8.5 Maintenance of Existing Bridge

Some maintenance works shall be carried out if the present conditions are kept as they are until the completion of the new bridge. Deck slab repairs shall be carried out if the cracks will progress to a type two, three and four condition. (see paragraph 8.3.1 (2)).

Additionally, widening of the existing pier caps shall be undertaken to avoid the dropping of spans which can be caused from the horizontal displacements caused by earthquake forces.

Maintenance works shall be continued on a routine basis. Periodic observation of bridge conditions shall be carried out especially in regard to the deck slab cracks and settlement of the foundations.

Expansion joints shall be repaired and pile caps shall be reinforced as necessary.

8.5.1 Maintenance Works and Costs

Deterioration of the existing bridge is substantial, necessitating that some maintenance works be carried out to keep the present service level of the bridge until the end of its useful life.

Maintenance cost for the existing bridge will be developed for rehabilitation of deck slab, pier caps, pile caps and expansion joints.

(1) Deck Slab

Based on the survey results summarized in Chapter 8, Table 8-1, areas of the deck to be rehabilitated and the method of rehabilitation are described below:

Table 8-12 Maintenance Works for the Deck Slab

	Area(m2)	Descripción
Superficie superior de la losa (hormigon no estructural de 7 cm de espesor)	833	A ser reparado utilizando asfalto para evitar la filtración de agua hacia el hormigón estructural de losa
	124	A ser reparado mediante carpeta asfáltica
Superficie inferior de la losa (hormigon estructural de 14cm de espesor)	95	A ser reparado mediante la inyección de lechados químicos para evitar la filtración de agua hacia el hormigón estructural de la losa
	4	A ser reparado mediante hormigón vaciado insitu

(2) Pier Cap

The widening of the tops of piers is useful and necessary to prevent the steel girders from falling due to major earthquake motion, as indicated in paragraph 8.3.1. The proposed method is shown in Fig. 8-8.

(3) Pile Cap

As for foundations of 37 piers at the San Pedro side, the connection between top of the piles and bottoms of the piers shall be strengthened by means of reinforced concrete lining at the tops of the concrete piles, and by providing connecting reinforcement bars so that the old piles and piers and the new pile caps would function as one unit.

The strengthening of pile caps at the 37 piers shall be carried out in the dry season December to April), to ease the construction work as well as to secure its quality while working under conditions of low water level. The proposed strengthening method is shown in Fig. 8-8.

(4) Expansion Joints

Regarding the rehabilitation of the expansion joints of the bridge, it is noted that 77 sets out of 103 sets of expansion joints need to be replaced with new ones either due to severe damage or because they are missing.

As mentioned in paragraph 8.3.1, it is clear that the damage to the expansion joints was caused mainly due to the weakness of the anchorage system. In addition, L-shaped steel members are inherently weak because they can easily be separated into two segments by traffic action.

The expansion joints shall be replaced by channel-shaped built-up steel frames with a depth of 23 cm. These frames should be connected by using high strength bolts and steel shims between the bottom of the channel-shaped steel frame and the top of the steel girder to suit the depth of the deck slab. The top of the channel-shaped steel frame shall also be connected to the concrete deck slab by means of steel anchor bars.

The opening between adjacent expansion joints should be filled with elastic material such as rubber, to prevent the steel girders and shoes from corrosion due to leaking water from the deck surface.

The proposed new expansion joints are shown in Fig. 8-8.

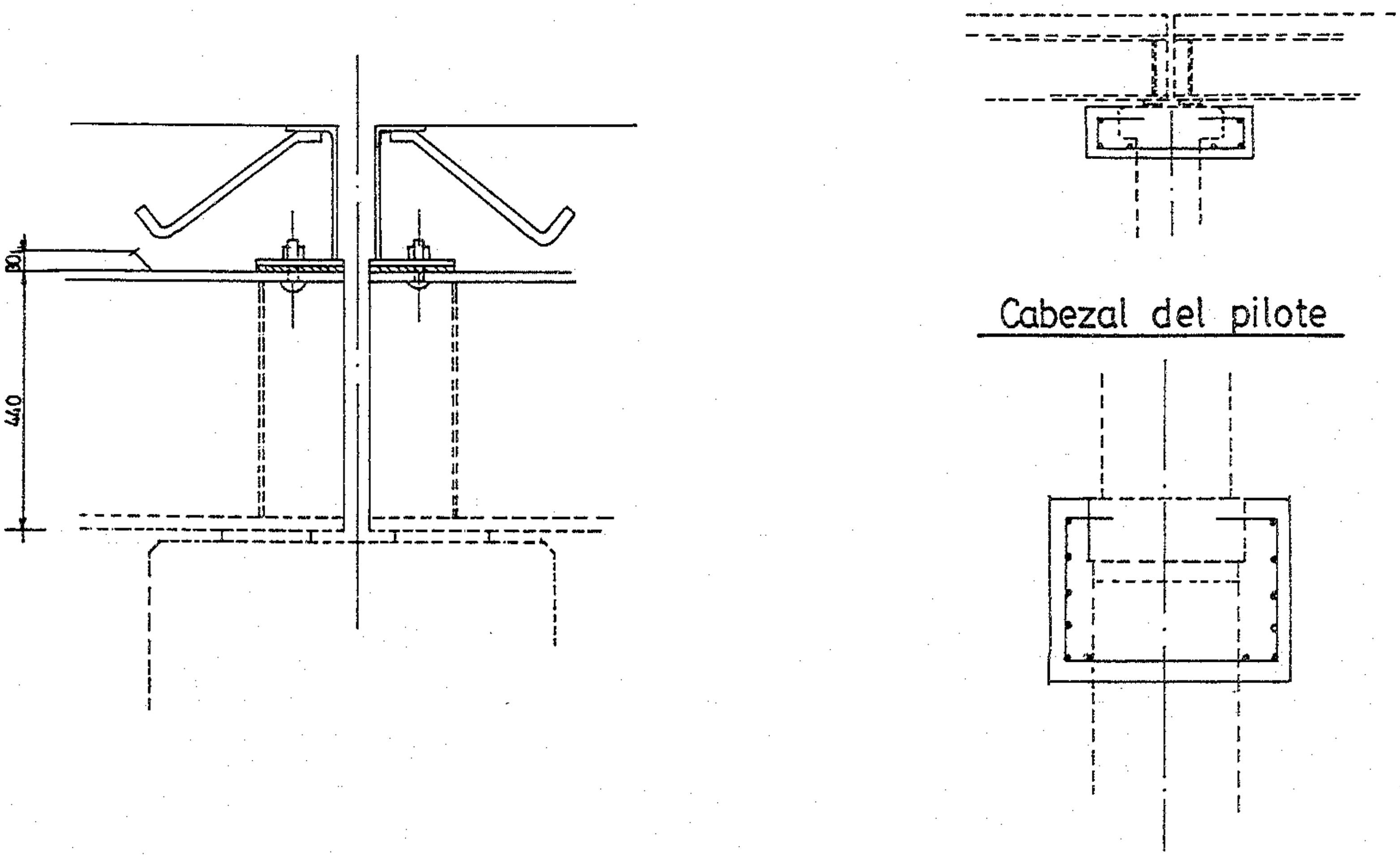
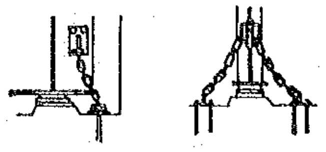
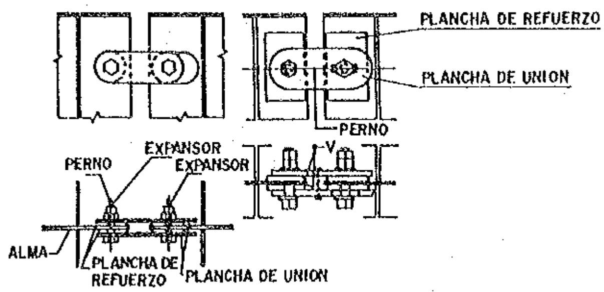


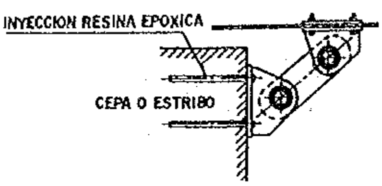
Fig. 8-8(1) Details of Maintenance Works



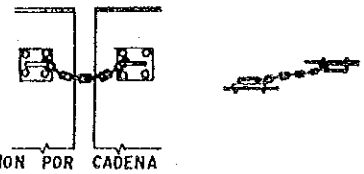
UNION VIGA A INFRAESTRUCTURA POR MEDIO DE CADENAS



i) UNION POR BARRAS TRANSMISORAS DE CARGA



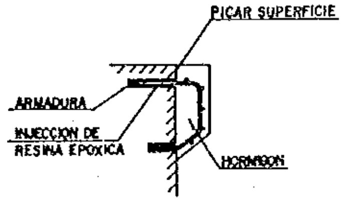
UNION VIGA A INFRAESTRUCTURA POR MEDIO DE PLACAS DE ACERO



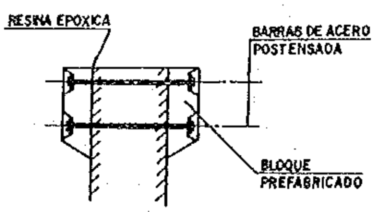
ii) UNION POR CADENA

UNION ENTRE VIGAS (FIJAS Y MOVILES)

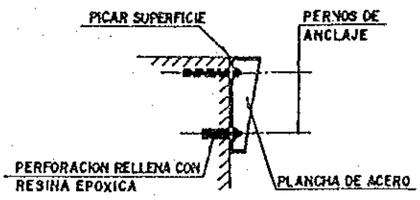
ALGUNOS ELEMETOS DE PROTECCION



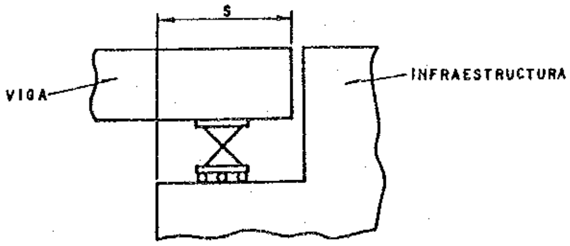
ALARGAMIENTO DE LA MESA DE APOYO
(DE HORMIGON ARMADO)



HORMIGON POSTENSADO
(PREFABRICADO)



PLANCHA DE ACERO



DISTANCIA DEL EXTREMO DE LA VIGA AL
BORDE EXTERIOR DE LA MESA DE APOYO

Fig. 8-8(2) Details of Maintenance Works

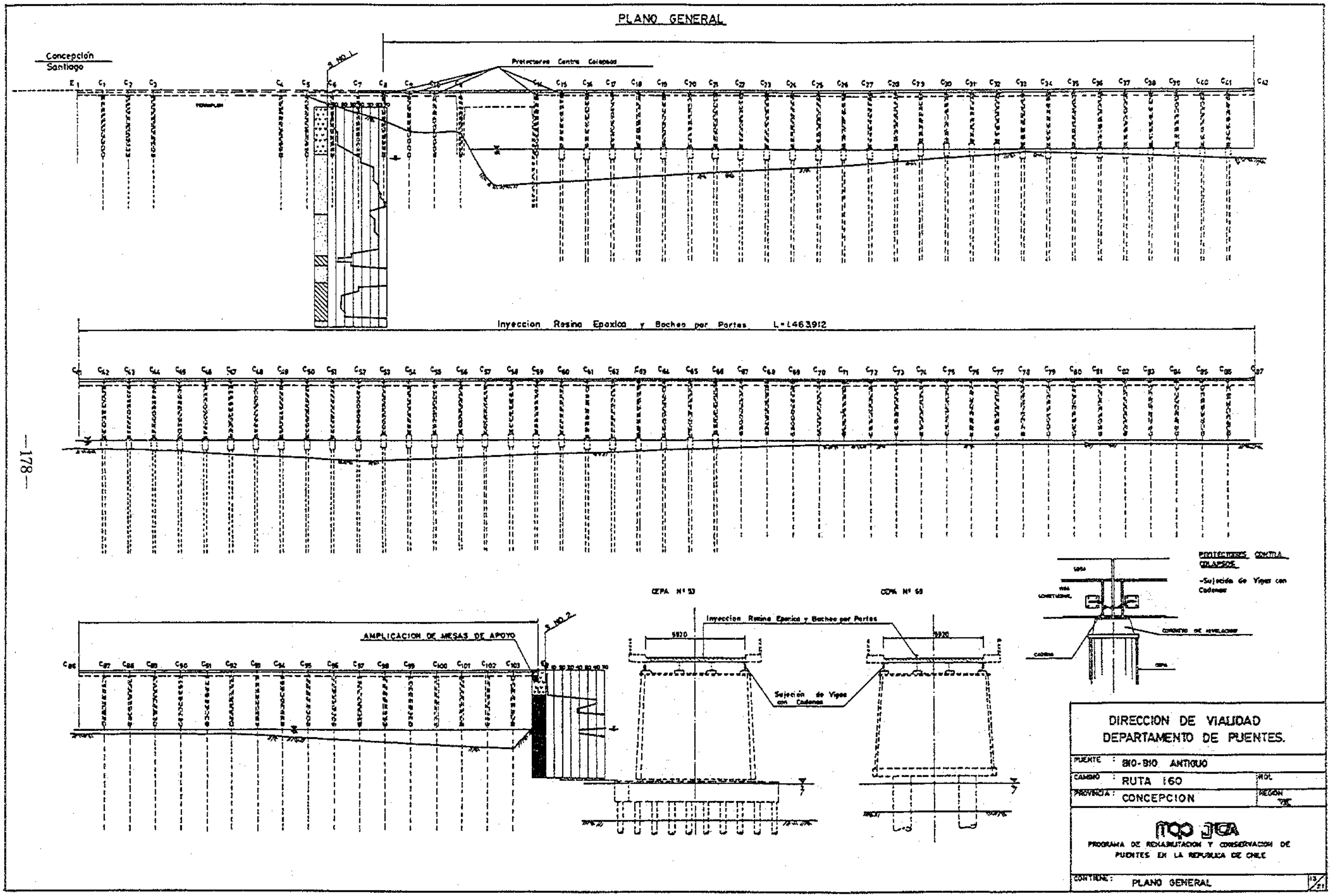


Fig. 8-8(3) Details of Maintenance Works

(5) Construction Time

To carry out the maintenance works for the existing bridge, a total time of 18 months is estimated.

(6) Maintenance Cost

Estimates of maintenance costs were made in accordance with methods proposed above. The results are tabulated below in Table 8-13.

Table 8-13 Cost of Maintenance Works

Descripción	Unid.	Canti.	Costo unitario		Totales	
			Ch.$	US$	1000 Ch.$(1)	US$(2)
Demolición de hormigón	m3	51	15.600	24,10	795,60	1.229,10
Inyección de resinas	m2	95	2.240	1,30	212,80	123,50
Reparación losa	m2	128	21.200	12,30	2.713,60	1.574,40
Paviment	m2	833	909	6,36	757,27	5.297,88
Moldaje	m2	1940	7.090	2,73	13.756,37	5.296,20
Barras de refuerzo	t	43,4	513.636	62,73	22.291,82	2.722,48
Andamio	m2	1800	4.346	3,68	7.822,80	6.624,00
Andamiaje	m3	2118	3.633	4,95	7.695,54	10.484,10
Hormigón(200kg/cm2)	m3	487,5	27.818	11,45	13.561,36	5.581,88
Hormigonada	m3	487,5	2.516	10,71	1.266,00	5.221,13
Junta de Expansión	m	470	2.909	62,73	1.367,27	29.483,10
Costo Directo					72.240,43	73.637,76
Gastos Generales	%	30			21.672,13	22.091,33
Costo de Construcción					93.912,56	95.729,09
Costo de Ingeniería	%	15			14.086,88	14.359,36
Imprevistos	%	10			9.391,26	9.572,91
IVA	%	18			21.130,33	21.539,95
Aqusición de Tierra					0,00	0,00
Costo Total de Construcción					138.521,02	141.200,41

Note : (1) Local component of cost
(2) Foreign component of cost

Total cost is the sum of local component and foreign component

8.6 Upgrading Works

8.6.1 Engineering Evaluation for Upgrading

It is recognized that process of upgrading the existing bridge cannot be combined with the process of the selection of alternative routes because existing traffic must go through San Pablo II Bridge during the upgrading period.

Upgrading can be considered only after completing the construction of the New Bridge, and after taking into consideration all technical and economic viewpoints.

Comparison will be made between upgrading of existing bridge and the construction of a new 2-lane bridge. The upgraded bridge will use parts of the existing facility.

As indicated in paragraphs 8.3 and 8.4 of this Chapter, the stability of existing bridge is substantially doubtful, and the Study team has concluded that it is not recommended to upgrade the bridge. The reasons will be clarified hereinafter from the viewpoint of bridge rehabilitation.

It is pointed out that most of the components of the bridge may not be suitable for upgrading due to many reasons described below. Existing components of the bridge will, however be utilized to reduce the cost for construction of a new bridge by using them as temporary facilities such as scaffoldings, stagings and temporary bridge for construction work.

(1) Superstructure

The stresses in the steel girders highly exceed the allowable stress of 1,320 kg/cm2 under HS-20 load, even for composite action, as shown in Table 8-8 .

The problem of vibration of the superstructure should be considered in the evaluation of stability of the superstructure taking into account the fatigue stresses. It is necessary that the depth of the girders be increased to reduce deflection as well as vibration. Cross frames should be provided as well.

The utilization of existing steel girders in the upgrading is considered uneconomical because of additional costs of dismantling, transportation from bridge site to fabricating shop, cleaning and refabrication, in addition to the cost of added steel for increasing girder depth and for cross frames.

The newly refabricated girders would most likely require some measure of stress relief prior to rewelding and fabrication making the cost of such upgrading too prohibitive. The problem of the fatigue of the existing steel would further add to the complication of the reuse of the existing girders, and might make it inadvisable to continue to subject the existing steel to more loading.

Additionally, there may be a problem of incompatibility in the steel grade between the old and the new steels.

Taking into account the above considerations, the program for upgrading would require that the superstructure be replaced with a new one to suit the 20 ton live load.

(2) Piers

The tops of piers should be widened in both directions transversely and longitudinally to fit into the new bridge. In the transverse direction, it is required to extend the width of the piers at the top from 6.5 m to 12.0 m to suit the arrangement of the girders as shown in Fig. 8-9.

In the longitudinal direction, the width at the top of the piers must also be increased from 0.7 m to 1.2 m in order to prevent the girders from falling under a major earthquake.

Some of the concrete cover in the pier shafts was spalled due to the corrosion of the reinforcing steel bars, and the neutralization of the concrete in the piers which has progressed deeply. The pier shafts should be strengthened by means of reinforced concrete lining and by providing connecting bars so that the old pier and the new lining would function as one unit.

For these rehabilitation works, the upper portion of (about 3.8 m) of the existing piers will be cut off and reconstructed.

(3) Foundations

In the original design of the foundations of the existing bridge, and utilizing the old codes, little consideration was given to designing against major earthquake forces. Furthermore, the dead load to be carried by the foundation must be increased owing to the widening requirements of the bridge and strengthening of the pier.

Strengthening of the foundations would need new piles. The old foundation piles would however be neglected, because there is no guarantee that the old piles would adequately share the loadings from the piers with the new piles.

8.6.2 Obstacle to Stream Flow

The thickness of existing pier shafts is 0.8 m at the bottom section longitudinally. The pier thickness to span ratio is 0.8/15.25 = 5.2 %. However, the thickness of those sections must be increased to 1.4 m if rehabilitated, and this would make the ratio 1.4/15.25 = 9.2 %. This is considerably higher than the ratio of 3 % to 5 % specified in the Specifications for Planning of River Structures. It is further noted that, for a great number of piers, the width of the foundation cap along the longitudinal axis of the bridge is about 3.4 m, and the ratio is more than 20 % of the gross span length.

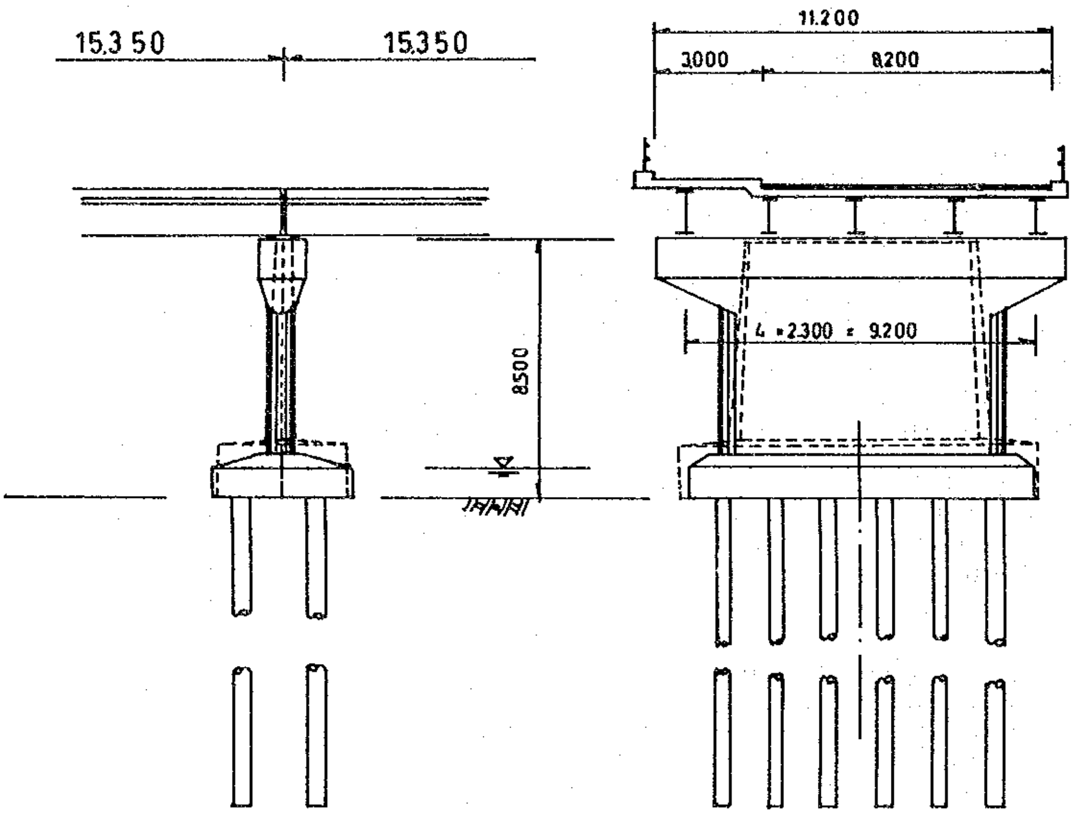


Fig. 8-9 Upgrading of Biobio Antiguo Bridge

To reduce the thickness to span ratio to less than 5 %, the span length should be more than 28 m, under the condition of 1.4 m thickness of pier.

When the actual clearance is less than 14 m, it is difficult to avoid creating obstacles in the river bed from debris, and further increase maintenance costs.

Spans of double the existing ones could be considered, and the steel girders should be new ones. If this scheme is followed, there would be added costs for demolition of every other pier.

8.6.3 Construction Cost

Based on the above considerations, the Study Team is of the opinion that the construction cost of the upgrading of the existing bridge, is not a practical undertaking. Furthermore, it is felt that the construction of a new bridge is more economical and in the best interest of the project. An upgraded bridge could not be considered as a permanent solution since all the work would be repair and since it would remain a 2-lane bridge.

8.6.4 Construction Time

The Study Team is of the opinion that the work period for the upgrading the existing bridge would be longer than that of constructing a new one because of the demolition and reconstruction of all the elements of the bridge including the deck, piers and foundations.

8.6.5 Conclusion

It is concluded that the upgrading of the existing bridge is not a practical solution, is not economical, and is therefore not recommended.

8.7 Recommendations Regarding the Existing Bridge

Based on the above findings, particularly with regard to the overstress in the structural steel girders, and the overstress in the steel reinforcement in the deck, the Study Team has reached the following conclusions:

1. Due to the excessive overstress of the structural components, this bridge should be closed to traffic to avoid loss of life and property.

2. The MOP may however, decide to carry out the above recommendation in two stages. a) By restricting the traffic to passenger and emergency vehicles only, and b) Complete closure of the bridge.

3. It is not recommended to upgrade the bridge.

4. The MOP should make arrangements for replacement of this bridge as soon as possible.

CHAPTER 9 STUDY OF ALTERNATIVE ROUTE PLANS FOR THE NEW BRIDGE

9.1 Basic Policy for the Study

9.1.1 Basic Policy

After further review of the various elements influencing the scope of the Study, the following criteria were adopted. These criteria are described below along with the rationale for their use.

The Study Team does not consider it advisable to recommend an ultimate situation where a 2-lane, 20 ton bridge is constructed adjacent to a 2-lane, 8-ton bridge (the current load restriction on the existing bridge), as the ultimate solution under this Study. Such condition will severely restrict the routing of the Public Transport which is a critical element of this Study creating the following situations:

1. If the existing (8 ton) 2-lane bridge is located side by side with a new (20 ton) 2-lane bridge and both lanes of each bridge are restricted to one-way traffic, with the new bridge carrying the buses and trucks, etc.the traffic would have to be routed for the return trip via Juan Pablo II Bridge.

2. If the existing (8 ton) 2-lane bridge is located side by side with a new (20 ton) 2-lane bridge and both bridges are used for 2-way traffic, then the buses and trucks will be restricted to use only the new bridge, creating a serious traffic management problem, in addition to not meeting the traffic demand for 2010.

In Chapter 8, the Study Team made recommendations regarding the Existing Bridge. It is further informed that the useful life of this bridge is limited, however, the MOP may consider maintaining the limited use of the existing bridge in lieu of its demolition, since this bridge is needed to act as detour during the construction of the new Bridge. In any event, the Study Team does not recommend that the costs of the new bridge construction be augmented by adding the demolition costs.

In summary, the Study Team recommends that the new bridge must have a standard capacity for truck loading, HS20-44, that it should be a 4-lane bridge, and that the demolition of the old bridge should not be considered in the costing for the new bridge.

In the Minutes of the Meeting of February 18, 1994 when the Interim Report was submitted, it was confirmed that the New Bridge should have a live load capacity of 20 % higher than the HS 20-44.

For the above reasons, the investigation of the alternative plans described in the following section are recommended.

9.1.2 Alternative Plans for the Study

In studying the various alternatives, the extent of the study is shown on Fig.9-7. The costs for each alternative include the following major items:

1. The cost for the intersection on the existing road (PEDRO AGUIRRE CERDA) and the access road to the new bridge at SAN PEDRO side.

2. The cost for the improvement of access road on the SAN PEDRO side including widening, relocation and land acquisition and other considerations which will affect each specific alternative.

3. The cost of intersection crossing the coastal road in the future is not included, however, the access road for the new bridge at the Concepcion side is included.

4. The cost of the overpass of the railway at Concepcion side.

On the SAN PEDRO side, there will be need for a substantial improvement of the road. This road is currently a two-lane road and must be widened to a four-lane facility. Since this road traverses a built-up area, there appears to be a need for land acquisition and compensation for the demolition of homes and other buildings.

The road widening may encroach on the railroad property, and it may be necessary to relocate a section of the track approximately 1000 m long along the Avenida PEDRO AGUIRRE CERDA. The cost for the widening of this approach is not included in this comparison since it is common to all the alternatives.
Based on the above, the following alternatives will be investigated. See Fig. 9-7:

(1) Alternative 1.

Construction of a new 4-lane bridge, parallel to the existing bridge, but slightly upstream. Closure of the existing bridge is recommended in this alternative.

(2) Alternative 2.

Construction of a new 4-lane bridge, along the alignment of the extension of Chacabuco Street. Closure of the existing bridge is recommended in this alternative.

(3) Alternative 3.

Construction of a new 4-lane bridge, connecting the end of Los Carrera Street and Avenida PEDRO AGUIRRE CERDA at San Pedro with the shortest bridge length.

(4) Alternative 4.

Construction of a new 4-lane bridge, along the alignment of extension of Los Carrera Street.

9.2 Planning Conditions and Design Criteria

9.2.1 Design Specifications

To design suitable bridge reconstruction to satisfy technical, economic and maintenance requirements, the Study Team will review the design specifications, existing standards and criteria such as geometric design standards, standards of clearance, design live loads to be applied, earthquake resistant design etc. Standards applicable to the Project are as follows:

- Standard Specifications for Highway Bridges, AASHTO, 1992
- A Policy on Geometric Design of Highway and Streets, AASHTO,1990
- Highway Manual Volume 2 (Procedure of Investigation), MOP, 1982
- Highway Manual Volume 3 (Design Instructions), MOP, 1982
- Highway Manual Volume 4 (Standard Design), MOP, 1982
- Highway Manual Volume 5 (Specification of Construction), MOP,1982
- Technical Specifications for Rehabilitation and maintenance of Bridges, MOP, 1983
- Urban Road Design Manual Volume 3, Ministry of Urban Housing MINVU 1984
- Specifications for Highway bridges, Japan Road Association, 1990
- Specifications for Road Design, Japan Road Association, 1983
- Specifications for Planning of River Structures, Japan River Association, 1991

The Project will propose that the principal criteria to be applied to the feasibility study, as a rule, should be based on Chile Standard (Nch) and Urban Road Design Manual, MOP. The design methodology and seismic applications, other than those in the Nch Code, will follow the Specifications for Highway Bridges of Japan Road Association.

9.2.2 Natural Conditions

(1) Hydrological Conditions

Refer to Chapter 7 for all hydrological information including design discharge and catchment area. See Fig. 9-1 for hydrological design values used in the Study.

(2) Soil Conditions

Results of the core borings were not available during the preparation of the Interim Report. At that time, the preliminary structural system used 10 m piles. The soils report was later completed and the results applied in the selection of the substructure system. Refer to Chapter 7.

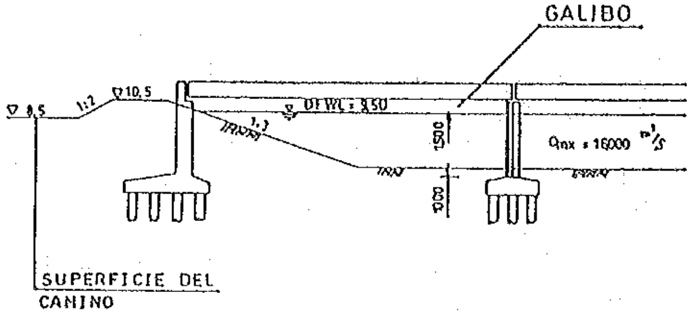


Figure 9-1 Hydrological Design Values Used in the Study

9.2.3 Geometric Conditions

For the geometric design of the bridge and access road, Chile Standards should be applied as a rule. The basic Geometric Conditions adopted for this project are shown in Table 9-1.

Table 9-1 Basic Geometric Conditions

Item	Estructura a diseñarse			
	Puente	Camino de Acceso	Rampa de un carril	Rampa de 2 carriles
Velocidad de diseño. (km/hr)	60	60	40	30
Ancho de carril. (m)	3.5	3.5	3.0	3.0
Pendiente máxima. (%)	7.5	7.5	10.0	11.0
Ancho de bermas. (m)	0.6	1.5	1.5	1.5
Ancho de pasillos. (m)	2.5	3.0	2.5	2.5
Radio mínimo de curvatura. (m)	200	200	60	30
Distancia de visibilidad. (m)	75	75	40	35

9.2.4 Roadway width

Roadway widths to be adopted for the Project are determined in accordance with the Highway Manual vol 3, MOP, and Urban Road Design Manual Vol 3, MINVU. The previous existing width and traffic data were reviewed to determine the proper width in the Project.

For the proposed bridge, 3.5 m lane width and 0.6 m shoulder will be used based on geometric roadway standard. Sidewalk width of 2.5 m as an urban road bridge shall be applied considering pedestrian and bicycle usage. In case of the proposed access road, 3.5 m for lane width and 1.5 m for shoulder are recommended. See Fig. 9-2 for roadway widths for bridges and Fig. 9-3 for access road.

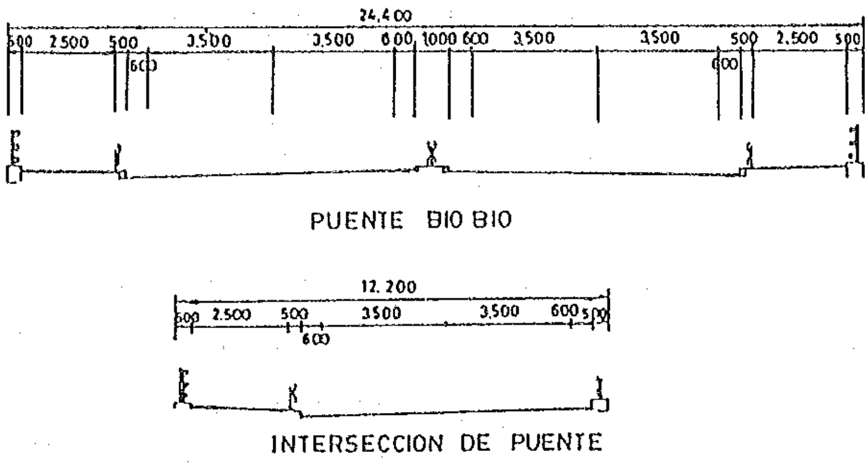


Figure 9-2 Roadway Widths for Bridge

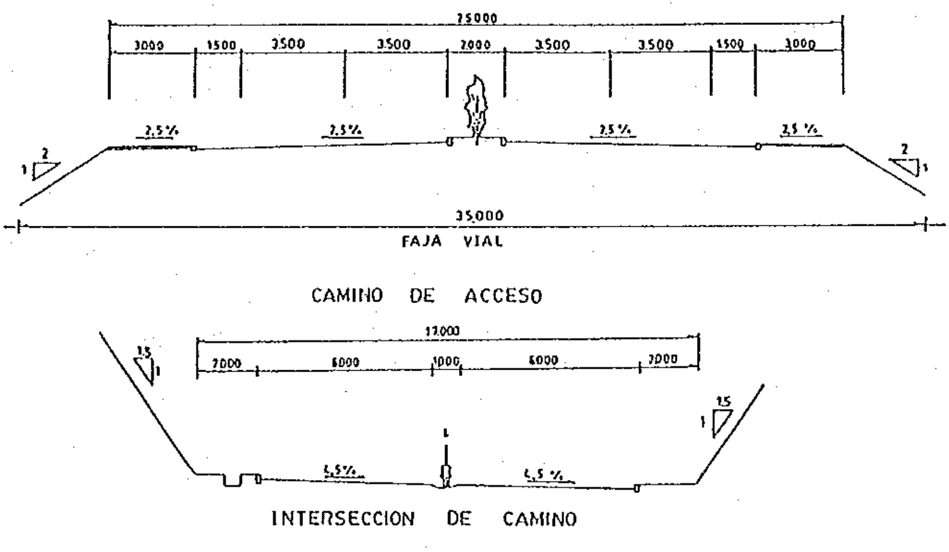


Figure 9-3 Roadway Widths for Access Road

9.2.5 Construction Clearance

(1) River

Vertical clearance under a bridge shall be determined taking into consideration the space needed for river navigational clearance, maintenance, etc. It was determined that a 1.5 m clearance shall be applied for this Project. This is because;

1. There is no specific figure for the clearance in Design Manual or Standard in Chile.
2. In general, a 1.0 m clearance is most frequently used in Chile.
3. 1.5 m of clearance should be adopted based on a design discharge of 15,000 m3/s to 20,000 m3/s using the criteria from the Specification for the Planning of River Structures in Japan.
4. It has been found that 1.5 m clearance will not result in adverse effects since the river width of approximately 2 km at the location of bridge is substantially more than required waterway opening width of 600 m to 850 m derived from the computed design discharge using " Lacey's regime formula for alluvial channels ".

(2) Road

Vertical clearance on the road is specified by the Highway Manual Vol 3, MOP. The reason why 5.0 m height shall be applied for the Project is because of satisfactory use of such clearance in Chile. Vertical clearance over the sidewalks shall be 2.5 m. From the viewpoint of traffic safety, sidewalks should be provided on both sides of the bridge. Pedestrians shall be prohibited from crossing carriageway of the bridge.

(3) Railway

Construction clearance for the railway is specified by the Railway Manual. The arrangement of the existing railway tracks around Project area is complicated. The tracks have been divided into a single-track,double-track, and triple-track. See Fig. 9-4 for clearances over railroad, obtained from Empresa de los Ferrocariles del Estado en Concepcion.

9.2.6 Minimum Span Length

Span lengths should be determined based on river conditions and economic aspects of bridge construction. It is generally known that shorter span lengths will make bridge construction more economical, however, it is recognized that piers in the river create obstacles to the river flow. Due consideration will be given to provide reasonable span lengths and to avoid creating obstacles in the stream bed from debris.

Based on the above considerations, it has been determined that the span lengths of the proposed bridge crossing the river, should be of the same order of length as those of the Juan Pablo II and the Railway bridges.

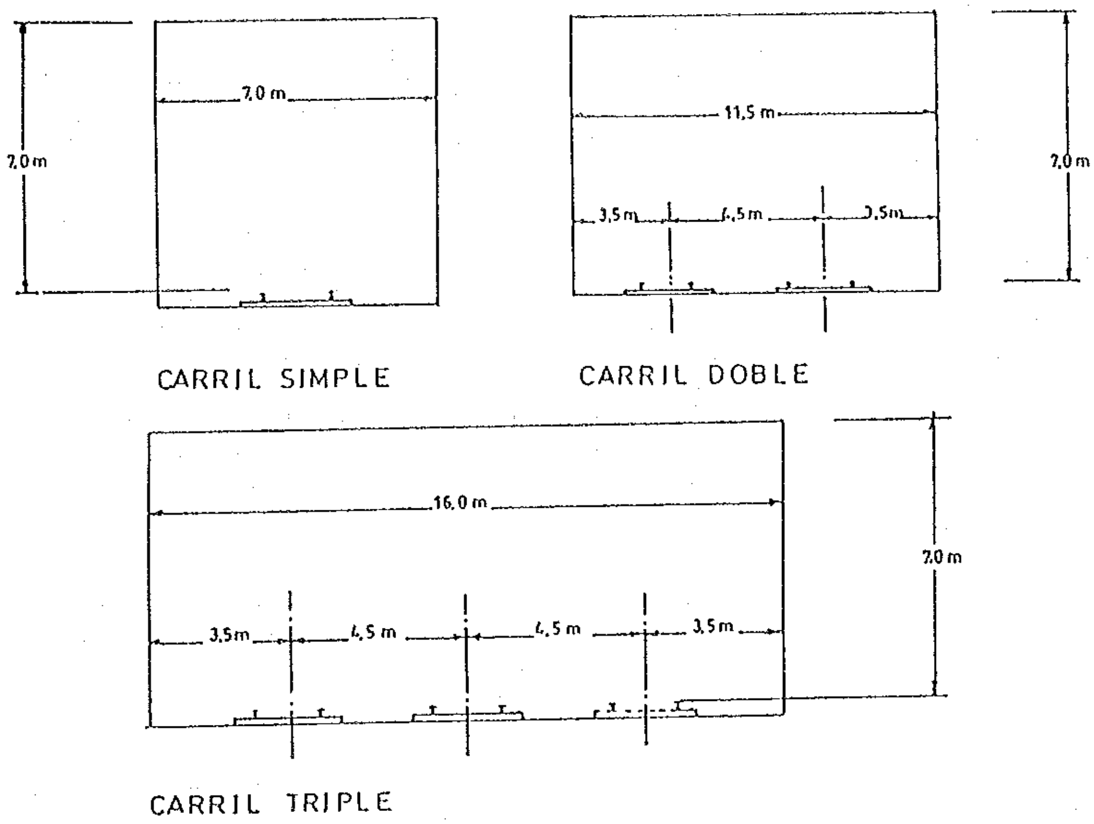


Figure 9-4 Construction clearance for Railway

9.2.7 Gradients to be used on the Bridge

In accordance with the geometric conditions, as specified in the previous section, the gradients to be used on the surface of the proposed bridge shall be as follows:

- 0.35 % longitudinal slope
- 2.50 % straight slope for crossfall on carriageway
- 2.50 % straight slope for crossfall on sidewalk

9.2.8 Live Load

For the Feasibility Study of the proposed bridge and access road, TL-20 loading (Japanese Standard) will be adopted as a rule. This is equivalent to the loading of current specifications used in the MOP. Following request from MOP, it was agreed to use a live load equivalent to 20 % above the HS 20-44.

The live load to be used for the design of the sidewalk slab itself shall be 500 kg/m2. The load from the sidewalk contributed to the girders shall be assumed to be 350 kg/m2 when designing the girders.

9.2.9 Thermal Force

Provision shall be made for stresses and movements resulting from variation in temperature. According to the data collected by the Study Team, the temperature in Concepcion varies from -3.8 C to 35.6 C. For the design of the proposed bridge, the temperature range to be used shall be from -5 C to 40 C.

9.2.10 Seismic Coefficient

Due to the seismic activity in Chile, and more specifically in Concepcion, the proposed bridge shall be designed to resist earthquake forces.

For seismic design of the proposed bridge, the seismic coefficient shall be 15% of the gravity load as a basic design standard. Special pier cap widenings shall be provided to mitigate against drop of girders. Connections between adjacent spans shall also be provided.

As for methodology to the earthquake-resistant design, the Japan Road Association standard will be adopted, and static forces shall be computed using the seismic coefficient.

9.2.11 Utilities

In urban areas, utilities such as water mains, telephone lines, electric lines and gas pipe lines are usually carried under or over the roadway. It is more economical to provide for them in the original bridge design than to consider them individually when required later. Provision should be made for the dead weight of such facilities.

The utilities to be considered in the design of the proposed bridge may include some or all of the following:

- water pipe
- electric lines
- telephone lines
- gas pipe

An allowance for the load from such utilities will be included in the detailed design.

9.2.12 Pavement

For the proposed bridge, asphalt concrete topping shall be placed above the reinforced concrete deck slab. This will help in the surface finishing and ease the rehabilitation when pot holes may arise. For the proposed bridge, a thickness of 70 mm should be used for the asphalt concrete topping.

9.3 Primary Study

9.3.1 Bridge Type and Span

During the initial investigation, a composite prestressed girder bridge was adopted for the design of the various alternatives for the following reasons:

(1) Concrete construction technology is considered more advanced and readily applicable in Chile.

(2) It would be more economical to maintain the prestressed concrete girder bridge than a bridge using structural steel girders, because the latter would require considerably more maintenance, such as painting.

(3) In general, substructure cost is cheaper where structural steel girders are used in the deck. This is because the deck would be lighter. This however, may not be significant if the cost of the foundations is not too high.

(4) The span lengths of 35 m were adopted since they are close to the span lengths used on the Juan Pablo II Bridge and on the Railway Bridge, and these bridges have performed well during the floods.

For the preliminary design submitted in the Final Report, the structural systems, etc. are described in Chapters 10 and 11.

9.3.2 Intersection Types

There are three types of intersections at each of the alternative routes such as grade crossing, overpass, and underpass crossing. The following intersection types are adopted for the study of alternative plans of route in consideration of structures, traffic, environment, and construction cost Table 9-2.

9.4 Comparative Study of Alternative Plans of Route

A comparative study for selection of bridge location was made for four alternative plans. These alternatives were described in paragraph 9.1.2, and are shown in Fig.9-7. (General Plan of the four alternatives).

For the preparation of the Interim Report, the type of bridge considered was composite post-tensioned girders with spans of 35 m.On that basis, unit costs and quantities were developed for four (4) alternative routes and preliminary total costs were derived (paragraph 9.4.4). Using these costs and applying an economic analysis involving costs and benefits, it was found that the most economically advantageous route was Alternative 4, located along the same alignment of Los Carrera, across the Biobio River.

Table 9-2 Adopted Intersection Types

Ruta	Ubicacion	Tipo	Evaluacion
Existente	Concepcion	Paso a nivel	Imposible
		Paso superior	Adoptado
		Paso inferior	Costoso
	San Pedro	Paso a nivel	Posible
		Paso superior	Adoptado
		Paso inferior	Posible
Chacabuco	Concepcion	Paso a nivel	Imposible
		Paso superior	Adoptado
		Paso inferior	Costoso
	San Pedro	Paso a nivel	Posible
		Paso superior	Adoptado
		Paso inferior	Posible
Los Carrera	Concepcion	Paso a nivel	Imposible
		Paso superior	Adoptado
		Paso inferior	Costoso
	San Pedro	Paso a nivel	Posible
		Paso superior	Adoptado
		Paso inferior	Posible

Note: Refer to Chapter 11 for additional information related to the intersections of Alternative 4.

9.4.1 Drawings for the Alternative Routes.

Separate drawings for the Alternative Routes have been prepared for each alternative, as well as other related information, See the figures described below.

Fig.9-5 General Plan of the four Alternative.
Fig.9-6 Plan of Route for Alternative 1.
Fig.9-7 Plan of Route for Alternative 2.
Fig.9-8 Plan of Route for Alternative 3.
Fig.9-9 Plan of Route for Alternative 4.
Fig.9-10 Profile of bridges for Alternatives 1 and 2.
Fig.9-11 rofile of bridges for Alternatives 3 and 4.
Fig.9-12 Typical Cross Sections.

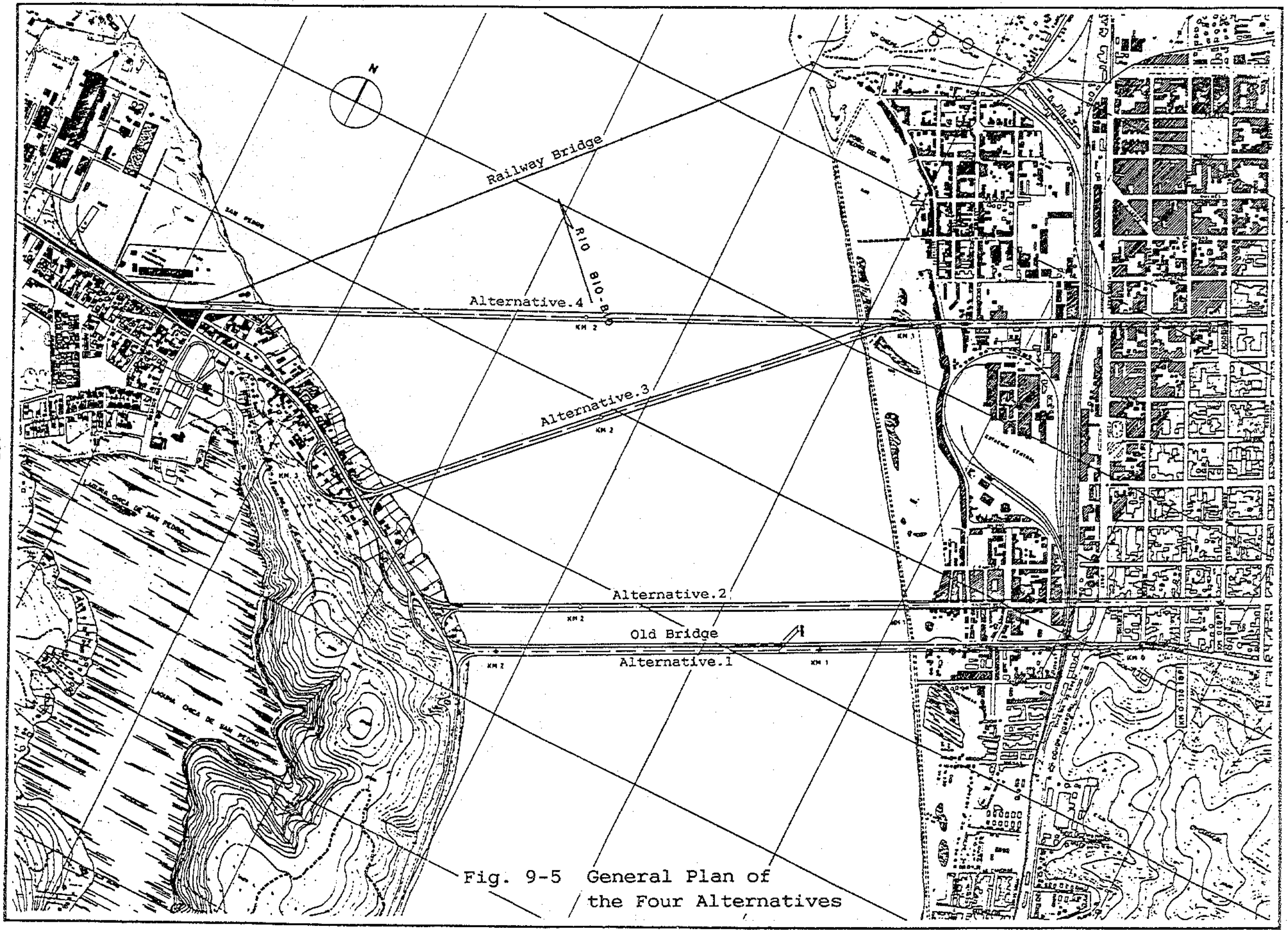


Fig. 9-5 General Plan of the Four Alternatives

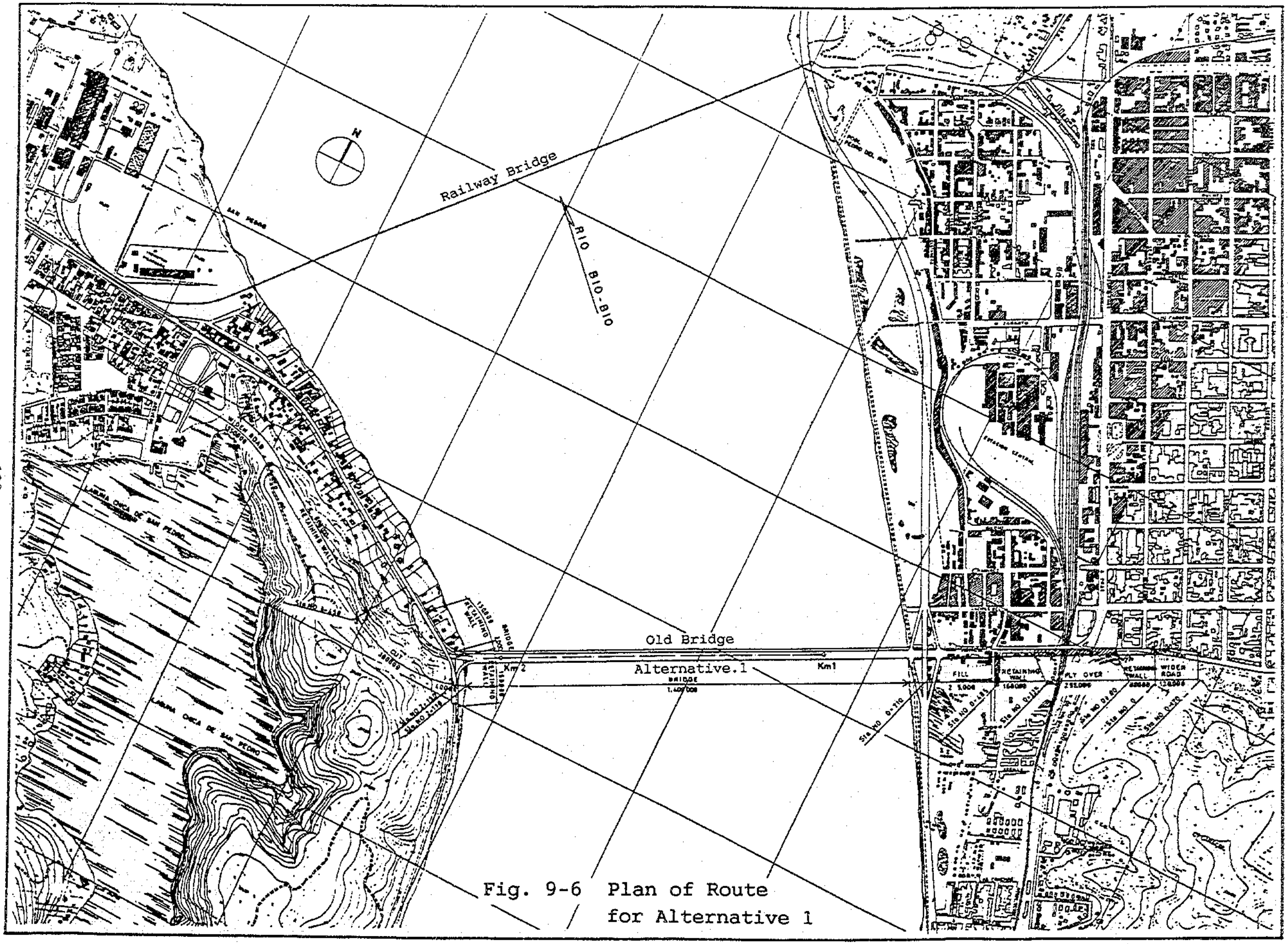


Fig. 9-6 Plan of Route for Alternative 1

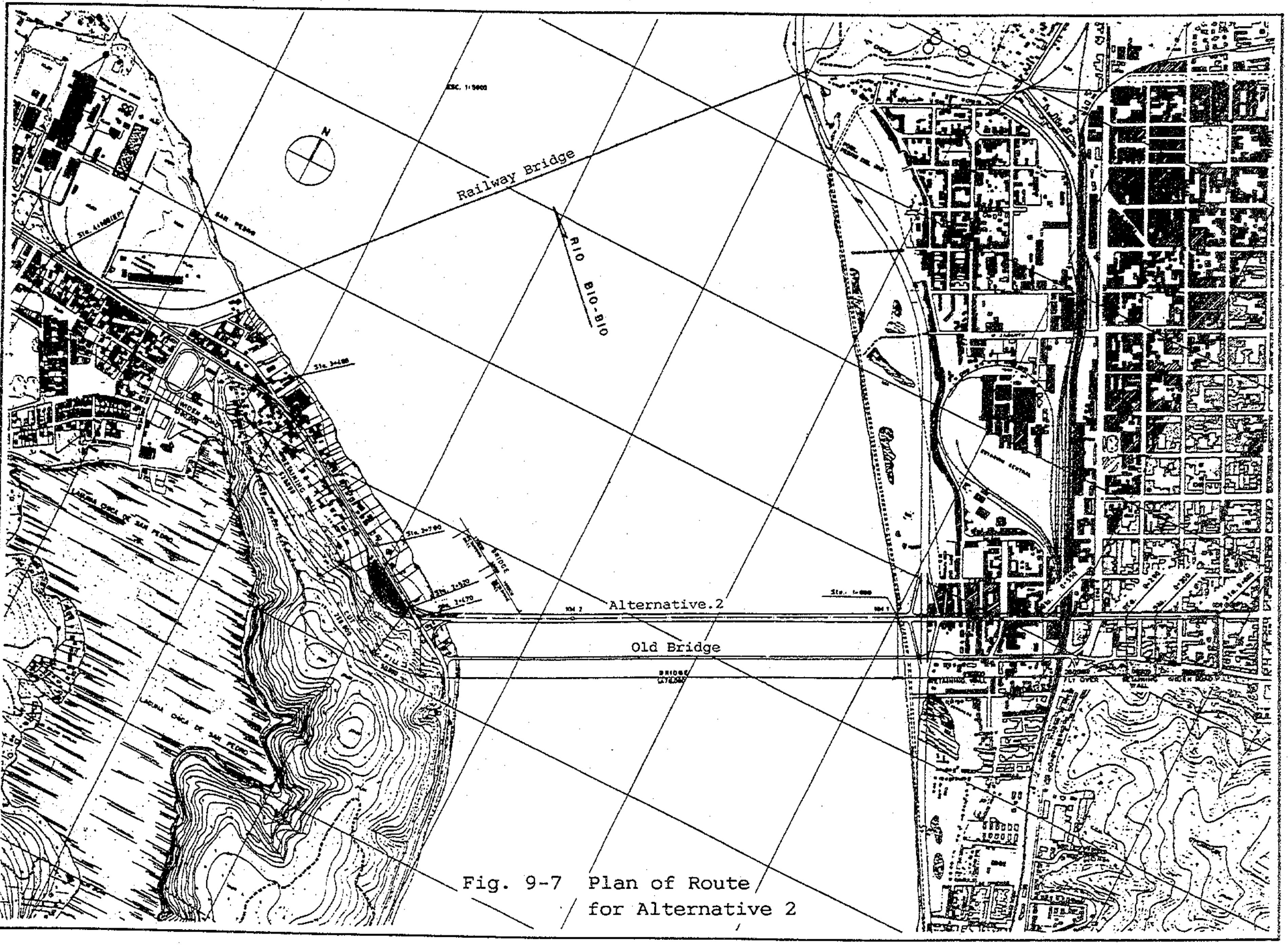


Fig. 9-7 Plan of Route for Alternative 2

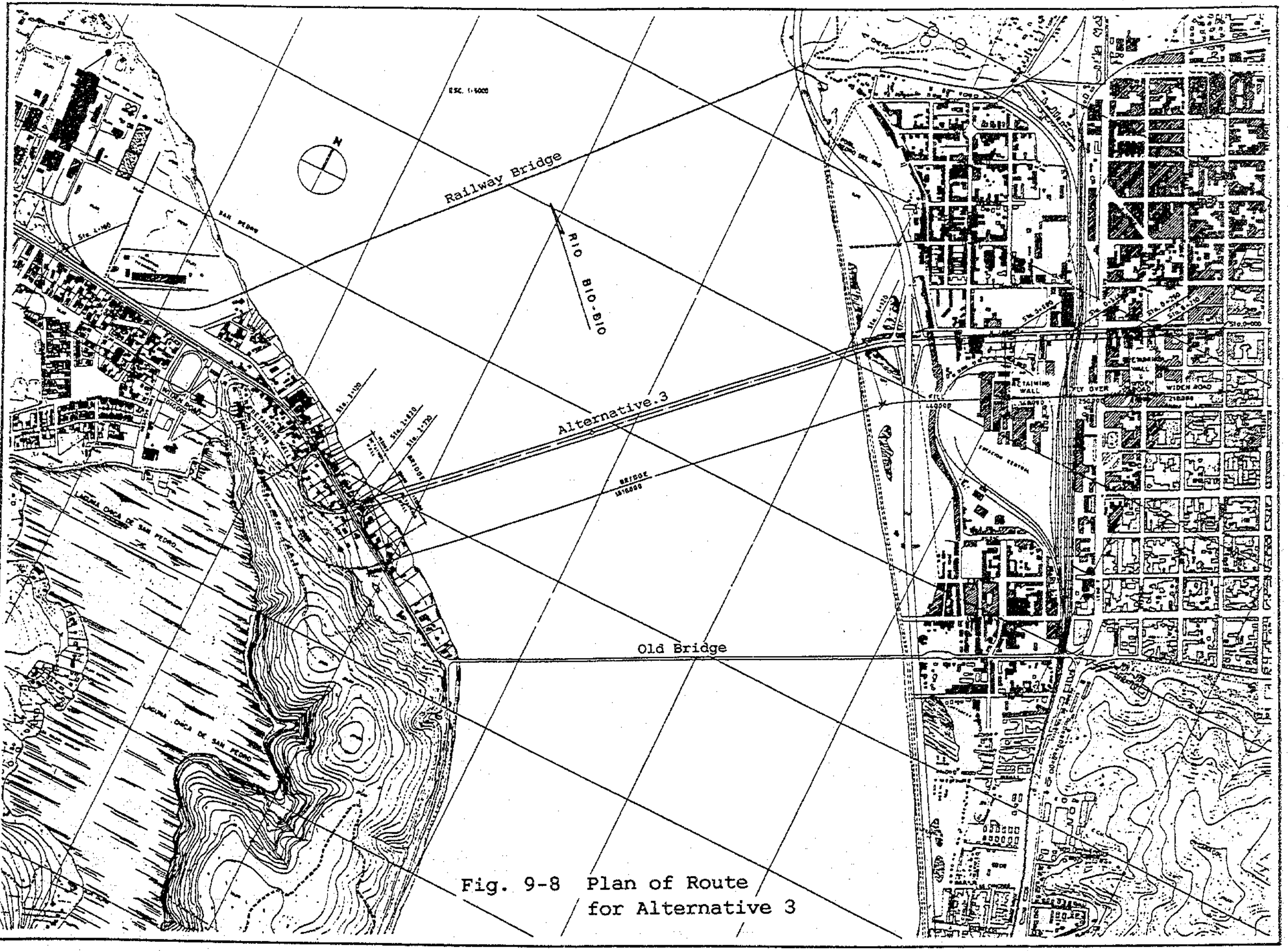


Fig. 9-8 Plan of Route for Alternative 3

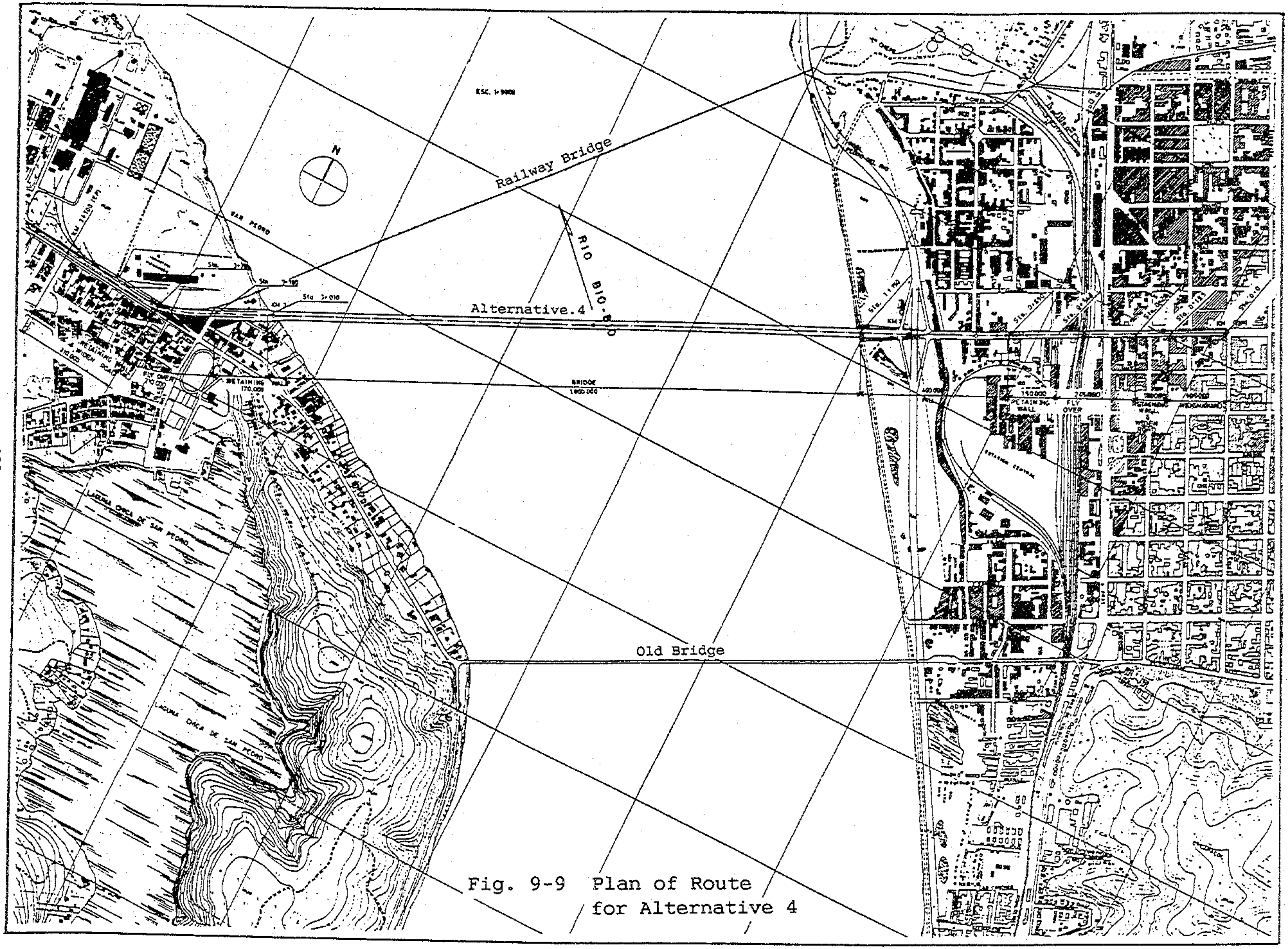


Fig. 9-9 Plan of Route for Alternative 4

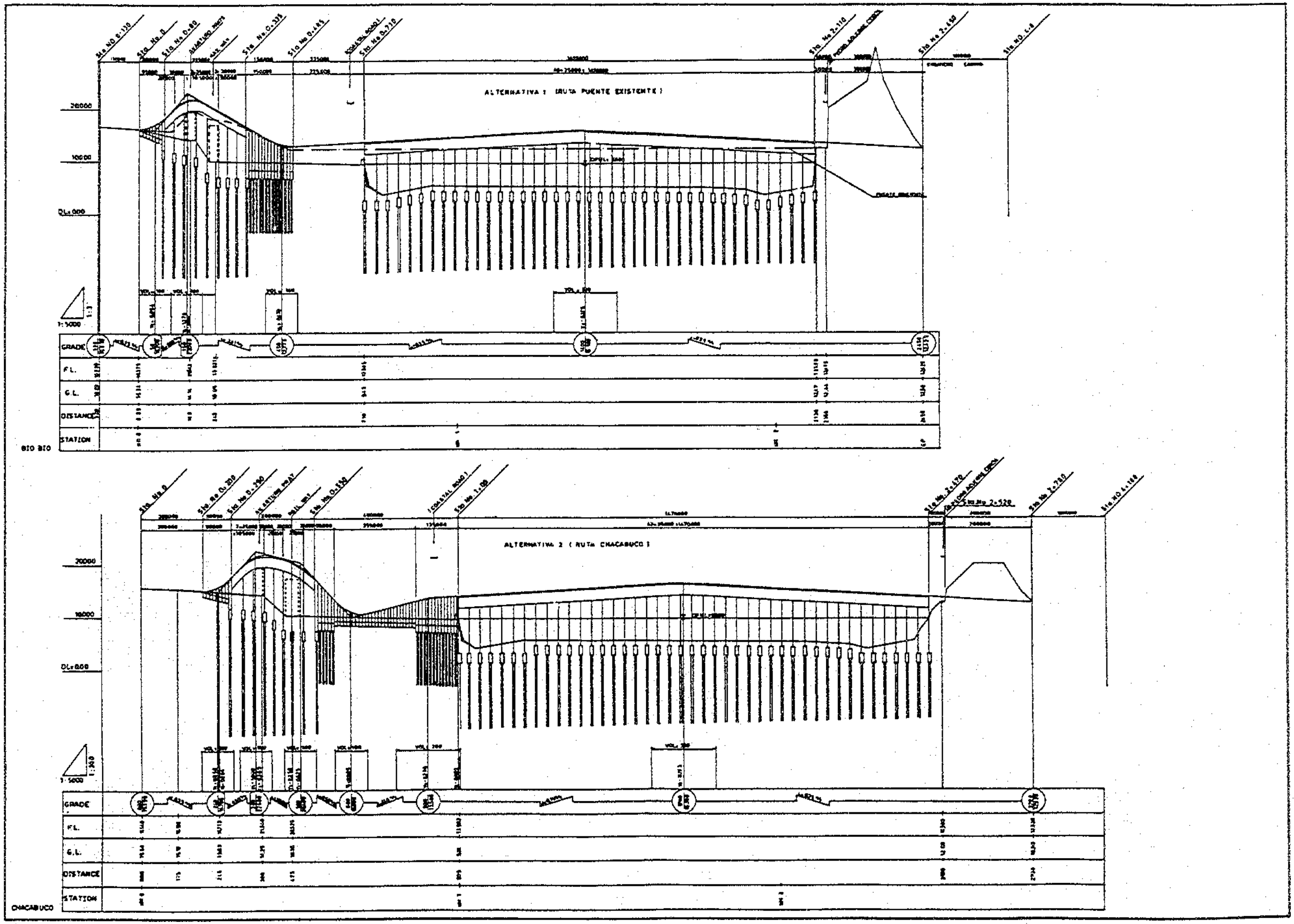


Fig. 9-10 Profile of Bridges for Alternatives 1 and 2

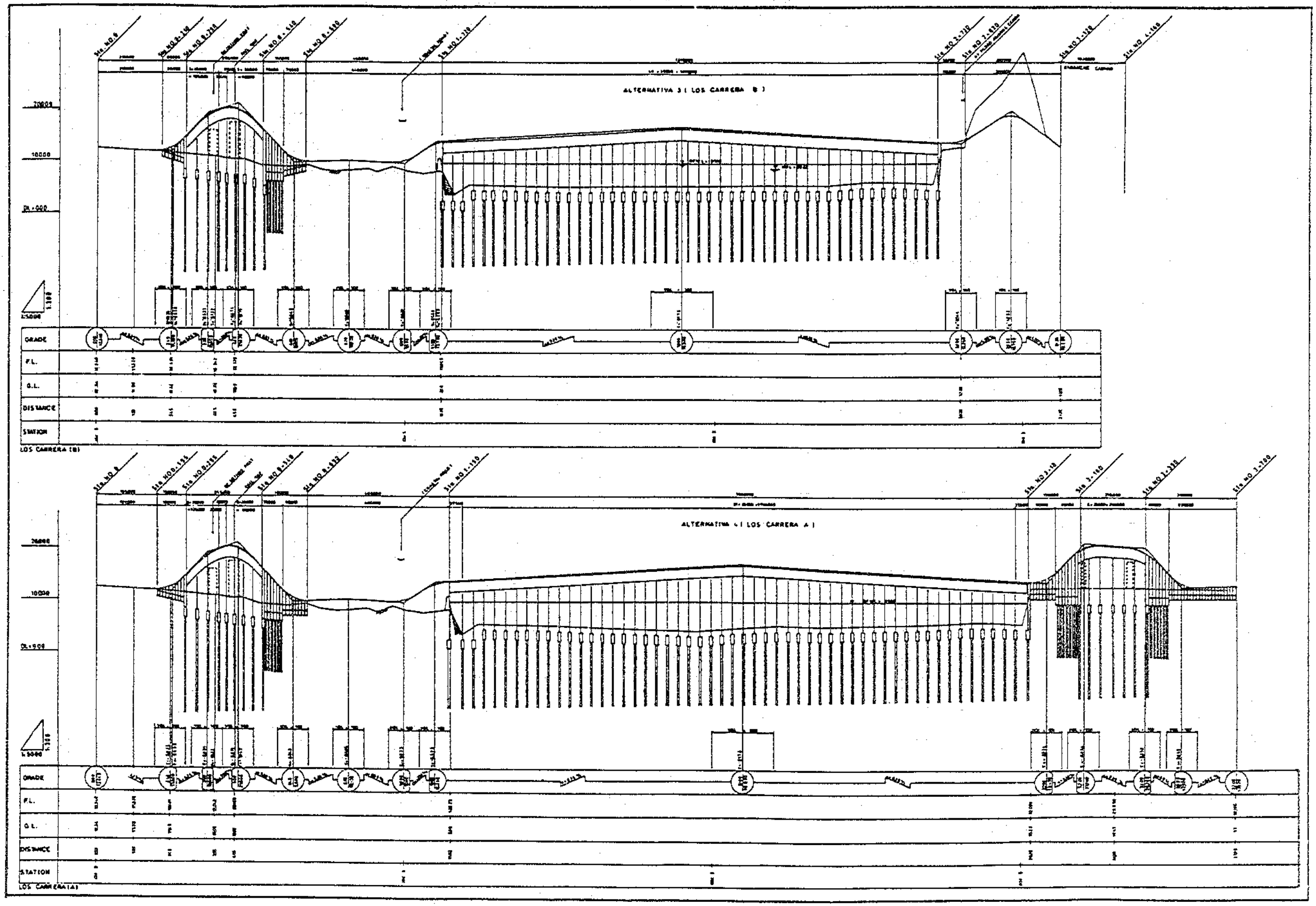


Fig. 9-11 Profile of Bridges for Alternative 3 and 4

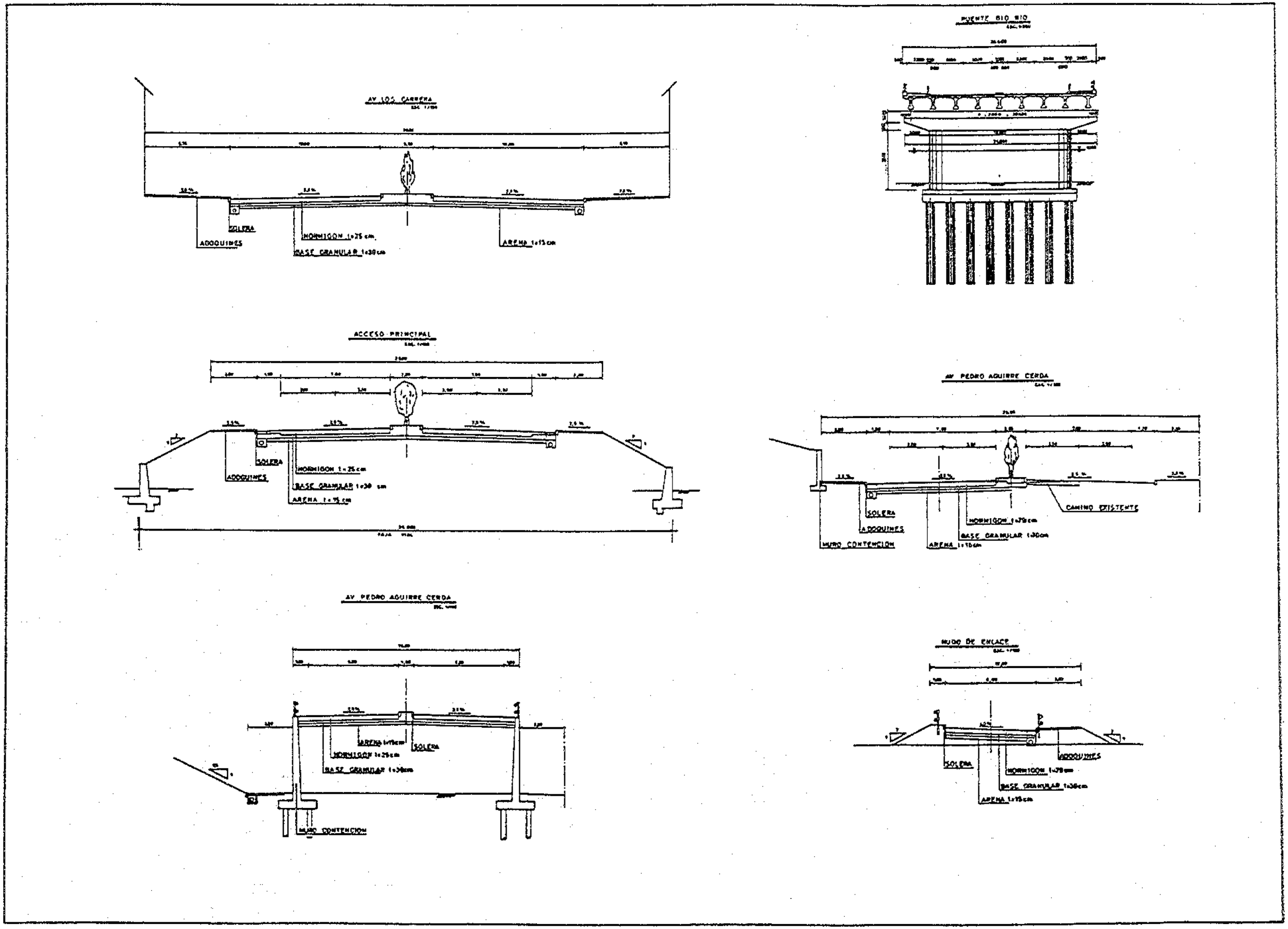


Fig. 9-12 Typical Cross Sections

9.4.2 Basic Items of Construction Related to the Various Alternatives

(1) New 4-lane bridge.

Superstructure: Nine 35 m composite post-tensioned concrete I-girders per span.
Alternative 1 : 40 spans @ 35 m. Total length 1,400 m.
Alternative 2 : 42 spans @ 35 m. Total length 1,470 m.
Alternative 3 : 46 spans @ 35 m. Total length 1,610 m.
Alternative 4 : 53 spans @ 35 m. Total length 1,860 m.

Substructure : T-shaped solid piers on pile caps and pile foundation. Cast-in-place, 1 m dia. concrete piles.

(2) Overpass (Fly over) Bridge over the Railway. (Common to all four alternatives)

Superstructure: New 4-lane. Nine 35 m composite post tensioned I girders/span. 8 spans @ 35m.
Substructure : Two-column bents on pile caps and pile foundation. Cast-in-place, 1 m dia. concrete piles.

(3) Intersection Bridge at San Pedro.

Superstructure: New 2-lane. Five 20, or 35m composite post-tensioned concrete I-girders per span.
For Alternative 1, 1 span @ 20 m.
For Alternative 2, 1 span @ 20 m.
For Alternative 3, 1 span @ 20 m.
For Alternative 4, 7 spans @ 35 m.
Substructure : Two-column bents on pile caps and pile foundation. Cast-in-place, 1 m dia. concrete piles.

(4) Access Road

Right of Way width : 35 m.
Fill slope : 1 to 2
Retaining Walls : Cantilever retaining wall. Gravity retaining wall.
Concrete Pavement : 25 cm.
Subbase Course : 30 cm.

The access road has various sections including, embankment section in the newly constructed area, widening section in the existing road area, intersections, ramps, etc.

9.4.3 Construction Methods, Schedule and Cost Estimates Related to the Selection of the Alternative Route

During the preparation of the Interim Report, the Study Team made early evaluations prior to availability of soil data, and suggested a structutal system for the deck using post-tensioned I-type girders with launching system and piers on concrete piles.

9.4.4 Construction Costs of the Four Alternatives

The total construction costs for the various alternatives developed are shown in Table 9-3:

Table 9-3 Construction Cost of Alternatives

Plan	L.C. miliones de Ch.$	F.C. miles de US$	Total millones de Ch.$	Total miles de US$
Alternativa 1	20,515	13,928	26,518	61,527
Alternativa 2	20,396	13,611	26,262	60,934
Alternativa 3	19,851	13,522	25,659	59,534
Alternativa 4	22,508	15,268	29,089	67,491

Note: L.C. means Local Costs expressed in Millions of Ch $.
F.C. means Foreign Costs expressed in Thousands of US $
Total cost is the sum of the L.C. and F.C. and is expressed in Millions of Ch $ or Thousands of US $, at the rate of Ch $ 431 = US $ 1.00

9.5 Evaluation and Selection of Alternatives

9.5.1 Methodology and Assumptions

Four alternative routes are evaluated in this section, from the economic viewpoint, based on the traffic assignment results stated in Chapter 6 and estimated project costs shown in the previous section.

(1) Assumptions

The purpose of the analysis in this section is not to examine the economic viability of the alternatives but to determine their relative priority. For the selected best alternative, economic feasibility will be studied later in Chapter 14, where the evaluation method and procedure are detailed. Almost same method and procedure were taken also in this section.

At this comparative evaluation stage, however, all the conditions needed for the economic evaluation are not set up yet. For example, investment schedule has not been established and the project cost at market price has not been converted into social cost. For this reason, several plausible conditions are assumed to simplify the problems. They are:

1) The new Biobio bridge will open at the beginning of 1999.

2) Construction of the bridge will take three years and 20% of the total cost will be invested in the first year of 1996 and 40% in each of 1997 and 1998.

3) Social cost of the project is assumed to be 75% of the total financial cost in terms of market price. This assumption seems reasonable, because in Chile the value added tax (IVA) is 18% and import duties of 11% is widely adopted. In addition, the shadow wage rate of unskilled labor is estimated at 60% by MIDIPLAN.

4) Economic benefit accruing by savings in travel time and vehicle operating cost will be counted for the twenty years after opening (1999-2019).

5) Residual values in 2020 of the bridge and roads constructed by the project is regarded to be 50% of the initial investment amount.

6) Maintenance costs of the new bridge is disregarded at this stage. They may be negligibly small (less than 1% of the initial investment) and will not affect the order of priority.

(2) Network Conditions

Cost and benefit are forecast through "with and without comparison" of the project on the base road network which is common to both of "with project" case and "without project" case. The base network is same as the present road network, with the following modification:

1) The existing old Biobio bridge is closed after opening the new Biobio bridge. The old one was found seriously deteriorated and dangerous for further use. Complete rehabilitation or upgrading of the old bridge will be too costly and not recommendable (see Chapter 8).

2) Construction of Costanera Avenue is a large project which will undoubtedly bring about significant impact on the traffic demand and benefit of the new Biobio bridge. The Chilean Government has decided to implement this project in the near future. Therefore, Costanera Avenue is added to the base network.

3) Widening and upgrading of Los Carrera Street and Prat Street are now under construction. Those projects are also incorporated in the base network.

9.5.2 Evaluation Results

(1) Traffic Assignment Results

Table 9-2 shows the summary of traffic assignment results of "without project" case and of each alternative case. If the new bridge is not constructed, total traffic volume will increase by 1.8 times during the forecast period from 1.48 million PCU-km in 1999 to 2.67 million PCU-km in 2010. As a result of this traffic increase, average travel speed of 41 km/hour (1,480/35.7) in 1999 will slow down to 25 km/hour in 2010 (2,672/108.0).

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3) Social cost of the project is assumed to be 75% of the total financial cost in terms of market price. This assumption seems reasonable, because in Chile the value added tax (IVA) is 18% and import duties of 11% is widely adopted. In addition, the shadow wage rate of unskilled labor is estimated at 60% by MIDIPLAN.

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By the construction of the new Biobio bridge, a sizable volume of traffic will be saved both in terms of PCU-km (by 9 to 12%) and PCU-hour(by 8 to 12%) even in 1999. These savings will become more significant in 2010; 15% of total PCU-km and more than 30% of PCU-hour. Consequently, over 30 km/hour of average travel speed will be maintained.

Comparing these saving effects by four Alternatives, No.4 has the largest savings both in PCU-km and PCU-hour, followed by No.3 and the other Alternatives No.2 and 1 are almost at the same level.

(2) Economic Evaluation

Savings in travel time and distance are converted into the moneyterm economic benefits and compared to the construction cost of each Alternative. The results are summarized in Table 9-4.

Table 9-4 Savings of PCU-Km and PCU-Hour by each Route Alternative

(1000 PCU-Km, 1000 PCU-Hr per day)

Ruta Alternativa	Año	Tránsito diario		Ahorros	
		PCU-Km	PCU-Hr	PCU-Km	PCU-HR
Sin Projectos	1999	1.480,53	35,71	-	-
	2010	2.672,04	108,00	-	-
1	1999	1.303,43	32,91	177,10	2,80
	2010	2.298,04	73,45	374,00	34,55
2	1999	1.350,70	32,73	129,83	2,98
	2010	2.298,69	73,46	373,35	34,54
3	1999	1.342,71	32,51	137,82	3,20
	2010	2.294,75	73,60	377,29	34,40
4	1999	1.312,49	31,37	168,04	4,34
	2010	2.255,81	71,09	416,23	36,91

Among others, the following points are to be noted:

1) Economic benefit from travel time savings, stands at aboutone half of total benefit both in 1999 and 2010.
2) All the Alternatives are judged to be highly feasible (IRR values are far over 12% which is regarded as the rate of capital opportunity in Chile).
3) Alternative No.4 implies the largest economic return, followed by No.3, No.2 and No.1, in this order. Net present value (NPV) of No.4 is 1.7 times larger than that of No.1.

Table 9-5 Economic Evaluation Indicators of Route Alternatives

Items	Alt.1	Alt.2	Alt.3	Alt.4
1. Costo del proyecto(Mill.$)				
Costo Financiero	26.518	26.262	25.659	29.089
Costo Económico	19.889	19.697	19.817	21.817
Valor Residual	9.944	9.622	9.622	10.908
2. Beneficio Anual (Mill.$)				
1999 de Tiempo	1.133,68	1.185,29	1.298,57	1.672,92
de Combustible	146,56	179,07	206,43	296,78
otros	571,60	753,42	861,35	1.2989,71
Total	1.851,84	2.117,78	2.366,35	3.259,41
2010 de Tiempo	3.084,07	3.091,74	3.238,47	4.215,387
de Combustible	623,19	626,39	639,70	828,454
Otros	2.729,11	2.710,29	2.757,15	1.640,835
Total	6.436,37	6.437,42	6.635,32	8.684,676
3. Indicadores de Evaluación				
TIR (%)	17,09	17,61	18,62	20,00
VAN (Mill.P)	9.952	10.818	12.525	16.985
B/C	1,57	1,63	1,74	1,89

9.5.3 Impact of Costanera Avenue and Old Biobio Bridge

Among the assumptions and preconditions stated in 9.5.1, most influential ones may be construction of Costanera Avenue and closure of the old Biobio bridge. Hence, their influences on the priority order of the Alternatives are to be studied by assuming that those conditions are not satisfied.

(1) Costanera Avenue

If Costanera Avenue is not constructed along the Concepcion bank, economic return of the new Biobio bridge would be much more larger, 1.6 to 1.8 times in IRR and 5 to 7 times in NPV comparing to the case with Costanera Avenue (Table 9-6).

If Costanera Avenue does not exist and the old Biobio bridge is closed in the future, approach from San Pedro side to Concepcion are limited to 21 de Mayo Street and Paicavi Street which are already congested with traffic between Concepcion and Talcahuano. Thus, traffic conditions in "without project" case will become worsened. This is the main reason why the benefit of the new bridge become larger under this condition.

Also under this condition, Alternative No.4 will have top priority from the economic point of view, without changing the priority order.

Table 9-6 Economic Evaluation Indicators

("without Costanera" Case)

Items	Alt.1	Alt.2	Alt.3	Alt.4
TIR(%)	30,50	31,33	32,85	33,57
VAN(Mill.P)	41.610	43.301	46.171	52.910
B/C	3,39	3,51	3,74	3,77

(2) Old Biobio Bridge

On the contrary, if the old Biobio bridge is maintained open, economic return of the new Biobio bridge will fall down significantly as shown in Table 9-7. With the operation of the Old bridge, construction of Alternative No.1 or 2 means only increase of capacity with no short-cut effect. Their IRR will be less than 12%. Under this condition, the priority order will not be changed and only Alternative No.4 exceeds its IRR over 12%.

Table 9-7 Economic Evaluation Indicators

("with Old Biobio Bridge" Case)

Items	Alt.1	Alt.2	Alt.3	Alt.4
TIR(%)	5,08	5,73	7,95	14,05
VAN(Mill.P)	- 9.748	- 8.583	- 5.567	3.699
B/C	0,44	0,50	0,67	1,19

9.5.4 Selection of Alternatives

As described above, Alternative No.4 is the most favorable from economic viewpoint, although its cost is the highest. Beside the economic aspect, there are several advantages in Alternative no.4:

1) Alternative No.3 and No.4 which connect with Los Carrera St. will apparently contribute most to the urban development in the riverside area (refer to "Region-wide Major Activity Center in Chapter 13) and also in the area along Los Carrera Avenue.

2) Alternative No.4 will need the least land acquisition and demolition of existing buildings and structures, while Alternative No.3 and No.2 will require more and Alternative No.1, most.

3) In case of Alternative No.1 and No.2, heavy traffic passing the river will come into Concepcion in the morning peak time, taking Victor Lamas St. or Chacabuco St. which are located in the southmost of downtown. Therefore, every vehicle from San Pedro side is forced to make left turn in order to enter the downtown. This will cause severe traffic congestion in the future.

Based on the reasons above, the route of Alternative No.4 is recommended as the best one for the further study.

CHAPTER 10 SELECTION OF OPTIMAL BRIDGE TYPE

10.1 General

The Study team studied the alternative routes for the new bridge in Chapter 9. The same type of bridge as Juan Pablo II was used for the route selection as a base model for comparison. It is a post tensioned concrete simple I- girder which is one of the common types available in Chile. Biobio bridge is one of the longest bridges in Chile and requires substantial funds for the construction. Optimal type of structures are studied in this section.

The possibility of other types of framing systems for the new bridge were studied in this section. Several types of superstructures and substructures and foundations were examined and their combination was studied to define optimal type of bridge for new Biobio bridge. The optimal type of bridge will be selected under the following fundamental guidelines:

1. Determine the basic design condition for the comparison.

2. Nominate four types of bridges considered adequate at the construction site.

3. Conduct a preliminary design and quantity calculation using 4 types of superstructures and substructures.

4. Using the above, costs of various range of spans of superstructures and sub structure are calculated. Then total cost of the main bridge is evaluated for four systems.

5. Determine the most advantageous or desirable system by using analytic hierarchy process. Construction cost, construction period, ease of construction,aesthetic point of view, ease of maintenance, and durability against earthquake are used as factors for the evaluation.

10.2 Basic Design Condition for Comparative Study

10.2.1 Total Bridge Length

Total bridge length is determined by correlation between the high water level and the location of the river bank. The bridge at the station No 1+150.00 m (Concepcion Side) and end at the station No 3+005.00 (San Pedro Side). Total bridge length is 1,855 m. Expected high water level used for the bridge design is higher than the elevation of the existing river bank at Concepcion side. The study team recommends to raise the river bank above the expected high water level of the Biobio River.

10.2.2 Soil Condition for the Foundation

In accordance with the soil investigation report, the stratum below 6 m depth, indicates good bearing capacity. Three borings at San Pedro side along the new bridge route show uniquely dense sands and one boring at Concepcion side shows silty sand at the depth of 13 m below the top of the bank.

The ground elevation of the boring at Concepcion side is about 7 m higher than that of three borings at San Pedro side. The ground elevations of the borings on the San Pedro side are about seven (7) m below the one on the Concepcion side, and are at about the same elevation of the stream bed. The support stratum for the foundation is considered to exist at 6 m below the river bed.

10.2.3 Scour Influence on the Foundation

A study of the river bed elevations shows that the maximum scour depth is 4.5 m below the river bed. As mentioned above the bearing stratum for the foundation exists at 6.0 m below the river bed. Maximum scour depth is expected to be 6.0 m below the river bed. Therefore the elevation of the bottom of foundations was set at 9 m below the river bed.

10.2.4 Span of the Superstructure.

Based on the River Structure Code of Japan, the minimum span for the New Biobio Bridge will be over 75 m. However, there are defferences between Japan and Chile, such as Japan suffers Typhoon every year. It is therefore, difficult to apply the Japanese code to Chile directly.

Minimum span of the new bridge, therefore will be 35 m taking into consideration the span of the Juan Pablo II bridge and the railway bridge. The maximum span length considered was 65 m because of the following reasons;

1. Subsurface conditions at the construction site are considered adequate for the foundation and the cost of the foundation will be less than for the superstructure. The total cost for the construction of the bridge tends to be influenced by the cost of the superstructure, which generally costs less when the spans are shorter.

2. Special considerations are required if the span of the bridge is over 60 m. Longer spans would require deeper girders, and more complicated systems not applicable in this specific situation. The extra depth will encroach on the clearance under the bridge, and increase the cost substantially.

3. The elevation at both ends of the bridge are more or less fixed. Therefore the space available for the superstructure, the water passage and the clearance is limited.

10.3 Bridge Types for Comparative Study

10.3.1 Type of Superstructure

Four types of superstructure were nominated for the determination of optimal type of bridge from among several types of bridges which would be adequate for the span mentioned above. Various types of bridges were considered adequate for the range of the span, however, the Study Team selected the type of bridge taking into consideration the site conditions and circumstances of Chile. The types of bridges which were examined, included:

1. Simple post tensioned concrete I - girder. (Fig. 10-1)
2. Continuous steel plate girder.(Fig. 10-2)
3. Continuous post tensioned concrete hollow slab.(Fig. 10-3)
4. Continuous post tensioned concrete box girder.(Fig. 10-4)

The arrangement for simple span girders and continuous span girders is shown in Fig. 10-5 and Fig. 10-6

10.3.2 Type of Foundation and Substructure

(1) Type of Foundation

The geological and hydrological survey shows the bottom of the foundation is expected at 9.0 m below the river bed. Direct foundation or caisson foundation are considered adequate type of foundation for such depth.

The pile bent type foundation can not be recommended as adequate for the following reasons:

1. Instability against earthquake.
2. The bad effects from scour at the columns of the pier
3. Disturbance of the water flow by the debris trapped between the columns.

Pile foundations can not be recommended for the following reasons:

1. Pile foundation is not recommendable because the pile length(5 m) is too short.
2. Erosion of the soil below the footing caused by scour is hard to recover.

Note : LP = DSB - DSF - DF = 5 m

where :	LP	:	Length of Pile (5 m)
	DSB	:	Depth from the Surface to the Bearing stratum (9 m)
	DSF	:	Depth from the surface to the Top of Footing (2 m)
	DF	:	Depth of Footing (2 m)

(2) Type of Substructure

Selection of type of a substructure is influenced by the type of superstructure being supported and type of foundation. The dumbbell pier or pile bent type pier was selected in Chile in the past for the economic reasons, but both are not recommendable for the new bridge. When the both type of substructure will be applied for the new bridge, pile cap or footing become unnecessarily big because of the long spacing between the columns of the pier. Therefore, two types of substructures are taken into consideration in this study.

1. Hammerhead pier (Fig 10-2)
2. Solid Shaft Pier (Fig 10-3, Fig 10-4)

10.4 Selection of Optimal Bridge Type

Selection of the optimal bridge type for the study will be done using the following procedure. Optimal type is described as the most suitable structure type for the site taking into consideration the span, costs of superstructure and substructure of various types, as well as other evaluation factors described below.

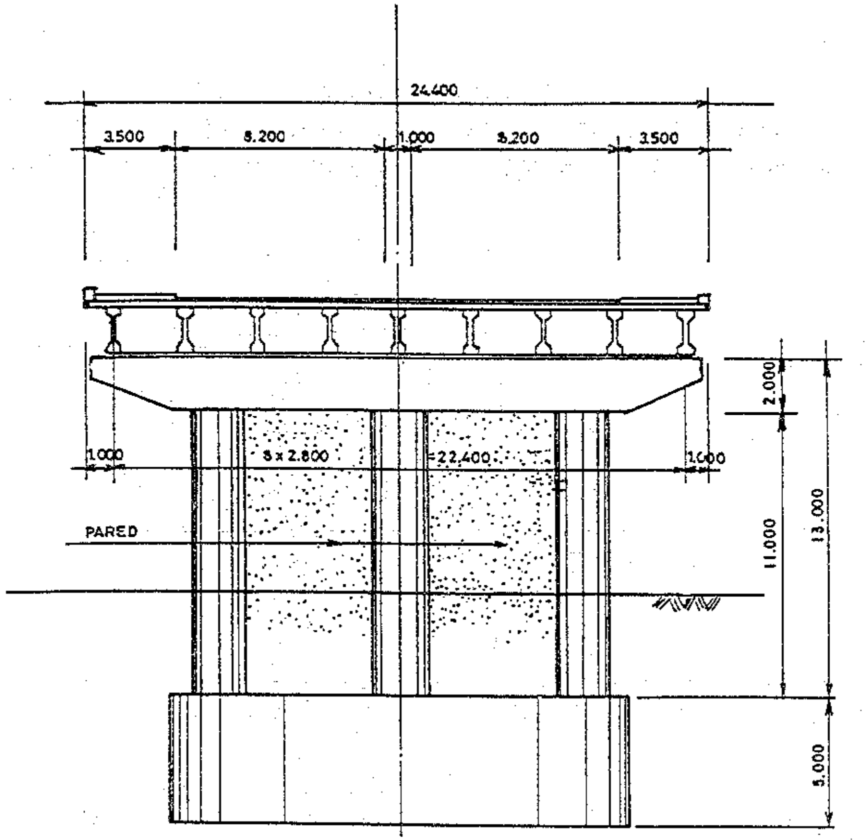


Fig. 10-1 Simple Post-tensioned Concrete I-Girder with Dumbell Pier on Caisson Foundation

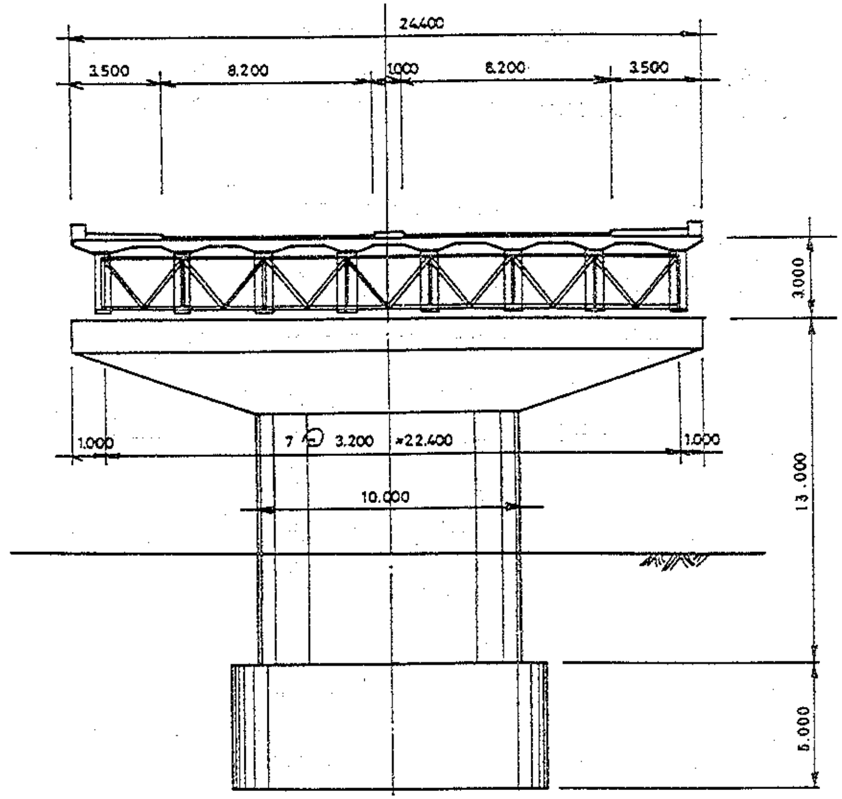


Fig. 10-2 Continuous Steel Plate Girder with Hammerhead Pier on Caisson Foundation

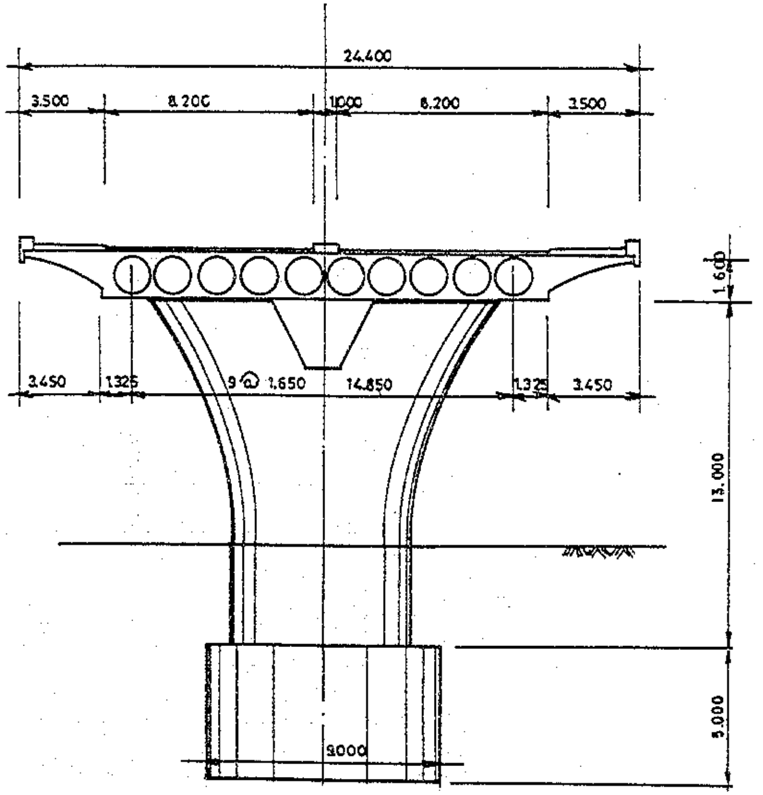


Fig. 10-3 Continuous Post-tensioned Concrete Hollow-slab with Solid Shaft Pier on Caisson Foundation

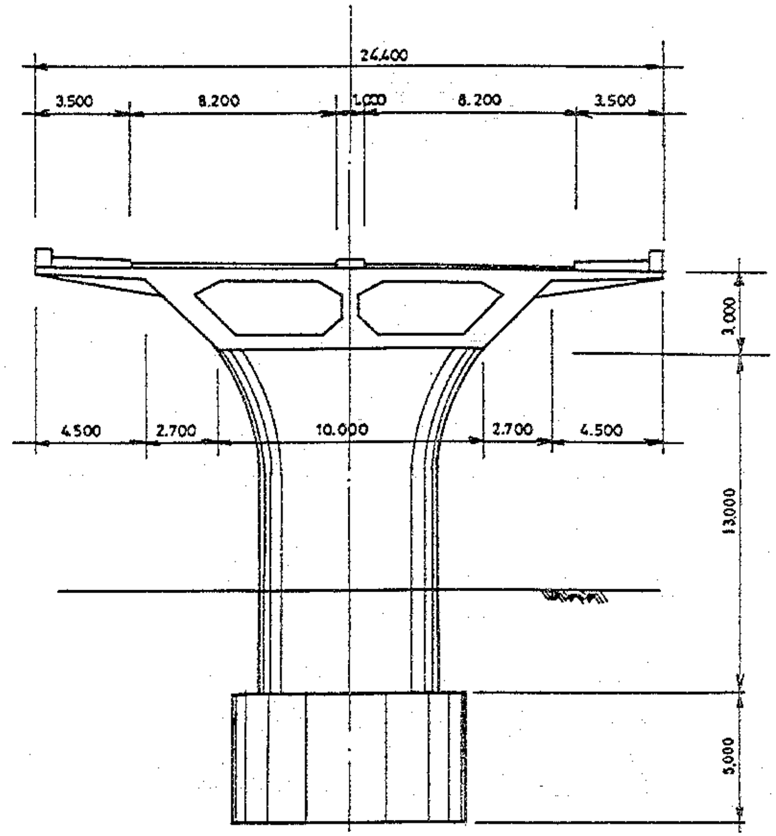


Fig. 10-4 Continuous Post-tensioned Concrete Box Girder with Solid Shaft Pier on Caisson Foundation

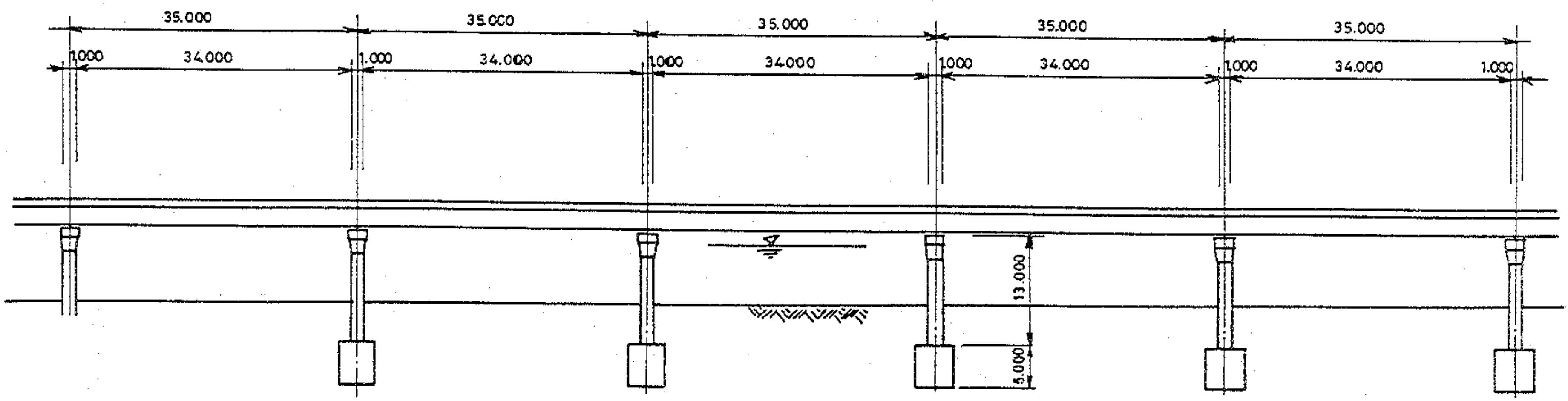


Fig. 10-5 Profile of Simple Span Girder

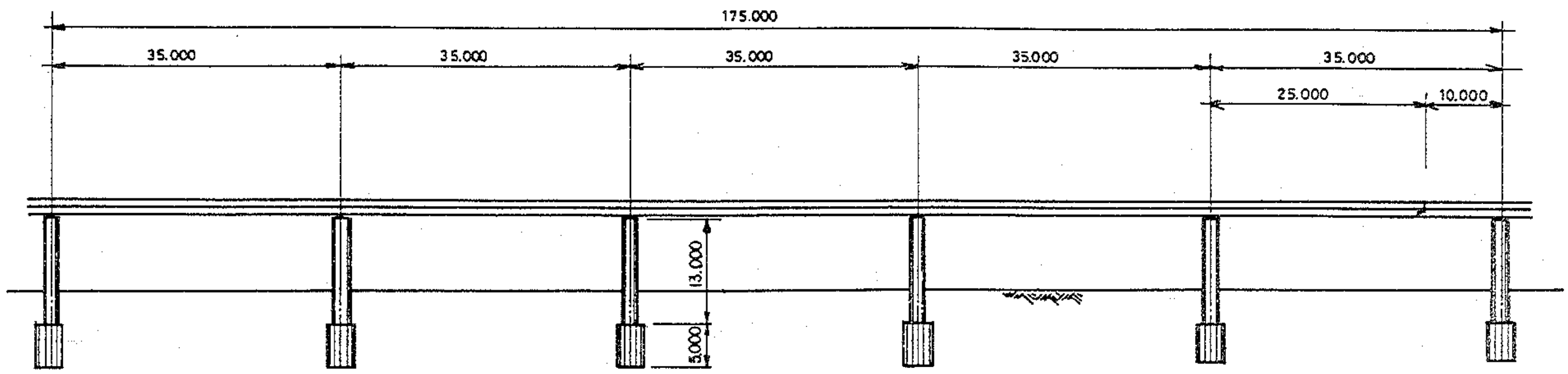


Fig. 10-6 Profile of Continuous Span Girder

10.4.1 Selection of Optimal Span

Optimal span for each type of bridge will be determined by the combined cost of superstructure and the cost of substructure which includes the cost of foundations as shown in Fig.10-7

10.4.2 Selection of Optimal Bridge Type

Analytic Hierarchy Process (AHP) is applied to solve the optimal bridge type setting in this study. The AHP is a priority ordering method for use as a factor in decision making. It is a systematic procedure which uses a matrix of pairwise comparison to derive relative priority. The several steps for setting priorities by AHP are as follows:

- Step 1. Determine the evaluation factors used for bridge priority setting.
- Step 2. Compare and evaluate the factors for relative importance.
- Step 3. Set the priorities of the bridge by using pairwise comparison matrix.

(1) Evaluation factors

The optimal bridge type will be selected not only by cost of construction, but also by considering various other factors. The factors considered for the selection of optimal bridge type are as follows;

1. Cost
2. Construction period
3. Ease of construction
4. Aesthetic point of view
5. Ease of maintenance
6. Durability against earthquake

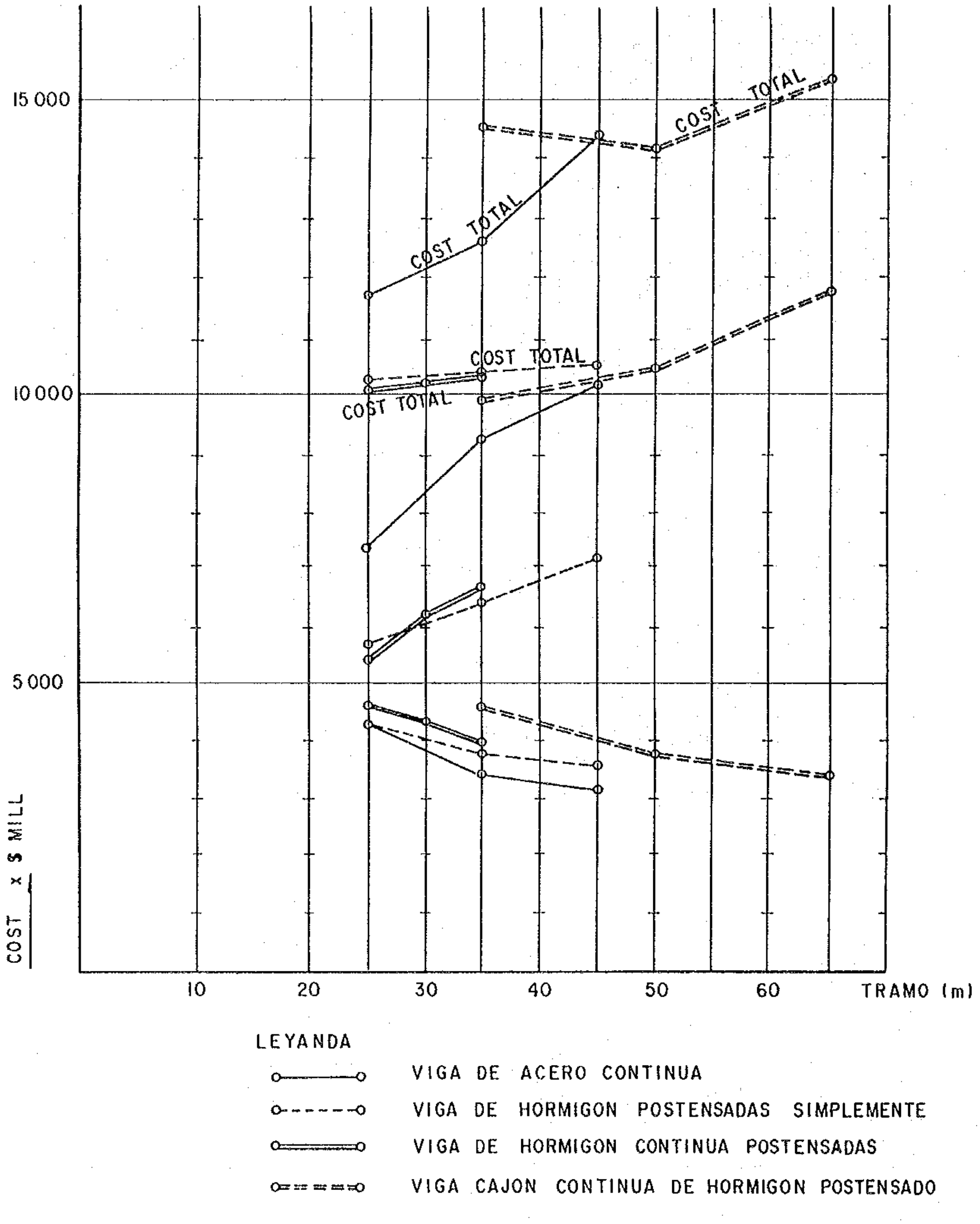


Fig. 10-7 Selection of Optimal Span

(2) Calculation of weight for each factor

The Process facilitates the computation of the significance (weight) of all the evaluation factors by obtaining a vector for each evaluation factor and using a relative value for each evaluation factor. The entire hierarchy of the AHP is shown in Fig 10-8. The evaluation factors are compared and evaluated to fill the pair wise comparison matrix by using the scale of relative importance. Pair wise comparison matrix are constructed as shown in Table 10-3 to Table 10-5.

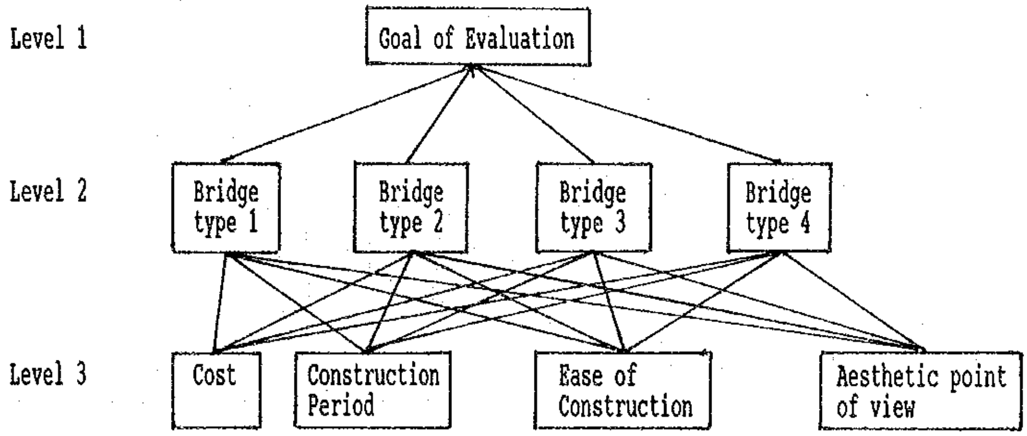


Fig. 10-8 Entire Hierarchy of AHP

Table 10-1 Absolute Value for Evaluation Items

Rank	Definition
1	Not important
2	Slightly important
3	Important
4	Considerably important
5	Extremely important

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 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 example of the method of calculation are shown in Figure 10-9

Factor	A	B	C	Eigen Vector	Weight
A	$\frac{W1}{W1}$	$\frac{W1}{W2}$	$\frac{W1}{W3}$	$\sqrt[3]{\frac{W1}{W1} \times \frac{W1}{W2} \times \frac{W1}{W3}} = a$	$\frac{a}{Total} = X1$
B	$\frac{W2}{W1}$	$\frac{W2}{W2}$	$\frac{W2}{W3}$	$\sqrt[3]{\frac{W2}{W1} \times \frac{W2}{W2} \times \frac{W2}{W3}} = b$	$\frac{b}{Total} = X2$
C	$\frac{W3}{W1}$	$\frac{W3}{W2}$	$\frac{W3}{W3}$	$\sqrt[3]{\frac{W3}{W1} \times \frac{W3}{W2} \times \frac{W3}{W3}} = c$	$\frac{c}{Total} = X3$

where : Total = a + b + c

Fig 10-9 Method of Priority Setting

Absolute value for each evaluation factor is shown in Table 10-2. The weight for each evaluation factor obtained from the said absolute values is as shown in Table 10-3.

Table 10-2 Absolute Value for Each Evaluation Factor

Evaluation Factor	Rank
1. Cost	5
2. Construction Period	3
3. Ease of construction	2
4. Aesthetic point of view	4
5. Ease of maintenance	3
6. Durability against earthquake	4

Tables 10-3 to Table 10-5 show the process of evaluation of optimal bridge type.

Table 10-3 Weight for Each Evaluation Factor

Factor de Evaluación	A	B	C	D	E	F	Vector Eiguen	Peso
A. Costo	1	3	4	2	3	2	2,289	0,332
B. Período de construcción	1/3	1	2	1/2	1	1/2	0,742	0,107
C. Facilidad de construcción	1/4	1/2	1	1/3	1/2	1/3	0,437	0,063
D. Estética	1/2	2	3	1	2	1	1,348	0,195
E. Facilidad de mantenimiento	1/3	1	2	1/2	1	1/2	0,742	0,107
F. Resistencia contra terremotos	1/5	2	3	1	2	1	1,348	0,195
Total							6,906	1,000

(3) Calculation of Weight for Each Type of Bridge over Each Evaluation Factors

The Table 10-4 shows the absolute value for each type of bridge over each evaluation factor.

Table 10-4 Absolute Value for Each Type of Bridge Over Evaluation Factors

Factor de Evaluación	A	B	C	D	E	F
1. Viga de hormigón postensado	5	4	4	4	4	4
2. Viga de acero	3	5	5	3	3	4
3. Losa alivianada postensada	5	4	3	5	5	5
4. Viga cajón postensada	3	3	3	5	5	5

Table 10-5(1) Weight for Each Type of Bridge for Cost

Factor de Evaluación	1	2	3	4	Vector Eiguen	Peso
1. Viga de hormigón postensado	1	3	1	3	1,732	0,375
2. Viga de acero	1/3	1	1/3	1	0,577	0,125
3. Losa alivianada postensada	1	3	1	3	1,732	0,375
4. Viga cajón postensada	1/3	1	1/3	1	0,577	0,125
Total					4,619	1,000

Table 10-5(2) Weight for Each Type of Bridge for Construction Period

Factor de Evaluación	1	2	3	4	Vector Eiguen	Peso
1. Viga de hormigón postensado	1	1/2	1	2	1,000	0,227
2. Viga de acero	2	1	2	3	1,861	0,423
3. Losa alivianada postensada	1	1/2	1	2	1,000	0,227
4. Viga cajón postensada	1/2	1/3	1/2	1	0,537	0,122
Total					0,398	1,000

Table 10-5(3) Weight for Each Type of Bridge for Ease of Construction

Factor de Evaluación	1	2	3	4	Vector Eiguen	Peso
1. Viga de hormigón postensado	1	1/2	2	2	1,189	0,263
2. Viga de acero	2	1	3	3	2,060	0,455
3. Losa alivianada postensada	1/2	1/3	1	1	0,639	0,141
4. Viga cajón postensada	1/2	1/3	1	1	0,639	0,141
Total					4,527	1,000

Table 10-5(4) Weight for Each Type of Bridge for Aesthetic Point of View

Factor de Evaluación	1	2	3	4	Vector Eiguen	Peso
1. Viga de hormigón postensado	1	2	1/2	1/2	0,841	0,189
2. Viga de acero	1/2	1	1/2	1/3	0,485	0,109
3. Losa alivianada postensada	2	3	1	1	1,565	0,351
4. Viga cajón postensada	2	3	1	1	1,565	0,351
Total					4,457	1,000

Table 10-5(5) Weight for Each Type of Bridge for Ease of Maintenance

Factor de Evaluación	1	2	3	4	Vector Eiguen	Peso
1. Viga de hormigón postensado	1	2	1/2	1/2	0,841	0,189
2. Viga de acero	1/2	1	1/3	1/3	0,485	0,109
3. Losa alivianada postensada	2	3	1	1	1,565	0,351
4. Viga cajón postensada	2	3	1	1	1,565	0,351
Total					4,457	1,000

Table 10-5(6) Weight for Each Type of Bridge for Durability Against Earthquake

Factor de Evaluación	1	2	3	4	Vector Eiguen	Peso
1. Viga de hormigón postensado	1	1/2	1/3	1/3	0,485	0,109
2. Viga de acero	2	1	1/2	1/2	0,841	0,189
3. Losa alivianada postensada	3	2	1	1	1,565	0,351
4. Viga cajón postensada	3	2	1	1	1,565	0,351
Total					4,457	1,000

Table 10-6 Total Evaluation for Optimal Bridge Type

Factor de Evaluación	A	B	C	D	E	F	Peso Total	Peso
	0,332	0,107	0,063	0,195	0,107	0,195		
1. Viga de hormigón postensado	0,375	0,227	0,263	0,189	0,189	0,109	0,244	2
2. Viga de acero	0,125	0,423	0,455	0,109	0,109	0,189	0,185	4
3. Losa alivianada postensada	0,375	0,227	0,141	0,351	0,351	0,351	0,332	1
4. Viga cajón postensada	0,125	0,122	0,141	0,351	0,351	0,351	0,238	3
Total							1,000	

10.5 Conclusion

Based on the above derivations, the scheme proposed by the Study Team is the one using Continuous Post Tensioned Concrete Hollow Slab spans, 35 m each.

CHAPTER 11 PRELIMINARY DESIGN FOR THE BRIDGE

11.1 General

Bridge construction routes were discussed in chapter 9 and the optimal bridge type was selected in chapter 10. The preliminary design for the selected route and bridge including overpass and approach road are studied in this chapter. Evaluation of construction method, construction period for the bridge over the Biobio river and fly-over at railroad and overpass over Av. Pedro Aguirre Cerda at San Pedro side are included in this chapter. Road improvement plan at intersections also discussed in this chapter.

11.2 Type of Structure for the Study

See Figure 11-1 and 11-2

11.2.1 Superstructure

The Study Team recommended a continuous post-tensioned concrete hollow slab bridge for the bridge over the Biobio river. This type of bridge can be constructed economically by using movable staging but the method can not be applied economically for the fly-overs because of the short bridge length. Therefore the simple post-tensioned I girder is considered adequate for the flyover for the railway and Av. Pedro Aguirre Cerda.

It is recommended that the number of the continuous spans for the post-tensioned concrete hollow slab over Biobio river should be eight to ten spans, supported on the rubber shoe. By using this system, the reaction and forces of the earthquake from the superstructure will be distributed through the rubber shoe uniformly from the superstructure to the substructure.

11.2.2 Substructure

Solid Shaft Pier with Caisson foundation are proposed as substructure for the bridge over the Biobio river. Rigid frame type piers are proposed for the fly-over. The seismic coefficient is 15% of the gravity load, the size of the foundation is not governed by the earthquake force, however, the reinforcement bars in the columns is influenced by earthquake loading. The combination of slender shaft and small size caisson make the construction cost small and good from the aesthetic point of view.

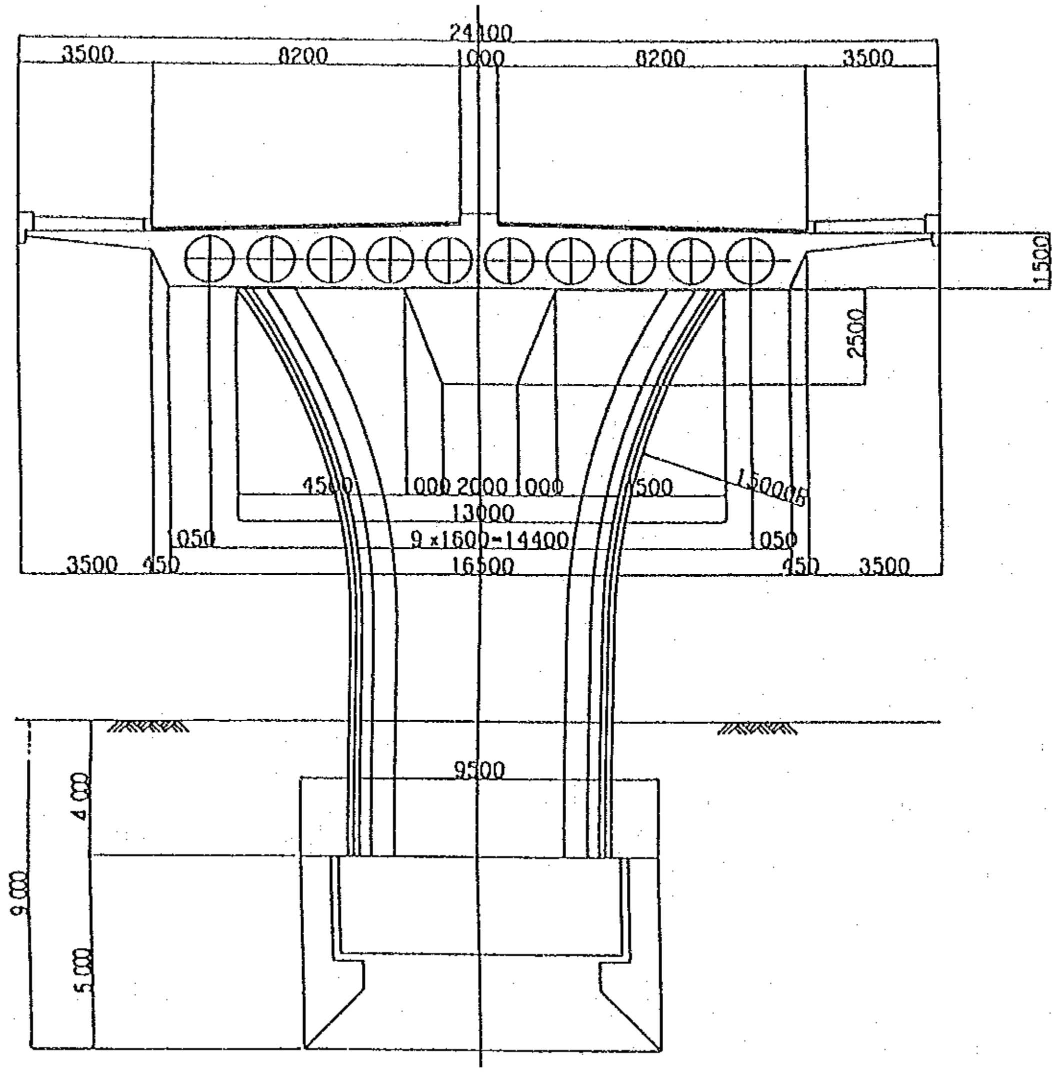


Fig. 11-1 Cross Section of New Biobio Bridge

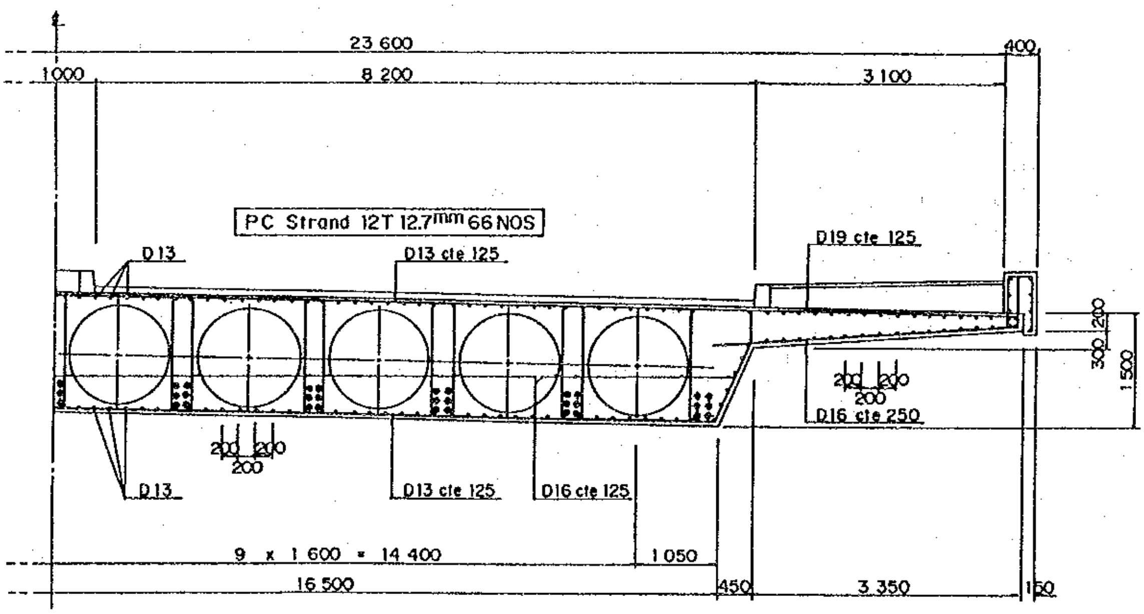


Fig. 11-2 Cross Section of PC Hollow Slab

11.3 Construction Method

11.3.1 Superstructure

As the post-tensioned concrete hollow slab is manufactured at the site on the piers, staging works are needed to support the concrete weight. This construction method is recommended using movable machinery making the construction safe and economical. The construction method is shown in Fig. 11-3. But the structure could be constructed by other staging method such as the one shown in Fig. 11-4. The advantages and disadvantages of the each construction method is as follows;

1. Full Staging Construction Method

   Special construction machineries are not necessary for this type of construction. It is economical when the clearance under the girder is less than 10 m to 15 m. It is necessary to reinforce the foundation for the staging. Staging will create obstacles for the river flow when the level of high water is above the staging foundation. There is some possibility that the staging may be washed away by the flood, therefore the Study Team does not recommend this method.

2. Construction by Movable Staging

   The progress of construction is not influenced by the problem of the clearance under the girder. Repeating of the same construction procedure helps to maintain a high quality of construction. The longer the bridge the lower the construction cost. The new Biobio bridge has sufficient length that encourages the use of movable staging. Fig.11-3 shows one example of the construction method using movable staging. Initial investments for the machinery is comparatively large. Skilled technique is required for the operation of the machinery.

11.3.2 Substructure

The construction method proposed below takes into consideration the site conditions, circumstances, technical and machinery conditions, construction period, construction cost and ease of construction. However, the construction method is greatly affected by the site conditions, especially the width of the Biobio river. The river shall be diverted during the construction by temporary embankment. Caisson foundation is recommended to support the new bridge structure. Most of the soils are dense or very dense fine granular materials, therefore there is some possibility that the caissons may have to be pushed in place through over load, vibratory equipment, jet and suction pumps. Example of the construction method for the caisson foundation is shown in Fig.11-5.

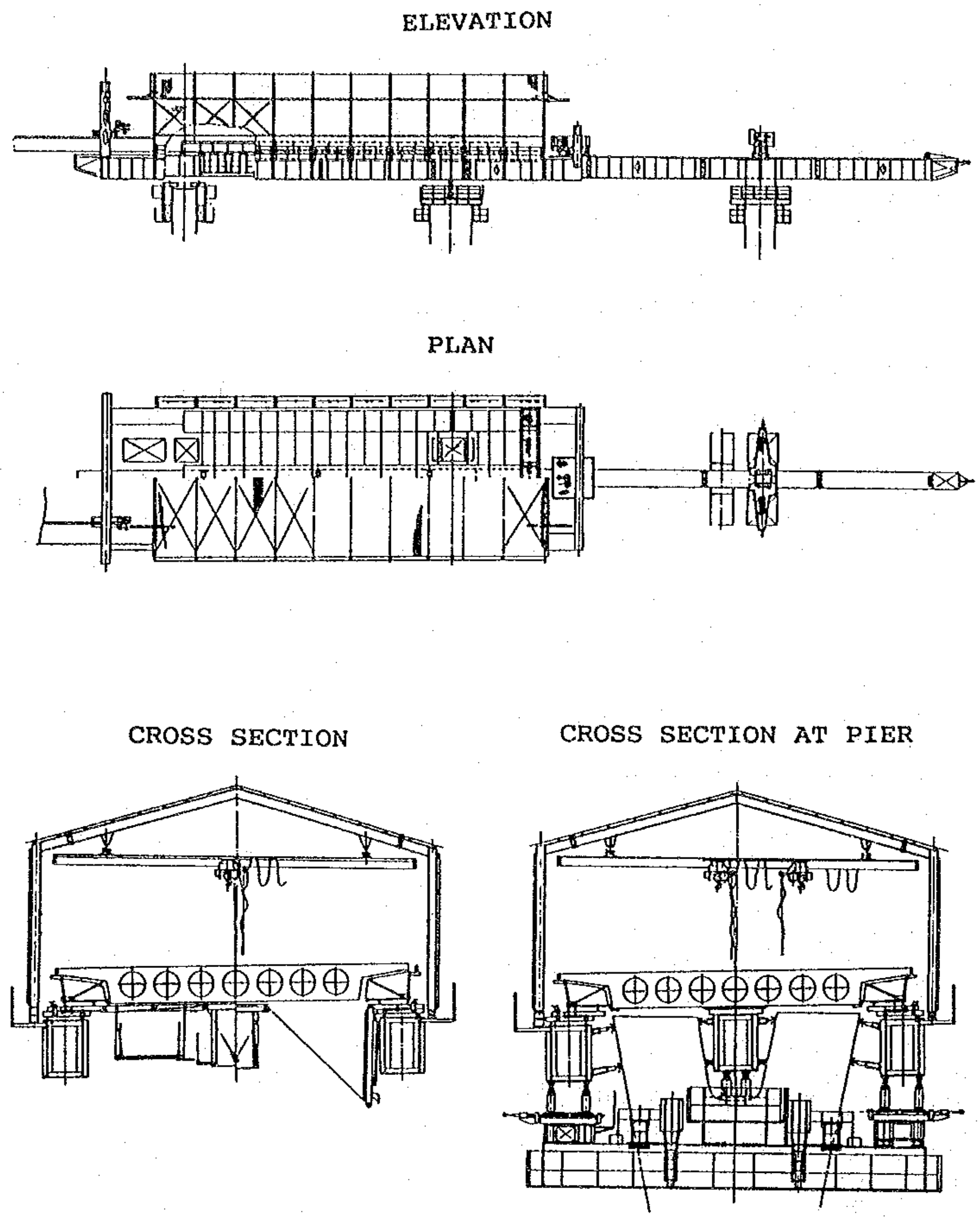
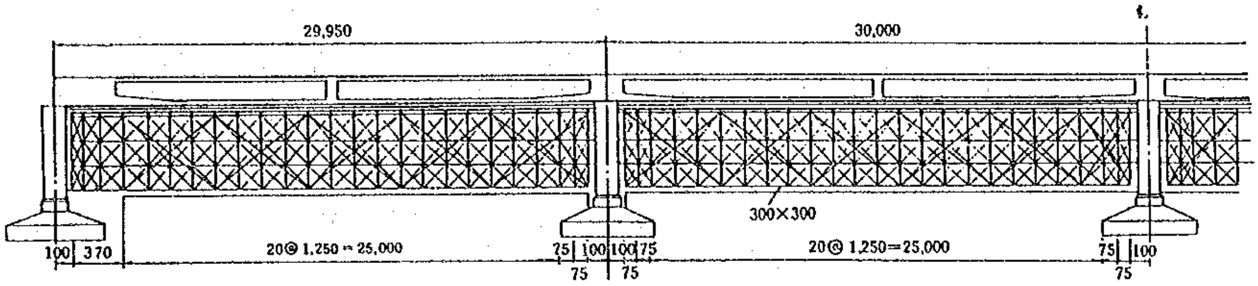


Fig. 11-3 Construction Method for Superstructure by Movable Staging

ELEVATION



CROSS SECTION

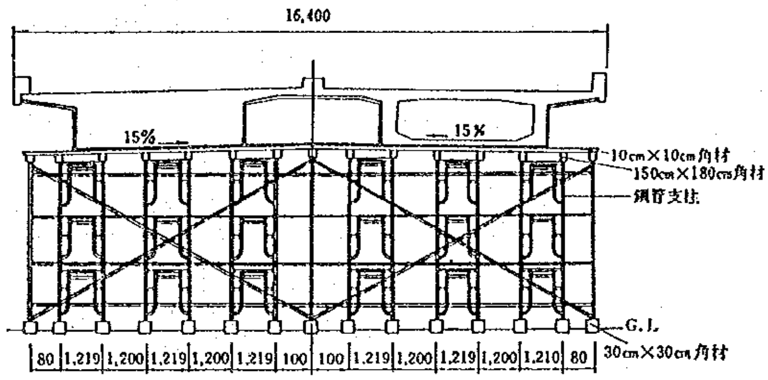


Fig. 11-4 Construction Method for Superstructure by Full Staging

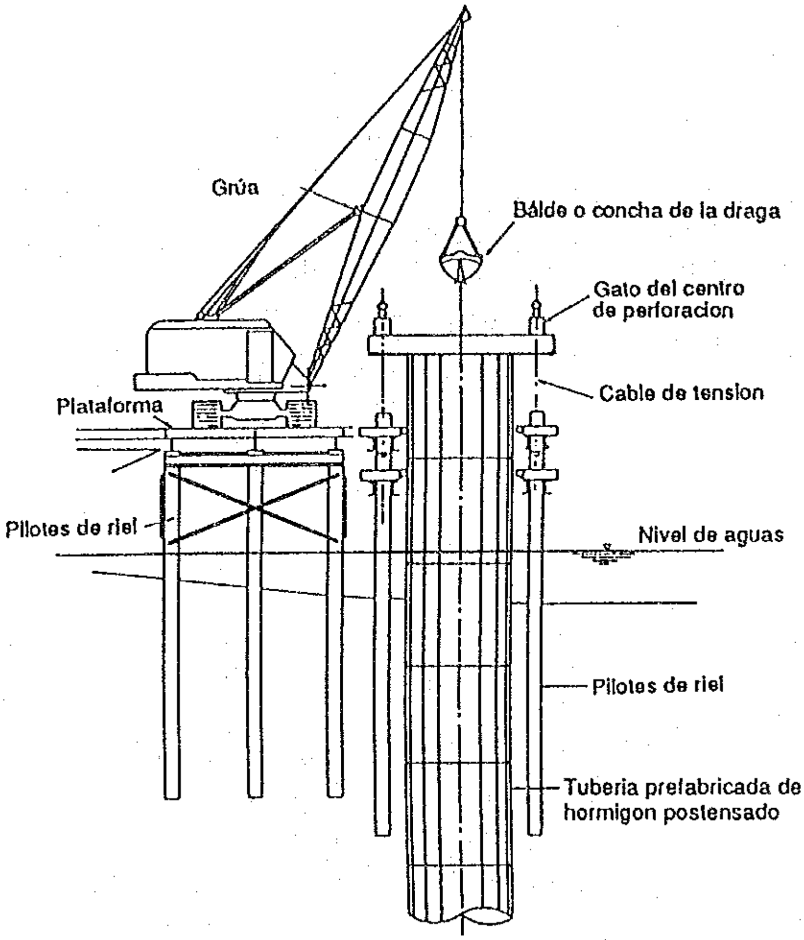


Fig. 11-5 Construction Method of Caisson

11.4 Tentative Construction Schedule

Tentative construction schedule using movable staging is shown in Fig 11-6.

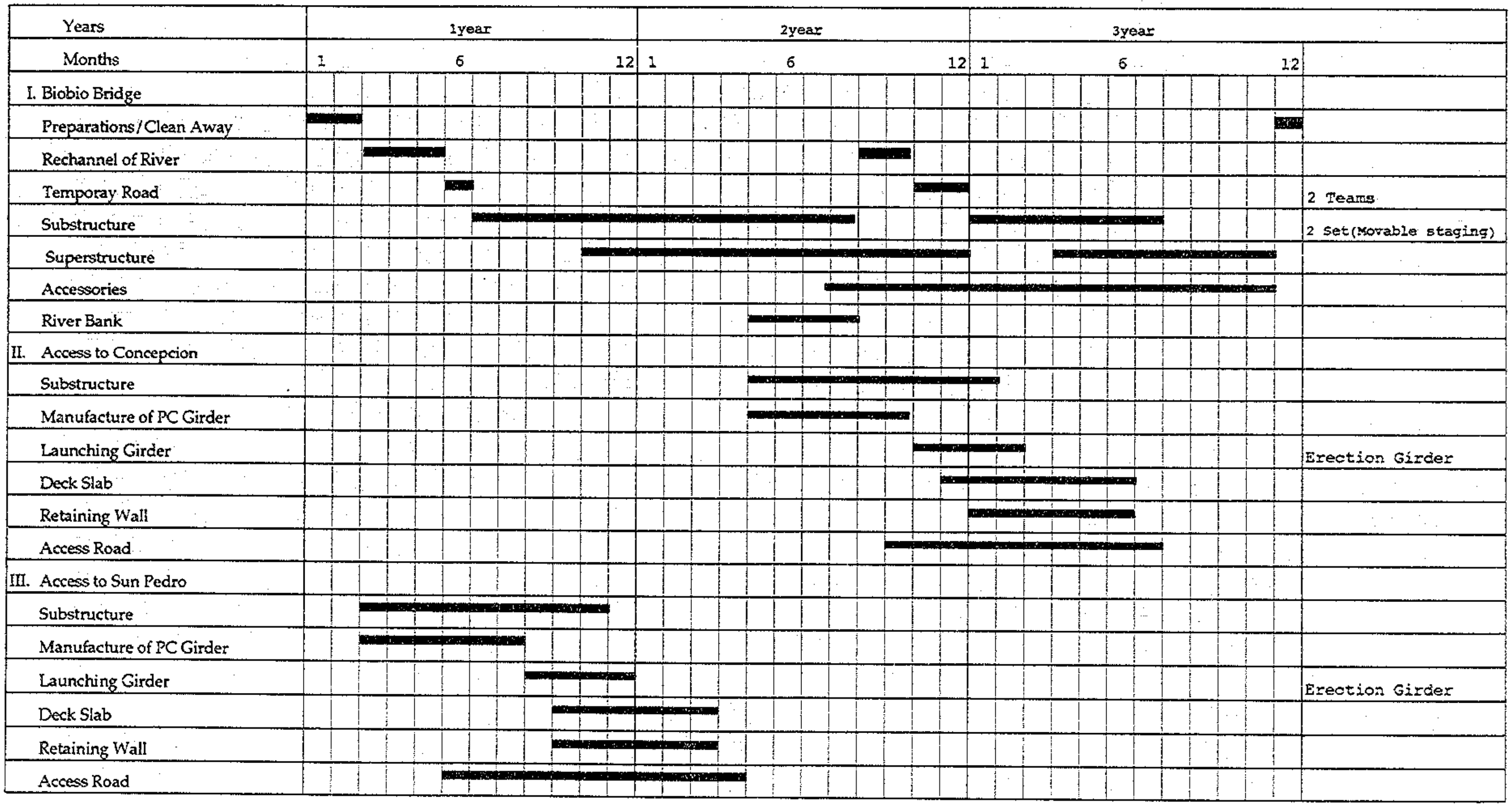


Fig. 11-6 Tentative Construction Schedule

11.5 Further Investigation for the Detailed Design

The Study Team recommends that during the implementation of this project, additional boring and stream bed elevations be taken for use in the detailed design of the bridge. Any modification of the type of foundations and/or the structural system would be studied and carried out at that time.

11.6 Access Road

The access road along Av.Los Carrera to the Biobio river is considered including connections with other existing roads. However, the following should be noted. In this study the word "access Road" is used to denote the road from the Angol intersection to the Biobio River along Los Carrera, including Av. Los Carrera. standard cross sections of roads are shown in Fig. 11-7.

Av.Los Carrera is in the process of being improved. Therefore, it is desirable that such improvement be taken into consideration. The section between the intersection on Av. Angol and the intersection on Av. Salas shall represent a typical cross section of the improved plan of Av. Los Carrera. This section is being improved under a separate project and therefore it is not included in the costing the new Biobio bridge.(see Fig. 11-8)

11.7 Overpass on the Concepcion Side and San Pedro Side

The access road of the new bridge includes two fly-overs, one on the Concepcion side and the other on the San Pedro side. These fly-overs accommodate two-way traffic, 2 lanes in each direction.

The segment of the road leading on to the fly-over or away from the fly-over consist principally of a four lane road 25.00 m wide out to out of the shoulders, with two 3.50 m lanes in each direction and 3.00 m wide sidewalks on each side of the two lanes.

As the road starts up the grade towards the fly-over, it consists of a four lane road with gravity retaining walls, and a total width of 17.00 m out to out of the gravity retaining walls. As the height of the retaining walls becomes more than 3.00 m the gravity walls change to cantilever retaining walls up to 8.00 m height, and the total width of the four lane road remains at 17.00 m out to out of the retaining walls. This arrangement continues until it reaches the abutment of the span of the fly-over. See Fig.11-7.

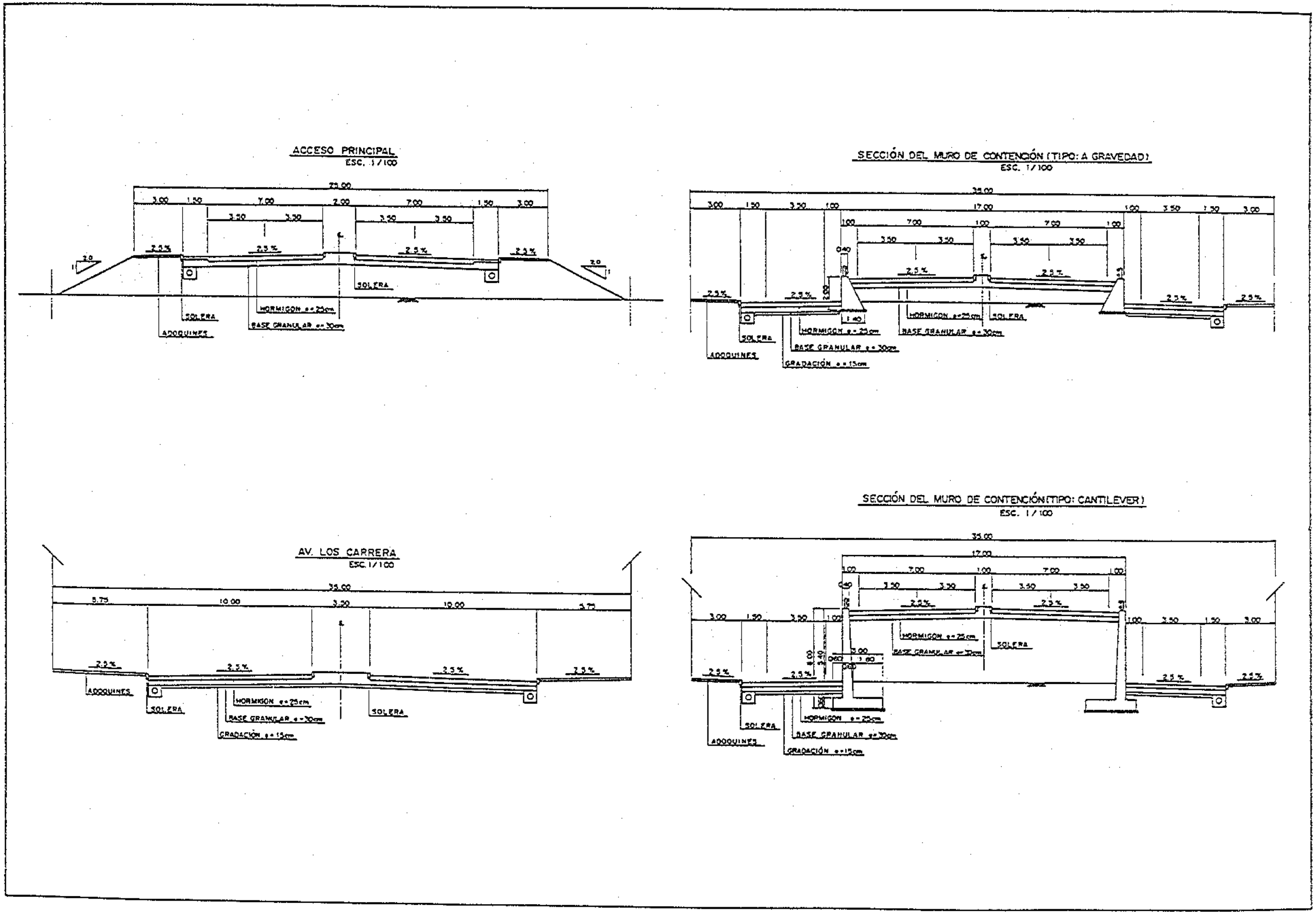


Fig. 11-7 Standard Cross Sections of Roads

11.8 Intersections and Fly-overs

The connections of the Access road at major intersections and at fly-overs are as follows:

(1) Intersection on Av.Serrano

At present, this intersection handles one-way traffic flow going towards Av.Chacabuco and a two-way traffic flow of Los Carrera. However, after construction, it is impossible to cross Av.Los Carrera because of the interruption caused by the construction of retaining walls of the grade separation. At the same time, vehicles will be able to turn right going toward the river from Av. Serrano onto Av.Los Carrera and from Av. Los Carrera the traffic can turn right going to Av. Serrano towards Av. Chacabuco.(see Fig. 11-9)

(2) Intersection on Av. Arturo Prat

The traffic flows at this intersection are important factors on the access road of the new bridge. When vehicles on Av. Los Carrera go from San Pedro to Concepcion, they will travel straight on the new bridge, and pass over the fly-over, the railroad and over Av. Arturo Prat. On the other hand, some vehicles traveling to Concepcion, do not need to go on the fly-over, but rather would cross the railroad tracks at grade, and turn right to Av.Arturo Prat or go straight to the central area of Concepcion.(see Fig.11-10)

(3) Intersection on New Road Under Fly-over

The Coordinating Committee has a plan to develop the area behind the existing railroad station. (refer to chapter 13) There are insufficient connection roads from the Access Road to the developed area. On the other hand, the traffic flow on the Access Road is interrupted by the connections of other roads. In this case, the crossing at grade should be kept to a minimum.

Therefore, connection roads and intersections should in general be located under the fly-over bridge where there is enough overhead clearance. This would facilitate the traffic flow between the new development area and the Access Road. (see Fig. 11-11)

(4) Intersection on Av. Lastarria

After the Fly-over, the Access Road(fill section) intersects with Av. Lasteria. As mentioned above, the development area is located in the vicinity and therefore this intersection is an important one. Consequently Av. Lastarria must be improved at this intersection. (see Fig. 11-12)

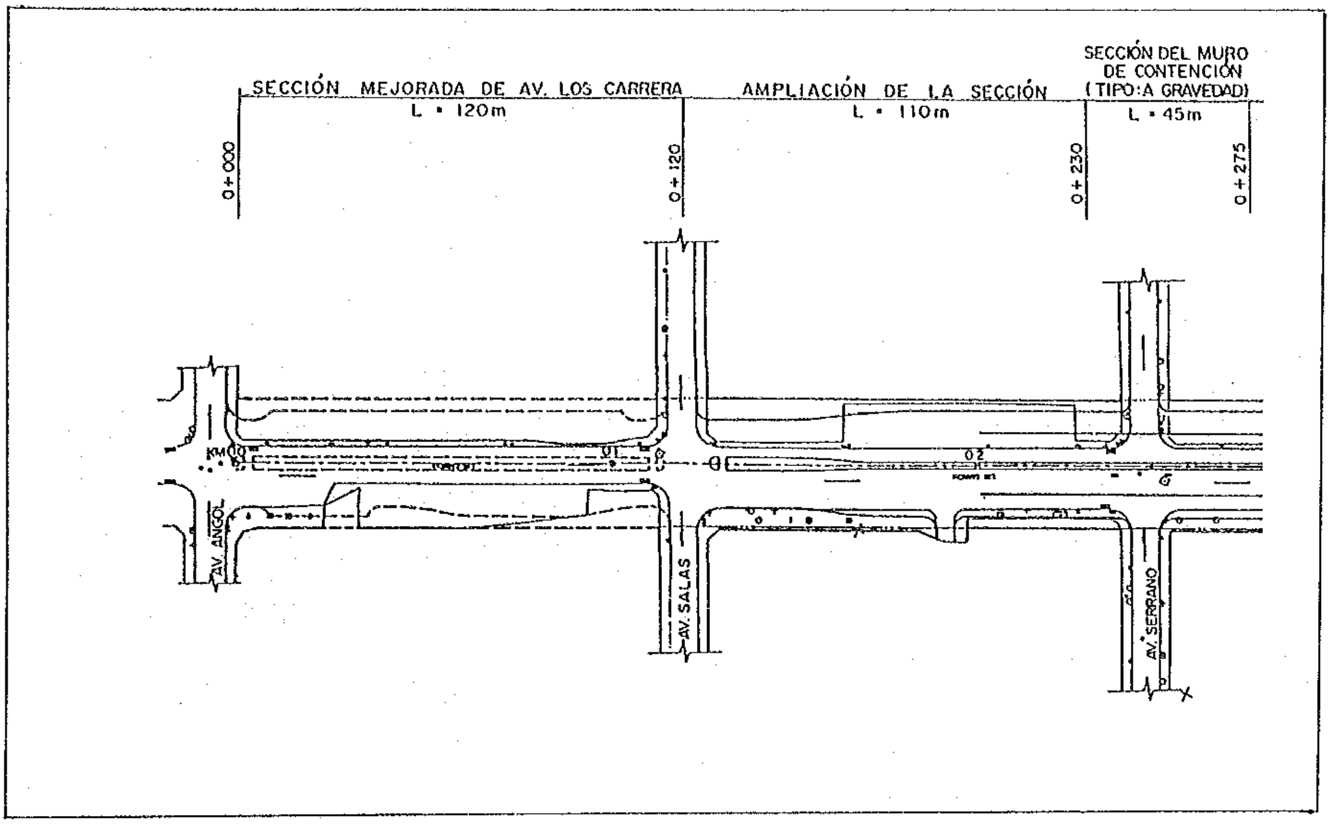


Fig. 11-8 Improved Plan of Av. Los Carrera

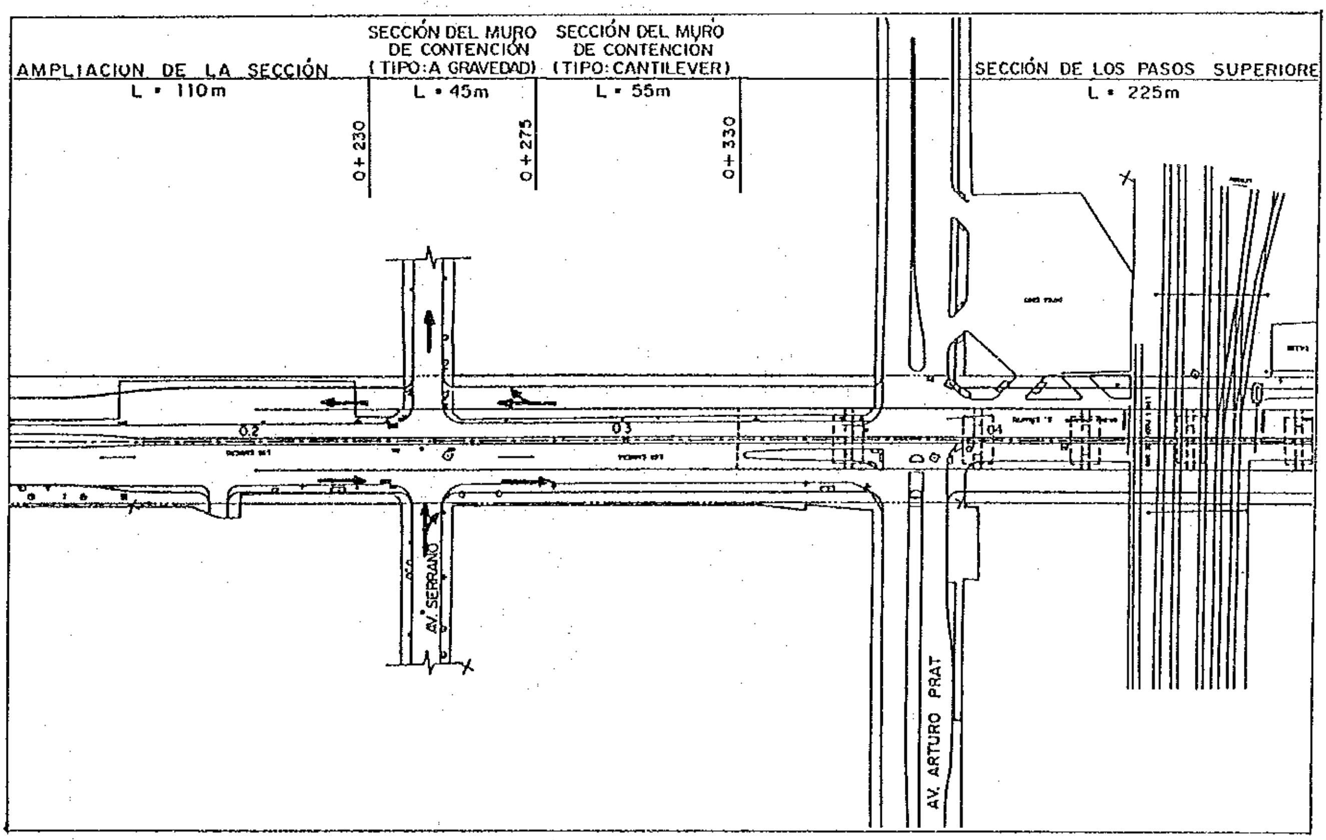


Fig. 11-9 Intersection on Av. Serrano

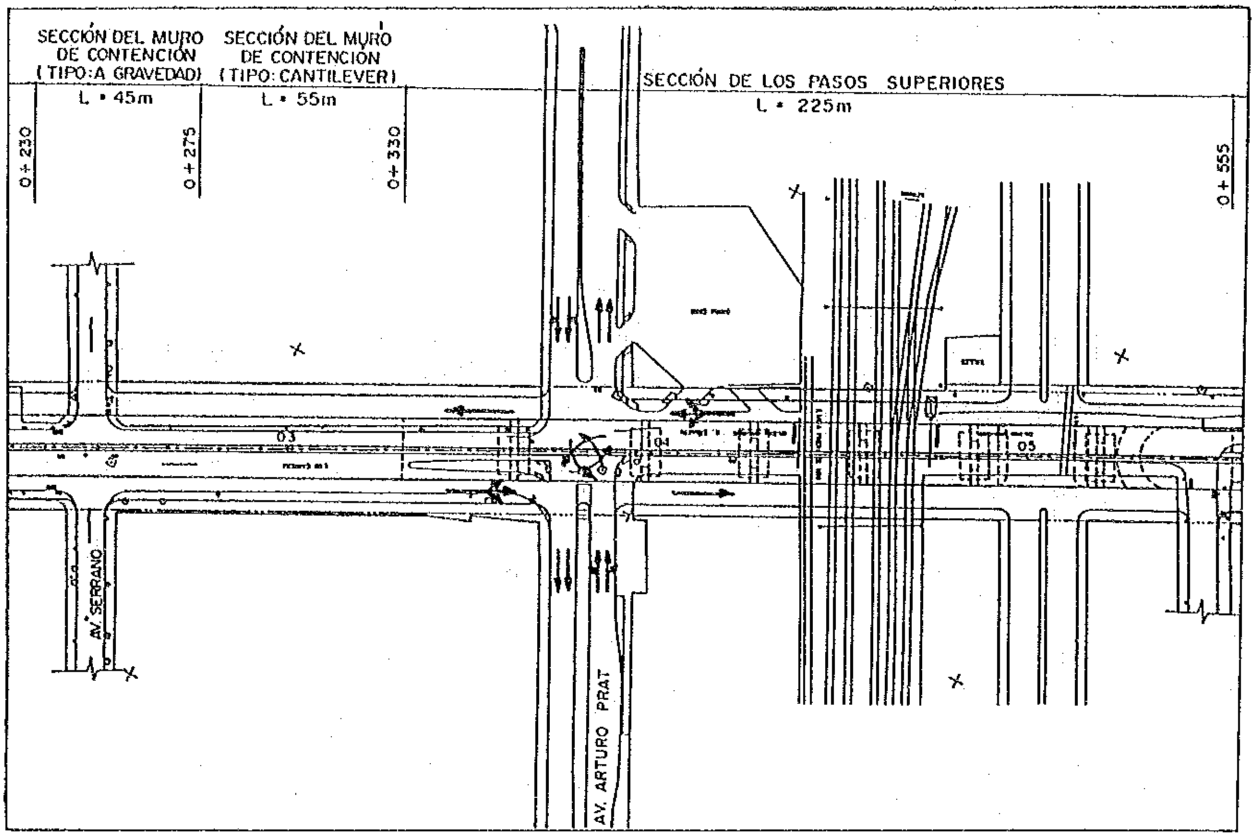


Fig. 11-10 Intersection on Av. Arturo Prat

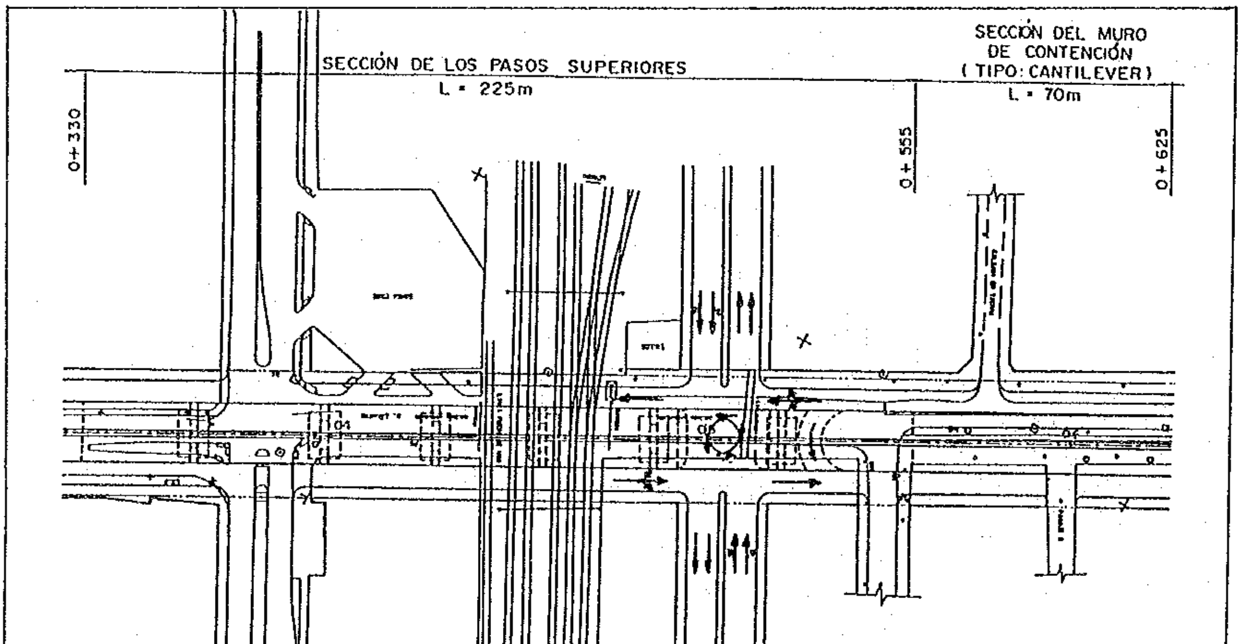


Fig. 11-11 Intersection on New Road under Fly-over

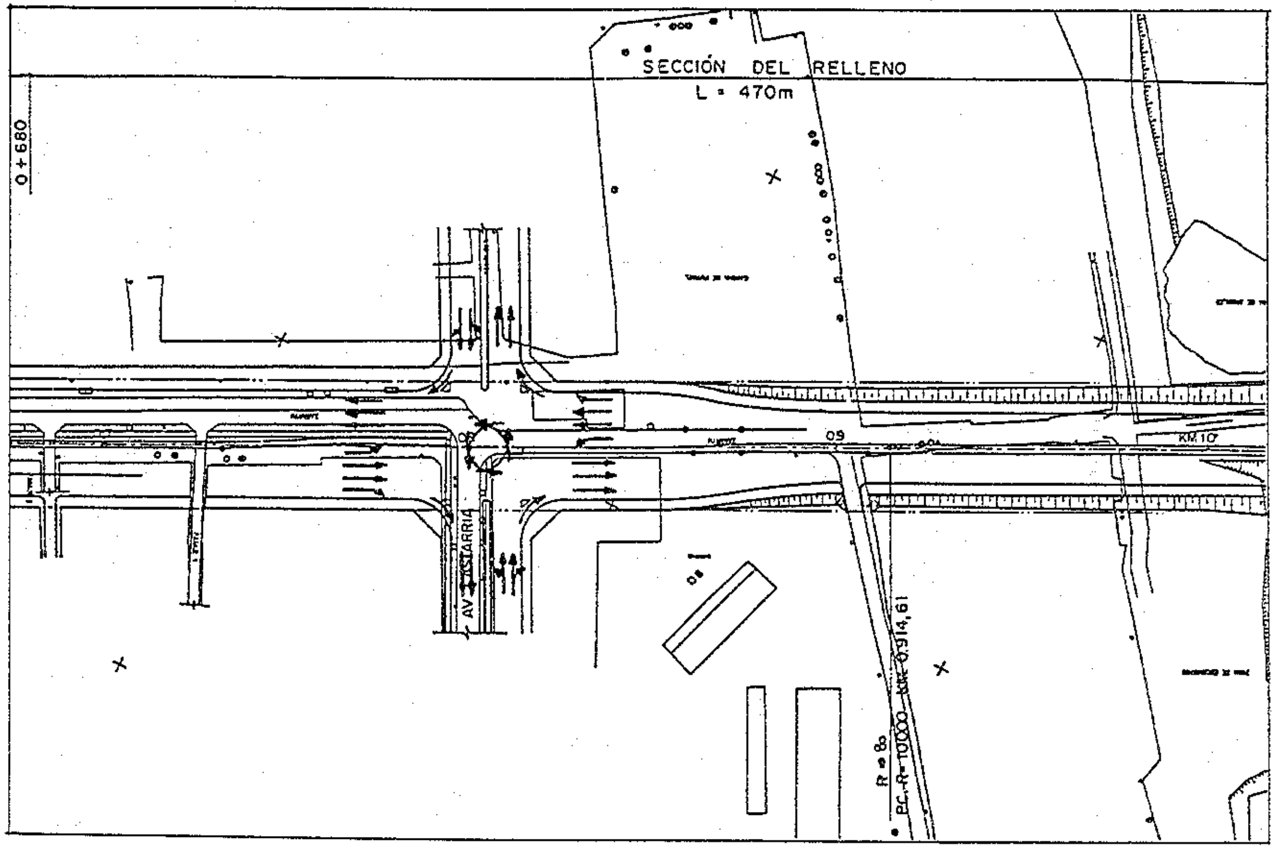


Fig. 11-12 Intersection on Av. Lasterria

(5) Connection with Coastal Road

Regarding the connection of the Access Road with Northern Coastal Road which is expected to be realized in the near future, it is necessary that a grade separation is established, since both roads are main roads with a large amount of traffic volume in each direction.

According to the vertical alignment of new bridge, it would be advisable that the elevation is kept as low as possible, since our objective is to keep the construction cost of new bridge as low as possible. As a result, it is recommended that the type of interchange shall be "Diamond type" which does not require too much space.(see Fig 11-13)

(6) Connection with A. Pedro Aguirre Cerda on the San Pedro side

A. Pedro Aguirre Cerda lies along the Biobio river as an existing road on San Pedro side. On the other hand, there is a wide road A.Luis Acevedo (within a residential area) which narrows down and intersects A. Pedro Aguirre Cerda at 90°. This road continues further and intersects with the approach to the Biobio River Bridge. (see Fig. 11-14)

A. Pedro Aguirre Cerda has a high traffic volume including heavy vehicles loaded with timber from the district upstream of Biobio river. These heavy vehicles generally cross the Juan Pablo II bridge on the way to Talcahuano. At the same time, this road carries heavy commuter traffic and commercial vehicles. In case of connections between A. Aguirre Cerda and A. Luis Acevedo, the grade crossing should have signaled control at this intersection.

11.9 Maintenance Program

Bridge maintenance activity is defined as all the works to maintain the original function of the bridge through its life span. A bridge is one of components of a road network system, and it is constructed over a river or a valley where it is difficult for the traffic to go over. In general, large amount of money is required to construct a bridge. Therefore, once the function of bridge is lost, adverse effects will occur, not only to road traffic but also to society and the economy of the impact area concerned. Bridges face many chances to suffer from natural disasters due to their functional characteristics. On the other hand, deteriorations with the passage of time are fundamentally inevitable due to the properties of materials.

The maintenance activity of a bridge, in above context, plays a major role to ensure safe and comfortable flow of road traffic and quality life of the public, hence it is important that maintenance activity be carried out through appropriate inspections. In general there are two types of inspections, periodic inspection and detailed inspection.

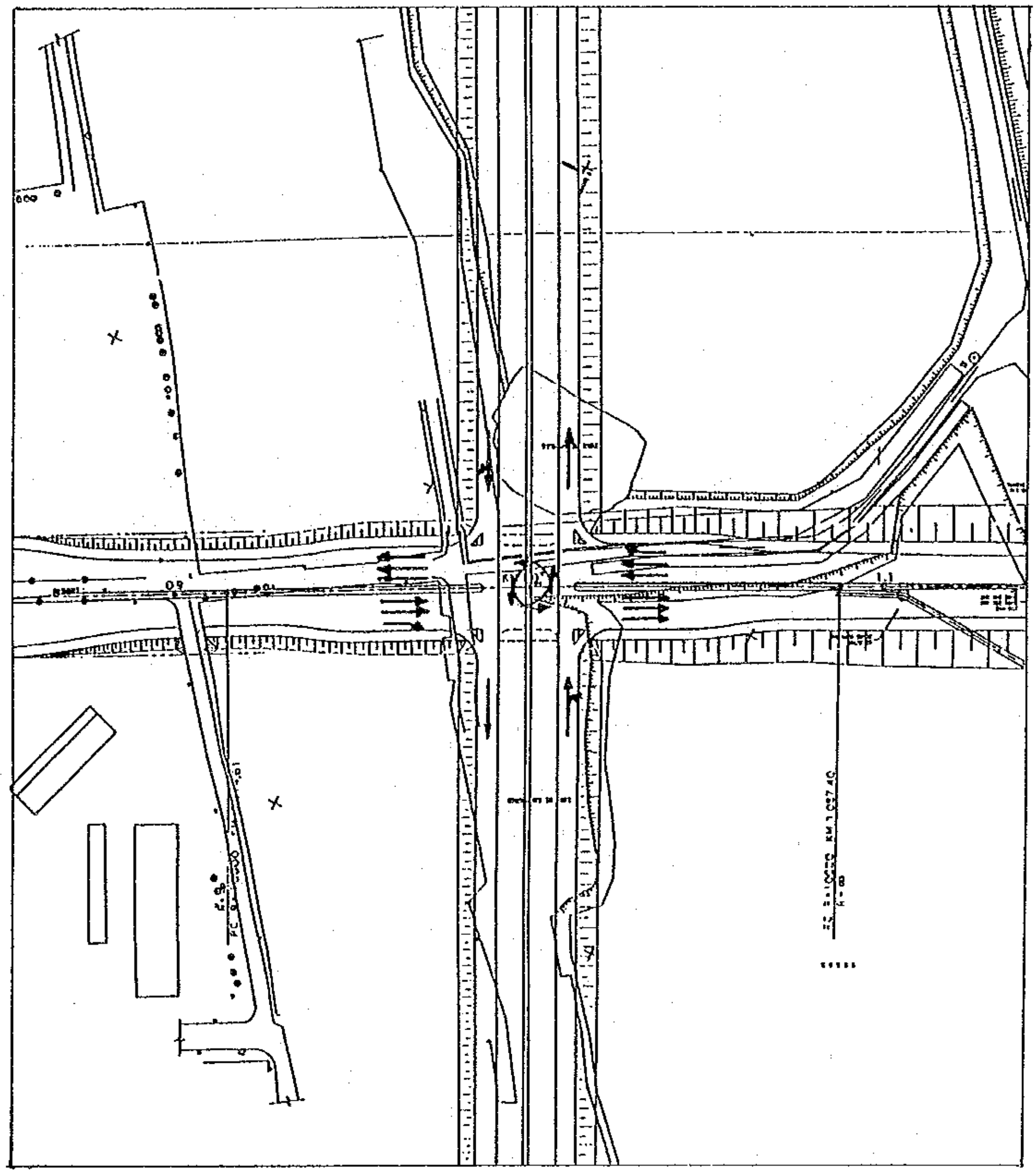


Fig. 11-13 Connection with Coastal Road

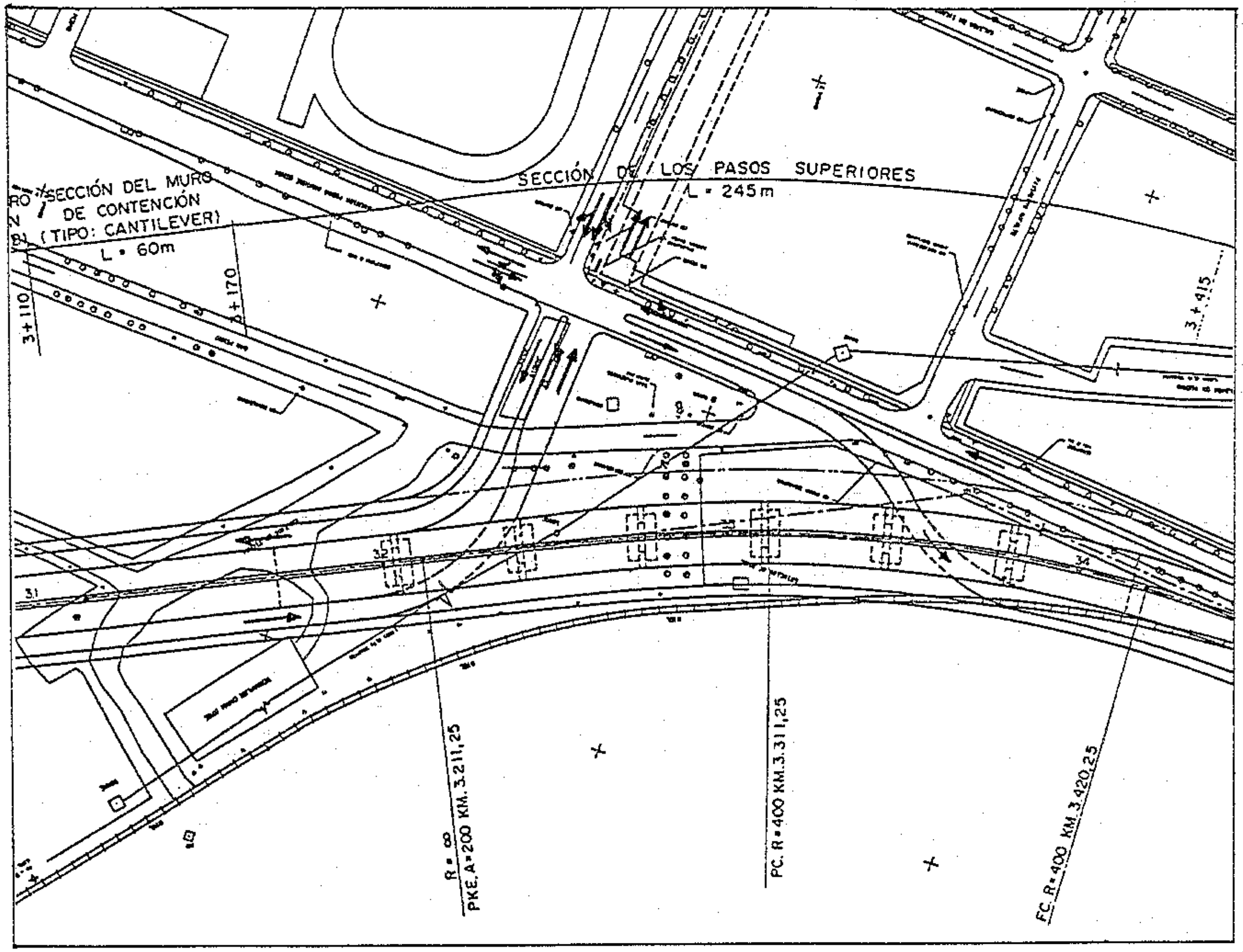


Fig. 11-14 Connection with Av. Pedro Aguirre Cerda on the San Pedro Side

Periodic inspections are carried out on all the existing bridges at certain intervals, normally every five years. The standard procedure of the inspection is focused on the following items:

1) Visual inspection for the degrees of corrosion, deterioration and deformation,

2) Measurement of main profile of the bridge, and

3) Photographing of the bridge profile and the defective portions of the bridge components.

Based on evaluation of the results of the periodic inspection, detailed inspection for the selected bridges should be carried out in order to decide either to rehabilitate or to replace the bridge, and to collect data to carry out any rehabilitation work if needed.

Furthermore, detailed inspections (as an extra inspection) should be carried out immediately after an earthquake to assess the damage resulting from a major earthquake. The procedures of the detailed bridge inspection are to be provided for each objectives of the maintenance works.

11.9.1 Maintenance Plan for New Biobio Bridge

The main components of the proposed new Biobio bridge are concrete elements. The bridge structure including superstructure and substructure generally require little maintenance. And the bridge is designed to comply with the design specification which is specified in consideration of traffic demand and natural environmental conditions of the bridge site. Therefore, the anticipated function of the bridge will be kept through the life expectancy of the bridge if proper maintenance works will be given for the bridge.

However, some of the bridge components may sometimes require some rehabilitation for ordinary maintenance. Such rehabilitation and repairing work requires the following:

1) Repairs of potholes,
2) Overlay or surface treatment to maintain a smooth riding surface,
3) Replacement of expansion joints if any,
4) Replacement of light bulbs, and
5) Painting of handrail

These maintenance works are to be carried out in the course of annual maintenance program of MOP.

On the other hand, it is unavoidable that defects such as deformation and deterioration induced by, or resulting from unexpected disasters or loading conditions will occur, even if the bridge is constructed correctly.

Measurement of the profile of the bridge during periodic inspections is one of the most important tasks in the evaluation of the condition of the bridge. In this case, it is important that the measurement of basic profile of the bridge at the time of its completion be carried out and the data be kept on file, because the data will be an important factor in defining the causes of deformation of the structure in future and useful to make countermeasures for the rehabilitation.

Periodic inspections of the bridge should be carried out as a part of bridge maintenance program of MOP. The guideline for bridge maintenance inspection was prepared and presented to MOP through "the Study on the Rehabilitation and Conservation Program of Bridges in the Republic of Chile" March 1993 by JICA.

11.9.2 Maintenance Plan for Biobio Antiguo Bridge

As for Biobio Antiguo bridge, the existing conditions were evaluated, based on our detailed inspections and recommendations regarding the utilization of the bridge. These are mentioned in Chapter 8.

However, even if MOP decides to close the bridge completely it would not take place until sometime in the future therefore, it is required that suitable maintenance works be carried out to secure safety for traffic and pedestrians.

It is actually difficult to forecast the life expectancy of the existing bridge. but from engineering view point, it is considered that the bridge has lasted longer than its life expectancy. Therefore, to maintain the bridge in reasonable condition is not easy and tends to be costly.

When work on the bridge is carried out, MOP should make countermeasures in addition to ordinary maintenance as follows:

1) To arrange for barricades at mouth of the access to the bridge to restrict traffic to passenger and emergency vehicles,
2) To close temporarily until completion and confirmation of the safety of the bridge following disasters, major earthquake or heavy flood, and
3) To remove debris from the river bed.

CHAPTER 12 COST ESTIMATES

12.1 Cost Estimation Method

A brief summary is given below for the cost estimation methods used by the MOP. Total construction costs can be expressed by the following equation.

Precio = (costo directo + gastos general + utilcompania) + IVA

$$P = (I + GG + UC) + IVA$$

where

P : Total construction costs (estimate for total construction costs or bid price)

I : Direct cost for construction (materials + labor + equipment + transportation + other expenses)

GG : General expenses, (indirect costs, administ-rative costs)

UC : Company profit

IVA : Tax (Government tax rate;18 %)

Of these, the direct construction costs (I) are calculated according to the "Plan nacional de puentes. Programa de rehabilitacion y conservacion vial." The general expenses (GG) and company profit (UC) vary from company to company, but examples of past projects show GG to be around 30 to 40 % of the direct construction costs. The tax rate at the present is 18 % of (I + GG + UC). Discussions with local contractors and the MOP concluded that it is common locally that contractors include the profit (UC) in the Direct Cost. Therefore, for this project, company profit will be included in the direct cost (I). Engineering service cost and contingency cost shall be shown separately from the construction cost. Sources used for reference in the cost estimation include the following:

- Plan nacional de puentes. Program de rehabilitacion y conservacion vial (Especificaciones tecnicas generales, Mayo 1983)
- ONDAC. El manual de la construccion
- Normas de autopistas (No.1 - No.5)

12.2 General Considerations

12.2.1 Price analysis of Labor, Materials, Equipments etc.

All factors which affect the three main components of the unit price in foreign and local currency costs namely:equipment, labor,materials, as well as other indirect costs will be considered. Listed below are the factors which could affect unit price of each pay item in the Project.

1. Labor

   - Adjustments in labor cost due to actual project conditions
   - Wage increases mandated by the Government
   - Effects of night differentials and other customary requirements

2. Materials

   - Accuracy of quantity take-off
   - Waste, loss and spoilage factors
   - Special inspection or testing requirements
   - Transportation cost of materials
   - Fuel costs

3. Indirect costs

   - Consideration of all probable overhead costs: job supervision and office personnel, engineering, site security, temporary facilities and utilities, service vehicle, supplies, communications and all other costs usually considered as overhead costs.

12.2.2 Breakdown of Foreign and Local Currency Portion

Cost estimates will be prepared for the project based on unit price analysis and the bill of quantities. The estimates will show the local and foreign currency requirements. Taxes shall be shown separately from the local cost component. The estimates shall be accompanied by a construction schedule and a program of expenditures in foreign and local currency.

The tentative rate of exchange for cost estimation will be applied as follows: US$ 1.00 = Ch $ 431.04 = Yen Y 111.33 (December 30, 1993)