	REG	COST (x1000 PS)	ADT	BA	COST/ ADT	COST/ BA*ADT	TE	L	S	I
1	29	PULLALLY	5	48916	4095	1552	11945	7.7	129	4	4	5
2	70	ANTIVERO PONIEN	6	26511	18182	1574	1458	0.9	120	5	4	3
3	53	PS TENIENTE PON	6	34990	15340	338	2281	6.7	130	4	4	5
1	137	DIGUILLIN	8	163725	12644	683	12949	19.0	124	4	5	5
2	123	NINQUIHUE	8	13313	6485	206	2053	10.0	130	4	4	5
3	140	LAJITA	8	8422	6593	304	1277	4.2	128	4	5	4
4	117	NIQUEN	8	4232	6485	261	653	2.5	122	4	5	3
5	142	BATUQUITO	8	65542	6593	144	9941	69.0	130	4	4	5
6	141	BATUCO	8	11192	6593	331	1698	5.1	125	5	4	4
7	152	BUREO	8	33899	5659	1408	5990	4.3	132	5	4	4
8	143	SALTO DEL LAJA	8	166744	6593	1187	25291	21.3	121	5	5	4
9	160	CHAMICHACO	9	5176	4366	163	1186	7.3	130	5	4	4
10	159	HUEQUEN	9	75540	4366	233	17302	74.3	125	5	5	5
11	165	CHANCO	9	6076	5429	203	1119	5.5	120	5	4	3
12	156	MININCO	9	29034	5659	588	5131	8.7	132	4	5	4
13	161	DUMO	9	85112	4366	294	19494	66.3	118	4	5	3
14	166	QUINO	9	79212	5429	578	14591	25.2	124	4	4	5
15	168	PS PUA	9	8620	5429	314	1588	5.1	123	5	4	4
16	213	RAHUE	10	62582	2898	1539	21595	14.0	123	5	5	5
17	233	TRAPEN BAJO	10	5853	2794	360	2095	5.8	113	4	5	3
				934691								

Table 5-2 Bridges Desirable Early Repair

NO	NO	NOMBRE	REG	COST	ADT	BA	COST/ ADT	COST/ BA/ADT	TE	L	S	I
1	54	PS TENIENTE ORI	6	17880	15340	324	1166	3.6	128	4	4	4
2	110	PIGUCHEN	7	13798	5971	194	2311	11.9	121	4	4	4
3	108	LONGAVI	7	75423	5971	3326	12632	3.8	128	4	4	4
4	138	RELBUN	8	117684	12644	443	9307	21.0	130	4	4	4
5	134	GALLIPAVO	8	12401	12644	306	981	3.2	128	4	4	4
6	150	BIO-BIO	8	300204	5659	1614	53049	32.9	134	4	4	4
7	124	MENELHUE	8	8082	6485	236	1246	5.3	129	4	4	4
8	149	DUQUECO	8	119631	5659	1505	21140	14.0	118	4	4	4
9	155	ESPERANZA	9	12074	5659	837	2134	2.5	132	4	4	4
10	181	CHADA	9	116063	2828	246	41041	166.8	123	4	4	4
11	171	CAUTIN	9	89613	4798	6713	18677	2.8	123	4	4	4
12	172	METRENCO	9	9222	4793	234	1924	8.2	123	4	4	4
13	188	LELFUCADE 2	10	2926	1856	124	1577	12.7	138	4	4	4
				895001								

ADT: Volumen de tránsito promedio diario
BA : Área del puente
TE : Evaluación total de prioridades de rehabilitación
L : Grado de deterioro de la losa
S : Grado de deterioro de la superestructura
I : Grado de deterioro de la infraestructura

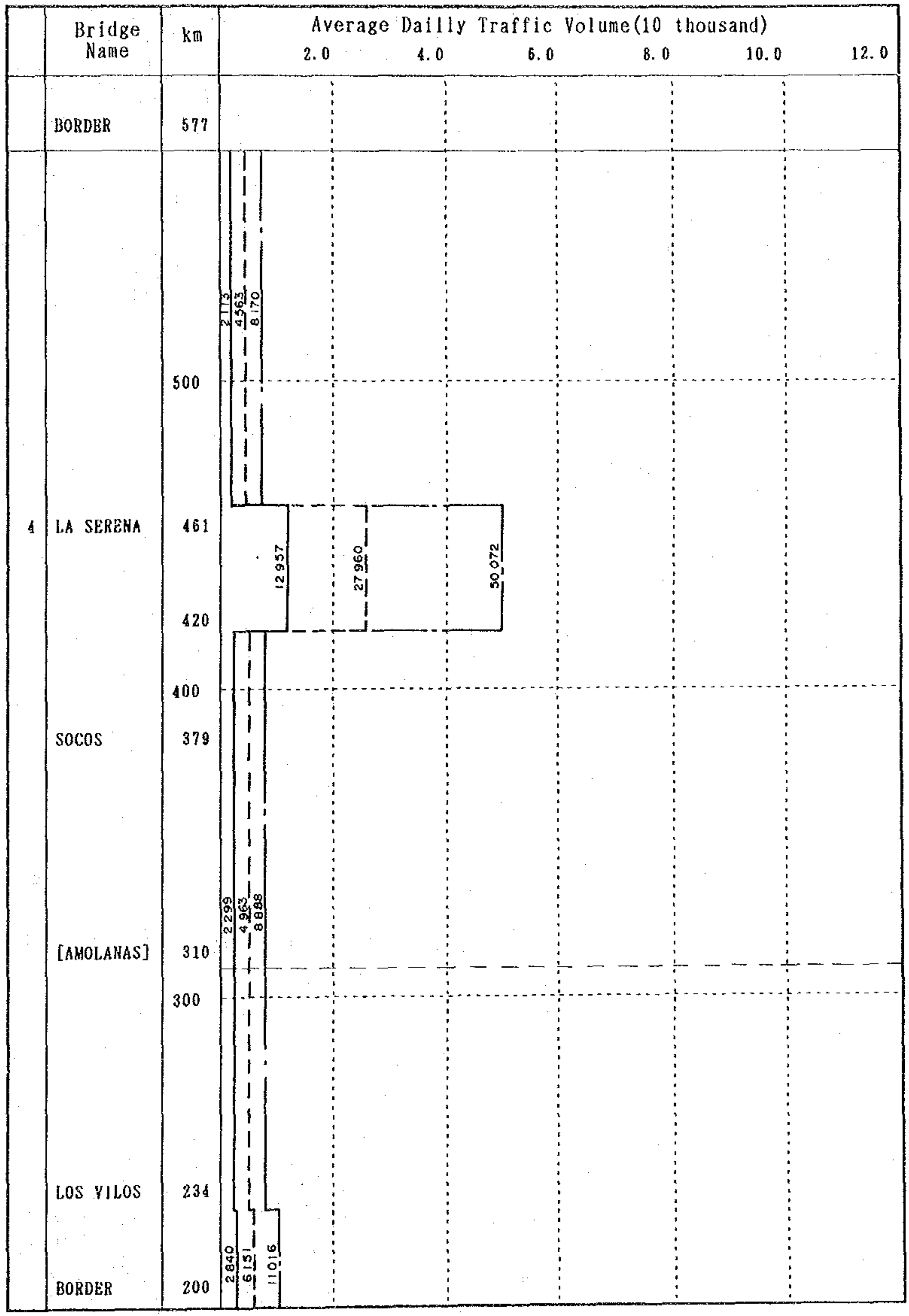


Figure 5-1 Traffic Volume on the Route 5 (Region 4)

1 9 9 2 (Year)
2 0 0 2
2 0 1 2

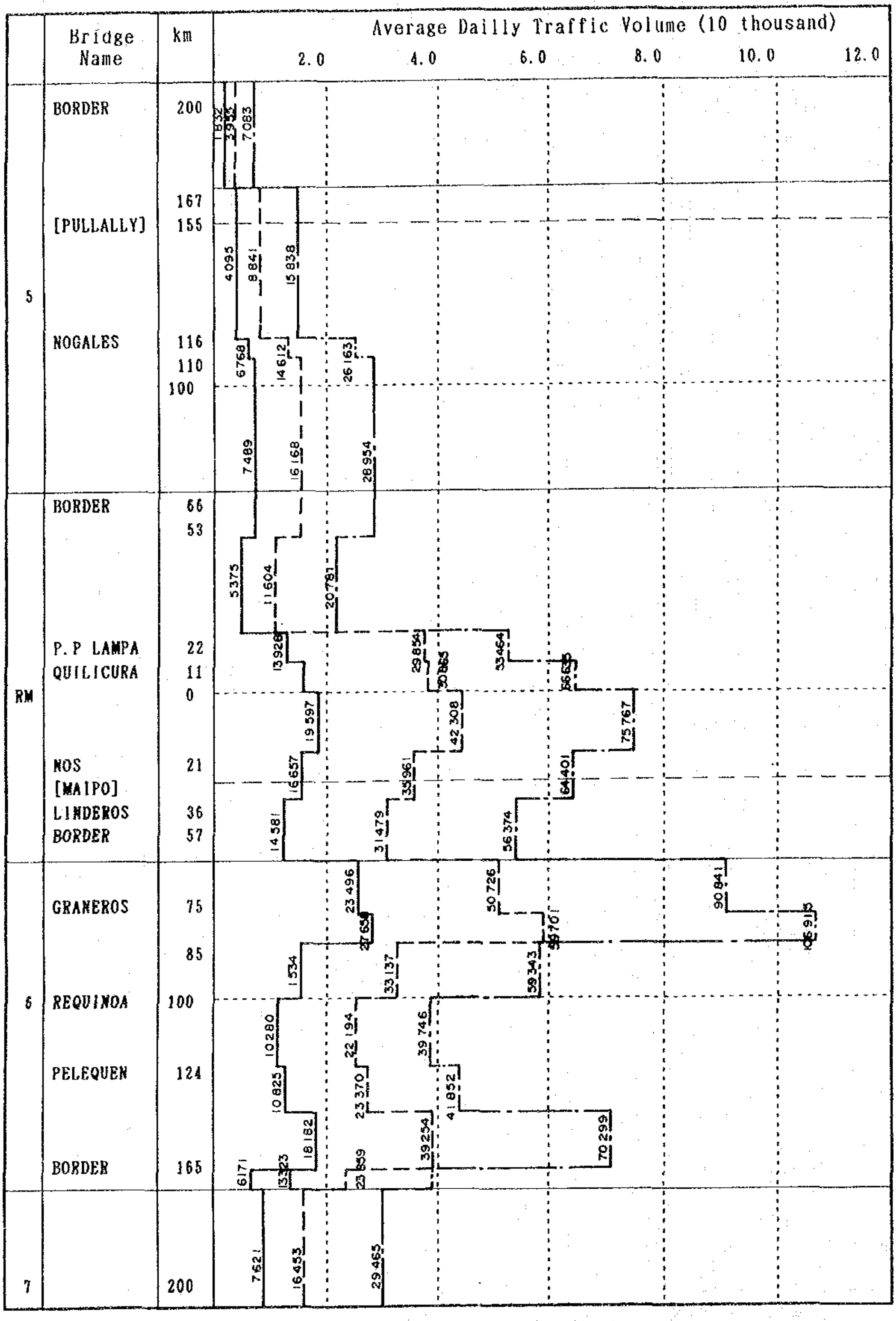


Figure 5-2 Traffic Volume on the Route 5 (Region 5, Region RM Region 6)

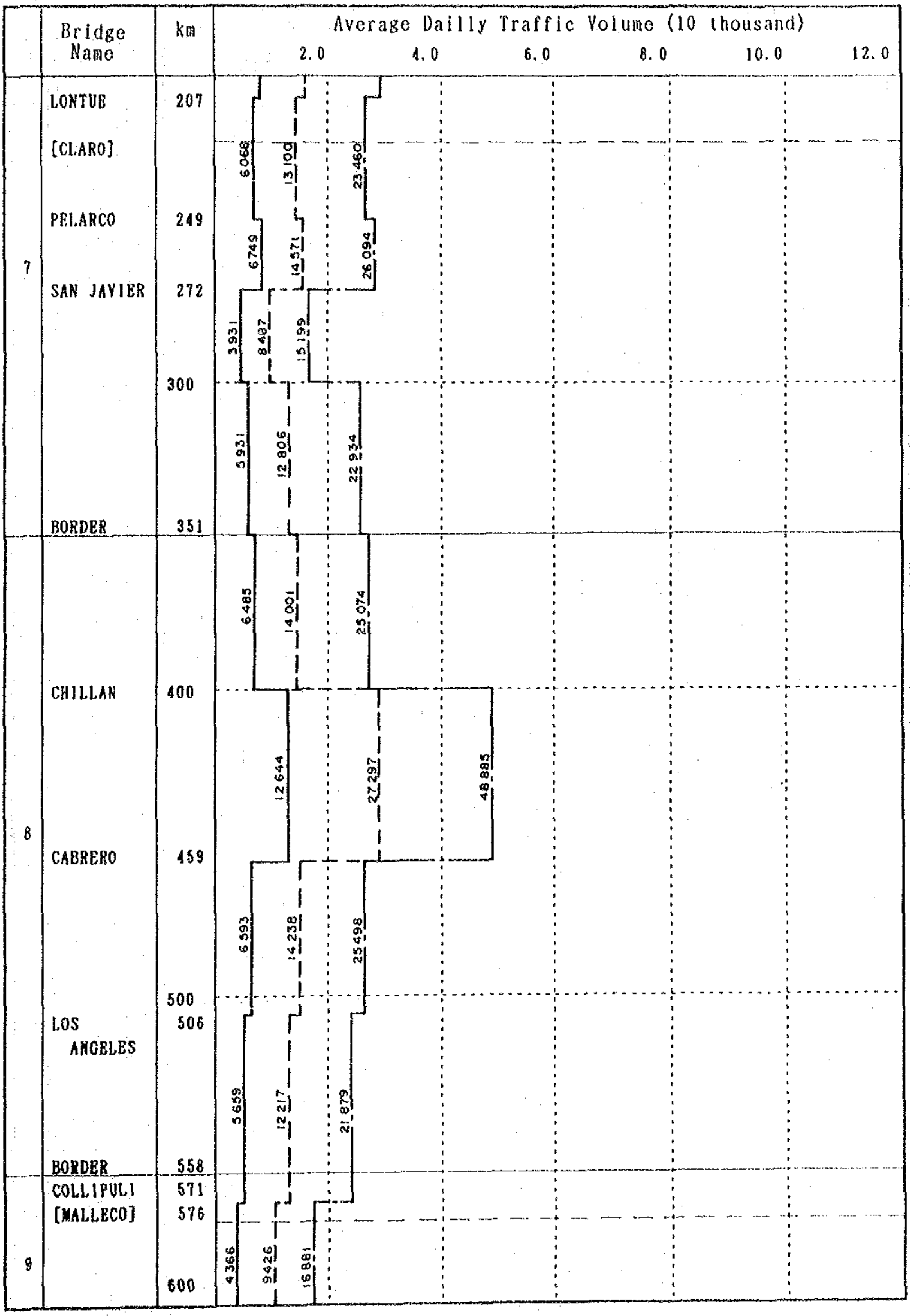


Figure 5-3 Traffic Volume on the Route 5 (Region 7,8)

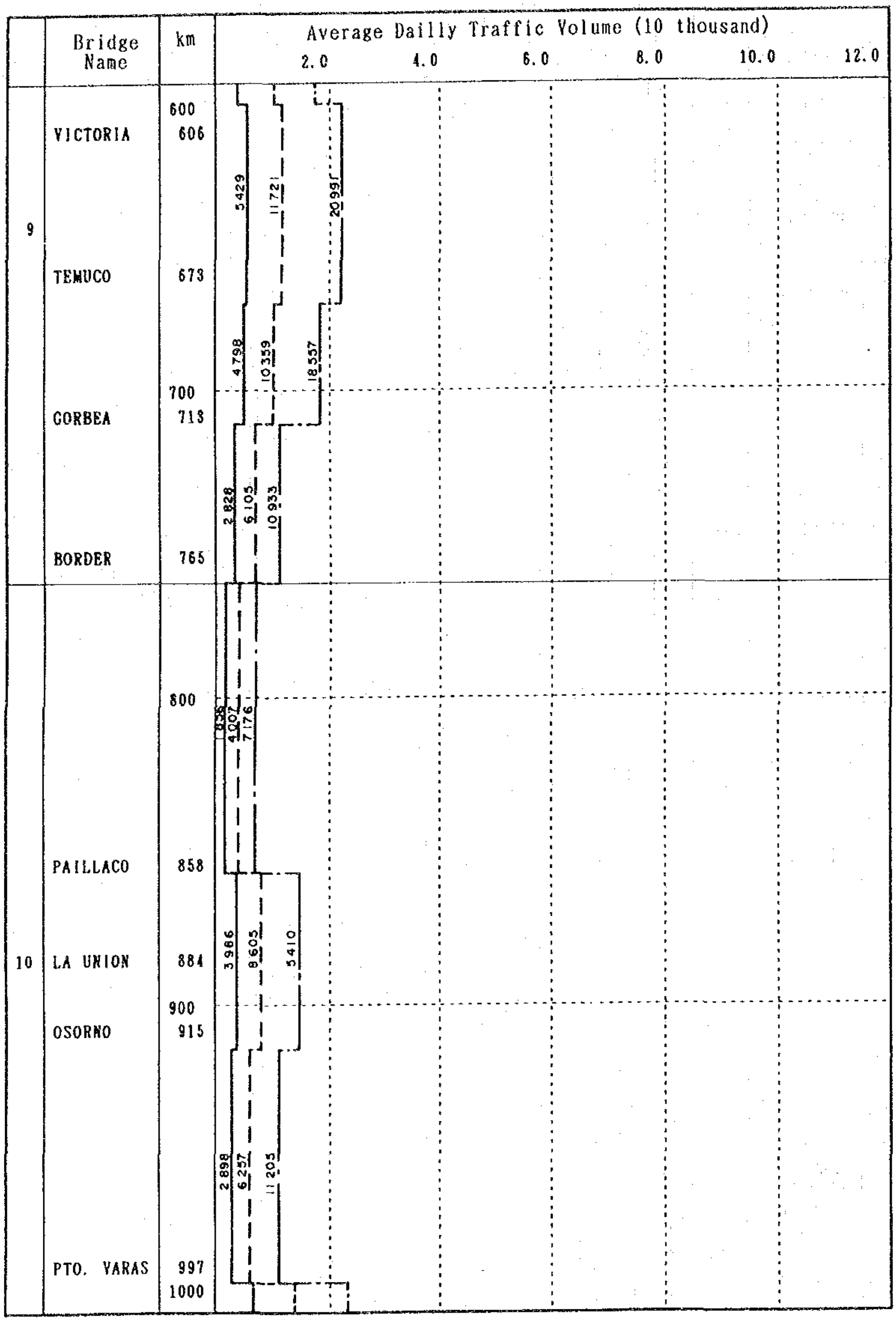


Figure 5-4 Traffic Volume on the Route 5 (Region 9,10)

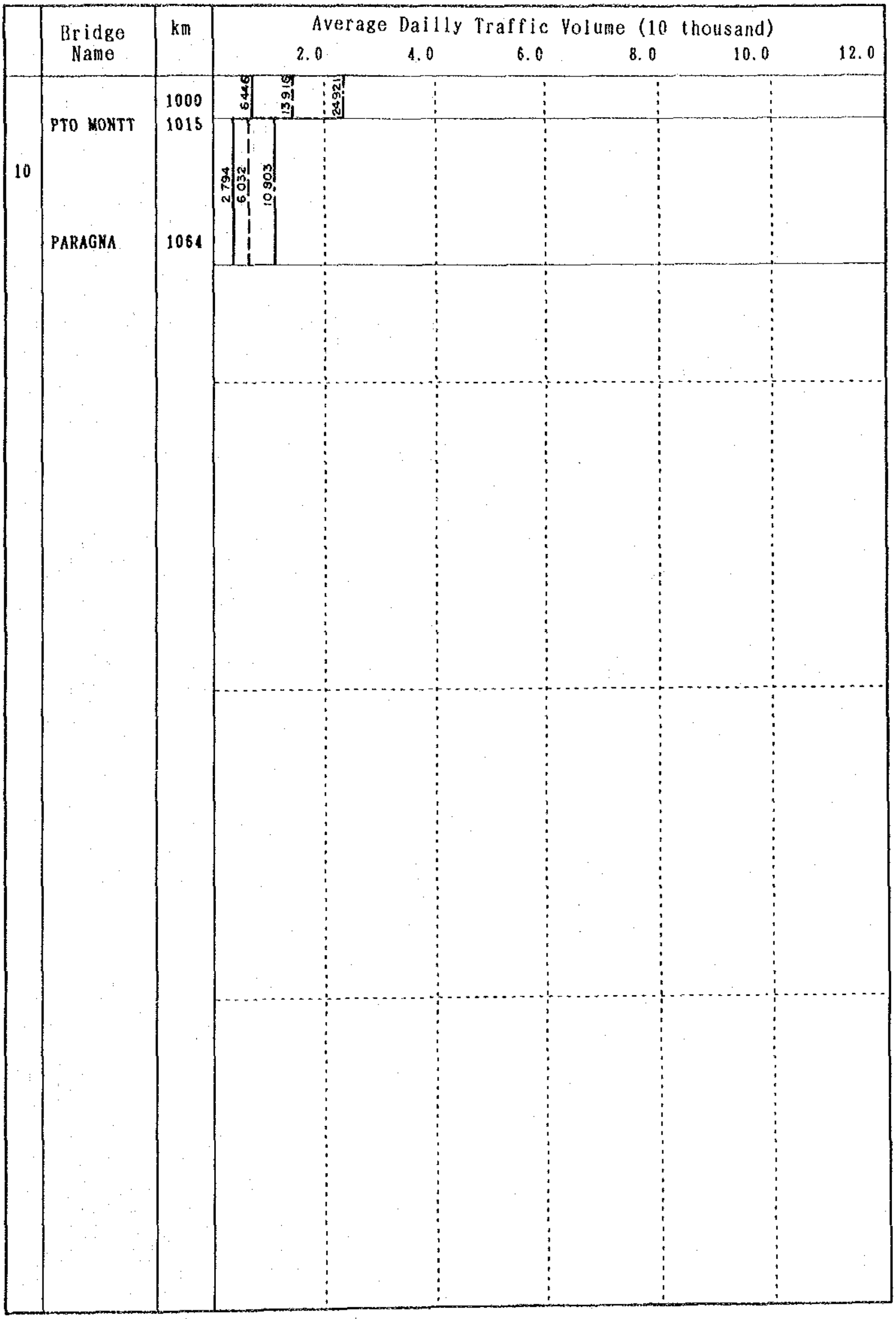


Figure 5-5 Traffic Volume on the Route 5 (Region 10)

Table 5-3 (1) Priority of Repair Evaluated by Integrated Evaluation Indication (TE)

	NO	NOMBRE	TIPO	REG	km	REHA.COST (x1000)	ADT	BA (m2)	COST /ADT	COST/BA /ADT	TE	EV. L	EV. S	EV. I
1	188	LELFUCADE 2	ACE	10	771.4	2,926	1,856	124	1,576	12.68	138	4	4	4
2	98	MAULE PONIENTE	MIX	7	269.5	381,783	6,749	2,874	56,569	19.69	137	5	5	5
3	99	MAULE ORIENTE	ACE	7	269.5	163,630	6,749	1,517	24,245	15.98	137	4	5	5
4	150	BIO-BIO	HAG	8	531.8	300,204	5,659	1,614	53,049	32.87	134	4	4	4
5	152	BUREO	HAG	8	545.6	33,899	5,659	1,408	5,990	4.25	132	5	4	4
6	155	ESPERANZA	HAG	9	561.7	12,074	5,659	837	2,134	2.55	132	4	4	4
7	156	MININCO	HAG	9	564.1	29,034	5,659	588	5,131	8.72	132	4	5	4
8	90	CLARO	ARS	7	218.4	17,358	6,068	1,059	2,861	2.70	131	5	5	3
9	53	PS TENIENTE PON	HA-	6	88.9	34,990	15,340	338	2,281	6.75	130	4	4	5
10	123	NINQUIHUE	LOS	8	387.5	13,313	6,485	206	2,053	9.96	130	4	4	5
11	138	RELBUN	HAG	8	448.3	117,684	12,644	443	9,307	21.00	130	4	4	4
12	142	BATUQUITO	LOS	8	484.6	65,542	6,593	144	9,941	69.25	130	4	4	5
13	160	CHAMICHACO	HA-	9	590.8	5,176	4,366	163	1,185	7.29	130	5	4	4
14	29	PULLALLY	ACE	5	155.2	48,916	4,095	1,552	11,945	7.70	129	4	4	5
15	124	MENELHUE	LOS	8	390.5	8,082	6,485	236	1,246	5.28	129	4	4	4
16	54	PS TENIENTE ORI	ACE	6	88.9	17,880	15,340	324	1,166	3.59	128	4	4	4
17	97	PIDUCO	LOS	7	257.4	39,535	6,749	371	5,858	15.80	128	5	5	5
18	108	LONGAVI	ACE	7	320.5	75,423	5,971	3,326	12,632	3.80	128	4	4	4
19	134	GALLIPAVO	LOS	8	429.7	12,401	12,644	306	981	3.21	128	4	4	4
20	140	LAJITA	ACE	8	474.8	8,422	6,593	304	1,277	4.20	128	4	5	4
21	141	BATUCO	LOS	8	483.6	11,192	6,593	331	1,698	5.13	125	5	4	4
22	159	HUEQUEN	LOS	9	589.0	75,540	4,366	233	17,302	74.37	125	5	5	5
23	137	DIGUILLIN	HA-	8	444.3	163,725	12,644	683	12,949	18.96	124	4	5	5
24	166	QUINO	ARN	9	619.5	79,212	5,429	578	14,590	25.24	124	4	4	5
25	168	PS PUA	LOS	9	622.0	8,620	5,429	314	1,588	5.05	123	5	4	4
26	171	CAUTIN	HAG	9	677.9	89,613	4,798	6,713	18,677	2.78	123	4	4	4
27	172	METRENCO	HA-	9	687.1	9,222	4,798	234	1,922	8.21	123	4	4	4
28	181	CHADA	LOS	9	713.0	116,063	2,828	246	41,041	166.72	123	4	4	4
29	213	RAHUE	ARN	10	959.4	62,582	2,898	1,539	21,595	14.03	123	5	5	5
30	117	NIQUEN	LOS	8	359.6	4,232	6,485	261	653	2.50	122	4	5	3
31	110	PIGUCHEN	LOS	7	320.5	13,798	5,971	194	2,311	11.92	121	4	4	4
32	143	SALTO DEL LAJA	ACE	8	486.4	166,744	6,593	1,187	25,291	21.31	121	5	5	4
33	70	ANTIVERO PONIEN	HAG	6	140.2	26,511	18,182	1,574	1,458	0.93	120	5	4	3

Tabla 5-3(2)

	NO	NOMBRE	TIPO	REG	km	REHA.COST (x1000)	ADT	BA (m2)	COST /ADT	COST/BA /ADT	TE	EV. L	EV. S	EV. I
34	165	CHANCO	ACE	9	618.0	6,076	5,429	203	1,119	5.51	120	5	4	3
35	149	DUQUECO	HPO	8	524.0	119,631	5,659	1,505	21,140	14.05	118	4	4	4
36	161	DUMO	ARS	9	600.9	85,112	4,366	294	19,494	66.36	118	4	5	3
37	233	TRAPEN BAJO	LOS	10	1097.0	5,853	2,794	360	2,095	5.81	113	4	5	3
38	167	EL SALTO	ACE	9	621.2	2,194	5,429	202	404	2.00	112	3	4	4
39	15	HUENTELAUQUEN	MIX	4	263.0	8,790	2,299	2,063	3,824	1.85	111	3	4	3
40	44	PEUCO ORIENTE	ACE	6	61.9	8,721	23,496	1,030	371	0.36	111	4	4	3
41	106	ACHIBUENO	HAG	7	305.5	43,610	5,971	2,685	7,304	2.72	111	4	3	4
42	88	PIRIHUIN	LOS	7	200.0	8,896	6,068	256	1,466	5.73	110	4	4	3
43	104	ANCOA 1	HAG	7	303.7	12,841	5,971	790	2,151	2.72	109	4	3	4
44	170	PUMALAL	MIX	9	665.4	28,977	5,429	668	5,337	7.99	109	4	4	2
45	175	QUEPE ANTIGUO	ACE	9	690.3	14,722	4,798	824	3,068	3.72	108	4	3	4
46	101	PS BOBADILLA	HAG	7	271.8	20,361	6,749	385	3,017	7.84	107	4	4	3
47	176	QUEPE NUEVO	MIX	9	690.3	59,710	4,798	720	12,445	17.28	107	3	3	5
48	151	DESCARGA	LOS	8	531.9	7,870	5,659	902	1,391	1.54	105	3	4	4
49	244	PAINE PONIENTE	ACE	13	48.3	2,759	14,581	190	189	1.00	105	3	4	4
50	169	QUILLEM	HAG	9	639.5	13,240	5,429	530	2,439	4.60	104	4	4	2
51	178	PERALES	ACE	9	696.6	4,251	4,798	204	886	4.34	104	2	4	4
52	36	EL LITRE	ACE	5	112.6	0	6,768	433	0	0.00	103	3	3	4
53	81	TENO	HAG	7	178.0	43,172	7,621	2,653	5,665	2.14	103	3	4	3
54	95	PS SAN CLEMENTE	HA-	7	252.8	10,432	6,749	283	1,546	5.46	103	4	4	3
55	122	NAVOTAVO	LOS	8	378.2	3,786	6,485	301	584	1.94	103	4	4	3
56	82	GUAIQUILLO ORIE	HAG	7	194.0	125,194	7,621	756	16,427	21.74	102	3	3	4
57	102	QUILIPIN	ACE	7	294.9	140,760	3,971	311	35,447	113.99	102	3	3	4
58	147	RARINCO	HA-	8	508.1	7,577	5,659	252	1,339	5.31	101	4	3	4
59	185	LO VASQUEZ 3	LOS	9	759.9	104,614	2,828	165	36,992	224.19	101	4	3	4
60	14	AMOLANAS	ARN	4	310.0	84,333	2,299	1,999	36,682	18.35	100	4	3	4
61	116	PERQUILAUQUEN	HAG	8	351.6	141,832	6,485	3,294	21,871	6.64	100	3	4	3
62	22	QUILIMARI	HAG	4	200.6	64,762	2,840	844	22,803	27.02	99	3	3	4
63	86	LONTUE ORIENTE	HAG	7	197.0	23,894	7,621	1,740	3,135	1.80	99	4	3	3
64	157	MALLECO	ACE	9	576.7	109,817	4,366	6,918	25,153	3.64	99	4	4	4
65	17	CHICUALOCO	HAG	4	244.6	0	2,299	440	0	0.00	98	3	4	3
66	38	ACONCAGUA-OCOA	HAG	5	100.0	2,062	7,489	1,326	275	0.21	98	3	3	4

Tabla 5-3(3)

	NO	NOMBRE	TIPO	REG	km	REHA.COST (x1000)	ADT	BA (m2)	COST /ADT	COST/BA /ADT	TE	EV. L	EV. S	EV. I
67	132	LARQUI	HAG	8	425.6	11,465	12,644	703	907	1.29	98	4	3	3
68	187	LELFUCADE 1	HAG	10	770.8	15,865	1,856	554	8,548	15.42	97	4	3	3
69	245	PAINE ORIENTE	ACE	13	48.3	0	14,581	202	0	0.00	95	3	3	4
70	203	CHOROY	ACE	10	870.6	4,432	3,986	272	1,112	4.09	94	3	4	3
71	13	EL TENIENTE	HAG	4	335.1	1,817	2,299	1,042	790	0.76	93	3	3	3
72	100	LAS VERTIENTES	HAG	7	270.0	34,595	6,749	486	5,126	10.56	93	3	4	3
73	105	ANCOA 2	HAG	7	304.8	7,581	5,971	960	1,270	1.32	93	3	3	4
74	31	TALAQUEN	LOS	5	149.3	3,176	4,095	108	776	7.18	92	3	3	4
75	158	PS PIDIMA	ACE	9	584.5	3,791	4,366	250	868	3.47	92	3	4	3
76	189	NEGRO	ACE	10	775.8	8,951	1,856	1,403	4,823	3.44	92	3	4	3
77	236	LO PINTO 1 ORI.	LOS	13	22.0	0	13,928	123	0	0.00	90	3	3	4
78	20	TOTORALILLO	HAG	4	211.1	0	2,840	676	0	0.00	88	3	3	3
79	79	PEOR ES NADA OR	HAG	6	164.5	0	6,171	626	0	0.00	88	3	3	3
80	107	LIGUAY	HA-	7	316.6	20,528	5,971	780	3,438	4.41	86	3	3	4
81	120	BULI	LOS	8	369.4	6,305	6,485	134	972	7.26	86	4	3	3
82	103	PUTAGAN	HA-	7	295.7	33,368	3,971	936	8,403	8.98	85	3	3	4
83	32	QUEBRADILLA	LOS	5	145.9	0	4,095	304	0	0.00	84	3	3	4
84	33	EL COBRE	LOS	5	123.4	0	4,095	562	0	0.00	84	3	3	4
85	205	CUNO CUNO	ACE	10	873.4	2,830	3,986	272	710	2.61	84	3	4	2
86	43	PEUCO PONIENTE	MIX	6	61.9	4,168	23,496	797	177	0.22	83	3	3	4
87	186	CRUCES	HAG	10	767.9	2,688	1,856	711	1,449	2.04	83	3	3	3
88	23	PS LOS MOLLES	LOS	5	188.0	0	1,832	181	0	0.00	82	3	3	4
89	48	BENITO PONIENTE	HA-	6	74.8	2,726	23,496	157	116	0.74	82	3	3	3
90	177	HUILQUILCO	ACE	9	693.3	4,009	4,798	203	836	4.12	82	3	4	2
91	35	NOGALES	HAG	5	116.0	2,562	6,768	932	379	0.41	81	3	3	3
92	84	PS MAQUEHUA ORI	HAG	7	194.6	11,764	7,621	772	1,544	2.00	81	4	3	2
93	179	PS FREIRE	LOS	9	699.3	3,078	4,798	135	641	4.75	81	4	3	3
94	60	CLARO ORIENTE	HAG	6	114.5	0	10,280	851	0	0.00	80	3	3	3
95	202	LLOLLELHUE	ACE	10	869.2	562	3,986	538	141	0.26	80	4	2	3
96	207	TRAIGUEN	ACE	10	887.1	9,302	3,986	604	2,334	3.86	80	3	4	2
97	92	PANGUE	HAG	7	245.0	8,091	6,068	1,133	1,333	1.18	79	3	3	3
98	24	CHIVATO	HAG	5	185.3	0	1,832	414	0	0.00	78	3	3	3
99	125	PS IANSA	LOS	8	393.6	1,213	6,485	125	187	1.49	78	4	3	3

Tabla 5-3(4)

	NO	NOMBRE	TIPO	REG	km	REHA.COST (x1000)	ADT	BA (m2)	COST /ADT	COST/BA /ADT	TE	EV. L	EV. S	EV. I
100	209	PILMAIQUEN	HPO	10	895.0	15,732	3,986	1,008	3,947	3.92	78	4	3	3
101	91	CHAGRES	HA-	7	223.4	2,111	6,068	282	348	1.24	77	2	3	4
102	184	LO VASQUEZ 2	HA-	9	759.5	5,313	2,828	144	1,879	13.03	77	2	3	3
103	16	MILLAHUE	LOS	4	261.5	2,391	2,299	311	1,040	3.34	76	3	3	3
104	27	LONGOTOMA 2	HA-	5	163.2	0	4,095	1,091	0	0.00	75	3	3	3
105	72	TINGUIRIRICA P	HAG	6	143.3	0	18,182	1,927	0	0.00	75	3	3	3
106	25	LA BALLENA	LOS	5	180.2	0	1,832	159	0	0.00	74	3	3	3
107	50	CADENA	LOS	6	80.3	11,935	27,653	312	432	1.38	74	3	3	3
108	64	RIGOLEMU ORIENT	HAG	6	126.3	0	10,820	480	0	0.00	74	3	3	3
109	111	PS COPIHUE	HAG	7	331.4	6,861	5,971	279	1,149	4.12	74	3	3	3
110	200	HUINA HUINA	ACE	10	833.5	5,623	1,856	480	3,030	6.31	74	3	4	2
111	204	NISCON	ACE	10	872.5	2,524	3,986	272	633	2.33	74	3	3	3
112	131	NEBUCO	HAG	8	414.9	0	12,644	1,384	0	0.00	73	3	3	2
113	214	CHIFIN	ACE	10	973.8	3,172	2,898	416	1,094	2.63	73	3	4	2
114	234	PEUCO ORIENTE	LOS	13	41.5	0	5,375	180	0	0.00	73	3	3	3
115	12	LA CEBADA	ACE	4	337.9	0	2,299	238	0	0.00	72	3	3	3
116	39	PS LA CALAVERA	MIX	5	94.2	0	7,489	409	0	0.00	72	3	3	3
117	45	PS TRONCO	LOS	6	66.5	1,006	23,496	249	43	0.17	72	3	3	3
118	56	PS LIRIOS ORIEN	ACE	6	96.7	0	15,340	665	0	0.00	72	3	3	3
119	57	PS LIRIOS PONIE	HAG	6	96.7	0	15,340	642	0	0.00	72	2	3	3
120	93	LIRCAY 1	HA-	7	251.3	0	6,749	1,192	0	0.00	72	3	3	3
121	113	COLLIGUAY	LOS	7	335.9	968	5,971	119	162	1.37	72	3	3	3
122	162	COLO	ARS	9	608.2	8,988	5,429	497	1,656	3.33	72	3	3	3
123	197	HUILLINCO	ACE	10	825.1	5,699	1,856	756	3,071	4.06	72	3	4	2
124	58	TIPAUME ORIENTE	HAG	6	113.3	0	10,280	360	0	0.00	71	3	3	3
125	78	PEOR ES NADA PO	HPO	6	164.5	0	6,171	702	0	0.00	71	3	3	3
126	4	CULEBRON PONIEN	ACE	4	463.5	0	2,113	558	0	0.00	70	3	3	3
127	42	LOS LOROS	LOS	5	77.8	0	7,489	309	0	0.00	70	3	3	4
128	21	PS PALO COLORAD	HA-	4	202.7	0	2,840	350	0	0.00	69	3	3	3
129	180	TOLTEN	ARN	9	704.0	42,506	4,798	4,070	8,859	2.18	69	3	3	3
130	193	INAQUE	ACE	10	804.0	2,379	1,856	896	1,282	1.43	68	4	3	2
131	7	CAMARONES 2	MIX	4	417.0	0	2,299	285	0	0.00	67	3	3	3
132	10	QUEBRADA SECA	LOS	4	396.7	0	2,299	599	0	0.00	66	3	3	3

Tabla 5-3(5)

	NO	NOMBRE	TIPO	REG	km	REHA.COST (x1000)	ADT	BA (m2)	COST /ADT	COST/BA /ADT	TE	EV. L	EV. S	EV. I
133	40	LAS VEGAS PO	MIX	5	88.4	0	7,489	286	0	0.00	66	3	3	3
134	112	COPIHUE	LOS	7	332.5	7,440	5,971	236	1,246	5.28	66	3	3	3
135	5	CULEBRON ORIENT	HA-	4	463.5	0	2,113	461	0	0.00	65	2	2	3
136	28	LONGOTOMA 1	LOS	5	163.0	0	4,095	156	0	0.00	65	3	3	3
137	34	EL MELON	LOS	5	120.3	0	4,095	1,048	0	0.00	65	3	3	3
138	118	COLLIGUAY	LOS	8	361.7	0	6,485	165	0	0.00	65	3	3	2
139	230	CEBADAL	LOS	10	1089.6	0	2,794	153	0	0.00	65	3	3	3
140	30	JAURURO	LOS	5	152.9	0	4,095	244	0	0.00	64	3	3	3
141	41	LAS VEGAS OR	MIX	5	88.4	0	7,489	286	0	0.00	64	3	3	3
142	46	STA. BLANCA PON	HA-	6	71.5	0	23,496	389	0	0.00	64	2	3	3
143	61	CLARO PONIENTE	HA-	6	114.5	0	10,280	846	0	0.00	64	3	3	3
144	148	QUILQUE	LOS	8	514.0	7,830	5,659	152	1,384	9.11	64	3	3	3
145	190	RUCACO	ACE	10	787.0	14,693	1,856	1,613	7,916	4.91	64	3	3	3
146	206	LA POZA	ACE	10	883.3	1,457	3,986	271	366	1.35	64	3	3	2
147	237	LO PINTO 1 PON.	HA-	13	22.0	0	13,928	183	0	0.00	64	3	3	3
148	65	RIGOLEMU PONIEN	ACE	6	126.3	0	10,820	624	0	0.00	63	2	3	3
149	139	ITATA	ARS	8	455.3	14,834	12,644	683	1,173	1.72	63	3	3	3
150	6	LAGUNILLAS	HA-	4	442.4	0	12,951	500	0	0.00	62	3	2	3
151	49	BENITO ORIENTE	LOS	6	74.8	0	23,496	239	0	0.00	62	3	3	3
152	121	GAONA	LOS	8	373.5	0	6,485	135	0	0.00	62	3	3	2
153	154	CANAL RIEGO	ACE	8	554.8	1,004	5,659	104	177	1.71	62	3	3	3
154	163	TRAIGUEN	ACE	9	609.2	4,204	5,429	300	774	2.58	62	3	3	2
155	164	TRICAUCO	ACE	9	614.2	1,669	5,429	201	307	1.53	62	3	3	2
156	235	PEUCO PONIENTE	ACE	13	41.5	0	5,375	162	0	0.00	62	2	3	3
157	242	PS PAINE ORIENT	HA-	13	45.3	0	14,581	236	0	0.00	62	3	3	3
158	243	PS PAINE PONIEN	ACE	13	45.3	0	14,581	230	0	0.00	62	3	3	3
159	247	PS HOSPITAL PON	MIX	13	51.2	0	14,581	733	0	0.00	62	3	3	3
160	208	RIO BUENO	HPO	10	889.2	28,500	3,986	3,338	7,150	2.14	61	4	2	2
161	2	FISCAL	HAG	4	474.1	0	2,113	1,191	0	0.00	60	2	2	3
162	26	HUAQUEN	HA-	5	171.4	0	1,832	632	0	0.00	60	3	2	3
163	133	PITE	LOS	8	426.8	0	12,644	216	0	0.00	60	3	3	2
164	135	ESPINAL	LOS	8	433.7	3,811	12,644	226	301	1.33	60	3	2	3
165	89	ESTERO SECO	HPO	7	201.1	0	6,068	328	0	0.00	58	2	2	2

Tabla 5-3(6)

	NO	NOMBRE	TIPO	REG	km	REHA.COST (x1000)	ADT	BA (m2)	COST /ADT	COST/BA /ADT	TE	EV. L	EV. S	EV. I
166	96	PS LIRCAY	HAG	7	255.8	887	6,749	445	131	0.30	57	2	2	3
167	3	PS LA SERENA	MIX	4	473.9	0	2,113	1,698	0	0.00	56	2	3	3
168	8	CAMARONES 1	MIX	4	416.0	0	2,299	502	0	0.00	56	2	2	3
169	218	EL BURRO	ACE	10	1002.9	3,643	6,446	161	565	3.51	56	2	3	2
170	18	CONCHALI	HPO	4	229.3	0	2,840	495	0	0.00	55	3	2	3
171	211	PUQUITRE	LOS	10	941.7	4,147	2,898	237	1,431	6.03	55	3	2	3
172	1	JUAN SOLDADO	ARN	4	503.6	0	2,113	1,542	0	0.00	54	3	3	2
173	9	EL ALMENDRO	MIX	4	411.9	0	2,299	199	0	0.00	54	2	2	3
174	11	LIMARI	ARN	4	378.1	0	2,299	1,648	0	0.00	54	3	3	2
175	153	CHUMULCO	HA-	8	551.6	919	5,659	214	162	0.76	54	3	3	2
176	191	PS MAFIL	ACE	10	799.7	0	1,856	335	0	0.00	54	2	3	3
177	217	PESCADO	ACE	10	997.7	2,949	6,446	161	457	2.84	54	1	3	2
178	221	ARENAS	LOS	10	1044.4	0	2,794	261	0	0.00	54	3	3	2
179	226	GAUDA	HA-	10	1077.2	1,153	2,794	169	413	2.44	54	3	3	2
180	59	TIPAUME PONIENT	HA-	6	113.3	0	10,280	468	0	0.00	53	3	2	3
181	126	NUBLE	HPO	8	397.7	0	6,485	10,228	0	0.00	52	3	3	2
182	195	MAFIL 2	ACE	10	808.5	1,887	1,856	259	1,016	3.93	52	3	3	2
183	216	PS CASMA	ACE	10	996.9	694	2,898	206	239	1.16	52	2	3	2
184	219	MAULLIN	HPO	10	1028.6	11,058	2,794	633	3,958	6.25	52	3	3	2
185	246	PS HOSPITAL ORI	HPO	13	51.2	0	14,581	730	0	0.00	52	3	2	3
186	19	PS EL NEGRO	LOS	4	218.5	0	2,840	419	0	0.00	51	2	2	3
187	173	PICHIQUEPE ANTI	ACE	9	689.9	0	4,798	192	0	0.00	50	3	1	2
188	194	MAFIL 1	ACE	10	808.3	5,232	1,856	259	2,819	10.89	50	1	3	2
189	192	RUCAPICHIO	ACE	10	800.7	0	1,856	632	0	0.00	48	2	3	2
190	73	TINGUIRIRICA O	HPO	6	143.3	0	18,182	2,850	0	0.00	47	2	2	3
191	119	VIRGUIN	LOS	8	365.8	0	6,485	140	0	0.00	47	2	2	2
192	196	MAFIL 3	ACE	10	808.8	1,239	1,856	627	668	1.06	47	3	3	1
193	232	LOS PALOS	LOS	10	1096.0	1,982	2,794	140	710	5.05	47	3	2	2
194	47	STA. BLANCA ORI	LOS	6	71.5	2,726	23,496	300	116	0.39	46	2	2	3
195	69	ANTIVERO ORIENT	HPO	6	140.2	0	18,182	1,574	0	0.00	45	2	2	3
196	77	DESCARGA 2 PONI	LOS	6	144.5	0	18,182	193	0	0.00	45	2	2	3
197	37	PS EL OLIVO	ACE	5	108.0	0	7,489	456	0	0.00	44	2	2	3
198	62	PS PELEQUEN PON	ACE	6	125.6	0	10,820	240	0	0.00	44	2	2	3

Tabla 5-3(7)

	NO	NOMBRE	TIPO	REG	km	REHA.COST (x1000)	ADT	BA (m2)	COST /ADT	COST/BA /ADT	TE	EV. L	EV. S	EV. I
199	63	PS PELEQUEN ORI	HPO	6	125.6	0	10,820	240	0	0.00	44	2	2	3
200	66	CHARQUICAN ORIE	HA-	6	133.0	0	10,820	240	0	0.00	44	2	2	3
201	67	CHARQUICAN PONI	HA-	6	133.0	0	10,820	240	0	0.00	44	2	2	3
202	74	DESCARGA 1 ORIE	HA-	6	144.4	0	18,182	228	0	0.00	44	2	2	3
203	75	DESCARGA 1 PONI	HA-	6	144.4	0	18,182	228	0	0.00	44	2	2	3
204	76	DESCARGA 2 ORIE	HA-	6	144.5	0	18,182	230	0	0.00	44	2	2	3
205	115	LA VEGA	HA-	7	347.4	3,094	5,971	213	518	2.44	44	3	2	2
206	144	CALIBORO	LOS	8	488.0	8,853	6,593	217	1,343	6.18	44	2	2	3
207	182	DONGUIL	ACE	9	721.0	0	2,828	773	0	0.00	44	2	2	2
208	210	HUITRAL	LOS	10	938.5	2,951	2,898	264	1,018	3.85	44	3	2	2
209	174	PICHIQUEPE NUEV	MIX	9	698.9	0	4,798	204	0	0.00	43	1	2	2
210	225	GOMEZ	HA-	10	1077.0	1,031	2,794	388	369	0.95	43	3	2	2
211	51	PS ALAMEDA	ACE	6	87.3	0	15,340	633	0	0.00	42	3	3	3
212	52	PS MACHALI	ACE	6	87.9	0	15,340	288	0	0.00	42	3	3	3
213	71	PS LAS TERMAS	LOS	6	140.4	0	18,182	291	0	0.00	42	3	3	3
214	114	PARRAL	HPO	7	339.0	0	5,971	164	0	0.00	42	2	2	2
215	183	PS LONCOCHE	MIX	9	756.4	0	2,828	1,760	0	0.00	42	3	2	2
216	222	TAYLOR	HA-	10	1064.2	1,128	2,794	166	404	2.44	42	2	3	1
217	238	PS LO SIERRA	ACE	13	13.2	0	19,597	912	0	0.00	42	3	3	3
218	239	FFCC SUR LOSA	LOS	13	13.7	0	19,597	355	0	0.00	42	3	3	3
219	240	PS SUR ACERO	ACE	13	13.7	0	19,597	326	0	0.00	42	3	3	3
220	241	MAIPO	HPO	13	31.1	2,167	16,657	9,450	130	0.01	42	3	3	3
221	127	PS CHILLAN	ACE	8	405.7	0	12,644	556	0	0.00	40	1	1	1
222	145	PASO DE PIEDRA	LOS	8	493.5	0	6,593	182	0	0.00	40	1	2	2
223	231	MURROR	LOS	10	1091.4	1,982	2,794	154	710	4.61	40	3	2	1
224	201	EL TREBOL	ACE	10	844.5	1,322	1,856	533	712	1.34	38	2	2	2
225	136	PAL PAL	HPO	8	440.3	0	12,644	350	0	0.00	37	2	2	2
226	87	LONTUE PONIENTE	HPO	7	197.0	0	7,621	2,954	0	0.00	34	2	2	2
227	220	RIO NEGRO	LOS	10	1044.2	2,775	2,794	214	993	4.64	34	2	2	2
228	215	FORRAHUE	ACE	10	977.1	0	2,898	422	0	0.00	33	1	1	2
229	198	SAN PEDRO	ACE	10	831.8	9,092	1,856	4,185	4,899	1.17	32	3	2	3
230	223	TRAPEN	HA-	10	1066.0	0	2,794	376	0	0.00	32	3	1	1
231	224	ARENAS 2	HA-	10	1068.9	0	2,794	144	0	0.00	32	2	1	1

Tabla 5-3(8)

	NO	NOMBRE	TIPO	REG	km	REHA.COST (x1000)	ADT	BA (m2)	COST /ADT	COST/BA /ADT	TE	EV. L	EV. S	EV. I
232	227	TENIO	LOS	10	1085.0	0	2,794	154	0	0.00	32	2	1	2
233	55	CACHAPOAL	ACE	6	91.5	0	15,340	4,223	0	0.00	31	2	2	3
234	83	GUAIQUILLO PONI	HPO	7	194.0	0	7,621	1,302	0	0.00	29	2	1	2
235	94	LIRCAY 2	HPO	7	251.8	0	6,749	983	0	0.00	29	2	1	2
236	129	PS CONFLUENCIA	LOS	8	410.0	0	12,644	213	0	0.00	29	2	2	1
237	228	ASTIL	LOS	10	1087.8	0	2,794	155	0	0.00	29	1	2	1
238	229	TAMBOR	LOS	10	1088.7	0	2,794	358	0	0.00	29	2	2	1
239	85	PS MAQUEHUA PON	HPO	7	194.6	0	7,621	750	0	0.00	25	1	1	2
240	212	DAMAS	HPO	10	949.4	3,484	2,898	684	1,202	1.76	25	1	1	2
241	68	PS SAN FERNANDO	HPO	6	137.8	0	10,820	340	0	0.00	24	2	2	3
242	80	ENDESA	ACE	7	177.1	5,467	7,621	650	717	1.10	24	3	2	2
243	109	HUACARNECO	HPO	7	320.5	0	5,971	240	0	0.00	24	2	1	1
244	130	PS SANTA ELISA	HA-	8	410.5	0	12,644	168	0	0.00	20	1	1	1
245	199	PS LOS LAGOS	ACE	10	831.8	2,115	1,856	227	1,139	5.02	15	2	1	2
246	128	PS COCHARCAS	HA-	8	406.9	0	12,644	277	0	0.00	0	1	1	1
		TOTAL				4,022,669		190,683						

Chapter 6 Outline of The Guideline

6-1 Introduction

A bridge is one of the structural facilities which compose a road network system. It normally requires the largest amount of cost for its construction and maintenance. It is also inclined to face greater chances to suffer from natural disasters due to its functional characteristics. When the time comes for a bridge not to be able to keep it function, it will put enormous adverse efforts not only on road transportation, but also to stability and security of the society. Furthermore, restoration of the bridge function requires a huge cost as well as long period of time. Therefore, maintenance activity of the bridge plays a very important role to ensure safe, smooth and comfortable flow of road traffic.

This guideline is prepared for the engineers concerned in charge of the bridge maintenance. It presents the basic principles, methods and standards of the bridge inspection and subsequent maintenance. Therefore it does not cover all sorts of bridge inspection methodologies, nor introduce the detailed rehabilitation methods. The guideline is composed of the following contents.

1) Basic principles of bridge inspection and maintenance
2) Definition of terminology related to bridge engineering
3) Standard procedures of periodic bridge inspection
4) Evaluation of the results of inspection and evaluation criteria
5) Standardized rehabilitation methods
6) Standard procedures of detailed bridge inspection
7) Case study of bridge rehabilitation

This guideline is separately prepared from the Main Text of the Study, and is entitled "Guideline for Bridge Maintenance Inspection".

6-2 Basic Principles of Bridge Inspection and Maintenance

Bridge maintenance activity is defined as all the works to maintain the original function of the bridge from the time of its completion until it is replaced. This section describes the contents of the maintenance activity with work classification and explanation.

6-3 Definition of Terminology Related to Bridge Engineering

An inspector to engage in the bridge maintenance is not always an expert for bridge engineering. Therefore, the Guideline presents the definition of terminology related to bridge engineering for the inspectors who are not well versed in bridge engineering and is designed for their clear understanding. The Study also prepared a bridge register for maintenance purpose, in which the registered bridges are classified by structural components with coding for computer input. The terminology is explained in this section according to this coding order.

6-4 Standard Procedures of Periodic Bridge Inspection

There are two kinds of bridge inspections; one is the periodic inspection and the other is the detailed inspection. The periodic inspection is to be carried out to all the existing bridges in a certain interval, and the standard procedures of this inspection is focused on the following three items.

1) Visual inspection on the degrees of decay, deterioration and deformation

2) Measurement of basic bridge dimensions

3) Photographing the bridge

6-5 Evaluation of the Results of Inspection and Evaluation Criteria

The evaluation of the bridge deterioration is one of the most important tasks of the periodic inspection, but the evaluation is inclined to differ by the personal judgment of each inspector. In order to avoid the difference of evaluation of the bridge deterioration and make an objective evaluation, the Study worked out a check list as the evaluation criteria, and explained the characteristics of each deterioration, together with the standard procedures of inspection.

6-6 Standardized Bridge Rehabilitation Methods

The Ministry of Public Works in the Republic of Chile has a specification on the Standardized methods for the civil works to be implemented by the ministry. The Guideline describes selected standardized work methods which are to be applied to the bridge rehabilitation.

6-7 Standard Procedures of Detailed Bridge Inspection

Based on the detailed bridge inspection carried out in the Study, this section describes the standard procedures of detailed bridge inspection which includes those methods as application of inspection instruments like Schmidt Hammer and measurement instruments for deformation. At the same time, the Guideline also introduces some of those inspection methods which will be needed in the future, although they are not actually used in the Study.

6-8 Case Study of Bridge Rehabilitation

In order to demonstrate the standardized rehabilitation methods presented in section 6-6, this section presents a detailed explanation of some of the bridge rehabilitation methods which are considered for adoption in many cases to the existing bridges in Chile.

Chapter 7 Bridge Maintenance Management Systems

7-1 System Concept

The bridge management system presented in this paper is a support system to aid planning of bridge maintenance programs in a way that is both scientific and practical. The system involves the use of a microcomputer to store bridge-related data in a data base system.

When supplied with data for a number of bridges the system is able to devise inspection schedules, determine the order of priority for various maintenance operations as well as diagnose the condition of existing bridges. The basic structure of the system is as shown in Figure 7-1.

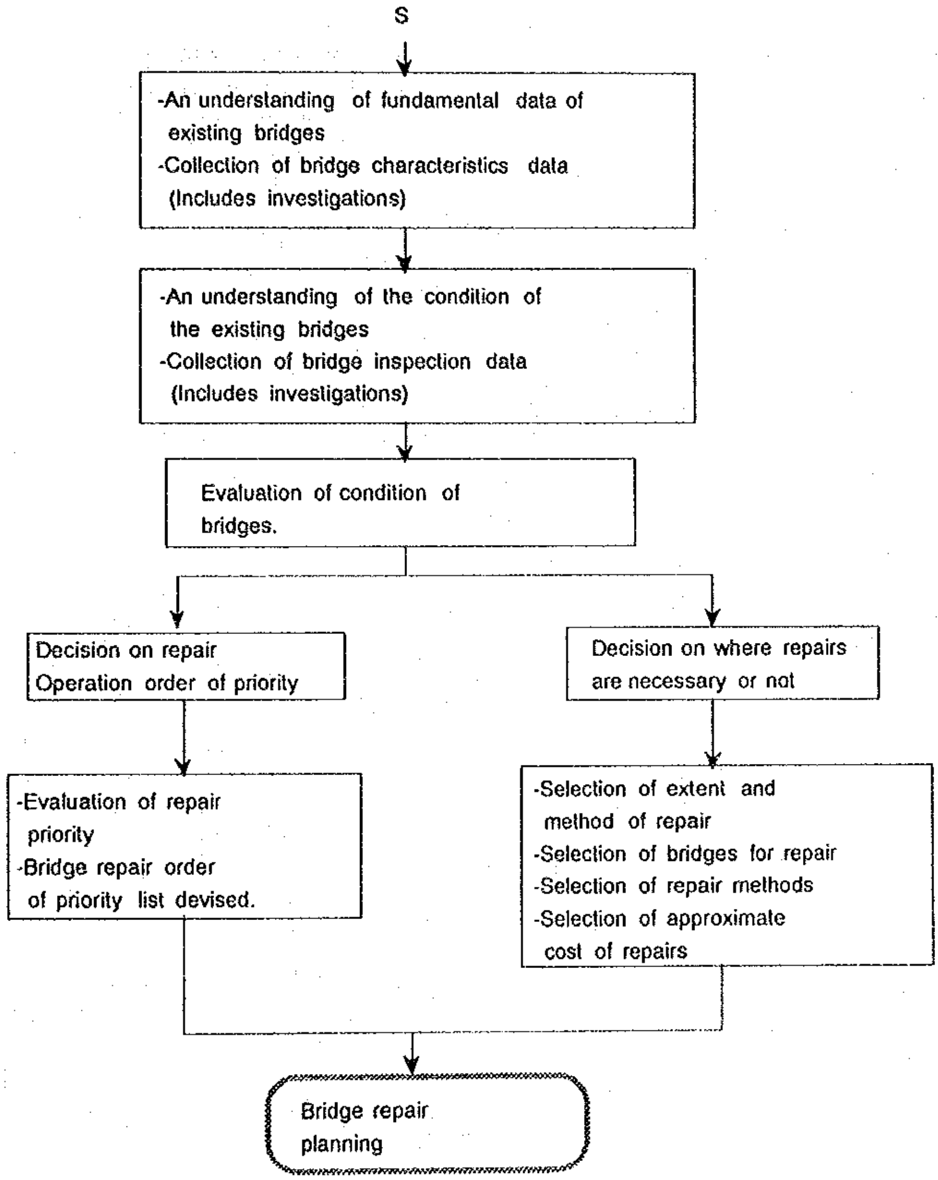


Figure 7-1 System concept

Figures 7-2 and 7-3 indicate the hardware and software used in the system.
(1) System structure

1) Software

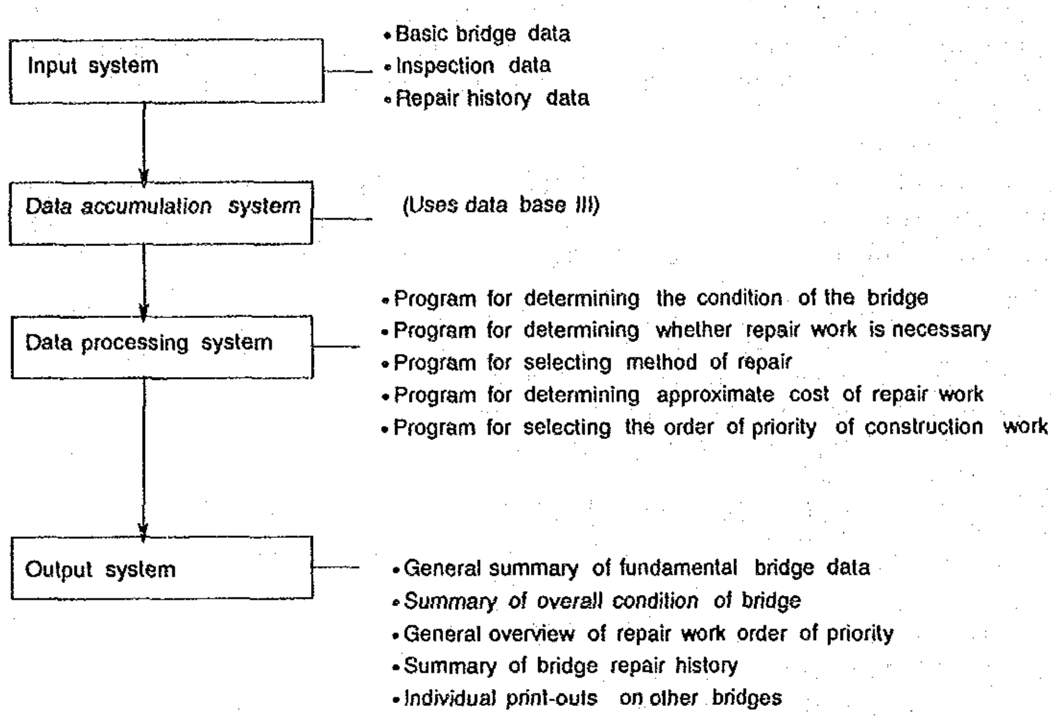


Figure 7-2 Structure of software

2) Hardware

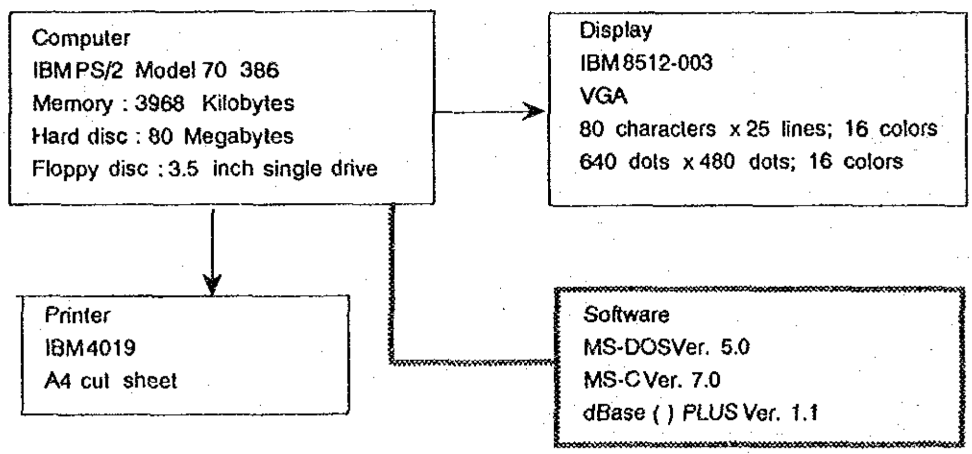


Figure 7-3 Hardware

(2) System processing block chart

Figure 7-4 uses a program processing block chart to indicate the processing software system for the bridge repair management system. Figure 7-5 divides the programs into input, accumulation, processing and output blocks and indicates the structure of the sub-programs.

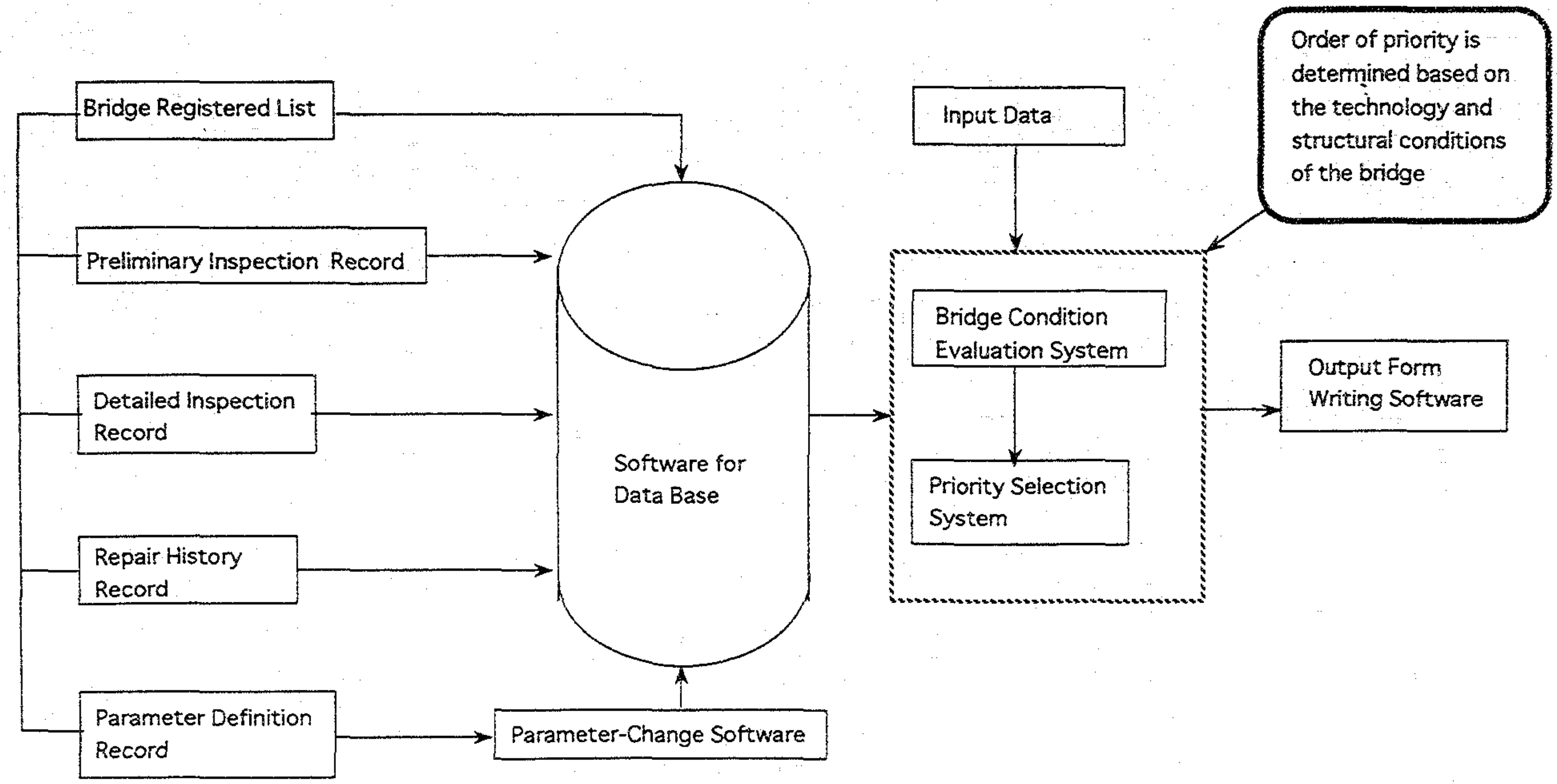


Figure 7-4 Bridge Maintenance Management System Processing Flowchart

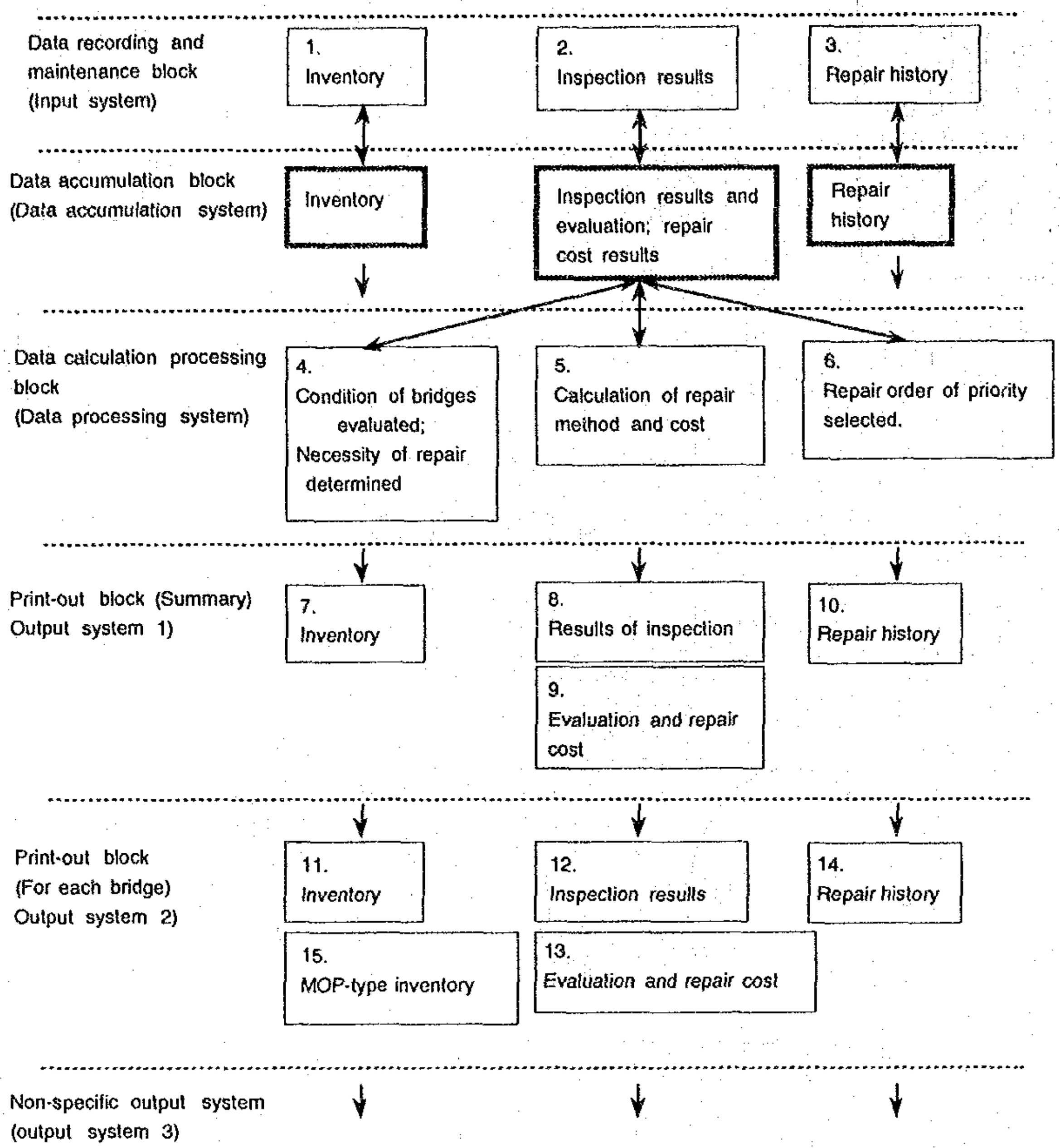


Figure 7-5 Bridge maintenance management system block diagram

7-2 Basic functions of the system

The functions of the system can be divided into those of data base and those of data processing.

(1) Data base functions

Data base functions include data recording, updating, storage, accumulation and retrieval/output functions. The following section describes these functions in detail.

1) Data recording and updating functions

Data recording and updating functions consist of the following:

a. The recording and updating of basic bridge data
b. The recording and updating of preliminary bridge data
c. The recording and updating of detailed bridge data
d. The recording and updating of bridge repair history
e. The recording and updating of system management parameter data

Each of the recording and updating functions in 1~4 have batch and on-screen interaction functions.

2) Data storage and accumulation functions

These comprise of interface software that assesses the dBase with the data record/update and the data retrieval/output screens. The basic software used here is dBase –Plus V – 3.5.

The main storage accumulation functions are as follows:

a. Data storage and accumulation (mainly data peculiar to the bridge being investigated) using a relational data base.
b. Data storage and accumulation (mainly code data and work files) using sequential files.

3) Data retrieval/output functions

Data retrieval/output consists of two functions. One of these functions, the fixed retrieval/output function, sets forms that are used every day and brings them on-screen after a code is entered. The other function retrieves specific data stored in the data base. To do this the operator enters the items to be retrieved, the retrieval/output and data editing parameters. The following list describes the content of these functions in detail:

A. Fixed retrieval/output function

The following documents may be retrieved for each state using the fixed retrieval/output function:

General bridge documents:
1 Bridge outline
2 Bridge inspection history
3 Bridge condition evaluation
4 Bridge maintenance history

Specific bridge documents
5 Fundamental bridge register
6 Bridge preliminary inspection document
7 Bridge condition evaluation
8 Bridge maintenance history
9 Fundamental bridge register (MOP format)

B. Optional retrieval/output functions

The optional retrieval/output functions allow the operator to retrieve optional items stored in the relational data base (d Base). The procedure for setting the conditions for retrieval/output is fixed. A fixed set of rules also applies to the number of pieces of data retrieved, the number of output items, the output format and the selection of the output unit. Such procedures and restrictions will be revealed during the detailed designing stage. The following is an outline of the optional retrieval/output function: Refer to Figure 7-6.

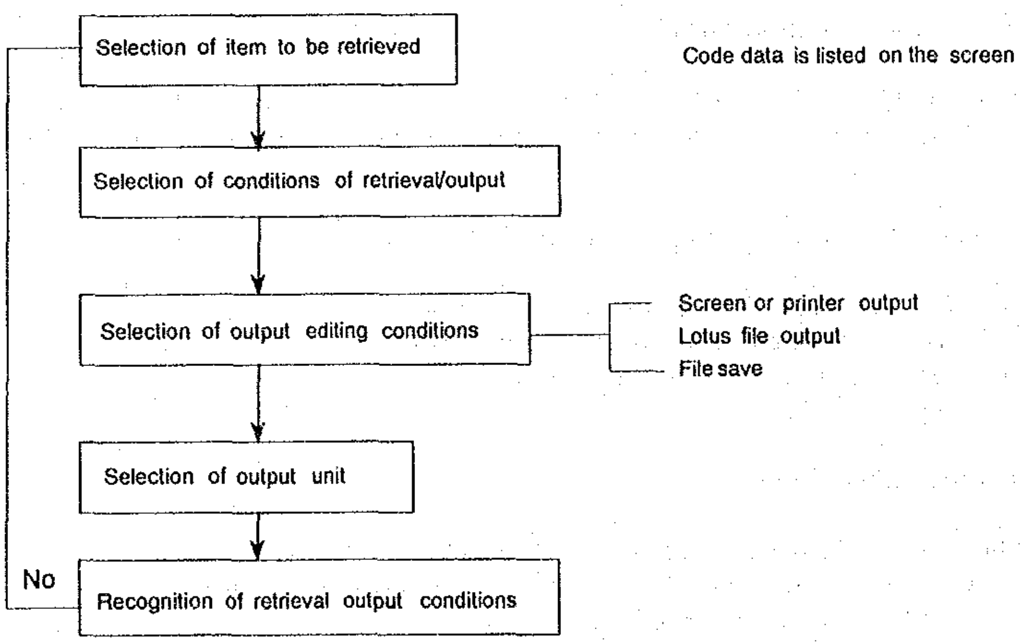


Figure 7-6 Outline of Optional retrieval/output function

(2) Data computing / processing functions

Data computing/processing functions are a set of application programs that carry out data processing /computing functions using the data and input data in the data base appropriate to the aim. The system we used has the two computing/processing blocks shown below as was shown in Figure 7-4

1) Bridge condition evaluation system

The bridge condition evaluation system uses the damage inspection data to evaluate the condition of the bridge and to determine whether repair is necessary. The system has the following three sub-routine programs:

1 Bridge sectional condition evaluation processing program
2 Bridge overall condition evaluation processing program
3 Repair method selection and rough estimate cost

2) System for determining the order of preference for Bridge repair/rebuilding

This system ranks and selects the bridges along say, the length of state highway 5 according to the degree of urgency of repair. The system bases its decisions on the results of the bridge condition evaluation while taking into account economic, social, technological, and political factors.

Chapter 8 System Design

8-1 Input system

Input system is divided into a data entry system and a file management system.

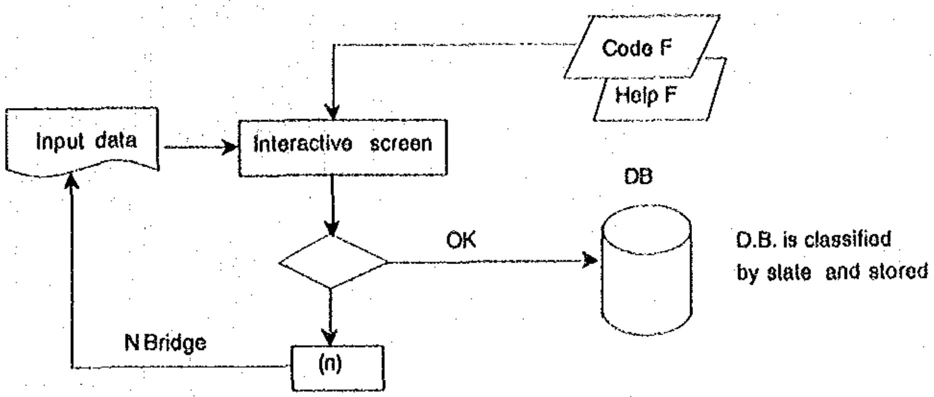
8-1-1 Data Registration System

The data to be registered into the system falls into the following three types; basic data for a bridge including the name, location, type and length of a bridge; preliminary check data for a bridge based on bridge deficiency evaluation surveys performed periodically; and bridge repair history data containing the details and history of a repaired bridge. Data registration flows together with the details of data to be entered and is described as follows. Refer to Figure 8-1.

1) Basic data for a bridge

a. Input data format, as shown in Table 8-1, IA

b. Registration procedure (Block chart)



Functions : Interactive screen mode
: As much data as possible are to be coded for input (the names of states, prefectures, managing offices, routes and etc.).
: Codes are managed by file data.
: "Help" function supports operation procedure (limited to this particular input system) and file inquiry
*File call, File list, Code list
*Error data correction, process suspension, returning to initial screen
: Outputs IA Chart as an output format per bridge.

Figure 8-1 Bridge basic data registration procedure

Table 8-1 IA Table

NOMBRE DEL PUENTE	KIROMETRO	NOMBRE DE LA VIA	ROL DE LA RUTA	PROVINCIA Y REGION	CODIGO DEL PUENTE

1. DATOS PRINCIPALES DEL PUENTE

NOMBRE DE LA OFICINA ADMINISTRADORA :			
CODIGO DE LA OFICINA :			
PROYECTISTA :			
CONTRATISTA :			
CARGA DEL DISEÑO :	AÑO DE CONSTRUCCION		
LIMITACIONES	POR CARGA	POR ALTURA	POR ANCHO
DISTANCIA AL MAR :			

2. C ARACTERISTICAS DEL CRUCE

TIPO (CODIGO)	☐
NOMBRE	
ESVIAJE	
ADMINISTRADOR	

3. DATOS FLUVIAES

NIVELES DE AGUAS MAXIMAS : m.

ANCHO PROMEDIO DEL RIO : m.

PENDIENTE PROMEDIO DEL LECHO :

MATERIAL DEL LECHO
ROCA ☐ GRAVA ☐ ARENA ☐ LIMO ☐ ARCILLA ☐ OTRO ☐ (DIAMETRO mm)

FORMA DE LAS RIVERAS : DIRECTA ☐ POCA CURVA ☐ MEANDRO ☐

PROTECTORES DE SOCAVACION : HAY ☐ NO HAY ☐ NO SE SABE ☐

MATERIAL DE FUNDACION
ROCA ☐ GRAVA ☐ ARENA ☐ LIMO ☐ ARCILLA ☐ OTRO ☐

4. LOSA	MATERIALES	TIPO (CODIGO)	ESPESOR
		☐	

5. RODADO (CODIGO) ☐

6. DIMENSIONES PRINCIPALES DEL PUENTE

LONG. TOTAL	ANCHO TOTAL	CALLZADA	PASILLOS	Nº DEVIAS
m.	m.	m.	m.	m.
EJE DEL PUENTE (CODIGO)		☐		(R= m)
ANGULO DEL PUENTE		DERECHA	ANGULO=	
		IZQUIERDA	ANGULO=	

7. DIMENSIONES PRINCIPALES DE LA SUPERESTRUCTURA

TRAMO	SENCILLO O CONTINUO	TIPO DE VIGA (CODIGO)	Nº DE VIGAS	LUZ TOTAL (m)
		☐☐☐☐		
		☐☐☐☐		
		☐☐☐☐		
		☐☐☐☐		
		☐☐☐☐		
		☐☐☐☐		
		☐☐☐☐		

8. INFRAESTRUCTURA			9. FUNDACIONES			
ESTRIBO CEPA Nº	TIPO (CODIGO)	ALTURA (m)	TIPO (CODIGO)	DIAMETRO (m)	LARGO (m)	Nº
	☐☐☐		☐			
	☐☐☐		☐			
	☐☐☐		☐			
	☐☐☐		☐			
	☐☐☐		☐			
	☐☐☐		☐			
	☐☐☐		☐			
ESTRIBO 2	☐☐☐		☐			

10. ALAS DE ESTRIBO ESTRIBO : SI ☐ NO ☐ ESTRIBO 2 : SI ☐ NO ☐

11. TIPO DE JUNTAS (CODIGO) ☐

12. TIPO DE APOYOS (CODIGO) ☐

13. ESTRUCTURA ANTI -SISMICA SI ☐ NO ☐

14. ESTRUCTURAS ADICIONALES :

15. MARGEN DE ALTURA : m. | 16. GALIBO : m.

17. ANCHO DE LOS ACCESOS : m. | 18. LONGITUD DEL DESVIO : km.

19. NO DE VIAS DE CIRCULACION : | 20. GAVIONES O ENROCADOS SI ☐ NO ☐

21. PROTECCION MEDIANTE MUROS SI ☐ NO ☐

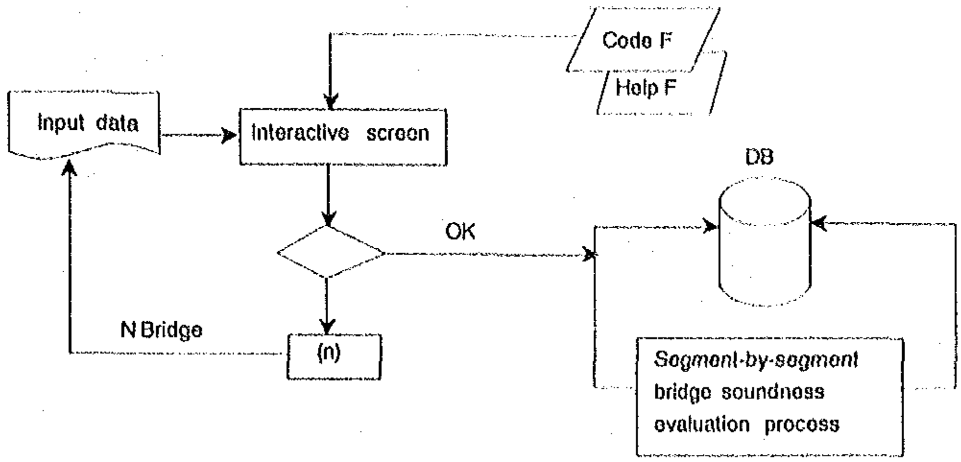
22. TRANSITO MEDIO DIARIO ANUAL (TMDA) Pasadas / Dia

AÑO				
TOTAL				
CAMIONES				
LOC.COLECTIVA				

2) Data for preliminary check of a bridge. Refer to Figure 8-2.

a. Input data format, as shown in Table 8-2, IB Table.

b. Entry process procedure (Block chart)



Functions : Interactive screen mode
: As much data as possible are to be coded for input.
: Codes are managed by file data.
: "Help" function is similar to entry process of basic bridge data.
: Soundness evaluation results are simultaneously corrected at the time of input data correction and revision.
: Outputs IB Chart as an output format per bridge.

Figure 8-2 Preliminary check data registration procedure

Table 8-2 IB Table

NOMBRE DEL PUENTE	KIROMETRO	NOMBRE DE LA VIA	ROL DE LA RUTA	PROVINCIA Y REGION	CODIGO DEL PUENTE

		TIPO DE DAÑO O DETERIORO Y SU CANTIDAD					
1 PAVIMENTO	ITEM	1 ALABEO	2 ENSURCADO O CARRILES	3 FISURAMIENTO	4 ASENTAMIENTO	5 OTROS	
	GRADO O CANTID						
2 BARANDAS	ITEM	1 DEFORMACION	2 OXIDAMIENTO	3 CORROSION	4 FISURAMIENTO	5 ARMADURA AL AIRE	6 OTROS
	GRADO O CANTID						
3 JUNTAS DE EXPANSION	ITEM	1 SONIDOS EXTRAÑOS	2 FILTRACION DE AGUAS	3 DEFORMACION	4 MOVIMIENTOS VERTICALES	5 JUNTAS OBSTRUIDAS	6 OTROS
	GRADO O CANTID						
4 LOSA	ITEM	1 FISURAS EN UNA DIRECCION	2 FISURAMIENTO EN RED	3 DESCASCA. RAMIENTO	4 ARMADURA AL AIRE	5 NIDOS DE PIEDRAS	6 EFLORES. CENCIAS
	GRADO O CANTID						
5 RIOSTRAS (PTES. DE ACERO)	ITEM	1 OXIDAMIENTO	2 CORROSION	3 DEFORMACION	4 ROTURA DE LAS UNIONES	5 ROTURA DE ARRIOSTRAMIENTOS	6 OTROS
	GRADO O CANTID						
6 VIGAPRINCIPAL DE ACERO (EN CHERCHAS)	ITEM	1 OXIDAMIENTO	2 CORROSION	3 DEFORMACION	4 PERDIDA DE PERNOS	5 FISURAS EN SOLADURAS	6 OTROS
	GRADO O CANTID						
7 RIOSTRAS (PTES. CONCRETO)	ITEM	1 FISURAS EN UNA DIRECCION	2 FISURAMIENTO EN RED	3 DESCASCA. RAMIENTO	4 ARMADURA AL AIRE	5 NIDOS DE PIEDRAS	6 EFLORES. CENCIAS
	GRADO O CANTID						
8 VIGA PRINCIPAL DE CONCRETO	ITEM	1 FISURAS EN UNA DIRECCION	2 FISURAMIENTO EN RED	3 DESCASCA. RAMIENTO	4 ARMADURA AL AIRE	5 NIDOS DE PIEDRAS	6 EFLORES. CENCIAS
	GRADO O CANTID						
9. APOYOS	ITEM	1 ROTURA DEL APOYO	2 ROTURA DE ACCESORIOS	3 SALIDA DE ANCLAJES	4 ROTURA DEL DISCO	5 DEFORMACIONES RARAS	6 OTROS
	GRADO O CANTID						
10 ESTRIBOS	ITEM	1 GRIETAS O DESCASCARAM	2 FISURAS A PARTIR APOYO	3 ROTURA DEL PARAPETO	4 INCLINACIONES	5 SOCAVACIONES	6 OTROS
	GRADO O CANTID						
11. CEPAS	ITEM	1 GRIETAS O DESCASCARAM	2 FISURAS A PARTIR APOYO	3 DEFORM DE CANTILEVER	4 INCLINACIONES	5 SOCAVACIONES	6 OTROS
	GRADO O CANTID						
12 PINTURA	ITEM	1 DECOLORACION	2 OXIDAMIENTO	3 AMPOLLAMIENTO	4 DESCASCARAM.	5 OTROS	
	GRADO O CANTID						
13 ARTICULACIONES DE VIGAS GERBER	ITEM	1 FISURAS EN UNA DIRECCION	2 FISURAMIENTO EN RED	3 AGRIETAMIENTO	4 ARMADURA AL AIRE	5 NIDOS DE PIEDRAS	6 EFLORES. CENCIAS
	GRADO O CANTID						
14 OTROS	ITEM	1 DERRUMBE TALUD.ESTRIBO	2 DAÑOS POR IMPACTO ROCAS	3 DAÑOS EN CABO VIGAS	4 SE EFECTUO REPARACION?	5 OTROS	
	GRADO O CANTID						
COMENTARIOS ESPECIALES	1 EXISTIERON DESBORDAMIENTOS a. SI b. NO c. NO SE SABE				2. EXISTEN EMPRESTITOS DE MATERIAL a. SI b. NO		

COMENTARIOS

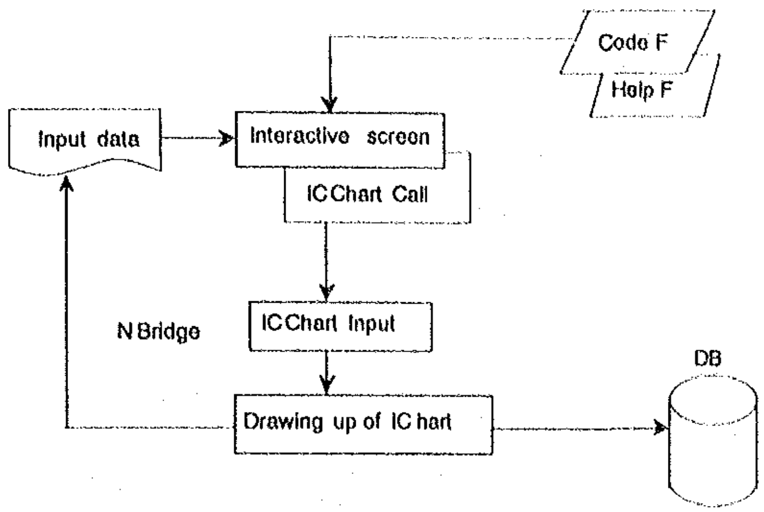
EVALUACION	GRADO DE DETERIORO	SOCAVACION
1	NO EXISTE DAÑO ALGUNO	NO EXISTE SOCAVACION
2	DAÑOS EN UNO O DOS PUNTOS	TENDENCIA A SOCAVAR
3	DAÑOS EN MUCHOS PUNTOS	EXIST.SOCAV.PERO NO HAY PELIGRO
4	MENOS DE LA MITAD DAÑADO	SOCAVACION PELIGROSA
5	CASI TODO DAÑADO	SITUACION DE EMERGENCIA

FECHA INSPECCION	NOMBRE INSPECTOR	
		FIRMA

3) Bridge repair history data. Refer to Table 8-3.

a. Input data format, as shown in Table 8-3, IC Chart

b. Registration procedure (Block chart)



Functions : Interactive screen mode
: The standard method of repairing is to be coded.
: Unit prices included in the IC chart are quoted from standard unit prices used for the standard method of repairing.

Figure 8-3 Bridge repair history registration procedure

8-1-2 File Management System

File management system registers evaluation weight for each evaluation item in IB chart used for deficiency evaluation. Damage degree evaluation, evaluation items, methods of repairing according to the evaluation, quantity computation expressions are to be coded and managed. A system that allows registration of such elements is to be prepared.

Table 8-3 IC Table

REPUBLICA DE CHILE
MINISTERIO DE OBRAS PUBLICAS
DIRECCION GENERAL DE OBRAS PUBLICAS
DIRECCION DE VIALIDAD
DEPARTAMENTO DE PUENTES
SUB. DEPTO. CONSERVACION DE PUENTES
① REHABILITACION 0 ② CABIOW

HISTORIA
REHABILITACION

PUENTE :
ROL DE VIA :
KILOMETRO :
PROVINCIA :
REGION :
CODIGO PUENTE :
FECHDATA :

ITEM	DESIGNACIONES	UNIDAD	CANTIDAD	VALORES		
				UNITARIO	PARCIALES	TOTALES
	I REFUERZO INFRAESTRUCTURA PTE RAUCO					
1.(Ii)						
.						
.						
.						
.						
1.(Ii=n)						
(1. 271	Hormigon para pavimente	m^3)				
	II. SUPERESTRUCTURA					
1.II j						
.						
.						
1.II j=n						
	III. VARIOS					
1.III k						
.						
.						
1.III k=						

Tabla 8-3: CUADRO DE INGRESO DE DATOS IC

8-2 Processing system

The detailed description of the method for bridge deficiency evaluation will be given in Section 8-3 "Bridge deficiency evaluation". The system configuration and the basic concept of the system are described here. The system judges the deficiency of a bridge as well as the repair priority using registered data.

8-2-1 Bridge Deficiency Evaluation System

For bridge deficiency evaluation, the following two types of subroutines are prepared.

a. Processing subroutine for segment-by-segment bridge deficiency evaluation (S u b - R-1)
b. Processing subroutine for overall bridge deficiency evaluation (S u b - R - 2)

1) Processing subroutine for segment-by-segment deficiency evaluation (S u b - R - 1)

a. System description

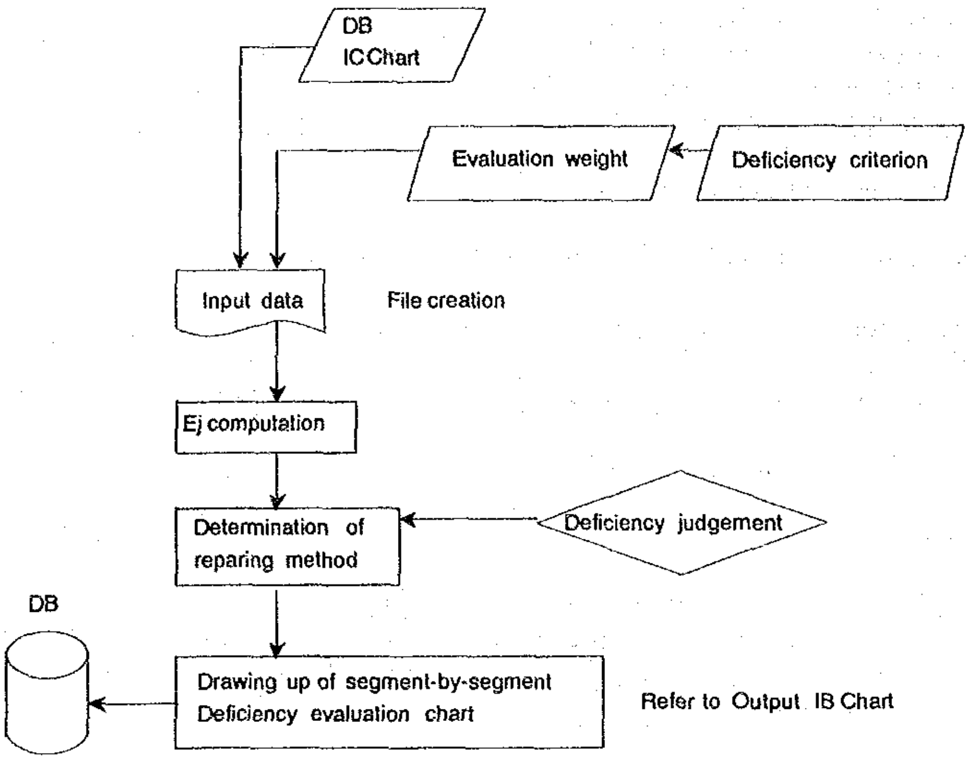
Objective : To compute evaluation values described from the results of segment-by-segment bridge checks listed on IC chart. Evaluation results are classified into five grades to determine the standard method of repairing.

Evaluation method : When there is only one item for check performed to determine the standard method of repairing, the checked value itself is used as a deficiency evaluation value. Whereas, when there are multiple check items, a mean value obtained by multiplying the weight registered into file management system will be considered to be the deficiency evaluation value of each checked segment. Refer to Figure 8-4.

$$E_j = W_{jk} \cdot S_{jk} / \sum (W_{jk} \cdot S_{jk}) \quad \text{or} \quad E_j = S_j \qquad \text{(Expression 8 - 1)}$$

E_j = Deficiency evaluation score for segment J
W_{jk} = Evaluation weight for the check result of the item k of the segment J
S_{jk} = The check result of the item k of the segment j (entered by an inspector) (refer to IB Table)

b. System process procedure (Block chart)



Functions : General expression using variables
: Output IB Chart is referred to for the establishment of segment-by-segment deficiency evaluation table.
: "Help" function allows call of evaluation values and check values.

Figure 8-4 Segment-by-segment bridge evaluation procedure

2) Overall bridge deficiency evaluation process (Sub - R-2), Refer to Figure 8-5.

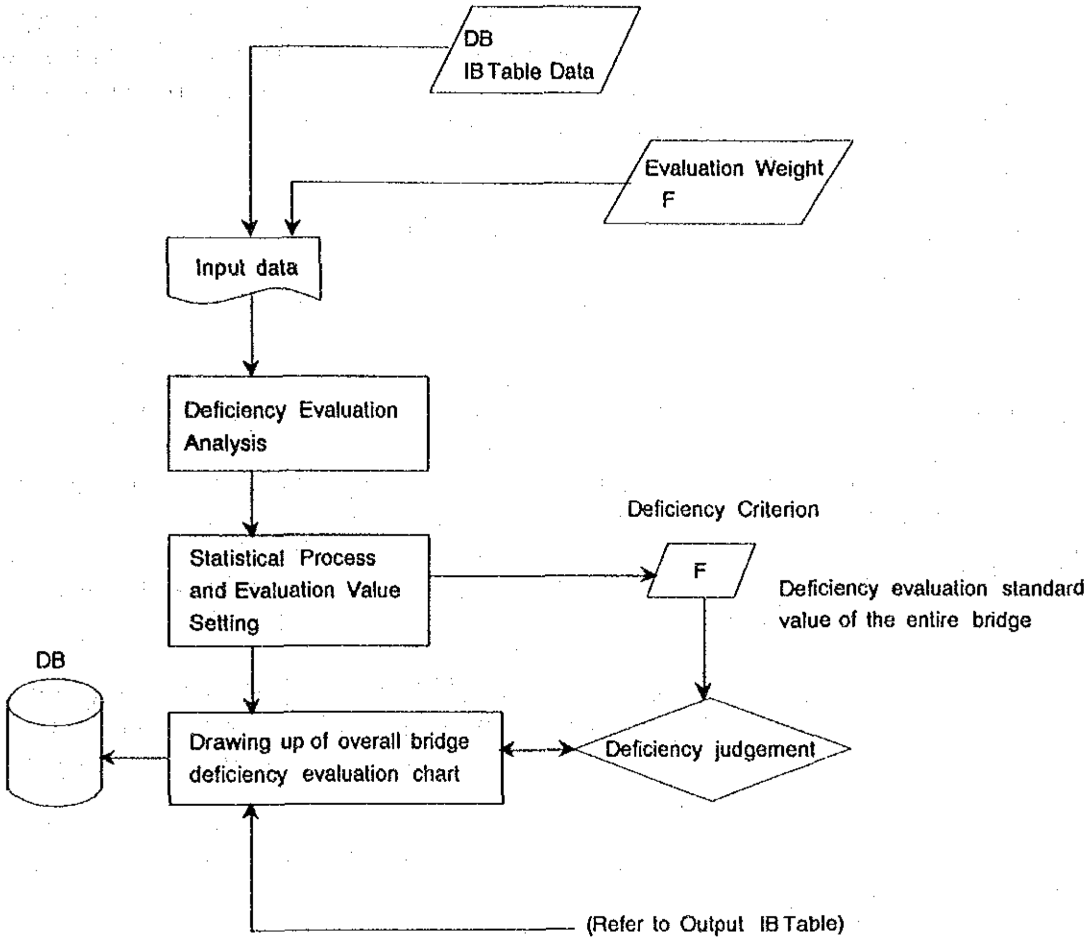
a. System description

Objective : To perform deficiency analysis and evaluative ranking per bridge. All the objective bridges along Route 5

Logic : An objective bridge is divided into three segments; its appurtenances, superstructure and substructure. The significance (weight) of each divided segment over the structure and functions of the entire bridge is relatively evaluated. Analytic Hierarchy Process which integrates this significance (weight) with segment-by-segment deficiency evaluation is used.

(Refer to Material - 1 for Analytic Hierarchy Process, Relative evaluation value, Classification of bridge segments, The way to find evaluation rank, weight value by bridge segments and grades)

b. System Process Block Chart



Functions : General expressions using variables.
: Output Format is made combining overall bridge deficiency evaluation chart and 2-2 segment-by-segment evaluation chart. (Refer to output IB Chart).
: "Help" allows call of evaluation weight and check value.

Figure 8-5 Overall bridge deficiency evaluation procedure

8-2-2 Repair Cost Computation Process (S U B - R 3)

1) System description

Objective : To compute repair cost for the standard method of repair for bridge segments.

Logic : The computation performed by the system is designed to serve for the determination of repair priority or the establishment of a mid-term plan. The result obtained from such computation is an estimated repair cost for the standard selected method of repairing based on the check results. The standard method of repairing or the estimated repair cost determined by the system are not used for the implementation of the practical repairing. As the determination of the repairing method or the computation of repair costs are likely to be performed using approaches other than the ones determined by the system, thorough examinations is required separately after the necessity of repair and repair plan has been decided. Accordingly, the computation of repair costs performed by the system is limited to the two functions; the computation of the unit cost per unit quantity of a given segment and the integration using the estimated repair work quantity.

2) Computation expression for repair costs per segment

$$P_X = V_i \times N_i \times n_i \times P_i$$

Px = The repair cost per segment
Vi = *The unit cost per unit quantity of the standard method of repairing* (Example:$/m2)
Ni = The estimated repair work quantity per segment (Example: per bridge for the dec; per pier or abutment for the substructure)
ni = The number of segments (Example : n = 2)
Pi = *The decrease rate of repair work quantity when deficiency rate is 4* (Example: Pi = 0.4)

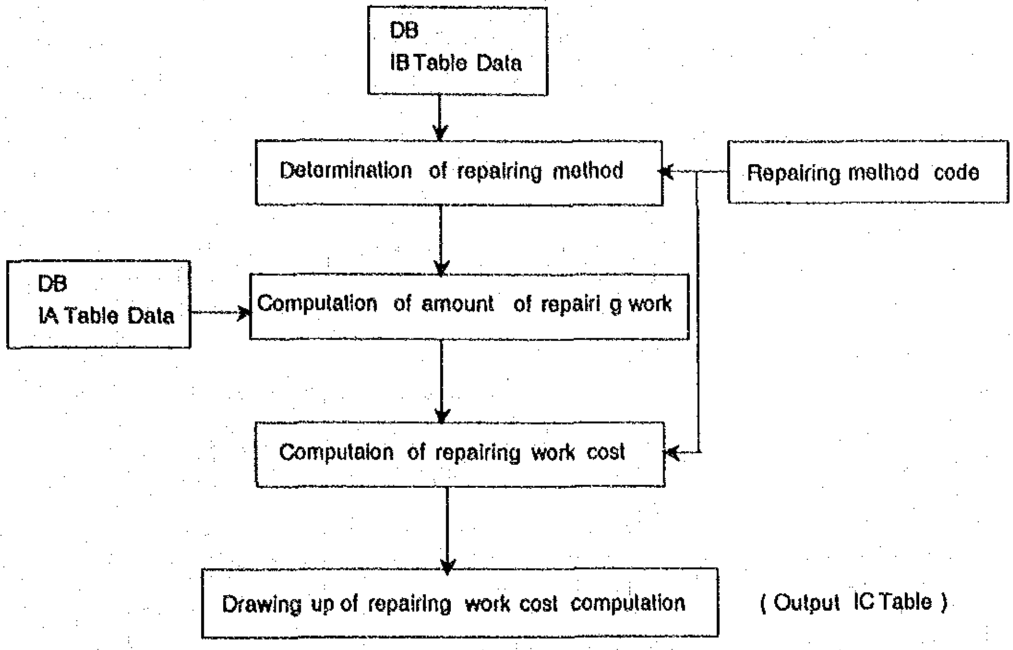
Table 8-3, IC chart provides a more visual image of how to perform computation. The determination of the standard method of repairing, the computation of the quantity of repair work and the computation of repair costs are performed according to the following procedure.

a. As shown in Table 8-5and 8-6, determine the method of repairing according to individual item of the check data (IB chart).

b. As shown in Table 8-7 and 8-8, determine the method of repairing according to the deficiency of each bridge segment.

c. As shown in Table 8-9 and 8-10, compute required quantity of repair work based on the basic data of the bridge.

3) System Process Block Chart. Refer to 8-6.



Functions: The following two types of IC Charts are prepared; The one for the computation to obtain the result of the computation performed through the unit cost chart of the standard repairing costs and the standard repair work quantity; and the other one for the computation of any repair costs through the external input of repairing costs and the quantity of repair work required for each segment.

Figure 8-6 Computation procedure of repairing work cost

Table 8-4(1) Standard Repairing Method

No	Item	Designation	Unit	Description
1	151	Bank Protection	m3	According the position, height,slope ,right of way shown in the plan. Based on the No 5-5707. Include excavation ,filling .
2	153	Gavion	m3	Construction of gavion at the position shown in the plan . Based on the No 5-5709.
3	244	Triple Rail pile	m	Preparation of material and swollen pile according to the plan of the project.
4	251	Form	m2	Preparation of material by the contractor.
5	261	Reinforcement Bar	Kg	Not applied for piles, approach slab, anchor bar, posttension girder. Based on INN NCH 204 of 67,NCH 210 of 67 standard.
6	275	Concrete (Sck240Kg/cm2)	m3	Include all the work such as supply of material, labor force, machine,and transportation.
7	341	Supply metal girder	T	Based on the AASHTO 1977. Include cut and welding.
8	342	Collocation of metal girder	T	Launching and collocation of metal girder include welding of channel of cross beam.
9	343	Painting of metal girder	T	Based on the SSPC SP6
10	352	Handrail of bridge with footway	m	Not include concrete, form and reinforcement bar.
11	354	Handrail of bridge without footway	m	Same above.
12	356	Bearing,anchor,drainage	Nos	Include supply of material and setting the bearing,anchor and drainage pipe.
13	511	Temporally bridge or detour	Nos	Include construction, maintenance and remove of detour for traffic. Minimum width of access road of the bridge is 5.0m.
14	521	Remove and demolition of existing bridge	Nos	Before or after of the construction of new bridge.
15	531	Upgrading of river bed	m2	Cleaning of river bed width of river and 50m upper and down of bridge.
16	541	Posting of sign	Nos	Supply, collocation, painting and posting of traffic sign.
17	551	Posting of sign	Nos	Supply, collocation ,painting for definition, construction and identification sign.
18	805	Collocation and extend of drainage	Nos	Collocation of drainage and extension of drainage steel pipe being galvanized indicate in the future slab planning.

Table 8-4(2) Standard Repairing Method

No	ITEM	Designation	Unit	Description
19	810	Waterproof for bridge slab	m2	Collocation of waterproof cloak for upper slab of the bridge and under the pavement of asphalt for total length of bridge. MOP inspection and permission for construction are required.
20	815	Repair of pavement	m2	Repair of pavement of bridge and replace of pavement with 5cm thickness of new asphalt pavement for total width of roadway.
21	820	Repair of Joint	m	Provision, replacement and collocation of steel angle for protection of the edge of structure of joint.
22	8	Sign and traffic control	m	based on the D,V, No.1826
23	830	Replacement of handrail	m	Provision and collocation of handrail based on ITEM352.
24	835	Repair and injection for crack	m	Repair of fissure and crack. Total separation of concrete less than 1.5mm is considered as fissure and more than 1.5mm is defined as crack. Fissure is repaired by injection of epoxy resin and crack is repaired by mortal. Based on the ITEM275.
25	840	Repair concrete crack	m2	Repair of concrete where being observed bad condition such as junk of concrete, erosion,flake,exposure of reinforcement bar fissure and crack of slab and foundation.
26	845	Cleaning and painting of bridge	m	Clean total surface of concrete such as remove of wire, cover junk and finally paint by lime or white cement milk.
27	850	Repair and Painting of existing handrail	m	Repair and replacement and painting of existing handrail. Form, type, volume and dimension of handrail are correspond to the existing bridge.
28	855	Reconstruction of joint	m	Provision and collocation of joint for superstructure, place, form, dimension, volume, level and slope of project are shown in plan of the project or instruction of inspection.
29	860	Cleaning and repair of bearing	sis	Cleaning and repair of all bearing of bridge. After cleaning of metal, metal bearings are repaired based on the ITEM343 and rubber bearing include concrete basement are repaired based on ITEM850.
30	880	Levelling of access	m	Levelling of bridge access which exist fall or bad compaction
31	885	Drawing of construction planning	No	All plans which define clearly all of structural element of the bridges and all the repair, reconstruction and rehabilitation job.
32	890	Demolition footway, part of slab and handrail	m3	Demolition of footway concrete and part of slab which has no damage in reinforcement bar. extend of road way width is from 6 to 8 m.

Table 8-5 Evaluation Items Corresponding to Deficiency Rate 4

Deficiency evaluation 4

Segments for repairing		Repairing method Code	Evaluation items
Pavement		805	All the items of Pavement
		810	All the items of Pavement
		815	All the items of Pavement
		880	All the items of Pavement
Expansion joint		820	All the items of Expansion joint
Handrail		850	All the items of Handrail
Bearing		860	All the items of Bearing
Painting		343	All the items of Painting
Deck		835	Items 1, 2 & 6 of Deck
		840	Items 3, 4 & 5 of Deck
Gerber			All the items of Gerber
Main beam	Steel		All the items of Main beam
	Concrete	835	Items 1, 2 & 6 of Main beam
		840	Items 3, 4 & 5 of Main beam
Floor system	Steel		All the items of Floor system
	Concrete	835	Items 1, 2 & 6 of Floor system
		840	Items 3, 4 & 5 of Floor system
Abuntment	Body	840	Items 1, 2 & 3 of Abuntment
	Differential settlement	244	Item 4 of Abuntment
		251	Item 4 of Abuntment
		261	Item 4 of Abuntment
		275	Item 4 of Abuntment
	Scour	153	Item 5 of Abuntment
		531	Item 5 of Abuntment
Pier	Body	840	Items 1, 2 & 3 of Pier
	Differential settlement	244	Item 4 of Pier
		251	Item 4 of Pier
		261	Item 4 of Pier
		275	Item 4 of Pier
	Scour	153	Item 5 of Pier
		531	Item 5 of Pier

Table 8-6 Evaluation Items Corresponding to Deficiency Rete 5

Segments for repairing		Repairing method Code	Evaluation items
Pavement		805	All the items of Pavement
		810	All the items of Pavement
		815	All the items of Pavement
		880	All the items of Pavement
Expansion joint		855	All the items of Expansion joint
Handrail		251	Items 4 & 5 of Handrail
		261	Items 4 & 5 of Handrail
		274	Items 4 & 5 of Handrail
		352	Items 1, 2 & 3 of Handrail (PASI>0.1)
		354	Items 1, 2 & 3 of Handrail (PASI<0.1)
		890	Item 4 & 5 of Handrail
Bearing		356	All the items of Bearing
		840	All the items of Bearing
Painting		343	All the items of Painting
Deck		251	All the items of Deck
		261	All the items of Deck
		275	All the items of Deck
		511	All the items of Deck
		521	All the items of Deck
Gerber		251	All the items of Gerber
		261	All the items of Gerber
		262	All the items of Gerber
		511	All the items of Gerber
		521	All the items of Gerber
Main beam	Steel	341	All the items of Main beam
		342	All the items of Main beam
		343	All the items of Main beam
		511	All the items of Main beam
		521	All the items of Main beam
	Concrete	251	All the items of Main beam
		261	All the items of Main beam
		275	All the items of Main beam
		511	All the items of Main beam
Floor system	Steel	341	All the items of Floor system
		342	All the items of Floor system
		343	All the items of Floor system
	Concrete	251	All the items of Floor system
		261	All the items of Floor system
		275	All the items of Floor system

Abuntment	Concrete	251	Items 1, 2 & 3 of Abuntment
		261	Items 1, 2 & 3 of Abuntment
		275	Items 1, 2 & 3 of Abuntment
	Differential settlement	244	Item 4 of Abuntment
		251	Item 4 of Abuntment
		261	Item 4 of Abuntment
		275	Item 4 of Abuntment
	Scour	153	Item 5 of Abuntment
		243	Item 5 of Abuntment
		531	Item 5 of Abuntment
Pier	Concrete	251	Items 1, 2 & 3 of Pier
		261	Items 1, 2 & 3 of Pier
		275	Items 1, 2 & 3 of Pier
	Differential settlement	244	Item 4 of Pier
		251	Item 4 of Pier
		261	Item 4 of Pier
		275	Item 4 of Pier
	Scour	153	Item 5 of Pier
		243	Item 5 of Pier
		531	Item 5 of Pier

Table 8-7 Standard Repairing Method for Each Part
Corresponding to Deficiency Rate 4

Segment		No.	Deficiency evaluation 4	Reparing method code
Pavement		1	Pavement repair	805, 810, 815, 880
Expansion joint		2	Expansion joint and Face plate repair	820
Handrail/curb		3	Mortar filling, Protection material application, Section repair	850
Bearing		4	Bearing reset, Bearing repair using mortar	860
Painting		5	Washing in water and repainting	343
Deck		6	Crack repair, Injection	835 and or 840
Gerber hinge		7	Repair using steel plates	Undecided
Main beam	Steel beam	8	Partial reinforcing using shape steel and steel plates	Undecided
	Concrete beam	9	Crack repair, Injection	835 and or 840
Floor system	Steel beam	10	Partial reinforcing using shaped steel and steel plates	Undecided
	Concrete beam	11	Crack repair, Injection	835 and or 840
Abuntment	Body	12	Mortar injection into cracks, Sectin repair	835 and or 840
	Differential settlement	13	Additional piles, Sole plate extention	244, 251, 261, 275
	Scour	14	Scour deffensive device	153, 531
Pier	Body	15	Mortar injection into cracks, Sectin repair	835, 840
	Differential settlement	16	Additional piles, Sole plate extention	244, 251, 261, 275
	Scour	17	Scour deffensive device	153, 531
Slope protection		18	Slope deffensive device	151

Table 8-8 Standard Repairing Method for Each Part Corresponding to Deficiency Rate 5

Segment		No.	Deficiency evaluation 5	Reparing method code
Pavement		1	Pavement repair	805, 810, 815, 880
Expansion joint		2	Expansion joint replacement	855
Handrail/curb		3	Curb and Handrail reconstruction	251, 261, 274, 352 or 354, 890
Bearing		4	Bearing replacement or repair (Mortar)	356, 840
Painting		5	Repainting	845
Deck		6	Deck reconstruction	251, 261, 275, 511, 521 (Note 1)
Gerber hinge		7	Gerber reconstruction	251, 261, 275, 511, 521 (Note 2)
Main beam	Steel beam	8	Beam replacement	251, 261, 275, 511, 521 (Note 3)
	Concrete beam	9	Reinforced concrete + section reinforcing using concrete	251, 261, 275
Floor system	Steel beam	10	Beam replacement and additional placing of cross beam	341, 342, 343
	Concrete beam	11	Reinforced concrete + section reinforcing using concrete	251, 261, 275
Abuntment	Body	12	Reinforced concrete + section reinforcing using concrete	251, 261, 275
	Differential settlement	13	Additional pile, Sole plate extension	244, 251, 261, 275
	Scour	14	Scour deffensive device	153, 243, 531
Pier	Body	15	Reinforced concrete + section reinforcing using concrete	251, 261, 275
	Differential settlement	16	Additional pile, Slope plate extension	244, 251, 261, 275
	Scour	17	Scour deffensive device	153, 243, 531, 760
Slope protection		18	Slope deffensive device	151

Note 1: Includes replacement of the pavement, hand rail and expansion joint accompanied by deck replacement.

Note 2: Includes replacement of the pavement, hand rail and expansion joint accompanied by gerber deck placement.

Note 3: Includes repalcement of the deck, pavement, handrail and expansion joint accompanied by beam replacement.

Note 4: The standaard methods of repairing NO.541, 551 and 885 are commonly included in all kinds of repairing.

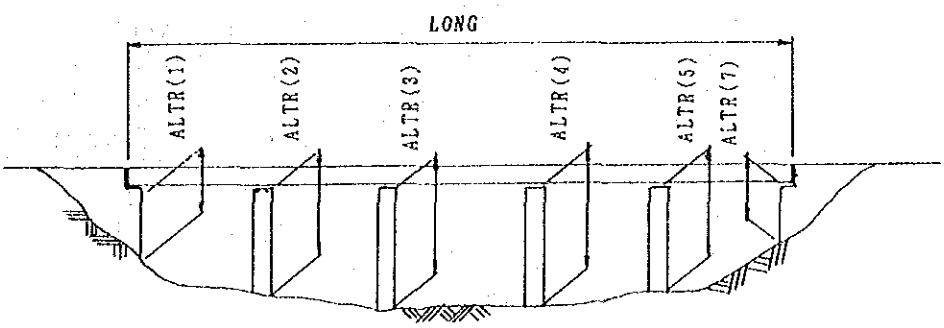
Table 8-9 Formula for Repairing Volume Caluculation
Corresponding to Deficiency Rate 4

Segments for repair		Repairing method code	Computation	Units
Pavement		805	LONG	NOS
		810	CALZ * LONG * 0.5	M2
		815	CALZ * LONG * 0.5	M2
		880	10	M1
Expansion joint		820	CALZ * 2 * SKEW * (TRAM + 1)	M1
Handrail		850	LONG * 2	M1
Bearing		860	TRAM + 1	SIS
Painting		343	ANCH * LONG * 0.2(t)	T
Deck		835	LONG * 3	M1
		840	ANCH * LONG * 0.2	M2
Gerber			TRAM – 1	NOS
Main beam	Steel		1	NOS
	Concrete	835	LONG * 3	M1
		840	ANCH * LONG * 0.1	M2
Floor system	Steel		1	NOS
	Concrete	835	ANCH * (TRAM + 1)	M1
		840	ANCH * (TRAM + 1) * 0.1	M2
Abuntment	Concrete	835	ANCH * 2 * 2	M1
		840	ANCH * (ALTR(1) + ALTR(7)) / 2 * 0.2	M2
	Slope	244	20(Nos) * 20(m)	M1
		251	(ANCH + 3(m)) * 2(m)	M2
		261	(ANCH * 3(m)) * 2(m) * 50(kg)	KG
		275	(ANCH * 3(m)) * 2(m)	M3
	Scour	153	ANCH * 3(m) * 2(m)	M3
		531	ANCH * 10(m)	M2
Pier	Concrete	835	ANCH * 2 * 2 * (TRAM – 1) / 2	M1
		840	ANCH * (ALTR(2)++ALTR(6))/(TRAM–1)*0.2	M2
	Slope	244	20(Nos) * 20(m)	M1
		251	(ANCH + 5(m)) * 2(m)	M2
		261	(ANCH * 5(m)) * 2(m) * 50(kg)	KG
		275	(ANCH * 5(m)) * 2(m)	M3
	Scour	153	ANCH * 5(m) * 2(m)	M3
		531	ANCH * (LONG – 10(m))	M2

Table 8-10 Formula for Repairing Volume Caluculation Corresponding to Deficiency Rate 5

Segments for repair		Repairing method code	Computation	Units
Pavement		805	LONG	NOS
		810	CALZ * LONG	M2
		815	CALZ * LONG	M2
		880	10	M1
Expansion joint		855	CALZ * 2 * SKEW * (TRAM + 1)	M1
Handrail		251	LONG * 2 * 2 * 0.3(m)	M2
		261	(LONG * 2 * 0.3(m) * 0.4(m)) * 50(kg)	KG
		274	LONG * 2 * 0.3(m) * 0.4(m)	M3
		352	LONG * 2	M1
		354	LONG * 2	M1
		890	LONG * 2 * 0.5(m) * 0.2(m)	M3
Bearing		356	TRAM + 1	NOS
		840	ANCH * 1(m) * (TRAM + 1)	M2
Painting		343	ANCH * LONG * 0.2(t)	T
Deck		251	LONG * ANCH	M2
		261	ANCH * LONG * 0.25(m) * 130(kg)	KG
		275	ANCH * LONG * 0.25(m)	M3
		511	1	G1
		521	1	G1
Gerber		251	(ANCH * 2(m)) * 5(m) * (TRAM – 1)/2	M2
		261	ANCH * 5(m) * 0.5(m) * (TRAM – 1)/2*100(kg)	KG
		262	ANCH * 5(m) * 0.5(m) * (TRAM – 1)/2	M3
		511	1	G1
		521	1	G1
Main beam	Steel	341	ANCH * LONG * 0.2(t)	T
		342	ANCH * LONG * 0.2(t)	T
		343	ANCH * LONG * 0.2(t)	T
		511	1	G1
		521	1	G1
	Concrete	251	LONG * (1.0(m) + ANCH * 0.3)	M2
		261	LONG * 0.5(m) * ANCH * 0.3 * 150(kg)	KG
		275	LONG * 0.5(m) * ANCH * 0.3(m)	M3
		511	1	G1
Floor system	Steel	341	ANCH * LONG * 0.05(t)	T
		342	ANCH * LONG * 0.05(t)	T
		343	ANCH * LONG * 0.05(t)	T
	Concrete	251	(1.0(m) * ANCH) * TRAM	M2
		261	(0.3(m) * 0.5(m)) * ANCH * TRAM * 150(kg)	KG
		275	(0.3(m) * 0.5(m)) * ANCH * TRAM	M3

Abuntment	Concrete	251	(ANCH + 1(m)) * (ALTR(1) + ALTR(7))	M2
		261	ANCH * (ALTR(1) + ALTR(7)) * 0.3 * 100(kg)	KG
		275	ANCH * (ALTR(1) + ALTR(7)) * 0.3	M3
	Slope	244	20(Nos) * 20(m) * 2	M1
		251	(ANCH + 3(m)) * 2(m) * 2	M2
		261	(ANCH * 3(m)) * 2(m) * 50(kg) * 2	KG
		275	(ANCH * 3(m)) * 2(m) * 2	M3
	Scour	153	ANCH * 3(m) * 2(m)	M3
		243	(ANCH + 5(m)) * 2 / 0.3 * 10(m)	M1
		531	ANCH * 10(m)	M2
Pier	Concrete	251	(ANCH*2(m))*(ALTR(2)++ALTR(6))/(TRAM-1)	M2
		261	ANCH * (ALTR(2)++ALTR(6))*0.6(m)*100(kg)	KG
		275	ANCH * (ALTR(2)++ALTR(6))*0.6(m)	M3
	Slope	244	20(Nos) * 20(m) * (TRAM - 1)	M1
		251	(ANCH + 5(m)) * 2(m) * (TRAM - 1)	M2
		261	(ANCH * 5(m)) * 2(m) * 50(kg) * (TRAM - 1)	KG
		275	(ANCH * 5(m)) * 2(m) * (TRAM - 1)	M3
	Scour	153	ANCH * 5(m) * 2(m) * (TRAM - 1)	M3
		243	(ANCH + 5(m)) * 2 / 0.5 * 10(m) * (TRAM - 1)	M1
		531	ANCH * (LONG - 10(m))	M2



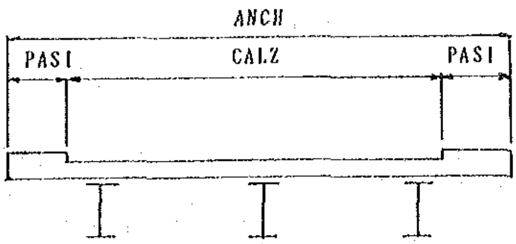


Figure 8-7 Variable for Caluculation of Repairing Volume

8-3 Evaluation of Bridge Deficiency Rate

8-3-1 Determination Of Significance (Weight) Used For Deficiency Evaluation

1) The absolute evaluation value for each evaluation item

The significance of each bridge segment and deficiency used for bridge deficiency evaluation was determined through the questionnaire survey by three engineers from Chile and three engineers of the survey team. The significance was determined in such a way that opinions of the above engineers on the significance of deficiency evaluation of each segment and deficiency were collected using 5-grade absolute evaluation criterion as shown in Table 8-10. The obtained mean weight value was determined as the absolute evaluation value for each segment and deficiency. Such absolute values for each evaluation item are as shown in Table 8-12.

Table 8-11 Absolute Value for Evaluation Items

Rank	Definition
1	Not significant
2	Slightly significant
3	Significant
4	Considerably significant
5	Extremely significant

2) Computation of significance (weight)

Deficiency evaluation was performed using Analytic Hierarchy Process. The Process facilitates the computation of the significance (weight) of all the evaluation items by obtaining a vector value for each evaluation item using a relative value of each evaluation item as shown in Table 8-11. Relative evaluation values are computed from the aforementioned absolute evaluation values using the following expression.

$$IR(A:B) = I(A) - I(B) + 1$$

IR (A : B) : Relative evaluation value for A to B
I (A): Absolute value for A
I (B): Absolute value for B

Where, when $I(A) < I(B)$,
$IR(B:A) = 1 / [IR(A:B)]$

For example, when an absolute evaluation value for a given evaluation item A is 5, and an absolute evaluation value for a given evaluation item B is 3, a relative value for A to B is 5 - 3 + 1 = 3. On the other hand, a relative value for B to A is 1 / 3.

The absolute values for each bridge segment and deficiency thus obtained are as shown in Table 8-12. The significance (weight) for each evaluation item obtained from the said absolute values is as shown in Table 8-13.

Table 8-12 Relative Value and Weight for Each Bridge Segment

	Appurtenances	Superstructure	Substructure	Vector value	Weight
Appurtenances	1	1/3	1/4	0.437	0.122
Superstructure	3	1	1/2	1.145	0.320
Substructure	4	2	1	2.000	0.558

3) Deficiency evaluation

To evaluate the significance of each segment of a bridge, the evaluation items are divided into three strata as shown in Figure 8-7: The first stratum includes the superstructure, substructure and appurtenance, three main components of a bridge. The second stratum includes all the individual segments of a bridge as shown in Table 8-2, IB Chart. The third stratum includes the deficiency of each segment. The deficiency evaluation values for each stratum can be obtained by the integration of evaluation value for the lower stratum.

Accordingly, the overall weight (W) can be computed from the following expression.

$W = W1 * W2 * W3$

where:
- $W1$ =the weight for the first rank
- $W2$ =the weight for the second rank
- $W3$ =the weight for the third rank

The deficiency evaluation value for the entire bridge can be obtained from the following expression.

$$R = \sum (Wi \times Ii)$$

where

R : Evaluation value for the entire value

Wi : Weight for each segment obtained from stratum analysis.

Ii : Evaluation value for the degree of deficiency determined at the time of bridge inspection.

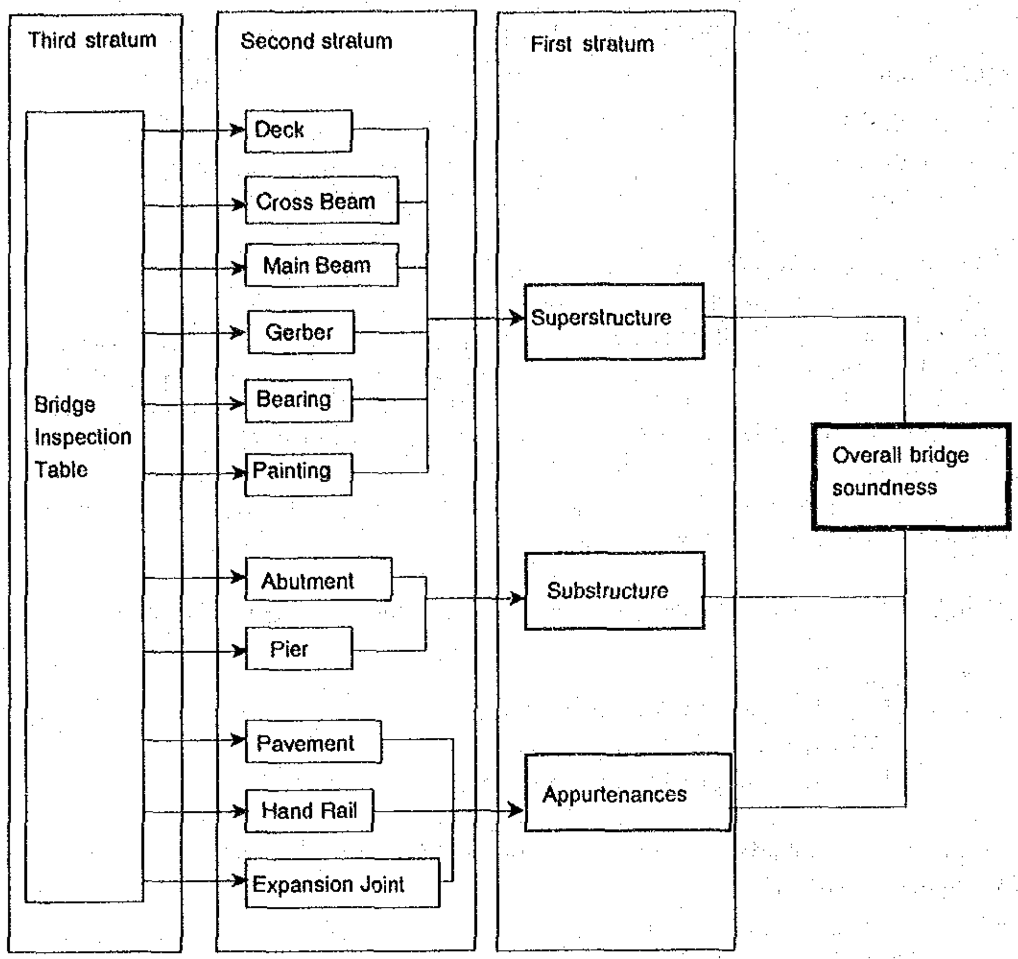


Figure 8-8 Stratum for Evaluation Weight Setting

Table 8-13 Absolute Value for Deficiency of Each Segment

Bridge segments	Deficient segments	1	2	3	4	5	6
	Pavement	Corrugation	Rutting	Cracking	Depression	Others	
	3.5	3.0	3.0	4.2	4.0		
Appurtenances	Handrail	Deformation	Rusting	Corrosion	Cracking	Stripping	Others
	2.5	2.4	2.6	4.0	2.8	3.4	
	Expansion joint	Abnormal sound	Leakage	Deformation	Settlement	Clogging	Others
2.0	3.7	3.0	2.8	3.4	3.8	3.6	
	Deck	Unidirectional cracking	Bidirectional cracking	Stripping	Reinforcing bar exposure	Honeycomb cavity	Free lime
	4.0	3.0	4.0	4.0	3.6	3.0	3.8
	Cross beam (Steel)	Rusting	Corrosion	Deformation	Joint failure	Cracking & Stripping	
	3.3	2.6	4.0	3.2	4.6	4.2	
	Main beam (Steel)	Rusting	Corrosion	Deformation	Joint failure	Cracking & Stripping	
	4.5	2.8	4.6	3.6	4.2	4.6	
	Cross beam (Concrete)	Unidirectional cracking	Bidirectional cracking	Stripping	Reinforcing bar exposure	Honeycomb cavity	Free lime
Superstructure	3.2	2.6	3.8	3.2	3.8	2.6	3.6
	Main beam (Concrete)	Unidirectional cracking	Bidirectional cracking	Stripping	Reinforcing bar exposure	Honeycomb cavity	Free lime
	4.7	2.8	4.0	3.4	4.2	3.2	3.6
	Bearing	Body failure	Appurtenance failure	Anchor bolt pull-out	Shoe seat failure	Abnormal displacement	Others
	3.0	4.6	3.0	3.8	3.6	2.8	
	Painting	Discoloration	Rusting	Swelling	Peeling	Others	
	2.5	1.8	3.0	3.4	3.8		
	Gerber	Unidirectional cracking	Bidirectional cracking	Stripping	Reinforcing bar exposure	Honeycomb cavity	Free lime
4.0	4.8	2.6	3.4	4.0	3.8	3.4	3.4
	Abuntment	Body cracking	Shoe seat disorder	Parapet failure	Differential settlement	Scour	Others
Substructure	4.8	3.2	2.8	3.0	4.8	4.4	
	Pier	Body cracking	Shoe seat disorder	Parapet failure	Differential settlement	Scour	Others
5.0	5.0	3.2	3.0	3.4	4.6	5.0	

Table 8-14 Significance (weight) for Deficiency of Each Segment

Bridge segments	Deficient segments	1	2	3	4	5	6
	Pavement	Corrugation	Rutting	Cracking	Depression	Others	
	0.373	0.161	0.161	0.362	0.315		
Appurtenances	Handrail	Deformation	Rusting	Corrosion	Cracking	Stripping	Others
	0.192	0.120	0.138	0.343	0.160	0.239	
	Expansion joint	Abnormal sound	Leakage	Deformation	Settlement	Clogging	Others
0.122	0.435	0.151	0.131	0.204	0.276	0.238	
	Deck	Unidirectional cracking	Bidirectional cracking	Stripping	Reinforcing bar exposure	Honeycomb cavity	Free lime
	0.171	0.106	0.219	0.219	0.162	0.106	0.188
	Cross beam (Steel)	Rusting	Corrosion	Deformation	Joint failure	Cracking & Stripping	
	Main beam (Steel)	Rusting	Corrosion	Deformation	Joint failure	Cracking & Stripping	
	Cross beam (Concrete)	Unidirectional cracking	Bidirectional cracking	Stripping	Reinforcing bar exposure	Honeycomb cavity	Free lime
Superstructure	0.177	0.099	0.228	0.149	0.228	0.099	0.197
	Main beam (Concrete)	Unidirectional cracking	Bidirectional cracking	Stripping	Reinforcing bar exposure	Honeycomb cavity	Free lime
	0.295	0.095	0.220	0.143	0.252	0.124	0.166
	Bearing	Body failure	Appurtenance failure	Anchor bolt pull-out	Shoe seat failure	Abnormal displacement	Others
	3.0	4.6	3.0	3.8	3.6	2.8	
	Painting	Discoloration	Rusting	Swelling	Peeling	Others	
	Gerber	Unidirectional cracking	Bidirectional cracking	Stripping	Reinforcing bar exposure	Honeycomb cavity	Free lime
0.320	0.103	0.069	0.154	0.240	0.209	0.154	0.154
	Abuntment	Body cracking	Shoe seat disorder	Parapet failure	Differential settlement	Scour	Others
Substructure	0.490	0.139	0.106	0.121	0.352	0.281	
	Pier	Body cracking	Shoe seat disorder	Parapet failure	Differential settlement	Scour	Others
0.558	0.510	0.121	0.106	0.139	0.281	0.352	

Note) 1. Lower column : Significance (weight)
2. As the weight varies depending on the combination of deficient segments, RC bridge with gerber is given here as an example.

8-3-2 Determination Of Deficiency Rate

In this survey, deficiencies are rated into five grades as shown in Tables 8-15 and 8-16. In the phase of deficiency evaluation, however, the product of a weight for each segment and an evaluation rate determined at the time of bridge check is recognized as a deficiency rate. In order to facilitate the determination of repair priority, this value was ranked into five grades through a statistic approach.

In this survey, the data distribution characteristic obtained from deficiency evaluation was verified by the following expression.

$$F(X) = \exp(-\exp(-a(X-u)))$$

where

F (x) : cumulative distribution of x (deficiency rate)

a : Inverse scale indicating the width of dispersion of random variable x

u : The maximum characteristic value for random variable

The deficiency rate can be obtained by using this probabilistic distribution. When the deficiency rate is computed. Refer to Figure 8-8.

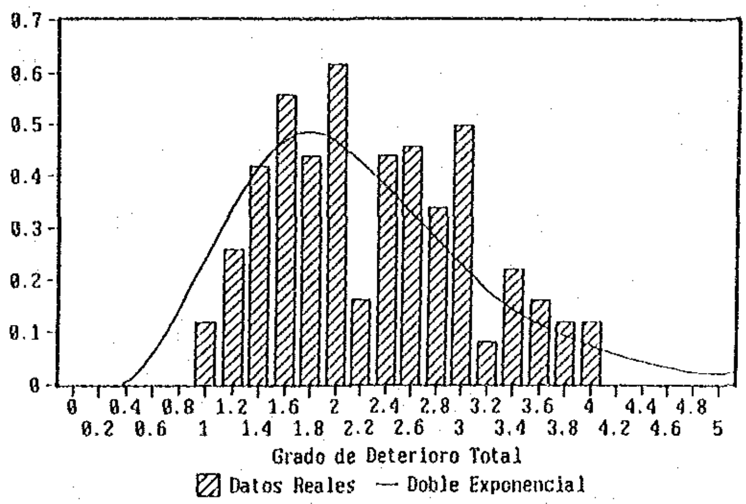


Figure 8-9 Deficiency Evaluation and Deficiency Rank

Table 8-15 Rank for Deficiency of Bridge

Rank	Definition
1	Not deficiency
2	Slightly deficiency
3	Deficiency
4	Considerably deficiency
5	Extremely deficiency

Table 8-16 Rank for Scouring of Foundation

Rank	Definition
1	Not Scouring
2	Slightly scouring
3	Scouring
4	Considerably scouring
5	Extremely scouring

8-4 A priority Determination System for Bridge Repairing and Reconstruction

8-4-1 An outline of the determination system

The evaluation items required for the priority determination of bridge repairing and construction vary depending on the regional characteristics, the structure of a managing organization and the aim of management, and so does the significance (weight) of each evaluation item. Besides the results of deficiency evaluation, evaluation items required for the priority determination of repairing and reconstruction and their significance rate were considered.

Various ideas have so far been proposed on the method of priority determination of repairing. In this survey, evaluation items that are independent from each other and have an effect on repairing and reconstruction priority have been included in the first evaluation level. Further in the second level, additional items have been prepared for the more detailed evaluation of the items in the first level. An evaluation technique with hierarchical structure that allows the consideration of the significance in each level has been employed.

The total weight of each item is to be set so as to become equivalent to or to exceed the weight possessed by each item of the upper level. For example, the structural condition deficiency is assumed to be an evaluation item of the first level with a weight of 50. Assuming that a deck, a superstructure and a substructure are set to be lower level items by which the said deficiency is evaluated. In this case, a deficiency evaluation value obtained by the multiplication of an evaluation value and it weight, as described in "8-3 deficiency evaluation of bridges", does not adequately represent the priority and urgency of repairing.

For example, in comparing two bridges, one with a critical deficiency in the substructure which requires an urgent countermeasure, and with a minor deficiency in the deck and superstructure which requires no immediate repairing; the other bridge with a deficiency evenly in the deck, superstructure and substructure which, nevertheless, requires no urgent repairing, the former may present a lower value in terms of overall deficiency evaluation. For that reason, a weight for each evaluation item was set in such a way that a deficiency and malfunction in key items would be reflected in the overall evaluation with a greater value.

8-4-2 Evaluation items and their weights

1) Structural condition deficiency (D e e)
   - a. Deck condition deficiency (C d l)
   - b. Superstructure condition deficiency (C d s)
   - c. Substructure condition deficiency (C d i)

2) Load capacity deficiency (D c c)

3) Functional condition deficiency (D e f)
   - a. Clear deck width deficiency (C a u)
   - b. Vertical clearance deficiency (C h u)

4) Structure type deficiency (D t d)

5) Remaining life deficiency (D v u)

6) Geographical condition deficiency (D p e)
a. Water way adequacy (C d e)
b. Deck geometry deficiency (C t c)

The hierarchical structure of the above evaluation items, together with their significance (weight), is as shown in Table 8-17.

In the above mentioned Table, the evaluation value of the evaluation items having no second level items such as "load capacity deficiency", is entered as the first level value. Meanwhile, as for the items having second level items such as "structural condition deficiency", the sum of the second level items is entered. However, the sum of the second level items can not exceed the significance (weight) set to the first level items.

Take "structural condition deficiency" for example. Suppose, in the second level evaluation items, deficiency in the deck, superstructure and substructure are 50, 40 and 30 respectively. The sum of those values are 120, which is evaluated as the highest order of 100 in the structural condition deficiency. Accordingly, even if the other segments in the second level evaluation items are determined sound, indication of remarkable deficiency in a specific segment.

Evaluation items and their weights have been determined after consultation with MOP, however, the evaluation results have not yet been obtained. It is assumed that further consideration is necessary on the weight setting after completion of the system.

Table 8-17 Synthetic Judgment of Repair Priority

Item	Level 1	Level 2
1) Structural condition deficiency	100	
a. Deck condition deficiency		50
b. Superstructure condition deficiency		50
c. Substructure condition deficiency		50
2) Load capacity deficiency	40	
3) Functional condition deficiency	30	
a. Clear deck width deficiency		20
b. Vertical clearance deficiency		10
4) Structure type deficiency	30	
5) Remaining life deficiency	10	
6) Geographical condition deficiency	20	
a. Water way adequacy		10
b. Deck geometry deficiency		20
Total Evaluation	230	

8-4-3 Evaluation Method

Although various expressions have so far been studied to determine evaluation levels, among them we decided to employ the most simple complementary expression. This is due to the fact that presently in Chile, the structure standard of the road(width, alignment regulation, load etc.) is not strictly set, and that the obtained data is not accurate enough to necessitate complicated expressions. It has also been concluded that the expression would provide enough data for an administrative judgment. Refer to Table 8-18 for evaluation value of deficiency.

1) Structural condition deficiency

$$Dee = Cdl + Cds + Cdi < 50$$

where :

Cdl : Cdl max · k (Cdl max = 40)

Cds : Cds max · k (Cds max = 50)

Cdi : Cdi max · k (Cdi max = 50)

Table 8-18 Evaluation Value for Deficiency

Evaluation value	Coefficient k	Cdl	Cds	Cdi
1	0.0	0	0	0
2	0.1	4	5	5
3	0.3	12	15	15
4	0.7	28	35	35
5	1.0	40	50	50

2) Load capacity deficiency

$$Dcc = Pcc \cdot (1 - Ccm / Cdr) < 40$$

where :

Pcc: The maximum evaluation value for load capacity deficiency Pcc = 40

Ccm: Load capacity deficiency of an objective bridge (t)

Cdr: Load capacity required for design (t)

Table 8-19 shows the design load by road classification.

Table 8-19 Design Load by Road Classification

Road classification		Designed load
Expressway		HS20-44+20%
National highway	A	HS20-44+20%
Principal local road	B	HS20-44
Local road	C	HS20-44
Regional road	D	HS15-44
Urban road	U	

3) Functional condition deficiency. Refer to Table 8-20.

Def = Cau + Chu < 30

where :
C a u: Clear deck width deficiency (Cau max = 20)
C h u: Vertical clearance deficiency (Chu max = 10)

a. Clear deck width deficiency evaluation

Cau = Pac · (Ar - Ae) / (Ar - Ama) < 20

where :
P a c: The maximum value for clear deck width deficiency evaluation (Pac=20)
A r : Designed clear deck width (m)
A e: Existing bridge width (m)
A m a : The minimum required width (m)

Table 8-20 Designed Road Width

(Unit : m)

Road classification	Designed width Ar	Minimum width Ama
Expressway	27.0	26.0
National highway	13.0	11.0
Principal local road	11.0	9.0
Local road	10.0	8.0
Regional road	9.0	8.0
Urban road	—	—

2. Vertical clearance deficiency. Refer to Table 8-21.

Chu = Phu · (Hr - He) / (Hr - Hma) < 10

where :
P h u: The maximum value for clear deck width deficiency evaluation (Phu=10)
H r : Space required for design (m)
H e : Existing vertical clearance (m)
H m a : The minimum required vertical clearance (m)

Table 8-21 Road Clearance

(Unit : m)

Road classification	Designed space Ar	Minimum space Ama
Expressway	5.0	4.7
National highway	5.0	4.7
Principal local road	5.0	4.7
Local road	5.0	4.7
Regional road	5.0	4.7
Urban road	5.0	4.7

4) Structure type deficiency evaluation. Refer to Table 8-22.

$$Dtd = Ptp \cdot Ktp < 30$$

where :
P t p : The maximum value for structure type deficiency evaluation (Ptp=30)
K t p : Evaluation factor for each structure type

Table 8-22 Evaluation for Structure Type

Structure type	Ktp
Fink truss type bridge	1.0
Suspension bridge	1.0
Timber bridge	0.6
Gerber bridge	0.3
Lattice truss type bridge	0.2

5) Remaining life deficiency evaluation. Refer to Table 8-23.

$$Dvr = Pvr \cdot (1 - (Vu - Ep) / 10) < 10$$

where :
D v r : The maximum value for remaining life deficiency evaluation (Pvr=10)
V u : Life (years)
E p : Age (years)

Table 8-23Remaining Life of Bridge

Construction materials	Vu
Steel	40
Concrete	50
Timber	8
Stone	50
Block (Brick, etc)	30

(Note) Bridge life is determined by the material having the shortest life used for the substructure, main girder and deck.

6) Geographical condition deficiency. Refer to Table 8-24.

$$Dpe = Cde + Ctc$$

where :
C d e : Water way adequacy (Cde max = 10)
C t c : Deck geometry deficiency (Ctc max = 20)

A. Water way adequacy evaluation

$$Cde = Pes \cdot (Ac - Lep) / (Ac - Lmp) < 10$$

where :
P e s : The maximum value for water way adequacy evaluation
A c : River width
L e p : Existing bridge length
L m p : The minimum required bridge length

B. Geographical condition deficiency evaluation

$$Ctc = Ptc \cdot Ktc < 20$$

where :
P t c : The maximum value for geographical condition deficiency evaluation (Ptc=20)
K t c : A factor for geographical condition deficiency evaluation (Tt)

Table 8-24 Evaluation Value for Geographical Condition

Evaluation value Tt	Ktc
1	0.0
2	0.2
3	0.4
4	0.7
5	1.0

A geographical condition deficiency evaluation value (Tt) is determined from the relationship between a longitudinal slope of a bridge or an access road and a plane curve as follows.

$Tt = Tp + Tc < 5$

where :
T t: Road alignment evaluation value (Tt max = 5)
T p: Longitudinal slope evaluation value (Tp max = 2)
T c: Plane curve evaluation value (Tc max = 5)

a. Longitudinal slope evaluation value Tp. Refer to Table 8-25.

Table 8-25 Longitudinal Slope Evaluation Value

The sum of longitudinal slopes	Evaluation value Tp
0% < Pe < 2%	0
2% < Pe < 4%	1
4% < Pe < 6%	2
6% < Pe < 8%	3
8% < Pe	4

b. Plane curve evaluation value Tc. Refer to Table 8-26.

$Tc = 5 \cdot (Cr - Ce) / (Cr - Cma) < 5$

where :
C e : a radius of curve of an existing bridge (m)
C r : Designed radius of curve (m)
C m a : The minimum radius of curve (m)

Table 8-26 Plane Curve Evaluation Value

(Unit : m)

Road classification	Designed speed	Radius of curve	Minimum radius of curve
Expressway	120 km/H	700	530
National highway	110 km/H	530	400
Principal local road	110 km/H	530	400
Local road	80 km/H	240	125
Regional road	60 km/H	125	55

Chapter 9 Conclusion And Recommendation

9-1 Conclusion

The Study on Rehabilitation and Conservation Program of Bridges was proceeded with the inspections of 256 existing bridges in total, 246 bridges among those on the National Route 5 and 10 bridges selected on the arteries branched out of it. Based on the results of inspections, a fairly comprehensive bridge inventory register was prepared, which was followed by bridge defect degree evaluation and priority rating for rehabilitation. Then, formulation of bridge rehabilitation plan was attempted. In parallel with these works, preparation of a guideline for bridge maintenance inspection, and development of a micro-computer system on bridge maintenance management were undertaken.

(1) Bridge Inspection and Rehabilitation Planning

Because of the reason that the design documents of the existing bridges subjected for inspections were not kept at the Ministry of Public Works, measurement of the major dimensions and photographing of the bridges and their surroundings were carried out at time of inspections, along with drawing of their general designs. By that way, a bridge inventory register was prepared and compiled. The outcomes of these works were not only very productive to formulation of the bridge rehabilitation plan, but also will be expected to contribute to the bridge maintenance activities of the ministry in the future. It is suggested that similar type of data collection and compilation of the existing bridges on the regional roads to be a proper bridge register will greatly contribute to the bridge maintenance activities and their rehabilitation planning in the future.

Among those bridges inspected on the National Route 5, the bridges which were evaluated to be of defective degree rankings of 4 and 5 were selected and incorporated in formulation of the bridge rehabilitation plan. The total budget of the plan worked out by accumulation of the estimated costs of rehabilitation works amounts to Chilean Pesos 4,000 million. It is to be pointed out that the proposed rehabilitation plan is intended to restore the originally required function of the existing bridges, with the standardized rehabilitation methods. Therefore, it is neither planned to strengthen this function, nor included large scale rehabilitation of the special types of bridges. For planning of large scale rehabilitation and for that of the special types of bridges, it would be necessary to undertake further detailed studies with different approach.

Many of the bridges included in the rehabilitation plan are quite widely ranged from very old ones to lately constructed ones. This means that there are great differences in the design concept and design specifications like design load, etc., according to the ages when the bridges were constructed. Apart from this fact, some bridges were found to have deformations at their girders and piers, regardless of the times of their design. Since there are no design documents at completion being kept at the administrative offices concerned, verification as to whether the deformations were caused at time or after the bridge construction was found to be very difficult.

Judging from these facts, for the future planning of development, improvement and maintenance of the bridges on a certain road network, consistency and integration in the design concept and standards would be necessary, in close coordination with those