11.3 Collection and Review of Existing Material

11.3.1 Collection of Existing Materials

The list of collected materials is shown in Table 11.7.

Table 11.7 List of Collected Materials

No.	Material	Issue	Contents	
1	Pre-F/S Report (Concept Design Report, January 2013)	ACP	Main Report	Chapter 1: Executive Summary (Road Design, Evaluation of Road) Chapter 9: Road Alternatives
			Drawing	Plan, Profile, Typical Cross Section
	Pre-F/S Report (Draft Final Report, November 2013)		Main Report	Chapter 1: Executive Summary (Road Design) Chapter 9: Preliminary Road Design
			Drawing	Plan, Profile, Typical Cross Section
2	Bridge of the Americas	MOP	Drawing	Typical Cross Section
3	Panamerican Highway	MOP	Drawing	Typical Cross Section

Source: JICA Study Team

11.3.2 Review of Previous Data

The results of reviewing the Pre-F/S (Concept Design (January 2013)) are described below.

(1) Scope of Review

The road standard, the design speed, the horizontal and vertical alignments, and the cross section elements of the Approach Road were reviewed.

Regarding the Connection Road on the east side and the Access Roads to the Bridge of the Americas on the west side, it should be noted that only the horizontal alignment was reviewed because the vertical alignment was unknown due to the lack of a profile.

The starting point of the Approach Road is the same location as in the Pre-F/S; however, the end point was changed to before the Howard intersection on the Panamerican Highway, based on instructions from SMP.

(2) Validity evaluation

1) Applied Design Standards

The Policy on the Geometric Design of Highway and Street (AASHTO) was applied for the road geometric design standard, and the review was done based on this standard. The pavement design was based on AASHTO and the drainage design on the MOP standard, “Chapter 4:·Drainage”. It is noted that no standards regarding road geometric design have been prepared in Panama.

2) Route selection

The purpose of this project is to alleviate traffic congestion of the Bridge of the Americas, which connects Panama City and the area west of the Canal. By connecting Omar Torrijos roundabout, which is an important traffic hub in Panama City, with the Pan American highway to the west, it is expected that this will contribute to relieving traffic congestion of the Bridge of the Americas. Thus, the studies to be conducted in this project shall be based on the route set in the Pre F/S conclusion.

3) Conditions for Road Planning and Design

An outline of the conditions for road planning and design is shown in Table 11.8. The design speed of 120km/hr is comparatively higher than the speed interval between the existing roads that connect to the project road. Therefore, design speeds should be set by allowing for reductions in specific areas, as mentioned below in Section 11.3.3.

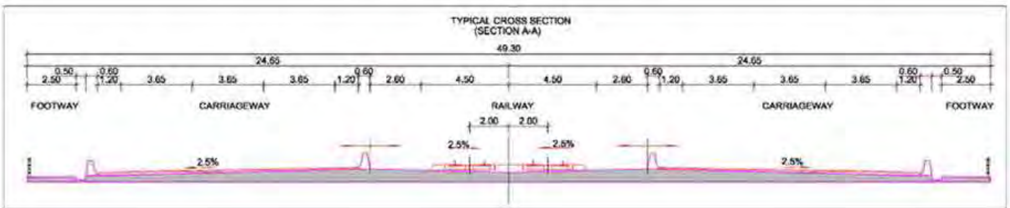
Table 11.8 Outline of Condition for Road Planning and Design

Item	Contents
Beginning Point/ End Point	Beginning Point: Connection to the Corredor Norte End point: Connection to the Hoard Intersection on the Panamerican Highway
Road Length	6,296m
Road Class	Arterial Road (AASHTO)
Design Speed	120km/hr (100km/hr: Roundabout Area on East side and Howard Intersection Area on West side)
Number of Lanes	6 lanes (4 lanes: Roundabout Area on East side and Howard Intersection Area on West side)
Geometric Design Standards *Parenthesis is in case of 100km/hr	Horizontal Alignment Minimum radius of curve: R=700m (R=394m) With Clothoid Curve: R=852m Without Superelevation: R=5,000m Minimum Clothoid Length: 67m Minimum Curve Length: L=55m Length of Superelevation Transition: L=114m (In case of 2 lanes)
	Vertical Alignment Minimum Gradient: i=0.5% Maximum: i=5% Minimum Vertical Curve (Crest): K=95(52) Minimum Vertical Curve (Sag): K=63(45) Vertical Clearance for Road: h=5.5m Vertical Clearance for Mono Rail: h=9.15m Navigation Clearance for Panama Canal: h=75m *above MLWS
	Cross Section Elements Width of Lane: 3.65m Width of Outside Shoulder: 3m (1.2m: Bridge Section) Width of Inside Shoulder: 1.2m Width of Sidewalk : 2.5m Width of Monorail : 9.0m Maximum Superelevation: e=8% *In case of R=667m Minimum Superelevation: e=2.5% Cross fall: 2.5%

Source: Pre-F/S (Concept Design Report (January 2013)) (ACP)

4) Typical Cross Section

A typical cross section of the 4th Panama Canal Bridge is shown in Figure 11.9. The railway was planned for the center, and sidewalks/footways were planned for the outer side of the road. As a result of discussion held with SMP, the monorail is placed on the left/south side of the project bridge and given sufficient width for it (Section 12.2.1(2)3)).



Source: Pre-F/S (Concept Design Report (January 2013)) (ACP)

Figure 11.9 Typical Cross Section of 4th Panama Canal Bridge

5) Road Alignment

The horizontal curve has been designed using a radius bigger than 700m, except for a 500m radius located between KM0+527 and KM0+640 and a 435m radius located between KM0+969 and KM1+164. The radius of 700m satisfies the minimum standard for a design speed of 120km/hr. However, the horizontal curve radiuses mentioned above were applied in order to match the existing road alignment and they satisfy the minimum standard for a design speed of 100km/hr. Therefore, the design speed was reduced to 100km/hr.

The Horizontal Alignment of the Access Road (Pre-F/S) is shown in Table 11.9.

Table 11.9 Horizontal Alignment of the Access Road

No.		Station	Coordinate		Beginning	Clothoid	Ending	Length (m)
			Y (X)	X(Y)	Radius (m)	Parameter (m)	Radius (m)	
1	BP1-0	0+000.000	992,400.693	659,462.318	-960.156	0.000	-960.156	24.367
2	EBC1-1	0+024.366	992,378.561	659,452.126	-5,000.000	0.000	-5,000.000	280.115
3	EC1-0	0+304.482	992,119.605	659,345.421	0.000	0.000	0.000	156.417
4	KA2-1	0+460.899	991,973.373	659,289.901	0.000	183.030	500.000	67.000
5	KE2-1	0+527.899	991,911.295	659,264.732	500.000	0.000	500.000	112.552
6	KEE2-1	0+640.451	991,815.100	659,206.755	500.000	192.931	5,000.000	67.000
7	KAE2-1	0+707.451	991,763.948	659,163.508	5,000.000	0.000	5,000.000	198.957
8	KA3-1	0+906.408	991,618.187	659,028.111	0.000	165.000	-435.000	62.586
9	KE3-1	0+968.994	991,572.169	658,985.714	-435.000	0.000	-435.000	194.883
10	KE3-2	1+163.877	991,400.087	658,897.758	-435.000	165.000	0.000	62..586
11	KA3-2	1+226.463	991,383.769	658,885.294	0.000	0.000	0.000	126.899
12	KA4-1	1+353.362	991,213.844	658,863.004	0.000	253.772	700.000	92.000
13	KE4-1	1+445.362	991,123.667	658,844.868	700.000	0.000	700.000	465.299
14	KE4-2	1+910.661	990,740.250	658,596.595	700.000	253.772	0.000	92.000
15	KA5-1	2+002.661	990,686.806	658,521.732	0.000	337.639	-1,500.000	76.000
16	KE5-1	2+078.661	990,643.485	658,459.290	-1,500.000	0.000	-1,500.000	277.930
17	KAE5-1	2+356.591	990,461.307	658,249.921	-1,500.000	315.832	-700.000	76.000
18	KEE5-1	2.+432.591	990,404,542	658,199.417	-700.000	0.000	-700.000	291.844
19	KE5-2	2+724.435	990,146.752	658,067.166	-700.000	230.651	0.000	76.000
20	KA6-1	2+800.435	990,072.752	658,049.889	0.000	230.651	700.000	76.000
21	KE6-1	2+876.435	989,998.752	658,032.613	700.000	0.000	700.000	375.916
22	KE6-2	3+252.350	989,679.057	657,843,551	700.000	230.651	0.000	76.000
23	KA6-2	3+328.350	989,628.266	657,787.028	0.000	0.000	0.000	1,137.935
24	KA7-1	4+466.285	988,883.127	656,926.992	0.000	277.489	700.000	110.000
25	KE7-1	4+576.285	988,813.318	656,842.021	700.000	0.000	700.000	1,224.901
26	KE7-2	5+801.186	989,068.270	655,798.208	700.000	277.489	0.000	110.000
27	KA8-1	5+911.186	989,169.390	655,754.987	0.000	400.999	-1,200.000	134.000
28	KE8-1	6+045.186	989,292.985	655,703.263	-1,200.000	0.000	-1,200.000	462.445
29	KE8-2	6+507.630	989,665.357	655,433.892	-1,200.000	400.999	0.000	134.000
30	KA8-2	6+641.630	989,753.160	655,332.691	0.000	0.000	0.000	247.412
31	EP	6+889.042	989,911.793	655,142.828	0.000	0.000	0.000	0.000

Source: Pre-F/S (Concept Design Report (January 2013)) (ACP)

The vertical alignment of the 4th Panama Canal Bridge section consists of a 4% gradient, a 9,500m convex vertical curve and a 6,000m concave vertical curve.

The design speed was decreased to 100km/hr in the vicinity of the beginning point, whereby the maximum gradient is 4.947%, the convex vertical curve length is 2,343m and the concave vertical curve length is 4,659m. The concave length satisfied the design standard (4,500m), while the convex curve does not satisfy the design standard (5,200m).

The vertical alignment of the Approach Road (Pre-F/S) is shown in Table 11.10.

Table 11.10 Vertical Alignment of Approach Road (Pre-F/S)

No.	IP	Station (km)	Length (m)	Crest /Sag	EL (m)	Grade (%)	V. Curve	
							Length (m)	Radius (m)
1	VIP1	0+000.000	-----	-----	-----	-----	-----	-----
2	VIP2	0+077.286	77.286	Crest	8.541	-0.57294	214.677	40,834.910
3	VIP3	0+286.159	208.873	Sag	6.246	-1.09866	110.000	7,509.956
4	VIP4	0+684.272	398.113	Sag	7.703	-0.366.062	169.317	4,659.355
5	VIP5	1+130.963	446.691	Crest	25.571	4.000	560.000	8,000
6	VIP6	1+771.423	640.460	Sag	6.357	-3.000	350.000	5,000
7	VIP7	3+800.000	2,028.577	Crest	87.500	4.000	760.000	9,500
8	VIP8	5+531.718	1,731.718	Sag	18.231	-4.000	192.388	6,685
9	VIP9	6+329.371	797.655	Sag	9.281	-1.12209	331,368	5,459.619
10	VIP10	6+619.103	289.732	Crest	23.615	4.947339	136.612	2,343.008
11	VIP11	6+811.139	192.036	Crest	21.919	-0.883267	89.416	2,396.517
12	VIP12	6+889.042	77.903	-----	18.324	4.614355	-----	-----

Source: Pre-F/S (Concept Design Report (January 2013)) (ACP)

11.3.3 Proposal of Road Alignment

Based on the verification/evaluation of the validity of the Pre-F/S, the following proposals were adopted.

(1) Proposal to Decrease the Design Speed of the Approach Road

1) Vicinity of the Beginning Point

At the beginning point, the merging and diverging noses are located in short distances. Therefore, the reduction of the design speed from 100km/hr to 80km/hr is proposed in consideration of traffic safety

2) Vicinity of the 4th Panama Canal Bridge

Before and after the 4th Panama Canal Bridge, the horizontal alignment has a 700m radius, a 4% gradient and a 9,500m convex vertical curve, which are values that satisfy the design standard.

The maximum gradient is 5% (urban arterial, flat land) if the design speed would be 120km/hr.

The travelling speed of trucks (Power/weight ratio: 10 horsepower/ton) decreases from 80km/hr to 34/km in the case of a 5% gradient, but only to 43km/hr in the case of a 4% gradient.

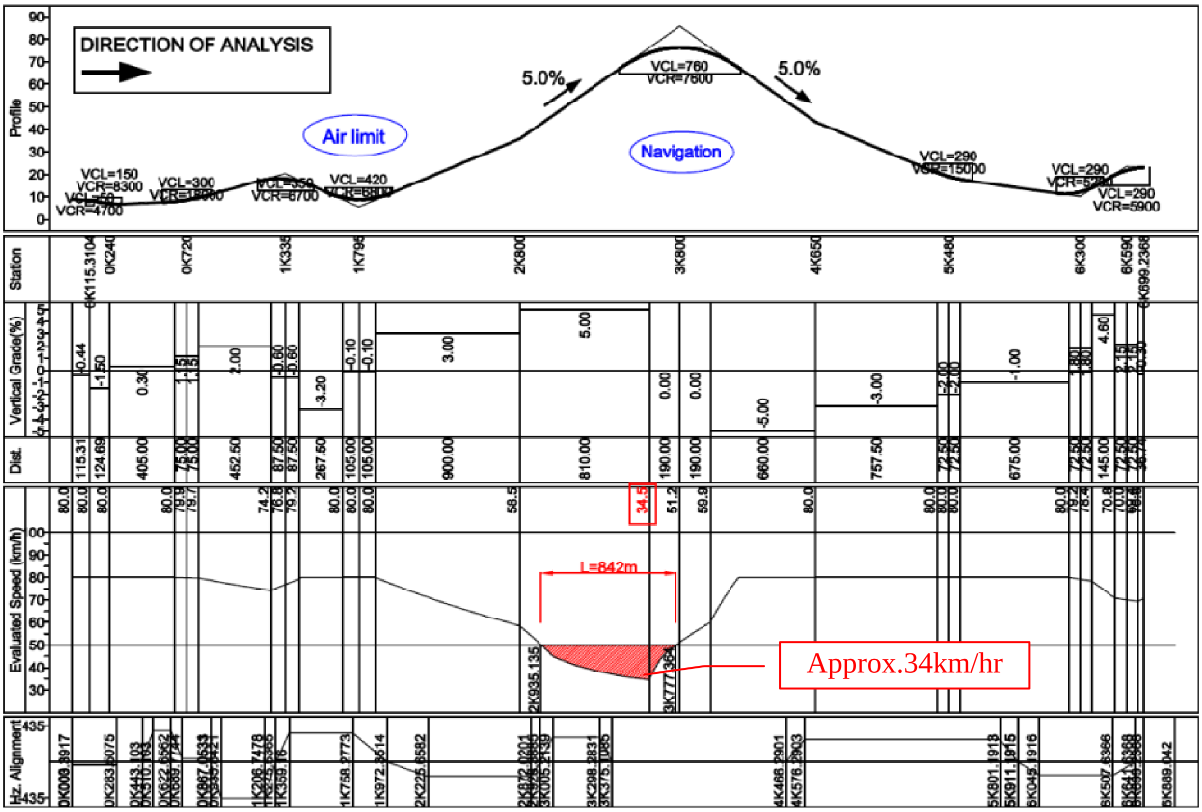
In the case of a 120 km/hr design speed, where the travelling speed of passenger cars is 100km/hr, then the difference in speeds between passenger cars and trucks becomes large. Therefore, the reduction of the design speed from 120km/hr to 100km/hr is proposed in consideration of traffic safety.

The speed performance curves of trucks on a 5% gradient and a 4% gradient are shown in Figures 11.10 to 11.13, respectively.

Table 11.11 Summary of Running Speed and Grades

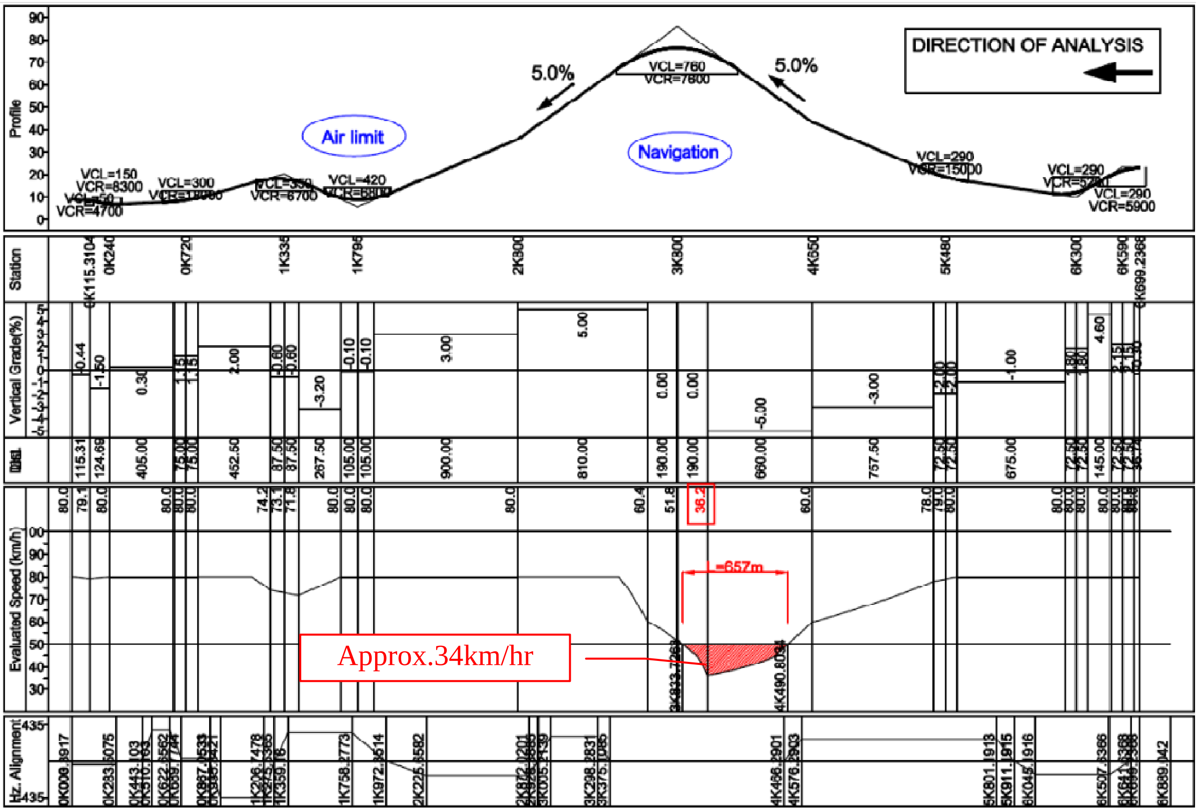
Vertical Gradient	Direction	Running Speed	Evaluation
5.0%	From BP to EP	34km/hr	Poor
	From EP to BP	34km/hr	
4.0%	From BP to EP	43km/hr	Good
	From EP to BP	43km/hr	

Source: JICA Study Team



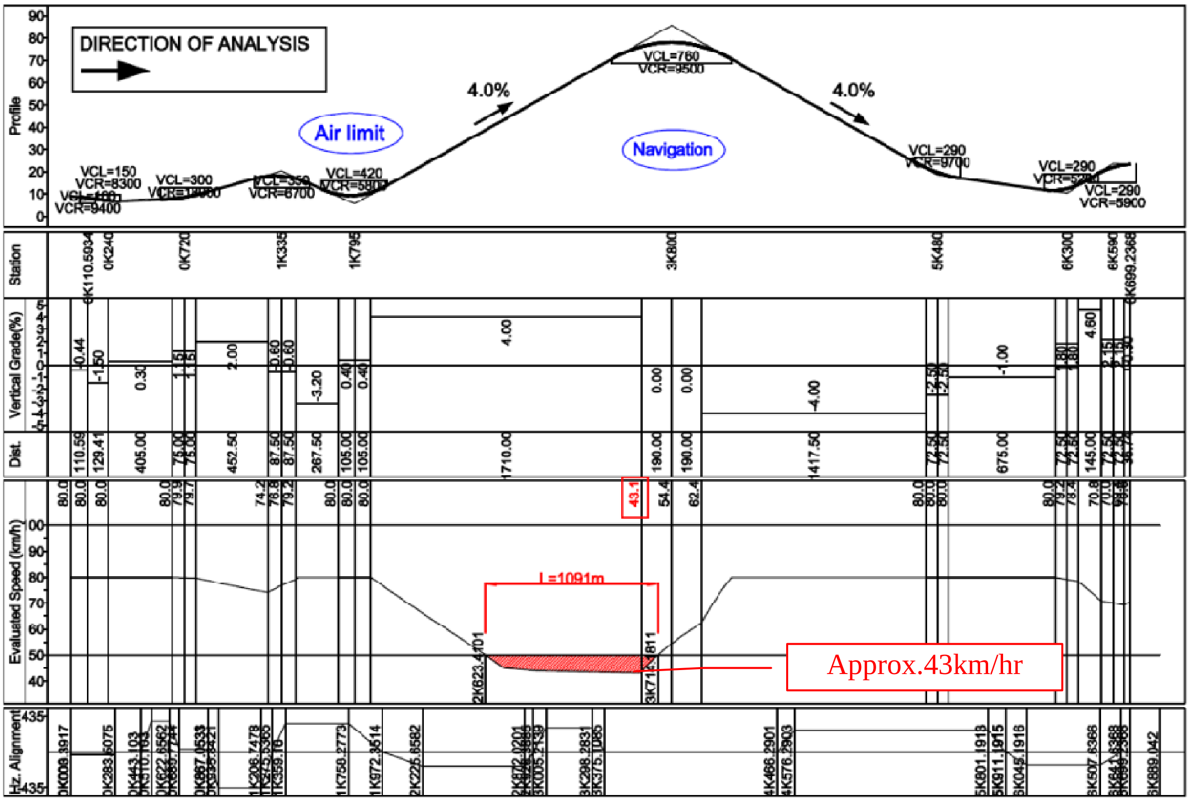
Source: JICA Study Team

Figure 11.10 Speed Performance Curve of Trucks on a 5% Up-grade (From BP to EP)



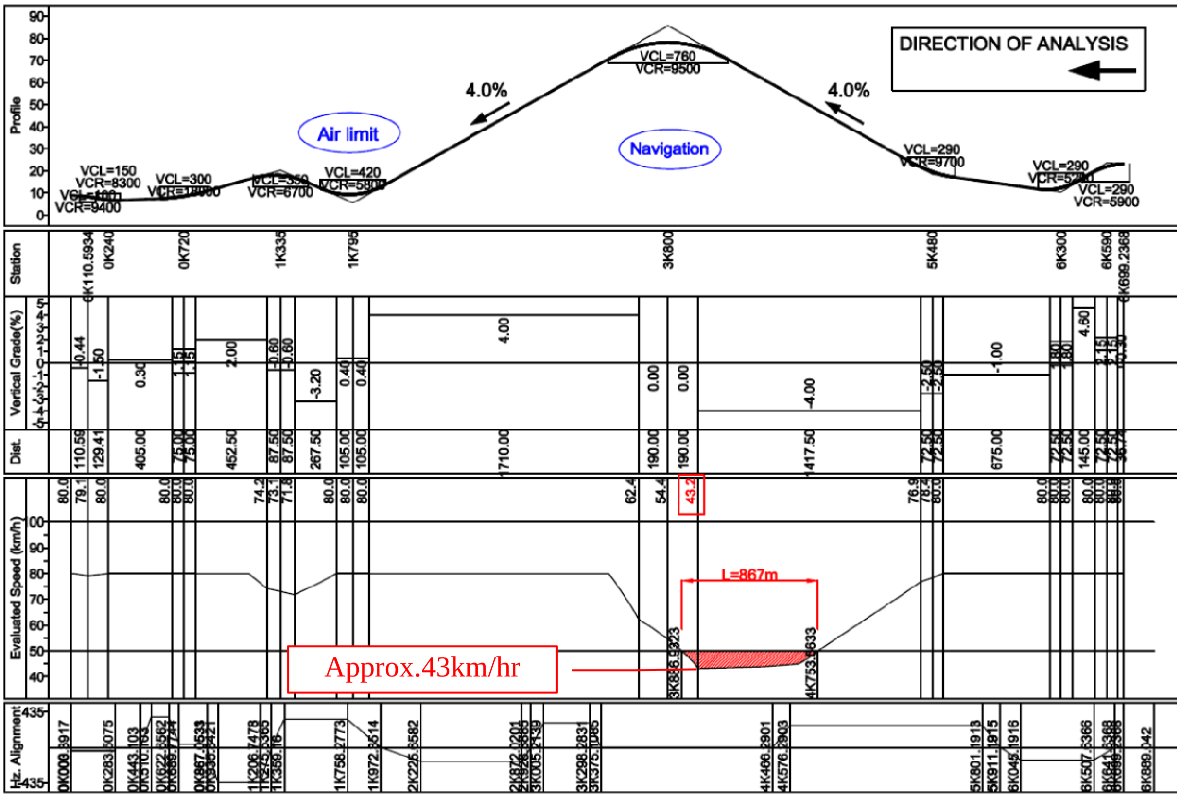
Source: JICA Study Team

Figure 11.11 Speed Performance Curve of Trucks on a 5% Up-grade (From EP to BP)



Source: JICA Study Team

Figure 11.12 Speed Performance Curve of Trucks on a 4% Up-grade (From BP to EP)



Source: JICA Study Team

Figure 11.13 Speed Performance Curve of Trucks on a 4% Up-grade (From EP to BP)

(2) Proposal to Change the Design Value of the Approach Road

In the vicinity of the beginning point, the minimum horizontal curve radius is 435m, which satisfies the design standard. But in the case of a design speed of 80km/hr, the superelevation would be 5.03%, and this does not satisfy the design standards (6.3%). Therefore, it is proposed that the superelevation in the curve section near the beginning point be changed to a suitable value for a design speed of 80km/hr.

The superelevation for a 700m radius at the 4th Panama Canal Bridge is 6.11%, and this does not satisfy the design standard of 100km/hr. Therefore, the improvement of the superelevation is proposed in accordance with the design standard.

The convex vertical curve radius in the vicinity of the end point is 2,400m corresponding to the design speed of 100km/hr, and this does not satisfy the design standards (5,200m). Therefore, the improvement of the vertical curve radius is proposed in accordance with the design standards.

The proposed new values corresponding to the Pre-F/S are shown in Table 11.12.

Table 11.12 Proposed Revised Value Corresponding to Pre-F/S

Item	Designed Value (Pre-F/S)	Revised Design Value (This Study)
Superelevation of curve section at BP (Design Speed:80km/hr)	Superelevation 5.03% (R=435m) Superelevation 5.38% (R=500m)	Superelevation 6.4% (R=435m) Superelevation 5.8% (R=500m)
Superelevation of curve section before and after 4th Panama Canal Bridge (Design Speed:100km/hr)	Superelevation 6.11% (R=700m) Superelevation 8% (Minimum Radius)	Superelevation 6.4% (R=700m)
Vertical Curve Radius at EP (Design Speed:100km/hr)	VCR (Convex): 2,343m and 2,396m	VCR (Convex): bigger than 5,200m

Source: JICA Study Team

(3) Proposal on Changing the Number of Lanes and Cross Section Width

The 3.0m width of the outer shoulder is adapted to 1.2m at the retaining wall sections as well as the bridge sections due to the limited space. On the other hand, on the west side of the Canal a return to the 3.0m shoulder width is proposed because of adequate space along the 1.2km section.

A sidewalk was designed for the 4th Panama Canal Bridge section in the Pre-F/S. This Study also follows that basic concept; however, the location was revised. A 4m wide sidewalk is located on the south side (Pacific side) between Pier 30 and Pier 33 to serve as a viewing deck.

The necessity of a sidewalk will be studied again in the D/D stage in consideration of security and economic aspects. In the case of eliminating the sidewalk, the construction cost including the elevators would be reduced by about USD 20 Million.

A detailed discussion of the elevators is made in Chapter 13.

11.4 Preliminary Design

11.4.1 Scope of Work

The Preliminary Design was carried out for the following roads corresponding to the scope of this project.

- Adjustment with the Panama City Urban Transportation Line-3 Project in its alignment and structure.
- Preliminary design of the East and West Approach Roads (new construction) of the 4th Panama Canal Bridge
- Preliminary design of the Connection Road on the east side (new construction)
- Preliminary design of the Access Roads to the Bridge of the Americas on the west side (reconstruction)

11.4.2 Design Conditions

(1) Crossing Conditions

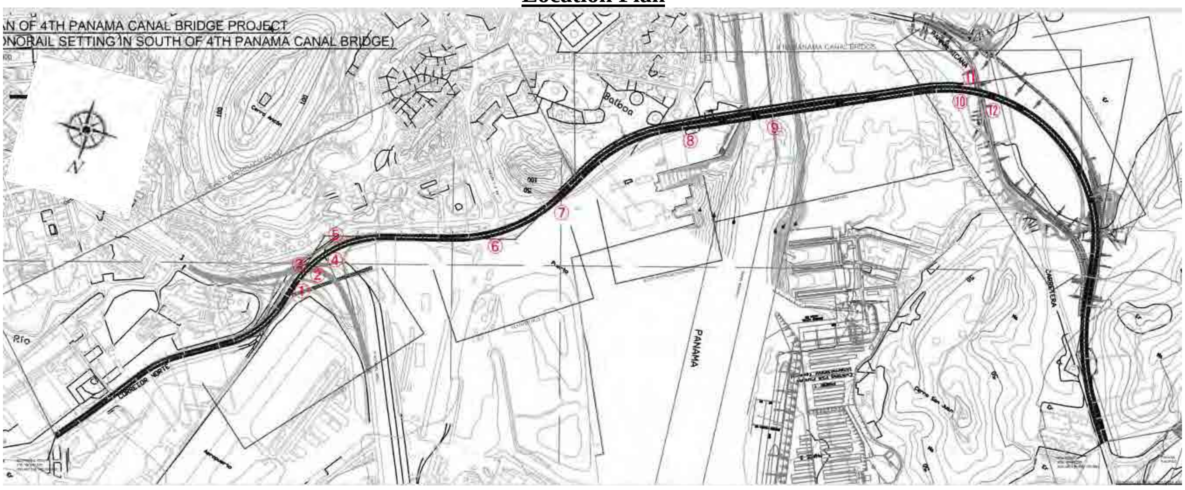
According to the alignment design discussed in 11.4.3(1), the crossing conditions related to the bridge planning were identified.

Table 11.13 shows the crossing conditions and Figure 11.14 shows clearance requirements.

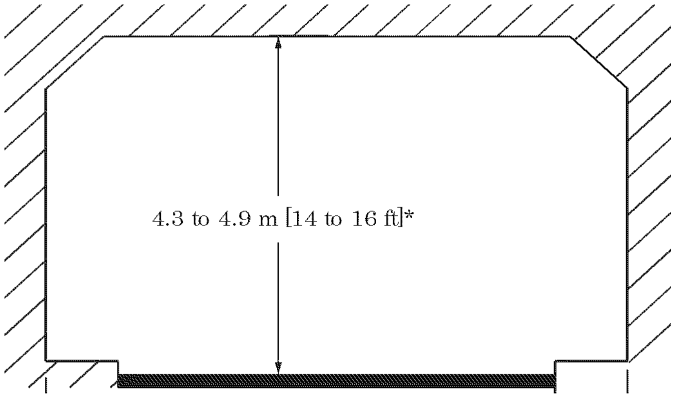
Table 11.13 Crossing Conditions

No.	Location (Chainage)	Cross. Facility	Vertical Clearance	Remarks
1-5	KM0+960-KM1+560	Road (Ramp)	4.90m	Omar Torrijos Intersection
6	KM2+360	Road (Junction)	4.90m	Balboa Port
7	KM2+600	Road	4.90m	
8	KM3+390	Road	4.90m	
9	KM3+800	Panama Canal	75.0m	Navigation Requirement
10	KM4+740	Road	4.90m	
11	KM4+775	Road	4.90m	
12	KM4+790	Road	4.90m	Pan American Highway

Location Plan



Source: JICA Study Team



Source: JICA Study Team

Figure 11.14 Clearance of Cross Road

(2) Geometric Design Standard

The geometric standard for the preliminary design is based on the observations made in Section 11.3 “Collection and Review of Existing Materials”. The target road is ranked as an Urban Arterial Road because it is expected to carry inner-city traffic as well as traffic between urban and rural areas.

The geometric design standard for the preliminary design is shown in Table 11.14.

Table 11.14 Geometric Design Standard (Preliminary Design)

Item	Standard Value		
Beginning/End Point(km)	Beginning Point: (-KM0+020.975) Albrook Station of MetroLine-3, connecting to Corredor Norte End point: (KM6+699.237) Before the Intersection of Howard area, connecting to Panamerican Highway		
Applied Standard	AASHTO, A Policy on the Geometric Design of Highway and Street, 6th Edition 2011		
Road Class	Urban Arterial Road (full access control, toll free operation)		
Design Speed	80km/hr (Section from the beginning point to the connection point with the ramp located on the west side of the roundabout) 100km/hr (Section after the connection point with the ramp located on the west side of the roundabout)		
Stopping Distance	185m (V=100km/hr), 130m (V=80km/hr)		
Number of Lanes	6 lanes (except for the following section) 4 lanes (section from beginning point to the connecting ramp on the west side of the roundabout) Typical Cross Sections are shown in Chapter 11.4.3.		
Geometric Design Standard	Design Speed	100km/hr	80km/hr
	Horizontal Alignment		
	Minimum Curve Radius	R=394m (e=8%)	R=229m (e=8%)
	Minimum Curve Radius with Clothoid	R=592m	R=379m
	Curve Radius without Superelevation	R=3,630m	R=2,440m
	Minimum Clothoid Length	L=56m	L=50m
	Maximum Superelevation	e=8%	e=8%
	Minimum Superelevation	e=2.5%	e=2.5%
	Cross fall	e=2.5%	e=2.5%
	Vertical Alignment		
	Maximum Gradient	i=5%	i=6%
	Minimum Gradient	i=0.3%	i=0.3%
	Minimum Vertical Curve(Convex)	VCR (Convex)=5,200m	VCR (Convex)=2,600m
	Minimum Vertical Curve(Concave)	VCR (Concave)=4,500m	VCR (Concave)=3,000m

Source: JICA Study Team

(3) Pavement Design Standard

The Guide for Design of Pavement Structures 1993 (AASHTO) was applied for the pavement design.

(4) Guard Rail Installation Standard

The Roadside Design Guide 3rd Edition 2006 (AASHTO) was applied for the design of barriers and medians.

11.4.3 Preliminary Design

(1) Alignment Design

1) Approach Road to the 4th Panama Canal Bridge

a) Horizontal Alignment

The horizontal alignment of the approach road is revised based on the results of reviewing the Pre-F/S. It should be noted that the station at the beginning point starts with a minus number due to the fixed station/coordination (KM3+800) at the center of the main bridge.

At the beginning point, the concept design is applied and the alignment is shifted to the south side of the existing road so that the two roads do not interfere with each other (see Section 11.5.1(4)1)).

Along Roosevelt Ave., the alignment is shifted to the north (Balboa Port side) in order to avoid the ACP facilities, make space for the monorail, and minimize the impact on Sosa Hill.

In the section of the 4th Panama Canal Bridge, a straight line was applied for the main span section considering its structural merit.

From the 4th Panama Canal Bridge to the end point, the alignment follows along the Pre-F/S alignment.

The superelevation and superelevation run-off of the curve sections were revised corresponding to the proposed design speed.

The elements of the horizontal alignment of the Approach Road (preliminary design) are shown in Table 11.15.

Table 11.15 Elements of the Horizontal Alignment of the Approach Road (Preliminary Design)

No.		Station	Coordinate		Beginning	Clothoid	Ending	Length
		(KM)	X (Y)	Y (X)	Radius (m)	Parameter (m)	Radius (m)	(m)
1	BC1-0	-0+020.975	992,400.693011	659,462.318005	-960.156		-960.156	24.367
2	EBC1-1	0+003.392	992,378.561011	659,452.126005	-5,000.000		-5,000.000	280.116
3	EC1-0	0+283.507	992,119.604793	659,345.420713	0.000		0.000	159.596
4	KA2-1	0+443.103	991,970.400482	659,288.774254	0.000	183.030	500.000	67.000
5	KE2-1	0+510.103	991,908.321932	659,263.605670	500.000		500.000	112.553
6	KEE2-1	0+622.656	991,812.126650	659,205.629037	500.000	193.101	5,000.000	67.118
7	KAE2-1	0+689.774	991,760.887873	659,162.301247	5,000.000		5,000.000	177.279
8	EC2-0	0+867.053	991,630.761073	659,041.920758	0.000		0.000	0.000
9	KA3-1	0+867.053	991,630.760899	659,041.920591	0.000	172.983	-435.000	68.789
10	KE3-1	0+935.842	991,579.878697	658,995.657555	-435.000		-435.000	270.906
11	KE3-2	1+206.748	991,331.734525	658,898.329179	-435.000	172.983	0.000	68.789
12	KA4-1	1+275.537	991,262.968085	658,897.663015	0.000	212.501	540.000	83.623
13	KE4-1	1+359.160	991,179.370386	658,896.898827	540.000		540.000	399.117
14	KE4-2	1+758.277	990,824.838986	658,734.168187	540.000	340.000	0.000	214.074
15	KA5-1	1+972.351	990,697.430323	658,562.602074	0.000	527.861	-1,100.000	253.307
16	KE5-1	2+225.658	990,552.179014	658,355.259721	-1,100.000		-1,100.000	646.362
17	KE5-2	2+872.020	990,022.481039	658,001.253609	-1,100.000	249.009	0.000	56.368
18	KA6-1	2+928.388	989,968.282476	657,985.770514	0.000	220.000	630.000	76.825
19	KE6-1	3+005.214	989,894.678160	657,963.802445	630.000		630.000	293.069
20	KE6-2	3+298.283	989,649.115259	657,808.719611	630.000	220.000	0.000	76.825
21	KA6-2	3+375.109	989,597.647590	657,751.699698	0.000		0.000	1,091.182
22	KA7-1	4+466.290	988,883.123222	656,926.998466	0.000	277.489	700.000	110.000
23	KE7-1	4+576.290	988,813.314094	656,842.027337	700.000		700.000	1,224.901
24	KE7-2	5+801.191	989,068.265953	655,798.214949	700.000	277.489	0.000	110.000
25	KA7-2	5+911.191	989,169.386219	655,754.993436	0.000		0.000	0.000
26	KA8-1	5+911.191	989,169.386219	655,754.993436	0.000	400.999	-1,200.000	134.000
27	KE8-1	6+045.192	989,292.981275	655,703.269829	-1,200.000		-1,200.000	462.445
28	KE8-2	6+507.637	989,665.353268	655,433.898538	-1,200.000	400.999	0.000	134.000
29	KA8-2	6+641.637	989,753.156916	655,332.697804	0.000		0.000	57.600
30	EP	6+699.237	989,790.088376	655,288.495685				0.000

Source: JICA Study Team

b) Vertical Alignment

The vertical alignment of the Approach Road is improved basically to accommodate the horizontal alignment based on the results of the review and the concept design (see Section 11.4.5) of the Pre-F/S.

At the beginning point, the horizontal alignment is followed, which is based on the result of the concept design (for Omar Torrijos Roundabout) (see Section 11.5.1(4)1)); therefore, the intersection point was shifted to the west (KM1+950) in consideration of the ramp crossing and also to minimize interference with the airspace restrictions, which are located near the beginning point.

The vertical alignment at the 4th Panama Canal Bridge section was matched, 4% to -4% (Intersection Point: km3+800), and the vertical curve radius is the same as that in the Pre-F/S.

The vertical alignment in the vicinity of the end point was revised so that the vertical curve radius satisfied the design speed of 100km/hr.

The vertical alignment elements of the Approach Road (preliminary design) are shown in Table 11.16.

Table 11.16 Vertical Alignment Elements of Approach Road (Preliminary Design)

No.	IP	Station	Length	Crest/	EL	Grade	V. Curve	
		(KM)	(m)	Sag	(m)	(%)	Length (m)	Radius (m)
1	VIP1	-0K020.975	131.568	-----	9.050	-0.440		
2	VIP2	0K110.593	129.407	Crest	8.471	-1.500	100.000	9,433.962
3	VIP3	0K240.000	480.000	Sag	6.530	0.300	150.000	8,333.333
4	VIP4	0K720.000	615.000	Sag	7.970	2.000	300.000	17,647.059
5	VIP5	1K335.000	460.000	Crest	20.270	-3.200	350.000	6,730.769
6	VIP6	1K795.000	2,005.000	Sag	5.550	4.000	420.000	5,833.333
7	VIP7	3K800.000	1,680.000	Crest	85.750	-4.000	760.000	9,500.000
8	VIP8	5K480.000	820.000	Sag	18.550	-1.000	290.000	9,666.667
9	VIP9	6K300.000	290.000	Sag	10.350	4.600	290.000	5,178.571
10	VIP10	6K590.000	109.237	Crest	23.690	-0.300	290.000	5,918.367
11	VIP11	6K699.237	114.237	--	23.362	-	-	-

Source: JICA Study Team

2) East Side Connection Road

The East Side Connection Road is a ramp (on/off) which connects to the Approach Road at the beginning point, and is the same as in the Pre-F/S.

The elements of the Horizontal/Vertical Alignment of the East Connection Road are shown in Table 11.17 to Table 11.20.

Table 11.17 Elements of the Horizontal Alignment of the East Side Connection Road (On ramp)

No.		Station （KM）	Coordinate		Radius（m）	Beginning Parameter （m）	Clothoid Radius（m）	Ending （m）
			X （Y）	Y （X）				
1	BP	0+000.000	659,006.860	991,572.870				43.790
2	BC 1-0	0+43.790	659,036.618	991,604.995	5000.000		5000.000	68.104
3	KA 2-1	0+111.894	659,083.237	991,664.641	5000.000	333.167	-1000.000	111.000
4	KE 2-1	0+222.894	659,158.260	991,736.429	-1000.000		-1000.000	109.205
5	KAE 2-1	0+332.009	659,224.376	991,823.277	-1000.000	232.108	-508.850	52.000
6	KEE 2-1	0+384.009	659,252.066	991,867.276	-508.850		-508.850	16.103
7	EP	0+400.202	659,259.830	991,881.383				

Source: JICA Study Team

Table 11.18 Elements of the Vertical Alignment of the East Side Connection Road (On ramp)

No.	IP	Station （KM）	Length （m）	Crest /Sag	EL （m）	Grade （%）	V. Curve	
							Length（m）	Radius（m）
1	VIP1	0+000.000	100.000	-----	5.740	0.560		
2	VIP2	0+100.000	300.202	Crest	7.630	-0.330	100.000	11260.120
3	VIP3	0+400.202	-	--	7.430		-	-

Source: JICA Study Team

Table 11.19 Elements of the Horizontal Alignment of the East Side Connection Road (Off ramp)

No.		Station (KM)	Coordinate		Radius (m)	Beginning Parameter (m)	Clothoid Radius (m)	Ending (m)
			X (Y)	Y (X)				
1	BC 1-0	0+000.000	659,258.753	991,919.550	532.342		532.342	13.464
2	KAE 1-1	0+13.464	659,253.108	991,907.327	532.342	233.913	435.000	23.000
3	KEE 1-1	0+36.464	659,242.722	991,886.808	435.000		435.000	97.532
4	KE 1-1	0+133.996	659,187.327	991,806.782	435.000	156.077	-2500.000	56.000
5	KA 2-1	0+189.996	659,148.735	991,766.218	-2500.000		-2500.000	92.296
6	EC 2-0	0+282.292	659,084.920	991,699.544				70.336
7	KA 3-1	0+352.628	659,037.233	991,647.843		151.526	-410.000	56.000
8	KE 3-1	0+408.628	659,000.220	991,605.835	-410.000		-410.000	155.711
9	KAE 3-1	0+564.339	658,927.808	991,469.041	-410.000	163.050	-220.000	56.000
10	KEE 3-1	0+620.339	658,916.207	991,414.348	-220.000		-220.000	4.652
11	EP	0+624.991	658,915.785	991,409.715				

Source: JICA Study Team

Table 11.20 Elements of the Vertical Alignment of the East Side Connection Road (Off ramp)

No.	IP	Station (KM)	Length (m)	Crest /Sag	EL (m)	Grade (%)	V. Curve	
							Length (m)	Radius (m)
1	VIP1	0+000.000	100.000	-----	7.310	0.320		
2	VIP2	0+100.000	524.991	Crest	7.630	-0.295	50.000	8126.910
3	VIP3	0+624.991	-	--	6.080		-	-

Source: JICA Study Team

3) Access Roads to the Bridge of the Americas

The Access Roads to the Bridge of Americas are roads connecting the Bridge of Americas and the Howard intersection, which is located at the end point. A road bound for Panama City starts from the Howard Intersection, and shifts to the west side. It then passes over the swamp area, and reaches the Bridge of Americas. A road bound for Arraijan starts at the Bridge of Americas utilizing the existing road and connects to the West Approach Road.

a) Horizontal Alignment

The horizontal alignment of the Access Roads to the Bridge of the Americas follows the Pre-F/S. The alignment elements for the east-bound and west-bound Access Roads (preliminary design) are shown in Tables 11.21 and 11.22, respectively.

Table 11.21 Horizontal Alignment of Access Bridge to the Bridge of Americas (East-bound for Panama City)

No.		Station (KM)	Coordinate		Beginning Radius (m)	Clothoid Parameter (m)	Ending Radius (m)	Length (m)
			X (Y)	Y (X)				
1	BC 1-0	0+000.000	655,769.178000	989,110.867000	-1304.451		-1304.451	111.800
2	KA 2-1	0+111.800	655,817.140000	989,009.915000		477.030	-800.000	110.000
3	KE 2-1	0+221.800	655,873.421000	988,915.469000	-800.000		-800.000	637.831
4	KE 2-2	0+859.631	656,394.666000	988,577.782000	-800.000	296.648		110.000
5	KA 2-2	0+969.631	656,503.709000	988,563.483000				199.727
6	KA 3-1	1+169.388	656,702.314000	988,542.058000		216.564	-700.000	67.000
7	KE 3-1	1+236.388	656,769.026000	988,535.935000	-700.000		-700.000	273.918
8	KE 3-2	1+510.305	657,038.685000	988,572.850000	-700.000	216.564		67.000
9	KA 3-2	1+577.305	657,101.298000	988,596.676000				5.094
10	EP	1+582.399	657,106.029000	988,598.563000				

Source: JICA Study Team

Table 11.22 Horizontal Alignment of Access Road to the Bridge of Americas (West-bound for Arraijan)

No.		Station (KM)	Coordinate		Beginning Radius (m)	Clothoid Parameter (m)	Ending Radius (m)	Length (m)
			X (Y)	Y (X)				
1	BC 1-0	0+000.000	657,053.260	988,580.280	428.299		428.299	108.364
2	KAE 1-1	0+108.364	656,945.989	988,567.123	428.299	236.796	340.000	34.000
3	KEE 1-1	0+142.364	656,912.039	988,568.740	340.000		340.000	191.994
4	KE 1-1	0+334.358	656,735.855	988,638.396	340.000	157.544		73.000
5	KA 1-1	0+407.358	656,681.506	988,687.075				291.759
6	KA 2-1	0+699.117	656,681.506	988,889.381		156.381	-335.000	73.000
7	KE 2-1	0+772.117	656,416.904	988,938.030	-335.000		-335.000	146.933
8	KE 2-2	0+919.05	656,284.901	988,999.843	-335.000	156.381		73.000
9	KA 2-2	0+992.05	656,212.716	989,010.457				166.807
10	EP	1+158.857	656,046.910	989,028.716		156.381		73.000

Source: JICA Study Team

b) Vertical Alignment

The vertical alignment of the Access roads to the Bridge of Americas was not included in the Concept Design of the Pre-F/S. Thus, the vertical alignment for the east-bound road for Panama City was studied based on a topographic map. The vertical alignment for the east-bound road is shown in Table 11.23.

Table 11.23 Vertical Alignment of the Access Road to the Bridge of the Americas (East-bound for Panama City)

No.	IP	Station (KM)	Length (m)	Crest /Sag	EL (m)	Grade (%)	V. Curve	
							Length (m)	Radius (m)
1	VIP1	0K+165.000	100.000	-----	16.500	1.000		
2	VIP2	0K+265.000	735.000	Crest	17.500	0.300	50.000	7143
3	VIP3	1K+000.000	400.000	Sag	19.705	2.574	100.000	4398
4	VIP4	1K+000.000	1.82.399	Crest	30.000	0.000	100.000	3885

Source: JICA Study Team

(2) Typical Cross Sections

The cross section elements of the Approach Roads are set based on the collection and review of the existing materials. Road width reduction is not applied even on the main bridge section. The cross section elements of the Approach Roads (Preliminary Design) are shown in Table 11.24.

Table 11.24 Cross Section Elements of Approach Roads (Preliminary Design)

Item	Standard Value	
Cross Section Elements	Cross Section Width	
	Lane	W=3.65m
	Median Strip	W=1.2m
	Outer Shoulder	W=1.2m (Bridge, Retaining Wall)
	Inner Shoulder	3.0m (Earth work)
	Sidewalk	W=2.5m (including Drainage Facilities)
	Monorail (including inspection walkway)	W=9.0m
	Road Clearance Limit	h=5.5m
	Panama Canal Navigation limit	h=75m (above MLWS)

Source: JICA Study Team

(3) Earth work Design

The earth work section and earth work structure of the Approach Roads are shown in Table 11.25. The gradient of the slope was decided as follows: Embankment 1:2.0, Cutting Earth 1:1.0, Soft Rock 1:0.5. In the eastern area, reinforced earth will be used due to the limited space between the project road and existing roads.

Table 11.25 Earth work Section and Earth work Structure of the Approach Roads

Station	Length	Average Height		Road Structure
		Embankment	Cutting	
-KM0+020.975～KM0+650	670.975m	0m	0m	Replacement of Pavement
KM0+650～KM1+050	400m	4.0m	-	Retaining wall (Reinforced Earth)
KM1+570～KM2+000	430m	4.0m	-	Retaining wall (Reinforced Earth)
KM2+740～KM2+847	107m	15m	30m	North Side: Retaining wall (Reinforced Earth) South Side: Cutting (Slope: 1:1 Earth,1:0.5Soft Rock) Retaining wall (Reinforced Earth)
KM5+390～KM6+150	760m	4.0m	-	Cutting (slope: 1:1)
KM6+150～KM6+500	350m	2.0m	-	Embankment (slope: 1:2)
KM6+500～KM6+699.237	199.237m	0m	0m	Replacement of Pavement

Source: JICA Study Team

(4) Soft Ground Treatment

The Access Road to the Bridge of Americas bound for Panama City passes over the swamp area, but a detailed study of this area was not carried out because a soil survey was not available. The road bound for Panama City consists of mostly bridge sections, and does not affect the preliminary cost estimate.

(5) Pavement Design

Regarding the pavement designs at the earth work section, similar to the Corredor Norte and Panamerican Highway, it was decided that the carriageways would have concrete pavement (JCP/Jointed Concrete Pavement) and the shoulders asphalt pavement. As the results of the traffic assignments indicated in chapter 3.4.4, the ESAL (18kip Equivalent Single Axle Load) is 7.64 million times in 20 years (2021 to 2040), which is less than the 10.96 million times in the Pre-F/S. Therefore, a concrete pavement of t=220mm and a base course of t=250mm (CBR is more than 80%) shall be applied.

The Pavement structure of the Approach Roads is shown in Table 11.26.

Table 11.26 Pavement Structure of the Approach Roads

Station	Length	Number of Lanes	Pavement Width	Pavement Structure	
KM0+020.975～KM1+050	1,070.975m	4	19.4m	Carriageway	Concrete Pavement (t=220) Base Course (t=250)
KM1+570～KM2+000	430m	4	19.4m		
KM2+740～KM2+847	107m	6	30.3m	Shoulder	Asphalt Pavement (t=220) Base Course (t=250)
KM5+390～KM6+699.237	1,309.237m	6	30.3m		

Source: JICA Study Team

(6) Road Facilities Design

1) Drainage Facility

A drainage ditch was planned for the earth work section of the Approach Road, the East Side Connection Road and the Access Roads to the Bridge of the Americas. The ditch (0.5mx0.5m) is installed at the toe of the embankment slope for drainage of surface water.

2) Traffic Safety and Control Facility

a) Barrier

In the Approach Roads, a concrete barrier (New Jersey Type, Testing Level 3, approved by FHWA) was planned for the median strip, and a guardrail was planned for the shoulder. A guardrail was planned for the embankment section of the East Side Connection Road and the Access roads to the Bridge of the Americas.

b) Road Marking

Road markings on the installation road were planned for the traffic lane lines and the lane edge for the whole section. Zebra markings were planned for the ramp terminals of the interchanges. Lane markings (division line and outside line) were planned for the whole section of the East side Connection Road and the Access Roads to the Bridge of the Americas.

c) Traffic Sign

On the Approach Roads, a speed limit sign was planned for indicating the design speed. Guide signs were planned for at the entrance and exit of the interchanges.

(7) Drawings of Preliminary Design

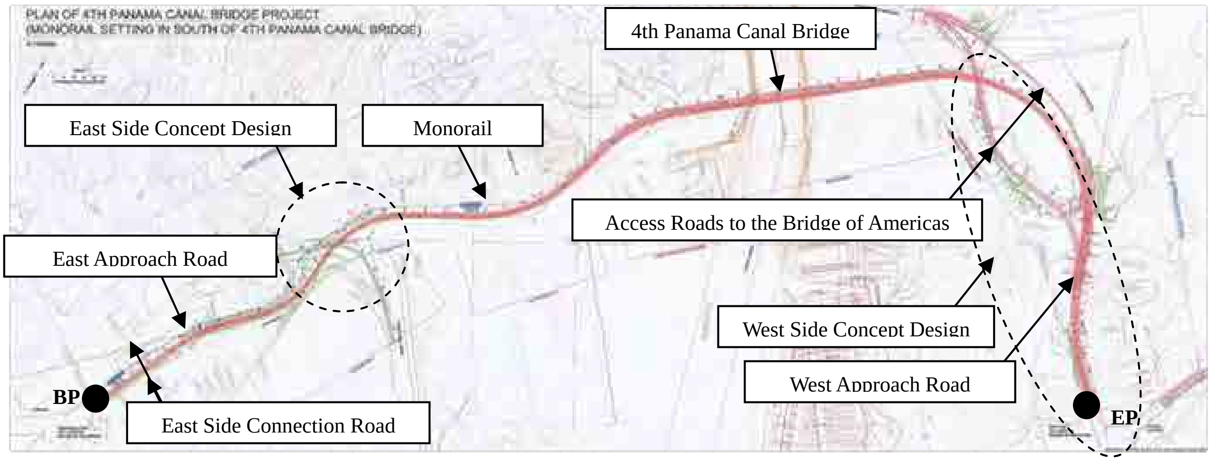
A list of the drawings of the preliminary design (Road Design) is shown in Table 11.27.

Table 11.27 List of Drawings of Preliminary Design (Road Design)

Drawing	Scale	Indicated Road	Drawing Size
Plan	S=1/15,000 S=1/4,000	Approach Road (Include Bridge Section) East Side Connection Road West Side Access Roads to the Bridge of the Americas (Include Bridge Section)	A3
Alignment plan	S=1/4,000	Approach Road (Include Bridge Section)	A3
Profile	H=1/4,000 V=1/400	Approach Road (Include Bridge Section)	A3
Typical Cross Sections	S=1/200	Approach Road	A3

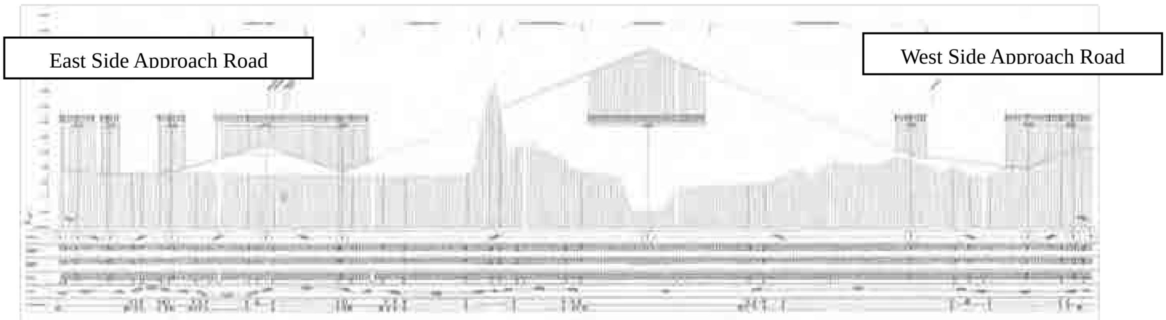
Source: JICA Study Team

The plan drawing indicates the Approach Roads, East Side Connection Roads, and the West Side Access Roads to the Bridge of the Americas, which will be constructed in this project. Furthermore, the concept designs of the connection roads to the Omar Torrijos Roundabout on the east side, and the additional ramps on the west side, are indicated in another plan drawing. The profile for the Approach Road was prepared, and the typical cross section was prepared for the Earth work section (2 way, 6 lanes) on the east side, and for the retaining wall section (2 way, 4 lanes) on the west side. The plan, profile and typical cross sections are shown in Figures 11.15 to 11.18, respectively.



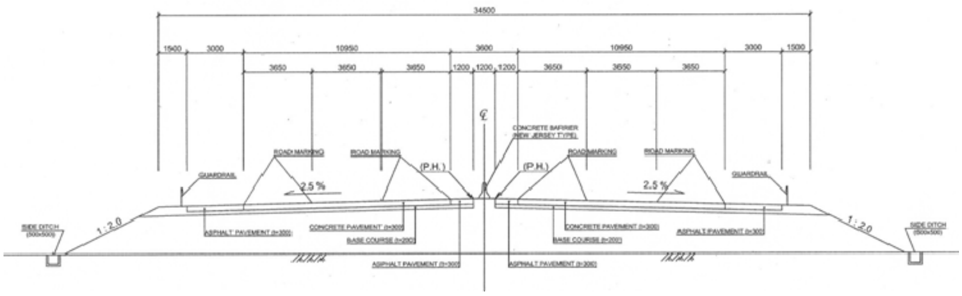
Source: JICA Study Team

Figure 11.15 Project Road Plan (Preliminary Design)



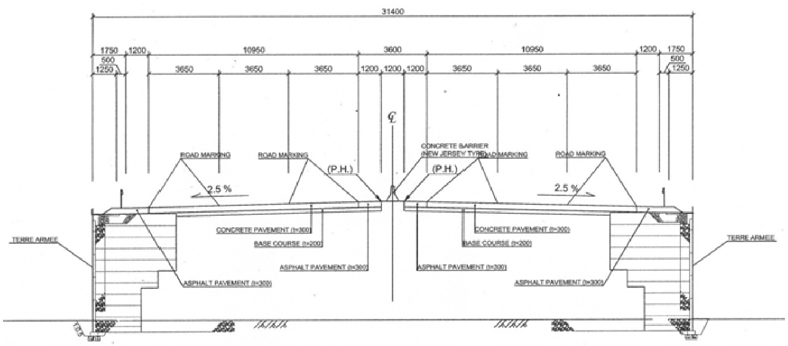
Source: JICA Study Team

Figure 11.16 Project Road Profile (Preliminary Design)



Source: JICA Study Team

Figure 11.17 Typical Cross Section, Earth work (6 lanes) (Preliminary Design)



Source: JICA Study Team

Figure 11.18 Typical Cross Section, Retaining Wall (4 lanes) (Preliminary Design)

(8) Construction Quantities

The main construction quantities for the road works are calculated based on the results of the preliminary design, as shown in Table 11.28.

Table 11.28 Main Construction Quantities for Road Works (Preliminary Design)

Road		Construction Work	Item	Unit	Quantities
Approach Roads	East Side -KM0+020.975～KM1+050 KM1+570～KM2+000 KM2+740～KM2+847 L=1,607.975m	Earth work	Clearing and Grubbing Demolition of Pavement Embankment Cutting (Earth) Cutting (Soft Rock) Slope Protection	m2 m2 m3 m3 m3 m3	20,255.0 21,940.0 166,862.5 10,328.0 41,312.1 5,597.7
		Drainage Work	Side Ditch (0.5x0.5) Catch Basin (1.0x1.0) Drainage Pipe (D=0.6)	m nos. m	3,214.0 34.0 241.1
		Pavement Work	Asphalt Pavement (t=300) Concrete Pavement (t=300) Base Course (t=200) Sidewalk	m2 m2 m2 m2	5,464.0 29,247.0 34,711.0 700.0
		Structure Work	Retaining Wall (Reinforced Earth) Demolition of Existing Flyover Demolition of Existing Retaining Wall	m2 m3 m3	10,780.0 41,870.0 4,000
		Road Facilities	Guard Rail Concrete Barrier Road Marking Traffic Sign	m m m2 nos	3,428.0 1,607.0 2,213.0 12.0
	West Side KM5+390~KM6+699.237 L=1,309.237m	Earth work	Clearing and Grubbing Demolition of Pavement Embankment	m2 m2 m2	50,476.0 4,708.0 274,890.0
		Drainage Work	Side Ditch (0.5x0.5) Catch Basin (1.0x1.0) Drainage Pipe (D=0.6)	m nos. m	2,618.0 27.0 60.0
		Pavement Work	Asphalt Pavement (t=300) Concrete Pavement (t=300) Base Course (t=200) Sidewalk	m2 m2 m2 m2	4,450.6 23,823.8 28,274.4 2,995.0
		Road Facilities	Guard Rail Concrete Barrier Road Marking Traffic Sign Fence	m m m2 nos. m	2,618.0 1,309.0 1,047.2 4.0 1,198.0
East Side Connection Road	On Ramp KM0+000~KM0+400.200 L=400.2m Off Ramp KM0+000~KM0+624.990 L=624.99m	Earth work	Clearing and Grubbing Demolition of Pavement Embankment	m2 m2 m3	9,079 2,312 37,100
		Drainage Work	Concrete Curb Catch Basin (1.0x1.0) Longitudinal Drainage Ditch (D=0.15)	m nos. m	1,000 50 175
		Pavement Work	Asphalt Pavement (t=300) Concrete Pavement (t=300) Base Course (t=200)	m2 m2 	2,400 7,200 9,600
		Structure Work	Retaining Wall (Reinforced Earth)	m2	3,500
		Road Facilities	Guard Rail Road Marking Traffic Sign	m m2 nos.	2,000 375 3
West Side Access Roads to the Bridge of the Americas	East-bound for Panama City KM0+000~KM1+582.40 L=1,582.4m West-bound for Arraijan KM0+000~KM1+588.00 L=1,588m	Earth work	Clearing and Grubbing Demolition of Pavement Embankment	m2 m2 m3	30,976.0 12,756.0 228,900.0
		Drainage Work	Concrete Curb Catch Basin (1.0x1.0) Drainage Pipe (D=0.6)	m nos. m	3,160.0 118.0 426.0
		Pavement Work	Asphalt Pavement (t=300) Concrete Pavement (t=300) Base Course (t=200)	m2 m2 m2	5,664.0 16,992.0 22,656.0
		Road Facilities	Guard Rail Road Marking Traffic Sign	m m2 nos.	4,720.0 885.0 9.0

Source: JICA Study Team

11.5 Concept Design

11.5.1 Study of the Concept Design

(1) Objective

A concept design study was executed in order to decide on the alignment of the Approach Roads and to improve the vehicular connectivity of the existing roads. The target road links are the existing roads on the east/west side of the 4th Panama Canal Bridge and the Approach Roads on each side.

Especially in eastern area, heavy traffic congestion as well as continued increase in traffic is expected. Therefore, to estimate and evaluate the traffic volume, a micro-simulation of the roundabout was carried out.

For reference, the preliminary construction cost was estimated for this concept design.

(2) Summary of the study

The approach road and existing roads are connected by ramps, and the best formation of the roundabout was determined by considering the location of the existing roads, the terrain and objects in the vicinity. The basic idea for improvement was to provide additional road links to the roundabout without making major changes in the shape of the roundabout.

The existing flyover seems to be almost decrepit and will be removed to allow the elongation of the new ramps,

(3) Design Condition

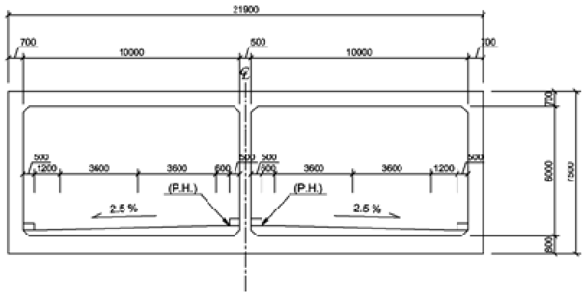
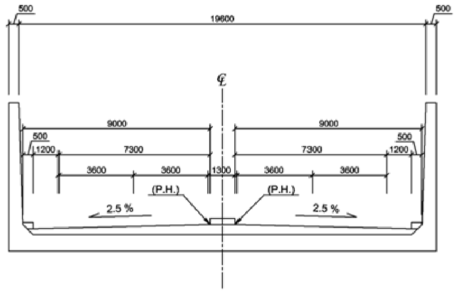
The design speed of the ramps was decided to be 40km/hr, and the number of lanes was decided based on the traffic volume.

The design condition of the ramps (concept design) is shown in Table 11.29, and the typical cross sections are shown in Figures 11.19 to 11.21.

Table 11.29 Design Condition of Ramps (Concept Design)

Item		East Side		West Side
Design Speed of Approach Road		80km/hr		100km/hr
Ramp	Design Speed	40km/hr		40km/hr
	Number of Lanes	1 way, 2 lanes		1 way, 1 lane
	Minimum Curve Radius	40m		40m
	Maximum Gradient	8%		8%
Underpass	Design Speed	60km/hr	40km (Ramp)	-----
	Number of Lane	2 way, 4 lanes	1 way, 1 lane	
	Minimum Curve Radius	150m	40m	
	Maximum Gradient	6%	8%	

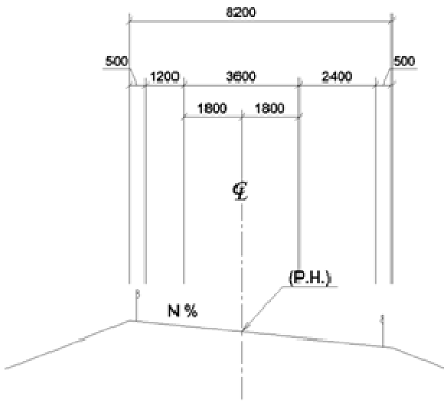
Source: JICA Study Team

Box Culvert Section Retaining Wall Section

Source: JICA Study Team

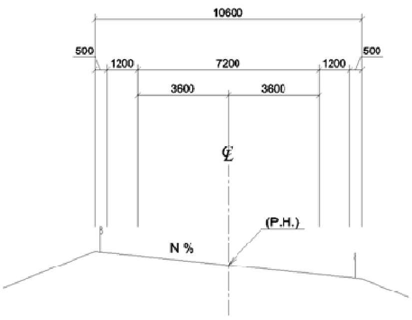
Figure 11.19 Typical Cross Sections of Underpass (Concept Design)



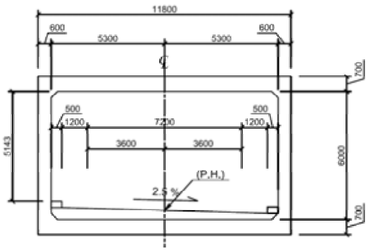
Earth work Section

Source: JICA Study Team

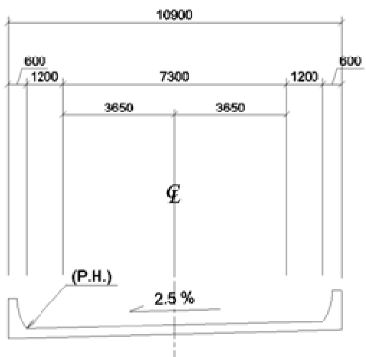
Figure 11.20 Typical Cross Section of 1 way, 1 lane Ramp (Concept Design)



Earth work Section



Box Culvert Section



Access Bridge on
the Access Road to
the Bridge of the Americas

Source: JICA Study Team

Figure 11.21 Typical Cross Section of 1 way, 2 lanes Ramp (Concept Design)

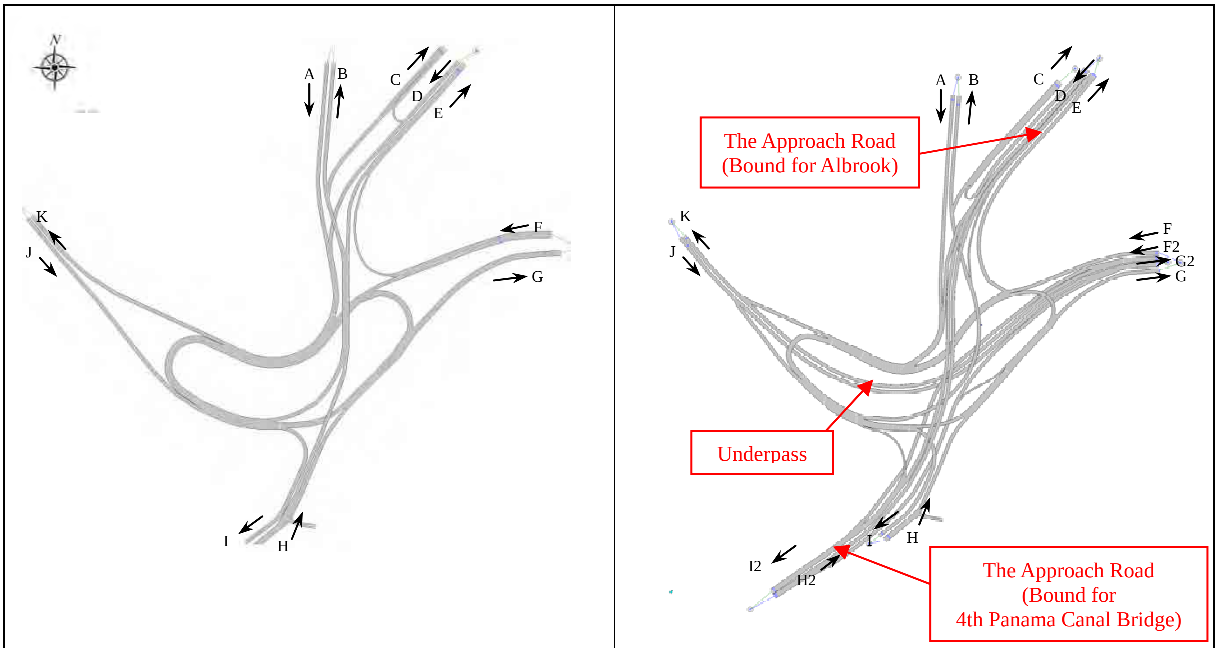
(4) Concept Design

1) East Side

The Approach Road passes over the Omar Torrijos roundabout by means of a flyover. A study was conducted on the connectivity between the Approach Road and the roundabout. The Omar Torrijos roundabout is located in an important area, being surrounded by the National Bus Terminal, Albrook Mall, Balboa Port, Albrook "Marcos A. Gelabert" Airport and ACP facilities; it also connects to the Bridge of Americas, as well as the roads along the Panama Canal.

As the discussion results with SMP, the existing shape of Omar Torrijos Intersection was not changed as can as possible in consideration of limited land use conditions at the site. North-south is the predominant direction of the traffic using the roundabout. Accordingly, this concept design provides an underpass for the north-south traffic so it will no longer enter the roundabout. As a result, it is expected that traffic in the Omar Torrijos roundabout will decrease, and traffic congestion will be eased. The underpass goes under the existing Curundu River box culvert (6m*5m*2) which is underground.

Figure 11.22 shows sketches of the existing road links, and the concept design road links with additional ramps and underpasses, connecting to the approach road or to neighboring roads.



The Existing Roundabout	The Roundabout with Concept Design

Source: JICA Study Team

Figure 11.22 Sketches of the Roundabout with/without Concept Design

Table 11.30 Travelling Speed of Object Road

Item	Approach road	Underpass	Existing road	Ramp	Roundabout
Running speed	80km/hr	60km/hr	50km/hr	40km/hr	30km/hr

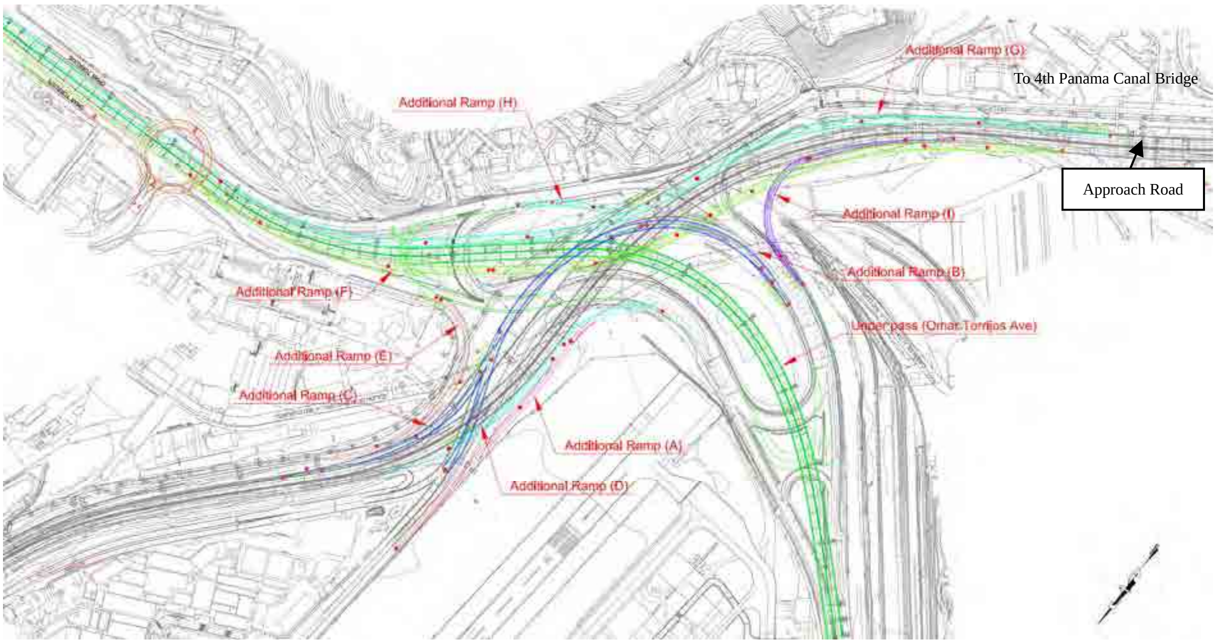
Source: JICA Study Team

As supplementary explanation, Table 11.31 presents a description of the roads of the concept design. The layout of the traffic flow of the Omar Torrijos roundabout is shown in Figure 11.23. The drawing list of the east side concept design is shown in Table 11.32.

Table 11.31 Description of the Roads of the East Side Concept Design

Name	Route Description
Underpass	For South-North traffic, a new underground bypass goes through the middle of the roundabout.
Additional ramp A	A road goes from the existing road near Albrook Airport and merges into the roundabout.
Additional ramp B	A road diverges from the roundabout and goes through the approach road. It heads for Albrook Airport.
Additional ramp C	A road diverges from ramp B, then heads for Albrook and merges onto the approach road.
Additional ramp D	A road diverges from the approach road and goes through the roundabout. It merges onto the ramp A.
Additional ramp E	A road comes from Panama city and merges onto the Approach road. It heads for Albrook.
Additional ramp F	A road diverges from the Underpass and goes through underground. After passing the roundabout, it goes up and merges with the approach road heading for the 4th Panama Canal Bridge.
Additional ramp G	A road diverges from the approach road between the 4th Panama Canal Bridge and the roundabout passing over the roundabout and goes underground. It then merges into the South-North underpass.
Additional ramp H	A road diverges from the ramp G and merges into the roundabout.
Additional ramp I	A road diverges from the roundabout and merges into the approach road bound for the 4th Panama Canal Bridge.

Source: JICA Study Team



Source: JICA Study Team

Figure 11.23 Layout of the Concept Design (East Side)

Table 11.32 Drawing List for the Concept Design (East Side)

Drawings		Scale
Plan		S=1/4,000
Alignment Plan		S=1/4,000
Profile	Approach Road	H=1/4,000 V=1/400
	Underpass	H=1/4,000 V=1/400
Typical Cross Section		S=1/200

Source: JICA Study Team

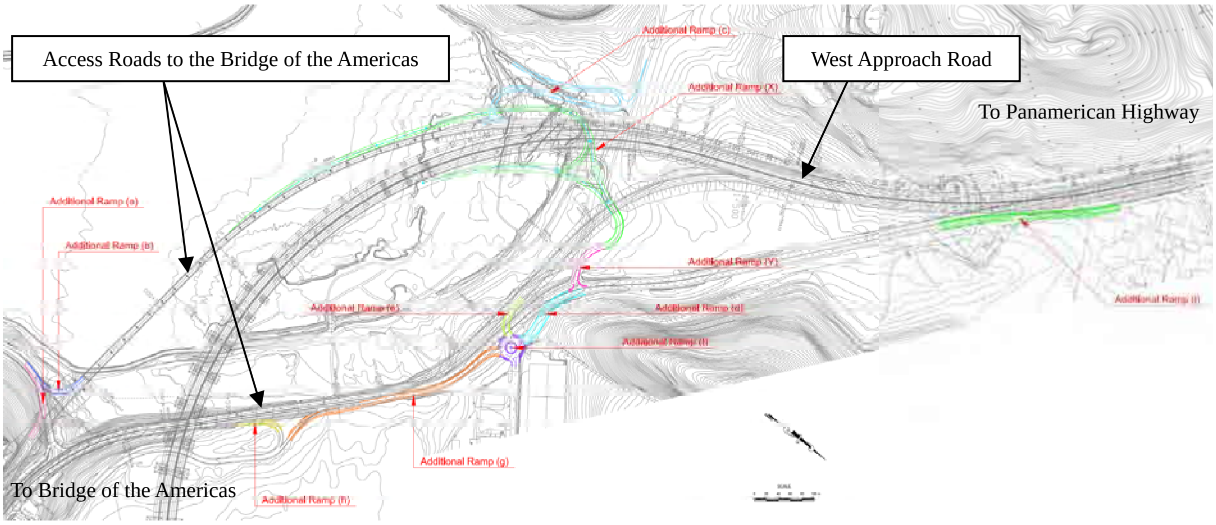
2) West Side

In the Pre-F/S, the traffic between the West Approach Road and the existing road creates difficulties even though the Panamerican Highway (Access Roads to the Bridge of the Americas) was planned to be a 2 way, 4 lane road in order to improve the connectivity to the vicinity.

Therefore, additional/extension ramps were planned for connecting the 4th Panama Canal Bridge, the West Approach Road, and the east-bound and west-bound Access Roads to the Bridge of the Americas through an intersection.

Additional Ramps (a) and (b) are located between the Access Bridge and the Bridge of the Americas, and connecting southern road. Additional Ramps (c) to (h) connect the Access Bridge/Road and the exist roads. Additional Ramps (X) and (Y) are off-ramps from the west approach road. Additional Ramp (i) is an alternative route of the existing road due to interference from the west approach road.

A layout of the west side concept design is shown in Figure 11.24, and the list of drawings of the west side concept design is shown in Table 11.33.



Source: JICA Study Team

Figure 11.24 Layout of the Concept Design (West Side)

Table 11.33 Drawing List for the Concept Design (West Side)

Drawing	Scale
Plan	S=1/4,000
Alignment Plan	S=1/4,000
Typical Cross Section	H=1/4,000,V=1/400

Source: JICA Study Team

(5) Main Construction Quantities

The main construction quantities for the road works in the concept design are shown in Table 11.34.

Table 11.34 Main Construction Quantities of the Roads in the Concept Design

Road		Construction Work	Item	Unit	Quantity
East Side	Improvement of Omar Torrijos Intersection	Earth work	Clearing and Grubbing	m2	26,376
			Demolition of Pavement	m2	8,961
			Embankment	m3	10,714
			Cutting (Earth)	m3	27,375
		Drainage Work	Concrete Curb	m	8,000
			Side Ditch (0.5x0.5)	m	5,550
			Catch Basin (1.0x1.0)	nos.	277
			Drainage Pipe (D=0.5)	m	2,820
			Drainage Pump (Underpass)	nos.	2
		Pavement Work	Asphalt Pavement (t=300)	m2	6,192
			Concrete Pavement (t=300)	m2	42,264
			Base Course (t=200)	m2	24,768
		Structure Work	Flyover (Ramp)	m2	11,250
			Widening of Flyover (Approach Road)	m2	1,920
			Box Culvert (10.6x6.0)	m	2,035
			Box Culvert (10.0x6.0x2)	m	1,000
			Retaining Wall (Reinforced Earth)	m2	5,600
			Retaining Wall (U Type: F Ramp)	m	140
			Retaining Wall (U Type: G Ramp)	m	140
			Retaining Wall (U Type: Omar Torrijos Ave.)	m	470
			Support of Existing Box Culvert (6mx5mx2,Pile Foundation)	nos.	1
		Road Facilities	Guard Rail	m	5,760
			Road Marking	m2	5,514
			Traffic Sign (Speed Limit)	nos.	12
			Traffic Sign (Guide)	nos.	18
West Side	Additional Ramps to the Existing Roads (Other than the Additional Ramp X)	Earth work	Clearing and Grubbing	m2	15,494
			Embankment	m3	26,918
			Cutting (Earth)	m3	3,198
			Slope Protection (Embankment)	m2	15,040
			Slope Protection (Cutting)	m2	585
		Drainage Work	Side Ditch (0.5x0.5)	m	1,790
			Catch Basin (1.0x1.0)	nos.	92
		Pavement Work	Asphalt Pavement (t=300)	m2	6,036
			Concrete Pavement (t=300)	m2	7,668
			Base Course (t=200)	m2	13,704
			Sidewalk	m2	1,700
		Road Facilities	Guard Rail	m	2,370
			Road Marking	m2	554
			Traffic Sign (Speed Limit)	nos.	16
			Traffic Sign (Guide)	nos.	16
	Additional Ramp X	Structure Work	Flyover (Ramp)	m2	9,266
			Widening of Flyover (Approach Road)	m2	1,640
		Road Facility	Road Marking	m2	519
			Traffic Sign (Speed Limit)	nos.	4
			Traffic Sign (Guide)	nos.	4

Source: JICA Study Team

11.5.2 Micro Simulation

(1) Objective

A micro simulation was conducted to detect the occurrence of traffic congestion in the improved Omar Torrijos intersection, which was proposed in 11.5.1.

(2) Method of Verification

The two cases below were simulated by utilizing the software "Aimsun 6". The design speed applied to each road in the network models is presented in Table 11.37.

Case	Applied Network Model	Applied Traffic Volume
Present Condition	Exiting Network *Figure 11.25	OD Traffic Volume in 2013 Spot Traffic Volume in 2013 (7:00am-8:00am) *Table 11.35
Improvement Plan	Future Network (Improvement) *Figure 11.25	OD Traffic Volume in 2050 (7:00am-8:00am) *Table 11.36

Table 11.35 OD Traffic Volume and Spot Traffic Volume in 2013 (7:00am-8:00am)

		Destination						Total
		K	I	G	E	B	C	
Origin	J	0	743	1,068	78	276	159	2,324
	H	589	0	339	56	247	207	1,438
	F	944	340	5	36	207	140	1,672
	D	505	314	419	0	55	86	1,379
	A	478	331	270	15	0	42	1,136
Total		2,516	1,728	2,101	185	785	634	7,949

	Total
A	1,299
B	812
C	638
D	1,511
E	150
F	1,849
G	2,135
H	1,690
I	1,736
J	2,703
K	2,537

Source: JICA Study Team

Table 11.36 OD Traffic Volume in 2050 (7:00am-8:00am)

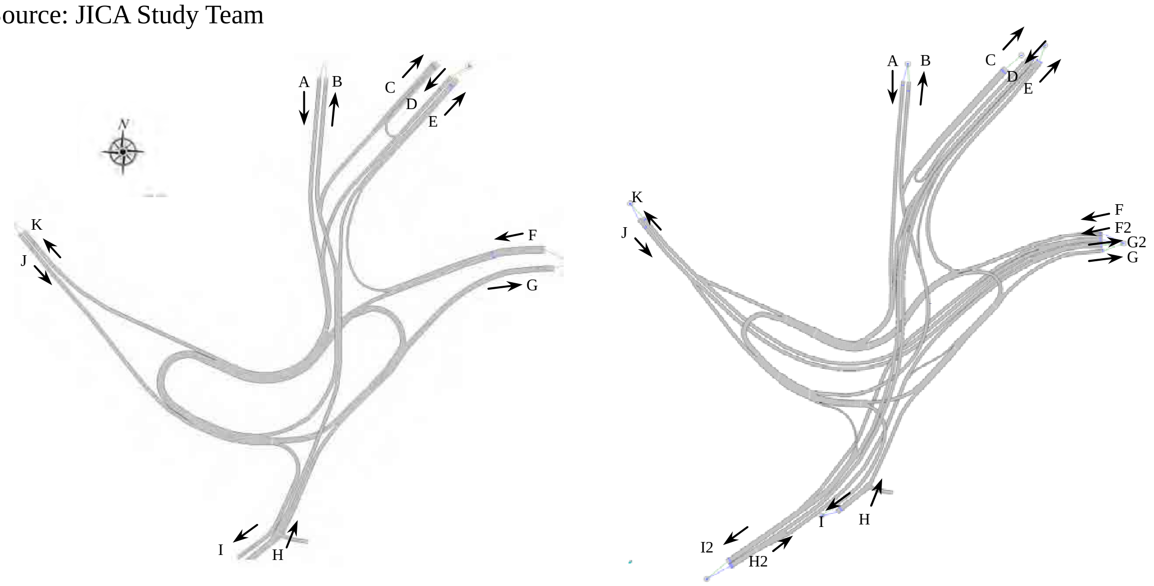
		Destination								Total
		K	I	G	E	B	C	G2	I2	
Origin	J	0	1,010	7	109	368	227	1,933	6	3,660
	H	784	0	803	284	333	55	0	0	2,259
	F	207	418	276	626	311	125	0	14	1,977
	D	674	411	305	0	82	112	0	298	1,882
	A	628	475	255	21	0	63	0	56	1,498
	F2	1,049	0	0	0	0	0	0	419	1,468
	H2	88	0	805	1,207	0	132	1,595	0	3,827
Total		3,430	2,314	2,451	2,247	1,094	714	3,528	793	16,571

Source: JICA Study Team

Table 11.37 Design Speed applied to the Network Models

	Approach Road	Underpass	Existing Road	Ramp	Roundabout
Existing Network Model Design Speed	-	-	50 km/hr	40 km/hr	30 km/hr
Future Network Model (Improved) Design Speed	80 km/hr	60 km/hr	50 km/hr	40 km/hr	30 km/hr

Source: JICA Study Team



Existing Network Mode   Future Network Model (Improved)

Source: JICA Study Team

Figure 11.25 Network Models applied to Micro Simulation (Existing and Future)

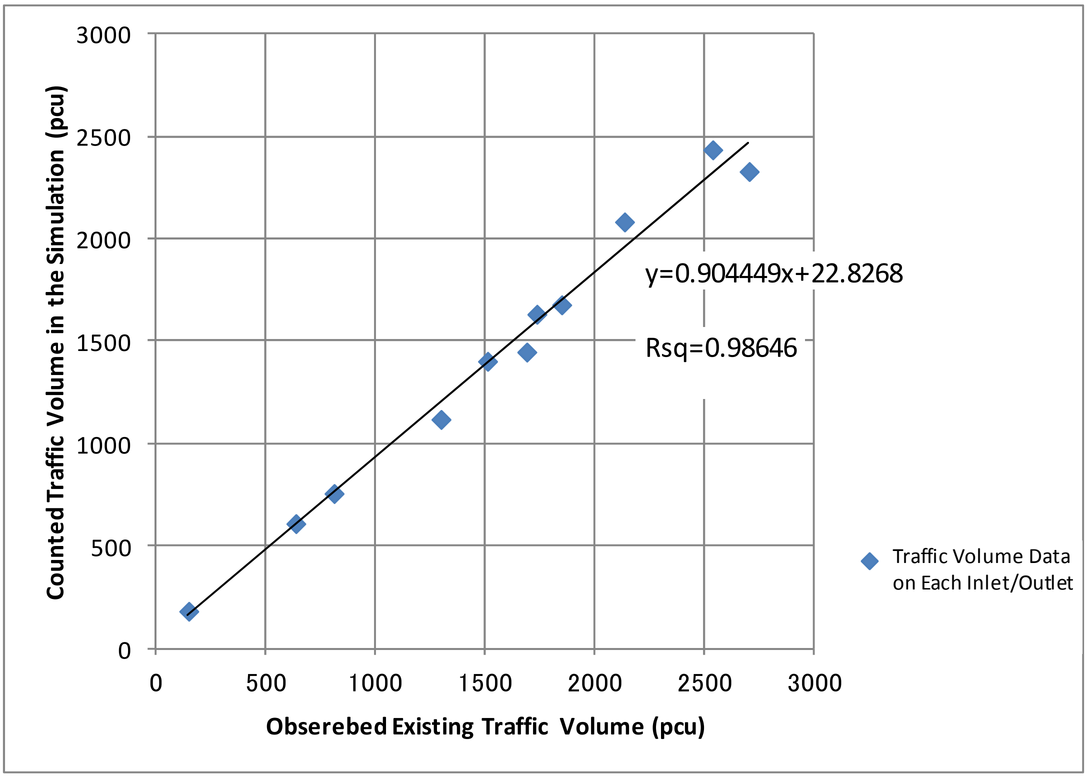
(3) Result

1) Verification of the Modeling of Present Conditions

Traffic flow is changed by various factors that include predictable as well as unpredictable situations. Some factors are difficult to faithfully reproduce in developing micro simulation models. Some of the vehicles that were observed at the inlet/outlet between 7:00 a.m. and 8:00 a.m. in the traffic volume survey did not reach the outlet in this simulation for some cause that was not reproduced in the modeling.

To check how accurate the existing network model was, the correlation between the observed traffic volume in the traffic volume survey (see Table 11.35) and the traffic volume in this simulation was verified.

Figure 11.26 shows the results of the correlation between the observed traffic volume at each inlet/outlet, and the traffic volume counted in the simulation. In general, if the correlation coefficient is more than 0.90 and error is not more than 2.5, the correlation is considered to be verified. In this case, the correlation coefficient (Rsq) was 0.98646 and the error (RMS) was 2, and thus the correlation was verified. The existing network model is well reproduced.



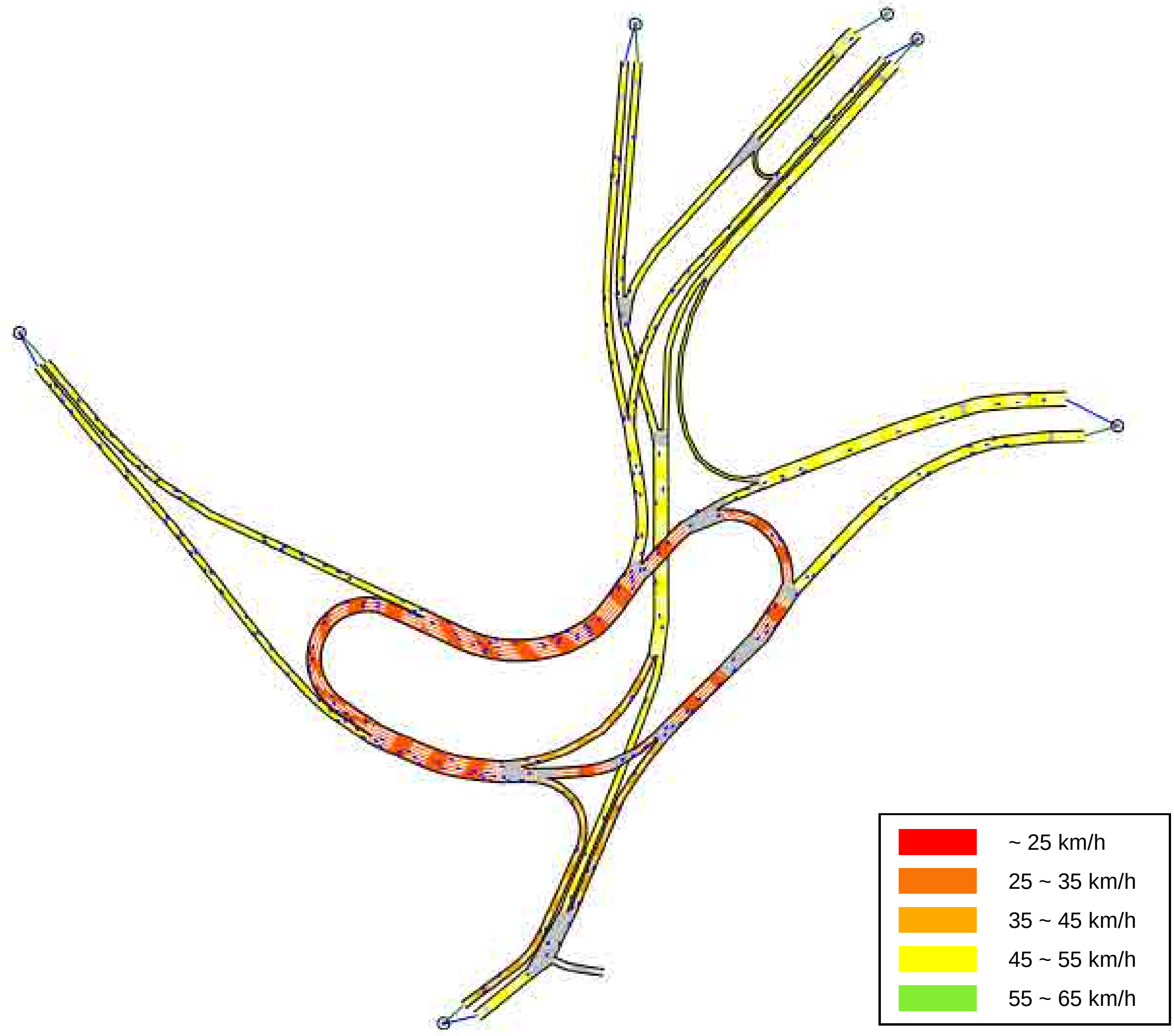
Source: JICA Study Team

Figure 11.26 Correlation between the Observed Traffic Volume and the Traffic Volume counted in the Simulation

2) Result and Evaluation

In general, the definition of traffic congestion varies according to the road types and among the responsible organizations. In this micro simulation, the evaluation was conducted by comparing the design speed and simulated speed in the existing network model and in the future network model.

Figure 11.27 shows the results (average simulated speed) of micro simulation on the existing network model. Figure 11.28 shows the results (average simulated speed) of micro simulation on the future network model.



Source: JICA Study Team

Figure 11.27 Results of Micro Simulation on Existing Network (Simulated Speed)

Source: JICA Study Team

Figure 11.28 Results of Micro Simulation on Future Network (Simulated Speed)

Table 11.38 Average Simulated Speed of Each Case

		Approach Road	Underpass	Existing Road	Ramp	Roundabout
Existing Network (Year 2013)	Design Speed (km/hr)	-	-	50	40	30
	Average Simulated Speed (km/hr)	-	-	52.8	43.9	31.0
Future Network (Year 2050)	Design Speed (km/hr)	80	60	50	40	30
	Average Simulated Speed (km/hr)	84.1	64.3	51.9	42.5	30.6

Source: JICA Study Team

In both the existing network and the future network (improved plan), the average simulated speed on each type of road is more than the design speed. The simulation also verified that traffic congestion would not occur in the future network.

Chapter 12 Preliminary Bridge Design

12.1 Summary of Preliminary Bridge Design

12.1.1 Objective

The objective of the study is to decide on the scope of the project and to estimate the preliminary project cost from the preliminary designs of the bridge structures and ancillary facilities, and the preparation of drawings and the calculation of work quantities.

12.1.2 Items included in the Preliminary Design

The Preliminary Design includes the following elements.

- Establishment of planning conditions and design criteria
- Establishment of cross sections
- Preliminary designs of bridges, which consist of bridge planning and determination of required structural sections
- Planning and design of bridge ancillary works
- Preparation of drawings
- Calculation of quantities

As a result of Chapter 10.1 Screening of Main Bridge Type for 4th Panama Canal Bridge, the Preliminary Design for the main 4th Panama Canal Bridge assumed two scenarios, using the navigation channel and without using the navigation channel in the bridge construction.

Furthermore, the improvement of the Omar Torrijos roundabout was conducted as a Concept Design in the Study (see Section 11.5); therefore, the bridge planning does not include the improvement of the Omar Torrijos roundabout.

12.1.3 Results of Preliminary Design

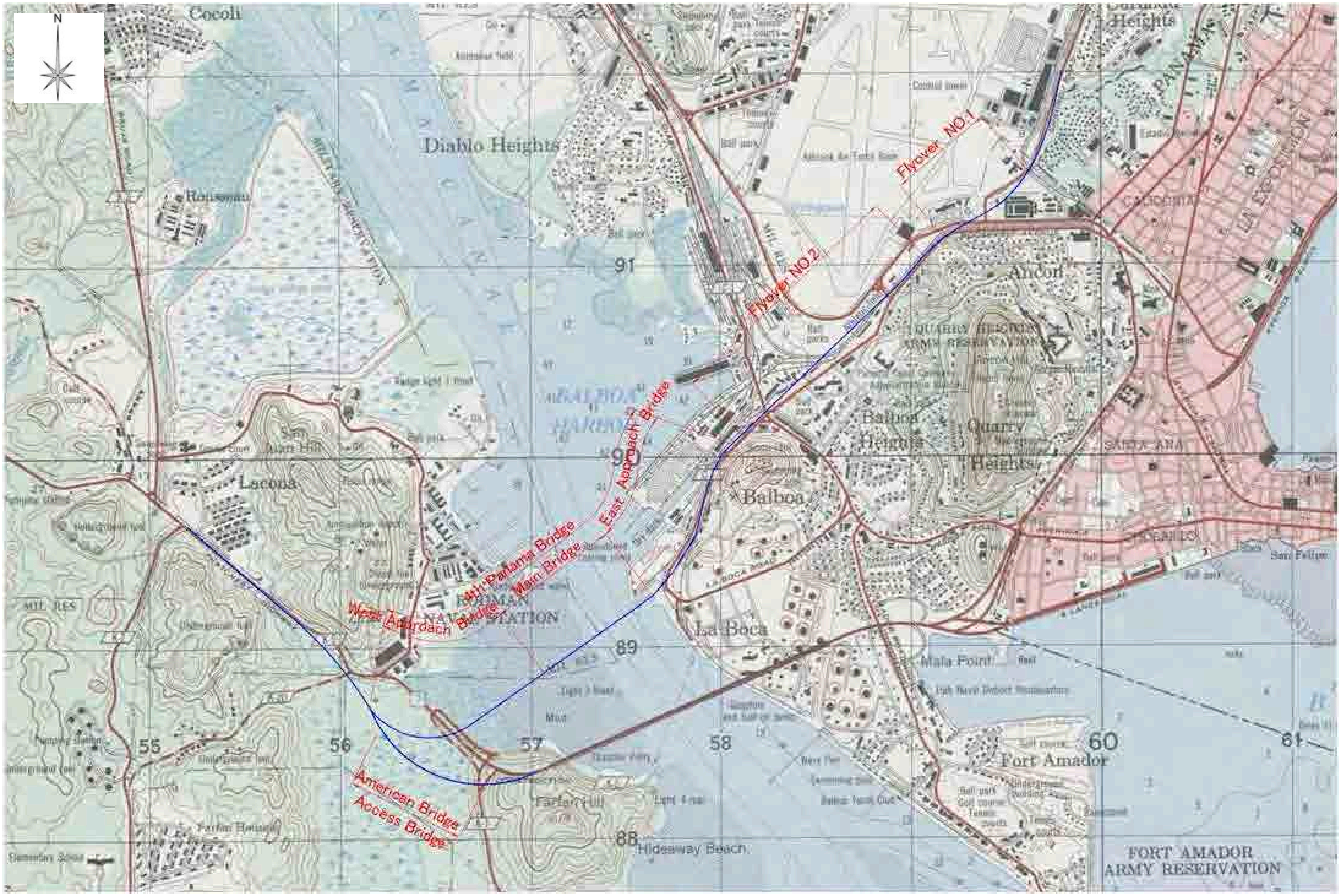
The results of the Preliminary Design are summarized in Table 12.1 and Figure 12.1.

Although the arch bridge can be built by two different erection methods, that is using the navigation channel and without using the navigation channel, the structural elements of the arch bridge were determined for its completed state, which is much more predominant than the construction methods. On the other hand, temporary facilities, construction period and construction costs are related to the construction method, depending on whether or not the navigation channel is used. These discussions are made in Chapter 15.

Table 12.1 Summary of Preliminary Bridge Design Results

No.	Route	Bridge Name		Location (KM)	Bridge Length	Span Arrangement	Width	Bridge Type
1	Project Road	Flyover No. 1		1+050 to 1+320 1+320 to 1+570	270m 250m	2@40m+30m+4@40m 50m+2@60m+45m+35m	22.100m	PC-I Steel Box
2		Flyover No. 2		2+000 to 2+260 2+260 to 2+740	260m 480m	5@40m+2@30m 60m+4@90m+60m	29.400m	PC-I Steel Box
3		4th Panama Canal Bridge	East Approach	2+847 to 3+380	533m	43m+60m+50m+90m+2@100m+90m	38.400m to 50.235m	Steel Box
4			Main Bridge	3+380 to 4+220	840m	150m+840m+150m	48.742m to 52.494m	Arch
5			West Approach	4+220 to 5+030 5+030 to 5+390	810m 360m	90m+3@100m+80m+5@60m 9@40m	38.400m to 48.742m 29.400m	Steel Box PC-I
6	Access Roads to the Bridge of Americas	Connection Bridge to the Bridge of the Americas		0+520 to 1+280	760m	19@40m	10.900m	PC-I

Source: JICA Study Team



Source: JICA Study Team

Figure 12.1 Bridge Location Map

12.2 Planning Conditions and Design Criteria

12.2.1 Planning Conditions

(1) Special items to be considered

The Project road is characterized as follows:

- Crosses over the Panama Canal
- Road construction is close to the Albrook "Marcos A. Gelabert" International Airport and Howard Airport
- It is an intra-city road that carries appurtenances and crosses a considerable number of existing public utilities

The conditions for planning the bridge structures are established taking the above aspects into consideration.

(2) Major Planning Conditions

1) Topography and Subsoil

i. Topographic Condition

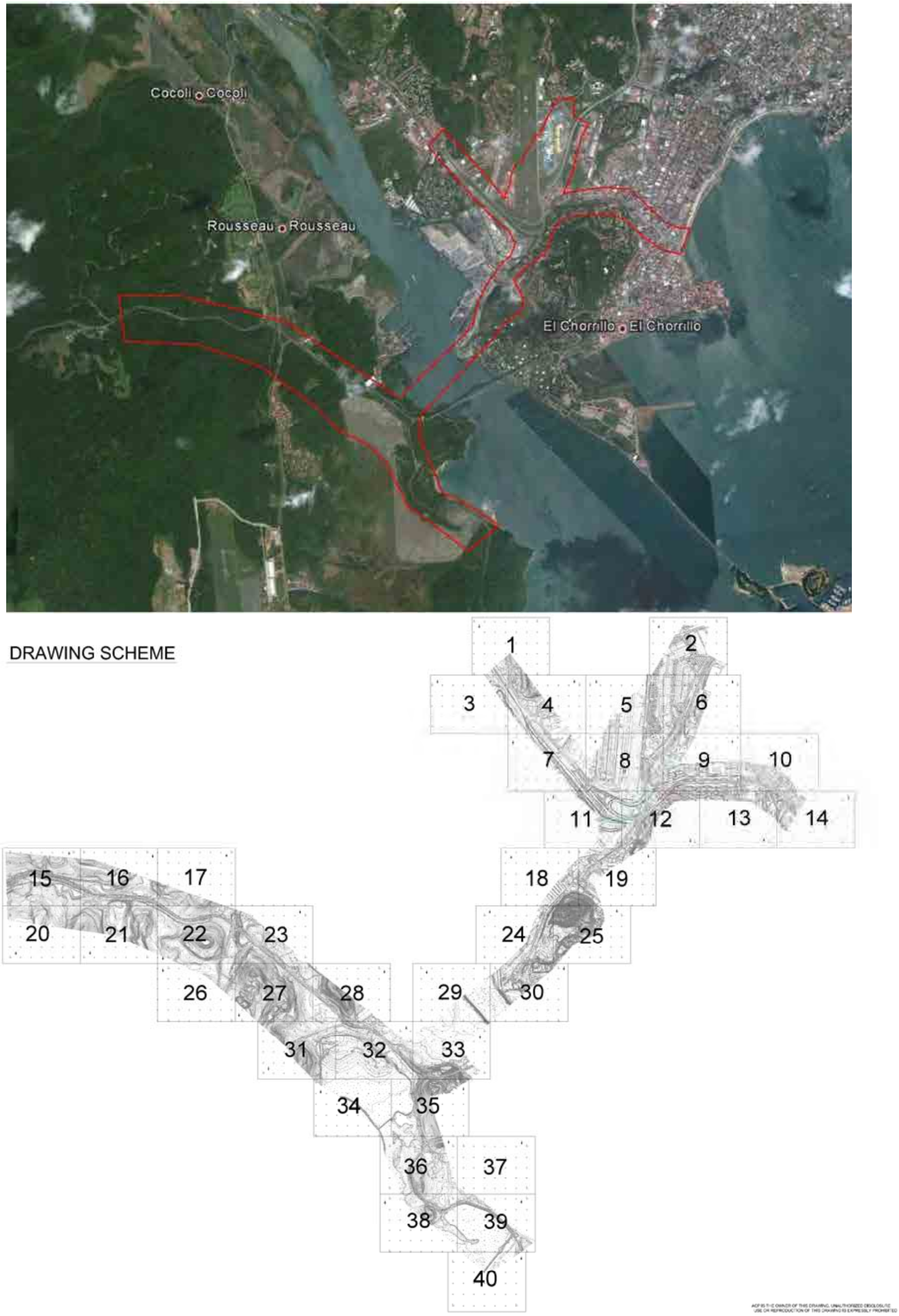
Panama is located in the Central America region, bordered by both the Caribbean Sea to the north and the Pacific Ocean to the south, and between Colombia to the east and Costa Rica to the west. The total land area of the country is 77,082km2. Panama is located on the narrow isthmus, where the Panama Canal connects the Pacific Ocean and Caribbean Sea. The specific area of the Study is located in the Panama Canal basin where both banks of the Panama Canal are formed by relatively gentle mountains.

The Study utilized the topographic data produced by the Pre-F/S on the basis of ASTER (Advanced Space-borne Thermal Emission and Reflection Radiometer) - DRM which was developed by NASA and METI (Ministry of Economy, Technology and Industry, Japan). The data obtained from the Pre-F/S was digitalized as follows.

- 10m contour CAD data/ WGS 84/ UTM

The Pre-F/S carried out supplementary surveys by using PTS-GPS to obtain 1m interval contour lines in addition to the above.

Figure 12.2 shows the data obtained by the Study.



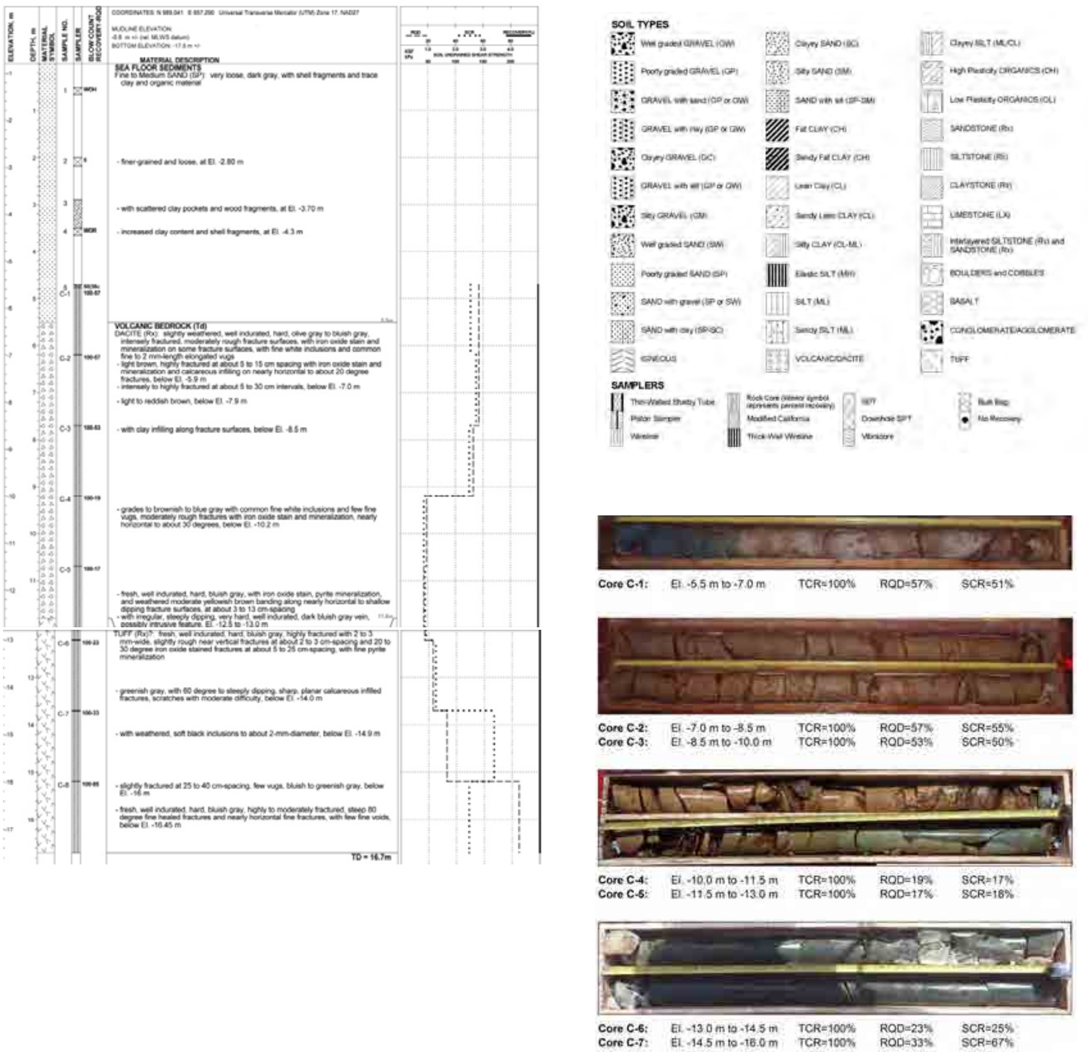
Source: Pre-F/S (Draft Final Report (November 2013)) (ACP)

Figure 12.2 Topographic Mapping Data used by the Study

ii. Subsoil Condition

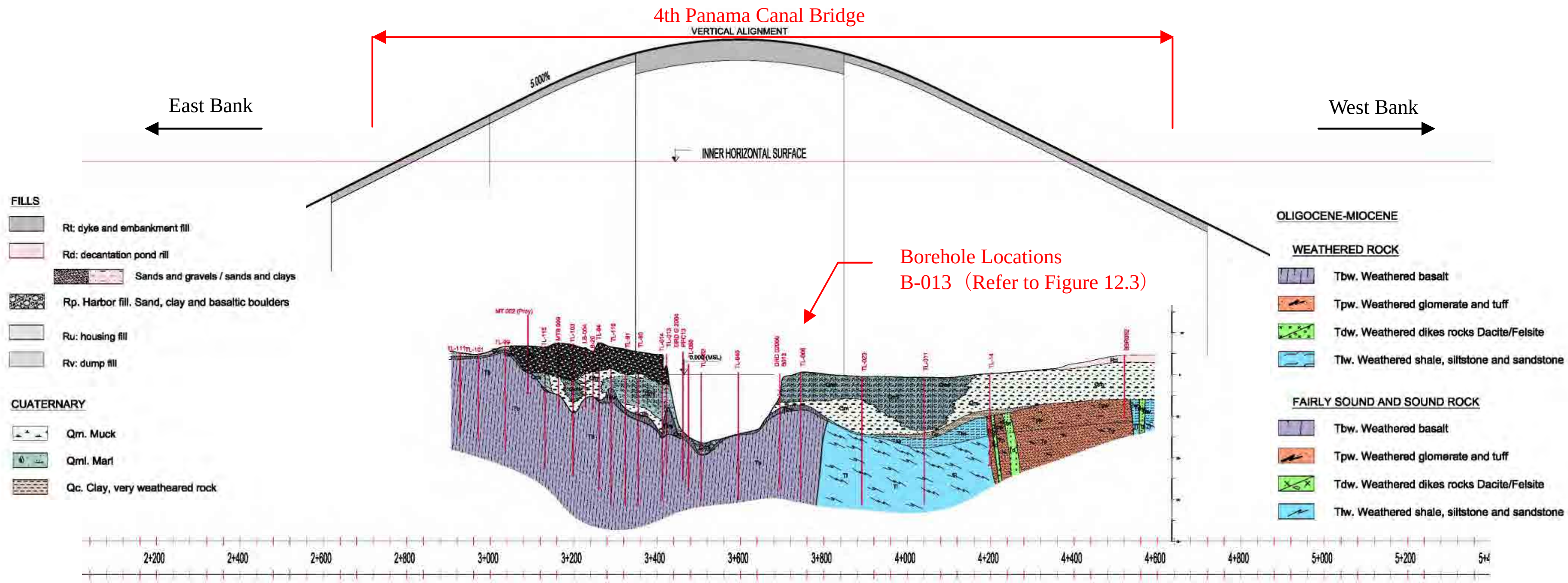
The intended area of study is delimited by the lowest point, at -15.0m in the navigation channel, with basalt rock on the eastern bank and siltstone, sandstone and tuff rock on the western bank. According to RQD, There are some cracks in the rock, but it is enough hard as the bearing strata.

Soft clayey soil, which is formed by coastal sediments, covers the shallow depths of the plain area as shown in Figure 12.3. On the eastern bank, an embankment constructed from marl and black soil covers the surface layer.



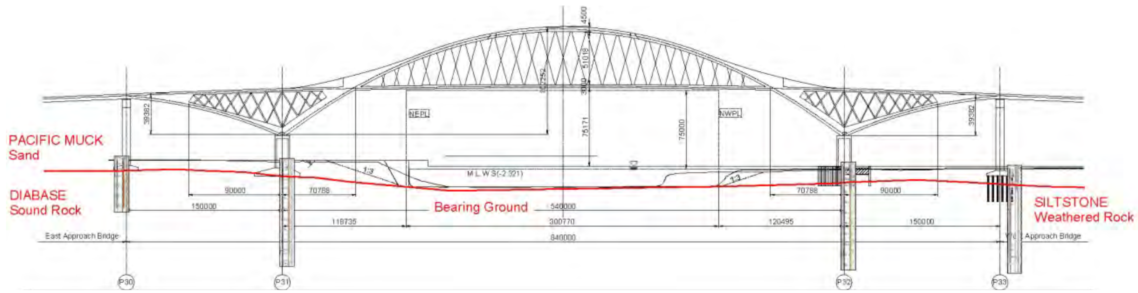
Source: Pre-F/S (Draft Final Report (November 2013)) (ACP)

Figure 12.3 Typical Subsoil Conditions in the Lowlands of the Study Area



Source: Pre-F/S (Draft Final Report (November 2013)) (ACP)

Figure 12.4 Subsoil Profile (4th Panama Canal Bridge)



Source: Pre-F/S (Draft Final Report (November 2013)) (ACP)

Figure 12.5 Bearing Stratum (4th Panama Canal Bridge)

2) Erection Conditions

The following two erection methods have been considered in the bridge plan and design.

- Using the navigation channel
- Without using the navigation channel

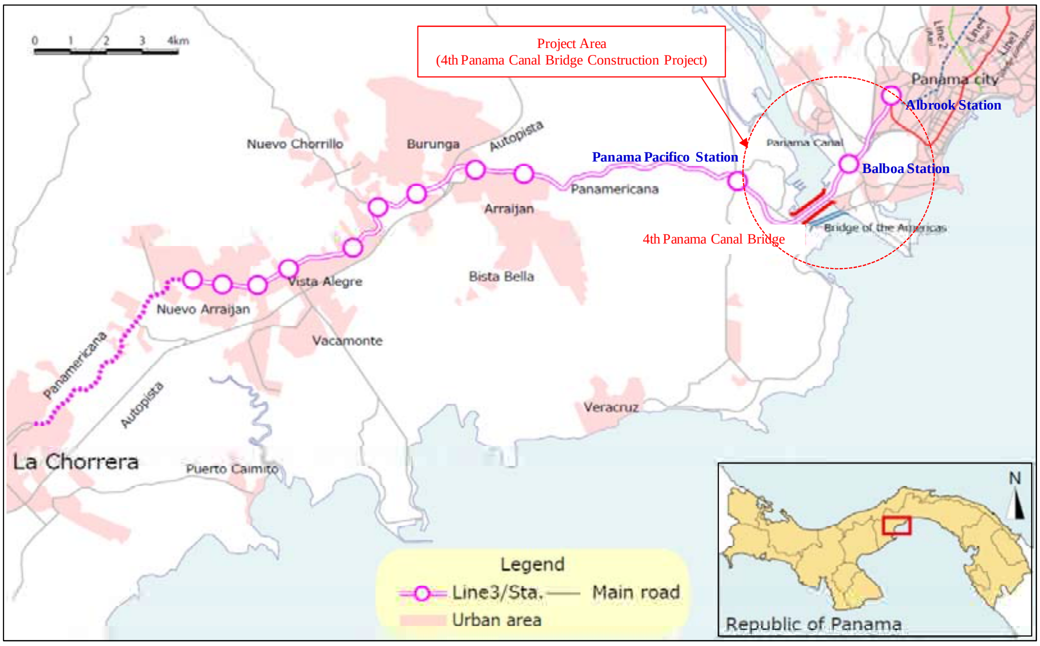
Detailed discussions are made in the subsequent Chapter 15.1. It should be noted that the permanent structural components of the arch bridge are not affected by the difference in the erection methods.

3) Accommodation Position of the Metro Line 3

The 4th Panama Canal Bridge is to be built as a highway cum metro (mass transit) rail bridge. Regarding the Metro line 3 project, three stations are to be within the study area of the 4th Panama Canal Bridge; namely Albrook Station, Balboa Station and Panama Pacifico Station. All three stations are to be located along the southern (Pacific) side of the road alignment of the 4th Panama Canal Bridge.

Accordingly, the position of the Metro Line 3 was decided to be along the southern side of the road alignment of the 4th Panama Canal Bridge.

Figure 12.6 shows the route of Metro Line 3 and the planned stations.



Source: JICA Study Team

Figure 12.6 Route of Metro Line 3 and Planned Stations

12.2.2 Design Standards and Criteria

(1) Design Standards

In principle, the design should be made on the basis of the AASHTO LRFD Bridge Design Specifications, 6th Edition, 2012, except for those parameters regarding the natural conditions specified by the design standards of Panama, or by the existing analysis results.

(2) Major Design Criteria

1) Operational Category

The “Critical Bridge” specified in the AASHTO LRFD Bridge Design Specifications should be adopted in the Study. Accordingly, the return period of seismic horizontal equivalent force and the acceleration response spectrum should be 2,500 years.

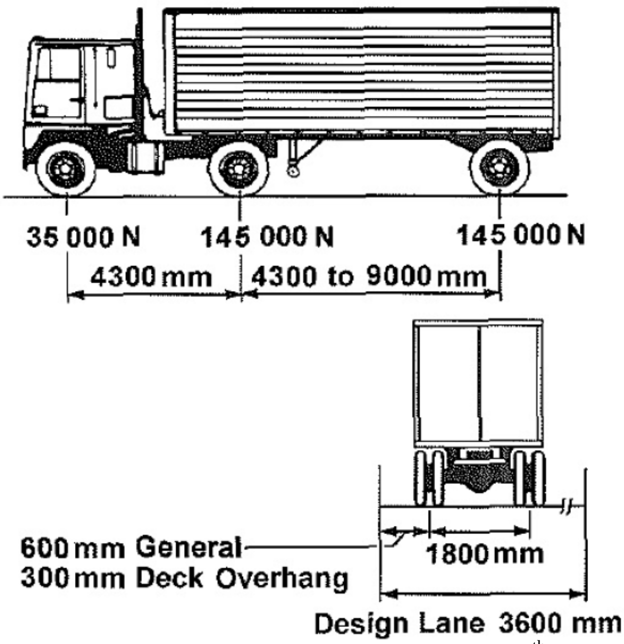
2) Design Life

The design life time should be 100 years.

3) Design Live Load

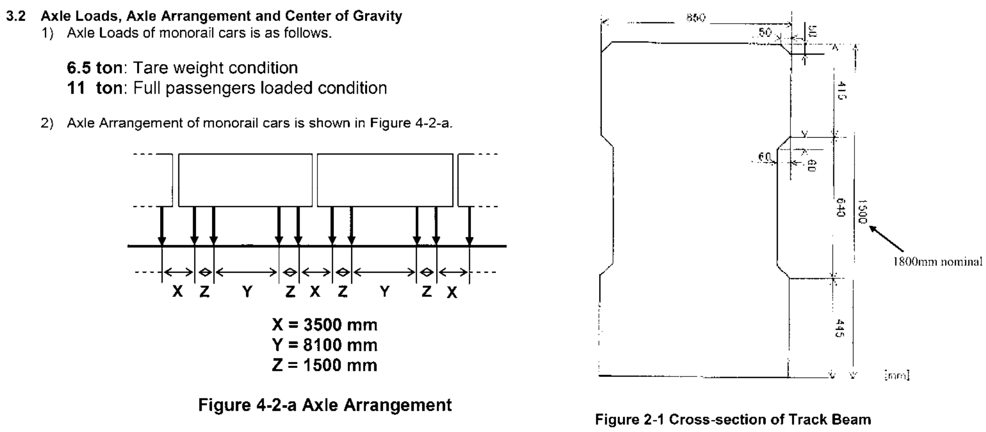
The HL-93 specified by AASHTO LRFD Bridge Design Specifications should be used.

The loadings of HL-93 for trucks and monorail are illustrated in Figures 12.7 and 12.8, respectively.



Source: AASHTO LRFD Bridge Design Specifications, 6th Editions, 2012

Figure 12.7 Loadings of HL-93



Source: Panama Metro Line 3 Panama-city Condition for Civil structure

Figure 12.8 Loadings of Monorail

4) Acceleration Response Spectrum and Design Horizontal Seismic Factor

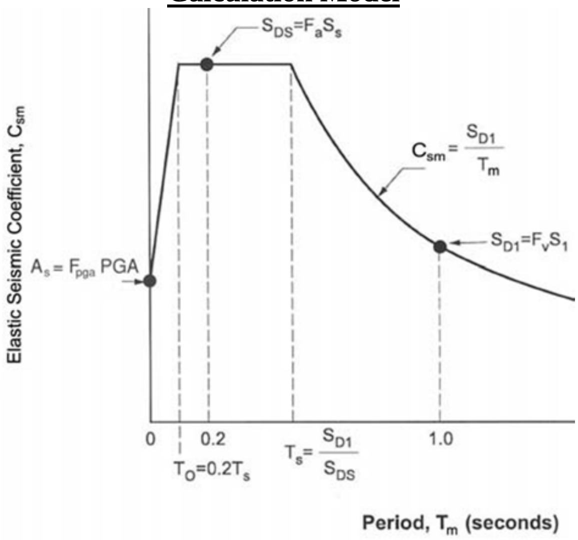
The acceleration response spectrum is based on the AASHTO LRFD Bridge Design Specifications. As for regional characteristics, the parameters referred to those obtained in the Seismic Hazard Assessment of the 2nd Panama Canal Bridge (Centennial Bridge).

The calculation method of acceleration response spectrum is outlined below.

i. Calculation Method of Acceleration Response Spectrum

Figure 12.9 shows the formula to calculate the acceleration response spectrum.

Calculation Model



Formula

$$C_{sm} = A_S + (S_{DS} - A_S)\,(T_m / T_0) \qquad (3.10.4.2\text{-}1)$$

in which:

$$A_S = F_{pga}\,PGA \qquad (3.10.4.2\text{-}2)$$

$$S_{DS} = F_a\,S_S \qquad (3.10.4.2\text{-}3)$$

where:

PGA = peak ground acceleration coefficient on rock (Site Class B)
S_S = horizontal response spectral acceleration coefficient at 0.2-sec period on rock (Site Class B)
T_m = period of vibration of mth mode (s)
T_0 = reference period used to define spectral shape = $0.2\ T_S$ (s)
T_S = corner period at which spectrum changes from being independent of period to being inversely proportional to period = S_{D1}/S_{DS} (s)

For periods greater than or equal to T_0 and less than or equal to T_S, the elastic seismic response coefficient shall be taken as:

$$C_{sm} = S_{DS} \qquad (3.10.4.2\text{-}4)$$

For periods greater than T_S, the elastic seismic response coefficient shall be taken as:

$$C_{sm} = S_{D1} / T_m \qquad (3.10.4.2\text{-}5)$$

in which:

$$S_{D1} = F_v\,S_1 \qquad (3.10.4.2\text{-}6)$$

where:

S_1 = horizontal response spectral acceleration coefficient at 1.0 sec period on rock (Site Class B)

Source：AASHTO LRFD Bridge Design Specifications, 6th Editions, 2012

Figure 12.9 Calculation Formula of Acceleration Response Spectrum

ii. Site Class

"Site Class B" should be employed in the case of bearing strata of basalt rock according to the AASHTO LRFD Bridge Design Specifications.

The bearing stratum is basalt rock that consists of very hard rock and soft rock containing some cracks. It is a matter of no importance that there is thin mud layer on the bearing strata at the west bridge pier. In the response spectrum calculation, a value of Site Class B is safer than one of Site Class A (hard rock). Site Class B (soft rock) is applied under the terms that it is desirable to expect the same seismic force on the same design oscillating unit.

Site Class	Soil Type and Profile
A	Hard rock with measured shear wave velocity, $\bar{v}_s > 5{,}000$ ft/s
B	Rock with 2,500 ft/sec < $\bar{v}_s$ < 5,000 ft/s
C	Very dense soil and soil rock with 1,200 ft/sec < $\bar{v}_s$ < 2,500 ft/s, or with either $\bar{N}$ > 50 blows/ft, or $\bar{s}_u$ > 2.0 ksf
D	Stiff soil with 600 ft/s < $\bar{v}_s$ < 1,200 ft/s, or with either 15 < $\bar{N}$ < 50 blows/ft, or 1.0 < $\bar{s}_u$ < 2.0 ksf
E	Soil profile with $\bar{v}_s$ < 600 ft/s or with either $\bar{N}$ < 15 blows/ft or $\bar{s}_u$ < 1.0 ksf, or any profile with more than 10 ft of soft clay defined as soil with $PI > 20$, $w > 40$ percent and $\bar{s}_u$ < 0.5 ksf
F	Soils requiring site-specific evaluations, such as: • Peats or highly organic clays (H > 10 ft of peat or highly organic clay where H = thickness of soil) • Very high plasticity clays (H > 25 ft with PI > 75) • Very thick soft/medium stiff clays (H >120 ft)

Exceptions: Where the soil properties are not known in sufficient detail to determine the site class, a site investigation shall be undertaken sufficient to determine the site class. Site classes E or F should not be assumed unless the authority having jurisdiction determines that site classes E or F could be present at the site or in the event that site classes E or F are established by geotechnical data.

where:

$\bar{v}_s$ = average shear wave velocity for the upper 100 ft of the soil profile
$\bar{N}$ = average Standard Penetration Test (SPT) blow count (blows/ft) (ASTM D1586) for the upper 100 ft of the soil profile
$\bar{s}_u$ = average undrained shear strength in ksf (ASTM D2166 or ASTM D2850) for the upper 100 ft of the soil profile
PI = plasticity index (ASTM D4318)
w = moisture content (ASTM D2216)

Source: AASHTO LRFD Bridge Design Specifications, 6th Editions, 2012

Figure 12.10 Site Class Definitions

Table 3.10.3.2-1—Values of Site Factor, F_{pga}, at Zero-Period on Acceleration Spectrum

Site Class	Peak Ground Acceleration Coefficient (PGA)[1]				
	PGA < 0.10	PGA = 0.20	PGA = 0.30	PGA = 0.40	PGA > 0.50
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F[2]	*	*	*	*	*

Table 3.10.3.2-2—Values of Site Factor, F_a, for Short-Period Range of Acceleration Spectrum

Site Class	Spectral Acceleration Coefficient at Period 0.2 sec (S_S)[1]				
	S_S < 0.25	S_S = 0.50	S_S = 0.75	S_S = 1.00	S_S > 1.25
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F[2]	*	*	*	*	*

Source: AASHTO LRFD Bridge Design Specifications, 6th Editions, 2012

Figure 12.11 Examples of values of site factor

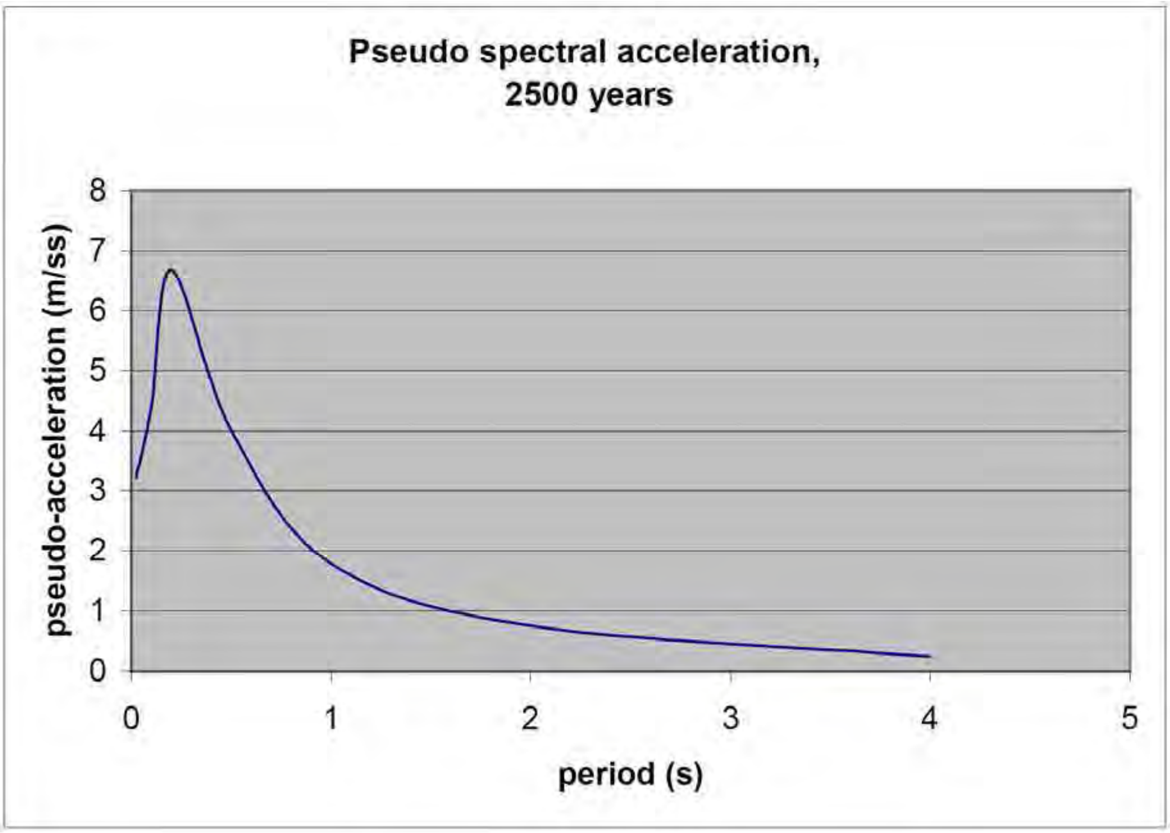
iii. Determination of Parameters

S1: Response Acceleration for Natural Period = 1 Sec. (Site Class B)

Referring to the Seismic Hazard Assessment of the 2nd Panama Canal Bridge (Centenary Bridge), 0.3g was adopted as S1.

Ss: Response Acceleration for Natural Period = 0.2 Sec. (Site Class B)

Referring to the Seismic Hazard Assessment of the 2nd Panama Canal Bridge (Centenary Bridge), 0.64g was adopted as Ss.



Source: Seismic Hazard Assessment of the 2nd Panama Canal Crossing (at page 9)

Figure 12.12 Reference Graph (Response Acceleration for Natural Period = 0.2 Sec. (Site Class B))

PGA: Peak Acceleration Coefficient (Site Class B)

Referring to the Seismic Hazard Assessment of the 2nd Panama Canal Bridge (Centenary Bridge), 0.33g was adopted as PGA.

Fpga, Fa and Fv (Site Class B)

The following parameters of Fpga, Fa and Fv are adopted according to the AASHTO LRFD Bridge Design Specifications.

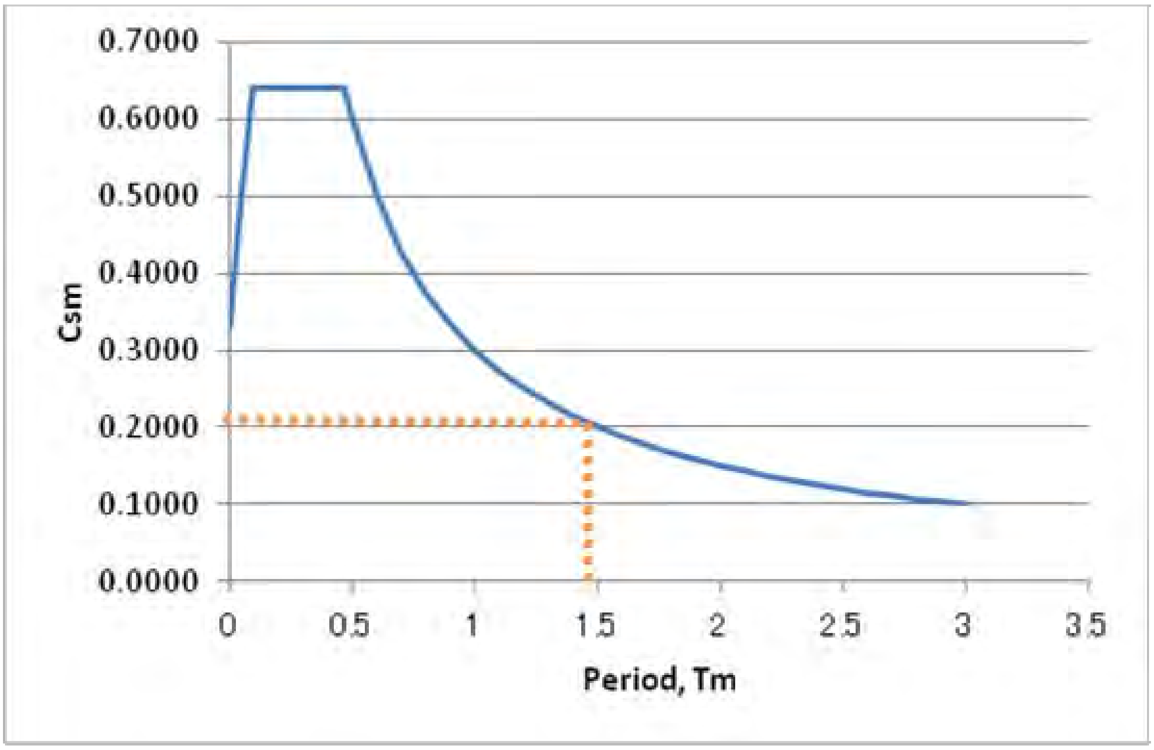
- Fpga : 1.0 (in case of Site Class B, PGA=0.30)
- Fa : 1.0 (in case of Site Class B, Ss=0.5 and 0.75)
- Fv : 1.5 (in case of Site Class B, S1=0.2)

iv. Acceleration Response Spectrum

The acceleration response spectrum in the Study was prepared based on the results of 12.2.2(2) 4) i. to iii, mentioned above.

Figure 12.13 shows the acceleration spectrum adopted in the Study.

From the acceleration spectrum shown in Figure 12.13 and the assumption that the natural period of structure in the Project is 1.5 Sec. or more, the design horizontal seismic factor of 0.2 was adopted.



Source: JICA Study Team

Figure 12.13 Acceleration Spectrum adopted in the Study

5) Design Wind Load

As discussed in 4.4.4, the maximum wind velocity around the Study area for the past 10 years was 81.9 km/hr. The wind velocity around the Study area was calculated in the following manner for a 100 year probability.

V (100) = 81.9/0.874 = 93.7km/hr

On the other hand, the design standards of Panama (REP) stipulate a maximum wind velocity of 115 km/hr. Taking the conservative side, the maximum wind velocity of 115 km/hr was adopted in the Study.

Wind forces can be obtained from the above maximum wind velocity and ASCE7-10 as shown in Figure 12.14.

6) Design Thermal Load

On the basis of Panama Standards (REP), the loads of thermal effect were calculated as follows:

- Base Temperature: 27C
- Temperature Fall and Rise: ±15C

12.3 Typical Cross Sections

Typical cross sections employed in the Study are sown in Figure 12.15.

WIND LOAD

ASCE7 ***VELOCITY PRESSURE***

風荷重 q_z	=	36.79	lb/ft2	Velocity Pressure			
		1760.33	N/m2				
Kz	=	1.73		velocity pressure coefficient defined in Section 6.5.6.6			
Kzt	=	1.664		topographic factor difined in Section 6.5.7.2, Figure6-4			
Kd	=	0.85		wind directionality factor defined in Section 6.5.4.4, Table6-4	Structure Type	Arched Roofs	
V	=	71.46	mph	design velocity (設計風速)			
		31.94	m/s		region	Pacific	
I	=	1.15		importance factor defoned in Table6-1	Category	V	
K1	=	0.29		Factor to account for shape of topographic feature and maximum	H/Lh	0.2	2-D Ridge
K2	=	1		Factor to account for reduction in speed-up with distance upwind	x/Lh	0	All Other Cases
K3	=	1		Factor to account for reduction in speed-up with height above loc	x/Lh	0	2-D Ridge
z	=	300	ft		Exposure	D	
		91.44	m				
Kh	=	1.73					

$$q_z = 0.00256 K_z K_{zt} K_d V^2 I$$

$$q_z = 0.613 K_z K_{zt} K_d V^2 I$$

Table6-4 Wind directionality factor

Structure Type		Kd
Buildings	Main Wind Force Rsisitiong System	0.85
	Components and Cladding	0.85
Arched Roofs	Arched Roofs	0.85
Chimneys, Tanks, and Similar Structures	Square	0.90
	Hexagonal	0.95
	Round	0.95
Solid Signs	Solid Signs	0.85
Open Signs and Lattice Framework	Open Signs and Lattice Framework	0.85
Trussed Towers	Triangular, square, rectangular	0.85
	All other cross sections	0.95

Figure6-4 Topographic Factor, Kzt

Topographic Multipliers for Exposure C										
H/Lh	K1 Multiplier			x/Lh	K2 Multiplier		x/Lh	K3 Multiplier		
	2-D Ridge	2-D Escarp.	3-D Axisym.		2-D Escarp.	All Other Cases		2-D Ridge	2-D Escarp.	3-D Axisym. Hill
0.20	0.29	0.17	0.21	0.00	1.00	1.00	0.00	1.00	1.00	1.00
0.25	0.36	0.21	0.26	0.50	0.88	0.67	0.10	0.74	0.78	0.67
0.30	0.43	0.26	0.32	1.00	0.75	0.33	0.20	0.55	0.61	0.45
0.35	0.51	0.30	0.37	1.50	0.63	0.00	0.30	0.41	0.47	0.30
0.40	0.58	0.34	0.42	2.00	0.50	0.00	0.40	0.30	0.37	0.20
0.45	0.65	0.38	0.47	2.50	0.38	0.00	0.50	0.22	0.29	0.14
0.50	0.72	0.43	0.53	3.00	0.25	0.00	0.60	0.17	0.22	0.09
				3.50	0.13	0.00	0.70	0.12	0.17	0.06
				4.00	0.00	0.00	0.80	0.09	0.14	0.04
							0.90	0.07	0.11	0.03
							1.00	0.05	0.08	0.02
							1.50	0.01	0.02	0.00
							2.00	0.00	0.00	0.00

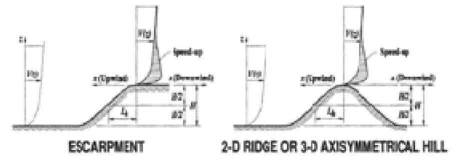


Table6-3 Velocity Pressure Exposure Coefficients, Kh and Kz

Height above ground lev		Exposure			
		B1	B2	C	D
ft	(m)	Case 1	Case 2	Case1&2	Case1&2
0-15	(0-4.6)	0.70	0.57	0.85	1.03
20	(6.1)	0.70	0.62	0.90	1.08
25	(7.6)	0.70	0.66	0.94	1.12
30	(9.1)	0.70	0.70	0.98	1.16
40	(12.2)	0.76	0.76	1.04	1.22
50	(15.2)	0.81	0.81	1.09	1.27
60	(18)	0.85	0.85	1.13	1.31
70	(21.3)	0.89	0.89	1.17	1.34
80	(24.4)	0.93	0.93	1.21	1.38
90	(27.4)	0.96	0.96	1.24	1.40
100	(30.5)	0.99	0.99	1.26	1.43
120	(36.6)	1.04	1.04	1.31	1.48
140	(42.7)	1.09	1.09	1.36	1.52
160	(48.8)	1.13	1.13	1.39	1.55
180	(54.9)	1.17	1.17	1.43	1.58
200	(61.0)	1.20	1.20	1.46	1.61
250	(76.2)	1.28	1.28	1.53	1.68
300	(91.4)	1.35	1.35	1.59	1.73
350	(106.7)	1.41	1.41	1.64	1.78
400	(121.9)	1.47	1.47	1.69	1.82
450	(137.2)	1.52	1.52	1.73	1.86
500	(152.4)	1.56	1.56	1.77	1.89

Table6-1 Importance factor

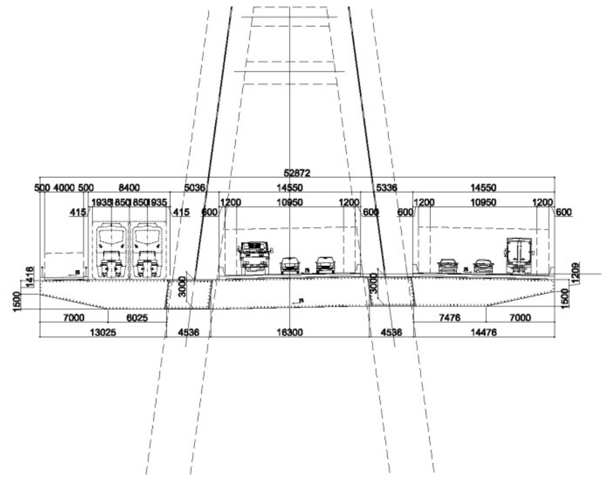
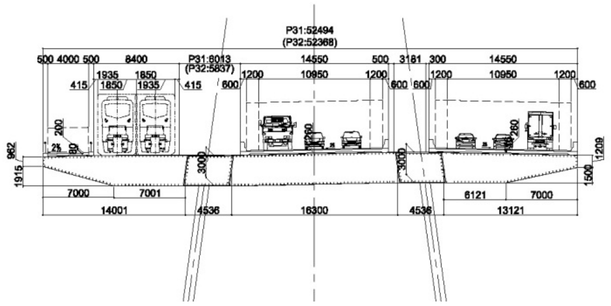
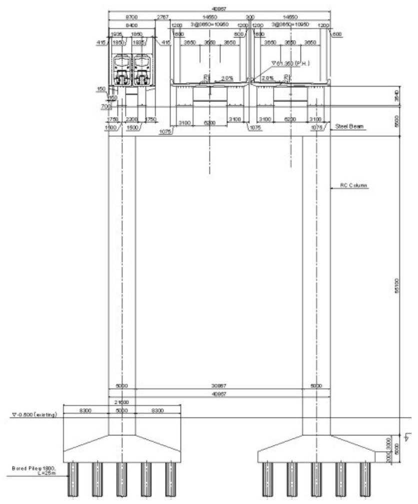
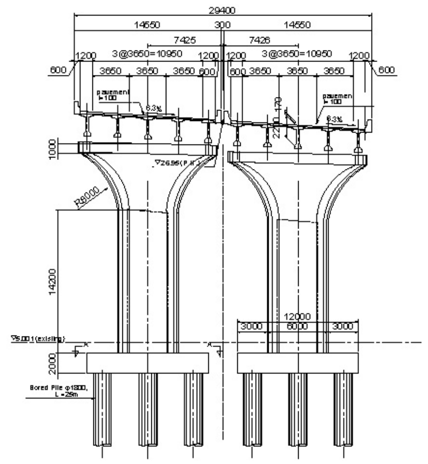
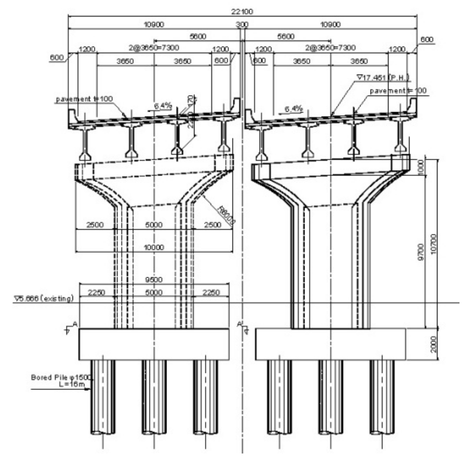
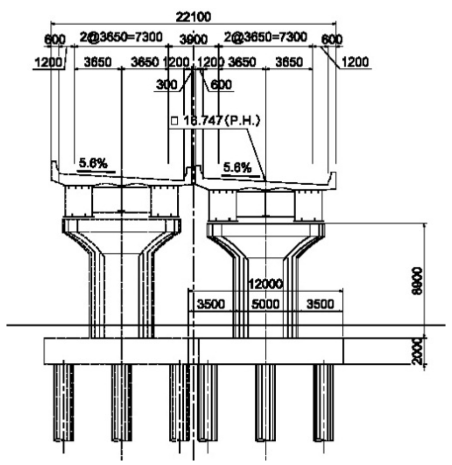
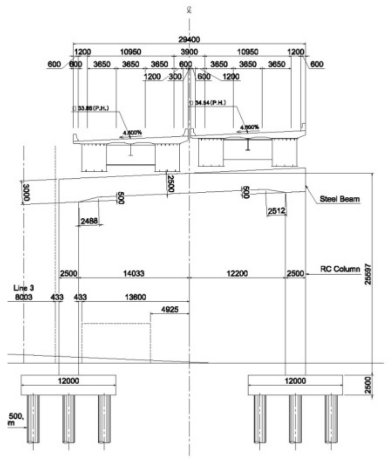
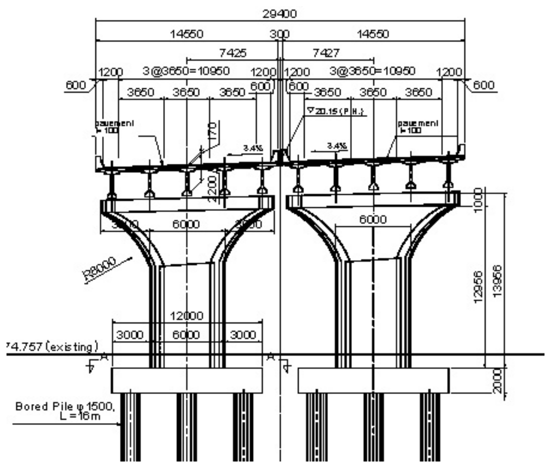
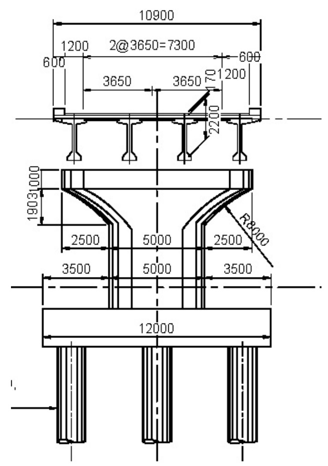
Category	Non-	Hurricane
I	0.87	0.77
II	1.00	1.00
III	1.15	1.15
IV	1.15	1.15

Pabama design velocity

REGION	VELOCITY IN 3 SECONDS	
	km/h	m/s
Pacific	115	31.94
Atlantic	140	38.89

Source: JICA Study Team

Figure 12.14 Design Wind Load

4th Panama Canal Bridge			Flyover No.1
Main Bridge	Approach Viaduct		
Arch	Steel Box Girder	PC-I Girder	PC-I Girder
Main Span  Side Span 		West Bank Approach 	
Flyover No.1	Flyover No.2		Connection Bridge on Access Road to the Bridge of the Americas
Steel Box Girder	Steel Box Girder	PC-I Girder	PC-I Girder
			

Source: JICA Study Team

Figure 12.15 Typical Cross Sections of Bridge Structures

12.4 Preliminary Designs of Bridge Structures

12.4.1 Main Bridge

(1) 4th Panama Canal Bridge

1) Main Bridge

i. Basis of Planning and Preliminary Design

A summary of the bridge planning and preliminary designs are discussed below.

Floor Deck Slab

Reinforced concrete (RC) slab is employed because Guss asphalt pavement on a steel orthotropic deck is difficult to maintain and is unattainable in Panama.

Splices of Steel Members

Since paint on high tension bolts will likely be worn and corrosion is likely to occur, field welding should be adopted instead of bolt splice so as to improve the future maintenance performance. In the places such as the diaphragms of the arch-rib and the stiffening girder where external environmental effects appear to be low, bolt splicing can be permitted.

Steel Materials

Stress concentration occurs at the corner sections of the conjunction of the arch-rib and stiffening girder, therefore, steel materials of SBHS (Steels for Bridge High Performance Structure) (considerable degree of SBHS500) were employed taking into consideration the advantages of welding workability.

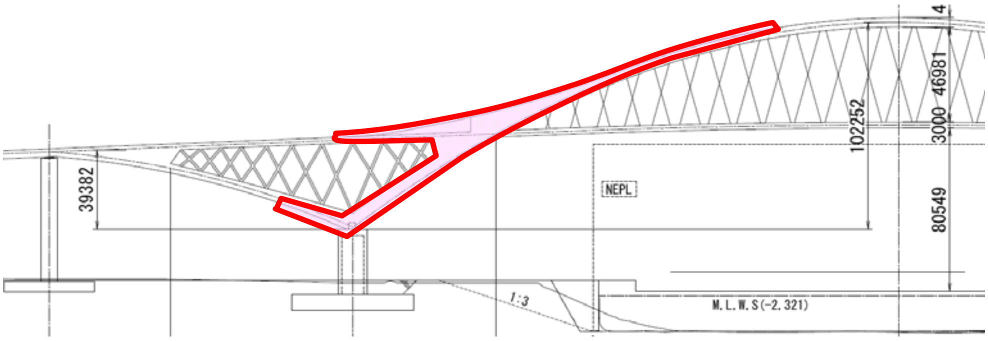
The characteristics of SBHS are as follows (see Section 20.3.1 in details).

- Increase the yield strength (SBHS500: 500N/mm2, SM570: 450N/mm2)
- High-grade workability and weldability, and a reduction of preheat time

Usually, the thickness of the steel used for a bridge is 100mm or less, since the thicker the steel is, the more inferior will be the weldability and the greater the weight. If a greater thickness of steel is designed, then a better grade of steel is adapted.

The main structural element consists of SM490Y. SBHS (considerable degree of SBHS500) is applied because of the reduction in preheat time in case of applying steel more than 40mm thick.

Based on the general design, the application for SBHS500 is as follows.



Source: JICA Study Team

Figure 12.16 Scope of application for SBHS500

The stronger steel material (SBHS700) is not adapted for this bridge because of the normal yield strength and few beneficial achievements.

Form of main structure

We decided that the form of the Solid rib arch is more adaptable than that of the Braced arch. The reasons are as follows.

- The number of steel members: The Braced arch has many steel members and entails greater work days and higher costs.
- The number of joints: It is easy for fluids and dust to accumulate in the joints of the steel members increasing the possibility of corrosion in these joints. The Braced arch is thus inferior in maintenance.

Positioning and Allocation of Vehicle Types on the Deck Slab

The positioning of a sidewalk, 2-track monorail, arch-rib (suspending hanger), 3-lane carriageway, arch-rib (suspending hanger) and 3-lane carriageway are allocated from the southern edge towards the northern edge at every cross section. The position of the monorail on the southern side is one of the preconditions according to the monorail alignment and 4th Panama Canal Bridge alignment. The cross section is split into three blocks and the arch rib is placed in between the two adjacent blocks. The light load of the pedestrian sidewalk is located at the southern tip.

For seismic stability and wind resistance stability at right angles to the bridge, the main member of the arch is inclined toward the inside. Both arch-ribs are connected at the center of the arch span, so the stiffness out of the arch plane is improved.

Floor framing of Stiffening Girder

The stiffening girder forms a monolith box in order to achieve a higher rigidity of the cantilever decks with the expectation of high wind stability transversally. Also, aiming at improving wind stability, the girder depths decline towards the cantilever tips.

Connection between the Arch-rib and Stiffening Girder (Tension members in the arch span)

The stiffening girder is suspended from the arch-rib via hanger cables (as Tension members) in the main span.

The form of the hanger cables is an X-form, which is stronger than a vertical form.

<u>Connection between the Arch-rib and Stiffening Girder (Compression members in the side spans)</u>

In the side spans and the part outside the main span's arch-rib, the stiffening girder is supported by the arch-rib via strut members (as Compression members). On these parts, the strut members adapt an X-form for its stiffness.

<u>Bearing Conditions</u>

The bearings at the springing points of the arch are a fixed type taking into consideration the benefit of structural rigidity like low displacement.

<u>Paint (weathering steel)</u>

Paint applied to steel materials should be an anti-corrosive type (see Section 20.3.2) as mentioned above. In addition to the anti-corrosive properties it provides for steel materials, paint should also be applied from the view point of maintenance and aesthetics.

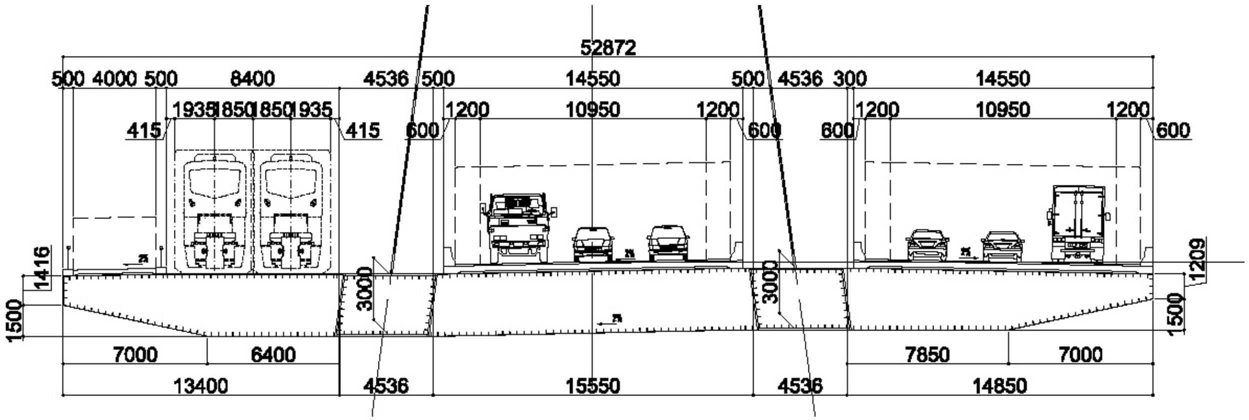
In areas where there are a lot of fragments with salt content, it is difficult for stable rust to form on weathering steel. Therefore, Nickelic high weathering steel was developed for this type of area. It was decided that this type of steel would be adapted for this bridge location.

It should be noted that samples of anti-corrosive type steel have been attached to the steel surface of the Bridge of Americas for checking the degree of weathering in the vicinity of the Project site. It will be necessary to make a study at the stage of execution design.

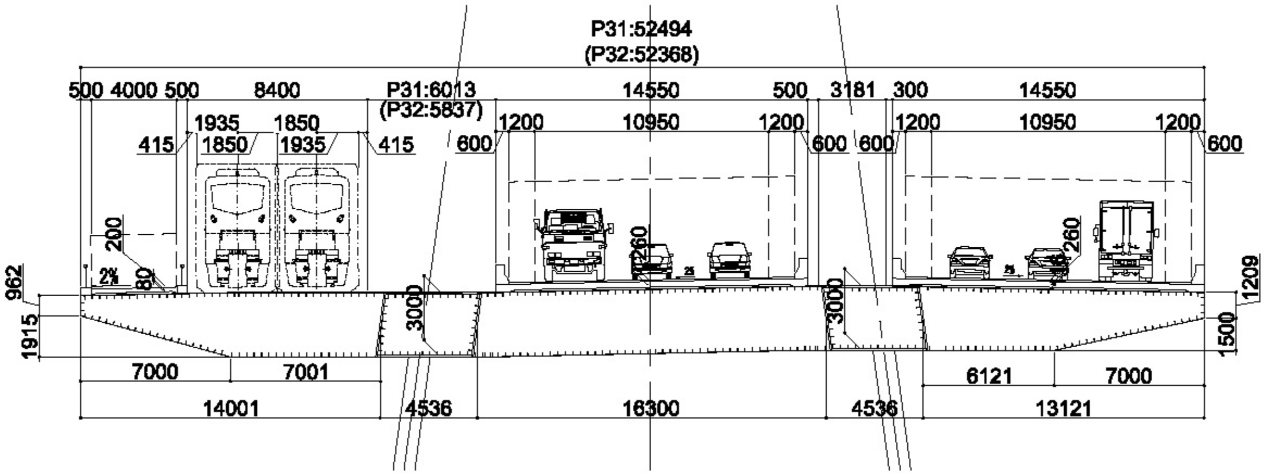
ii. Typical Cross Sections

Figure 12.17 shows the typical cross sections of the main bridge (arch bridge).

Main Span



Side Span



Source: JICA Study Team

Figure 12.17 Typical Cross Sections of Main Bridge (Arch Bridge)

iii. Bridge Length and Span Arrangement

Main Span

The proposed location of the arch bridge piers follows the same location of the cable stayed bridge piers determined by the Pre-F/S. The pier locations had been agreed upon among the concerned organizations through various meetings, so that the pier locations were set back a sufficient distance from the Prism Line. Accordingly, the main span length was decided to be 540m, which is the same as in the Pre-F/S.

Table 12.2 shows the pier locations along with the reasoning for the decision.

Table 12.2 Pier Locations and reasons for the Decision

No.	Pier (Coordinates)	Reasons for the Pier Location	Set-back Distance (from Prism Line to the Pier)
1	Pier on East Bank (X=657613.96 (Coordinate)) (Y=989297.18 (NAD27))	Agreed between ACP and Balboa Port	119.0m
2	Pier on West Bank (X=657205.83 (Coordinate)) (Y=988943.580 (NAD27))	Risk Analysis against Ship Collision	120.5m

Source: Pre-F/S (Draft Final Report (November 2013)) (ACP)

Side Span

The side span length was decided to be 150m taking into consideration the following:

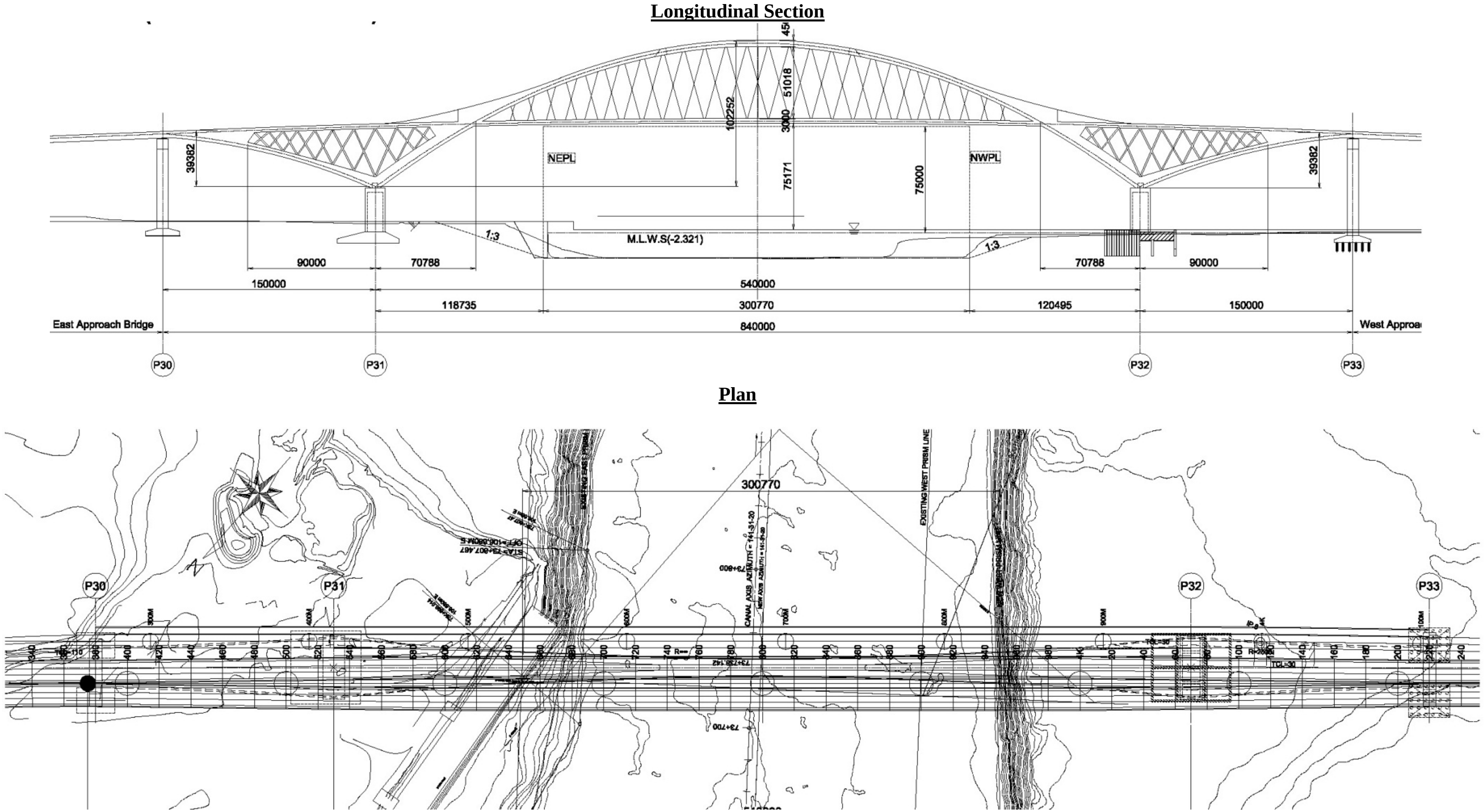
- Extending to the length where negative reaction does not occur
- Eliminate the transition curve (clothoid) within the arch bridge
- Reducing the horizontal Reaction induced by the arch

Figure 12.18 shows the span arrangement of the main bridge (arch bridge).

Bridge Length and Span Arrangement

Bridge Length = 840m

Span Arrangement: 150m+540m+150m



Source: JICA Study Team

Figure 12.18 Span Arrangement of Main Bridge (Arch Bridge)

iv. Structural Analyses and Design of the Superstructure

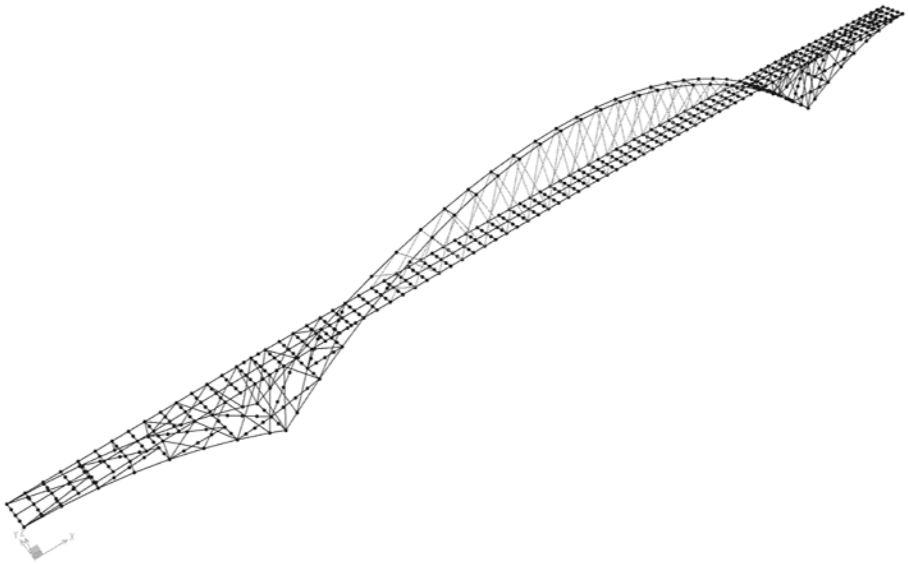
An outline of the structural analyses is explained below.

Loading Cases

Dead load, live load and seismic force are considered.

Skelton Model of Structural Analyses

A 3D static elastic model was used for the analyses as shown in Figure 12.19.



Source: JICA Study Team

Figure 12.19 Skelton Model of Superstructure Analyses

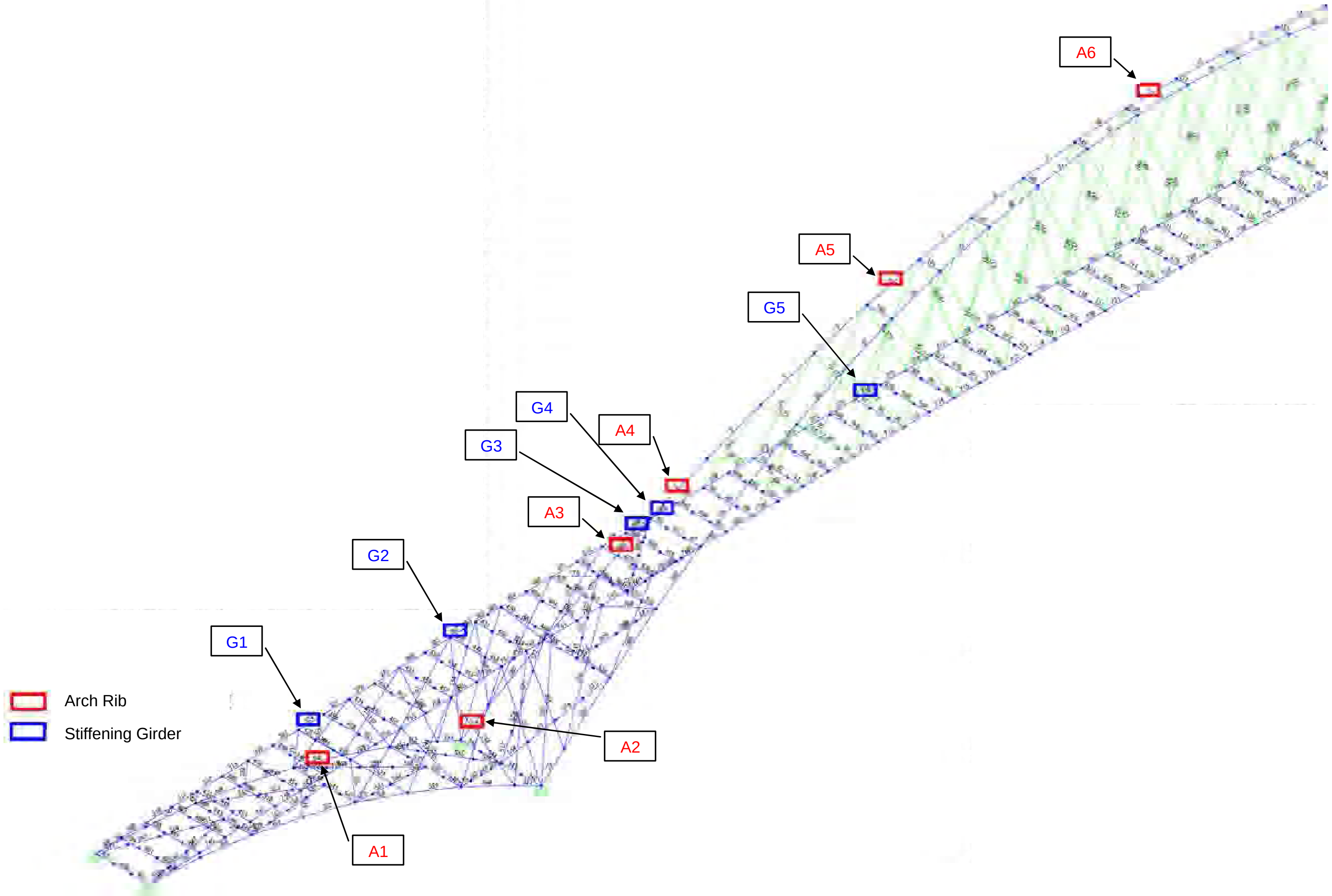
Designated points for Stress Calculation

Table 12.3 explains the designated points for stress calculation and Figure 12.20 shows the designated points.

Table 12.3 Designated Points for Stress Calculation

No.	Component	Stress Calculation Point	Remarks
1	Arch-Rib	A1	Typical point representing the side span
2		A2	Arch springing where the maximum main span forces occur - representing the conjunction between arch-rib and stiffening girder
3		A3	Lower side section of conjunction
4		A4	Upper side section of conjunction
5		A5	Quarter point of arch-rib span
6		A6	Highest point of arch-rib
7	Stiffening Girder	G1	Section corresponding to A1of arch-rib
8		G2	Section corresponding to A2of arch-rib
9		G3	Section corresponding to A3of arch-rib
10		G4	Section corresponding to A4 of arch-rib
11		G5	Point representing the suspended span of the stiffening girder

Source: JICA Study Team



Source: JICA Study Team

Figure 12.20 Designated Points for Stress Calculation

<u>Results of Stress Calculation</u>

Table 12.4 shows the summary of the stress calculation and Figure 12.21 shows the designed sections based on the stress calculations.

Table 12.4 Summary of Stress Calculation

Arch Rib

断面番号	Frame	Case	軸力 N kN	水平剪断 Sx kN	鉛直剪断 Sy kN	ねじり T kNm	鉛直曲げ Mx kNm	水平曲げ My kNm	最大応力度 σ N/mm2
A1,A2		D	-36788	-170	-3623	1185	-85111	-4099	
A2=0.689m2		L	-4532	102	-223	1258	-5542	3141	
		W	1199	203	-6	609	-221	7497	
		EQx	-30048	132	348	79	-11379	1892	
		EQy	9680	1606	-97	7421	-1432	52556	
	350	T	11923	-123	-148	-150	2178	6694	148.3
		D+L	-41320	-68	-3847	2443	-90653	-957	
		(D+EQx)/1.50	-44558	-25	-2183	843	-64327	-1471	
		(D+EQy)/1.50	-18072	957	-2481	5737	-57695	32305	
		(D+W)/1.25	-28471	26	-2904	1435	-68265	2719	
		(D+T)/1.15	-21622	-255	-3280	901	-72115	2257	
A3		D	-197058	2188	20918	-6017	506369	40981	
A3=2.83m2		L	-15422	805	4192	-13915	124061	25275	
		W	-24414	-2752	2940	749	94597	-123328	
		EQx	10364	-2877	-29425	-3731	-888002	-49126	
		EQy	-153711	-22288	21987	37820	749777	-1007982	
	1	T	-2244	15605	802	2731	6172	491930	321.2
		D+L	-212480	2993	25109	-19932	630430	66256	
		(D+EQx)/1.50	-124462	-459	-5671	-6499	-254422	-5430	
		(D+EQy)/1.50	-233846	-13400	28603	21202	837430	-644667	
		(D+W)/1.25	-177177	-451	19086	-4214	480773	-65878	
		(D+T)/1.15	-173306	15473	18887	-2857	445687	463401	
A4		D	-177809	-321	-1892	-5205	-326654	15049	
A4=2.025m2		L	-14532	1034	793	-14575	-37159	38243	
		W	-19906	-2178	46	763	-19972	-66368	
		EQx	13191	-242	4760	-1009	134067	-5936	
		EQy	-119558	-19180	-2982	39808	-216634	-610414	
	502	T	-5553	-3078	381	1254	-5551	-59453	292.3
		D+L	-192341	714	-1099	-19779	-363813	53292	
		(D+EQx)/1.50	-109745	-375	1912	-4142	-128392	6075	
		(D+EQy)/1.50	-198245	-13000	-3249	23068	-362192	-396910	
		(D+W)/1.25	-158172	-1999	-1477	-3553	-277301	-41055	
		(D+T)/1.15	-159445	-2956	-1313	-3436	-288874	-38612	
A5		D	-142616	220	-5197	-12	-168298	4849	
A5=1.067m2		L	-12222	192	-664	5606	-25040	11492	
		W	-14779	-885	336	5787	-6447	-25981	
		EQx	-2275	128	2019	919	108441	2021	
		EQy	-62957	-3066	-342	22803	-71987	38029	
	2	T	3257	-833	-40	-284	-622	-48624	251.7
		D+L	-154838	413	-5860	5594	-193338	16341	
		(D+EQx)/1.50	-96594	232	-2119	605	-39905	4580	
		(D+EQy)/1.50	-137049	-1897	-3692	15194	-160190	28585	
		(D+W)/1.25	-125916	-532	-3889	4620	-139796	-16906	
		(D+T)/1.15	-121182	-533	-4554	-257	-146887	-38066	
A6		D	-145341	167	1193	519	30868	2387	
A6=0.954m2		L	-11696	-213	185	4943	8912	-4860	
		W	-7844	-655	371	-1047	7769	-6730	
		EQx	-1478	115	184	251	9194	1689	
		EQy	-33456	-2403	2479	-9842	51969	-24600	
	6	T	2614	-54	-51	-61	-847	-3136	194.3
		D+L	-157037	-45	1378	5462	39780	-2473	
		(D+EQx)/1.50	-97879	188	918	513	26709	2717	
		(D+EQy)/1.50	-119198	-1490	2448	-6215	55225	-14809	
		(D+W)/1.25	-122548	-391	1251	-422	30910	-3475	
		(D+T)/1.15	-124110	99	992	398	26105	-651	
SEC20		D	-140237	19	940	14	10784	-295	
A7=0.796m2		L	-10982	70	171	4247	6403	-2274	
		W	4677	-163	-6	-414	206	7813	
		EQx	-340	-1	73	2	1324	-5	
		EQy	10860	-582	-25	-1709	837	18791	
	11	T	2093	-3	0	-1	4	-522	206.7
		D+L	-151219	88	1112	4261	17187	-2568	
		(D+EQx)/1.50	-93718	12	676	11	8072	-200	
		(D+EQy)/1.50	-86251	-375	610	-1130	7747	12331	
		(D+W)/1.25	-108449	-116	747	-320	8792	6014	
		(D+T)/1.15	-120125	14	818	11	9381	-710	

Remarks: N=Axial force Sx=Horizontal shear force Sy=Vertical shear force
T=Torsion Mx=Vertical Bending Moment My=Horizontal Bending Moment
σ=Stress

Source: JICA Study Team

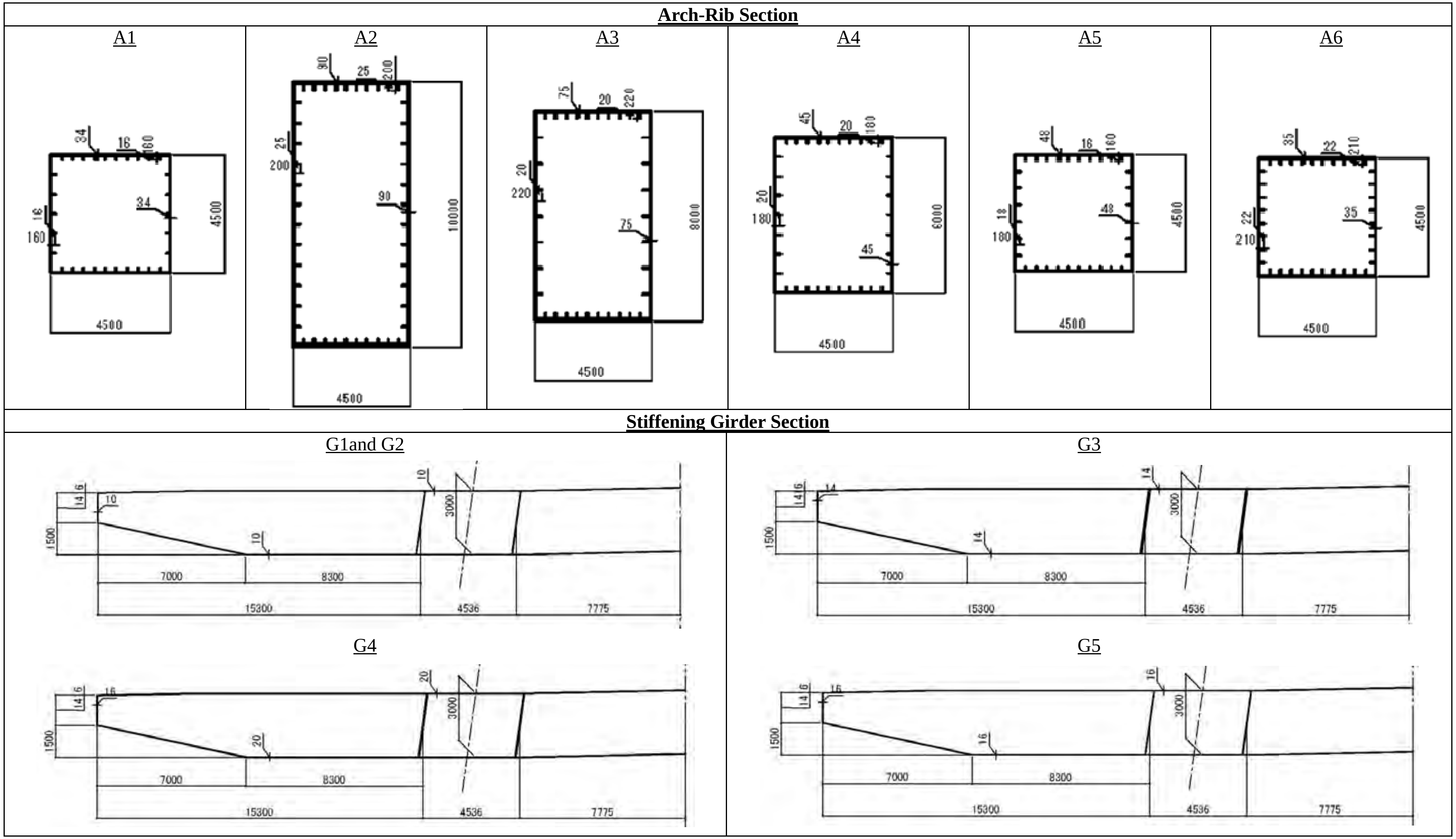
Table 12.4 Summary of Stress Calculation (2/2)

Stiffening Girder

	Frame	Case	軸力	水平剪断	鉛直剪断	ねじり	鉛直曲げ	水平曲げ	最大応力度
			N	Sx	Sy	T	Mx	My	σ
			kN	kN	kN	kNm	kNm	kNm	N/mm2
G1,G2 G2=0.559m2	324	D	34484	−558	−5309	833	−56726	−4500	179.3
		L	3810	345	−982	−7691	−4390	−6682	
		W	−595	319	36	2145	628	4485	
		EQx	14638	44	−162	23	−4936	396	
		EQy	−2605	3102	166	20201	3806	61379	
		T	−12383	153	−73	−87	−954	3816	
		D+L	38294	−213	−6290	−6858	−61116	−11182	
		(D+EQx)/1.50	32748	−343	−3647	571	−41108	−2736	
		(D+EQy)/1.50	21253	1696	−3428	14023	−35280	37919	
		(D+W)/1.25	27111	−191	−4218	2383	−44878	−12	
		(D+T)/1.15	19218	−353	−4679	649	−50156	−595	
G3 G3=0.771m2	382	D	76918	115	−1198	−71	−22240	−1451	116.3
		L	6337	400	−780	7011	−3465	−13170	
		W	−719	617	21	1387	−787	−22227	
		EQx	4931	60	1016	227	13681	1236	
		EQy	−4416	6163	129	12710	−6067	−180378	
		T	−12662	−660	−42	−178	−772	−7386	
		D+L	83255	515	−1978	6940	−25705	−14621	
		(D+EQx)/1.50	54566	117	−121	104	−5706	−143	
		(D+EQy)/1.50	48335	4185	−712	8426	−18871	−121219	
		(D+W)/1.25	60959	585	−942	1053	−18422	−18942	
		(D+T)/1.15	55875	−475	−1078	−216	−20010	−7684	
G3 G3=0.771m2	680	D	53205	1116	3509	−1282	−40687	−10394	203.1
		L	6486	−899	1166	13124	−7112	33402	
		W	−1101	744	411	−18423	1986	−90233	
		EQx	14182	−270	−963	1184	13255	2281	
		EQy	−4337	8496	4015	−135261	−24302	−863735	
		T	−20747	593	69	−593	377	−5452	
		D+L	59691	217	4675	11842	−47799	23008	
		(D+EQx)/1.50	44925	564	1698	−65	−18288	−5409	
		(D+EQy)/1.50	32578	6408	5016	−91029	−43326	−582753	
		(D+W)/1.25	41683	1488	3136	−15764	−30960	−80502	
		(D+T)/1.15	28225	1486	3112	−1630	−35052	−13780	
G4 G4=1.084m2	268	D	20335	−1717	−13834	1697	−219278	−19963	209.9
		L	4849	−872	−1605	−20962	−22689	−24590	
		W	−3061	−1639	−1521	17494	−21283	10897	
		EQx	30365	490	848	−1347	42062	7018	
		EQy	−37732	−19884	−11311	160253	−156143	−336752	
		T	−31754	−297	−206	822	−3285	−17593	
		D+L	25184	−2589	−15439	−19265	−241967	−44553	
		(D+EQx)/1.50	33800	−818	−8657	233	−118144	−8630	
		(D+EQy)/1.50	−11598	−14401	−16764	107967	−250281	−237810	
		(D+W)/1.25	13820	−2685	−12284	15353	−192449	−7253	
		(D+T)/1.15	−9929	−1752	−12208	2191	−193533	−32657	
G5 G5=0.861m2	276	D	34215	−275	−3354	1124	15678	−1617	111.5
		L	5508	−468	−827	−13434	8878	−13657	
		W	4370	−971	−51	−2099	350	46434	
		EQx	17010	2	126	−277	7163	114	
		EQy	32191	−11894	−161	9234	2387	420093	
		T	−30854	−55	0	168	−61	−2417	
		D+L	39723	−742	−4181	−12309	24556	−15274	
		(D+EQx)/1.50	34150	−182	−2152	565	15228	−1002	
		(D+EQy)/1.50	44271	−8113	−2343	6906	12044	278984	
		(D+W)/1.25	30868	−997	−2724	−779	12822	35853	
		(D+T)/1.15	2922	−287	−2916	1124	13580	−3508	

Remarks: N=Axial force; Sx=Horizontal shear force; Sy=Vertical shear force; T=Torsion; Mx=Vertical Bending Moment; My=Horizontal Bending Moment; σ=Stress

Source: JICA Study Team



Source: JICA Study Team

Figure 12.21 Designed Sections based on the Stress Calculation

v. Design of Substructure and Foundation

Design Policy

Piers and Foundations Supporting the Arch Springing

The piers should be a reinforced concrete structure to support the external forces such as horizontal forces and bending moment transmitted from the arch structural system.

As for the foundation, a spread foundation is used where the bearing strata appear at shallow depth, and a well foundation with steel pipe sheet piles (SPSP) is used where the bearing strata are deep.

Piers Supporting the End Bearings

Piers should support both the end span bearings of the arch bridge (main bridge) and the approach viaducts. As the piers are of a high-rise structure and likely to receive large seismic force in the transverse direction, the piers should be a reinforced concrete structure, but not a fully concrete-filled monolith to reduce its own weight.

The beam of the pier consists of steel for the reduction of moment on the bottom of the pier in the case of an earthquake.

Foundations supporting Arch Springing and End Bearing (East side)

The East pier of the Arch-rib or the East pier of the end bearing is on the ground. The bearing ground (rock) lies 14m under the surface of the earth. The spread foundation is adapted for this point for the purpose of cost benefit.

Foundations supporting Arch Springing (West side)

The West foundation of the Arch-rib is under water. The bearing ground lies about 15m under the riverbed. The caisson foundation or the steel pipe sheet pile (see Section 20.3.3) is adaptable for this location, the reason being that a reinforced concrete cast-in-place pile foundation would not be applicable.

Regarding the caisson foundation, it would be unrealistic for this point because of the area of construction. For this reason, the steel pipe sheet pile is applied, which is effective in reducing the foundation installation.

Foundations supporting the End Bearings (West side)

A reinforced concrete cast-in-place pile foundation, which is widely used in Panama, shall be employed.

Design Principle

Materials to be used

Concrete Strength: 30MPa

Re-bars: SD 345

External Forces Transmitted to Substructures

For the purpose of the substructures and foundation design, Table 12.5 shows the external forces transmitted from the superstructure, and Figure 12.22 shows the step-wise reactions transmitted to the substructure during bridge erection.

Table 12.5 External Forces transmitted from the Superstructure (Main Bridge)

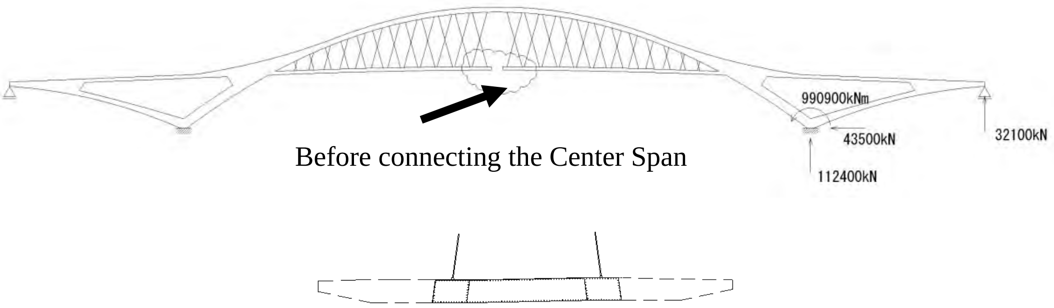
	Erection STEP	Longitudinal Lateral Reaction [kN]	Vertical Reaction [kN]	Rotational Moment [kNm]
End Pier	STEP1	0	32100	0
	STEP2	0	24900	0
	STEP3 (Dead)	0	23500	0
	Dead + Live	0	29850	0
Arch Bottom Pier	STEP1	43500	112400	990900
	STEP2	5	120100	233600
	STEP3 (Dead)	69600	171900	125000
	Dead + Live	94600	196350	384990

	Load Case	Longitudinal Lateral Reaction [kN]	Vertical Reaction [kN]	Rotational Moment [kNm]
End Pier	Longitudinal EarthQuake Effect + Dead Load	4240	80200	0
Arch Bottom Pier	Longitudinal EarthQuake Effect + Dead Load	207960	343800	1444000

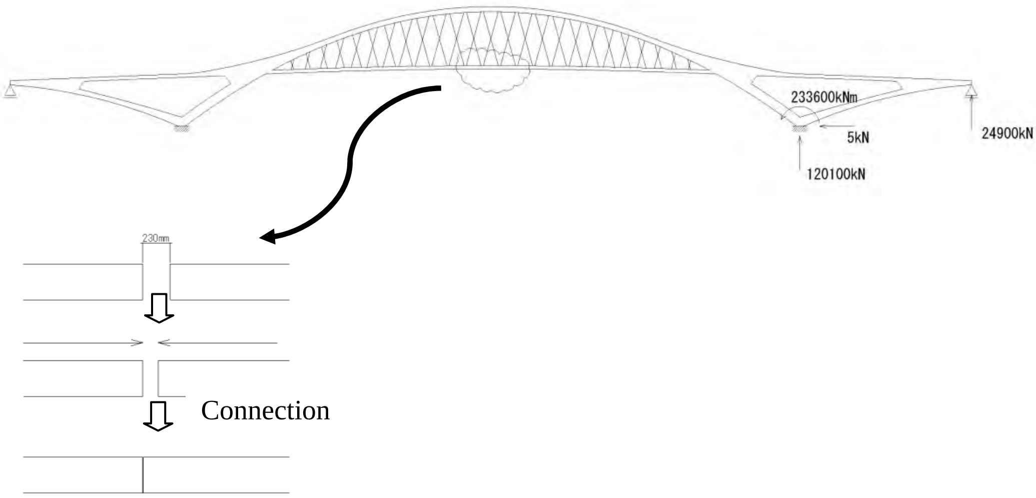
	Load Case	Transverse Lateral Reaction [kN]	Vertical Reaction [kN]	Rotational Moment [kNm]
End Pier	Transverse EarthQuake Effect + Dead Load	4240	80200	65000
Arch Bottom Pier	Transverse EarthQuake Effect + Dead Load	68760	343800	2892960

Source: JICA Study Team

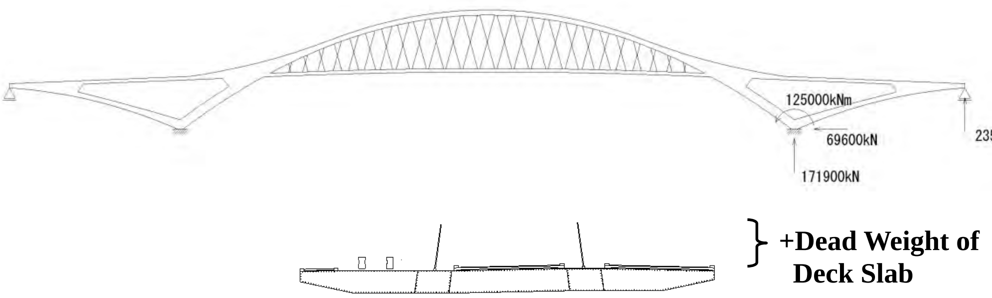
Step-1



Step 2



Step 3



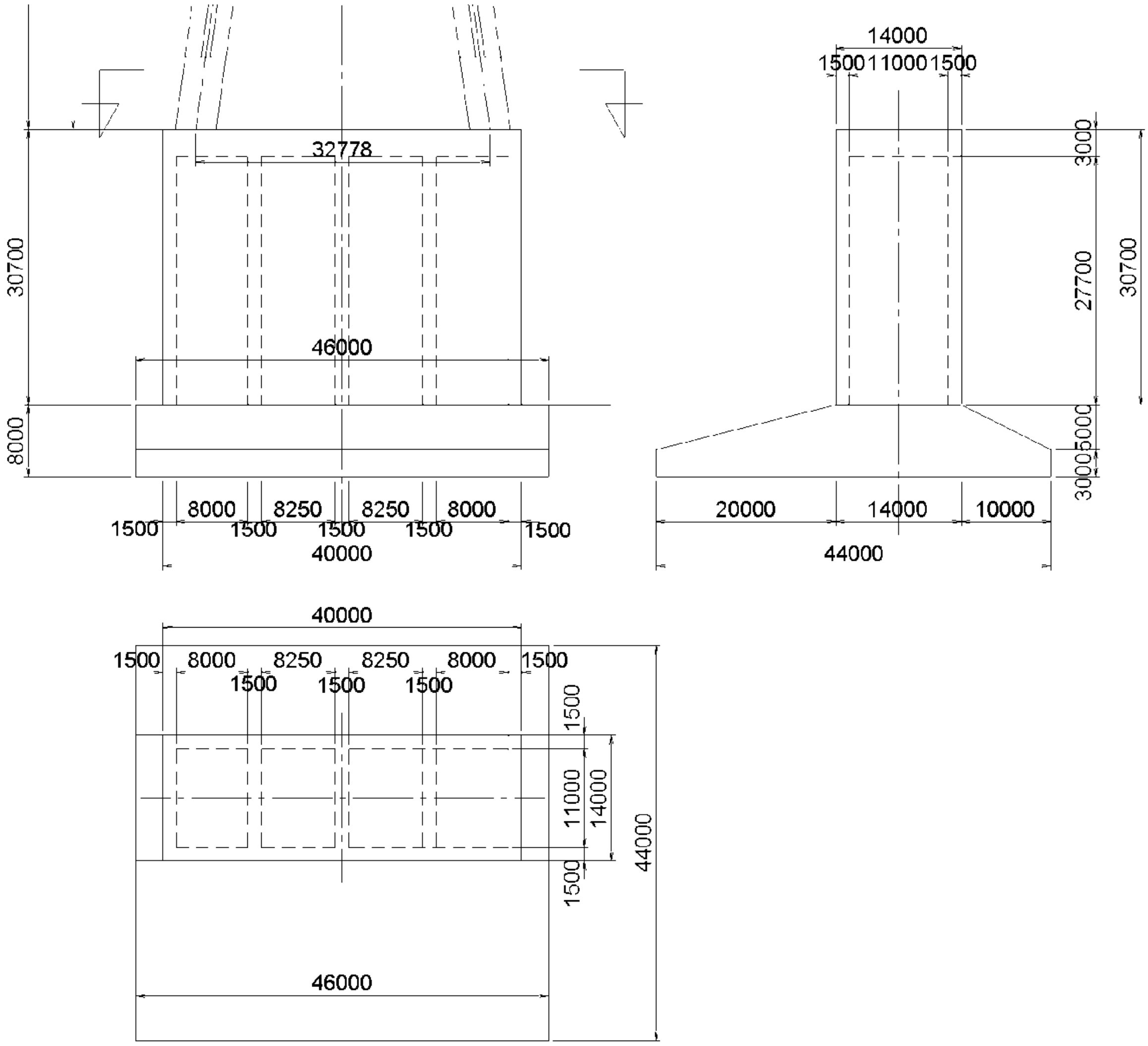
Source: JICA Study Team

Figure 12.22 Step-wise Reactions transmitted to the Substructure

Design Outcomes

Figures 12.23 to 12.26 show the design outcomes for the substructure and foundation.

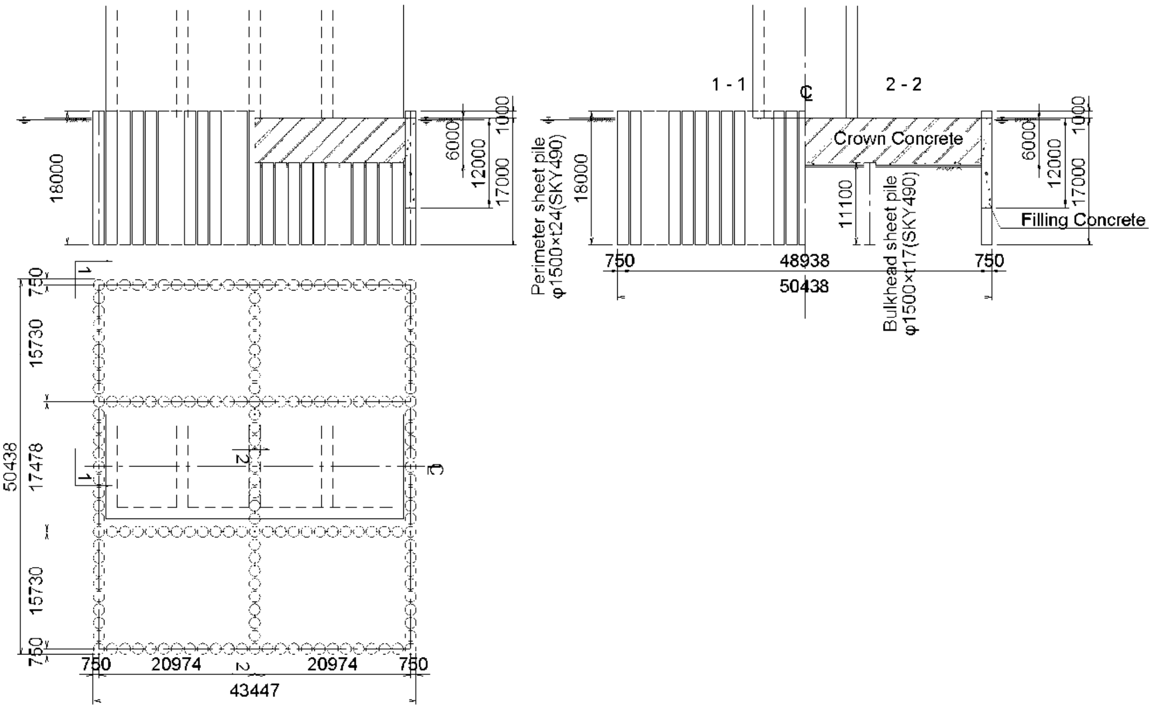
Pier and Foundation at the P31 Pier (Spread Foundation)



Source: JICA Study Team

Figure 12.23 Outcomes of the Substructure and Foundation Designs (1)

Well Foundation with Steel Pipe Sheet Piles at the P32 Pier (SPSP)

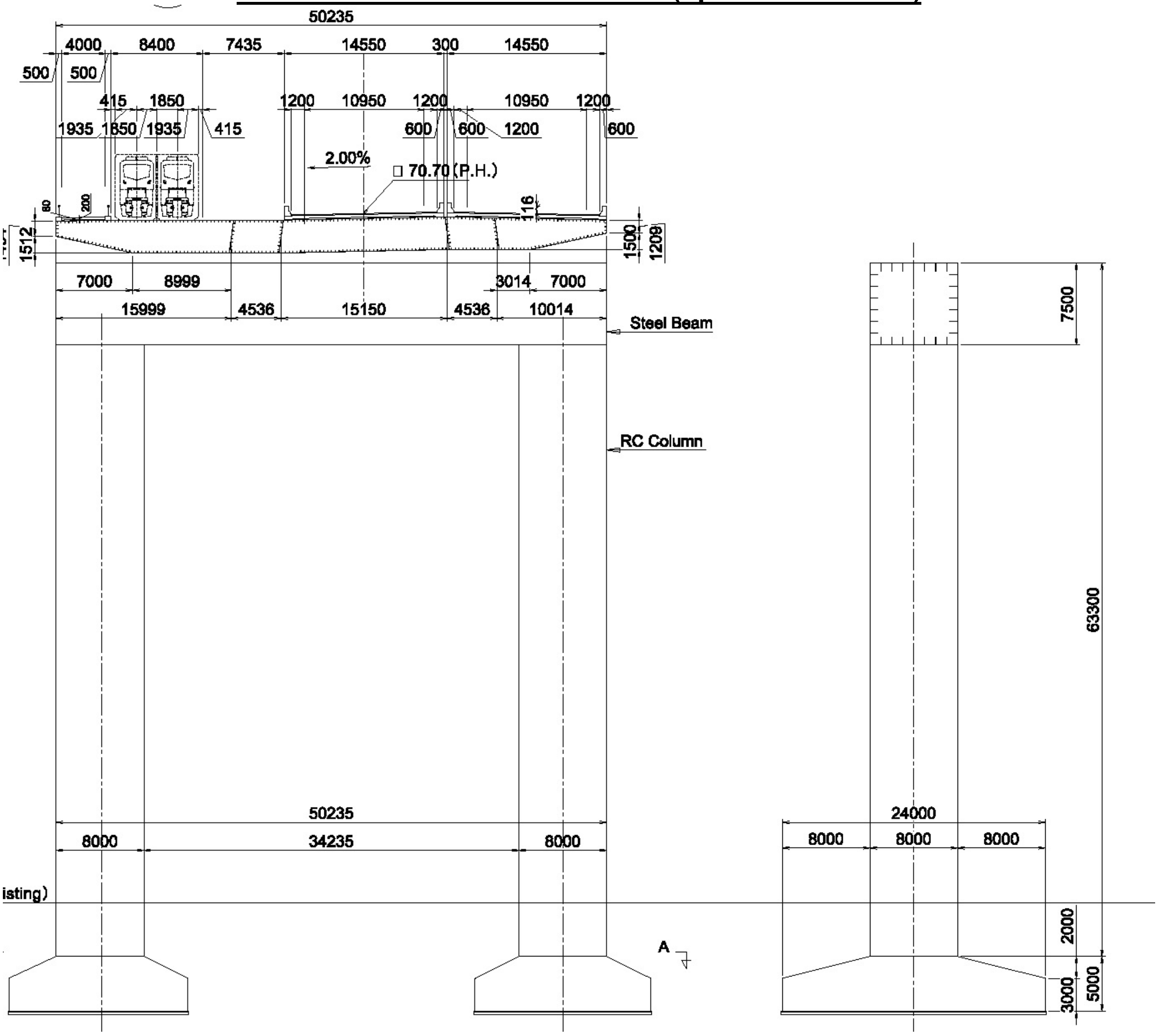


Source: JICA Study Team

Figure 12.24 Outcomes of the Substructure and Foundation Designs (2)

It is assumed that the bottom of the SPSP will penetrate deeply into the bearing ground for the bearing force. The bearing force is reduced up to a ratio of 5 of the embedded length (embedded length / radius of pile). At the same moment, it is necessary to exercise constraint to prevent pile break during embedding (Japan specifications for highway bridges will be applied). A bearing force test needs to be carried out for the sheet-pile driving.

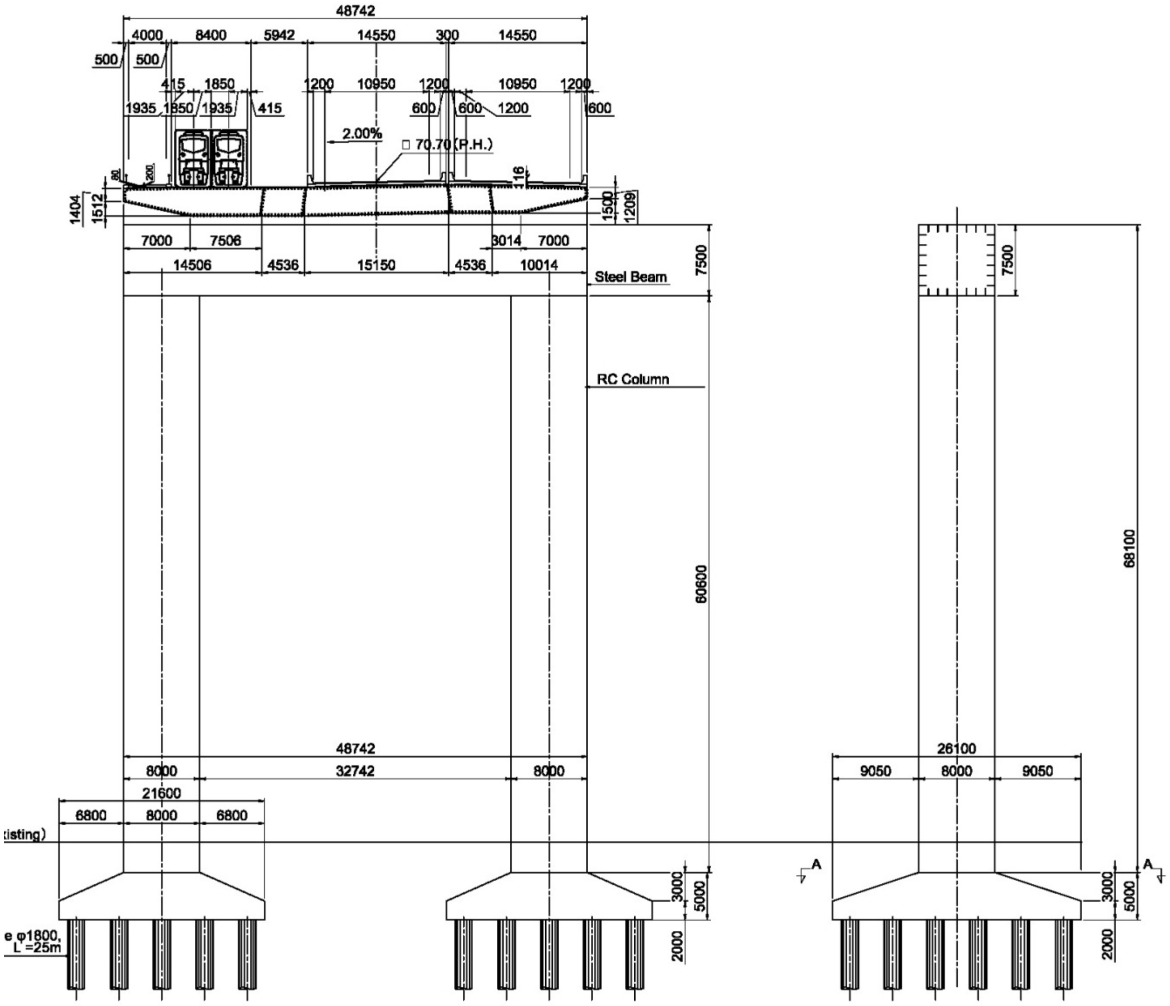
Pier and Foundation at the P30 Pier (Spread Foundation)



Source: JICA Study Team

Figure 12.25 Outcomes of the Substructure and Foundation Designs (3)

Pier and Foundation at the P33 Pier (Cast in Place Pile Foundation)



Source: JICA Study Team

Figure 12.26 Outcomes of the Substructure and Foundation Designs (4)

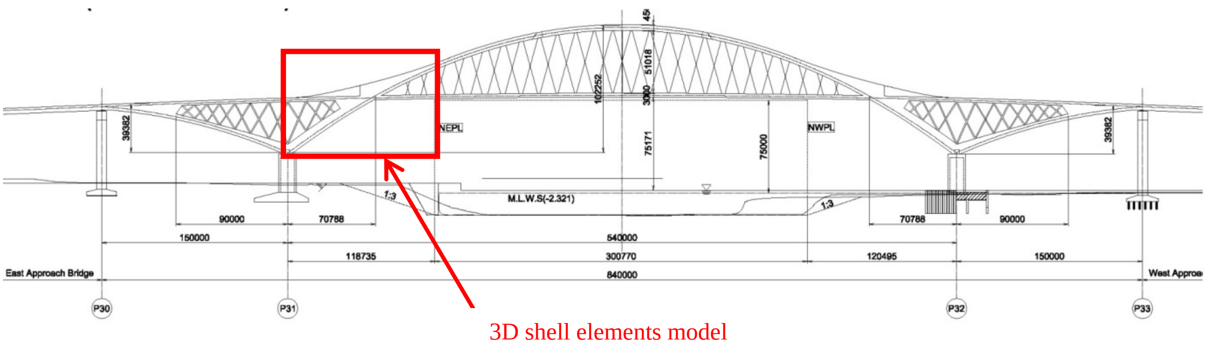
vi. Detail Analysis of the main structure

The connections between the arch-rib and the stiffening girder are carried out with FEM analysis.

<u>Abstract of the FEM analysis</u>

The stress transferring mechanism of the connection between the arch-rib and the stiffening girder is complicated. There are the axial force of the dead load and the moment of seismic load for out-of-plane at the rigid connection. This connection is carried out with the 3D FEM analysis. The properties of stress transferring and stress concentration are verified.

<u>Cross point between arch-rib and stiffening girder</u>



Source: JICA Study Team

Figure 12.27 Modeling of cross point between the arch-rib and the stiffening girder

<u>Analysis conditions</u>

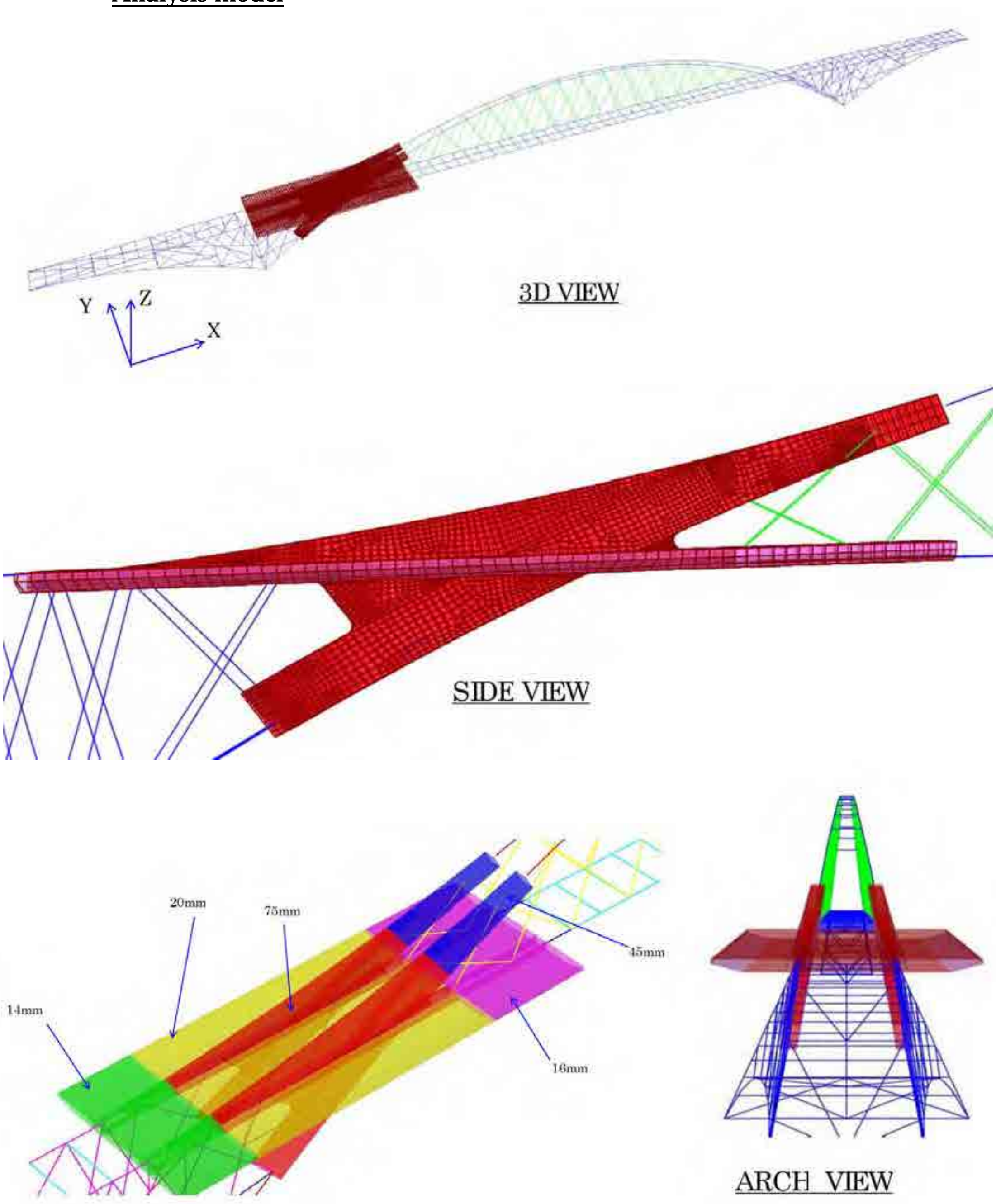
Table 12.6 shows the analysis conditions.

Table 12.6 Analysis Conditions

Item	Content	
Element Type	3D shell element、3D line element	
Material	Elastic material, E module 2.0×10^5N/mm2、Poisson ratio 0.3	
Modeling Scope	Total bridge (3D shell element、about 110m from P31 to arch span)	
Load	Same Load as the superstructure analysis	
Boundary condition	Rigid element between 3D shell elements and 3D line element	
Restricted condition	Fixed points at the bottom of arch-rib	
Case	CASE1	Dead Load
	CASE2	Seismic Load (direction Y)
	CASE3	Dead Load+ Seismic Load (direction Y)

Source: JICA Study Team

Analysis model



Source: JICA Study Team

Figure 12.28 Analysis Model

Results of FEM analysis

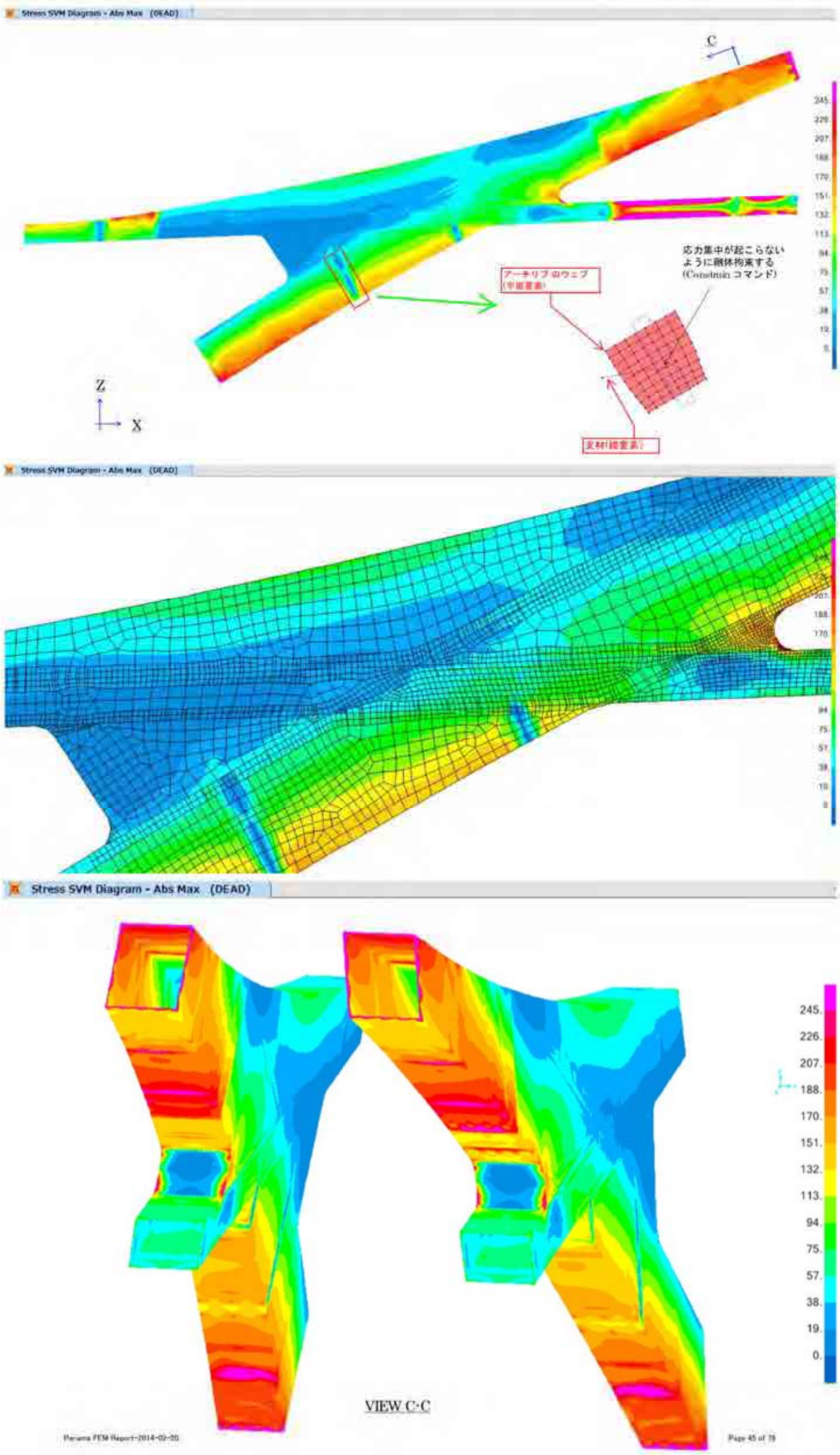
The results of the FEM analysis are calculated with Von Mises stress. As a result, the fillet at the corner of the connection between the arch-rib and the stiffening girder has the stress concentration.

The maximum value of stress concentration (CASE3: Dead Load + Seismic Load) is

402.1 N/mm2 (average of element's value) < 500 N/mm2 (the yield point of SBHS500)

The results of the FEM analysis are as follows.

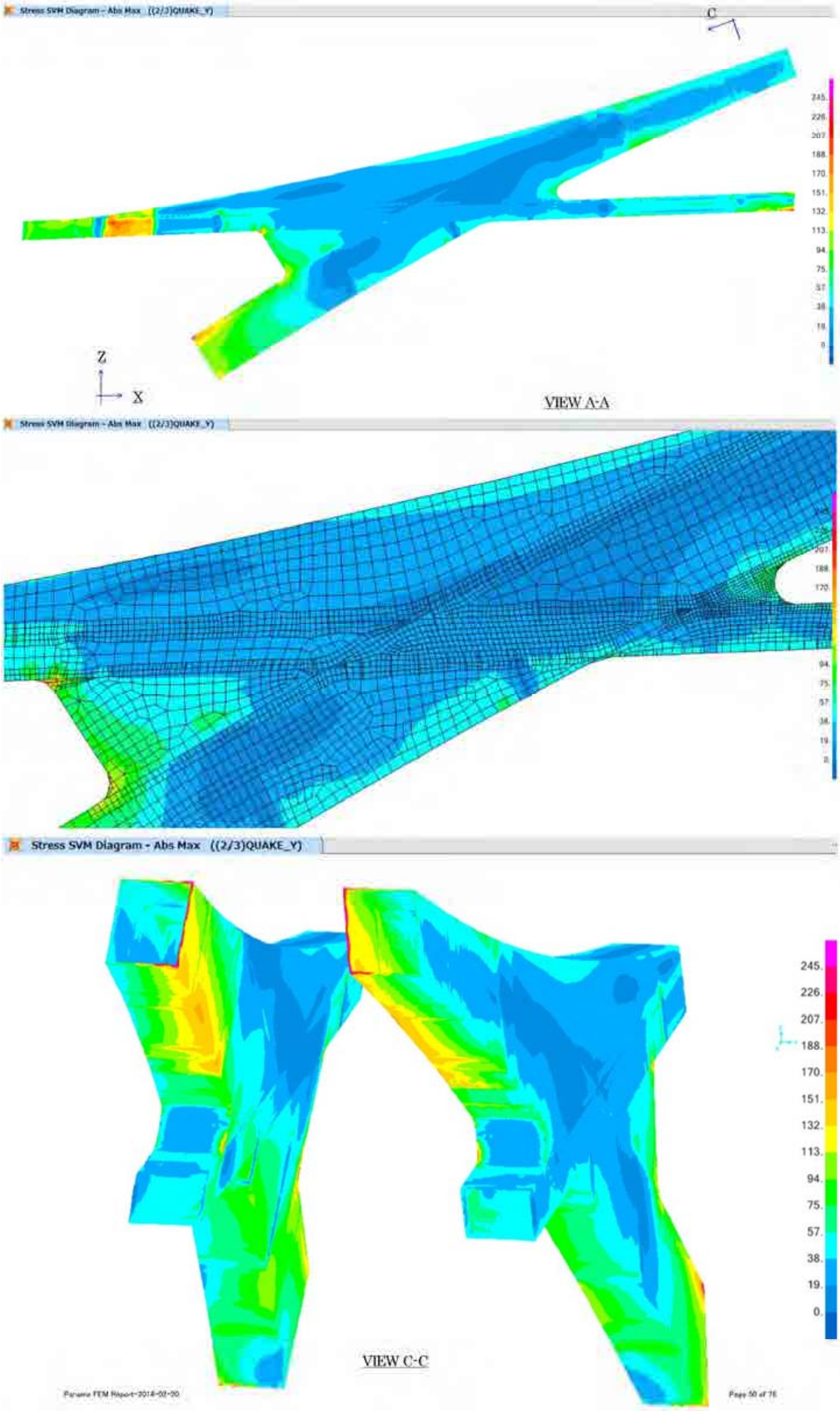
<u>CASE1</u> Dead Load



Source: JICA Study Team

Figure 12.29 Results of the FEM analysis CASE1

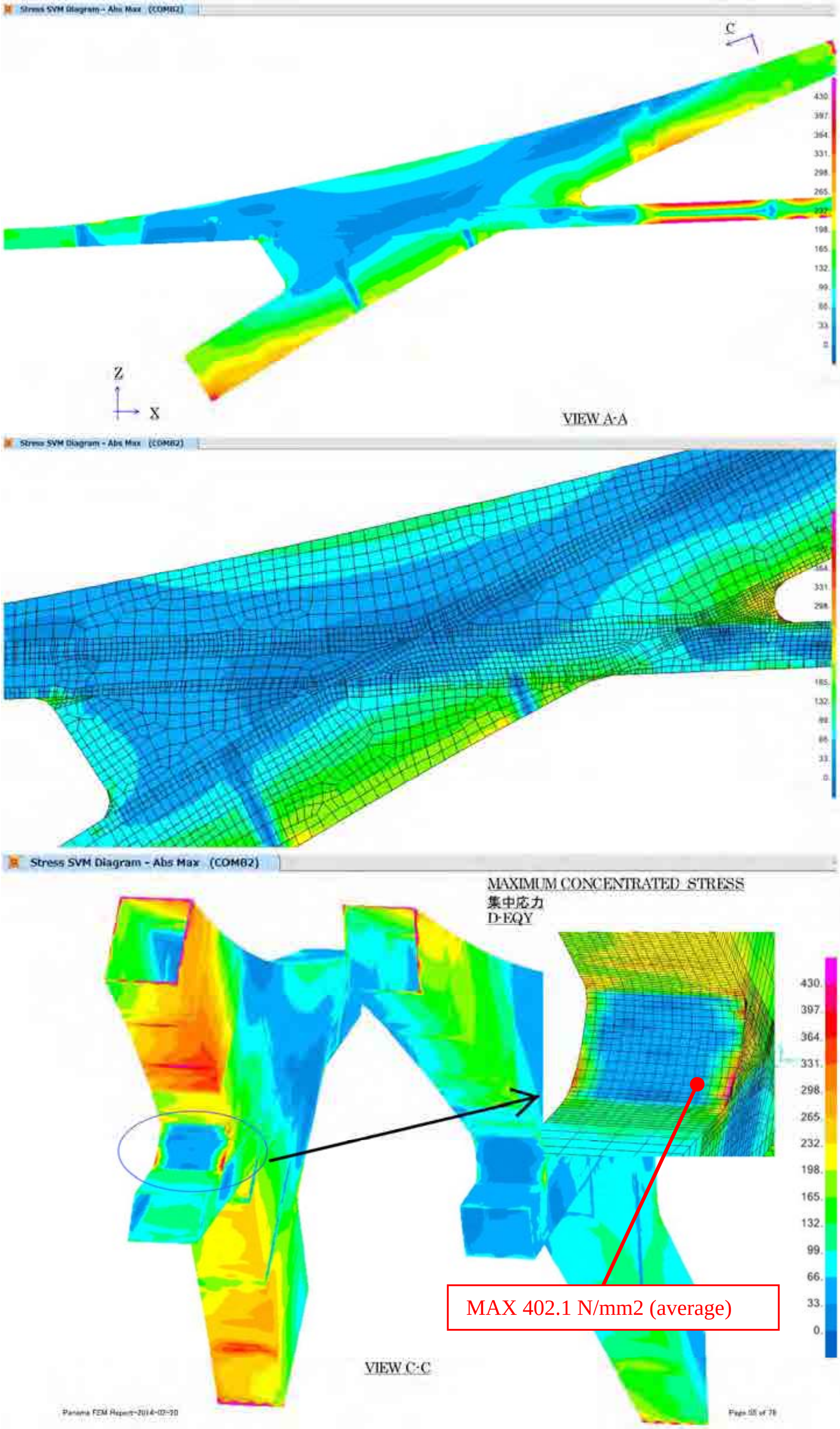
<u>CASE2</u> Seismic Load (Direction Y)



Source: JICA Study Team

Figure 12.30 Results of the FEM analysis CASE2

<u>CASE3</u> Dead Load + Seismic Load (Direction Y)



Source: JICA Study Team

Figure 12.31 Results of the FEM analysis CASE3

2) Approach Viaduct

i. Design Principles of Planning and Design

<u>Superstructure</u>

The types of superstructure have been selected by the span lengths as shown in Table 12.7 taking into consideration the structural aspect and economic aspect. In the case of 40m lengths or less, the PC-I girder was chosen because it is often applied in Panama. For span lengths greater than 40m the PC box girder and the steel box girder were compared. As a result of the comparison, the construction cost of the PC box girder was found to be 1.34 times greater than that of the steel box girder. Therefore, the steel box girder is economically advantageous.

Table 12.7 Structure Types by Span Lengths

No.	Span Length	Structure Type
1	40m or less	PC-I Girder
2	Over 40m	Steel Box Girder

Source: JICA Study Team

<u>Substructures</u>

Inverted T type abutments were selected taking into consideration the structural aspect and economic aspect.

As for the piers, their structural types differ depending on whether the pier is independently carrying only the road viaduct or is a combined structure carrying both the Metro Line 3 and the road viaduct as per Table 12.8.

Table 12.8 Pier Types

No.	Independent or Combined Structure	Structure Type
1	Independent	Cantilever Pier
2	Combined	Portal Rigid Frame Pier

Source: JICA Study Team

<u>Foundations</u>

The type of foundation was selected based on the results of the geological survey.

Flyover No.1 and No.2: Since the depth of the support layer is about 15m, the Cast-in-place pile (φ1500) was selected, which is common in Panama.

East Bank Approach Bridge: Since the depth of the support layer is less than 10m, the Spread footing foundation was selected.

West Bank Approach Bridge and Access bridges to the Bridge of the Americas: Since the depth of the support layer is more than 20m, the Cast-in-place pile (φ1800) was selected.

<u>Conjunction between the Approach Viaduct and Metro Line 3</u>

The Metro Line 3 Project has planned to locate the Balboa Station before the 4th Panama Canal Bridge and the Panama Pacifico Station after the bridge. The conjunctions with Metro Line 3 were studied taking into consideration the longitudinal profile of Metro Line 3 and the planned deck level of the 4th Panama Canal Bridge.

Table 12.9 shows the conjunction points between Metro Line 3 and the 4th Panama Canal Bridge.

On the other hand, the maximum span length used in Metro line-3 is 50m in this study. Therefore in the case of the steel box girder and the arch bridge the combined pier structure will be used. The PC-I girder structure will used for the individual pier structures.

Table 12.9 Conjunction Points with Metro Line 3

No.	Location	Chainage (KM)
1	East Bank Side	2+717
2	West Bank Side	5+065

Source: JICA Study Team

ii. Bridge Length and Span Arrangement

Locations of Abutments

The locations of the abutments were determined to be where the abutment height is 10m.

Table 12.10 shows the chainage of the abutment locations.

Table 12.10 Locations of Viaduct Abutments

No.	Viaduct Name	Abutment ID	Chainage (KM)
1	East Bank Approach Viaduct	Abutment A5	KM2+847
2	West Bank Approach Viaduct	Abutment A6	KM5+390

Source: JICA Study Team

Bridge Length and Span Arrangement

The span arrangements were determined based on the following:

- Avoid crossing existing structures
- Adjust the span length based on the economic aspect

Table 12.11 shows the most favorable span lengths by pier heights and types of approach viaducts to the 4th Panama Canal Bridge, and Table 12.12 shows the bridge lengths and span arrangements.

Table 12.11 Most Favorable Span Length by Pier Heights

No.	Pier Height	Most Favorable Span Lengths (Viaduct Types)
1	30m or less	40m (PC-I Girder)
2	Over 30m to 50m	60m (Steel Box Girder)
3	Over 50m	100m (Steel Box Girder)

Source: JICA Study Team

Table 12.12 Bridge Lengths and Span Arrangements

No.	Viaduct Name	Chainage (KM)	Bridge Length	Span Arrangement
1	East Bank Approach	2+847~3+380	533m	43m+60m+50m+90m+2@100m+90m
2	West Bank Approach	4+220~5+390	1,170m	90m+3@100m+80m+5@60m+40m+9@40m

Source: JICA Study Team

iii. Superstructure Design

Since the total width of the superstructure is great, the superstructure was divided into three parts, from the view point of economic benefit; namely, a 3-lane road carriageway towards the city center, a 3-lane road carriageway toward Arraijan, and a 2-track monorail with a 4m sidewalk.

Figure 12.33 shows the typical cross section of the East Bank Approach Viaduct and Figure 12.34 shows that of the West Bank Approach Viaduct.

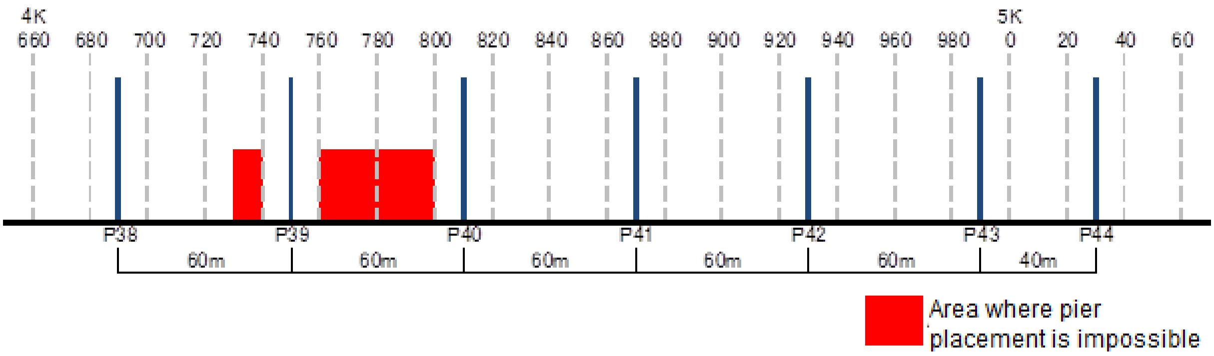
In the East Bank Approach Bridge, the piers up to 30m in height carry steel box girder with a maximum span length of 60m. Piers higher than 30m have steel box girder with a maximum span length of 90m. For the substructure the portal rigid frame pier is used.

West Bank Approach Bridge No.1; for piers 40m or higher, the steel box girder is selected for the superstructure, which has a maximum span length of 100m.

West Bank Approach Bridge No.2; the pier height varies from 10m to 40m,this section is integrated with the monorail with some crossing structure. Therefore, the steel box girder superstructure is selected with a maximum span length of 60m.

West Bank Approach Bridge No.3; since the pier height is less than 10m, with no crossing structure, the PC-I girder superstructure is selected.

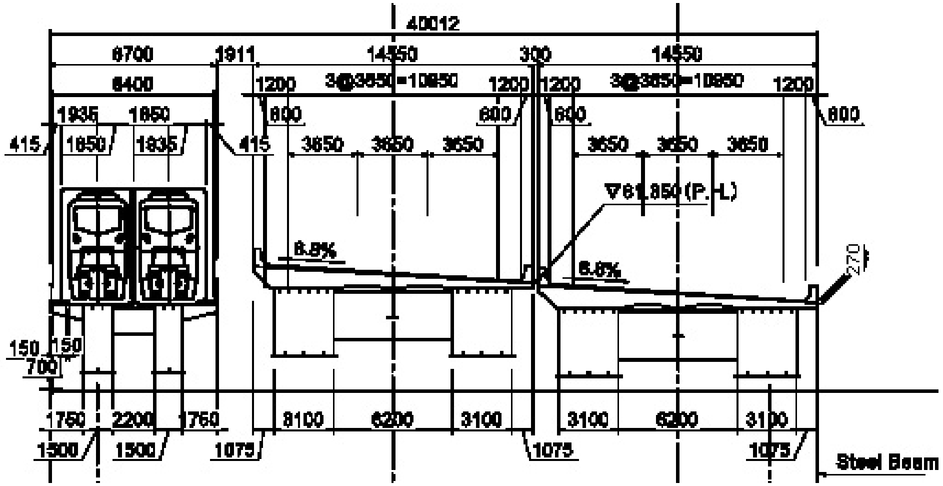
Figure 12.32 shows the span arrangement of the West Bank Approach Bridge No.2 with the crossing structure.



Source: JICA Study Team

Figure 12.32 Span arrangement of the West Bank Approach Viaduct No.2

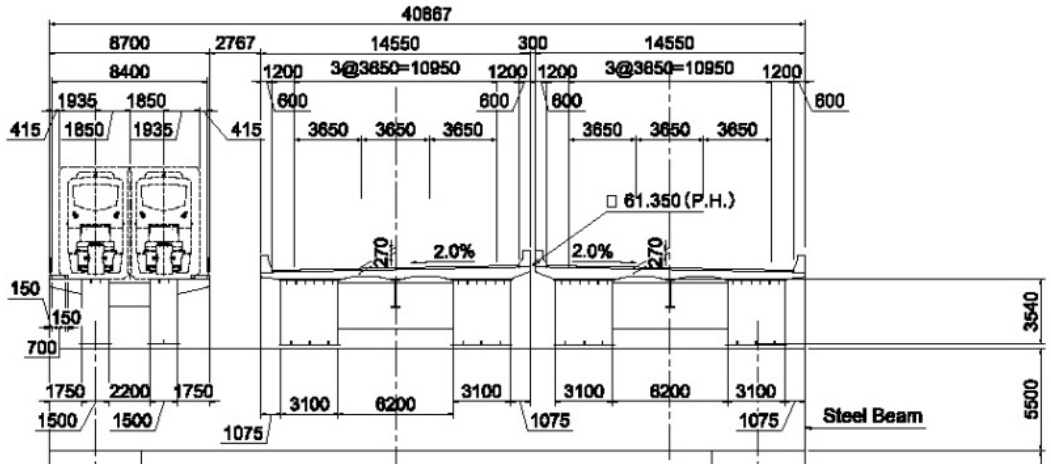
Superstructure: Steel Box Girder



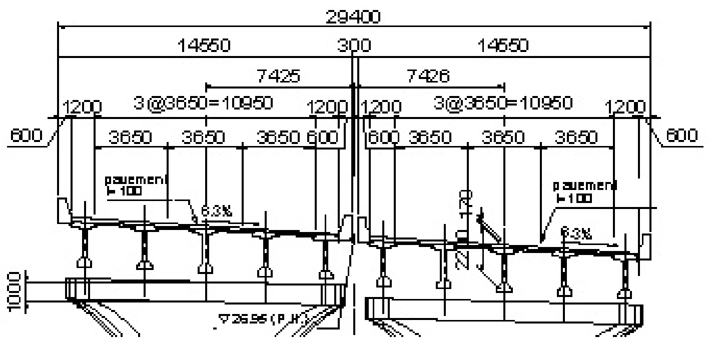
Source: JICA Study Team

Figure 12.33 Typical Cross Section of the East Bank Approach Viaduct

Superstructure: Steel Box Girder



Superstructure: PC-I Girder



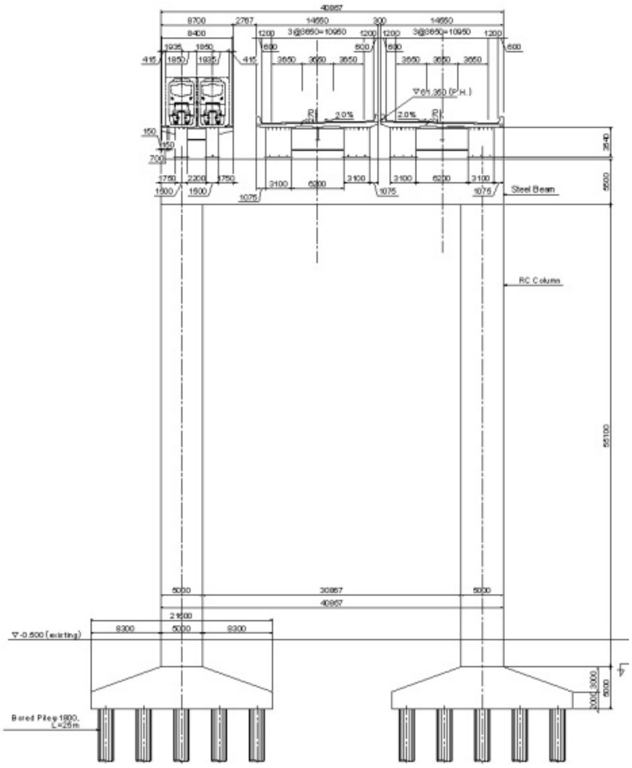
Source: JICA Study Team

Figure 12.34 Typical Cross Section of the West Bank Approach Viaduct

iv. Substructure and Foundation Design

Combined Section of Metro Line 3 and Approach Viaduct

A portal rigid frame was employed in the section where the Metro Line 3 and the approach viaduct are combined as per Figure 12.35.



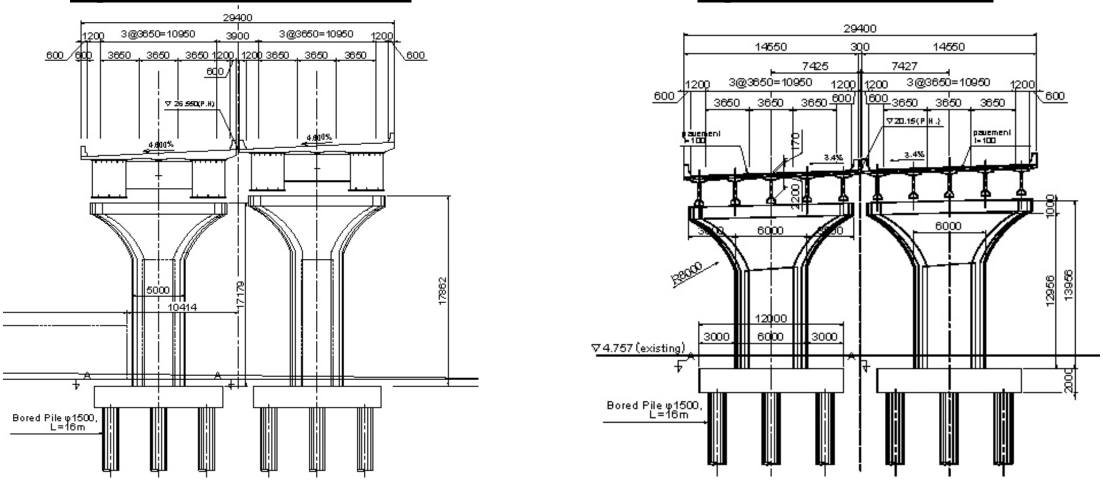
Source: JICA Study Team

Figure 12.35 Portal Rigid Frame for the Combined Section of Metro Line 3 and Approach Viaduct

Independent (Separate) Section

In the section where the structures of Metro Line 3 and the approach viaducts to the 4th Panama Canal Bridge are built independently, cantilever type piers were employed as per Figure 12.36.

Superstructure: Steel Box Girder **Superstructure: PC-I Girder**



Source: JICA Study Team

Figure 12.36 Cantilever type Piers at the Independent (Separate) Section

(2) Flyover

1) Principles for Planning and Design

As with the approach viaduct discussed in 12.4.1(1)2)i, flyovers were also planned and designed.

2) Bridge Length and Span Arrangement

Abutment Locations

As with the approach viaduct, the places where the abutment height is 10m were selected for the abutment locations.

Table 12.13 shows the abutment locations.

Table 12.13 Abutment Locations (Flyover)

No.	Flyover Name	Abutment ID	Chainage
1	Flyover No.1	Abutment A1(Inbound)	KM1+070
2		Abutment A1(Outbound)	KM1+050
3		Abutment A2	KM1+570
4	Flyover No.2	Abutment A3	KM2+000
5		Abutment A4	KM2+740

Source: JICA Study Team

Bridge Length and Span Arrangement

Table 12.14 shows the bridge lengths and span arrangements of the flyovers.

Table 12.14 Bridge Length and Span Arrangements of Flyovers

No.	Flyover Name	Bridge Length	Span Arrangement
1	Flyover No.1(Inbound)	500m	6@40m+2@50m+60m+2@50m
2	Flyover No.1(Outbound)	520m	2@40m+30m+4@40m +50m+2@60m+45m+35m
3	Flyover No.2	740m	5@40m+2@30m +60m+4@90m+60m

Source: JICA Study Team

3) Superstructure

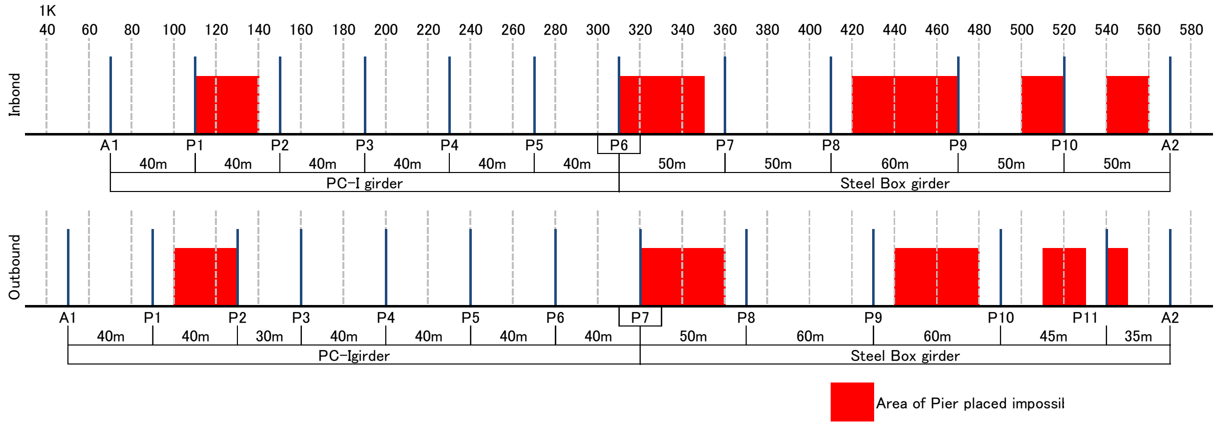
The typical cross sections of the flyovers are shown in Figure 12.40.

The pier heights in Flyover No.1 are less than 10m., however it has many cross structures.

Therefore the Bridge plan is as follows.

- A separate span arrangement is applied to each outbound and inbound line.
- From the A1 abutment to 1K +320, the number of cross-structures is less and the distances where piers cannot be placed are less than 40m. Therefore in this range the PC-I girder with a 40m span is applied.
- From 1K+320 to the A2 abutment, the number of cross-structures is greater and the distance where it is impossible to place piers is 60m. Therefore in this range the Steel box girder with a 60m span is applied.

Figure 12.37 shows the span arrangement of Flyover No.1 with the cross structures.



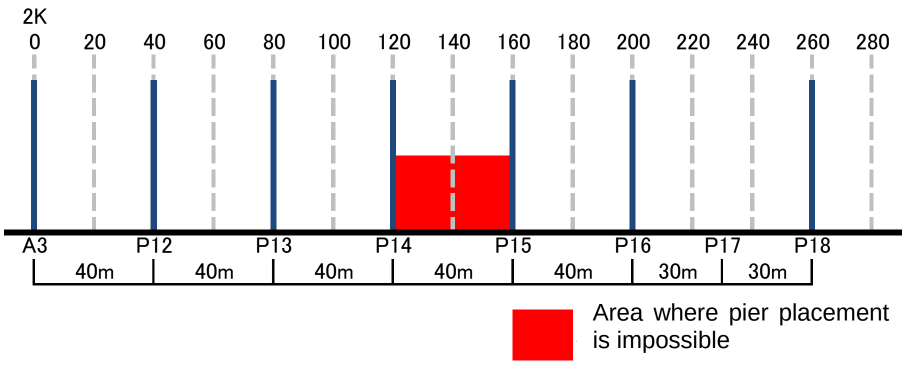
Source: JICA Study Team

Figure 12.37 Span Arrangement of Flyover No.1

Flyover No.2 is divided into two depending on the conditions of the cross-structures.

Figure 12.38 shows the span arrangement of Flyover No.2-1.

Flyover No.2-1 is a PC-I girder bridge with a span length of 40m. The span arrangement also avoids the ACP communication facility.

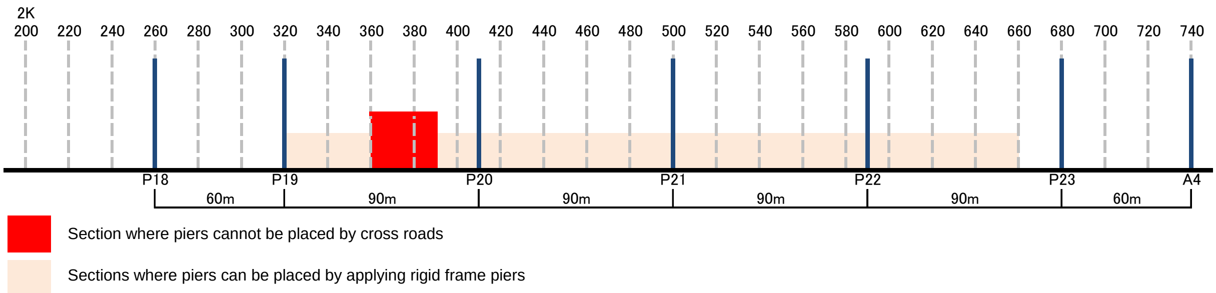


Source: JICA Study Team

Figure 12.38 Span Arrangement of Flyover No.2-1

Figure 12.39 shows the span arrangement of Flyover No.2-2.

Because the angle of intersection of the crossing street is shallow, a portal rigid frame pier will be used if a pier is needed in this range. Since the extension for the rigid frame piers is 320m, steel box girders with a 90m span length will be applied. A portal rigid frame pier will be used from P20 to P22.

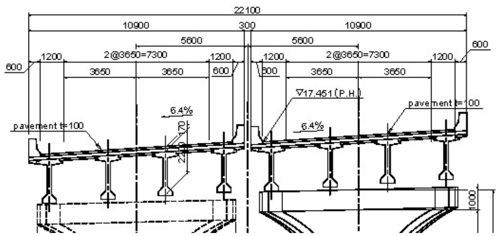


Source: JICA Study Team

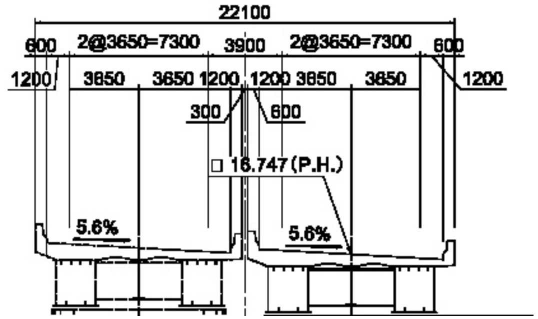
Figure 12.39 Span Arrangement of Flyover No.2-2

Flyover No.1

Superstructure: PC-I Girder

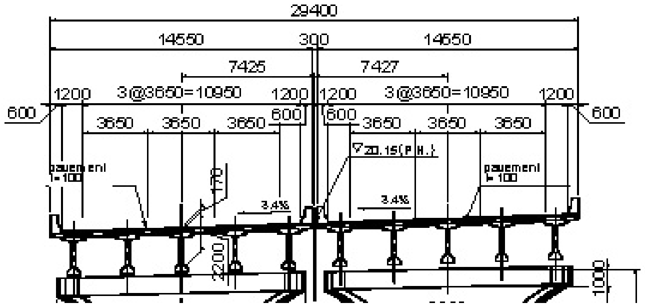


Superstructure: Steel Box Girder

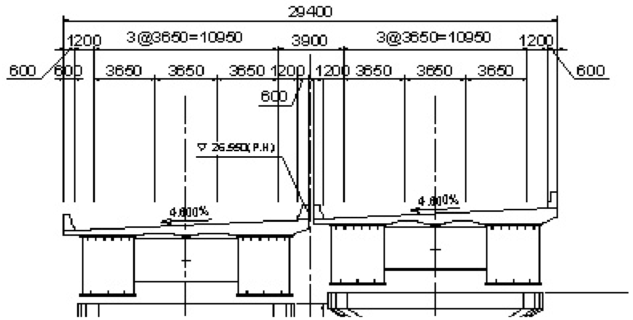


Flyovers No.2

Superstructure: PC-I Girder



Superstructure: Steel Box Girder



Source: JICA Study Team

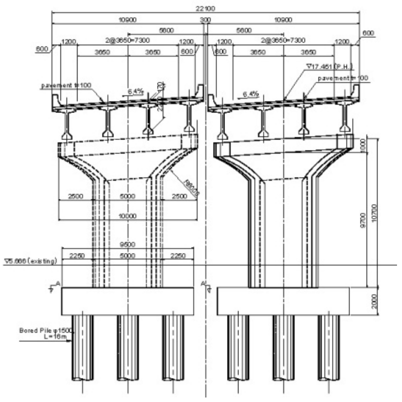
Figure 12.40 Typical Cross Sections of Flyovers

4) Substructures and Foundations

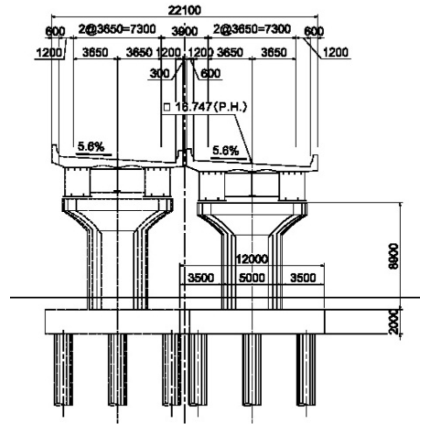
Figure 12.41 shows the cantilever type piers for supporting the flyover superstructures.

Flyover No.1

Superstructure: PC-I Girder (Individual)

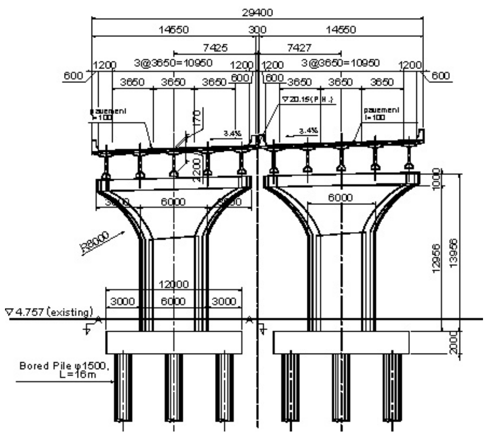


Superstructure: Steel Box Girder (Individual)

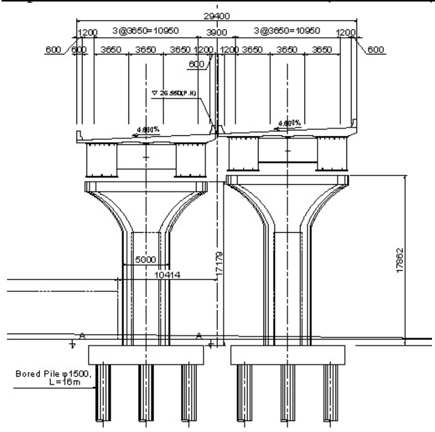


Flyover No.2

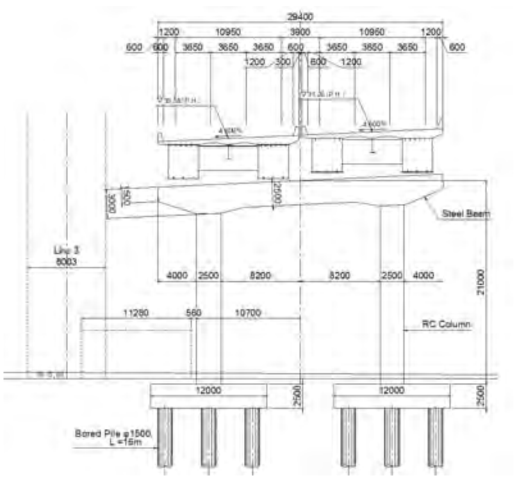
Superstructure: PC- Girder (Individual)



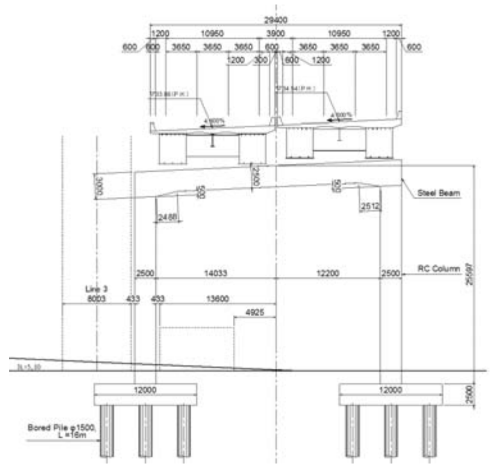
Superstructure: Steel Box Girder (Individual)



Superstructure: Steel Box Girder (Portal Rigid Frame P20)



Superstructure: Steel Box Girder (Portal Rigid Frame P21)



Source: JICA Study Team

Figure 12.41 Cross Sections of Cantilever Type Piers for Flyovers

12.4.2 Access Bridges to the Bridge of the Americas

(1) Principles in Planning and Design

As with the approach viaducts discussed in 12.4.1(1)2)i, the same principles were also considered here.

(2) Span Arrangement

Abutment Location

As with the approach viaduct, the places where the abutment height is 10m were selected for the abutment locations.

Table 12.15 shows the abutment locations.

Table 12.15 Abutment Locations

No.	Bridge Name	Abutment ID	Chainage
1	Access Bridge to the Bridge of the Americas	Abutment A1	KM0+520
2		Abutment A2	KM1+280

Source: JICA Study Team

Bridge Length and Span Arrangement

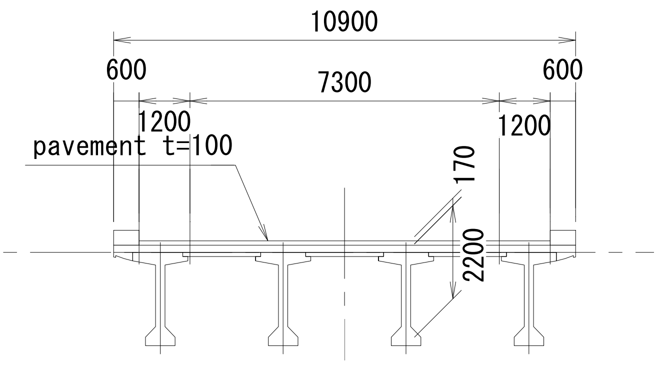
As with the approach viaducts discussed in 12.4.1(1)2) ii, the PC-I girder was selected as the superstructure type for the access road bridges to the Bridge of the Americas. The total number of spans is 19, which are divided into 2 continuous structures consisting of 9 spans and 10 spans in order to eliminate the adverse effect of concrete creeps.

Bridge Length: 760m

Span Arrangement: 9@40m + 10@40m

(3) Superstructure

Figure 12.42 shows the typical cross section of the access bridges to the Bridge of the Americas.

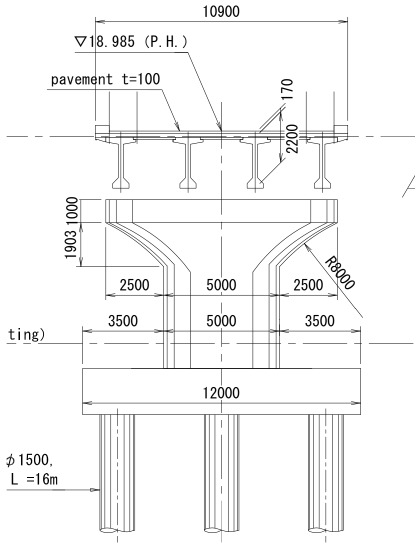


Source: JICA Study Team

Figure 12.42 Typical Cross Section of Access Bridges to the Bridge of the Americas

(4) Substructure and Foundation

Figure 12.43 shows the pier cross section of the access bridges to the Bridge of the Americas.



Source: JICA Study Team

Figure 12.43 Typical Pier Section of Access Bridges to the Bridge of the Americas

12.4.3 Bridge Ancillary Works

(1) Expansion Joint

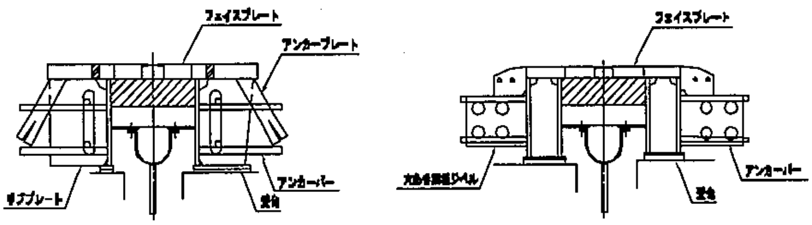
The types of expansion joints were determined according to the horizontal displacement and the bridge type. Since all the bridge types in the Project have horizontal displacements of 30mm or more, the finger type load support joints were selected.

Table 12.16 shows the expansion joints and Figure 12.44 illustrates the images of the expansion joints.

Table 12.16 Summary Table of Expansion Joints

No.	Route	Bridge Name		Type	Chainage (KM)	Displacement (mm)
1	4th Panama Canal Bridge	Flyover No.1	Inbound	Steel Finger Type Joint	A1 : 1+070 P6 : 1+310 A2 : 1+570	-30 to +84 -30 to +84 -30 to +84
			Outbound		A1 : 1+050 P7 : 1+320 A2 : 1+570	-30 to +84 -30 to +84 -30 to+84
2		Flyover No.2			A3 : 2+000 P18 : 2+260 A4 : 2+740	-16 to +45 -24 to+67 -24 to+67
3		4th Panama Canal Bridge	East Bank Approach		A5 : 2+847 P26 : 3+000	-8 to +22 -8 to +22
4			Main Bridge		P30 : 3+380 P33 : 4+220	-189 to +189 -189 to +189
5			West Bank Approach		P38 : 4+690 A6 : 5+390	-35 to +98 -18 to +50
6	Access Roads to the Bridge of the Americas	Access Bridges to the Bridge of the Americas			A1 : 0+520 P9 : 0+880 A2 : 1+280	-18 to +50 -38 to +106 -20 to +56

Source: JICA Study Team



Source: Design guide of the expansion joint for a steel bridge

Figure 12.44 Image of Expansion Joint

(2) Bearings

The types of bearings were determined taking into consideration the bridge types and constructability.

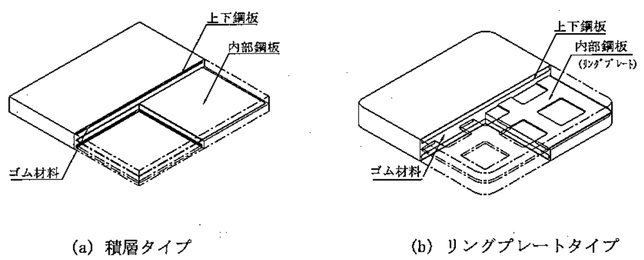
Table 12.17 shows a summary of the bearings and Figure 12.45 shows the images of the bearings.

Table 12.17 Summary of Bearings

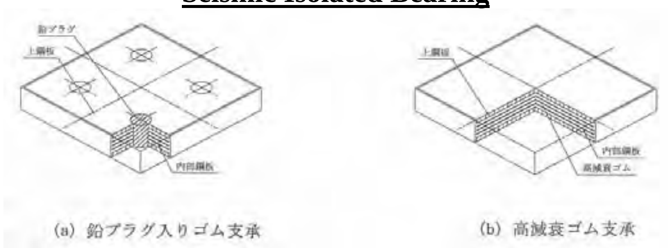
No.	Superstructure Type	Bearing	Reasons for Selection
1	PC-I Girder	Elastomeric Rubber	Install simply rubber bearings at the girder ends Elastomeric rubber bearing is generally used.
2	Steel Box Girder	Elastomeric Rubber	Elastomeric rubber bearing is generally used.
3	Arch	Iron Fixed Bearing Elastomeric Rubber	Fixed at Arch Springing At arch end bearing

Source: JICA Study Team

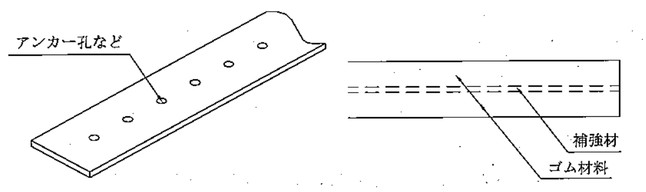
Elastomeric Rubber



Seismic Isolated Bearing



Belt-like Elastomeric Rubber



Source: Bearing handbook for highway bridges

Figure 12.45 Images of Bearings

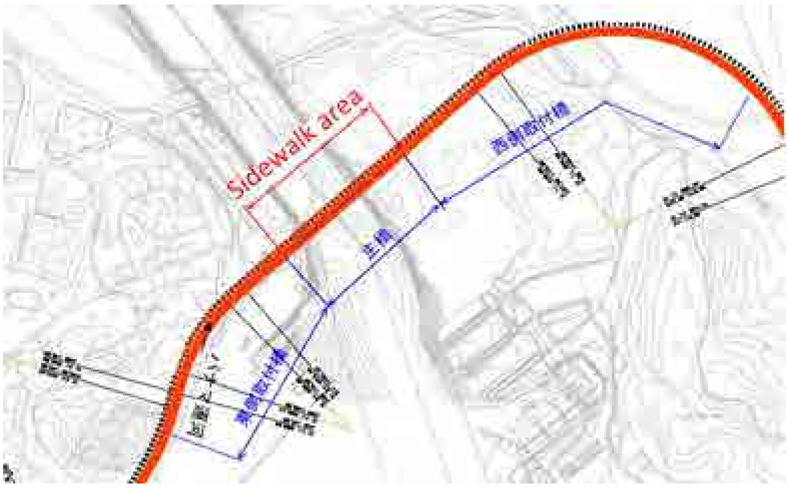
(3) Sidewalk

A sidewalk is accommodated along the southern edge of the bridge deck in the area from P30 to P33 as a panoramic viewing facility. Connection between the ground level roads and the bridge sidewalk is achieved by way of elevators to be installed at the P30.

The necessity of a bridge deck will be studied again in the D/D stage in consideration of security and economic aspects. In case the bridge deck is eliminated, the construction cost including the elevators will be reduced by about USD 20 Million.

Figure 12.46 shows the sidewalk area of the Project.

A detailed discussion of the elevators is made in Chapter 13.



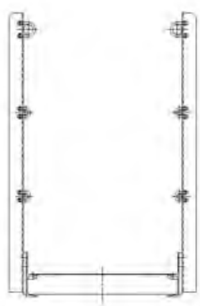
Source: JICA Study Team

Figure 12.46 Area where Sidewalk is to be installed

(4) Maintenance Walkways

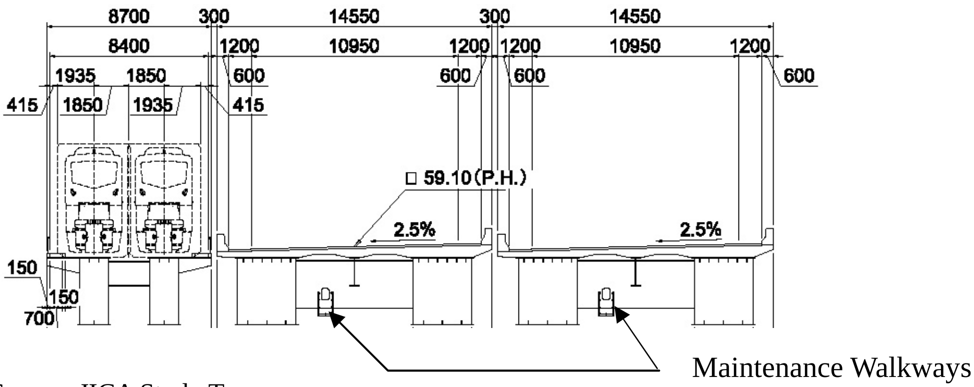
- There is no maintenance walkway for PC-I girders that at a low level. Instead, they can be accessed from the ground level.
- There are maintenance walkways in the stiffening girders of the main bridge.
- There are also maintenance walkways under the floor boards of the steel Box girders. It is possible to perform maintenance inside a Box girder, but maintenance cannot be done on the outer surface of the floor board. Therefore, maintenance walkways including manholes at the cross girders are planned for.

A typical cross-section of maintenance walkway is shown in Figure 12.47. Maintenance walkways will be installed as per Figure 12.48.



Source: JICA Study Team

Figure 12.47 Typical cross-section of maintenance walkways



Source: JICA Study Team

Figure 12.48 Indicative Locations of Maintenance Walkways

(5) Paint (weathering steel)

Paint applied to steel materials should be an anti-corrosive type as mentioned above. In addition to the anti-corrosive properties it provides for steel materials, paint should also be applied from the view point of maintenance and aesthetics.

In areas where there are a lot of fragments with salt content, it is difficult for stable rust to form on weathering steel. Therefore, Nickelic high weathering steel was developed for this type of area. It was decided that this type of steel would be adapted for this bridge location.

It should be noted that samples of anti-corrosive type steel have been attached to the steel surface of the Bridge of Americas for checking the degree of weathering in the vicinity of the Project site. It will be necessary to make a study at the stage of execution design.

12.4.4 Drawings of Preliminary Design

The drawings of the preliminary design are shown in Appendix 5.

- Appendix 5.1.3: Bridge Drawings

12.4.5 Preliminary Quantities

The preliminary quantities of the bridge works were taken off from the preliminary drawings.

The preliminary quantities are shown in Appendix 7.

12.5 Pending Studies for the D/D

The studies that need to be conducted for the detailed design are as follows.

- Geological survey: A survey under the piers is necessary. If the width of foundation is large, several points under each pier need to be surveyed.
- Survey (including a bathymetry)
- Wind tunnel test: 2D model of the stiffening girder or 3D model of the cantilever erection.
- Simulation of vessel collision: investigation of the impact of ship collision on the main frame.
- Survey of tide levels and tidal stream: for the navigation plan of the barges used in construction.
- Road alignment: the positions of the bearings are high and the slope of pier's beams is sharp at the some points in this plan. The road alignment needs to be reviewed with its sharply-sloping superelevations in each direction.

Chapter 13 Preliminary Electrical and Mechanical Design

13.1 Summary

13.1.1 Objective

In this study, the preliminary designs of the electrical and mechanical equipment for the bridge, including the preparation of design drawings and the calculation of estimated work quantities, are prepared in order to estimate the project cost and to determine the project scope.

13.1.2 Study Items

In the preliminary designs, the following items are considered:

- Selection criteria of the equipment necessary for the Project
- Coordination with the Metro Line-3 Project
- Equipment installation plan
- Development of preliminary designs for equipment
  (only for the necessary equipment, for estimating the work quantities)
- Plan for attaching public utility facilities to the 4th Panama Canal Bridge
  (out of the scope of the Project)
- Plan for relocating existing public utility facilities
- Preparation of drawings for the preliminary designs
- Calculation of the estimated work quantities

Furthermore, the improvement of the Omar Torrijos roundabout was conducted as a Concept Design in the Study (see Section 11.5); therefore, the electrical and mechanical design does not include the improvement of the Omar Torrijos roundabout.

13.1.3 Study Results

The results of the preliminary designs for the bridge equipment are summarized below.

(1) Equipment Plan

The Pre-F/S assumed that the equipment would be managed from a control center with full-time managers, and remote control and monitoring equipment were identified as necessary. This study proposes, however, not to set up a control center with full-time managers, but rather to install only the minimum equipment necessary for general roads as agreed upon in the discussions held with relevant authorities. Furthermore, the installation of outdoor cubicles is also proposed for the necessary power supply instead of constructing an electric room.

Table13.1 shows a list of the necessary equipment.

Table 13.1 List of Necessary Equipment

No.	Category	Equipment		Function	Location of Installation
1	Electrical Equipment	Lighting Equipment	Bridge Lighting	Provide sufficient illumination of the bridge at night	Entire bridge
2			Road Lighting	Provide sufficient illumination of the road at night	Entire road
3		Warning Lights	Airplane Warning Light	Signal the location of the bridge for airplanes	Top of 4th Panama Canal Bridge
4			Marine Warning Light	Signal the location of the bridge for marine vessels	Bridge piers of 4th Panama Canal Bridge
5		Illumination		Illuminate the bridge for aesthetic purposes	4th Panama Canal Bridge
6		Power Supply Equipment		Supply power	3 locations on the land sections
7		Protection from Lightning Damage	Lightning Protection Equipment	Protect equipment from lightning damage	Each equipment location
8	Communication Equipment	Meteorological Observation Equipment	Anemometer	Measure the wind speed on the bridge	Central part of 4th Panama Canal Bridge
9			Rain Gauge	Measure rainfall on the bridge	Ditto
10			Precipitation Detector	Detect the start and end of precipitation on the bridge	Ditto
11			Visibility Meter	Measure fog density on the bridge	Ditto
12			Thermometer	Measure the temperature on the bridge	Ditto
13		CCTV Camera		Monitor the road condition	Top of the road; entrances to the 4th Panama Canal Bridge
14	Mechanical Equipment	Elevator		Used for movement between the ground level and the bridge.	Entrances to the 4th Panama Canal Bridge sidewalk

Source: JICA Study Team

(2) Equipment Design

In this study, the preliminary designs of lighting equipment and meteorological observation equipment are carried out in order to estimate the work quantities. Since the lighting equipment is required for providing an adequate level of luminance along the bridge and road, appropriate arrangements of lighting equipment were determined in consideration of the structure of the civil engineering facilities. Furthermore, in light of Panama's tropical climate, meteorological observation equipment that warns drivers of weather conditions were also selected.

(3) Plan for Attaching Public Utility Facilities

The plan for attaching public utility facilities to the bridge includes water supply pipelines, high-voltage power lines and communication lines. However, the scope of the Project is to only provide the space for the public utilities and install support frames since it is the respective utility providers that are in charge of their installation.

(4) Plan for Relocating Existing Public Utility Facilities

One of the greatest concerns regarding the existing public utility facilities is the power transmission lines and their supporting towers near the Balboa Station, which will affect the construction of the 4th Panama Canal Bridge. These transmission lines and their supporting towers will have to be relocated. As a result of discussions held with the Power Company, it is proposed that the current aerial power lines be replaced with underground lines. In addition to burying the power lines, a mechanical maintenance plant will also need to be relocated. Regarding the existing underground facilities, underground water pipes connected to a Chill Water Plant, other water mains and drainage pipes, and power and communication lines will all affect the positioning of the foundations for the road and the monorail bridge piers. The relocating of these underground facilities should be kept to a minimum and only when they obstruct the positions of the bridge piers.

Regarding the improvement of the Omar Torrijos roundabout, the study was conducted only at the level of a concept design; therefore, a relocation plan for public utilities was not prepared.

13.1.4 Conclusion

The planning and preliminary designs for all the necessary electrical and mechanical equipment have been carried out for the Project. The installation plan is based on the technical standards of Panama for the following equipment.

- Airplane warning lights
- Marine warning lights
- Elevators

In addition to the above, the Study established a relocation plan for existing public utility facilities through discussions held with relevant authorities.

13.2 Equipment Plan

13.2.1 Selection Criteria of Necessary Equipment

(1) Equipment plan in the Pre-F/S

Table 13.2 shows a list of the equipment identified in the Pre-F/S.

Table 13.2 List of the Equipment Identified in the Plan (Pre-F/S)

No.	Category	Equipment
1	Electrical Equipment	Power receiving and transforming equipment
2		Lightning protection equipment
3		Road lighting equipment
4		Airplane warning lights
5		Marine warning lights
6		SCADA system
7		Fire fighting equipment
8	Communication Equipment	CCTV camera
9		Emergency telephone system
10	Mechanical Equipment	Ventilating equipment

Source: Pre-F/S (Draft Final Report (November 2013)) (ACP)

(2) Selection of Necessary Equipment for the Project

In this study, discussions with the relevant authorities of Panama were held and the following criteria are proposed for selecting the necessary equipment for the Project:

- The minimum equipment necessary for the management of the road and bridge as a general road will be installed.
- Since the road and the Metro Line-3 will be established in parallel, some of the equipment could be shared by both. However, it was proposed that the equipment for the road and Metro Line-3 NOT be shared in consideration of their different operation, maintenance and management systems.
- In Panama, the Land Transit and Transportation Authority (Autoridad del Tránsito y Transporte Terrestre, ATTT) is responsible for the management and maintenance of equipment for general roads. In the Project as well, ATTT is in charge of the management and maintenance of the equipment, and no additional, independent control center for the Project will be established. The equipment to be operated and maintained by ATTT will be the meteorological observation equipment and CCTV cameras. Their installation is proposed within the scope of the project.
- Since no additional and independent control center will be established in the Project, any equipment that ATTT is not managing and monitoring by remote control will not be installed.

13.2.2 Coordination with the Metro Line-3 Project

In this study, it is proposed that no equipment will be shared with Metro Line-3.

Since the pipes/lines of the meteorological observation equipment, Variable Message Sign (VMS) boards and CCTV cameras to be installed on the road will require a relatively small area, they will use the cable rack for the Metro Line-3in consideration of its maintainability. Table 13.3 shows a comparison between the equipment of the Project and that of Metro Line-3, and Table 13.4 describes the reasons for not sharing equipment with Metro Line-3.

Table 13.3 Comparison with the Equipment for Metro Line-3

Category		Function	This Project	Metro Line-3
Lighting Equipment		Provide illumination of the road at night	Included	Included
Power Supply Equipment		Supply power	Included	Included
Electric Room		Location for installing power supply equipment		Included
Signal		Warn users of danger		Included
Lightning Protection Equipment		Protect equipment from lightning damage	Included	Included
Meteorological Observation Equipment	Anemometer	Observe meteorological conditions for traffic regulation	Included	Included
	Rain gauge		Included	
	Precipitation detector		Included	
	Visibility meter		Included	
	Thermometer		Included	
	Seismometer			
Variable Message Sign (VMS)		Provide users with information	Included	
CCTV Camera		Remotely monitor any accidents and fallen objects	Included	Included
Emergency Communication System		Radio equipment for when general telephones cannot be used due to power outage or other reasons		Included
Elevator		Used for movement between the ground level and the bridge	Included	
Remote Control and Monitoring (Control Center)		Location forremote control and monitoring		Included

Source: JICA Study Team

Table 13.4 Reasons for Not Sharing Equipment with the Metro Line-3

Equipment	Reason for not sharing
Lighting Equipment	The luminance levels required for the road and Metro Line-3 are different.
Power Supply Equipment	Since maintenance and management will be carried out by different companies, it is difficult to clarify the demarcation of the O&M works between the companies and to properly allocate the electricity costs and equipment replacement costs to each company.
Lightning Protection Equipment	Lightning protection will be provided for each road equipment , and along the entire track for Metro Line-3. Therefore, the equipment cannot be shared.
Meteorological Observation equipment	While only the anemometers could be shared, the maintenance and management company are not the same.
CCTV Camera	Although the cameras could be shared, they will not be due to different administrators in charge of monitoring and control.

Source: JICA Study Team

13.2.3 Electrical Equipment

(1) Lighting Equipment Plan

In this study, continuous lighting was planned for along the entire length of the road of this Project. For lighting equipment, CIE 132-1999: “Design Methods for Lighting of Roads” was applied as the design standard to determine the number of lighting devices based on lighting calculation (see 13.3.2).

(2) Plan for Warning Lights

1) Examination of the Need for Warning Lights

The Project site is close to an airport, and seagoing vessels pass under the bridge. Therefore, warning lights are required to signal the location of the bridge at night and in poor visibility conditions. Airplane warning lights are installed for airplanes, and marine warning lights for ships. The functions of the warning lights are summarized below.

a) Airplane Warning Lights

Airplane warning lights are installed to signal the location of large structures such as high buildings, airport control towers and power stations, as well as steel towers, to airplanes flying at night. Blinking or steady red or white lights are used as warning lights..

Article 51 of the Civil Aeronautics Act of Japan, which sets the Japanese standard, requires warning lights to be installed on buildings and other objects with a height of 60 meters or more from the ground. Some buildings with a framed structure and tall slender chimneys are required to be painted red and white. AAC (Civil Aviation Authority) of Panama indicated that airplane warning lights are to be installed on public roads in accordance with the regulations of Panama. This study only calculated the estimated cost for airplane warning lights.

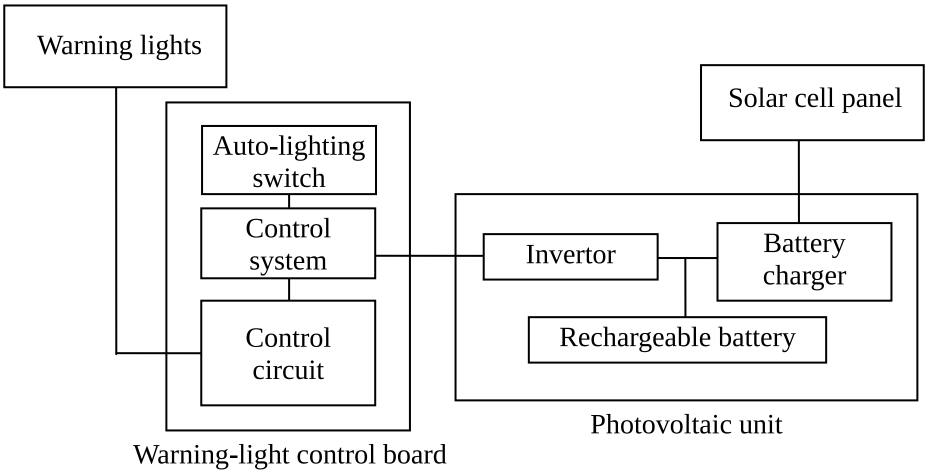
b) Marine Warning Lights

Marine warning lights are installed to allow vessels to determine the distance to structures for safe navigation. Lighthouses are a type of marine warning lights.

The International Association of Lighthouse Authorities (IALA) specifies an international standard for marine warning lights. ACP (Panama Canal Authority) is responsible for the planning and installation of these lights in the Canal channel. This study only calculated the estimated cost for marine warning lights.

2) Emergency Power Supply

Airplane and marine warning lights are essential equipment that must function even in the event of a power failure. The lights are powered by solar cells both under regular operation and in the case of power failure since their power demand is low.



Source: JICA Study Team

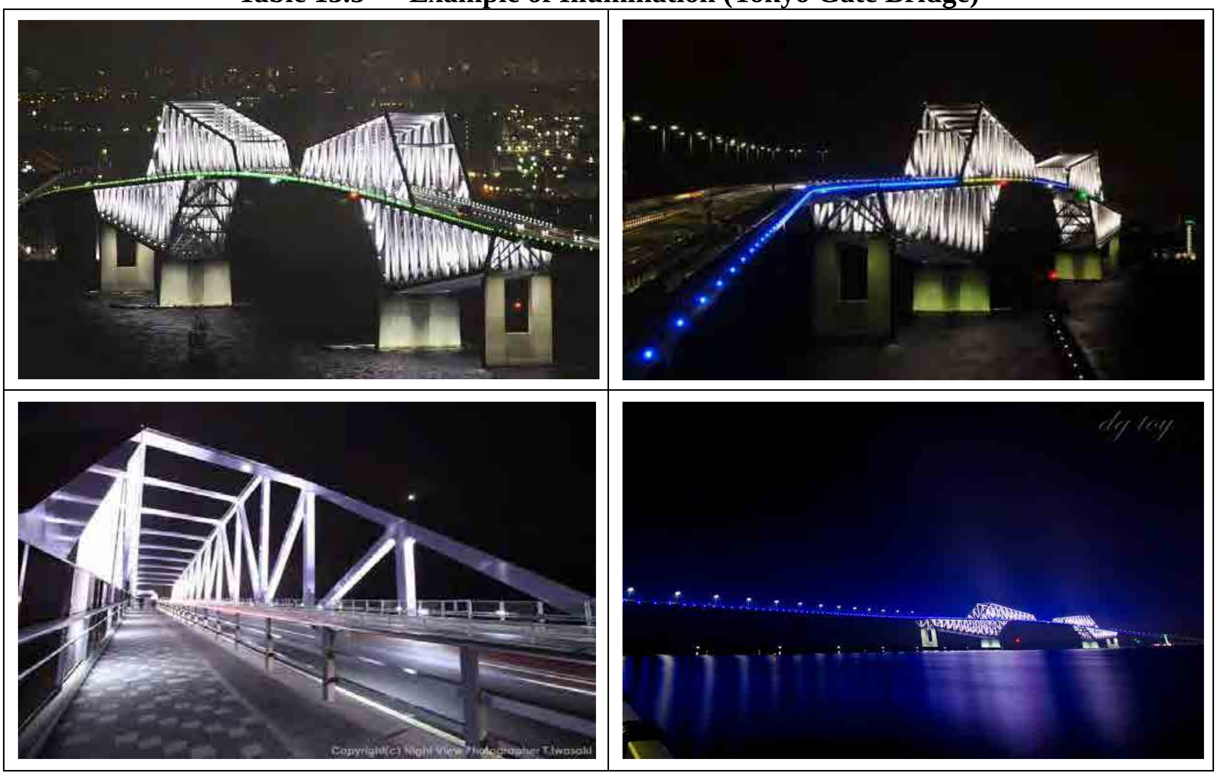
Figure 13.1 System Diagram of a Warning Light

(3) Illumination Plan

Since the main bridge of the 4th Panama Canal Bridge can be a landmark of the area, it is expected that illumination will be provided. A specific plan will be discussed at the detail design stage. This study only calculated the estimated cost for the illumination.

Table 13.5 shows an example of bridge illumination in Japan (Tokyo Gate Bridge) for reference.

Table 13.5 Example of Illumination (Tokyo Gate Bridge)



Source: Bureau of Port and Harbor, Tokyo Metropolitan Government

(4) Power Supply Equipment Plan

There are two methods for supplying power to equipment as described below. In this study, the use of power distributed by the power company was selected because a minimal number of equipment is required and the possibility of power outage is low.

Table 13.6 compares the two power supply methods.

Table 13.6 Comparison of Power Supply Methods

Item	Use of power distributed by the power company	Supply of power through installation of continuous power generators
Outline	High- or low-voltage power is received from a power company and supplied to each of the facilities.	Continuous power generators are installed to supply power to each load.
Feeding Method	Power receiving points are set in the area covered by the Project to feed power from a commercial power supply in the neighborhood.	Diesel or gas turbine power generators for continuous use are installed to supply power.
Reliability of the power Supply System	Power supply is interrupted in the event of outage. Emergency power supply system is required for essential equipment.	Power can be supplied in a more reliable manner with continuous power generators.
Maintenance and Management	As the power company is responsible for the maintenance and management of the power generators, the Project only needs to cover from the power receiving points onward.	A system for quick recovery from power abnormality in the power generating facilities as well as for their enhancement will need to be established
Economic Efficiency	Initial cost: low Running cost: high (electricity fee)	Initial cost: high Running cost: high (fuel/maintenance cost)

Source: JICA Study Team

(5) Lightning Damage Prevention Plan

There are two types of lightning protection equipment: a lightning rod installed on each device; and an overhead ground wire that covers a wide area. The Project will employ lightning rods because the number of target equipment to be installed is minimal.

13.2.4 Communication Equipment

(1) Plan for Meteorological Observation Equipment

Meteorological observation equipment measures the weather conditions of the site where it is installed. The data is used for disaster prevention and forecasting future conditions. In the Project, the equipment will measure weather conditions on the bridge and warn traffic of dangers, such as foggy conditions, heavy rain and gales. Upon consulting with relevant authorities, it was decided that meteorological observation equipment and VMS boards would be installed to inform drivers of the weather conditions on the bridge.

1) Traffic regulation plan

Traffic is regulated for the three purposes mentioned below.

- To avoid accidents when it is dangerous to drive on the bridge due to adverse weather.
- To prevent rear-end collisions and other secondary accidents after a traffic accident has occurred.
- To conduct inspections/repairs using a closed lane.

The thresholds for rainfall, wind speed and other conditions need to be established in order to warn the traffic in the relevant sections if any of the thresholds are exceeded.

2) Identification of the Events when Traffic Regulation is needed

Table 13.7 shows a list of common events when traffic is regulated due to adverse weather.

Table 13.7 Common Events that May Require Traffic Regulation Due to Adverse Weather

Cause	Outline	Needed in the Project
Rainfall	Traffic is regulated based on continuous rainfall or hourly rainfall. Traffic regulation based on continuous rainfall happens when continuous rainfall from the start has reached the threshold. Traffic regulation based on hourly rainfall happens when rainfall in a certain period of time has reached the threshold.	Yes
Snow Fall	In consideration of the icy condition of the road surface due to snowfall, traffic is regulated with speed limits, requirement of tire chains or specific types of tires, road/lane closure, etc.	No
Tidal Wave	Traffic is regulated due to the impact of tsunami on the road.	No
Wind Speed	Traffic is regulated due to wind strength. This often happens when hit by a hurricane.	Yes
Visibility	Traffic is regulated due to poor visibility. This often happens in a foggy region.	Yes
Freezing	Traffic is regulated due to the icy condition of the road caused by unusually low temperature.	No
Earthquake	Traffic is regulated when a major earthquake has occurred.	No

Source: JICA Study Team

3) Reference Values for Regulation Standards

Although there are regional differences, the major regulatory standards in Japan are shown below.

- Rainfall: continuous rainfall of 150 to 300 mm
- Wind speed: maximum speed of 15 m/s or more (limits entry and/or speed)
- Fog: visibility of 50 m or less according to a visibility meter

4) Traffic Regulation Method on the 4th Panama Canal Bridge

Since no control center is to be established, the Project will adopt an automatic display on VMS boards to regulate traffic when the meteorological observation equipment detects a value beyond the regulation standard. In consideration of Panama’s climate, the following meteorological observation devices will be installed. ATTT (Land Transport and Transit Authority) performs the maintenance of this equipment.

- Rain gauge
- Precipitation detector
- Anemometer
- Visibility meter
- Thermometer

No snowfall meter will be installed because it does not snow in Panama. No seismometer will be installed, in accordance with discussions held with relevant authorities, because the system is very complex and difficult to maintain. While the thermometer is in fact unnecessary for traffic regulation, it will be installed to display temperature as part of the information on the ambient condition under normal conditions.

(2) CCTV Camera Installation Plan

CCTV cameras are equipment to remotely identify any accidents on the bridge and check the road surface condition. ATTT is implementing the remote control and monitoring of public roads in Panama. Since remote control and monitoring is required in this Project, it will need to be connected to the ATTT system. Specific plans will be drawn up in the detailed design stage.

13.2.5 Mechanical Equipment

(1) Elevator Installation Plan

Elevators will be installed under the Project for the purpose of providing access to/from bridge deck (see Section 11.3.3(3)).

One requirement for their installation is to have a secure contact with the outside in the case of an emergency for safety reason. As the Project plans to have no control center and the maintenance of the elevators is out of the responsibility of ATTT, the installation of elevators will not be allowed without such a communication system.

The Study confirmed with an elevator installer and distributor in Panama, that the company can offer maintenance services and respond to emergency situations. Thus, there is no problem with the installation.

Specific plans will be developed in the detailed design. This study only calculated the estimated cost for the elevator.

The necessity of a bridge deck will be studied again in the D/D stage in consideration of security and economic aspects. In case the bridge deck us eliminated, the construction cost including the elevators will be reduced by about USD 20 Million.

13.3 Preliminary Designs

13.3.1 Design Scope

Regarding the equipment design, only the equipment that requires a preliminary design for calculating the cost of the Project was examined. The relevant equipment is listed below.

- Lighting equipment
- Power supply equipment
- Meteorological observation equipment

13.3.2 Lighting Equipment

(1) Selection of the Light Source

Light sources include sodium lamps, which have been commonly used, and LED lamps, which consume less power. Table 13.8 compares the two lighting sources.

Table 13.8 Comparison of Two Light Sources

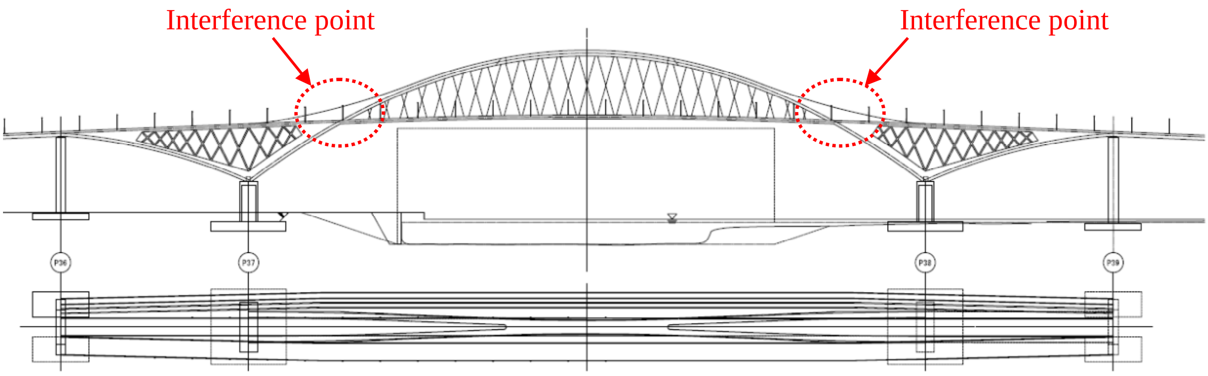
Item	Sodium lamp	LED lamp
Life of lamp	18,000 hours	60,000 hours
Replacement frequency	15 years	20 years
Installation cost	100%	140%
Maintenance cost	100%	30%
Power consumption	100%	40%
CO2 emissions	100%	40%

Source: JICA Study Team

LED lamps have been developed recently and involve a high cost. However, it is expected that the cost will decline with the increased manufacture of LED lamps in the future. Assuming a future decrease in cost, LED lamps will be employed. They are superior to sodium lamps for lower power consumption and maintenance cost.

(2) Selection of the Lighting System

In this study, pole lighting, which is common in Panama, is adopted. On the bridge, there is a section that would interfere with the installation of poles. The interference points are shown in figure 13.2 below. At such interference points, low-pole lighting will be adopted as a countermeasure to the interference as explained in table 13.9.



Source: JICA Study Team

Figure 13.2 Locations for Installing Low-Position Lighting

Table 13.9 Measures for Interference points

No.	Items	Non-Lighting	Low-pole lighting	Low-position lighting	Lighting attached to Bridge
1	Description	Non-Lighting	Low-Pole (6m) lighting installed as a specific measure	Low-position lighting installed as a specific measure	Lighting attached to the Arch rib
2	Disadvantage	Uniformity of luminance cannot be ensured.	Installation needs to be in the direction of alignment. Installed base is larger.	Installation needs to be in the direction of alignment. Installed base is larger. No previous experience in Panama.	Needs to be installed on the preceding Arch rib. Maintenance is difficult.
3	Evaluation	—	Adopted	To be re-considered in the detailed design	—

Source: JICA Study Team

A common road lighting system illuminates the road from a high position using poles. In places where it is difficult to install or maintain poles, lighting fixtures have to be installed without poles to ensure safe and smooth driving at night. The lighting system without poles (see Section 20.3.4) is also adopted where poles cannot be installed due to the structure of the civil engineering facilities or obtrusive light from the road to the neighborhood needs to be prevented. Table 13.10 compares the two lighting systems.

Table 13.10 Comparison of Two Lighting Systems

Item	Low-position lighting	Pole lighting
Example of Installation		
Installation Cost	High	Low
Leak of Light	Almost no light is leaked. This system is used in the places where a leakage of light should be prevented, such as in the vicinity of an airport or farm.	A significant amount of light leaks behind the lamps.
Maintenance and Inspection	No vehicles are needed for working at heights.	Vehicles for working at heights are needed.
Location of Installation	Installed on handrails or guardrails.	Elevated structure for exclusive use is needed.
How a Road is Illuminated	The uniformity ratio of luminance is high.	The road is illuminated in stripes depending on the positions of the lighting fixtures.
Reliability	The possibility of failure is low because the lamps are not affected by traffic vibration or strong wind.	The lamps may fail to turn on due to connection problems caused by traffic vibration or strong wind. Measures to prevent dropping have to be taken in places where there are often strong winds.

Source: JICA Study Team

In Panama there is no experience yet in installing low-position lighting. However, it would be predominantly for the bridge lighting, as shown below. As a result of discussing with SMP, the use of low-position lighting should be re-considered in the detailed design.

- Maintenance and inspection of low-position lighting can be performed without lane closure because there is no need to use vehicles for working at heights.
- Pole lighting may fail to turn on due to vibration caused by strong wind.
- Installation is easier than the pole lighting.

(3) Calculation of Bridge Lighting

1) Applicable Standards

CIE 132-1999: Design Methods for Lighting of Roads

2) Design Conditions

Table 13.11 shows the conditions for lighting calculation.

Table 13.11 Conditions for Lighting Calculation

Item		Unit	Requirement
Roadway Width		m	3 lanes: 3.65m*3, 2 lanes: 3.65m*2
Total Width		m	3 lanes: 10.95m, 2 lanes: 7.3m
Traffic System		-	One way
Average Road Surface Luminance		cd/m^2	2.0 (cd/m^2)
Uniformity Ratio of Luminance	Overall Uniformity Ratio	-	0.4 or more
	Longitudinal Uniformity Ratio	-	0.7 or more

Source: JICA Study Team

3) Results of Lighting Calculation

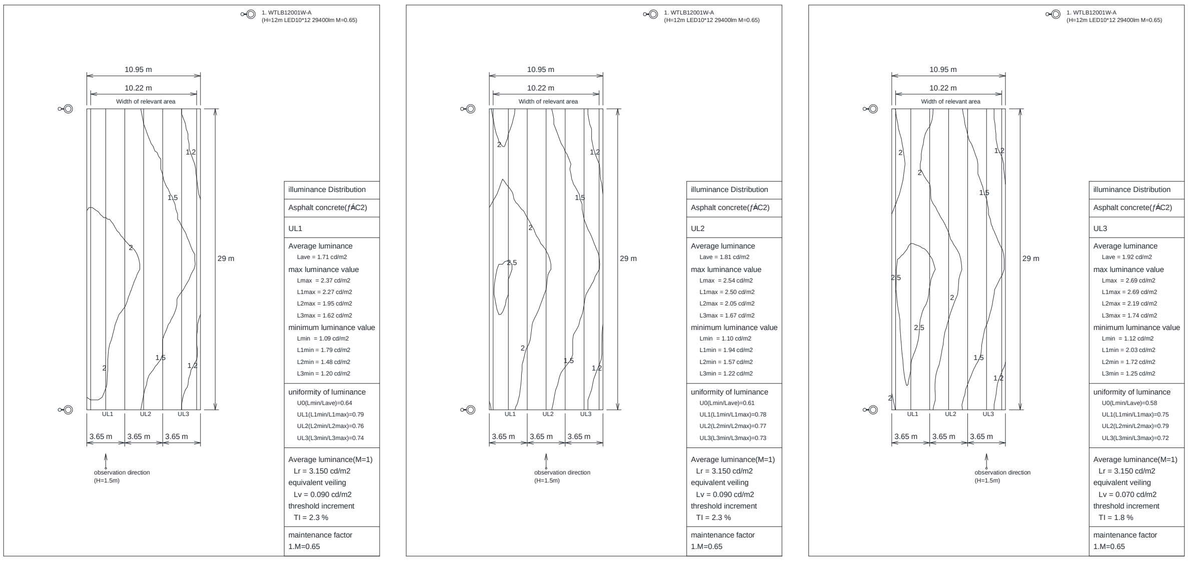
The maximum distance between lighting fixtures was calculated to provide an average road surface luminance of 2 cd/m^2.

Table 13.12 shows the results of the lighting calculation. Figures 13.3 and 13.4, respectively, present the results of the calculation for lighting on a 3-lane road and lighting on a 2-lane road.

Table 13.12 Results of Lighting Calculation

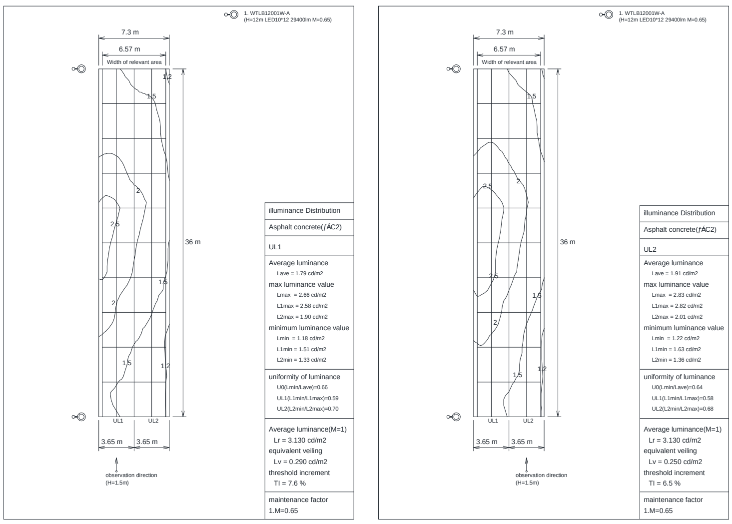
Calculation Category	Distance between Lighting Fixtures
Results of calculation of road lighting (3 lanes)	29m (installed on one side)
Results of calculation of road lighting (2 lanes)	36m (installed on one side)

Source: JICA Study Team



Source: JICA Study Team

Figure 13.3 Results of Calculation of Road Lighting (3 Lanes)



Source: JICA Study Team

Figure 13.4 Results of Calculation of Road Lighting (2 Lanes)

13.3.3 Power Supply Equipment

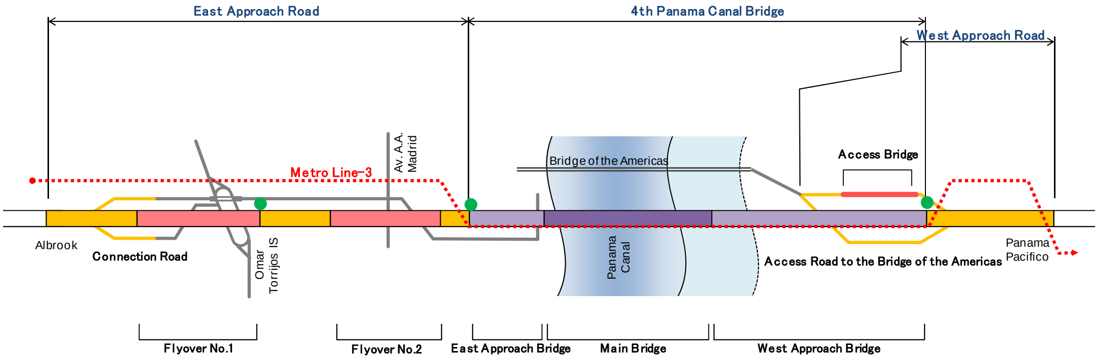
(1) Power Receiving Points

A power feeding device is needed at a power receiving point. The Project plans to install outdoor cubicles, instead of an electric room, to feed power from a commercial power supply source. A power receiving point should be set every 3 km, which means that the Project has to set three points. The Study has identified and selected the locations that meet the following criteria for power receiving points.

- Houses and other facilities in the vicinity that receive low-voltage power.
- Existing roads in the vicinity, as well as electric power poles.

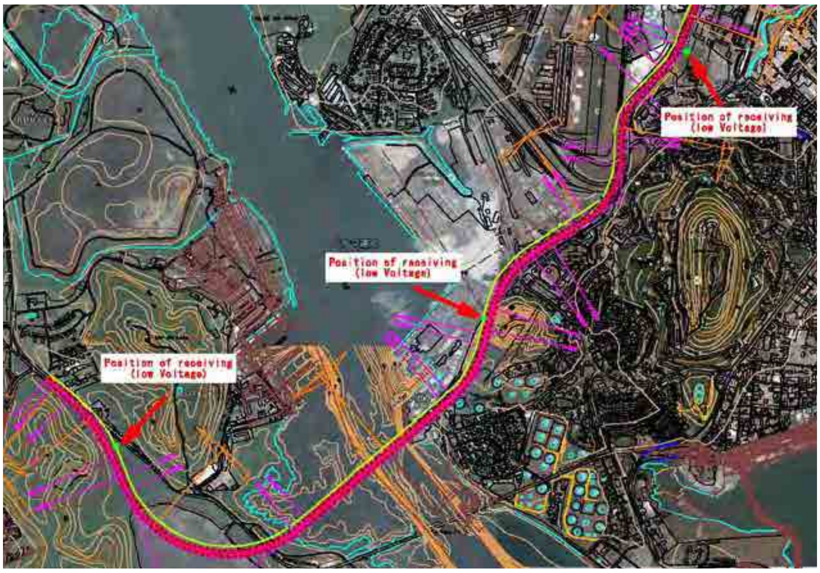
The detailed positions and method of installation will be discussed at the detailed design stage taking into consideration the structure of the civil engineering facilities. In the detailed design, the power company will be consulted on how to acquire the necessary amount of power and the power contract.

Figures 13.5 and 13.6 show a schematic diagram of the power receiving points and positions for installing the power receiving equipment, respectively.



Source: JICA Study Team

Figure 13.5 Schematic Diagram of Power Receiving Points



Source: JICA Study Team

Figure 13.6 Positions to Install Power Receiving Equipment

(2) Power receiving System

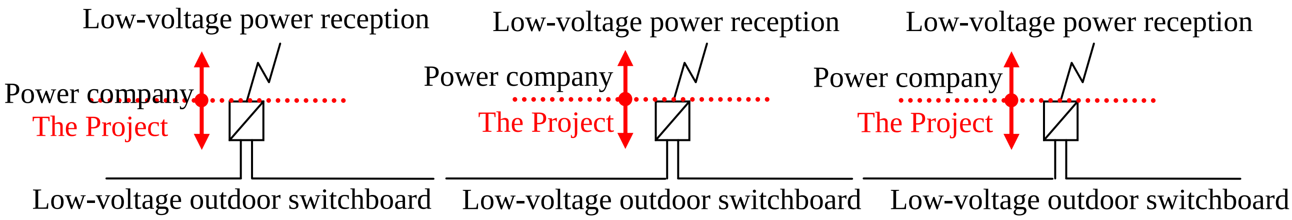
Three power receiving systems, as possible options, are shown in Figures 13.7 to 13.9.

As a result of consulting with the power company, Option 1, which involves low initial construction cost and easy maintenance, was selected.

<u>Option 1: Receiving Low-voltage Power</u>

Advantage: The initial construction and maintenance costs are low and the maintenance is easy.

Disadvantage: There is concern that it could take time to restore power after a power outage.



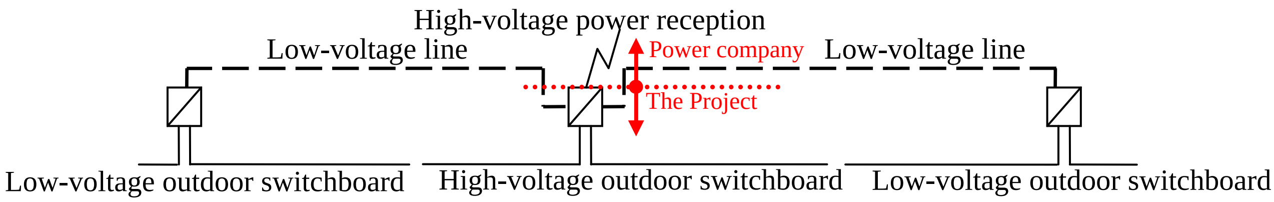
Source: JICA Study Team

Figure 13.7 Power Receiving System (Low-voltage Power)

<u>Option 2: Receiving High-voltage Power (Low-voltage Distribution)</u>

Advantage: Power can be restored quickly after a power outage because the power is received at one point.

Disadvantage: The initial construction and maintenance costs are higher than those of Option 1. Maintenance involves the inspection of more items.



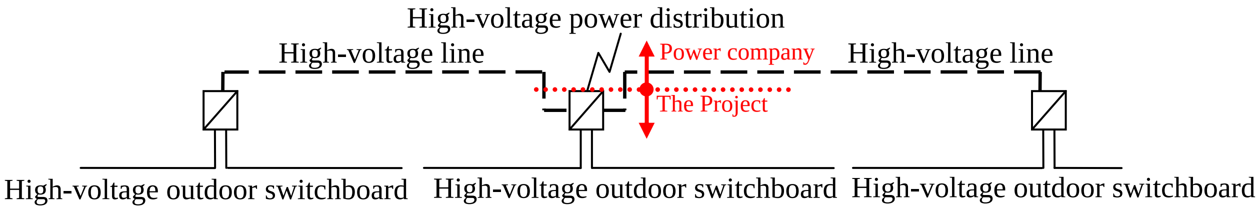
Source: JICA Study Team

Figure 13.8 Power Receiving System (High-voltage Power (Low-voltage Distribution))

<u>Option 3: Receiving High-voltage Power (High-voltage Distribution)</u>

Advantage: Power can be restored quickly after power outage because the power is received at one point.

Disadvantage: The initial construction and maintenance costs are higher than those of the other two options.



Source: JICA Study Team

Figure 13.9 Power Receiving System (High-voltage Power (High-voltage Distribution))

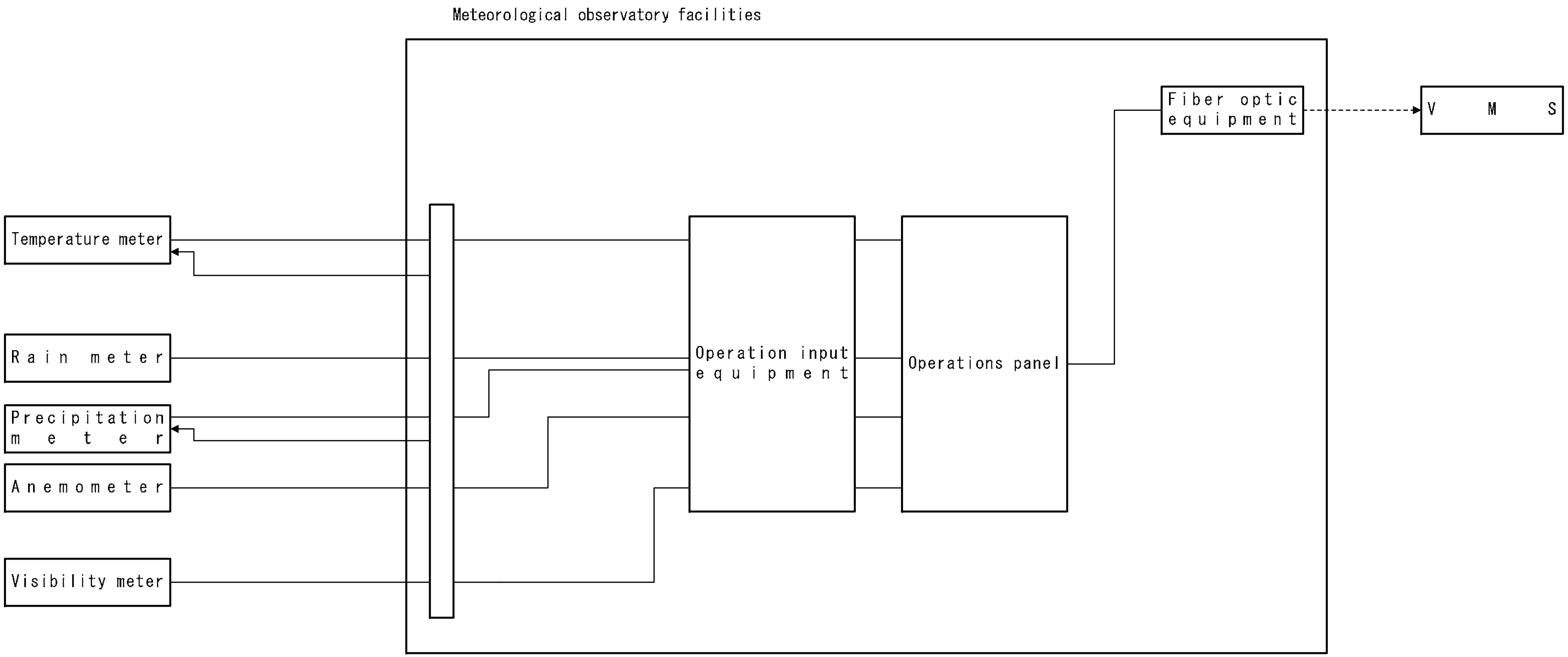
13.3.4 Communication Equipment

(1) Operation and Composition of the Meteorological Observation Equipment

In the Project, traffic will be regulated in the case of adverse weather (wind, rain and/or fog). As no control center is to be established, the meteorological observation equipment will be automatically operated according to the following rules.

- When any value measured by the meteorological observation equipment exceeds the standard value, VMS boards installed at the entrances of the bridge will automatically show information on speed limit or warning of rain, fog, etc.
- When the lanes are closed due to an adverse weather or an accident, ATTT, which is in charge of the maintenance and management of the meteorological equipment, will call for the cooperation of the police and request road closure.
- Although it is possible to automatically announce bridge closure with the VMS boards, they will not be used for announcing road closure in order to avoid erroneous indications due to equipment failure, etc., which could cause accidents and/or confusion in the public transportation.

Figure 13.10 shows the composition of the meteorological observation equipment.

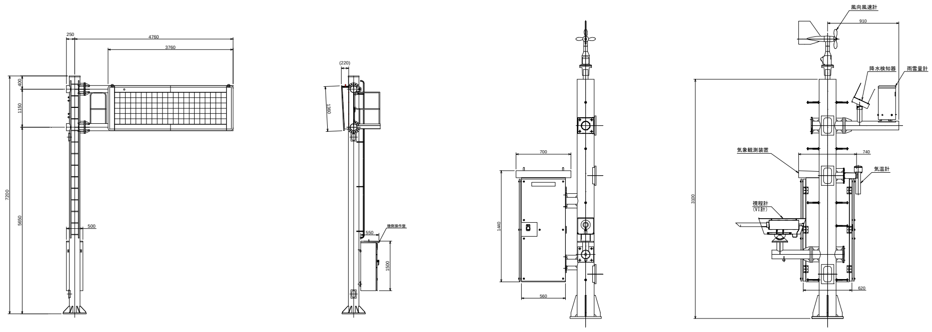


Source: JICA Study Team

Figure 13.10 Composition of the Meteorological Observation Equipment

(2) Position for Installing the Meteorological Observation Equipment

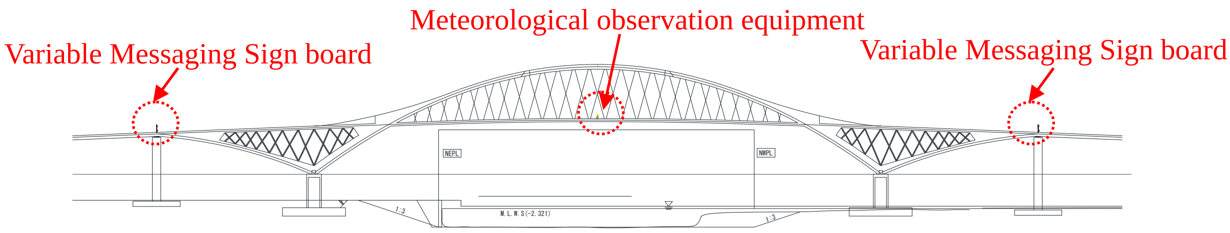
Figures 13.11 and 13.12 show the meteorological observation equipment and the installation locations, respectively.



Variable Message Sign (VMS) board Meteorological observation equipment

Source: JICA Study Team

Figure 13.11 Diagrams of Meteorological Observation Equipment and VMS Board



Source: JICA Study Team

Figure 13.12 Locations for Installing Meteorological Observation Equipment

13.4 Utility Installation Plan (Out of the Scope of the Project)

13.4.1 Identification of the Utilities to be Installed

The Project needs to provide space for installing water pipelines, high-voltage lines and communication lines. Accordingly, the Study Team decided that such utilities would be installed underground on the north side of both the bridge and earthwork sections taking into consideration the connection to be made with the existing utilities.

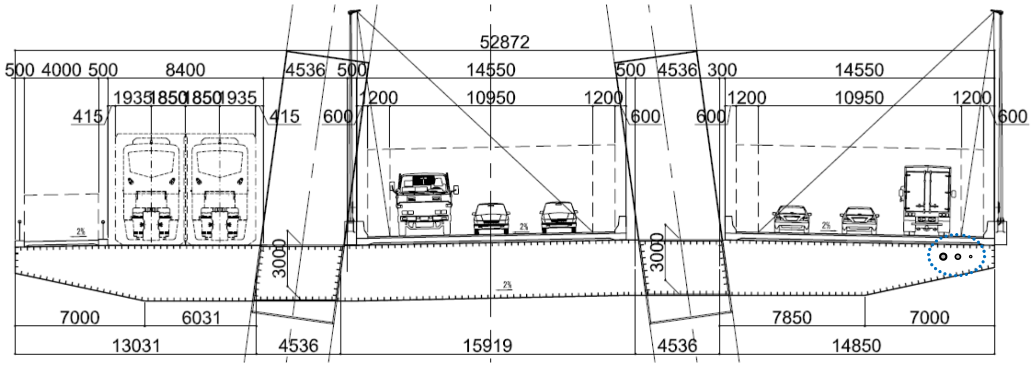
The connections at the bridge and earthwork sections will use stretch joints. As PVC pipes do not stretch, but could be broken by the deflection of the bridge, stretch joints will be attached at an interval of 50 m. Pipes will be used for connecting to the existing utilities. Valves will be also installed to the joints in order to facilitate maintenance. As the utility service providers are in charge of installing the respective utilities (including pipes/lines), the Project only covers the provision of the space and the installation of the supporting frames.

Table 13.13 shows a list of the utilities to be installed, and Figure 13.13 presents the locations for placing the utilities (bridge section).

Table 13.13 List of the Utilities to Be Installed

Type	Use	Quantity	Total size in inches (centimeter)	Piping Class
Water Supply Pipe	Drinking water	1	18 (45.72)	PVC
High Voltage Line	General power supply	24	6 (15.24)	HDPE
Communication Line	Telephone, Internet	6	4 (10.16)	HDPE

Source: JICA Study Team



Source: JICA Study Team

Figure 13.13 Locations for Placing the Utilities (Bridge Section)

13.5 Drawings of Preliminary Designs and Estimated Work Quantities

13.5.1 Drawings of Preliminary Design

In the Study, the drawings of the preliminary design for the equipment listed below have been prepared in order to estimate the work quantities.

- Lighting equipment
- Meteorological observation equipment

The preliminary design drawings for the equipment are shown in Appendix 5-1-4.

13.5.2 Estimated Work Quantities

The estimated work quantities for electrical and mechanical facilities are shown in Appendix 7.

13.6 Plan for Relocating Existing Utilities

13.6.1 Identification of Existing Utilities

The existing utilities located in the area covered by the Project were identified through inquiries with the relevant authorities.

Table 13.14 shows a list of the existing utilities in the Project area.

As shown in Table 13.14 below, some of the existing facilities are located outside the Project's target area. Those facilities do not need to be relocated.

As for the improvement of the Omar Torrijos roundabout, the study was conducted only at the level of a concept design; therefore, a relocation plan for public utilities was not prepared.

Table 13.14 List of Existing Utilities in the Project Area

No.	Facility	Location (within the project targeted land or not)	Management company
Existing Utilities (above ground)			
1	Telecommunication Building	Yes	ACP
2	Chill water Plant	No	ACP
3	Substation	No	ACP
4	High-voltage Transmission Tower	Yes	ACP
5	Marine Traffic Control Building	No	ACP
6	Mechanical Maintenance Plant	Yes	ACP
7	Oil tank	No	ACP
Existing Utilities (underground)			
8	Power line	Yes (only APC owned lines)	ACP, Gas Natural fenosa,
9	Water pipeline	Yes (only APC owned pipes)	ACP, IDAAN
10	Drainage pipe	Yes (only APC owned pipes)	ACP, IDAAN
11	Communication line	Yes (only APC owned lines)	ACP, Cable Onda, Cable and Wireless
12	Water pipe (Chill water plant)	Yes (only APC owned pipes)	ACP
13	Gas line	No	ACP
14	Oil line	No	ACP

Source: Respective Service Providers

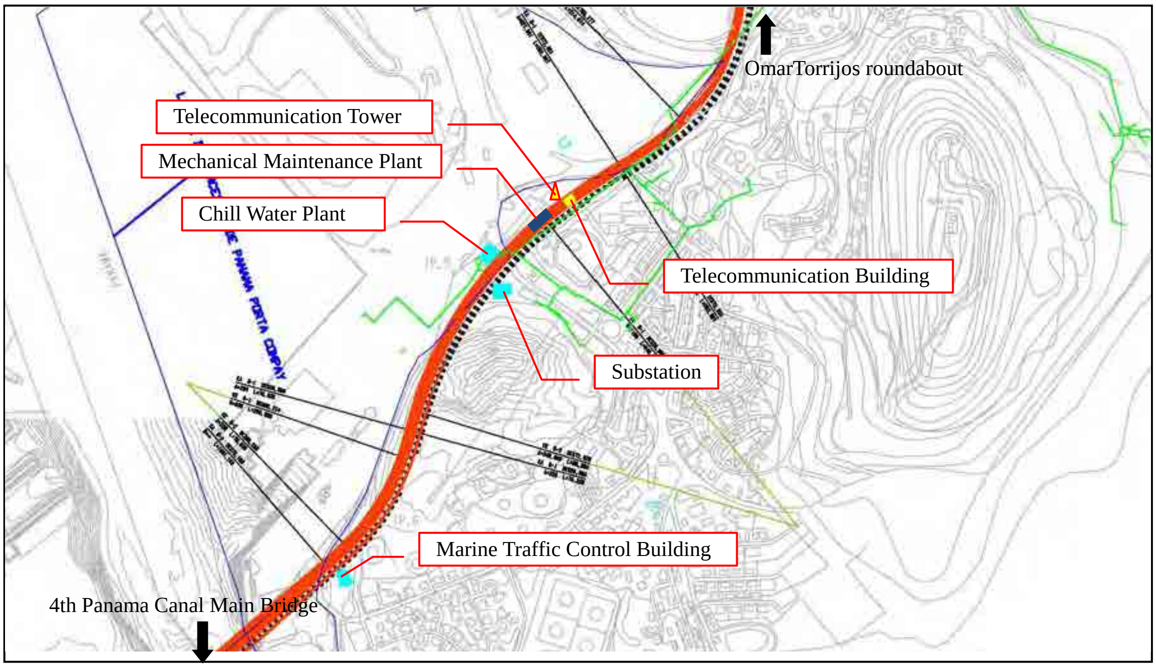
13.6.2 Plan for Relocating Existing Utilities and Underground Installations

Table 13.15 shows the possibility of relocating each existing utility identified through discussions with relevant authorities. Figure 13.14 illustrates the location of the major utilities.

Table 13.15 Possibility to Relocate the Existing Utilities

No.	Equipment	Relocation situation	Relocation level
1	Telecommunication Building (Include communication towers)		4
2	Chill water Plant		5
3	Substation		5
4	High-voltage Transmission Tower	Possible	3
5	Marine Traffic Control Building		5
6	Mechanical Maintenance Plant	Possible	3
7	Oil tank		1
8	Power line	Possible	2
9	Water pipeline	Possible	2
10	Drainage pipe	Possible	2
11	Communication wire	Possible	2
12	Water pipes (Chill water plant)	Possible	3
13	Gas line		1
14	Oil line		1

Note: Relocation level: 5 No relocation, 4 No relocation, if possible, 3 Relocation is possible, 2 Simple relocation, 1 Excluded from Project
Source: Respective institutions



Source: Respective institution

Figure 13.14 Location of Major Existing Utilities

It is difficult to set the road and monorail alignments to avoid all the facilities. Thus, a final alignment was proposed that would avoid those facilities that the relevant authorities indicated should not be relocated. As a result, the facilities that are to be relocated are listed below. Regarding the Telecommunication Building, it is located under Flyover No.2; however, the road can pass over the building because it is an unmanned facility. Therefore, the piers only need to be located appropriately to avoid the building. However, the telecommunication tower will need to be heightened because if would obstruct the line of sight of Flyover No.2.

Existing facilities that require relocation:

- Mechanical Maintenance Plant
- High-voltage Transmission Tower
- Underground utilities

In order to ensure the smooth implementation of the Project, said utilities should be relocated before the commencement of the Project's construction work.

It should be noted that the existing facilities listed up above are based on the information provided by each relevant authority, however some unexpected utilities may be identified at a later stage. Such utilities shall also be appropriately relocated during construction.

(1) Relocation of the Mechanical Maintenance Plant

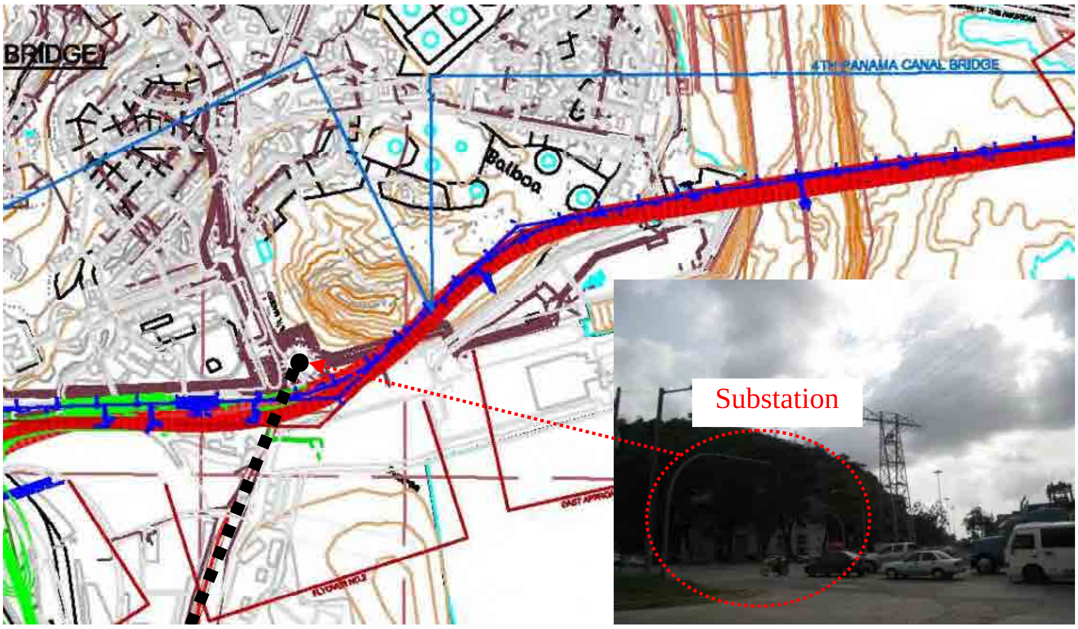
The Chill Water Plant, Electrical Substation, and the Marine Traffic Control Building are important facilities that the relevant authorities confirmed would be impractical to relocate. The relocation of important facilities has been avoided and only the Mechanical Maintenance Plant will need to be relocated.

Since the Mechanical Maintenance Plant is owned by ACP (Panama Canal Authority), it will be in charge of implementing the relocation. The relocation costs were calculated in the Study. Details of the relocation plan and building costs are described in the Chapter on Environmental and Social Considerations.

(2) Relocation of the high-voltage power transmission lines

In the implementation phase, the power lines from the substation located near Balboa Station will constitute a significant obstacle to the construction work.

Figure 13.15 presents a diagram of the existing power lines, followed by an outline of the measures for relocating the lines.



Source: Gas Natural fenosa

Figure 13.15 Diagram of the Existing Power Grids

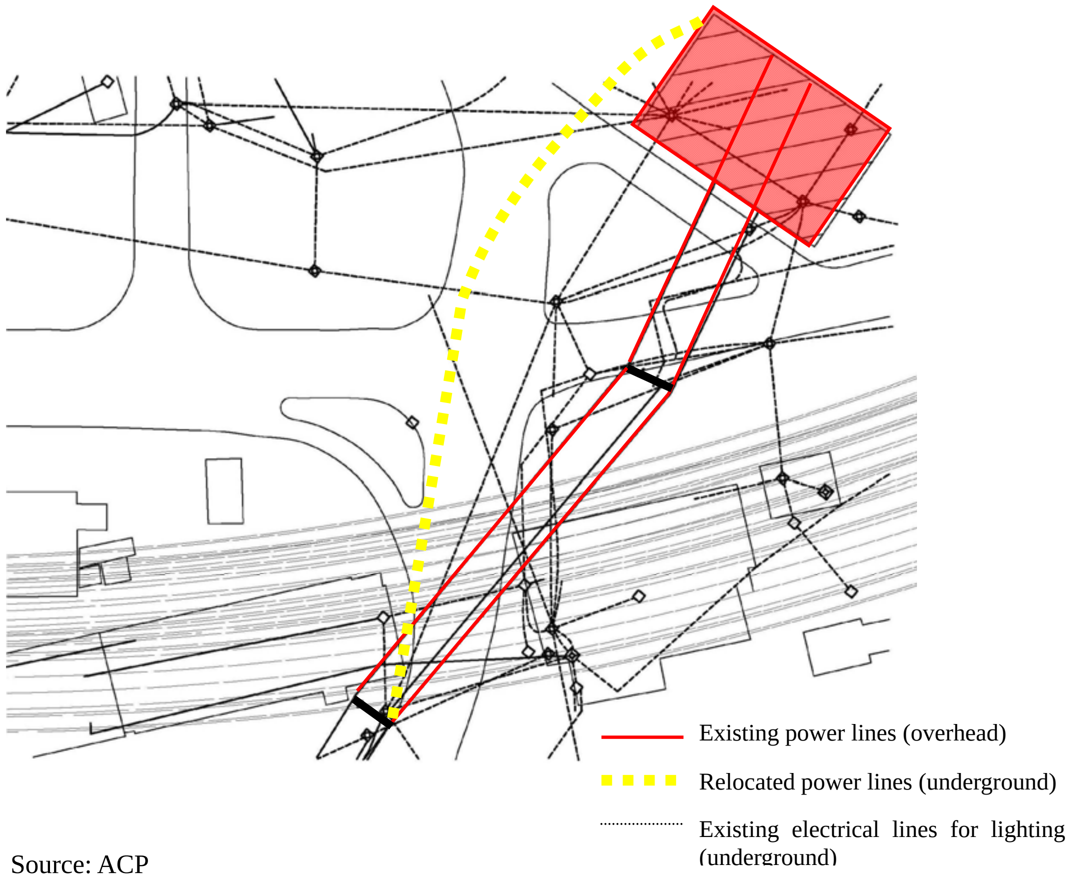
There are two possible ways to relocate the power lines as explained below.

- Relocate the lines and change the route of the road
- Bury the overhead lines underground without changing the route

The road alignment developed by the Project will pass very close to the substation connected to the power grid; therefore the option to change the alignment is very impracticable. Upon consulting with Gas Natural Fenosa, which is in charge of the power grid, the option to relocate the overhead power lines by burying them underground was selected.

When burying the power lines, the existing underground electrical lines for lighting need to be considered. It was learned from Gas Natural Fenosa that the underground electrical lines are buried 600 mm below the ground. The power lines to be relocated will be installed 1,200 mm below ground, below the electrical lines for lighting. The plan is to bury six φ130 pipes.

Figure 13.15 shows a schematic plan of the underground installation of the power lines.



Source: ACP

Figure 13.16 Schematic Plan of the Underground Installation of Power Grids

(3) Relocation of Underground Utilities

Under the Project, the following types of existing underground utilities will have to be relocated:

- Power lines
- Water pipelines and drainage pipes, and
- Communication lines.

These underground utilities are to be moved under the following conditions.

- Only those underground utilities that obstruct the bridge piers shall be relocated and only the minimum necessary.
- The section to be relocated shall be between two terminal points of the underground utility, such as a manhole, in order to facilitate cable re-installation.
- Each utility service provider shall be in charge of the relocation of its respective utility.
- Underground pipelines inside the embankment section shall not be relocated, but shall be reinforced with concrete in consideration of increased of soil pressure.

Table 13.16 below shows the list of underground utilities to be relocated. The location map of underground utilities within the Project target area is shown in Appendix 6.

Table 13.16 List of Existing Underground Utilities to be relocated

No.	Utility	Countermeasure	Managing Bodies	Length (m)	Reference Drawing (Appendix 6)
1	Power lines	Relocation	ACP,	63	Power line relocation (1 of 5)
2		Relocation	ACP	33	Power line relocation (1 of 5)
3		Relocation	ACP	25	Power line relocation (1 of 5)
4		Relocation	ACP,	22	Power line relocation (2 of 5)
5		Relocation	ACP	55	Power line relocation (2 of 5)
6		Relocation	ACP	26	Power line relocation (2 of 5)
7		Relocation	ACP,	50	Power line relocation (2 of 5)
8		Relocation	ACP	38	Power line relocation (2 of 5)
9		Relocation	ACP	84	Power line relocation (2 of 5)
10		Relocation	ACP,	51	Power line relocation (2 of 5)
11		Relocation	ACP	80	Power line relocation (2 of 5)
12		Relocation	ACP	20	Power line relocation (3 of 5)
13		Relocation	ACP	150	Power line relocation (3 of 5)
1	Water pipelines and drainage pipes	Concrete Protection	ACP	20	Water pipeline relocation (2 of 5)
2		Concrete Protection	ACP	79	Water pipeline relocation (2 of 5)
3		Relocation	ACP	160	Water pipeline relocation (2 of 5)
4		Relocation	ACP,	175	Water pipeline relocation (2 of 5)
5		Footing Foundation	ACP	11	Water pipeline relocation (2 of 5)
6		Footing Foundation	ACP	15	Water pipeline relocation (2 of 5)
7		Footing Foundation	ACP,	12	Water pipeline relocation (2 of 5)
8		Relocation	ACP	28	Water pipeline relocation (3 of 5)
9		Relocation	ACP	103	Water pipeline relocation (3 of 5)
10		Concrete Protection	ACP	40	Water pipeline relocation (4 of 5)
11		Concrete Protection	ACP,	38	Water pipeline relocation (4 of 5)
12		Concrete Protection	ACP	215	Water pipeline relocation (4 of 5)
1	Communication	Relocation	ACP	72	Communication line relocation (1 of 5)

Source: JICA Study Team

The method for relocating the water pipelines shall be well examined taking into consideration the water pressure in the later stage.

13.7 Conclusion

Plans and preliminary designs were developed for all of the electrical and mechanical equipment necessary for the Project. Specific plans for the following facilities should be reviewed in the detailed design.

- Adoption of low-position lighting
- Method for connecting the weather observation equipment and CCTV cameras with ATTT's central system with
- Adoption of illumination
- Introduction of elevator facility

Regarding the improvement of the Omar Torrijos roundabout, the study was conducted only at the level of a concept design; therefore, a relocation plan was not prepared. The relocation plan will be studied with the preliminary design by GOP.

Chapter 14 Preliminary Operation and Maintenance Plan

14.1 Summary

14.1.1 Objective

In order to calculate the estimated operation and maintenance costs, the preliminary operation and maintenance plan, to be implemented after project completion, was examined.

14.1.2 Study Items

In the study, the following items were considered:

- Examination of the outline of the operation, maintenance and management plan.
- Examination of the operation, maintenance and management system.
- Development of an outline for the maintenance and management plan.

As the Project involves the development of a bridge for road and railway, the preliminary operation and maintenance plan was studied in order to support the efficiency of the different operation and maintenance service providers.

14.1.3 Survey Results

The road to be developed by the Project is a general road so tolls will not be collected under this plan. It was also decided that the operation, maintenance and management services in the road Project would be separated from those of Metro Line-3 because of the different service providers.

Under this plan, the maintenance and management entity for the civil engineering facilities constructed by the Project is the MOP (Ministry of Public Works of Panama), while the Land Transit and Transportation Authority (Autoridad del Tránsito y Transporte Terrestre, ATTT) is responsibility for traffic management and equipment maintenance.

Table 14.1 shows the relevant service providers and their respective areas of responsibility, and Table 14.2 indicates the entities in charge of the operation, maintenance and management of the equipment installed by the Project.

Table 14.1 Relevant Service Providers and their Respective Areas of Responsibility

No.	Category	Service Required	Operator/Service Provider
1	4th Panama Canal Bridge	Bridge management	Ministry of Public Works (MOP)
2		Management of the Metro Line-3	Panama Metro Secretariat (SMP)
3		Road traffic management	Land Transit and Transportation Authority (ATTT)
4	Other Roads[1)]	Road traffic management	Land Transit and Transportation Authority (ATTT)
5	Panama Canal	Navigation channel	Panama Canal Authority (ACP)
6	Albrook Airport	Airport management	Civil Aviation Authority (AAC)
7	Overall Facilities	Response to accidents and disasters	Police, fire department, emergency service
8	Elevator	Response to emergency contacts	Elevator maintenance company

1) East Side Connection Road, Access Roads to the Bridge of the Americas, Omar Torrijos roundabout, West Side Connection Roads
Source: Respective Service Providers

Table 14.2 Operation and Maintenance of the Equipment

No.	Category	Equipment	Administrator
1	Electrical Equipment	Bridge lighting	Gas Natural Fenosa
2		Road lighting	Gas Natural Fenosa
3		Airplane warning lights	MOP
4		Marine warning lights	ACP
5		Illumination	MOP
6		Power supply equipment	Gas Natural Fenosa
7	Communication Equipment	Anemometer	ATTT
8		Rain gauge	
9		Precipitation detector	
10		Visibility meter	
11		Thermometer	
12		CCTV camera	
13	Mechanical Equipment	Elevators	MOP

Source: JICA Study Team

14.1.4 Conclusion

The maintenance and management entity for the civil engineering facilities of the Project is the MOP (Ministry of Public Works of Panama), whereas the relevant agencies of each of the other facilities are responsible for traffic management and equipment maintenance. There is a need to create an operational manual that summarizes the maintenance methods and management system for the future. Specific plans will be drawn up in the detailed design.

14.2 Preliminary Operation and Maintenance Plan

14.2.1 Development Plan

The Project consists of the following roads:

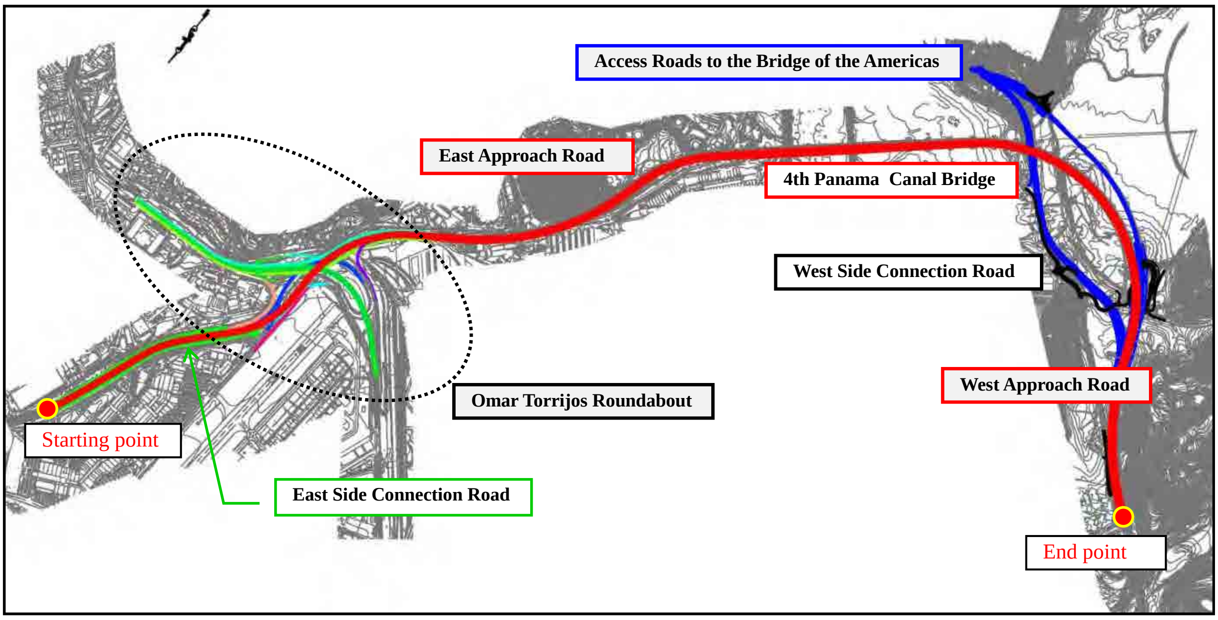
- 4th Panama Canal Bridge (including East and West Approach Roads)
- East Side Connection Roads
- Access Road to the Bridge of the Americas (West Side)
- Omar Torrijos Roundabout
- West Side Connection Roads (excluding Additional Ramp X (future))

Table 14.3 shows the features of the project (scope of construction works) and Figure 14.1 presents a map illustrating the project location.

Table 14.3 Project Features (Scope of Construction Works)

No.	Route	Segment		Item	Description
1	4th Panama Canal Bridge (Construction)	Whole segment			Road Length: 6,720.212m (-KM0+020.975 to KM6+699.237) No. of Lanes: 6 lanes (2*3 lanes) (BP～Omar Torrijos Roundabout: 4 lanes (2*2 lanes))
		Break-down	Civil	East Approach Road	Road Length: 2,867.975m
				4th Panama Canal Bridge	Road Length: 2,543m
				West Approach Road	Road Length: 1,309.237m
			Utilities	Whole Section	Electrical, communication and mechanical facilities
2	East Side Connection Road (Construction)	Whole segment			Road Length: 1,025.19m, No. of Lanes: 2 lanes
		Break-down	Civil	Additional Ramps	On Ramp, Off Ramp
			Utilities	Whole Section	Electrical facilities (road lighting)
3	Access Roads to the Bridge of the Americas	Whole			Road Length: 3,170.4m, No. of Lanes: 4 lanes (2*2 lanes)
		Break-down	Civil	East, to Panama City West, to Arraijan	Reconstruction of east-bound to Panama City. and west-bound, to Arraijan
	(Reconstruction)		Utilities	Whole Section	Electrical Facilities (road lighting)
4	Omar Torrijos Roundabout (Improvement)	Whole segment			Road Length: 5,690m No. of Lanes: Ramps - 1way, 1or 2 lanes Underpass: 4 lanes (2x2 lanes)
		Break-down	Civil	Additional Ramps	Additional ramps, Flyover[1)], Underpass
				Existing Roundabout	Widening of existing roundabout
			Utilities	Whole Section	Electrical facilities (road lighting)
				Underpass Section.	Mechanical facilities (drainage pumps)
5	West Side Additional Ramps (Reconstruction)	Whole segment			Road Length: 1,130m, No. of Lanes: 1way, 2 lanes
		Break-down	Civil	Additional Ramps	Additional Ramp Y and ramps a to i
			Utilities	Whole Section	Electrical facilities (road lighting)

1) Assumption
2) Except Additional Ramp X (For the future)
Source: JICA Study Team



Source: JICA Study Team

Figure 14.1 Project Location Map

14.2.2 Division of the Operation and Maintenance Services

As the road to be developed in the Project will require a wide range of services, including the management of the road, the Metro Line-3 and utilities (water supply, electricity and communication), the plan will distribute the operation and maintenance services among the different service providers.

It would be possible to share lighting, power supply and meteorological observation equipment, as well as the CCTV cameras, between the road and Metro Line-3. However, Metro Line-3 plans to introduce complicated systems, such as an automatic fare payment system and a CCTV monitoring system, and to operate their equipment in a different manner than the Project since their objectives and uses are different. Accordingly, under the Project plan, the facilities to be installed and their locations will not be jointly shared by the Project and Metro Line-3.

14.2.3 Operation and Maintenance Entity

As the road to be developed is a general road, the operation, maintenance and management entity is the Ministry of Public Works (Ministerio de Obras Publicas, MOP). Nonetheless, as in the case of other general roads, the use of other service providers and the outsourcing of services will also be considered.

To ensure the long-term operation of the equipment, standards and other documents should be developed describing the work procedures for the Project facilities. In the case of outsourcing, this would also help the external service providers in understanding their duties. The standards should include the following items:

- Specifications of the equipment to be serviced
- Operation and inspection methods, inspection frequency, etc. of the equipment
- Cleaning and other procedures
- Emergency responses
- Emergency communication system

14.2.4 Operation Method

(1) Toll

Since the road is categorized as an urban arterial road, tolls will not be collected.

(2) Traffic Management

The traffic on the road to be developed in the Project will be managed as a general road. While the Ministry of Public Works is the entity responsible for the operation, maintenance and management of the general roads, ATTT is solely responsible for traffic management on the general roads.

In Panama there is generally no traffic management even under adverse weather conditions (wind, rain, fog). Accordingly, the types of traffic regulations to be implemented on the Project's road, and their standard values need to be established. Upon consulting with the relevant authorities, the following rules were adopted for traffic management in the Project:

- When any value measured with meteorological observation equipment exceeds the standard value, the display boards installed at the entrances of the bridge will automatically show information on speed limit or warning of rain, fog, etc.
- When the lanes are closed due to an accident, ATTT, which is in charge of traffic management, will call for the cooperation of the police and request road closure.
- Although it is possible to announce closure with the display boards, they will not be used for announcing road closure in order to avoid erroneous closure caused by fallen objects or equipment failure, which could cause accidents and complaints.
- Although the services of Metro Line-3 would also be restricted or shut down in the case of adverse weather (only for gale winds), such regulations will not be conducted jointly with the road because their form of operation is different.

According to the traffic regulation rules for Metro Line-3, services will be restricted at a wind speed of 20m/s and shut down at a wind speed of 25m/s. In such cases, the control center will inform the train drivers by telephone if the value measured by the anemometer exceeds the standard value. The services will not be restricted by rain or fog because neither has impact on the operation of monorails.

There are two types of traffic regulations and it is necessary to confirm which types of traffic regulation will be applied in the future.

Regulation on vehicles

Height Regulation

The height of vehicles and cargo is regulated to ensure safety on bridges.

Width Regulation

The width of vehicles and cargo is regulated to ensure safety on narrow roads, etc.

Weight Regulation

The weight of vehicles and cargo is regulated to ensure safety on bridges, etc.

Cargo Regulation

The passage of vehicles carrying hazardous objects through long tunnels and underwater tunnels is restricted.

(This regulation is applicable to the underpass at the Omar Torrijos roundabout as well).

Regulation for Road Work

Traffic is regulated due to road work and services, as well as for construction work in the vicinity.

(3) Facility Management

1) Civil Facilities and Equipment

Facility maintenance and management in general involves the following services:

<u>Patrol Service</u>

A patrol car is used on a regular basis (roughly once a day) to inspect for obstruction by falling objects on the road and, if necessary, to performs minor maintenance work.

<u>Maintenance</u>

Daily maintenance services include road cleaning, pruning of street trees and grass cutting.

<u>Inspection</u>

The equipment is inspected periodically to compare its functioning with that of the previous inspection. The road is inspected with a patrol car to check the road surface. The bridge is inspected once every five years by visually checking for cracks and other damages to evaluate the soundness of the bridge.

<u>Repair</u>

Repairs are made based on the results of equipment, road and bridge inspections.

<u>Administrative Work</u>

This includes application for occupancy and approval of the passage of special vehicles.

<u>Consultation Services</u>

The administration office offers consultation services to give advice and respond to complaints from the public.

While all of the maintenance and management services mentioned above are required in the Project, they will be outsourced because the Ministry of Public Works has no technical section dedicated to repairs, which requires specialized skills.

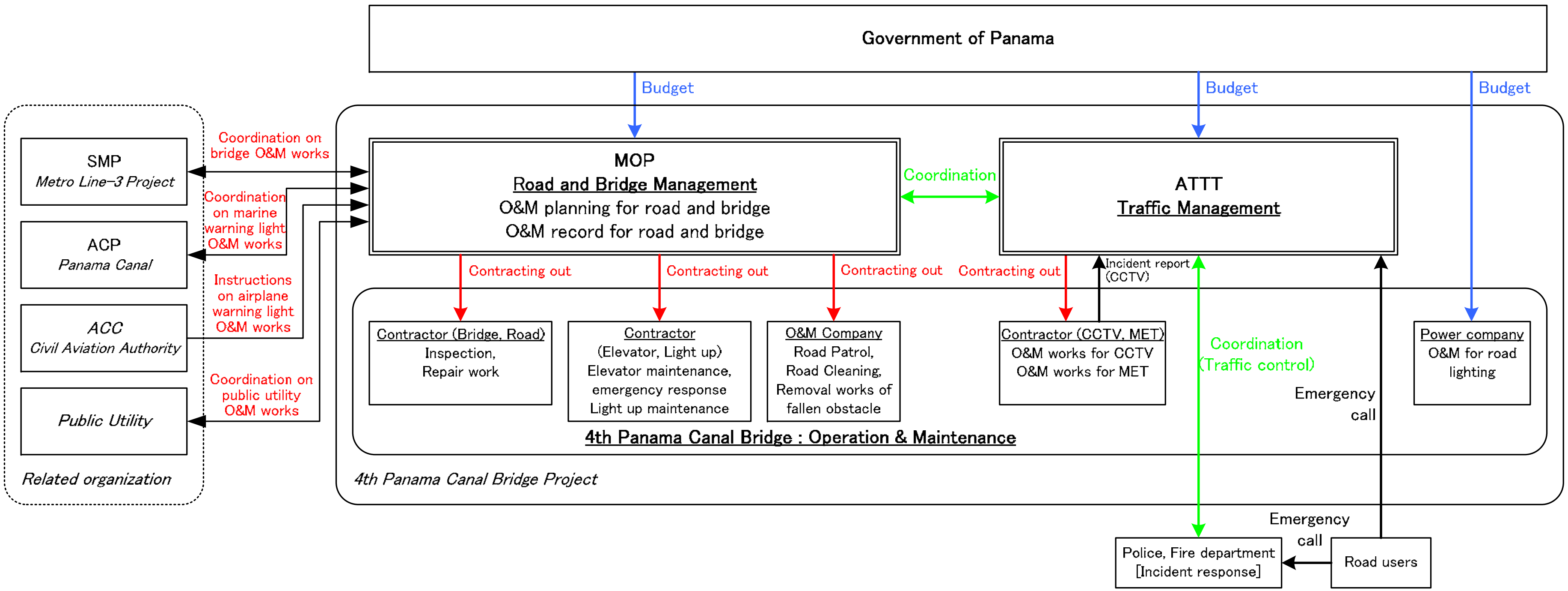
The functioning of the equipment needs to be maintained above a certain level through regular inspections as well as emergency repairs if necessary. A replacement schedule should also be developed.

2) Utilities

While utilities such as water supply pipelines, high-voltage lines and communication lines need to be installed in the Project, operation and maintenance services for the utilities will be performed by the respective service providers.

14.3 Outline of the Operation, Maintenance and Management System

Figures 14.2 illustrate the organizational chart of the operation and maintenance system for the completed Project and a schematic diagram of the system.



Source: JICA Study Team

Figure 14.2 Organizational Chart of the Operation and Maintenance System

14.4 Preliminary Maintenance Plan

A preliminary maintenance plan was developed for the Project based on the results of the civil engineering and equipment designs in this study in order to estimate the operation and maintenance costs as explained below.

14.4.1 Civil Structures

Table 14.4 shows the preliminary maintenance plan in the Project (civil structures).

Table 14.4 Preliminary Maintenance Plan in the Project (Civil Structures)

Category		Structures	Specifications	Maintenance Method	Frequency (Year)
Common		Road markings	White color	Repaint	10
		Road signs	F-type, Single pole type	Replace	10
Road		Pavement (Vehicle way)	Concrete	Replace, Overlay	30
		Pavement (Shoulder)	Surface course: dense-grade asphalt	Remove old surface, overlay	10
		Retaining wall	Reinforced earth	Replace surface panel	50
		Cut slope protection	Mortar spraying	Re-spray	20
		Embankment slope treatment	Seeding	Trim a slope, Re-seeding	20
		Side ditch, catch pit	Concrete	Replace	15
		Guardrails	Flexible guard fence	Partially replace	10
Bridge	Common	Wall Barrier	Concrete	Replace	100
		Pavement (Surface course)	Dense-grade asphalt	Remove old one surface, overlay	10
		Pavement (Binder course , waterproofing)	Dense-grade asphalt	Remove old layer, overlay	30
		Pavement (Sidewalk)	Asphalt	Remove old pavement, overlay	30
		Catch pit	Steel	Replace	50
		Accessories (partial)	—	Cleaning, patching, repair	5
	Arch	Painting	Equivalent to Class C-5	Scraping, re-painting	40
		Painting (partial)	Equivalent to Classes C-5/D-5	Scraping, re-painting	15
		Scaffolding for re-painting	—	—	40
		Cable strands	PWS	Replace	100
		Deck slab	RC deck slab	Replace	100
		Deck slab (partial)	RC deck slab	Repair the section	15
		Bearings	Rubber type	Replace	100
		Expansion joint	Steel	Replace	40
		Substructure (partial)	RC	Repair the section	10
	Steel Box Girder	Painting	Equivalent to Class C-5	Scraping, re-painting	40
		Painting (partial)	Equivalent to Classes C-5/D-5	Scraping, re-painting	15
		Scaffolding for re-painting	—	—	40
		Deck slab	RC deck slab	Replace	100
		Deck slab (partial)	RC deck slab,	Repair the section	15
		Bearings	Rubber type	Replace	100
		Expansion joint	Steel	Replace	40
		Substructure (partial)	RC	Repair the section	10
	PC-I Girder	Main girder (partial)	PC	Repair the section	15
		Bearings	Rubber type	Replace	100
		Expansion joint	Steel	Replace	40
		Substructure (partial)	RC	Repair the section	10

Source: JICA Study Team

14.4.2 Electrical and Mechanical Equipment

The functions and level of reliability required for similar electrical & mechanical equipment may differ according to the objectives, conditions and locations. The equipment that is to be installed needs to be appropriate to the objectives, and proper and necessary maintenance needs to be carried out to ensure that the equipment can fulfill the required functions.

Basic maintenance services for electrical & mechanical equipment include periodical inspection to check and analyze the condition of the various electrical and communication devices that are installed and operated, in order to extend their service through steady improvement measures.

Inspections made in a planned manner help to determine the proper timing for replacing the equipment, maintain its functions, performance and reliability, and reduce the lifecycle cost.

Table 14.5 shows the preliminary maintenance plan in the Project (for electrical and mechanical equipment).

Table 14.5 Preliminary Maintenance Plan in the Project (Electrical and Mechanical Equipment)

Item		Inspection item	Inspection Frequency	Replacement Frequency
Lighting Facilities	Pole Lighting	- Deterioration of poles - Power consumption - Cleaning	Twice a year	Pole: every 30 years LED lamp: every 15 years
	Road Lighting (Underpass)	- Deterioration of lighting fixture - Power consumption - Deterioration of cable and conduit - Cleaning	Twice a year	Lighting fixture: every 30 years LED lamp: every 15 years
	Airplane Warning Light	- Deterioration of control parts - Deterioration of solar cell	Twice a year	Solar cell: every 10 years Control panel: every 15 years
	Marine Warning Light	- Deterioration of control parts - Deterioration of solar cell	Twice a year	Solar cell: every 10 years Control panel: every 15 years
Power Supply Facilities	Illumination	- Deterioration of fixtures * Lamps are replaced in case of failure	Twice a year	Fixture: every 30 years LED lamp: every 15 years
	Outdoor Switchboard	- Voltage measurement - Deterioration of internal devices - Deterioration of piping/wiring	Once a year	Every 30 years
Communication Facilities	Meteorological observation equipment	- Function of measurement parts - Deterioration of display devices - Deterioration of piping/wiring	Twice a year	Meteorological observation equipment: every 20 years Pole: every 30 years Measurement device: every 15 years
	Variable Massaging Sigh Board	- Function of measurement parts - Deterioration of display devices - Deterioration of piping/wiring	Twice a year	Information board: every 15 years Pole: every 30 years
	CCTV Camera	- Function of measurement parts - Deterioration of display devices - Deterioration of piping/wiring	Twice a year	CCTV camera: every 10 years Pole: every 30 years Optical cable: every 20 years
Mechanical Facilities	Elevator Equipment	- Function of elevators - Function of emergency power generators - Deterioration of wires - Emergency communication system - Blinking of display devices	Twice a year	Elevator apparatus: every 20 years Shaft: every 50 years Driving system: every 15 years
	Drain pump	- Function of pump - Pump tank - Function of control equipment - Cleaning	Once a year	Every 30 years

Source: JICA Study Team

14.4.3 Environmental Monitoring

Environmental monitoring should carry out the monitoring on air quality, noise, vibration, water quality, soil quality, and waste water during the first three years of the operation stage.

The detail of environmental monitoring plan was described in Section 19.

14.5 Conclusion

The preliminary operation and maintenance plan was studied.

Most of the operation and maintenance services for the equipment installed by the Project will be provided by ATTT. The administrative system for the equipment has to be determined after confirming with ATTT on how it operates other general roads.

While electricity charges account for a large proportion of the equipment operation and maintenance cost, the lighting cost for general roads is borne by the power company. Therefore the lighting bill for the bridge and other public roads of this Project will be paid by the power company. Information on the electricity charges for road lighting in this project is based on the electricity tariff list obtained from the power company in this Study.

Table 14.6 shows the electricity charges given in the power supply tariff list.

Table 14.6 Electricity Charges for Electric Power Supply

Monthly Base Charge	First 10kWh: 2.21dollars
Daily Extra Electricity Charges	0.16572dollars/kWh

Source: Gas Natural fenosa