8.6 Study on Bridge Accessories

8.6.1 Bearings

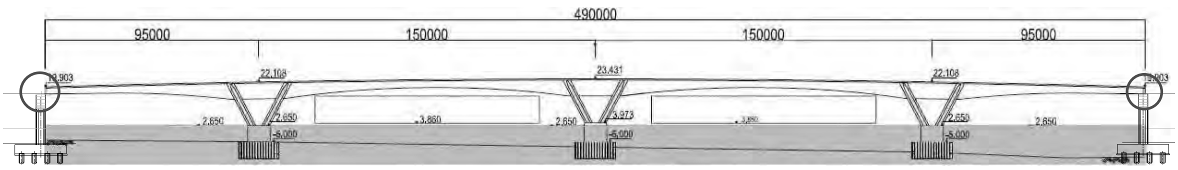
8.6.1.1 Design of Bearings for Main Bridge

(1) Features on Selecting Bearing type for Main Bridge

On the contrary to the continuous girder bridge like Approach Bridge, the bearings are needed only at the end piers for Main Bridge which is supported by 3 V-shaped piers with rigid connection. Therefore, not only vertical force but also horizontal force are dispersed to the piers and it is not necessarily the case that the assembly of laminated elastomeric shoes for dispersing horizontal force is applied.

One of other features in Main Bridge for selection of bearing type is large longitudinal displacement by temperature change and concrete shrinkage due to large length of the bridge.

In this section, a comparative study for selecting the appropriate bearing shoe type on the end pier of Main Bridge is presented by taking into account the above-mentioned features.



Source: Study Team

Figure 8.6.1-1 Location for installation of Bearings in Main Bridge

(2) Selection of Bearing Type for Main Bridge

1) Conditions of Comparative study

A comparative study was performed, by introducing following alternatives;

- ●- Alternative -1: Pot Bearings (Unidirectional and multidirectional bearings)
- ●- Alternative -2: Elastomeric Bearings and Anchor Bars
- ●- Alternative -3: Elastomeric Bearings with Anchored Plates and Anchor Bars

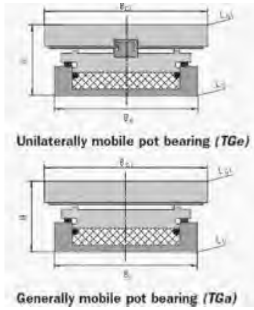
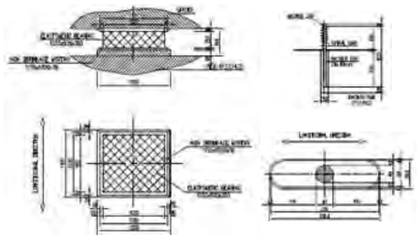
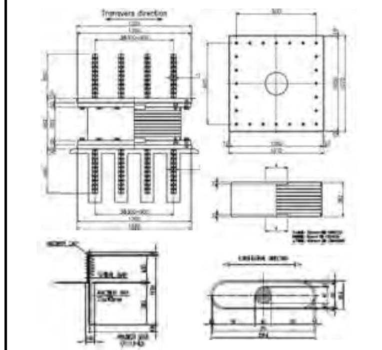
In cases with elastomeric bearings, Alternatives-2 and 3, anchor bars are to be installed for joint protection during earthquake. In the case with pot bearings, Alternative-1, the unidirectional bearing guides the girder to move in the longitudinal direction so that the joint can be protected from transversal movement of the girder.

2) Result of Comparative Study

The result of comparative study is shown in the table on the next page.

As shown in the table, Alternative -1, Pot Bearing, is recommended because of its advantages in investment cost and adaptability for large displacement.

Table8.6.1-1 Comparison on Type of Bearing for Main Bridge

Evaluation Items	Max. Point	Alternative-1 Pot Bearing		Alternative-2 Elastomeric Bearing + Anchor Bars		Alternative-3 Elastomeric Bearing for seismic force dispersing +Anchor Bars	
Schematics		 The dimensions are tentative		 The dimensions in the schematics are tentative.		 The dimensions in the schematics are tentative.	
		H= 156, Bu= 640, BGL=700		1050 x 1050 x 32 x 9Layers		1050 x 1050 x 32 x 9Layers	
		H= 138, Bu= 610, BGL=660		Anchors: 6 x D40		Anchors: 6 x D40	
Structural Aspect and Stability	10	- Suitable for large displacement and large - Suitable for large displacement and large vertical reaction - The longitudinal seismic force is not transmitted to the pier under the bearing and the fixed V-shaped piers will share the force.	10	- Simple Structure - Dimension can be flexiblly designed. - Need anchor bars with large blockouts which may cause interference with rebar arrangement. - Thick (approx. 40cm) and Large (Approx. 1m x 1m)	6	- This type is for sharing the seismic horizontal force on all the piers - Suitable for continuous grider bridge - The whle bearing system with plates and anchors are pre-fablicated. - Thick (approx. 40cm) and Large (Approx. 1m x 1m)	10
Construction Cost	40	Bearing Shoe (per pier) 905,142,374 VND VND Total 905,142,374 VND Ratio 1.00	40	Bearing Shoe (per pier) 1,071,716,100 VND Anchors & Caps (per pier) 49,832,954 VND Total 1,121,549,054 VND Ratio 1.24	24	Bearing Shoe (per 1pier) 4,465,339,105 VND Anchors & Caps (per pier) 49,832,954 VND Total 4,515,172,059 VND Ratio 4.99	0
Construction Plan and Period	10	Workability is Superior because no anchor bars are needed to be instaled.	6	Workability is superior because no anchors for the bearings are needed.	8	Workability is inferior because of lots of anchors for the bearings and anchor bars should be installed.	6
Maintenance	15	Inferior in maintenance because of difficulty in replacement.	9	Superior in maintenance because of simple method for replacement	12	Inferior in maintenance because of dificulty in replacement.	9
STEP Clearance	10	Procurement Ratio: 100%	10	Procurement Ratio: 95%	10	Procurement Ratio: 99%	10
Aesthetics	5	- Superior in Aesthetics with smaller bearings. - Superior in Aesthetics without anchor bars.	5	- Unbalanced comparing to the adjacent bearing - Inferior in Aesthetics with anchor cap block.	3	- Unbalanced comparing to the adjacent bearing - Inferior in Aesthetics with anchor cap block	3
New Technology	5	Commonly used in Vietnam	3	Commonly used in Vietnam	3	Rubber bearing for seismic force sharing is new	5
Traffic Management/ Environmental Aspect	5	No sigunificant differences among the alternatives	4	No sigunificant differences among the alternatives	4	No sigunificant differences among the alternatives	4
Evaluation	100	This alternative is the chiepest and superior in adopting big displacement	87	Construction cost is lower than Alternative-3 but higher than Alternative-1. Inferior in adopting big displacement.	70	Construction cost is the highest . Inferior in adopting big displacement. This alternative is suitable for continuous girders such as Approach Bridge.	47
		Recommended		Less Recommended		Not Recommended	

Source : Study Team

Table 8.6.1-1 Comparison on Type of Bearing for Main Bridge

(3) Design of Bearings for Main Bridge

1) Conditions

The conditions for designing the bearings are as follows,

Table 8.6.1-2 Reaction Forces and Displacements at Bearings

(1) Service Limit State

Items		Displacement (m)	Reaction Forces (kN)		Note
			Vertical	Transversal	
P75	Uni-directional	153.4	5855	623	
	Multi-directional	153.4	5728	-	
P79	Uni-directional	151.9	5917	621	
	Multi-directional	151.9	5770	-	

(2) Extreme Event Limit State

Items		Displacement (m)	Reaction Forces (kN)		Note
			Vertical	Transversal	
P75	Left	107.1	9100	2777	
	Right	107.1	9107	-	
P79	Left	109.8	10220	2990	
	Right	109.8	10211	-	

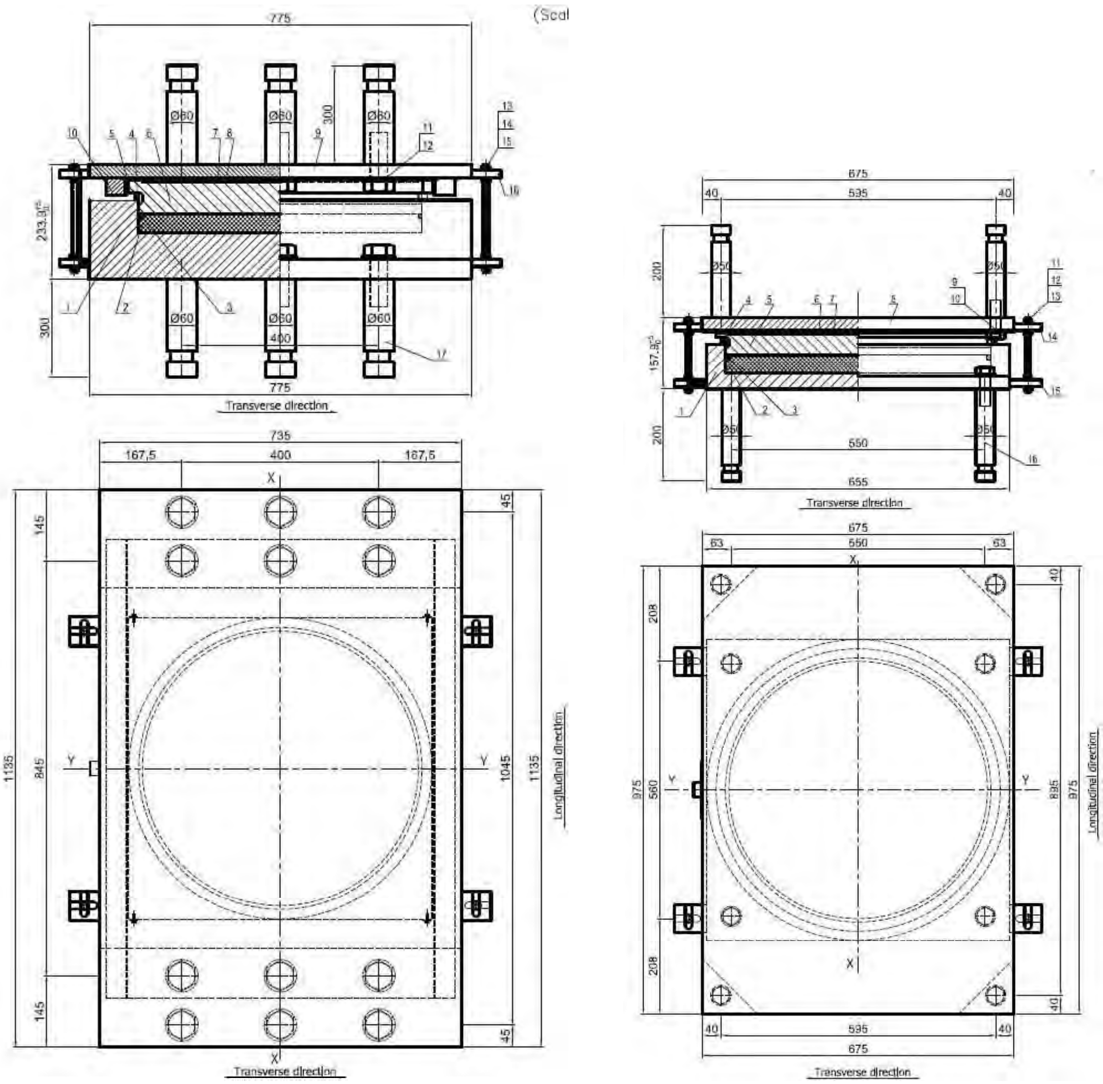
Source: Study Team

2) Results of Design

The items for checking are as follows,

- Thickness of Pot Ring
- Thickness of Pot Bottom
- Dimensions of Upper Plate
- Dimensions of Lower Plate
- Dimensions of Anchor Bolts
- Dimensions of Anchor Dowels
- Checking of Separation

The calculation note is shown in Design Report on Main Bridge. The resultant dimensions are shown in the figure in the next page.



(1) Unidirectional Sliding (2) Free Sliding

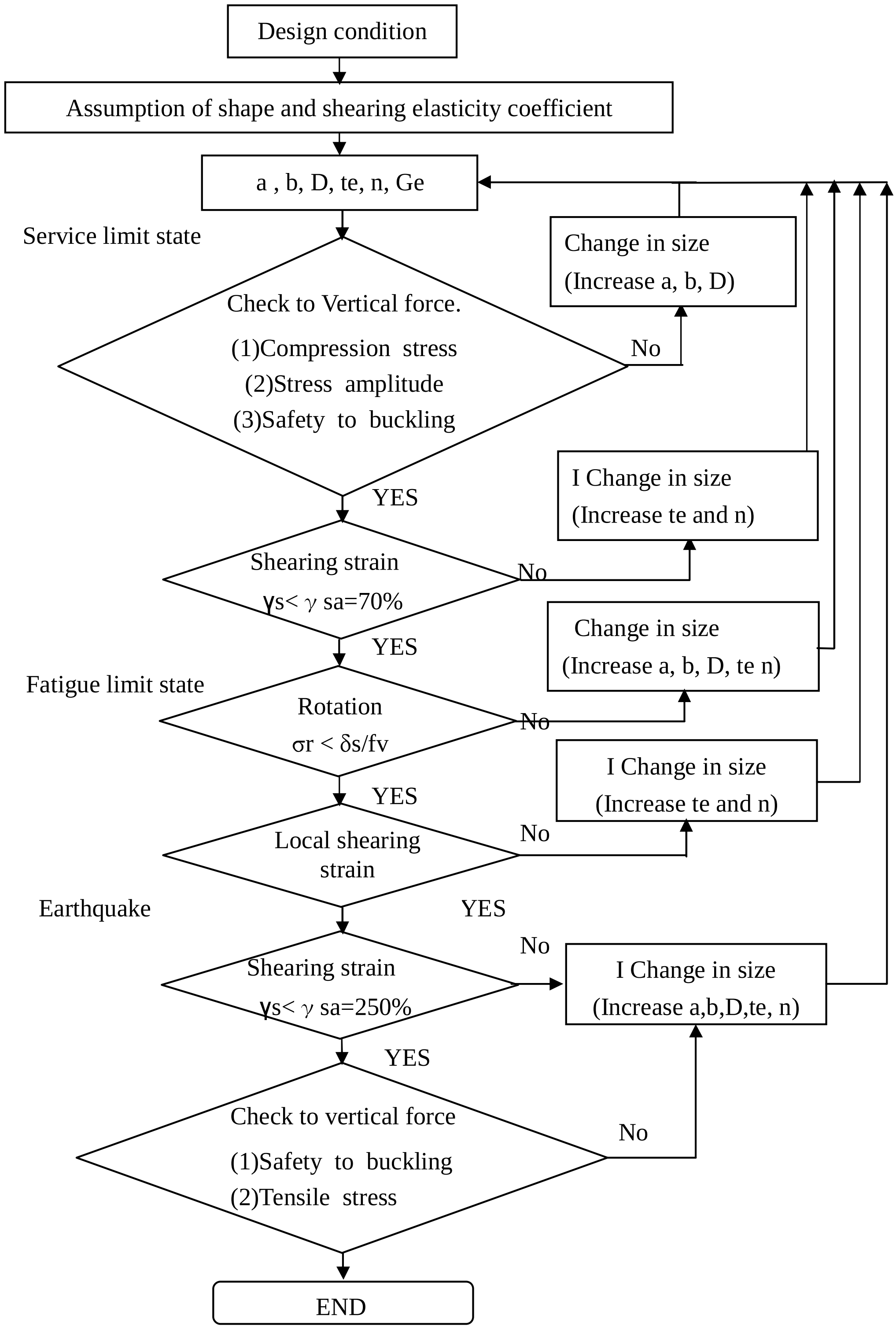
Source: Study Team

Figure 8.6.1-2 Dimensions of Pot Bearings

8.6.1.2 Design of Bearings for Approach Bridge

(1) Outline of design

The design procedure of rubber bearing is as shown in the figure below.



Source: Study Team

Figure 8.6.1-3 Flow of Bearing Design

(2) Hai An side Approach Bridge

1) Design condition

a) Design force

< CASE-1(5@60m=300m) >

The reaction force of Rubber bearing is shown in the table below.

Table 8.6.1-3 Reaction force of rubber bearing

No	Maximum Reaction		Miniumum Reaction	Live Load Max	Dead Load Reaction Max	Dead Load Reaction Min	Dead Load Total
	Rmax1	Rmax2	Rmin	$R_{L+I}max$	Rdmax	Rdmin	ΣRd
	kN	kN	kN	kN	kN	kN	kN
A1	5690	5121	4520	1080	4610	4610	9220
P1	10810	9729	8860	1680	9130	9130	18260
P2	10680	9612	8800	1660	9020	9020	18040
P3	10770	9693	8890	1660	9110	9110	18220
P4	10750	9675	8800	1680	9070	9070	18140
P5	5670	5103	4500	1070	4600	4600	9200
W	----	----	----	----	----	----	91080

Source: Study Team

< CASE-2(53m+3@60m+53m) >

Table 8.6.1-4 Reaction force of rubber bearing

No	Maximum Reaction		Miniumum Reaction	Live Load Max	Dead Load Reaction Max	Dead Load Reaction Min	Dead Load Total
	Rmax1	Rmax2	Rmin	$R_{L+I}max$	Rdmax	Rdmin	ΣRd
	kN	kN	kN	kN	kN	kN	kN
P55	5140	4626	4000	1030	4110	4110	8220
P56	10250	9225	8340	1750	8630	8630	17260
P57	10700	9630	8850	1660	9040	9040	18080
P58	10770	9693	9300	1460	9310	9310	18620
P59	10200	9180	8290	1620	8580	8580	17160
P60	5130	4617	3990	1030	4100	4100	8200
W	----	----	----	----	----	----	87540

Source: Study Team

b) Amount of Movement

< CASE-1 (5@60m=300m) >

Table 8.6.1-5 Amount of Movement at each bearing

Span	Span Length	Temperature change		Creep,Shrinkage etc.
	L	Δt	Δt'	Δscp
	m	mm	mm	mm
A1～ P1	59.00	±11.8	±23.6	-35.7
P1～ P2	60.00	±12.0	±24.0	-36.4
P2～ P3	60.00	±12.0	±24.0	-30.1
P3～ P4	60.00	±12.0	±24.0	-27.3
P4～ P5	59.00	±11.8	±23.6	-25.0

Source: Study Team

< CASE-2 (53m+3@60m+53m) >

Table 8.6.1-6 Amount of Movement in each support

Span	Span Length	Temperature change		Creep,Shrinkage etc.
	L	Δt	Δt'	Δscp
	m	mm	mm	mm
P55～ P56	51.98	±10.4	±20.8	-28.3
P56～ P57	60.00	±12.0	±24.0	-35.6
P57～ P58	60.00	±12.0	±24.0	-30.3
P58～ P59	60.00	±12.0	±24.0	-27.3
P59～ P60	51.98	±10.4	±20.8	-18.0

Source: Study Team

c) Allowable value

< Rubber >

The restriction stress of the body of rubber is as shown in the table below.

Table 8.6.1-7 Allowable value of rubber

Item				Sign	Unit	Value
Compression Stress	Maximum Compression stresse (At an effective area)	S1≦8		σmaxa	N/mm2	8
		8＜S1＜12				S1
		12≦S1				12
	Minimum Compression stress			σmina	N/mm2	1.5
	Stress amplitude	S1≦8		Δσa	N/mm2	5.0
		8＜S1＜12				5＋0.375･(S1-8)
		12≦S1				6.5
Shearing distorsion		service Loade		γsa	%	70
		Earthquake	Level1	γea	%	150
			Level2	γea	%	250
Local Shearing distorsion		Total distorsion at Service limitted state		γta	%	γu/fs
				fs	---	1.5
		Breaking growth rate		γu	%	depends on the table below.
Tensile Stress	Earthquake	G6		σta	N/mm2	1.2
		G8				1.6
		G10 or more				2.0

Source: Study Team

< Inner steel plate >

Table 8.6.1-8 Allowable value of Inner Steel Plate

Kind of Material	unit	Yield Strength	bending stress
SS400	N/mm2	235	140

Source: Study Team

d) Detail dimension of Bearing

Table 8.6.1-9 Detail Dimension of Bearing

< CASE-1 (5@60m) >

No	function	b	a	te	n	Σte	ts	Ge
		mm	mm	mm	layer	mm	mm	N/mm2
A1	Dispersion	950	950	30	7	210	6.0	1.20
P1	Dispersion	1200	1200	32	4	128	6.0	1.20
P2	Dispersion	1200	1200	32	4	128	6.0	1.20
P3	Dispersion	1200	1200	32	4	128	6.0	1.20
P4	Dispersion	1200	1200	32	4	128	6.0	1.20
P5	Dispersion	950	950	30	7	210	6.0	1.20

< CASE-2 (53m+3@60m+53m) >

No	function	b	a	te	n	Σte	ts	Ge
		mm	mm	mm	layer	mm	mm	N/mm2
P55	Dispersion	950	950	30	7	210	6.0	1.20
P56	Dispersion	1200	1200	32	4	128	6.0	1.20
P57	Dispersion	1200	1200	32	4	128	6.0	1.20
P58	Dispersion	1200	1200	32	4	128	6.0	1.20
P59	Dispersion	1200	1200	32	4	128	6.0	1.20
P60	Dispersion	950	950	30	7	210	6.0	1.20

Source: Study Team

e) Service Limited state

- Movement at service state

Longitudinal movement of Service limit state is shown in the table below.

Table 8.6.1-10 Longitudinal movement

< CASE-1 (5@60m) >

	Expansion length from center	Thermal movement (uniform temperature change)				Movement of creep and shrinkage			Live load	Combination	
		for horizontal force		for bearig design		Creep and shrinkage	Dead	amount			
		ΔLt		ΔLt'		ΔLscp	ΔLd	ΔL'	ΔLr	ΔL	
		+20℃	-20℃	+40℃	-40℃	----	----	----	----	+40℃	-40℃
	L	①	②	③	④	⑤	⑥	⑦	⑧	③+⑦+⑧	④+⑦+⑧
No	m	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
A1	-149.00	-29.8	29.8	-59.6	59.6	83.7	----	83.7	----	24.1	143.3
P1	-90.00	-18.0	18.0	-36.0	36.0	48.0	----	48.0	----	12.0	84.0
P2	-30.00	-6.0	6.0	-12.0	12.0	11.6	----	11.6	----	-0.4	23.6
P3	30.00	6.0	-6.0	12.0	-12.0	-18.5	----	-18.5	----	-6.5	-30.5
P4	90.00	18.0	-18.0	36.0	-36.0	-45.8	----	-45.8	----	-9.8	-81.8
P5	149.00	29.8	-29.8	59.6	-59.6	-70.8	----	-70.8	----	-11.2	-130.4

< CASE-2 (53m+3@60m+53m) >

	Expansion length from center	Thermal movement (uniform temperature change)				Movement of creep and shrinkage			Live load	Combination	
		for horizontal force		for bearig design		Creep and shrinkage	Dead	amount			
		ΔLt		ΔLt'		ΔLscp	ΔLd	ΔL'	ΔLr	ΔL	
		+20℃	-20℃	+40℃	-40℃	----	----	----	----	+40℃	-40℃
	L	①	②	③	④	⑤	⑥	⑦	⑧	③+⑦+⑧	④+⑦+⑧
No	m	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
P55	-141.98	-28.4	28.4	-56.8	56.8	75.8	----	75.8	----	19.0	132.6
P56	-90.00	-18.0	18.0	-36.0	36.0	47.5	----	47.5	----	11.5	83.5
P57	-30.00	-6.0	6.0	-12.0	12.0	11.9	----	11.9	----	-0.1	23.9
P58	30.00	6.0	-6.0	12.0	-12.0	-18.4	----	-18.4	----	-6.4	-30.4
P59	90.00	18.0	-18.0	36.0	-36.0	-45.7	----	-45.7	----	-9.7	-81.7
P60	141.98	28.4	-28.4	56.8	-56.8	-63.7	----	-63.7	----	-6.9	-120.5

Source: Study Team

- Design result of Service limit state

The result of the maximum compression stress, the stress amplitude, and the buckling stress is shown in the table below.

< CASE-1 (5@60m) >

Table 8.6.1-11 Check result of stress

	Movement	bearig area	Efective bearig area	Bearing stress					Buckling stress		Modulas of longitudinal elasticity
				Maximum		minimum	Stress amplitude				
	ΔLm	Ae	Acn	σmax	≦σmaxa	σmina	Δσ	≦ Δσa	σcra	≧σmax	E(※)
No	mm	m2	m2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2
A1	143.3	0.9025	0.7664	7.42	8.0	5.01	2.42	5.0	17.19	7.42	498.5
P1	84.0	1.4400	1.3393	8.07	9.4	6.15	1.92	5.5	42.19	8.07	697.6
P2	23.6	1.4400	1.4117	7.57	9.4	6.11	1.45	5.5	42.19	7.57	697.6
P3	30.5	1.4400	1.4033	7.67	9.4	6.17	1.50	5.5	42.19	7.67	697.6
P4	81.8	1.4400	1.3418	8.01	9.4	6.11	1.90	5.5	42.19	8.01	697.6
P5	130.4	0.9025	0.7786	7.28	8.0	4.99	2.30	5.0	17.19	7.28	498.5

Source: Study Team

The result of the Shearing strain and rotation is shown in the table below.

Table 8.6.1-12 Check result of transformation performance

	Vertical displacement				Loacal shear strain					Tensile stress of inner steel plate	
	Rotation	Compression	1/2*Liveload	Maximum	Vertical	Horizontal	Rotation	Amount	Allowable strain		
	δr	≦δc/fv	δcl	δo	γc	γs	γr	γt	≦γu/1.5	σs	≦σsa
No	mm	mm	mm	mm	%	%	%	%	%	N/mm2	N/mm2
A1	1.58	2.76	0.38	4.69	100.2	68.2	23.9	192.3	333	74.2	140
P1	1.00	1.69	----	2.62	92.2	65.6	29.3	187.1	333	86.1	140
P2	1.00	1.67	----	2.46	86.4	18.4	29.3	134.1	333	80.7	140
P3	1.00	1.68	----	2.49	87.7	23.9	29.3	140.8	333	81.9	141
P4	1.00	1.68	----	2.60	91.5	63.9	29.3	184.8	333	85.5	142
P5	1.58	2.75	0.37	4.60	98.3	62.1	23.9	184.3	333	72.8	140
Allowable value	----	----	≦ 1.00	----	----	≦ 70	----	----	----	----	----

Source: Study Team

< CASE-2 (53m+3@60m+53m) >

The result of the maximum compression stress, the stress amplitude, and the buckling stress is shown in the table below.

Table 8.6.1-13 Check result of stress

	Movement	bearig area	Efective bearig area	Bearing stress					Buckling stress		Modulas of longitudinal elasticity
				Maximum		minimum	Stress amplitude				
	ΔLm	Ae	Acn	σmax	≦σmaxa	σmina	Δσ	≦ Δσa	σcra	≧σmax	E(※)
No	mm	m2	m2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2
P55	132.6	0.9025	0.7765	6.62	8.0	4.43	2.19	5.0	17.19	6.62	498.5
P56	83.5	1.4400	1.3398	7.65	9.4	5.79	1.86	5.5	42.19	7.65	697.6
P57	23.9	1.4400	1.4113	7.58	9.4	6.15	1.44	5.5	42.19	7.58	697.6
P58	30.4	1.4400	1.4035	7.67	9.4	6.46	1.22	5.5	42.19	7.67	697.6
P59	81.7	1.4400	1.3420	7.60	9.4	5.76	1.84	5.5	42.19	7.60	697.6
P60	120.5	0.9025	0.7880	6.51	8.0	4.42	2.09	5.0	17.19	6.51	498.5

Source: Study Team

The result of the Shearing strain and rotation is shown in the table below.

Table 8.6.1-14 Check result of transformation performance

	Vertical displacement				Loacal shear strain					Tensile stress of inner steel plate	
	Rotation	Compression	1/2*Liveload	Maximum	Vertical	Horizontal	Rotation	Amount	Allowable strain		
	δr	≦δc/fv	δcl	δo	γc	γs	γr	γt	≦γu/1.5	σs	≦σsa
No	mm	mm	mm	mm	%	%	%	%	%	N/mm2	N/mm2
P55	1.58	2.49	0.36	4.18	89.4	63.1	23.9	176.4	333	66.2	140
P56	1.00	1.60	----	2.49	87.4	65.2	29.3	181.9	333	81.6	140
P57	1.00	1.67	----	2.46	86.6	18.7	29.3	134.6	333	80.9	140
P58	1.00	1.68	----	2.49	87.7	23.7	29.3	140.7	333	81.9	141
P59	1.00	1.59	----	2.47	86.8	63.8	29.3	179.9	333	81.1	142
P60	1.58	2.49	0.36	4.11	87.9	57.4	23.9	169.1	333	65.1	140
Allowable value	----	----	≦ 1.00	----	----	≦ 70	----	----	----	----	----

Source: Study Team

f) Earthquake

- Movement at earthquake

The amount of the movement at earthquake is shown in the table below.

< CASE-1 (5@60m) >

Table 8.6.1-15 The amount of the movement at earthquake

	Longitudinal direction				Transvers direction		
	2nd Effect	Level 1(at earthquake)	Level 2		Level 1(at earthquake)	Level 2	
			TYPE Ⅰ	TYPE Ⅱ		TYPE Ⅰ	TYPE Ⅱ
	ΔL'	ΔLe	ΔLe	ΔLe	ΔLe	ΔLe	ΔLe
No	mm	mm	mm	mm	mm	mm	mm
A1	83.7	70.8	142.7	142.7	70.8	150.0	150.0
P1	48.0	70.8	142.7	142.7	70.8	150.0	150.0
P2	11.6	70.8	142.7	142.7	70.8	150.0	150.0
P3	18.5	70.8	142.7	142.7	70.8	150.0	150.0
P4	45.8	70.8	142.7	142.7	70.8	150.0	150.0
P5	70.8	70.8	142.7	142.7	70.8	150.0	150.0

< CASE-2 (53m+3@60m+53m) >

	Longitudinal direction				Transvers direction		
	Secondary force	ΔLe	Level 2		ΔLe	Level 2	
			TYPE Ⅰ	TYPE Ⅱ		TYPE Ⅰ	TYPE Ⅱ
	ΔL'	ΔLe	ΔLe	ΔLe	ΔLe	ΔLe	ΔLe
No	mm	mm	mm	mm	mm	mm	mm
P55	75.8	68.1	144.2	150.0	68.1	150.0	150.0
P56	47.5	68.1	144.2	150.0	68.1	150.0	150.0
P57	11.9	68.1	144.2	150.0	68.1	150.0	150.0
P58	18.4	68.1	144.2	150.0	68.1	150.0	150.0
P59	45.7	68.1	144.2	150.0	68.1	150.0	150.0
P60	63.7	68.1	144.2	150.0	68.1	150.0	150.0

Source: Study Team

- Design result of earthquake

The result of the buckling stress, shearing strain and tensile stress is shown in the table below.

Table 8.6.1-16 The result of the buckling stress, shearing strain and tensile stress

< CASE-1 (5@60m) >

	Buckling stress			Tensil stress			Shearing strain		Tensile stress of inner steel plate	
	Londitudinal	Transvers	Allowable	Londitudinal	Transvers	Allowable	Londitudinal	Transvers	Londitudinal	Transvers
	σce	σce	≦σcra	σte	σte	≦ σta	γse	γse	σs	σs
No	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	%	%	N/mm2	N/mm2
A1	8.52	8.02	28.7	----	----	2.0	107.8	71.4	85.2	80.2
P1	9.57	9.83	70.3	----	----	2.0	148.9	117.2	102.1	104.9
P2	9.13	9.73	70.3	----	----	2.0	120.5	117.2	97.4	103.7
P3	9.28	9.81	70.3	----	----	2.0	126.0	117.2	99.0	104.7
P4	9.49	9.77	70.3	----	----	2.0	147.3	117.2	101.2	104.3
P5	8.35	8.01	28.7	----	----	2.0	101.7	71.4	83.5	80.1
Allowable value	----	----	----	----	----	----	≦ 250	≦ 250	≦ 235	≦ 235

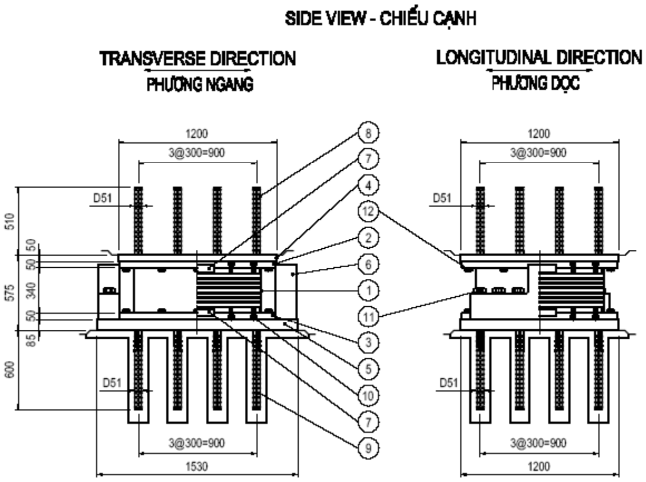
< CASE-2 (53m+3@60m+53m) >

	Buckling stress			Tensil stress			Shearing strain		Tensile stress of inner steel plate	
	Londitudinal	Transvers	Allowable	Londitudinal	Transvers	Allowable	Londitudinal	Transvers	Londitudinal	Transvers
	σce	σce	≦σcra	σte	σte	≦ σta	γse	γse	σs	σs
No	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	%	%	N/mm2	N/mm2
P55	7.59	7.22	28.7	----	----	2.0	107.5	71.4	75.9	72.2
P56	9.11	9.35	70.3	----	----	2.0	154.3	117.2	97.2	99.8
P57	9.22	9.75	70.3	----	----	2.0	126.5	117.2	98.3	103.9
P58	9.55	10.00	70.3	----	----	2.0	131.5	117.2	101.9	106.7
P59	9.04	9.31	70.3	----	----	2.0	152.9	117.2	96.4	99.3
P60	7.44	7.20	28.7	----	----	2.0	101.8	71.4	74.4	72.0
Allowable value	----	----	----	----	----	----	≦ 250	≦ 250	≦ 235	≦ 235

Source: Study Team

g) Detailed dimension of Rubber bearing

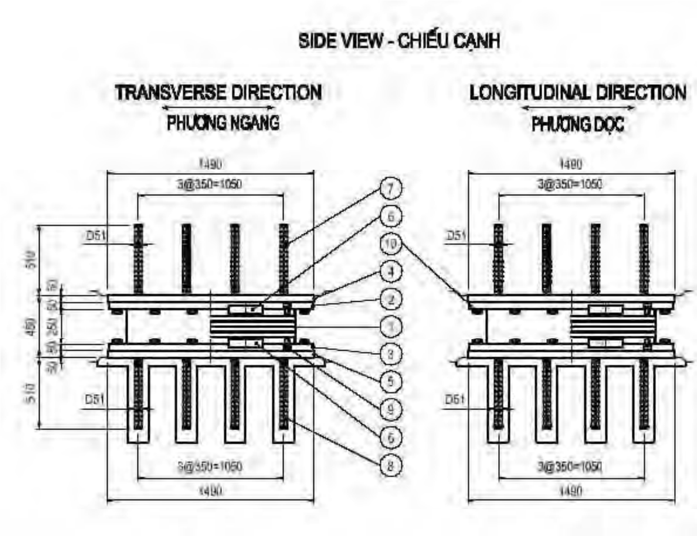
- End support Bearing



Source: Study Team

Figure 8.6.1-4 Dimension of End support bearing

- Middle support Bearing



Source: Study Team

Figure 8.6.1-5 Dimension of middle support bearing

(3) Cat Hai side Approach Bridge

1) Design condition

a) Design force

< CASE-1(53.8m+3@60m+53.8m) >

The reaction force of Rubber bearing is shown in the table below.

Table 8.6.1-17 Reaction force of rubber bearing

	Maximum Reaction		Miniumum Reaction	Live Load Max	Dead Load Reaction		Dead Load Total
					Max	Min	
	Rmax1	Rmax2	Rmin	$R_{L+I}max$	Rdmax	Rdmin	ΣRd
No	kN	kN	kN	kN	kN	kN	kN
P79	4440	3996	3290	1040	3400	3400	6800
P80	12360	11124	10400	1750	10710	10710	21420
P81	11770	10593	9880	1670	10100	10100	20200
P82	11770	10593	9880	1670	10100	10110	20210
P83	12360	11124	10400	1650	10710	10710	21420
P84	4440	3996	3290	1040	3400	3400	6800
W	----	----	----	----	----	----	96850

Source: Study Team

< CASE-2(53.8m+2@60m+53.8m) >

Table 8.6.1-18 Reaction force of rubber bearing

	Maximum Reaction		Miniumum Reaction	Live Load Max	Dead Load Reaction		Dead Load Total
					Max	Min	
	Rmax1	Rmax2	Rmin	$R_{L+I}max$	Rdmax	Rdmin	ΣRd
No	kN	kN	kN	kN	kN	kN	kN
P84	4440	3996	3290	1040	3400	3400	6800
P85	12400	11160	10440	1750	10750	10750	21500
P86	11700	10530	9740	1750	9950	9950	19900
P87	12300	11070	10590	1770	10750	10750	21500
A2	4300	3870	3290	900	3400	3400	6800
W	----	----	----	----	----	----	76500

Source: Study Team

b) Amount of Movement

< CASE-1 (53.8m+3@60m+53.8m) >

Table 8.6.1-19 Amount of Movement in each support

	Span Length	Temperature change		Creep,Shrinkage etc.
	L	Δt	Δt'	Δscp
Span	m	mm	mm	mm
P79～ P80	53.80	±10.8	±21.5	-19.9
P80～ P81	60.00	±12.0	±24.0	-17.9
P81～ P82	60.00	±12.0	±24.0	-18.2
P82～ P83	60.00	±12.0	±24.0	-18.3
P83～ P84	53.80	±10.8	±21.5	-19.7

Source: Study Team

< CASE-2(53.8m+2@60m+53.8m) >

Table 8.6.1-20 Amount of Movement in each support

	Span Length	Temperature change		Creep,Shrinkage etc.
	L	Δt	Δt'	Δscp
Span	m	mm	mm	mm
P84～ P85	53.80	±10.8	±21.5	-19.5
P85～ P86	60.00	±12.0	±24.0	-17.3
P86～ P87	60.00	±12.0	±24.0	-17.3
P87～ A2	53.80	±10.8	±21.5	-19.5

Source: Study Team

c) Allowable value

< Rubber >

The restriction stress of the body of rubber is as shown in the table below.

Table 8.6.1-21 Allowable value of rubber

<table>
<tr><th colspan="4">Item</th><th>Sign</th><th>Unit</th><th>Value</th></tr>
<tr><td rowspan="7">Compression Stress</td><td rowspan="3">Maximum Compression stresse (At an effective area)</td><td colspan="2">S1≦8</td><td rowspan="3">σmaxa</td><td rowspan="3">N/mm2</td><td>8</td></tr>
<tr><td colspan="2">8＜S1＜12</td><td>S1</td></tr>
<tr><td colspan="2">12≦S1</td><td>12</td></tr>
<tr><td colspan="3">Minimum Compression stress</td><td>σmina</td><td>N/mm2</td><td>1.5</td></tr>
<tr><td rowspan="3">Stress amplitude</td><td colspan="2">S1≦8</td><td rowspan="3">Δσa</td><td rowspan="3">N/mm2</td><td>5.0</td></tr>
<tr><td colspan="2">8＜S1＜12</td><td>5＋0.375･(S1-8)</td></tr>
<tr><td colspan="2">12≦S1</td><td>6.5</td></tr>
<tr><td colspan="2" rowspan="3">Shearing distorsion</td><td colspan="2">service Loade</td><td>γsa</td><td>%</td><td>70</td></tr>
<tr><td rowspan="2">Earthquake</td><td>Level1</td><td>γea</td><td>%</td><td>150</td></tr>
<tr><td>Level2</td><td>γea</td><td>%</td><td>250</td></tr>
<tr><td colspan="2" rowspan="3">Local Shearing distorsion</td><td colspan="2" rowspan="2">Total distorsion at Service limitted state</td><td>γta</td><td>%</td><td>γu/fs</td></tr>
<tr><td>fs</td><td>---</td><td>1.5</td></tr>
<tr><td colspan="2">Breaking growth rate</td><td>γu</td><td>%</td><td>depends on the table below.</td></tr>
<tr><td rowspan="3">Tensile Stress</td><td rowspan="3">Earthquake</td><td colspan="2">G6</td><td rowspan="3">σta</td><td rowspan="3">N/mm2</td><td>1.2</td></tr>
<tr><td colspan="2">G8</td><td>1.6</td></tr>
<tr><td colspan="2">G10 or more</td><td>2.0</td></tr>
</table>

Source: Study Team

< Inner steel plate >

Table 8.6.1-22 Allowable value of Inner Steel Plate

Kind of Material	unit	Yield Strength	bending stress
SS400	N/mm2	235	140

Source: Study Team

d) Detail dimension of Bearing

Table 8.6.1-23 Detail Dimension of Bearing

< CASE-1 (53.8m+3@60m+53.8m) >

		b	a	te	n	Σte	ts	Ge
No	function	mm	mm	mm	layer	mm	mm	N/mm2
P79	Dispersion	850	850	32	5	160	6.0	1.20
P80	Dispersion	1300	1300	32	3	96	6.0	1.20
P81	Dispersion	1300	1300	32	3	96	6.0	1.20
P82	Dispersion	1300	1300	32	3	96	6.0	1.20
P83	Dispersion	1300	1300	32	3	96	6.0	1.20
P84	Dispersion	850	850	32	5	160	6.0	1.20

< CASE-2 (53.8m+2@6m+53.8m) >

		b	a	te	n	Σte	ts	Ge
No	function	mm	mm	mm	layer	mm	mm	N/mm2
P84	Dispersion	850	850	32	4	128	6.0	1.20
P85	Dispersion	1300	1300	32	3	96	6.0	1.20
P86	Dispersion	1300	1300	32	3	96	6.0	1.20
P87	Dispersion	1300	1300	32	3	96	6.0	1.20
A2	Dispersion	850	850	32	4	128	6.0	1.20

Source: Study Team

e) Service Limit state

- Movement at service state

Longitudinal movement of Service limit state is shown in the table below.

< CASE-1 (53.8m+3@60m+53.8m) >

Table 8.6.1-24 Longitudinal movement

	Expansion length from center	Thermal movement (uniform temperature change)				Movement of creep and shrinkage			Live load	Combination	
		for horizontal force		for bearig design		Creep and shrinkage	Dead	amount			
		ΔLt		ΔLt'		ΔLscp	ΔLd	ΔL'	ΔLr	ΔL	
		+20℃	-20℃	+40℃	-40℃	----	----	----	----	+40℃	-40℃
	L	①	②	③	④	⑤	⑥	⑦	⑧	③+⑦+⑧	④+⑦+⑧
No	m	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
P79	-143.80	-28.8	28.8	-57.5	57.5	47.0	----	47.0	----	-10.5	104.5
P80	-90.00	-18.0	18.0	-36.0	36.0	27.1	----	27.1	----	-8.9	63.1
P81	-30.00	-6.0	6.0	-12.0	12.0	9.2	----	9.2	----	-2.8	21.2
P82	30.00	6.0	-6.0	12.0	-12.0	-9.0	----	-9.0	----	3.0	-21.0
P83	90.00	18.0	-18.0	36.0	-36.0	-27.3	----	-27.3	----	8.7	-63.3
P84	143.80	28.8	-28.8	57.5	-57.5	-47.0	----	-47.0	----	10.5	-104.5

< CASE-2 (53.8m+2@60m+53.8m) >

	Expansion length from center	Thermal movement (uniform temperature change)				Movement of creep and shrinkage			Live load	Combination	
		for horizontal force		for bearig design		Creep and shrinkage	Dead	amount			
		ΔLt		ΔLt'		ΔLscp	ΔLd	ΔL'	ΔLr	ΔL	
		+20℃	-20℃	+40℃	-40℃	----	----	----	----	+40℃	-40℃
	L	①	②	③	④	⑤	⑥	⑦	⑧	③+⑦+⑧	④+⑦+⑧
No	m	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
P84	-113.80	-22.8	22.8	-45.5	45.5	36.8	----	36.8	----	-8.7	82.3
P85	-60.00	-12.0	12.0	-24.0	24.0	17.3	----	17.3	----	-6.7	41.3
P86	0.00	0.0	0.0	0.0	0.0	0.0	----	0.0	----	0.0	0.0
P87	60.00	12.0	-12.0	24.0	-24.0	-17.3	----	-17.3	----	6.7	-41.3
A2	113.80	22.8	-22.8	45.5	-45.5	-36.8	----	-36.8	----	8.7	-82.3

Source : Study Team

- Design result of Service limit state

< CASE-1 (53.8m+3@60m+53.8m) >

The result of the maximum compression stress, the stress amplitude, and the buckling stress is shown in the table below.

Table 8.6.1-25 Check result of stress

	Movement	bearig area	Efective bearig area	Bearing stress					Buckling stress		Modulas of longitudinal elasticity
				Maximum		minimum	Stress amplitude				
	ΔLm	Ae	Acn	σmax	≦σmaxa	σmina	Δσ	≦ Δσa	σcra	≧σmax	E(※)
No	mm	m2	m2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2
P79	104.5	0.7225	0.6337	7.01	8.0	4.55	2.45	5.0	16.93	7.01	351.8
P80	63.1	1.6900	1.6080	7.69	10.2	6.15	1.53	5.8	66.02	7.69	818.0
P81	21.2	1.6900	1.6624	7.08	10.2	5.85	1.23	5.8	66.02	7.08	818.0
P82	21.0	1.6900	1.6627	7.08	10.2	5.85	1.23	5.8	66.02	7.08	818.0
P83	63.3	1.6900	1.6077	7.69	10.2	6.15	1.53	5.8	66.02	7.69	818.0
P84	104.5	0.7225	0.6337	7.01	8.0	4.55	2.45	5.0	16.93	7.01	351.8

The result of the Shearing strain and rotation is shown in the table below.

Table 8.6.1-26 Check result of transformation performance

	Vertical displacement				Loacal shear strain					Tensile stress of inner steel plate	
	Rotation	Compression	1/2*Liveload	Maximum	Vertical	Horizontal	Rotation	Amount	Allowable strain		
	δr	≦δc/fv	δcl	δo	γc	γs	γr	γt	≦γu/1.5	σs	≦σsa
No	mm	mm	mm	mm	%	%	%	%	%	N/mm2	N/mm2
P79	1.42	2.44	0.41	4.02	112.4	65.3	23.5	201.3	333	74.7	140
P80	1.08	1.14	----	1.73	81.1	65.7	45.8	192.7	333	82.0	140
P81	1.08	1.09	----	1.59	74.7	22.1	45.8	142.6	333	75.5	140
P82	1.08	1.09	----	1.59	74.7	21.9	45.8	142.4	333	75.5	141
P83	1.08	1.14	----	1.73	81.1	65.9	45.8	192.9	333	82.0	142
P84	1.42	2.44	0.41	4.02	112.4	65.3	23.5	201.3	333	74.7	140
Allowable value	----	----	≦ 1.00	----	----	≦ 70	----	----	----	----	----

Source : Study Team

< CASE-2 (53.8m+2@60m+53.8m) >

The result of the maximum compression stress, the stress amplitude, and the buckling stress is shown in the table below.

Table 8.6.1-27 Check result of stress

	Movement	bearig area	Efective bearig area	Bearing stress					Buckling stress		Modulas of longitudinal elasticity
				Maximum		minimum	Stress amplitude				
	ΔLm	Ae	Acn	σmax	≦σmaxa	σmina	Δσ	≦ Δσa	σcra	≧σmax	E(※)
No	mm	m2	m2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2
P84	82.3	0.7225	0.6525	6.80	8.0	4.55	2.25	5.0	21.17	6.80	351.8
P85	41.3	1.6900	1.6363	7.58	10.2	6.18	1.40	5.8	66.02	7.58	818.0
P86	0.0	1.6900	1.6900	6.92	10.2	5.76	1.16	5.8	66.02	6.92	818.0
P87	41.3	1.6900	1.6363	7.52	10.2	6.27	1.25	5.8	66.02	7.52	818.0
A2	82.3	0.7225	0.6525	6.59	8.0	4.55	2.04	5.0	21.17	6.59	351.8

Source : Study Team

The result of the Shearing strain and rotation is shown in the table below.

Table 8.6.1-28 Check result of transformation performance

	Vertical displacement				Loacal shear strain					Tensile stress of inner steel plate	
	Rotation	Compression	1/2*Liveload	Maximum	Vertical	Horizontal	Rotation	Amount	Allowable strain		
	δr	≦δc/fv	δcl	δo	γc	γs	γr	γt	≦γu/1.5	σs	≦σsa
No	mm	mm	mm	mm	%	%	%	%	%	N/mm2	N/mm2
P84	1.42	1.95	0.33	3.12	109.2	64.3	29.4	202.9	333	72.6	140
P85	1.08	1.14	----	1.71	80.0	43.0	45.8	168.8	333	80.8	140
P86	1.08	1.08	----	1.56	73.1	0.0	45.8	118.9	333	73.8	140
P87	1.08	1.13	----	1.69	79.3	43.0	45.8	168.2	333	80.2	141
A2	1.42	1.89	0.29	3.02	105.7	64.3	29.4	199.5	333	70.3	142
Allowable value	----	----	≦ 1.00	----	----	≦ 70	----	----	----	----	----

Source : Study Team

f) Earthquake

- Movement at earthquake

< CASE-1 (53.8m+3@60m+53.8m) >

The amount of the movement at earthquake is shown in the table below.

Table 8.6.1-29 The amount of the movement at earthquake

	Longitudinal direction				Transvers direction		
	Secondary force	Level 1(at earthquake)	Level 2		Level 1(at earthquake)	Level 2	
			TYPE Ⅰ	TYPE Ⅱ		TYPE Ⅰ	TYPE Ⅱ
	ΔL'	ΔLe	ΔLe	ΔLe	ΔLe	ΔLe	ΔLe
No	mm	mm	mm	mm	mm	mm	mm
P79	47.0	50.8	117.6	117.6	50.8	150.0	150.0
P80	27.1	50.8	117.6	117.6	50.8	150.0	150.0
P81	9.2	50.8	117.6	117.6	50.8	150.0	150.0
P82	9.0	50.8	117.6	117.6	50.8	150.0	150.0
P83	27.3	50.8	117.6	117.6	50.8	150.0	150.0
P84	47.0	50.8	117.6	117.6	50.8	150.0	150.0

b) CASE-2 (53.8m+2@60m+53.8m)

	Longitudinal direction				Transvers direction		
	Secondary force	Level 1(at earthquake)	Level 2		Level 1(at earthquake)	Level 2	
			TYPE Ⅰ	TYPE Ⅱ		TYPE Ⅰ	TYPE Ⅱ
	ΔL'	ΔLe	ΔLe	ΔLe	ΔLe	ΔLe	ΔLe
No	mm	mm	mm	mm	mm	mm	mm
P84	36.8	49.7	103.5	103.5	49.7	150.0	150.0
P85	17.3	49.7	103.5	103.5	49.7	150.0	150.0
P86	0.0	49.7	103.5	103.5	49.7	150.0	150.0
P87	17.3	49.7	103.5	103.5	49.7	150.0	150.0
A2	36.8	49.7	103.5	103.5	49.7	150.0	150.0

Source : Study Team

2) Design result of Earthquake

The result of the buckling stress, shearing strain and tensile stress is shown in the table below.

Table 8.6.1-30 The result of the buckling stress, shearing strain and tensile stress

< CASE-1 (53.8m+3@60m+53.8m) >

	Buckling stress			Tensil stress			Shearing strain		Tensile stress of inner steel plate	
	Londitudinal	Transvers	Allowable	Londitudinal	Transvers	Allowable	Londitudinal	Transvers	Londitudinal	Transvers
	σce	σce	≦σcra	σte	σte	≦ σta	γse	γse	σs	σs
No	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	%	%	N/mm2	N/mm2
P79	7.41	8.28	28.2	----	----	2.0	102.9	93.8	79.1	88.3
P80	9.06	10.89	110.0	----	----	2.0	150.7	156.3	96.6	116.1
P81	8.41	10.42	110.0	----	----	2.0	132.1	156.3	89.7	111.2
P82	8.41	10.42	110.0	----	----	2.0	131.9	156.3	89.7	111.2
P83	9.06	10.89	110.0	----	----	2.0	150.9	156.3	96.6	116.1
P84	7.41	8.28	28.2	----	----	2.0	102.9	93.8	79.1	88.3
Allowable value	----	----	----	----	----	----	≦ 250	≦ 250	≦ 235	≦ 235

< CASE-2 (53.8m+2@60m+53.8m) >

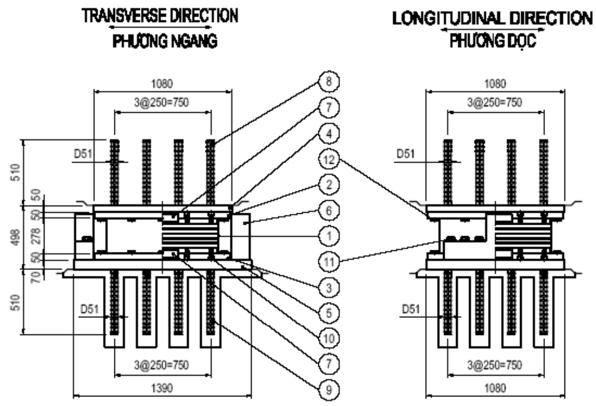
	Buckling stress			Tensil stress			Shearing strain		Tensile stress of inner steel plate	
	Londitudinal	Transvers	Allowable	Londitudinal	Transvers	Allowable	Londitudinal	Transvers	Londitudinal	Transvers
	σce	σce	≦σcra	σte	σte	≦ σta	γse	γse	σs	σs
No	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	%	%	N/mm2	N/mm2
P84	7.16	8.70	35.3	----	----	2.0	109.6	117.2	76.3	92.8
P85	8.91	10.92	110.0	----	----	2.0	125.8	156.3	95.0	116.4
P86	8.12	10.31	110.0	----	----	2.0	107.8	156.3	86.7	109.9
P87	8.91	10.92	110.0	----	----	2.0	125.8	156.3	95.0	116.4
A2	7.16	8.70	35.3	----	----	2.0	109.6	117.2	76.4	92.8
Allowable value	----	----	----	----	----	----	≦ 250	≦ 250	≦ 235	≦ 235

Source : Study Team

g) Detailed dimension of Rubber bearing

- End support Bearing

< P79 and P84 >



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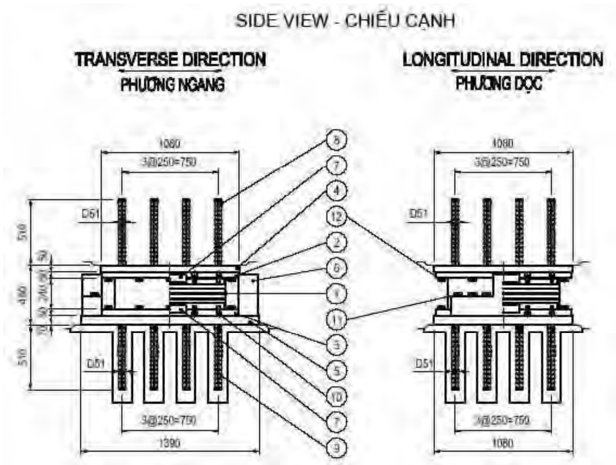
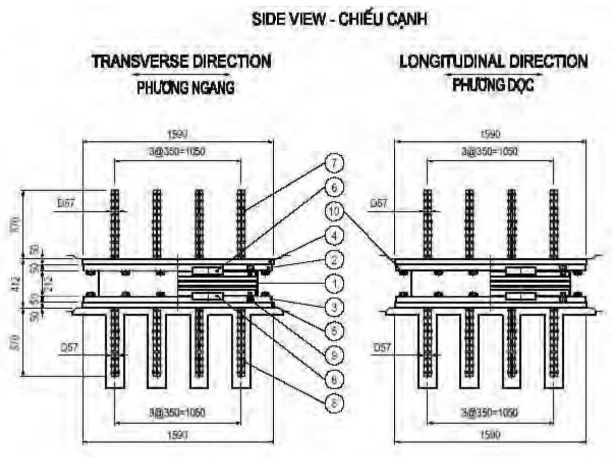


< Middle support Bearing >



Source : Study Team

Figure 8.6.1-6 Dimension of middle support bearing

8.6.2 Expansion Joint

8.6.2.1 Design of Expansion Joint for Main Bridge

(1) Selection of Type of Expansion Joint between Main Bridge and Approach Bridge

In order to select appropriate types of expansion joint for Approach Bridge and Main Bridge, the comparative study was conducted.

1) Comparative Study on Type Selection

a) General

For optimizing the type of expansion joint, the comparative study was performed by introducing various types of expansion joint as follows,

Alternative-1: Rubber Joint (Transversal Type)

Alternaitve-2: Steel Finger Joint

Alternative-3: Steel Joint (Module Type)

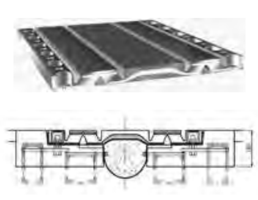
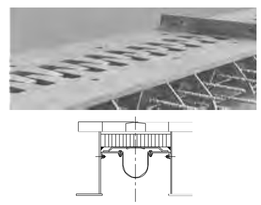
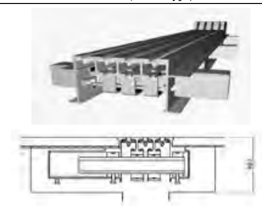
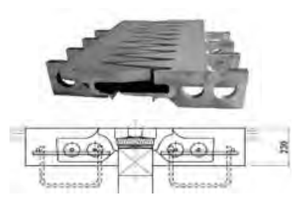
Altenrative-4: Aluminum Alloy Joint (Triangle Comb Type)

b) Result of Comparative Study

The result of comparative study is shown in the table on the next page.

As shown in the Table, Alternative-4, Aluminum Alloy Joint (Triangle Comb Type), is recommended because of its advantages in lifecycle cost and durability. In case of large longitudinal displacement, however, because this type of joint has limitation in adapting up to 250m of the expansion, Alternative-2, Steel Finger Joint, which can be fabricated by order-made for adjusting its dimensions, is recommended.

Table 8.6.2-1 Comparison on Type of Expansion

Evaluation Item	Score	Alternative No.1 Rubber Joint (Transverse Type)		Alternative No.2 Steel Finger Joint		Alternative No.3 Steel Joint (module type)		Alternative No.4 Aluminum Alloy Joint (Triangle comb type)	
General View									
Structure Aspect and Stability	10	It is rubber and steel integral structure, and expands by shearing deformation of rubber. It can expand in the transverse direction a little as well as longitudinal direction. Wheel load is supported at load support plate at center, and its load influence can be decreased by the rubber cushion for impact. Type is load support type. Allowable Expansion : 200mm (±100mm) Notch Depth: 180mm	4	Expansion amount is secured by center clearance of the comb-shaped face plate (both sides). It's distance is order made depend on the design condition (bridge deformation). Vehicle load is supported by steel face plates. Since it's comb-shaped, horizontal (transverse direction) movement cannot be responded. Water cut-off shall be done by elastic sealing and rubber materials setting below face plates. This is load support type. Allowable Expansion: Any expansion amount is available. Notch Depth: Approximately 400mm	8	Basic structure is a composition of steel frame and seal rubber. Support beam is set at 1.5m interval and in the expanding direction in principle, and has control device between support beam. It is movable in transverse direction too. This is load support type. Allowable Expansion: 240 (±120) Notch Depth: 400mm	6	The body is aluminum composition steel so it is light weight and durable against salt, oil and rust. Waterproof rubber is honey comb structure made by ethylene propylene rubber. It open/close by comb shaped structure and cannot follow any horizontal (transverse direction) movement. This is load support type. Allowable Expansion: 230 (±115) Notch Depth: 230mm	8
Cost (Upper: Investment Lower: Life Cycle)	40	Investment at first ¥ 721,000 /m Material ¥ 601,000 /m Construction ¥ 120,000 /m 1.00 Maintenance and repair ¥ 751,000 /m Material ¥ 601,000 /m Construction ¥ 150,000 /m Life cycle cost 9/100 years 721,000 + (751,000×9) = 7,480,000 /m 2.83 7,480,000 / 100 = 74,800 /year	20 0	Investment at first ¥ 970,000 /m Material ¥ 820,000 /m Construction ¥ 150,000 /m 1.35 Maintenance and repair ¥ 1,000,000 /m Material ¥ 820,000 /m Construction ¥ 180,000 /m Life cycle cost 2.33/100 years 970,000 + (1,000,000×2.33) = 3,300,000 /m 1.25 3,300,000 / 100 = 33,000 /year	8 12	Investment at first ¥ 782,000 /m Material ¥ 622,000 /m Construction ¥ 160,000 /m 1.08 Maintenance and repair ¥ 822,000 /m Material ¥ 622,000 /m Construction ¥ 200,000 /m Life cycle cost 4/100 years 782,000 + (822,000×4) = 4,070,000 /m 1.54 4,070,000 / 100 = 40,700 /year	16 8	Investment at first ¥ 772,000 /m Materia ¥ 652,000 /m Construction ¥ 120,000 /m 1.07 Maintenance and repair ¥ 802,000 /m Material ¥ 652,000 /m Construction ¥ 150,000 /m Life cycle cost 2.33/100 years 772,000 + (802,000×2.33) = 2,640,660 /m 1.00 2,640,660 / 100 = 26,400 /year	16 20
Construction Plan and Period	10	Construction condition does not serious restriction due to shallow depth of cutting deck.. After steel expansion joint is anchored at anchorage reinforcing bars, concrete is placed. Therefore, this is quite simple way of construction.	10	Since it is set up before deck slab concrete placing in case of steel girder, control of girder deformation at every stage of deck concrete placing and the control of flatness of both side face plate is quite complicated,	6	It is needed to have big blockout for concrete member (deck). Weight of the body is big so it would be large scaled construction by heavy crane.	6	Blockout is a bit deep, but there is comparatively no inhibited for deck plate. Construction is taken place by setting expansion joint which is adjusted in the bridge width, and then reinforcing bars are arranged and welded. And finally, placing concrete is executed. It is quite efficient construction method.	10
Maintenance and Durability	15	Load is absorbed and distributed by rubber elasticity and steel rigidity, and as the results, it is possible to decrease any bad affect to deck place. Rust proof is secured by adopting rubber material which are good for weathering and oil resistant together with all coated structure. But it need any artifice for sear-out of rubber surface. When replacement, no need to chip the concrete, and it is possible to change only device of joint. It takes minimum time for replacement and it is easily constructed. Duration of Life : 10 years	6	It is strong from structural view point and durable. It is concerned that stripping of the elastic seal for water cut-off occurs. Expansion joint itself cannot be removed alone, so it need to have a lot of work such as chipping concrete at large area. Durable Period: 30 years	12	It is steel structure and quite strong. Waterproof rubber is set at beam conduit, so it doesn't need to be worried for chipping off. It is possible to do small scaled maintenance by changing parts by parts, however, it possibly would be large scaled by using heavy crane with big amount of budget and time. Durable Period: 20 years	9	The body is steel so rigidity is high and it is durable. There is a concern that any abruption of water cut-off rubber set in the joint occurs. It is possible to change parts by parts, but cannot change the expansion body itself only. When need it, it is needed to chip the concrete at large area to change the expansion body. Durable Period: 30 years	12
STEP Clearance	10	Procurement Ratio: 83%	10	Procurement Ratio: 85%	10	Procurement Ratio: 80%	10	Procurement Ratio: 84%	10
Aesthetics	5	There is no major difference in appearance.	5	There is no major difference in appearance.	5	There is no major difference in appearance.	5	There is no major difference in appearance.	5
New Technology	5	Transversal Type Rubber Joint is new technology.	5	Commonly used in Vietnam	3	Commonly Used in Vietnam	3	Aluminum Alloy Joint is new technology.	5
Environmental Impact/ ROW / Traffic Management	5	Impact by load passing is absorbed by surface rubber and coated rubber. It is corresponded to uneven deck place by rotation of girder. Road surface water drainage is in good condition by surface rubber pattern, so slip is not easily occurred. The expansion joint is comb-shaped, and road surface water drainage is good. There are seal material & downspout which is second water cut-off function. Noise is minimum due to absorption and distribution of impact of vehicle passing by the rubber elasticity. Back up material is inserted at the water cut-off rubber, so noise is shut off to downward.	5	Unless any gap is appeared in structural left and right face plates , performance is quite good for certain level of gradient and rotation. There is concern that any step appears in case of slender bridge like steel bridge. There is function of water cut-off using elastic seal material. It is concerned that flaking should be occurred by stress to be concentrated to boundary face of the elastic seal material. If road surface is not even by girder rotation, impact noise between comb-shaped joints is comparatively big. But the noise is not easily to go down because of filling of elastic seal material below joint.	4	This system responds to the unevenness by rotation of the girder by bearing at top/bottom. Some numbers of beam adjustment conduit exist, so it cause the vibration by vehicle running. As for drainage, simple structure such as sealing rubber put into end beam and middle beam is adopted. So, water is gathered into drain box different from the left hand side 2 alternatives. Regular maintenance is needed to keep quality of performance for water cut-off. Impact noise is comparatively big when vehicle crosses the beam adjustment conduit. Noise which goes through down from the adjustment room is also big.	3	Unless any step (gap) appears between left and right faces from structural viewpoint, performance is quite good for certain level of gradient and rotation. There is concern that any step (gap) appears in case of slender bridge like steel girder. It is efficient for water cut-off because waterproof rubber is set by pressing in the expansion inside but not using joint. There is a concern that soil and sand coming into the comb-shaped device, which causes abruption at adhesive bonding part. Vehicle running is smooth by triangle face plate and it has artifice to decrease the vehicle running noise. However, noise at joint going down is possibly big.	5
Evaluation	100	**Not Recommended.** Although the investment cost is the lowest, this alternative is inferior in maintenance and life cycle cost due to short durability of the material.	65	**Recommended.** Its durability is superior to others, but comparatively inferior in cost, environment, and construction aspect to others. In case that the necessary expansion gap is more than 230mm, this altenrative shall be selected.	68	**Less recommended.** Although durability, construction, and water cut-off ability are not so bad, performance and economic efficiency are not advantageous.	66	**Most recommended.** It is superior in durability to others as well as steel finger joint, but inferior in construction and maintenance aspects. It is economically efficient.	91

Source : Study Team

(2) Design of Expansion Joint between Main Bridge and Approach Bridge

1) Calculation of Necessary Expansion between Main Bridge and Approach Bridge

The necessary expansion between Main Bridge and Approach Bridge was calculated based on the results of the structural analyses for the design of the main girders.

a) Conditions of Analyses

The conditions are as follows;

- Temperature Range: 40 degrees
- Coefficient of thermal expansion: 1.08E-05
- Model of Creep and Shrinkage: CEB-FIP90
- Degree of Humidity: 80%

b) Results of Calculation

The results of analysis are as follows;

Table 8.6.2-2 Longitudinal Movement at Ends of Main Girders

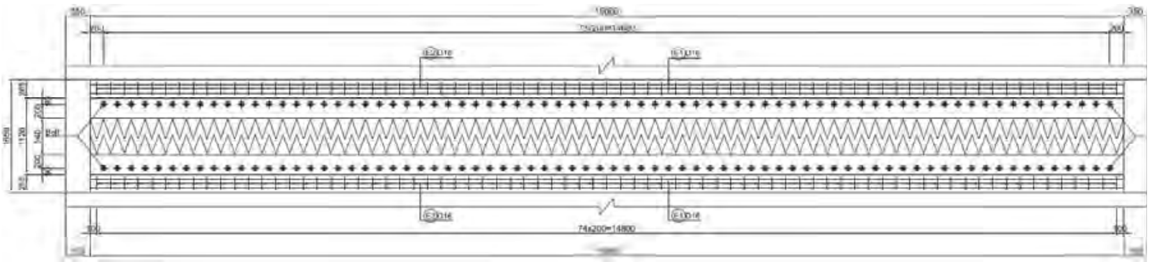
	Main Bridge	Approach Bridge	Total
Movement due to Temperature Alternation	103.8	59.0	162.8
Movement due to Creep & Shrinkage	84.2	58.3	142.5
Total	187.9	117.3	305.2

Unit: mm

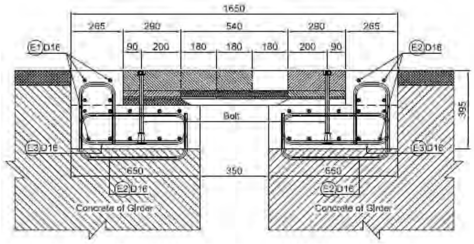
Source : Study Team

c) Expansion Joint to be applied

The expansion joint to be applied between Main Bridge and Approach Bridge is a steel finger type joint as shown in the figure below because the necessary expansion is more than 250mm. The gap between the edges of the main girders is set as the standard gap of the type of the joint.



(a) Plan View



(b) Longitudinal Cross Section

Source: Study Team

Figure 8.6.2-1 Expansion Joint between Main Bridge and Approach Bridge

8.6.2.2 Design of Expansion Joint for Approach Bridge

In the design of Expansion joint, it is necessary to decide the following matters.

(1) Decision of Expansion gap

(2) Amount of movement of girder end

When the above-mentioned item is decided, it is necessary to calculate the amount of the movement of girder end. The amount of the movement applies the result of calculation from the structure analysis on a main girder.

(1) Hai an side Approach Bridge

1) Movement of main girder

The amount of the movement is calculated by the structure analysis on the main girder, and is shown in the table below.

Table 8.6.2-3 Amount of the movement

Unit : mm

Item	Position / Node Num,	E1 / 1	P1 / 23	P2 / 44	P3 / 65	P4 / 86	E2 / 108
①	Dead Load	-8.9	-8.5	-3.8	-2.1	-0.7	-0.7
②	Prestress	26.9	16.1	3.8	-3.1	-7.7	-10.4
③	Creep and Shrinkage	59.6	34.7	10.6	-12.6	-35.3	57.6
④	Temperture 40℃	58.9	35.5	11.7	11.9	35.7	59.2
⑤	Earth Quick Kh=0.18	142.7	142.6	142.6	142.6	142.6	142.7

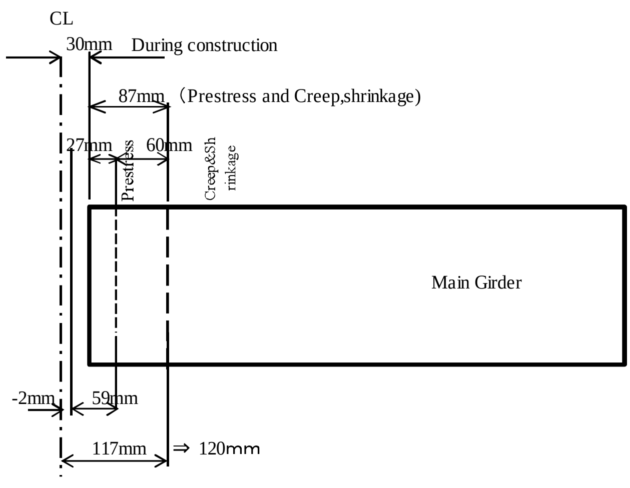
Source: Study Team

2) Decision of expansion gap

Expansion gap of girder end is decided to the following conditions.

a) Expansion gap when the girder end Segment is set up is assumed to be 30mm.

Expansion gap must be secured for temperature change (temperature increase 40℃) immediately after structure completion.



Source: Study Team

Figure 8.6.2-2 Movement of girder end

Expansion gap from the pier center or front parapet is assumed to be 120mm as shown in the above figure at the point of Creep and shrinkage end.

Expansion gap requirement L= 117mm

Therefore, it is provided 120mm as Expansion gap

3) Design movement of expansion joint

The design movement applied to the expansion joint considers the movement after the girder is completed. Because after girder is completed, expansion joint is set up.

Table 8.6.2-4 The design movement applied to the expansion joint considers the movement after the girder

Item	unit	Movement	Remarks
1. Creep and Shrinkage	mm	59.6	
2. Temperature change(40℃)	mm	58.9	
3. design margin	mm	1.5	
Design movement	mm	120.0	

Source: Study Team

Therefore, the amount of design movement at the abutment and pier is as shown in following table.

Table 8.6.2-5 The amount of design movement at the abutment and pie

Place	unit	Movement	Remarks
Abutment A1	mm	120	
Pier	mm	240	

Source: Study Team

4) Selection of expansion joint

Expansion joint is selected according to the result of comparative Study on Type Selection of main bridge.

The design movement of Hai an side approach Bridge is comparatively small with 120mm and 240mm.Therefore,it adopts made of the aluminum alloy.

a) Relation between allowance and design movement of expansion joint.

< A1Abuttment >

Cipec joint Wj -160.			Design movement	
allowable movement :	160mm	>	120	mm
allowable expansion gap :	150mm	>	120	mm
		Ok		

< Pier >

Cipec joint WY-320.			Design movement	
allowable movement :	250mm	>	240	mm
Allowable expansion gap :	435mm	>	240	mm
		OK		

(2) Cat Hai side Approach Bridge

1) Movement of main girder

The amount of the movement is calculated by the structure analysis on the main girder, and is shown in the table below.

Table 8.6.2-6 Amount of the movement

Unit; mm

Item	Position / Node Num,	E1 1	P1 16	P2 34	P3 52	P4 70	E2 85
①	Dead Load	-1.6	-0.9	0.0	0.0	1.0	1.7
②	Prestress	6.7	3.0	1.1	-0.8	-3.0	-6.6
③	Creep and Shrinkage	41.2	25.0	9.0	-7.3	-23.4	-39.5
④	Temperture 40℃	58.2	36.7	13.0	10.6	34.3	-55.7
⑤	Earth Quick Kh=0.18	117.6	117.5	117.4	117.3	117.3	117.3

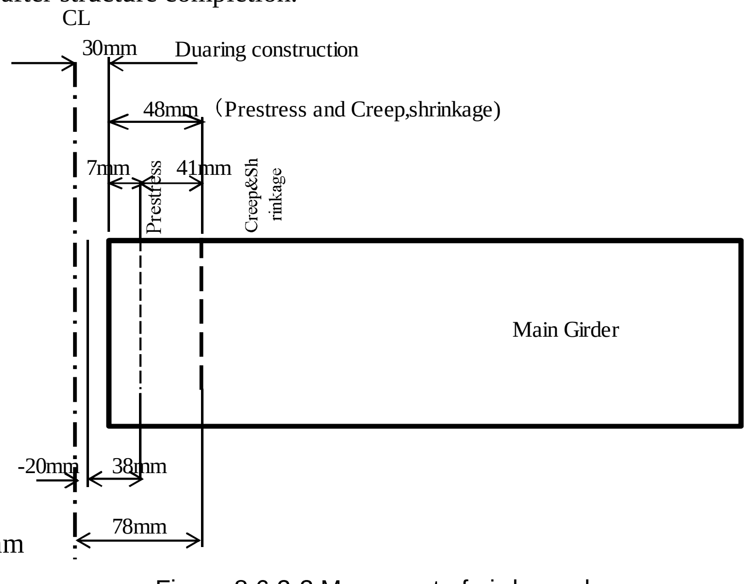
Source: Study Team

2) Decision of expansion gap

Expansion gap of girder end is decided to the following conditions.

a) Expansion gap when the girder end Segment is set up is assumed to be 30mm.

Expansion gap must be secured for temperature change (temperature increase 40˚C) immediately after structure completion.



Source: Study Team

Figure 8.6.2-3 Movement of girder end

Expansion gap from the pier center or front parapet is assumed to be 120mm as shown in the above figure at the point of creep and shrinkage end.

Expansion gap requirement L= 78 + 20 = 98mm → 120mm

Therefore, it is provided 120mm as Expansion gap

3) Design movement of expansion joint

The design movement applied to the expansion joint considers the movement after the girder is completed. Because after girder is completed, expansion joint is set up.

Table 8.6.2-7 The design movement applied to the expansion joint considers the movement after the girder

Item	unit	Movement	Remarks
1. Creep and Shrinkage	mm	41.2	
2. Temperature change(40℃)	mm	58.2	
3. design margin	mm	20.6	
Design movement	mm	120.0	

Source: Study Team

Therefore, the amount of design movement at the abutment and pier is as shown in following table.

Table 8.6.2-8 The amount of design movement at the abutment and pie

Place	unit	Movement	Remarks
Abutment A2	mm	120	
Pier	mm	240	

Source: Study Team

4) Selection of expansion joint

Expansion joint is selected according to the result of comparative Study on Type Selection of main bridge.

The design movement of Hai an side approach Bridge is comparatively small with 120mm and 240mm.Therefore,it adopts made of the aluminum alloy.

a) Relation between allowance and design movement of expansion joint.

< A1Abuttment >

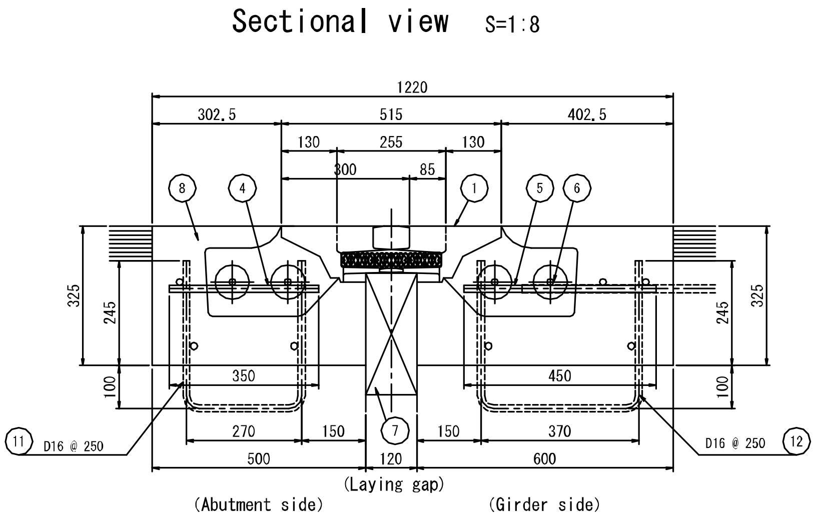
Cipec joint Wj -160.			Design movement	
allowable movement :	160mm	>	120	mm
allowable expansion gap :	150mm	>	120	mm
		Ok		

< Pier >

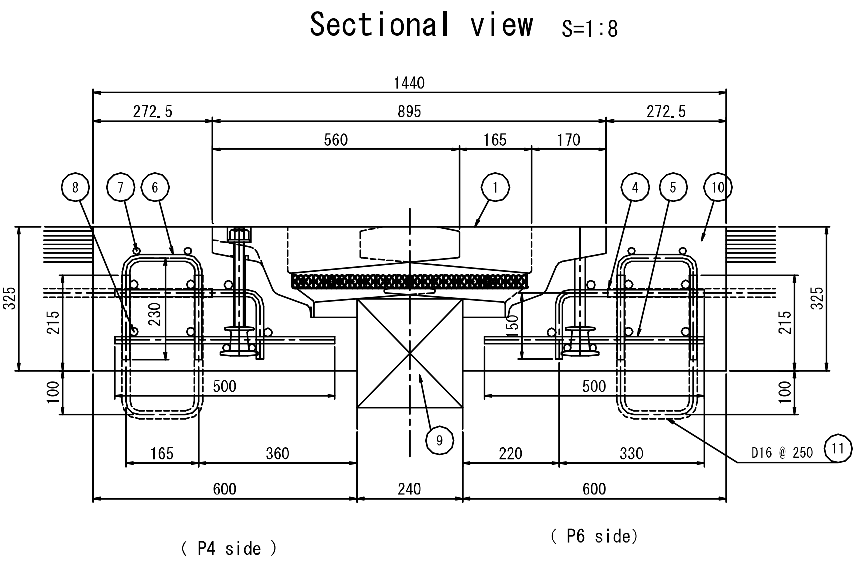
Cipec joint WY-320.			Design movement	
allowable movement :	250mm	>	240	mm
Allowable expansion gap :	435mm	>	240	mm
		OK		

(3) dimension of Expansion joint

< A1 and A2 Abutment >



< Pier >



Source: Study Team

Figure 8.6.2-4 Expansion Joint on Approach Bridge

8.6.2.3 Joint Protectors

For Main Bridge, the unidirectional pot bearing guides the girder to move in the longitudinal direction so that the joint can be protected from transversal movement of the girder.

For Approach bridge, the laminated elastomeric shoe with side blocks guides the girder to move in the longitudinal direction so that the joint can be protected from transversal movement of the girder.

8.6.3 Railing

8.6.3.1 Comparative Study on Handrail

(1) Conditions of Study

In order to select the most reasonable type of Guardrail, alternatives for comparison are introduced as follows,

- Alternative -1: Aluminum Handrail
- Alternative -2: Steel Handrail
- Alternative -3: Concrete Wall + Steel Handrail
- Alternative -4: Concrete Wall

The handrail is an item which generally requires periodical replacement. Therefore, lifecycle cost is also introduced in addition to investment cost in the evaluation item for cost so that cost for replacement can be evaluated quantitatively.

(2) Result of Study

1) Results of Comparative Study

The table on the next page shows the result of the comparative study.

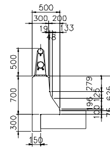
As shown in the table, results of comparison reveal that Alternative-3, Concrete Wall + Steel Handrail, is most preferable for the following reasons;

- Reinforced concrete wall resists the impact of collision.
- Reasonable Cost.
- Superior in Aesthetics.

The precaution is noted as follows,

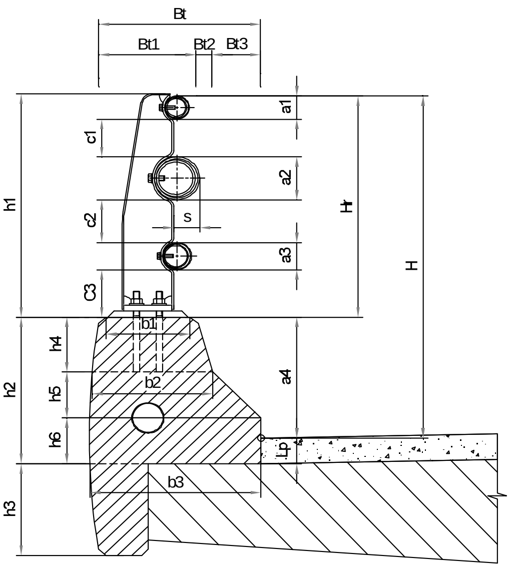
Regarding anti-corrosion for concrete wall, appropriate cover is generally considered in accordance with design standards. However, because it will be difficult to keep sufficient cover for costal condition, surface coating is recommended to protect against salt attack.

Table 8.6.3-1 Comparison on Type for Handrail

Evaluation Items		Alternative-1 Aluminum Handrail		Alternative-2 Steel Handrail		Alternative-3 Concrete Wall + Steel Handrail		Alternative-4 Concrete Wall	
General View		  The photo in the left side is a bridge constructed in Tokyo Bay area 14 years ago. There is no defect. The photo in the right side is a bridge constructed in on shore area of Shizuoka Prefecture. After 15 years passed, there is no defect except a little		  The photo in the left side shows an example which passed 13 years after completion in urban area. If the timing for ordinary re-painting is delayed, corrosion (rust) The photo in the right side is a bridge constructed in rural area of Chiba Prefecture 30 years ago. Top rail is made of aluminum which was added later.		  Hand railing is made of galvanized steel and concrete wall is made of concrete. This type is typical design in Vietnam.		  This alternative is concrete type which is similar to Florida Type in USA.	
Structural Aspect and Stability	10	The structural members are deformed in case of collision.	6	The structural members are deformed in case of collision.	6	Reinforced concrete resists the impact of collision. Heavier than Alternatives 1 and 2.	8	Reinforced concrete resists the impact of collision. Due to heavy wait, the dimensions of superstructure and substructure are required to be larger than other alternatives.	6
Construction Cost Upper: Investment Lower: Life cycle	40	Investment at first ¥ 65,200 /m Material ¥ 58,700 /m Construction ¥ 6,500 /m Ratio 2.222	0	Investment at first ¥ 55,200 /m Material ¥ 48,700 /m Construction ¥ 6,500 /m Ratio 1.881	8	Investment at first ¥ 29,360 /m Material ¥ 16,185 /m Concrete Coating ¥ 13,175 /m Ratio 1.001	20	Investment at first ¥ 29,345 /m Material ¥ 11,520 /m Concrete Coating ¥ 17,825 /m Ratio 1.000	20
		Maintenance and repair ¥ 68,700 /m Material ¥ 58,700 /m Construction ¥ 10,000 /m Life cycle cost Replacement Once/100 years 65,200 + (68,700×1) = 133,900 /m 133,900 / 100 = 1,330 /year Ratio 1.617	8	Maintenance and repair ¥ 58,700 /m Material ¥ 48,700 /m Construction ¥ 10,000 /m Life cycle cost Replacement 3times /100 years 55,200 + (58,700×3) = 231,300 /m 231,300 / 100 = 2,310 /year Ratio 2.793	0	Maintenance and repair ¥ 21,475 /m Material ¥ 8,300 /m Rail and Concrete Coating ¥ 13,175 /m Life cycle cost Rail replacement and concrete coating 3times 29,360 + (8300*3+13175*3) = 93,785 /m 93,785 / 100 = 930 /year Ratio 1.132	16	Maintenance and repair ¥ 17,825 /m Material ¥ - /m Construction ¥ 17,825 /m Life cycle cost Concrete coating 3 times/100 years 29,345 + (17,825×3) = 82,820 /m 82,820 / 100 = 820 /year Ratio 1.000	20
Construction Plan and Period	10	The weight is low, which make it easy handling.	8	Due to heavy weight, a crane is required. Furthermore, it is necessary to handle very carefully in order to avoid damage of painted surface.	6	Construction works are in-situ concrete placing and rail setting, which are simple and ordinary.	8	Construction work is in-situ concrete placing, which is simple and ordinary.	8
Maintenance	15	Producing oxidized coat by itself, it is superior in anti-corrosion and can resist against salty attack. Even there is no surface coating, only micro holes (diameter is less than 0.3mm) would be observed and not structurally deteriorated. Generally, it is coated by anodized aluminum which increases anti-corrosion ability remarkably. Even on-shore or off-shore, it is hardly corroded or rusted. In principle, maintenance free. Since the members are connected by bolts and nuts, exchange/replace of member is easy. Life year: 50 years	15	In principle, galvanization is recommended. In many cases, surface was painted after galvanization from aesthetic and durability view points . For painting, polyester powder paint is generally adopted by the following reasons: (1)It is possible to paint uniformly with certain thickness. (2) Good harmonization with galvanization. (3) Although cost is not so high, enough durability can be expected. In severe condition like heavy industrial zone and on/off shore area, fluorine resin paint or ceramic paint are preferable. Since site welding is possible, remedial work is easy. Although it is durable owing to development and improvement of paint technology, periodical cleaning and repainting are required. Life year: 30 years	9	Hand Rail is to be galvanized. Regarding anti-corrosion for concrete wall, appropriate cover is considered in accordance with design standards. However, because it is difficult to keep sufficient cover for coastal condition, surface coating is required to protect against salt attack. Since galvanized steel rail is not durable for a long term, coating as described in Alternative 2 is recommended. Periodical cleaning and repainting are required. Life year: Handrail:30 years, Concrete Wall: 100 years	9	Regarding anti-corrosion for concrete wall, appropriate cover is considered in accordance with design standards. However, because it is difficult to keep sufficient cover for coastal condition, surface coating is required to protect against salt attack. Extra concrete protection is required. Life year: 100 years	12
STEP Clearance	10	90% (Preliminary Estimate)	10	88% (Preliminary Estimate)	10	62% (Preliminary Estimate)	10	10% (Preliminary Estimate)	4
Aesthetics	5	In case with anodized aluminum coating, silver, brown and grey colors are available. The color is hardly faded, it is possible to keep aesthetics for a long time.	5	Slender appearance owing to higher strength. It is difficult to keep aesthetics for a long time because of rust and color irregularity due to re-paintings.	4	Similar appearance with Alternative-2.	4	The high wall makes oppressing feelings and shuts the side scenery from driver.	2
New Technology	5	No new technology is used.	3	No new technology is used.	3	No new technology is used.	3	No new technology is used.	3
Environmental Aspect	5	No major environmental impact.	3	No major environmental impact.	3	No major environmental impact.	3	No major environmental impact.	3
Evaluation	100	This alternative is superior in maintenance and aesthetic points. Less Recommended	**58**	This alternative is most inferior in economic points. Not Recommended	**49**	This alternative is superior in structural stability, economic and aesthetics. **Most Recommended**	**81**	This alternative is superior in economic ,but inferior in aesthetics. Heavy weight is also disadvantage for the superstructure and substructure. Less Recommended	**78**

Source : Study Team

The structure and the dimensions of the guardrail is shown in the following figure.



Sign	Value (mm)	Sign	Value (mm)
h1	500	b1	300
h2	700	b2	319
h3	300	b3	500
h4	279		
h5	321		
h6	100		
S	25		
Hr	500		
H	1126		
c1	150		
c2	140		
c3			
a1	88		
a2	112		
a3			
a4	626		
Lp	74		
Bt1	300		
Bt2	19		
Bt3	181		
Bt	500		

Source: Study Team

Figure 8.6.3-1 Expansion Joint on Approach Bridge

8.6 Study on Bridge Accessories

8.6.1 Bearings

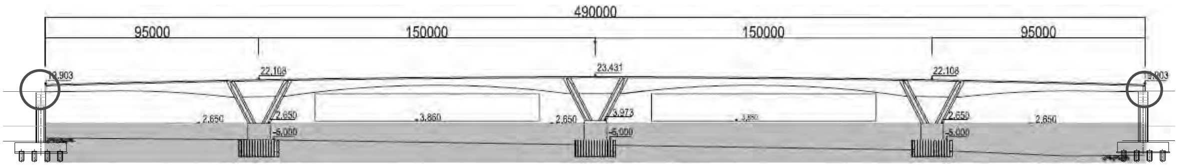
8.6.1.1 Design of Bearings for Main Bridge

(1) Features on Selecting Bearing type for Main Bridge

On the contrary to the continuous girder bridge like Approach Bridge, the bearings are needed only at the end piers for Main Bridge which is supported by 3 V-shaped piers with rigid connection. Therefore, not only vertical force but also horizontal force are dispersed to the piers and it is not necessarily the case that the assembly of laminated elastomeric shoes for dispersing horizontal force is applied.

One of other features in Main Bridge for selection of bearing type is large longitudinal displacement by temperature change and concrete shrinkage due to large length of the bridge.

In this section, a comparative study for selecting the appropriate bearing shoe type on the end pier of Main Bridge is presented by taking into account the above-mentioned features.



Source: Study Team

Figure 8.6.1-1 Location for installation of Bearings in Main Bridge

(2) Selection of Bearing Type for Main Bridge

1) Conditions of Comparative study

A comparative study was performed, by introducing following alternatives;

- ●- Alternative -1: Pot Bearings (Unidirectional and multidirectional bearings)
- ●- Alternative -2: Elastomeric Bearings and Anchor Bars
- ●- Alternative -3: Elastomeric Bearings with Anchored Plates and Anchor Bars

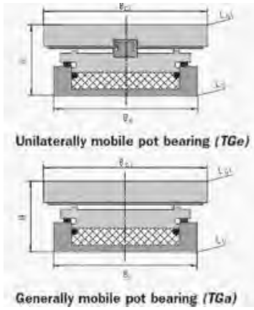
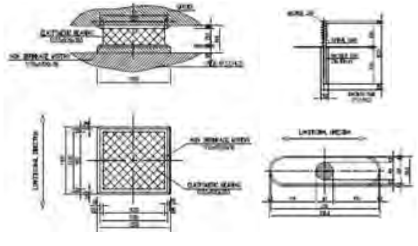
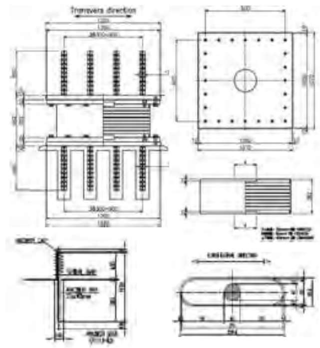
In cases with elastomeric bearings, Alternatives-2 and 3, anchor bars are to be installed for joint protection during earthquake. In the case with pot bearings, Alternative-1, the unidirectional bearing guides the girder to move in the longitudinal direction so that the joint can be protected from transversal movement of the girder.

2) Result of Comparative Study

The result of comparative study is shown in the table on the next page.

As shown in the table, Alternative -1, Pot Bearing, is recommended because of its advantages in investment cost and adaptability for large displacement.

Table8.6.1-1 Comparison on Type of Bearing for Main Bridge

Evaluation Items	Max. Point	Alternative-1 Pot Bearing		Alternative-2 Elastomeric Bearing + Anchor Bars		Alternative-3 Elastomeric Bearing for seismic force dispersing +Anchor Bars	
Schematics		 The dimensions are tentative		 The dimensions in the schematics are tentative.		 The dimensions in the schematics are tentative.	
		H= 156, Bu= 640, BGL=700		1050 x 1050 x 32 x 9Layers		1050 x 1050 x 32 x 9Layers	
		H= 138, Bu= 610, BGL=660		Anchors: 6 x D40		Anchors: 6 x D40	
Structural Aspect and Stability	10	- Suitable for large displacement and large - Suitable for large displacement and large vertical reaction - The longitudinal seismic force is not transmitted to the pier under the bearing and the fixed V-shaped piers will share the force.	10	- Simple Structure - Dimension can be flexiblly designed. - Need anchor bars with large blockouts which may cause interference with rebar arrangement. - Thick (approx. 40cm) and Large (Approx. 1m x 1m)	6	- This type is for sharing the seismic horizontal force on all the piers - Suitable for continuous grider bridge - The whle bearing system with plates and anchors are pre-fablicated. - Thick (approx. 40cm) and Large (Approx. 1m x 1m)	10
Construction Cost	40	Bearing Shoe (per pier) 905,142,374 VND VND Total 905,142,374 VND Ratio 1.00	40	Bearing Shoe (per pier) 1,071,716,100 VND Anchors & Caps (per pier) 49,832,954 VND Total 1,121,549,054 VND Ratio 1.24	24	Bearing Shoe (per 1pier) 4,465,339,105 VND Anchors & Caps (per pier) 49,832,954 VND Total 4,515,172,059 VND Ratio 4.99	0
Construction Plan and Period	10	Workability is Superior because no anchor bars are needed to be instaled.	6	Workability is superior because no anchors for the bearings are needed.	8	Workability is inferior because of lots of anchors for the bearings and anchor bars should be installed.	6
Maintenance	15	Inferior in maintenance because of difficulty in replacement.	9	Superior in maintenance because of simple method for replacement	12	Inferior in maintenance because of dificulty in replacement.	9
STEP Clearance	10	Procurement Ratio: 100%	10	Procurement Ratio: 95%	10	Procurement Ratio: 99%	10
Aesthetics	5	- Superior in Aesthetics with smaller bearings. - Superior in Aesthetics without anchor bars.	5	- Unbalanced comparing to the adjacent bearing - Inferior in Aesthetics with anchor cap block.	3	- Unbalanced comparing to the adjacent bearing - Inferior in Aesthetics with anchor cap block	3
New Technology	5	Commonly used in Vietnam	3	Commonly used in Vietnam	3	Rubber bearing for seismic force sharing is new	5
Traffic Management/ Environmental Aspect	5	No signuficant differences among the alternatives	4	No signuficant differences among the alternatives	4	No signuficant differences among the alternatives	4
Evaluation	100	This alternative is the chiepest and superior in adopting big displacement	87	Construction cost is lower than Alternative-3 but higher than Alternative-1. Inferior in adopting big displacement.	70	Construction cost is the highest . Inferior in adopting big displacement. This alternative is suitable for continuous girders such as Approach Bridge.	47
		Recommended		Less Recommended		Not Recommended	

Source : Study Team

Table 8.6.1-1 Comparison on Type of Bearing for Main Bridge

(3) Design of Bearings for Main Bridge

1) Conditions

The conditions for designing the bearings are as follows,

Table 8.6.1-2 Reaction Forces and Displacements at Bearings

(1) Service Limit State

Items		Displacement (m)	Reaction Forces (kN)		Note
			Vertical	Transversal	
P75	Uni-directional	153.4	5855	623	
	Multi-directional	153.4	5728	-	
P79	Uni-directional	151.9	5917	621	
	Multi-directional	151.9	5770	-	

(2) Extreme Event Limit State

Items		Displacement (m)	Reaction Forces (kN)		Note
			Vertical	Transversal	
P75	Left	107.1	9100	2777	
	Right	107.1	9107	-	
P79	Left	109.8	10220	2990	
	Right	109.8	10211	-	

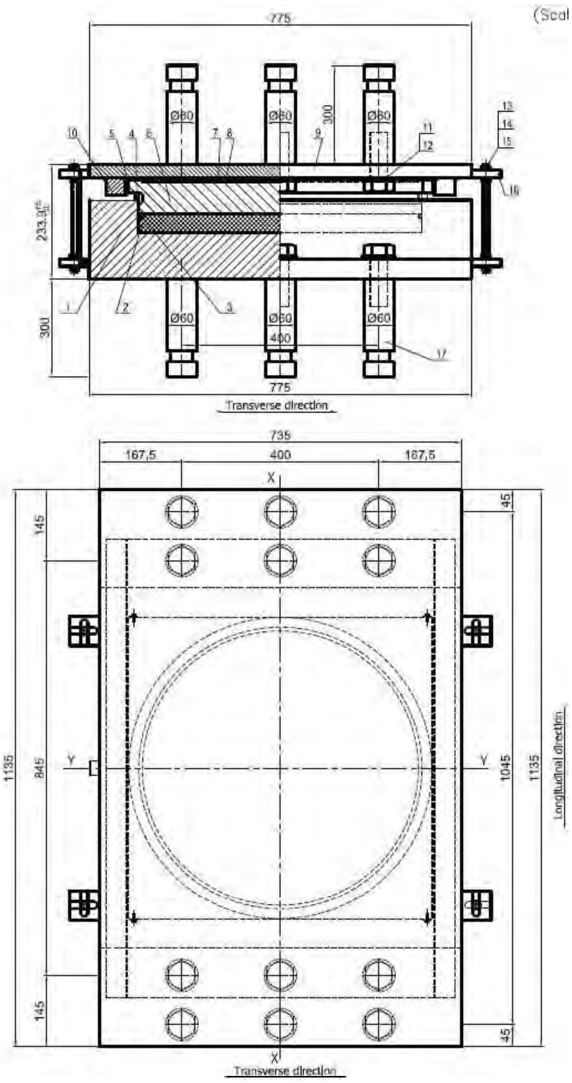
Source: Study Team

2) Results of Design

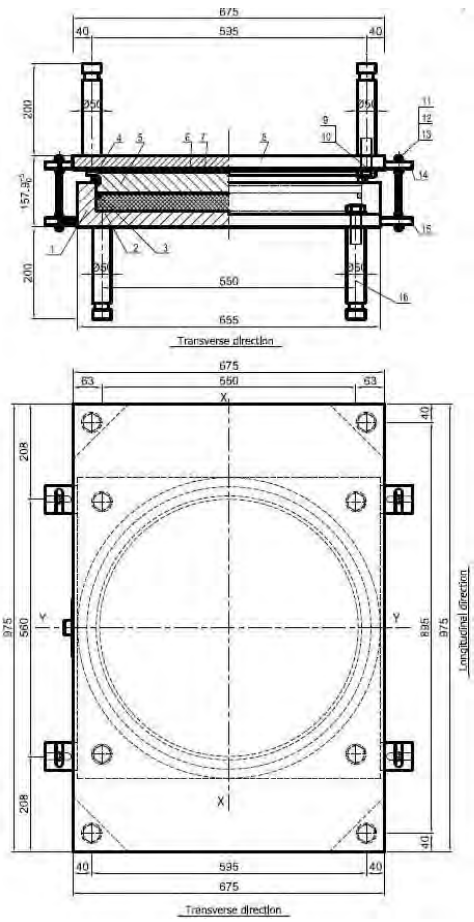
The items for checking are as follows,

- Thickness of Pot Ring
- Thickness of Pot Bottom
- Dimensions of Upper Plate
- Dimensions of Lower Plate
- Dimensions of Anchor Bolts
- Dimensions of Anchor Dowels
- Checking of Separation

The calculation note is shown in Design Report on Main Bridge. The resultant dimensions are shown in the figure in the next page.



(1) Unidirectional Sliding



(2) Free Sliding

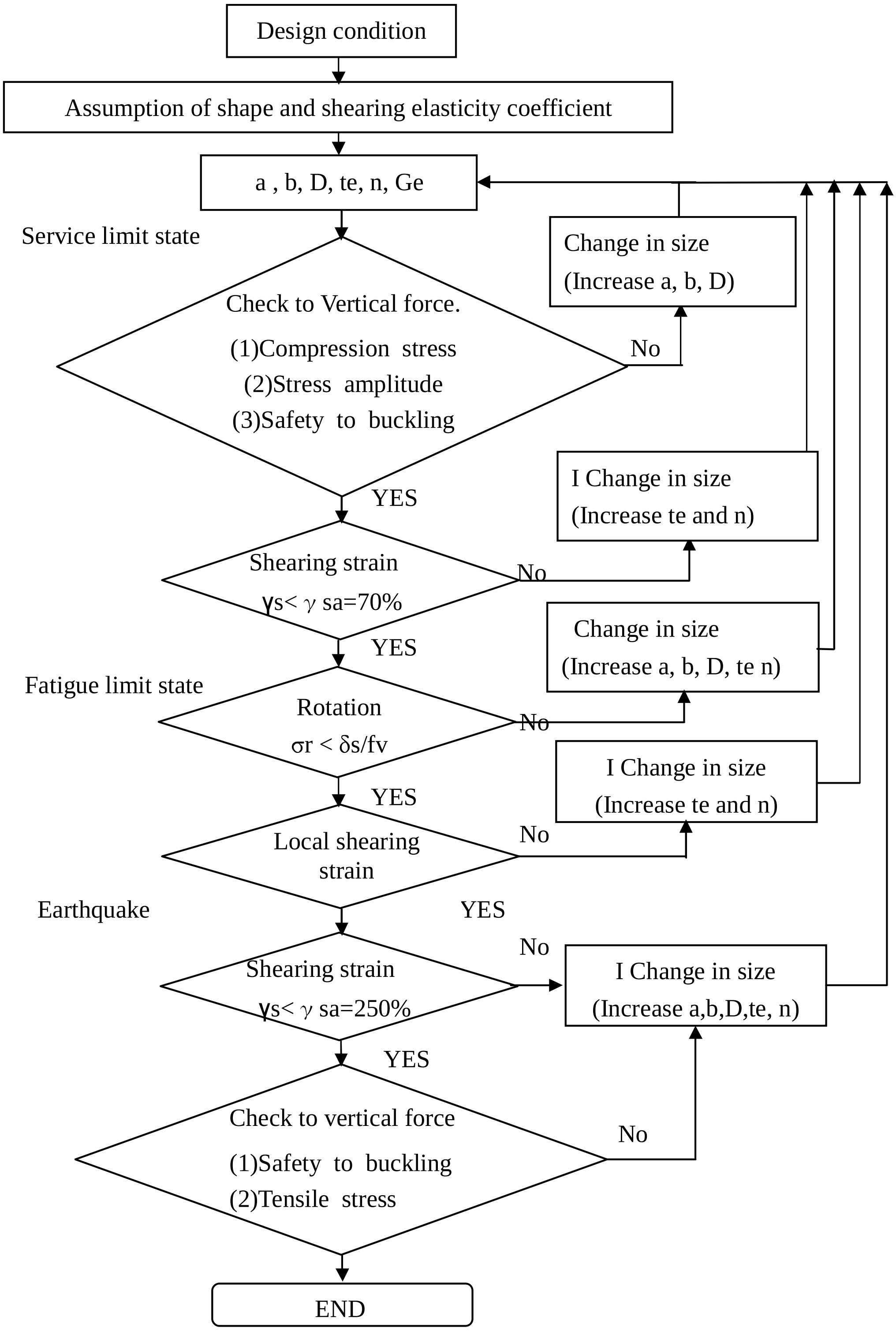
Source: Study Team

Figure 8.6.1-2 Dimensions of Pot Bearings

8.6.1.2 Design of Bearings for Approach Bridge

(1) Outline of design

The design procedure of rubber bearing is as shown in the figure below.



Source: Study Team

Figure 8.6.1-3 Flow of Bearing Design

(2) Hai An side Approach Bridge

1) Design condition

a) Design force

< CASE-1(5@60m=300m) >

The reaction force of Rubber bearing is shown in the table below.

Table 8.6.1-3 Reaction force of rubber bearing

No	Maximum Reaction		Miniumum Reaction	Live Load Max	Dead Load Reaction Max	Dead Load Reaction Min	Dead Load Total
	Rmax1	Rmax2	Rmin	$R_{L+I}max$	Rdmax	Rdmin	ΣRd
	kN	kN	kN	kN	kN	kN	kN
A1	5690	5121	4520	1080	4610	4610	9220
P1	10810	9729	8860	1680	9130	9130	18260
P2	10680	9612	8800	1660	9020	9020	18040
P3	10770	9693	8890	1660	9110	9110	18220
P4	10750	9675	8800	1680	9070	9070	18140
P5	5670	5103	4500	1070	4600	4600	9200
W	----	----	----	----	----	----	91080

Source: Study Team

< CASE-2(53m+3@60m+53m) >

Table 8.6.1-4 Reaction force of rubber bearing

No	Maximum Reaction		Miniumum Reaction	Live Load Max	Dead Load Reaction Max	Dead Load Reaction Min	Dead Load Total
	Rmax1	Rmax2	Rmin	$R_{L+I}max$	Rdmax	Rdmin	ΣRd
	kN	kN	kN	kN	kN	kN	kN
P55	5140	4626	4000	1030	4110	4110	8220
P56	10250	9225	8340	1750	8630	8630	17260
P57	10700	9630	8850	1660	9040	9040	18080
P58	10770	9693	9300	1460	9310	9310	18620
P59	10200	9180	8290	1620	8580	8580	17160
P60	5130	4617	3990	1030	4100	4100	8200
W	----	----	----	----	----	----	87540

Source: Study Team

b) Amount of Movement

< CASE-1 (5@60m=300m) >

Table 8.6.1-5 Amount of Movement at each bearing

Span	Span Length	Temperature change		Creep,Shrinkage etc.
	L	Δt	Δt'	Δscp
	m	mm	mm	mm
A1～ P1	59.00	±11.8	±23.6	-35.7
P1～ P2	60.00	±12.0	±24.0	-36.4
P2～ P3	60.00	±12.0	±24.0	-30.1
P3～ P4	60.00	±12.0	±24.0	-27.3
P4～ P5	59.00	±11.8	±23.6	-25.0

Source: Study Team

< CASE-2 (53m+3@60m+53m) >

Table 8.6.1-6 Amount of Movement in each support

Span	Span Length	Temperature change		Creep,Shrinkage etc.
	L	Δt	Δt'	Δscp
	m	mm	mm	mm
P55～ P56	51.98	±10.4	±20.8	-28.3
P56～ P57	60.00	±12.0	±24.0	-35.6
P57～ P58	60.00	±12.0	±24.0	-30.3
P58～ P59	60.00	±12.0	±24.0	-27.3
P59～ P60	51.98	±10.4	±20.8	-18.0

Source: Study Team

c) Allowable value

< Rubber >

The restriction stress of the body of rubber is as shown in the table below.

Table 8.6.1-7 Allowable value of rubber

<table>
<tr><th colspan="4">Item</th><th>Sign</th><th>Unit</th><th>Value</th></tr>
<tr><td rowspan="7">Compression Stress</td><td rowspan="3">Maximum Compression stresse (At an effective area)</td><td colspan="2">S1≦8</td><td rowspan="3">σmaxa</td><td rowspan="3">N/mm2</td><td>8</td></tr>
<tr><td colspan="2">8＜S1＜12</td><td>S1</td></tr>
<tr><td colspan="2">12≦S1</td><td>12</td></tr>
<tr><td colspan="3">Minimum Compression stress</td><td>σmina</td><td>N/mm2</td><td>1.5</td></tr>
<tr><td rowspan="3">Stress amplitude</td><td colspan="2">S1≦8</td><td rowspan="3">Δσa</td><td rowspan="3">N/mm2</td><td>5.0</td></tr>
<tr><td colspan="2">8＜S1＜12</td><td>5＋0.375･(S1-8)</td></tr>
<tr><td colspan="2">12≦S1</td><td>6.5</td></tr>
<tr><td colspan="2" rowspan="3">Shearing distorsion</td><td colspan="2">service Loade</td><td>γsa</td><td>%</td><td>70</td></tr>
<tr><td rowspan="2">Earthquake</td><td>Level1</td><td>γea</td><td>%</td><td>150</td></tr>
<tr><td>Level2</td><td>γea</td><td>%</td><td>250</td></tr>
<tr><td colspan="2" rowspan="3">Local Shearing distorsion</td><td colspan="2" rowspan="2">Total distorsion at Service limitted state</td><td>γta</td><td>%</td><td>γu/fs</td></tr>
<tr><td>fs</td><td>---</td><td>1.5</td></tr>
<tr><td colspan="2">Breaking growth rate</td><td>γu</td><td>%</td><td>depends on the table below.</td></tr>
<tr><td rowspan="3">Tensile Stress</td><td rowspan="3">Earthquake</td><td colspan="2">G6</td><td rowspan="3">σta</td><td rowspan="3">N/mm2</td><td>1.2</td></tr>
<tr><td colspan="2">G8</td><td>1.6</td></tr>
<tr><td colspan="2">G10 or more</td><td>2.0</td></tr>
</table>

Source: Study Team

< Inner steel plate >

Table 8.6.1-8 Allowable value of Inner Steel Plate

Kind of Material	unit	Yield Strength	bending stress
SS400	N/mm2	235	140

Source: Study Team

d) Detail dimension of Bearing

Table 8.6.1-9 Detail Dimension of Bearing

< CASE-1 (5@60m) >

		b	a	te	n	Σte	ts	Ge
No	function	mm	mm	mm	layer	mm	mm	N/mm2
A1	Dispersion	950	950	30	7	210	6.0	1.20
P1	Dispersion	1200	1200	32	4	128	6.0	1.20
P2	Dispersion	1200	1200	32	4	128	6.0	1.20
P3	Dispersion	1200	1200	32	4	128	6.0	1.20
P4	Dispersion	1200	1200	32	4	128	6.0	1.20
P5	Dispersion	950	950	30	7	210	6.0	1.20

< CASE-2 (53m+3@60m+53m) >

		b	a	te	n	Σte	ts	Ge
No	function	mm	mm	mm	layer	mm	mm	N/mm2
P55	Dispersion	950	950	30	7	210	6.0	1.20
P56	Dispersion	1200	1200	32	4	128	6.0	1.20
P57	Dispersion	1200	1200	32	4	128	6.0	1.20
P58	Dispersion	1200	1200	32	4	128	6.0	1.20
P59	Dispersion	1200	1200	32	4	128	6.0	1.20
P60	Dispersion	950	950	30	7	210	6.0	1.20

Source: Study Team

e) Service Limited state

- Movement at service state

Longitudinal movement of Service limit state is shown in the table below.

Table 8.6.1-10 Longitudinal movement

< CASE-1 (5@60m) >

	Expansion length from center	Thermal movement (uniform temperature change)				Movement of creep and shrinkage			Live load	Combination	
		for horizontal force		for bearig design		Creep and shrinkage	Dead	amount			
		ΔLt		ΔLt'		ΔLscp	ΔLd	ΔL'	ΔLr	ΔL	
		+20℃	-20℃	+40℃	-40℃	----	----	----	----	+40℃	-40℃
	L	①	②	③	④	⑤	⑥	⑦	⑧	③+⑦+⑧	④+⑦+⑧
No	m	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
A1	-149.00	-29.8	29.8	-59.6	59.6	83.7	----	83.7	----	24.1	143.3
P1	-90.00	-18.0	18.0	-36.0	36.0	48.0	----	48.0	----	12.0	84.0
P2	-30.00	-6.0	6.0	-12.0	12.0	11.6	----	11.6	----	-0.4	23.6
P3	30.00	6.0	-6.0	12.0	-12.0	-18.5	----	-18.5	----	-6.5	-30.5
P4	90.00	18.0	-18.0	36.0	-36.0	-45.8	----	-45.8	----	-9.8	-81.8
P5	149.00	29.8	-29.8	59.6	-59.6	-70.8	----	-70.8	----	-11.2	-130.4

< CASE-2 (53m+3@60m+53m) >

	Expansion length from center	Thermal movement (uniform temperature change)				Movement of creep and shrinkage			Live load	Combination	
		for horizontal force		for bearig design		Creep and shrinkage	Dead	amount			
		ΔLt		ΔLt'		ΔLscp	ΔLd	ΔL'	ΔLr	ΔL	
		+20℃	-20℃	+40℃	-40℃	----	----	----	----	+40℃	-40℃
	L	①	②	③	④	⑤	⑥	⑦	⑧	③+⑦+⑧	④+⑦+⑧
No	m	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
P55	-141.98	-28.4	28.4	-56.8	56.8	75.8	----	75.8	----	19.0	132.6
P56	-90.00	-18.0	18.0	-36.0	36.0	47.5	----	47.5	----	11.5	83.5
P57	-30.00	-6.0	6.0	-12.0	12.0	11.9	----	11.9	----	-0.1	23.9
P58	30.00	6.0	-6.0	12.0	-12.0	-18.4	----	-18.4	----	-6.4	-30.4
P59	90.00	18.0	-18.0	36.0	-36.0	-45.7	----	-45.7	----	-9.7	-81.7
P60	141.98	28.4	-28.4	56.8	-56.8	-63.7	----	-63.7	----	-6.9	-120.5

Source: Study Team

- Design result of Service limit state

The result of the maximum compression stress, the stress amplitude, and the buckling stress is shown in the table below.

< CASE-1 (5@60m) >

Table 8.6.1-11 Check result of stress

	Movement	bearig area	Efective bearig area	Bearing stress						Buckling stress		Modulas of longitudinal elasticity
				Maximum		minimum	Stress amplitude					
	ΔLm	Ae	Acn	σmax	≦σmaxa	σmina	Δσ	≦ Δσa		σcra	≧σmax	E(※)
No	mm	m2	m2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2		N/mm2	N/mm2	N/mm2
A1	143.3	0.9025	0.7664	7.42	8.0	5.01	2.42	5.0		17.19	7.42	498.5
P1	84.0	1.4400	1.3393	8.07	9.4	6.15	1.92	5.5		42.19	8.07	697.6
P2	23.6	1.4400	1.4117	7.57	9.4	6.11	1.45	5.5		42.19	7.57	697.6
P3	30.5	1.4400	1.4033	7.67	9.4	6.17	1.50	5.5		42.19	7.67	697.6
P4	81.8	1.4400	1.3418	8.01	9.4	6.11	1.90	5.5		42.19	8.01	697.6
P5	130.4	0.9025	0.7786	7.28	8.0	4.99	2.30	5.0		17.19	7.28	498.5

Source: Study Team

The result of the Shearing strain and rotation is shown in the table below.

Table 8.6.1-12 Check result of transformation performance

	Vertical displacement				Loacal shear strain					Tensile stress of inner steel plate	
	Rotation	Compression	1/2*Liveload	Maximum	Vertical	Horizontal	Rotation	Amount	Allowable strain		
	δr	≦δc/fv	δcl	δo	γc	γs	γr	γt	≦γu/1.5	σs	≦σsa
No	mm	mm	mm	mm	%	%	%	%	%	N/mm2	N/mm2
A1	1.58	2.76	0.38	4.69	100.2	68.2	23.9	192.3	333	74.2	140
P1	1.00	1.69	----	2.62	92.2	65.6	29.3	187.1	333	86.1	140
P2	1.00	1.67	----	2.46	86.4	18.4	29.3	134.1	333	80.7	140
P3	1.00	1.68	----	2.49	87.7	23.9	29.3	140.8	333	81.9	141
P4	1.00	1.68	----	2.60	91.5	63.9	29.3	184.8	333	85.5	142
P5	1.58	2.75	0.37	4.60	98.3	62.1	23.9	184.3	333	72.8	140
Allowable value	----	----	≦ 1.00	----	----	≦ 70	----	----	----	----	----

Source: Study Team

< CASE-2 (53m+3@60m+53m) >

The result of the maximum compression stress, the stress amplitude, and the buckling stress is shown in the table below.

Table 8.6.1-13 Check result of stress

	Movement	bearig area	Efective bearig area	Bearing stress						Buckling stress		Modulas of longitudinal elasticity
				Maximum		minimum	Stress amplitude					
	ΔLm	Ae	Acn	σmax	≦σmaxa	σmina	Δσ	≦ Δσa		σcra	≧σmax	E(※)
No	mm	m2	m2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2		N/mm2	N/mm2	N/mm2
P55	132.6	0.9025	0.7765	6.62	8.0	4.43	2.19	5.0		17.19	6.62	498.5
P56	83.5	1.4400	1.3398	7.65	9.4	5.79	1.86	5.5		42.19	7.65	697.6
P57	23.9	1.4400	1.4113	7.58	9.4	6.15	1.44	5.5		42.19	7.58	697.6
P58	30.4	1.4400	1.4035	7.67	9.4	6.46	1.22	5.5		42.19	7.67	697.6
P59	81.7	1.4400	1.3420	7.60	9.4	5.76	1.84	5.5		42.19	7.60	697.6
P60	120.5	0.9025	0.7880	6.51	8.0	4.42	2.09	5.0		17.19	6.51	498.5

Source: Study Team

The result of the Shearing strain and rotation is shown in the table below.

Table 8.6.1-14 Check result of transformation performance

	Vertical displacement				Loacal shear strain					Tensile stress of inner steel plate	
	Rotation	Compression	1/2*Liveload	Maximum	Vertical	Horizontal	Rotation	Amount	Allowable strain		
	δr	≦δc/fv	δcl	δo	γc	γs	γr	γt	≦γu/1.5	σs	≦σsa
No	mm	mm	mm	mm	%	%	%	%	%	N/mm2	N/mm2
P55	1.58	2.49	0.36	4.18	89.4	63.1	23.9	176.4	333	66.2	140
P56	1.00	1.60	----	2.49	87.4	65.2	29.3	181.9	333	81.6	140
P57	1.00	1.67	----	2.46	86.6	18.7	29.3	134.6	333	80.9	140
P58	1.00	1.68	----	2.49	87.7	23.7	29.3	140.7	333	81.9	141
P59	1.00	1.59	----	2.47	86.8	63.8	29.3	179.9	333	81.1	142
P60	1.58	2.49	0.36	4.11	87.9	57.4	23.9	169.1	333	65.1	140
Allowable value	----	----	≦ 1.00	----	----	≦ 70	----	----	----	----	----

Source: Study Team

f) Earthquake

- Movement at earthquake

The amount of the movement at earthquake is shown in the table below.

< CASE-1 (5@60m) >

Table 8.6.1-15 The amount of the movement at earthquake

	Longitudinal direction				Transvers direction		
	2nd Effect	Level 1(at earthquake)	Level 2		Level 1(at earthquake)	Level 2	
			TYPE Ⅰ	TYPE Ⅱ		TYPE Ⅰ	TYPE Ⅱ
	ΔL'	ΔLe	ΔLe	ΔLe	ΔLe	ΔLe	ΔLe
No	mm	mm	mm	mm	mm	mm	mm
A1	83.7	70.8	142.7	142.7	70.8	150.0	150.0
P1	48.0	70.8	142.7	142.7	70.8	150.0	150.0
P2	11.6	70.8	142.7	142.7	70.8	150.0	150.0
P3	18.5	70.8	142.7	142.7	70.8	150.0	150.0
P4	45.8	70.8	142.7	142.7	70.8	150.0	150.0
P5	70.8	70.8	142.7	142.7	70.8	150.0	150.0

< CASE-2 (53m+3@60m+53m) >

	Longitudinal direction				Transvers direction		
	Secondary force	ΔLe	Level 2		ΔLe	Level 2	
			TYPE Ⅰ	TYPE Ⅱ		TYPE Ⅰ	TYPE Ⅱ
	ΔL'	ΔLe	ΔLe	ΔLe	ΔLe	ΔLe	ΔLe
No	mm	mm	mm	mm	mm	mm	mm
P55	75.8	68.1	144.2	150.0	68.1	150.0	150.0
P56	47.5	68.1	144.2	150.0	68.1	150.0	150.0
P57	11.9	68.1	144.2	150.0	68.1	150.0	150.0
P58	18.4	68.1	144.2	150.0	68.1	150.0	150.0
P59	45.7	68.1	144.2	150.0	68.1	150.0	150.0
P60	63.7	68.1	144.2	150.0	68.1	150.0	150.0

Source: Study Team

- Design result of earthquake

The result of the buckling stress, shearing strain and tensile stress is shown in the table below.

Table 8.6.1-16 The result of the buckling stress, shearing strain and tensile stress

< CASE-1 (5@60m) >

No	Buckling stress			Tensil stress			Shearing strain		Tensile stress of inner steel plate	
	Londitudinal	Transvers	Allowable	Londitudinal	Transvers	Allowable	Londitudinal	Transvers	Londitudinal	Transvers
	σce	σce	≦σcra	σte	σte	≦ σta	γse	γse	σs	σs
	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	%	%	N/mm2	N/mm2
A1	8.52	8.02	28.7	----	----	2.0	107.8	71.4	85.2	80.2
P1	9.57	9.83	70.3	----	----	2.0	148.9	117.2	102.1	104.9
P2	9.13	9.73	70.3	----	----	2.0	120.5	117.2	97.4	103.7
P3	9.28	9.81	70.3	----	----	2.0	126.0	117.2	99.0	104.7
P4	9.49	9.77	70.3	----	----	2.0	147.3	117.2	101.2	104.3
P5	8.35	8.01	28.7	----	----	2.0	101.7	71.4	83.5	80.1
Allowable value	----	----	----	----	----	----	≦ 250	≦ 250	≦ 235	≦ 235

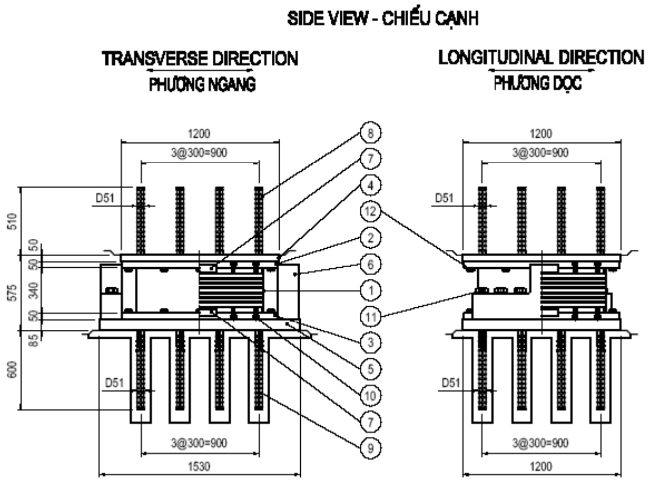
< CASE-2 (53m+3@60m+53m) >

No	Buckling stress			Tensil stress			Shearing strain		Tensile stress of inner steel plate	
	Londitudinal	Transvers	Allowable	Londitudinal	Transvers	Allowable	Londitudinal	Transvers	Londitudinal	Transvers
	σce	σce	≦σcra	σte	σte	≦ σta	γse	γse	σs	σs
	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	%	%	N/mm2	N/mm2
P55	7.59	7.22	28.7	----	----	2.0	107.5	71.4	75.9	72.2
P56	9.11	9.35	70.3	----	----	2.0	154.3	117.2	97.2	99.8
P57	9.22	9.75	70.3	----	----	2.0	126.5	117.2	98.3	103.9
P58	9.55	10.00	70.3	----	----	2.0	131.5	117.2	101.9	106.7
P59	9.04	9.31	70.3	----	----	2.0	152.9	117.2	96.4	99.3
P60	7.44	7.20	28.7	----	----	2.0	101.8	71.4	74.4	72.0
Allowable value	----	----	----	----	----	----	≦ 250	≦ 250	≦ 235	≦ 235

Source: Study Team

g) Detailed dimension of Rubber bearing

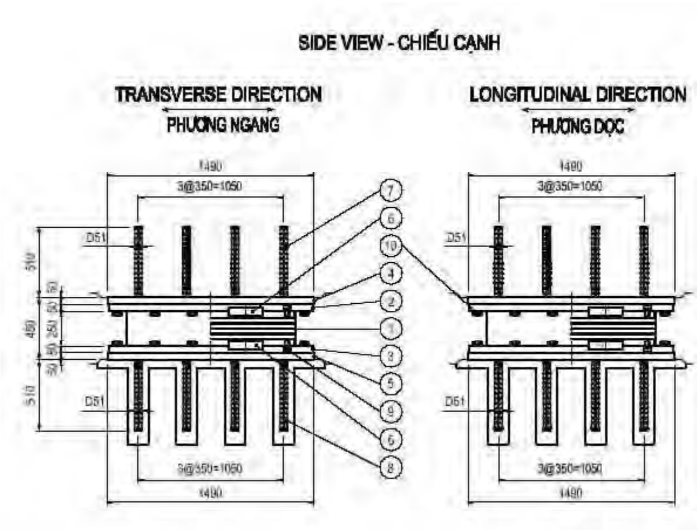
- End support Bearing



Source: Study Team

Figure 8.6.1-4 Dimension of End support bearing

- Middle support Bearing



Source: Study Team

Figure 8.6.1-5 Dimension of middle support bearing

(3) Cat Hai side Approach Bridge

1) Design condition

a) Design force

< CASE-1(53.8m+3@60m+53.8m) >

The reaction force of Rubber bearing is shown in the table below.

Table 8.6.1-17 Reaction force of rubber bearing

	Maximum Reaction		Miniumum Reaction	Live Load Max	Dead Load Reaction		Dead Load Total
					Max	Min	
	Rmax1	Rmax2	Rmin	$R_{L+I}max$	Rdmax	Rdmin	ΣRd
No	kN	kN	kN	kN	kN	kN	kN
P79	4440	3996	3290	1040	3400	3400	6800
P80	12360	11124	10400	1750	10710	10710	21420
P81	11770	10593	9880	1670	10100	10100	20200
P82	11770	10593	9880	1670	10100	10110	20210
P83	12360	11124	10400	1650	10710	10710	21420
P84	4440	3996	3290	1040	3400	3400	6800
W	----	----	----	----	----	----	96850

Source: Study Team

< CASE-2(53.8m+2@60m+53.8m) >

Table 8.6.1-18 Reaction force of rubber bearing

	Maximum Reaction		Miniumum Reaction	Live Load Max	Dead Load Reaction		Dead Load Total
					Max	Min	
	Rmax1	Rmax2	Rmin	$R_{L+I}max$	Rdmax	Rdmin	ΣRd
No	kN	kN	kN	kN	kN	kN	kN
P84	4440	3996	3290	1040	3400	3400	6800
P85	12400	11160	10440	1750	10750	10750	21500
P86	11700	10530	9740	1750	9950	9950	19900
P87	12300	11070	10590	1770	10750	10750	21500
A2	4300	3870	3290	900	3400	3400	6800
W	----	----	----	----	----	----	76500

Source: Study Team

b) Amount of Movement

< CASE-1 (53.8m+3@60m+53.8m) >

Table 8.6.1-19 Amount of Movement in each support

	Span Length	Temperature change		Creep,Shrinkage etc.
	L	Δt	Δt'	Δscp
Span	m	mm	mm	mm
P79～ P80	53.80	±10.8	±21.5	-19.9
P80～ P81	60.00	±12.0	±24.0	-17.9
P81～ P82	60.00	±12.0	±24.0	-18.2
P82～ P83	60.00	±12.0	±24.0	-18.3
P83～ P84	53.80	±10.8	±21.5	-19.7

Source: Study Team

< CASE-2(53.8m+2@60m+53.8m) >

Table 8.6.1-20 Amount of Movement in each support

	Span Length	Temperature change		Creep,Shrinkage etc.
	L	Δt	Δt'	Δscp
Span	m	mm	mm	mm
P84～ P85	53.80	±10.8	±21.5	-19.5
P85～ P86	60.00	±12.0	±24.0	-17.3
P86～ P87	60.00	±12.0	±24.0	-17.3
P87～ A2	53.80	±10.8	±21.5	-19.5

Source: Study Team

c) Allowable value

< Rubber >

The restriction stress of the body of rubber is as shown in the table below.

Table 8.6.1-21 Allowable value of rubber

Item				Sign	Unit	Value
Compression Stress	Maximum Compression stresse (At an effective area)	S1≦8		σmaxa	N/mm2	8
		8＜S1＜12				S1
		12≦S1				12
	Minimum Compression stress			σmina	N/mm2	1.5
	Stress amplitude	S1≦8		Δσa	N/mm2	5.0
		8＜S1＜12				5＋0.375･(S1-8)
		12≦S1				6.5
Shearing distorsion		service Loade		γsa	%	70
		Earthquake	Level1	γea	%	150
			Level2	γea	%	250
Local Shearing distorsion		Total distorsion at Service limitted state		γta	%	γu/fs
				fs	---	1.5
		Breaking growth rate		γu	%	depends on the table below.
Tensile Stress	Earthquake	G6		σta	N/mm2	1.2
		G8				1.6
		G10 or more				2.0

Source: Study Team

< Inner steel plate >

Table 8.6.1-22 Allowable value of Inner Steel Plate

Kind of Material	unit	Yield Strength	bending stress
SS400	N/mm2	235	140

Source: Study Team

d) Detail dimension of Bearing

Table 8.6.1-23 Detail Dimension of Bearing

< CASE-1 (53.8m+3@60m+53.8m) >

		b	a	te	n	Σte	ts	Ge
No	function	mm	mm	mm	layer	mm	mm	N/mm2
P79	Dispersion	850	850	32	5	160	6.0	1.20
P80	Dispersion	1300	1300	32	3	96	6.0	1.20
P81	Dispersion	1300	1300	32	3	96	6.0	1.20
P82	Dispersion	1300	1300	32	3	96	6.0	1.20
P83	Dispersion	1300	1300	32	3	96	6.0	1.20
P84	Dispersion	850	850	32	5	160	6.0	1.20

< CASE-2 (53.8m+2@6m+53.8m) >

		b	a	te	n	Σte	ts	Ge
No	function	mm	mm	mm	layer	mm	mm	N/mm2
P84	Dispersion	850	850	32	4	128	6.0	1.20
P85	Dispersion	1300	1300	32	3	96	6.0	1.20
P86	Dispersion	1300	1300	32	3	96	6.0	1.20
P87	Dispersion	1300	1300	32	3	96	6.0	1.20
A2	Dispersion	850	850	32	4	128	6.0	1.20

Source: Study Team

e) Service Limit state

- Movement at service state

Longitudinal movement of Service limit state is shown in the table below.

< CASE-1 (53.8m+3@60m+53.8m) >

Table 8.6.1-24 Longitudinal movement

	Expansion length from center	Thermal movement (uniform temperature change)				Movement of creep and shrinkage			Live load	Combination	
		for horizontal force		for bearig design		Creep and shrinkage	Dead	amount			
		ΔLt		ΔLt'		ΔLscp	ΔLd	ΔL'	ΔLr	ΔL	
		+20℃	-20℃	+40℃	-40℃	----	----	----	----	+40℃	-40℃
	L	①	②	③	④	⑤	⑥	⑦	⑧	③+⑦+⑧	④+⑦+⑧
No	m	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
P79	-143.80	-28.8	28.8	-57.5	57.5	47.0	----	47.0	----	-10.5	104.5
P80	-90.00	-18.0	18.0	-36.0	36.0	27.1	----	27.1	----	-8.9	63.1
P81	-30.00	-6.0	6.0	-12.0	12.0	9.2	----	9.2	----	-2.8	21.2
P82	30.00	6.0	-6.0	12.0	-12.0	-9.0	----	-9.0	----	3.0	-21.0
P83	90.00	18.0	-18.0	36.0	-36.0	-27.3	----	-27.3	----	8.7	-63.3
P84	143.80	28.8	-28.8	57.5	-57.5	-47.0	----	-47.0	----	10.5	-104.5

< CASE-2 (53.8m+2@60m+53.8m) >

	Expansion length from center	Thermal movement (uniform temperature change)				Movement of creep and shrinkage			Live load	Combination	
		for horizontal force		for bearig design		Creep and shrinkage	Dead	amount			
		ΔLt		ΔLt'		ΔLscp	ΔLd	ΔL'	ΔLr	ΔL	
		+20℃	-20℃	+40℃	-40℃	----	----	----	----	+40℃	-40℃
	L	①	②	③	④	⑤	⑥	⑦	⑧	③+⑦+⑧	④+⑦+⑧
No	m	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
P84	-113.80	-22.8	22.8	-45.5	45.5	36.8	----	36.8	----	-8.7	82.3
P85	-60.00	-12.0	12.0	-24.0	24.0	17.3	----	17.3	----	-6.7	41.3
P86	0.00	0.0	0.0	0.0	0.0	0.0	----	0.0	----	0.0	0.0
P87	60.00	12.0	-12.0	24.0	-24.0	-17.3	----	-17.3	----	6.7	-41.3
A2	113.80	22.8	-22.8	45.5	-45.5	-36.8	----	-36.8	----	8.7	-82.3

Source : Study Team

- Design result of Service limit state

< CASE-1 (53.8m+3@60m+53.8m) >

The result of the maximum compression stress, the stress amplitude, and the buckling stress is shown in the table below.

Table 8.6.1-25 Check result of stress

	Movement	bearig area	Efective bearig area	Bearing stress					Buckling stress		Modulas of longitudinal elasticity
				Maximum		minimum	Stress amplitude				
	ΔLm	Ae	Acn	σmax	≦σmaxa	σmina	Δσ	≦ Δσa	σcra	≧σmax	E(※)
No	mm	m2	m2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2
P79	104.5	0.7225	0.6337	7.01	8.0	4.55	2.45	5.0	16.93	7.01	351.8
P80	63.1	1.6900	1.6080	7.69	10.2	6.15	1.53	5.8	66.02	7.69	818.0
P81	21.2	1.6900	1.6624	7.08	10.2	5.85	1.23	5.8	66.02	7.08	818.0
P82	21.0	1.6900	1.6627	7.08	10.2	5.85	1.23	5.8	66.02	7.08	818.0
P83	63.3	1.6900	1.6077	7.69	10.2	6.15	1.53	5.8	66.02	7.69	818.0
P84	104.5	0.7225	0.6337	7.01	8.0	4.55	2.45	5.0	16.93	7.01	351.8

The result of the Shearing strain and rotation is shown in the table below.

Table 8.6.1-26 Check result of transformation performance

No	Vertical displacement				Loacal shear strain					Tensile stress of inner steel plate	
	Rotation	Compression	1/2*Liveload	Maximum	Vertical	Horizontal	Rotation	Amount	Allowable strain		
	δr	≦δc/fv	δcl	δo	γc	γs	γr	γt	≦γu/1.5	σs	≦σsa
	mm	mm	mm	mm	%	%	%	%	%	N/mm2	N/mm2
P79	1.42	2.44	0.41	4.02	112.4	65.3	23.5	201.3	333	74.7	140
P80	1.08	1.14	----	1.73	81.1	65.7	45.8	192.7	333	82.0	140
P81	1.08	1.09	----	1.59	74.7	22.1	45.8	142.6	333	75.5	140
P82	1.08	1.09	----	1.59	74.7	21.9	45.8	142.4	333	75.5	141
P83	1.08	1.14	----	1.73	81.1	65.9	45.8	192.9	333	82.0	142
P84	1.42	2.44	0.41	4.02	112.4	65.3	23.5	201.3	333	74.7	140
Allowable value	----	----	≦ 1.00	----	----	≦ 70	----	----	----	----	----

Source : Study Team

< CASE-2 (53.8m+2@60m+53.8m) >

The result of the maximum compression stress, the stress amplitude, and the buckling stress is shown in the table below.

Table 8.6.1-27 Check result of stress

No	Movement	bearig area	Efective bearig area	Bearing stress					Buckling stress		Modulas of longitudinal elasticity
				Maximum		minimum	Stress amplitude				
	ΔLm	Ae	Acn	σmax	≦σmaxa	σmina	Δσ	≦ Δσa	σcra	≧σmax	E(※)
	mm	m2	m2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2
P84	82.3	0.7225	0.6525	6.80	8.0	4.55	2.25	5.0	21.17	6.80	351.8
P85	41.3	1.6900	1.6363	7.58	10.2	6.18	1.40	5.8	66.02	7.58	818.0
P86	0.0	1.6900	1.6900	6.92	10.2	5.76	1.16	5.8	66.02	6.92	818.0
P87	41.3	1.6900	1.6363	7.52	10.2	6.27	1.25	5.8	66.02	7.52	818.0
A2	82.3	0.7225	0.6525	6.59	8.0	4.55	2.04	5.0	21.17	6.59	351.8

Source : Study Team

The result of the Shearing strain and rotation is shown in the table below.

Table 8.6.1-28 Check result of transformation performance

No	Vertical displacement				Loacal shear strain					Tensile stress of inner steel plate	
	Rotation	Compression	1/2*Liveload	Maximum	Vertical	Horizontal	Rotation	Amount	Allowable strain		
	δr	≦δc/fv	δcl	δo	γc	γs	γr	γt	≦γu/1.5	σs	≦σsa
	mm	mm	mm	mm	%	%	%	%	%	N/mm2	N/mm2
P84	1.42	1.95	0.33	3.12	109.2	64.3	29.4	202.9	333	72.6	140
P85	1.08	1.14	----	1.71	80.0	43.0	45.8	168.8	333	80.8	140
P86	1.08	1.08	----	1.56	73.1	0.0	45.8	118.9	333	73.8	140
P87	1.08	1.13	----	1.69	79.3	43.0	45.8	168.2	333	80.2	141
A2	1.42	1.89	0.29	3.02	105.7	64.3	29.4	199.5	333	70.3	142
Allowable value	----	----	≦ 1.00	----	----	≦ 70	----	----	----	----	----

Source : Study Team

f) Earthquake

- Movement at earthquake

< CASE-1 (53.8m+3@60m+53.8m) >

The amount of the movement at earthquake is shown in the table below.

Table 8.6.1-29 The amount of the movement at earthquake

	Longitudinal direction				Transvers direction		
	Secondary force	Level 1(at earthquake)	Level 2		Level 1(at earthquake)	Level 2	
			TYPE Ⅰ	TYPE Ⅱ		TYPE Ⅰ	TYPE Ⅱ
	ΔL'	ΔLe	ΔLe	ΔLe	ΔLe	ΔLe	ΔLe
No	mm	mm	mm	mm	mm	mm	mm
P79	47.0	50.8	117.6	117.6	50.8	150.0	150.0
P80	27.1	50.8	117.6	117.6	50.8	150.0	150.0
P81	9.2	50.8	117.6	117.6	50.8	150.0	150.0
P82	9.0	50.8	117.6	117.6	50.8	150.0	150.0
P83	27.3	50.8	117.6	117.6	50.8	150.0	150.0
P84	47.0	50.8	117.6	117.6	50.8	150.0	150.0

b) CASE-2 (53.8m+2@60m+53.8m)

	Longitudinal direction				Transvers direction		
	Secondary force	Level 1(at earthquake)	Level 2		Level 1(at earthquake)	Level 2	
			TYPE Ⅰ	TYPE Ⅱ		TYPE Ⅰ	TYPE Ⅱ
	ΔL'	ΔLe	ΔLe	ΔLe	ΔLe	ΔLe	ΔLe
No	mm	mm	mm	mm	mm	mm	mm
P84	36.8	49.7	103.5	103.5	49.7	150.0	150.0
P85	17.3	49.7	103.5	103.5	49.7	150.0	150.0
P86	0.0	49.7	103.5	103.5	49.7	150.0	150.0
P87	17.3	49.7	103.5	103.5	49.7	150.0	150.0
A2	36.8	49.7	103.5	103.5	49.7	150.0	150.0

Source : Study Team

2) Design result of Earthquake

The result of the buckling stress, shearing strain and tensile stress is shown in the table below.

Table 8.6.1-30 The result of the buckling stress, shearing strain and tensile stress

< CASE-1 (53.8m+3@60m+53.8m) >

	Buckling stress			Tensil stress			Shearing strain		Tensile stress of inner steel plate	
	Londitudinal	Transvers	Allowable	Londitudinal	Transvers	Allowable	Londitudinal	Transvers	Londitudinal	Transvers
	σce	σce	≦σcra	σte	σte	≦ σta	γse	γse	σs	σs
No	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	%	%	N/mm2	N/mm2
P79	7.41	8.28	28.2	----	----	2.0	102.9	93.8	79.1	88.3
P80	9.06	10.89	110.0	----	----	2.0	150.7	156.3	96.6	116.1
P81	8.41	10.42	110.0	----	----	2.0	132.1	156.3	89.7	111.2
P82	8.41	10.42	110.0	----	----	2.0	131.9	156.3	89.7	111.2
P83	9.06	10.89	110.0	----	----	2.0	150.9	156.3	96.6	116.1
P84	7.41	8.28	28.2	----	----	2.0	102.9	93.8	79.1	88.3
Allowable value	----	----	----	----	----	----	≦ 250	≦ 250	≦ 235	≦ 235

< CASE-2 (53.8m+2@60m+53.8m) >

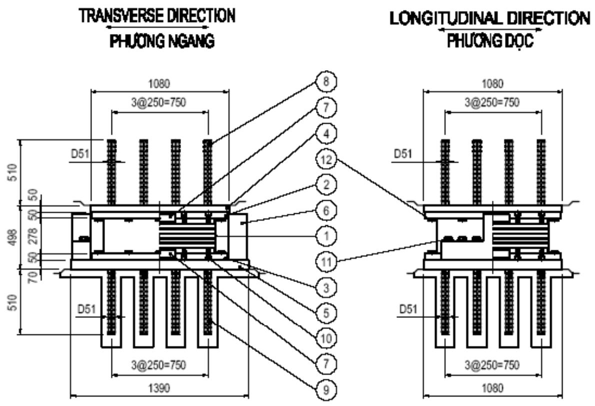
	Buckling stress			Tensil stress			Shearing strain		Tensile stress of inner steel plate	
	Londitudinal	Transvers	Allowable	Londitudinal	Transvers	Allowable	Londitudinal	Transvers	Londitudinal	Transvers
	σce	σce	≦σcra	σte	σte	≦ σta	γse	γse	σs	σs
No	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	N/mm2	%	%	N/mm2	N/mm2
P84	7.16	8.70	35.3	----	----	2.0	109.6	117.2	76.3	92.8
P85	8.91	10.92	110.0	----	----	2.0	125.8	156.3	95.0	116.4
P86	8.12	10.31	110.0	----	----	2.0	107.8	156.3	86.7	109.9
P87	8.91	10.92	110.0	----	----	2.0	125.8	156.3	95.0	116.4
A2	7.16	8.70	35.3	----	----	2.0	109.6	117.2	76.4	92.8
Allowable value	----	----	----	----	----	----	≦ 250	≦ 250	≦ 235	≦ 235

Source : Study Team

g) Detailed dimension of Rubber bearing

- End support Bearing

< P79 and P84 >



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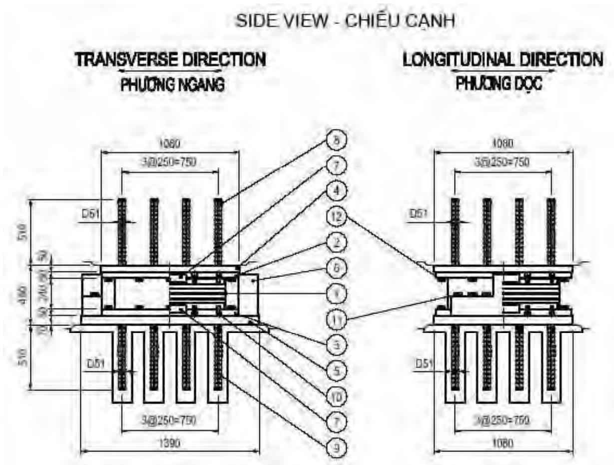
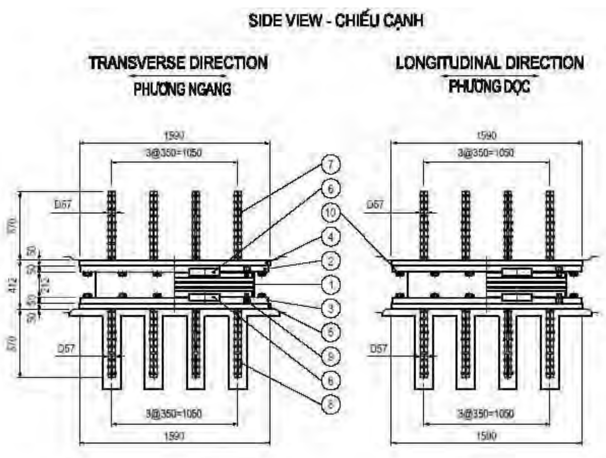


< Middle support Bearing >



Source : Study Team

Figure 8.6.1-6 Dimension of middle support bearing

8.6.2 Expansion Joint

8.6.2.1 Design of Expansion Joint for Main Bridge

(1) Selection of Type of Expansion Joint between Main Bridge and Approach Bridge

In order to select appropriate types of expansion joint for Approach Bridge and Main Bridge, the comparative study was conducted.

1) Comparative Study on Type Selection

a) General

For optimizing the type of expansion joint, the comparative study was performed by introducing various types of expansion joint as follows,

Alternative-1: Rubber Joint (Transversal Type)

Alternaitve-2: Steel Finger Joint

Alternative-3: Steel Joint (Module Type)

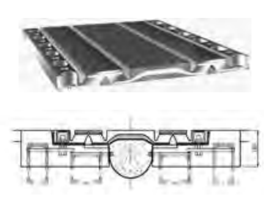
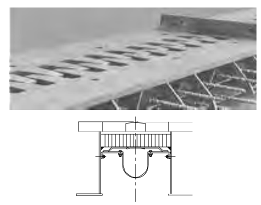
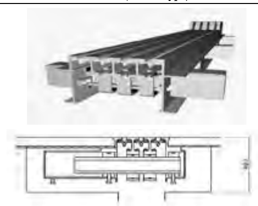
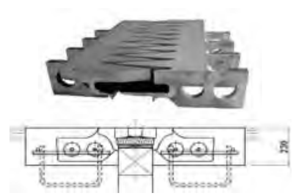
Altenrative-4: Aluminum Alloy Joint (Triangle Comb Type)

b) Result of Comparative Study

The result of comparative study is shown in the table on the next page.

As shown in the Table, Alternative-4, Aluminum Alloy Joint (Triangle Comb Type), is recommended because of its advantages in lifecycle cost and durability. In case of large longitudinal displacement, however, because this type of joint has limitation in adapting up to 250m of the expansion, Alternative-2, Steel Finger Joint, which can be fabricated by order-made for adjusting its dimensions, is recommended.

Table 8.6.2-1 Comparison on Type of Expansion

Evaluation Item	Score	Alternative No.1 Rubber Joint (Transverse Type)		Alternative No.2 Steel Finger Joint		Alternative No.3 Steel Joint (module type)		Alternative No.4 Aluminum Alloy Joint (Triangle comb type)	
General View									
Structure Aspect and Stability	10	It is rubber and steel integral structure, and expands by shearing deformation of rubber. It can expand in the transverse direction a little as well as longitudinal direction. Wheel load is supported at load support plate at center, and its load influence can be decreased by the rubber cushion for impact. Type is load support type. Allowable Expansion : 200mm (±100mm) Notch Depth: 180mm	4	Expansion amount is secured by center clearance of the comb-shaped face plate (both sides). It's distance is order made depend on the design condition (bridge deformation). Vehicle load is supported by steel face plates. Since it's comb-shaped, horizontal (transverse direction) movement cannot be responded. Water cut-off shall be done by elastic sealing and rubber materials setting below face plates. This is load support type. Allowable Expansion: Any expansion amount is available. Notch Depth: Approximately 400mm	8	Basic structure is a composition of steel frame and seal rubber. Support beam is set at 1.5m interval and in the expanding direction in principle, and has control device between support beam. It is movable in transverse direction too. This is load support type. Allowable Expansion: 240 (±120) Notch Depth: 400mm	6	The body is aluminum composition steel so it is light weight and durable against salt, oil and rust. Waterproof rubber is honey comb structure made by ethylene propylene rubber. It open/close by comb shaped structure and cannot follow any horizontal (transverse direction) movement. This is load support type. Allowable Expansion: 230 (±115) Notch Depth: 230mm	8
Cost (Upper: Investment Lower: Life Cycle)	40	Investment ¥ 721,000 /m at first Material ¥ 601,000 /m Construction ¥ 120,000 /m 1.00	20	Investment ¥ 970,000 /m at first Material ¥ 820,000 /m Construction ¥ 150,000 /m 1.35	8	Investment ¥ 782,000 /m at first Material ¥ 622,000 /m Construction ¥ 160,000 /m 1.08	16	Investment ¥ 772,000 /m at first Materia ¥ 652,000 /m Construction ¥ 120,000 /m 1.07	16
		Maintenance ¥ 751,000 /m and repair Material ¥ 601,000 /m Construction ¥ 150,000 /m Life cycle cost 9/100 years 721,000 + (751,000×9) = 7,480,000 /m 2.83 7,480,000 / 100 = 74,800 /year	0	Maintenance ¥ 1,000,000 /m and repair Material ¥ 820,000 /m Construction ¥ 180,000 /m Life cycle cost 2.33/100 years 970,000 + (1,000,000×2.33) = 3,300,000 /m 1.25 3,300,000 / 100 = 33,000 /year	12	Maintenance ¥ 822,000 /m and repair Material ¥ 622,000 /m Construction ¥ 200,000 /m Life cycle cost 4/100 years 782,000 + (822,000×4) = 4,070,000 /m 1.54 4,070,000 / 100 = 40,700 /year	8	Maintenance ¥ 802,000 /m and repair Material ¥ 652,000 /m Construction ¥ 150,000 /m Life cycle cost 2.33/100 years 772,000 + (802,000×2.33) = 2,640,660 /m 1.00 2,640,660 / 100 = 26,400 /year	20
Construction Plan and Period	10	Construction condition does not serious restriction due to shallow depth of cutting deck.. After steel expansion joint is anchored at anchorage reinforcing bars, concrete is placed. Therefore, this is quite simple way of construction.	10	Since it is set up before deck slab concrete placing in case of steel girder, control of girder deformation at every stage of deck concrete placing and the control of flatness of both side face plate is quite complicated,	6	It is needed to have big blockout for concrete member (deck). Weight of the body is big so it would be large scaled construction by heavy crane.	6	Blockout is a bit deep, but there is comparatively no inhibited for deck plate. Construction is taken place by setting expansion joint which is adjusted in the bridge width, and then reinforcing bars are arranged and welded. And finally, placing concrete is executed. It is quite efficient construction method.	10
Maintenance and Durability	15	Load is absorbed and distributed by rubber elasticity and steel rigidity, and as the results, it is possible to decrease any bad affect to deck place. Rust proof is secured by adopting rubber material which are good for weathering and oil resistant together with all coated structure. But it need any artifice for sear-out of rubber surface. When replacement, no need to chip the concrete, and it is possible to change only device of joint. It takes minimum time for replacement and it is easily constructed. Duration of Life : 10 years	6	It is strong from structural view point and durable. It is concerned that stripping of the elastic seal for water cut-off occurs. Expansion joint itself cannot be removed alone, so it need to have a lot of work such as chipping concrete at large area. Durable Period: 30 years	12	It is steel structure and quite strong. Waterproof rubber is set at beam conduit, so it doesn't need to be worried for chipping off. It is possible to do small scaled maintenance by changing parts by parts, however, it possibly would be large scaled by using heavy crane with big amount of budget and time. Durable Period: 20 years	9	The body is steel so rigidity is high and it is durable. There is a concern that any abruption of water cut-off rubber set in the joint occurs. It is possible to change parts by parts, but cannot change the expansion body itself only. When need it, it is needed to chip the concrete at large area to change the expansion body. Durable Period: 30 years	12
STEP Clearance	10	Procurement Ratio: 83%	10	Procurement Ratio: 85%	10	Procurement Ratio: 80%	10	Procurement Ratio: 84%	10
Aesthetics	5	There is no major difference in appearance.	5	There is no major difference in appearance.	5	There is no major difference in appearance.	5	There is no major difference in appearance.	5
New Technology	5	Transversal Type Rubber Joint is new technology.	5	Commonly used in Vietnam	3	Commonly Used in Vietnam	3	Aluminum Alloy Joint is new technology.	5
Environmental Impact/ ROW / Traffic Management	5	Impact by load passing is absorbed by surface rubber and coated rubber. It is corresponded to uneven deck place by rotation of girder. Road surface water drainage is in good condition by surface rubber pattern, so slip is not easily occurred. The expansion joint is comb-shaped, and road surface water drainage is good. There are seal material & downspout which is second water cut-off function. Noise is minimum due to absorption and distribution of impact of vehicle passing by the rubber elasticity. Back up material is inserted at the water cut-off rubber, so noise is shut off to downward.	5	Unless any gap is appeared in structural left and right face plates , performance is quite good for certain level of gradient and rotation. There is concern that any step appears in case of slender bridge like steel bridge. There is function of water cut-off using elastic seal material. It is concerned that flaking should be occurred by stress to be concentrated to boundary face of the elastic seal material. If road surface is not even by girder rotation, impact noise between comb-shaped joints is comparatively big. But the noise is not easily to go down because of filling of elastic seal material below joint.	4	This system responds to the unevenness by rotation of the girder by bearing at top/bottom. Some numbers of beam adjustment conduit exist, so it cause the vibration by vehicle running. As for drainage, simple structure such as sealing rubber put into end beam and middle beam is adopted. So, water is gathered into drain box different from the left hand side 2 alternatives. Regular maintenance is needed to keep quality of performance for water cut-off. Impact noise is comparatively big when vehicle crosses the beam adjustment conduit. Noise which goes through down from the adjustment room is also big.	3	Unless any step (gap) appears between left and right faces from structural viewpoint, performance is quite good for certain level of gradient and rotation. There is concern that any step (gap) appears in case of slender bridge like steel girder. It is efficient for water cut-off because waterproof rubber is set by pressing in the expansion inside but not using joint. There is a concern that soil and sand coming into the comb-shaped device, which causes abruption at adhesive bonding part. Vehicle running is smooth by triangle face plate and it has artifice to decrease the vehicle running noise. However, noise at joint going down is possibly big.	5
Evaluation	100	**Not Recommended.** Although the investment cost is the lowest, this alternative is inferior in maintenance and life cycle cost due to short durability of the material.	65	**Recommended.** Its durability is superior to others, but comparatively inferior in cost, environment, and construction aspect to others. In case that the necessary expansion gap is more than 230mm, this altenrative shall be selected.	68	**Less recommended.** Although durability, construction, and water cut-off ability are not so bad, performance and economic efficiency are not advantageous.	66	**Most recommended.** It is superior in durability to others as well as steel finger joint, but inferior in construction and maintenance aspects. It is economically efficient.	91

Source : Study Team

(2) Design of Expansion Joint between Main Bridge and Approach Bridge

1) Calculation of Necessary Expansion between Main Bridge and Approach Bridge

The necessary expansion between Main Bridge and Approach Bridge was calculated based on the results of the structural analyses for the design of the main girders.

a) Conditions of Analyses

The conditions are as follows;

- Temperature Range: 40 degrees
- Coefficient of thermal expansion: 1.08E-05
- Model of Creep and Shrinkage: CEB-FIP90
- Degree of Humidity: 80%

b) Results of Calculation

The results of analysis are as follows;

Table 8.6.2-2 Longitudinal Movement at Ends of Main Girders

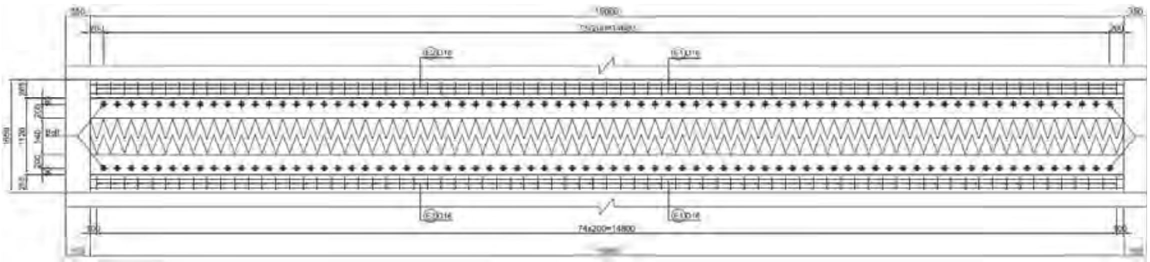
	Main Bridge	Approach Bridge	Total
Movement due to Temperature Alternation	103.8	59.0	162.8
Movement due to Creep & Shrinkage	84.2	58.3	142.5
Total	187.9	117.3	305.2

Unit: mm

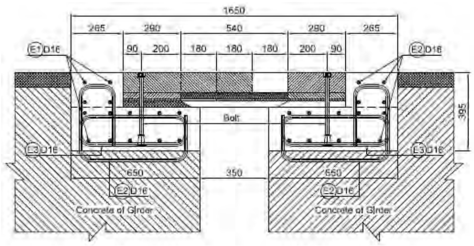
Source : Study Team

c) Expansion Joint to be applied

The expansion joint to be applied between Main Bridge and Approach Bridge is a steel finger type joint as shown in the figure below because the necessary expansion is more than 250mm. The gap between the edges of the main girders is set as the standard gap of the type of the joint.



(a) Plan View



(b) Longitudinal Cross Section

Source: Study Team

Figure 8.6.2-1 Expansion Joint between Main Bridge and Approach Bridge

8.6.2.2 Design of Expansion Joint for Approach Bridge

In the design of Expansion joint, it is necessary to decide the following matters.

(1) Decision of Expansion gap

(2) Amount of movement of girder end

When the above-mentioned item is decided, it is necessary to calculate the amount of the movement of girder end. The amount of the movement applies the result of calculation from the structure analysis on a main girder.

(1) Hai an side Approach Bridge

1) Movement of main girder

The amount of the movement is calculated by the structure analysis on the main girder, and is shown in the table below.

Table 8.6.2-3 Amount of the movement

Unit : mm

Item	Position / Node Num,	E1 1	P1 23	P2 44	P3 65	P4 86	E2 108
①	Dead Load	-8.9	-8.5	-3.8	-2.1	-0.7	-0.7
②	Prestress	26.9	16.1	3.8	-3.1	-7.7	-10.4
③	Creep and Shrinkage	59.6	34.7	10.6	-12.6	-35.3	57.6
④	Temperture 40℃	58.9	35.5	11.7	11.9	35.7	59.2
⑤	Earth Quick Kh=0.18	142.7	142.6	142.6	142.6	142.6	142.7

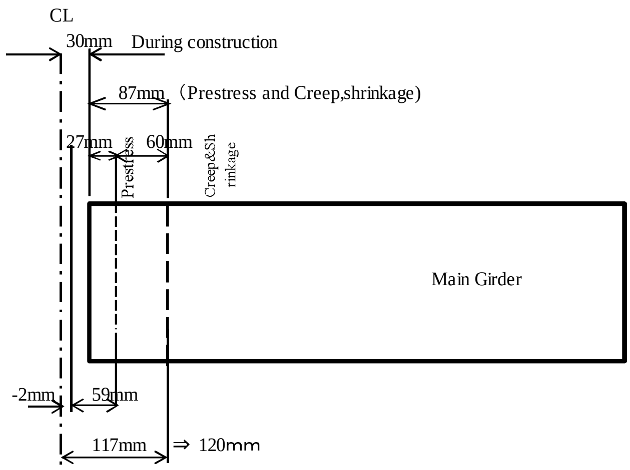
Source: Study Team

2) Decision of expansion gap

Expansion gap of girder end is decided to the following conditions.

a) Expansion gap when the girder end Segment is set up is assumed to be 30mm.

Expansion gap must be secured for temperature change (temperature increase 40℃) immediately after structure completion.



Source: Study Team

Figure 8.6.2-2 Movement of girder end

Expansion gap from the pier center or front parapet is assumed to be 120mm as shown in the above figure at the point of Creep and shrinkage end.

Expansion gap requirement L= 117mm

Therefore, it is provided 120mm as Expansion gap

3) Design movement of expansion joint

The design movement applied to the expansion joint considers the movement after the girder is completed. Because after girder is completed, expansion joint is set up.

Table 8.6.2-4 The design movement applied to the expansion joint considers the movement after the girder

Item	unit	Movement	Remarks
1. Creep and Shrinkage	mm	59.6	
2. Temperature change(40℃)	mm	58.9	
3. design margin	mm	1.5	
Design movement	mm	120.0	

Source: Study Team

Therefore, the amount of design movement at the abutment and pier is as shown in following table.

Table 8.6.2-5 The amount of design movement at the abutment and pie

Place	unit	Movement	Remarks
Abutment A1	mm	120	
Pier	mm	240	

Source: Study Team

4) Selection of expansion joint

Expansion joint is selected according to the result of comparative Study on Type Selection of main bridge.

The design movement of Hai an side approach Bridge is comparatively small with 120mm and 240mm.Therefore,it adopts made of the aluminum alloy.

a) Relation between allowance and design movement of expansion joint.

< A1Abuttment >

Cipec joint Wj -160.			Design movement	
allowable movement :	160mm	>	120	mm
allowable expansion gap :	150mm	>	120	mm
		Ok		

< Pier >

Cipec joint WY-320.			Design movement	
allowable movement :	250mm	>	240	mm
Allowable expansion gap :	435mm	>	240	mm
		OK		

(2) Cat Hai side Approach Bridge

1) Movement of main girder

The amount of the movement is calculated by the structure analysis on the main girder, and is shown in the table below.

Table 8.6.2-6 Amount of the movement

Unit; mm

Item	Position / Node Num,	E1 1	P1 16	P2 34	P3 52	P4 70	E2 85
①	Dead Load	-1.6	-0.9	0.0	0.0	1.0	1.7
②	Prestress	6.7	3.0	1.1	-0.8	-3.0	-6.6
③	Creep and Shrinkage	41.2	25.0	9.0	-7.3	-23.4	-39.5
④	Temperture 40℃	58.2	36.7	13.0	10.6	34.3	-55.7
⑤	Earth Quick Kh=0.18	117.6	117.5	117.4	117.3	117.3	117.3

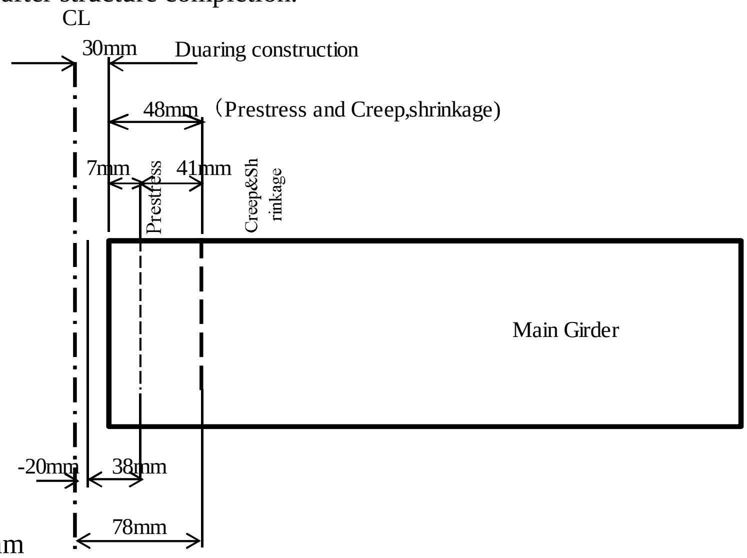
Source: Study Team

2) Decision of expansion gap

Expansion gap of girder end is decided to the following conditions.

a) Expansion gap when the girder end Segment is set up is assumed to be 30mm.

Expansion gap must be secured for temperature change (temperature increase 40˚C) immediately after structure completion.



Source: Study Team

Figure 8.6.2-3 Movement of girder end

Expansion gap from the pier center or front parapet is assumed to be 120mm as shown in the above figure at the point of creep and shrinkage end.

Expansion gap requirement L= 78 + 20 = 98mm → 120mm

Therefore, it is provided 120mm as Expansion gap

3) Design movement of expansion joint

The design movement applied to the expansion joint considers the movement after the girder is completed. Because after girder is completed, expansion joint is set up.

Table 8.6.2-7 The design movement applied to the expansion joint considers the movement after the girder

Item	unit	Movement	Remarks
1. Creep and Shrinkage	mm	41.2	
2. Temperature change(40℃)	mm	58.2	
3. design margin	mm	20.6	
Design movement	mm	120.0	

Source: Study Team

Therefore, the amount of design movement at the abutment and pier is as shown in following table.

Table 8.6.2-8 The amount of design movement at the abutment and pie

Place	unit	Movement	Remarks
Abutment A2	mm	120	
Pier	mm	240	

Source: Study Team

4) Selection of expansion joint

Expansion joint is selected according to the result of comparative Study on Type Selection of main bridge.

The design movement of Hai an side approach Bridge is comparatively small with 120mm and 240mm.Therefore,it adopts made of the aluminum alloy.

a) Relation between allowance and design movement of expansion joint.

< A1Abuttment >

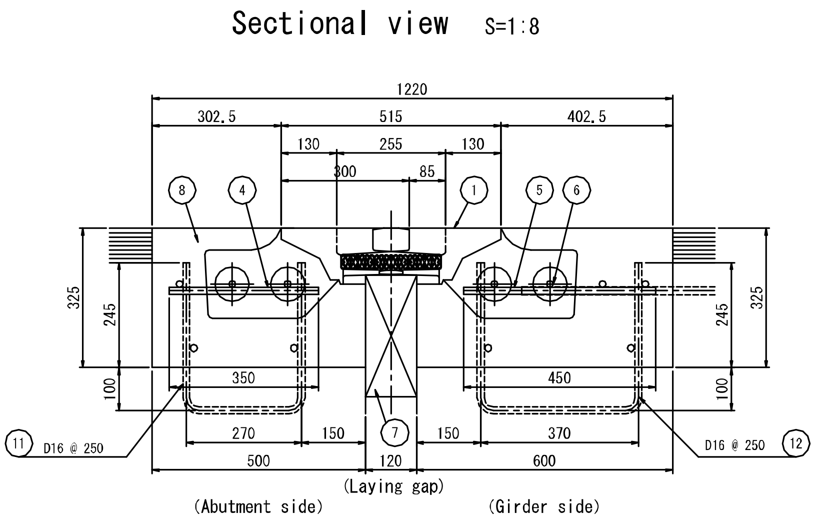
Cipec joint Wj -160.			Design movement	
allowable movement :	160mm	>	120	mm
allowable expansion gap :	150mm	>	120	mm
		Ok		

< Pier >

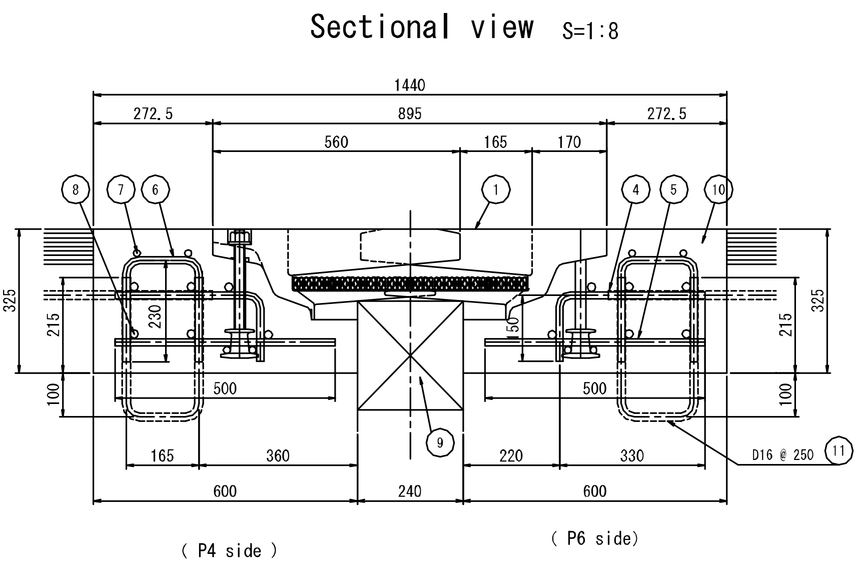
Cipec joint WY-320.			Design movement	
allowable movement :	250mm	>	240	mm
Allowable expansion gap :	435mm	>	240	mm
		OK		

(3) dimension of Expansion joint

< A1 and A2 Abutment >



< Pier >



Source: Study Team

Figure 8.6.2-4 Expansion Joint on Approach Bridge

8.6.2.3 Joint Protectors

For Main Bridge, the unidirectional pot bearing guides the girder to move in the longitudinal direction so that the joint can be protected from transversal movement of the girder.

For Approach bridge, the laminated elastomeric shoe with side blocks guides the girder to move in the longitudinal direction so that the joint can be protected from transversal movement of the girder.

8.6.3 Railing

8.6.3.1 Comparative Study on Handrail

(1) Conditions of Study

In order to select the most reasonable type of Guardrail, alternatives for comparison are introduced as follows,

- Alternative -1: Aluminum Handrail
- Alternative -2: Steel Handrail
- Alternative -3: Concrete Wall + Steel Handrail
- Alternative -4: Concrete Wall

The handrail is an item which generally requires periodical replacement. Therefore, lifecycle cost is also introduced in addition to investment cost in the evaluation item for cost so that cost for replacement can be evaluated quantitatively.

(2) Result of Study

1) Results of Comparative Study

The table on the next page shows the result of the comparative study.

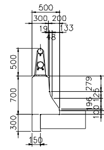
As shown in the table, results of comparison reveal that Alternative-3, Concrete Wall + Steel Handrail, is most preferable for the following reasons;

- Reinforced concrete wall resists the impact of collision.
- Reasonable Cost.
- Superior in Aesthetics.

The precaution is noted as follows,

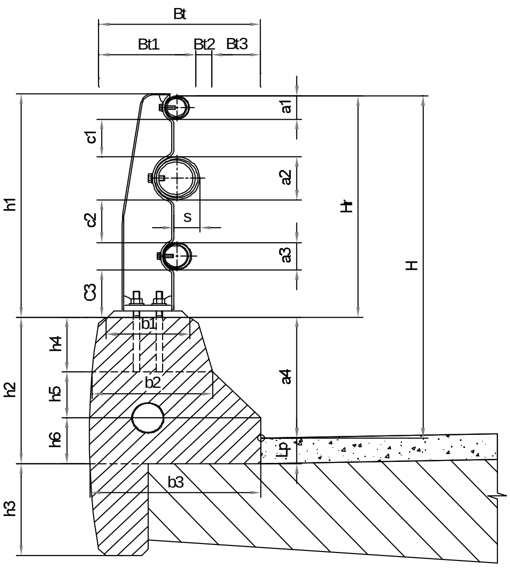
Regarding anti-corrosion for concrete wall, appropriate cover is generally considered in accordance with design standards. However, because it will be difficult to keep sufficient cover for costal condition, surface coating is recommended to protect against salt attack.

Table 8.6.3-1 Comparison on Type for Handrail

Evaluation Items		Alternative-1 Aluminum Handrail		Alternative-2 Steel Handrail		Alternative-3 Concrete Wall + Steel Handrail		Alternative-4 Concrete Wall	
General View		  The photo in the left side is a bridge constructed in Tokyo Bay area 14 years ago. There is no defect. The photo in the right side is a bridge constructed in on shore area of Shizuoka Prefecture. After 15 years passed, there is no defect except a little		  The photo in the left side shows an example which passed 13 years after completion in urban area. If the timing for ordinary re-painting is delayed, corrosion (rust) The photo in the right side is a bridge constructed in rural area of Chiba Prefecture 30 years ago. Top rail is made of aluminum which was added later.		  Hand railing is made of galvanized steel and concrete wall is made of concrete. This type is typical design in Vietnam.		  This alternative is concrete type which is similar to Florida Type in USA.	
Structural Aspect and Stability	10	The structural members are deformed in case of collision.	6	The structural members are defomed in case of collision.	6	Reinforced concrete resists the impact of collision. Heavier than Alternatives 1 and 2.	8	Reinforced concrete resists the impact of collision. Due to heavy wait, the dimensions of superstructure and substructure are required to be larger than other alternatives.	6
Construction Cost Upper: Investment Lower: Life cycle	40	Investment at first ¥ 65,200 /m Material ¥ 58,700 /m Construction ¥ 6,500 /m Ratio 2.222	0	Investment at first ¥ 55,200 /m Material ¥ 48,700 /m Construction ¥ 6,500 /m Ratio 1.881	8	Investment at first ¥ 29,360 /m Material ¥ 16,185 /m Concrete Coating ¥ 13,175 /m Ratio 1.001	20	Investment at first ¥ 29,345 /m Material ¥ 11,520 /m Concrete Coating ¥ 17,825 /m Ratio 1.000	20
		Maintenance and repair ¥ 68,700 /m Material ¥ 58,700 /m Construction ¥ 10,000 /m Life cycle cost Replacement Once/100 years 65,200 + (68,700×1) = 133,900 /m 133,900 / 100 = 1,330 /year Ratio 1.617	8	Maintenance and repair ¥ 58,700 /m Material ¥ 48,700 /m Construction ¥ 10,000 /m Life cycle cost Replacement 3times /100 years 55,200 + (58,700×3) = 231,300 /m 231,300 / 100 = 2,310 /year Ratio 2.793	0	Maintenance and repair ¥ 21,475 /m Material ¥ 8,300 /m Rail and Concrete Coating ¥ 13,175 /m Life cycle cost Rail replacement and concrete coating 3times 29,360 + (8300*3+13175*3) = 93,785 /m 93,785 / 100 = 930 /year Ratio 1.132	16	Maintenance and repair ¥ 17,825 /m Material ¥ - /m Construction ¥ 17,825 /m Life cycle cost Concrete coating 3 times/100 years 29,345 + (17,825×3) = 82,820 /m 82,820 / 100 = 820 /year Ratio 1.000	20
Construction Plan and Period	10	The weight is low, which make it easy handling.	8	Due to heavy weight, a crane is required. Furthermore, it is necessary to handle very carefully in order to avoid damage of painted surface.	6	Construction works are in-situ concrete placing and rail setting, which are simple and ordinary.	8	Construction work is in-situ concrete placing, which is simple and ordinary.	8
Maintenance	15	Producing oxidized coat by itself, it is superior in anti-corrosion and can resist against salty attack. Even there is no surface coating, only micro holes (diameter is less than 0.3mm) would be observed and not structurally deteriorated. Generally, it is coated by anodized aluminum which increases anti-corrosion ability remarkably. Even on-shore or off-shore, it is hardly corroded or rusted. In principle, maintenance free. Since the members are connected by bolts and nuts, exchange/replace of member is easy. Life year: 50 years	15	In principle, galvanization is recommended. In many cases, surface was painted after galvanization from aesthetic and durability view points . For painting, polyester powder paint is generally adopted by the following reasons: (1)It is possible to paint uniformly with certain thickness. (2) Good harmonization with galvanization. (3) Although cost is not so high, enough durability can be expected. In severe condition like heavy industrial zone and on/off shore area, fluorine resin paint or ceramic paint are preferable. Since site welding is possible, remedial work is easy. Although it is durable owing to development and improvement of paint technology, periodical cleaning and repainting are required. Life year: 30 years	9	Hand Rail is to be galvanized. Regarding anti-corrosion for concrete wall, appropriate cover is considered in accordance with design standards. However, because it is difficult to keep sufficient cover for coastal condition, surface coating is required to protect against salt attack. Since galvanized steel rail is not durable for a long term, coating as described in Alternative 2 is recommended. Periodical cleaning and repainting are required. Life year: Handrail:30 years, Concrete Wall: 100 years	9	Regarding anti-corrosion for concrete wall, appropriate cover is considered in accordance with design standards. However, because it is difficult to keep sufficient cover for coastal condition, surface coating is required to protect against salt attack. Extra concrete protection is required. Life year: 100 years	12
STEP Clearance	10	90% (Preliminary Estimate)	10	88% (Preliminary Estimate)	10	62% (Preliminary Estimate)	10	10% (Preliminary Estimate)	4
Aesthetics	5	In case with anodized aluminum coating, silver, brown and grey colors are available. The color is hardly faded, it is possible to keep aesthetics for a long time.	5	Slender appearance owing to higher strength. It is difficult to keep aesthetics for a long time because of rust and color irregularity due to re-paintings.	4	Similar appearance with Alternative-2.	4	The high wall makes oppressing feelings and shuts the side scenery from driver.	2
New Technology	5	No new technology is used.	3	No new technology is used.	3	No new technology is used.	3	No new technology is used.	3
Environmental Aspect	5	No major environmental impact.	3	No major environmental impact.	3	No major environmental impact.	3	No major environmental impact.	3
Evaluation	100	This alternative is superior in maintenance and aesthetic points. Less Recommended	**58**	This alternative is most inferior in economic points. Not Recommended	**49**	This alternative is superior in structural stability, economic and aesthetics. **Most Recommended**	**81**	This alternative is superior in economic ,but inferior in aesthetics. Heavy weight is also disadvantage for the superstructure and substructure. Less Recommended	**78**

Source : Study Team

The structure and the dimensions of the guardrail is shown in the following figure.



Sign	Value (mm)	Sign	Value (mm)
h1	500	b1	300
h2	700	b2	319
h3	300	b3	500
h4	279		
h5	321		
h6	100		
S	25		
Hr	500		
H	1126		
c1	150		
c2	140		
c3			
a1	88		
a2	112		
a3			
a4	626		
Lp	74		
Bt1	300		
Bt2	19		
Bt3	181		
Bt	500		

Source: Study Team

Figure 8.6.3-1 Expansion Joint on Approach Bridge

CHAPTER 9 ELECTRIC WIRING AND LIGHTING FACILITY

9.1 General

This Chapter describes the design base of the electric wiring and lighting facility for the Lach Huyen Port Construction Project.

9.1.1 Design concept for Electric Wiring.

1) All cable to be used for roadway lighting shall be of the type and size shown on the Drawings.
2) Cables shall be pulled into a pole through conduit installed in the foundation of the pole and shall be connected to the terminals in the terminal box installed in the pole.
3) The mounting boxes of all poles shall include an approved terminal block and circuit fuse rated 6 amperes 220 volts accessible through the access plate of pole. The circuit fuse shall protect both the poles and electrical control ballast.
4) Cables installed in the pole shall have two conductors of minimum cross section of 2.5 mm^2.
5) Cables shall be attached to the lighting fixture so that lighting fixture terminals do not carry the cable weight.
6) Power supply cables to lighting fixture shall be attached to the terminal block so those terminal blocks do not carry the cable weight which shall be fixed by cable tie before reached terminal block.
7) All cables shall be delivered with an appropriate test certificate and approved by the Engineer before use.

9.1.1.2 Design concept for Lighting Facility.

The design for the road lighting facility shall maximize the efficient use of energy source as appropriate for the area served. To save energy, the following design criteria are applied to the lighting facility:

1) High pressure sodium vapour lamp(HPSV) is recommended for road lighting with reasons listed below.

   Luminaries for the road light shall be selected in the products being available in the local market to secure easy maintenance and execute economical design.

   The following product is presently available in Vietnam:

Table 9.1.1-1 Available Product in Vietnam

Incandescent lamp	
Mercury vapour lamp	
High pressure sodium vapour lamp	(pressure sodium lamp will be preferably used for the highway lighting **)
Low pressure sodium vapour lamp	
Fluorescent lamp	

**Reasons why used in highway

*Being presently used for the highway in Vietnam

*Being most efficient and maintain long life 132lm/w against 50lm/w of mercury vapour lamp

*10000 hours against 9000 hours of fluorescent lamp

*Low insect gathering

Source : Study Team

2) Lighting control of road lighting will employ photocell switches which shall be required minimum maintenance activity.
3) Layout of road lighting will be technically well designed.

9.1.2 Scope of Works

The work covers the design of the complete lighting facility for the following items;

1) The road lighting facility for Tan Vu Interchange, Dinh Vu Intersection and approach and main Bridge.
2) The navigation bridge light at the main Bridge for the ship.
3) The signal system on Tan Vu interchange shall be considered since the previously planned run-about has been changed to T-junction.
4) The lighting system inside the box girders in the bridge section between Km 4.5 and Km 9.99.

9.2 Design standards

The design, manufacture, test and installation of electrical equipment will comply with the latest edition of the standards, codes and regulations, consisting of the following:

1) · Standard of Electrical Facilities 11TCN - 18; 19; 20; 21- 2006.
2) Construction Code of Vietnam QCXDVN 01:2008
3) Vietnamese Construction Standard TCXDVN 259:2001 Standard for designing the lighting system of road, street, and urban squares.
4) Vietnamese Construction Standard TCXD 333:2005 Design standard for artificial lighting outside urban public and technical infrastructures.
5) Vietnamese Standard TCVN 4756:89 Specification on grounding for electrical equipment.
6) The letter No1175/TCT-ĐHDA HN-HP dated 29th Oct 2008 of VIDIFI. JSC. Subject: Accepting the electric detail design application plan, Hanoi-Haiphong Expressway Project.
7) Technical Regulation on Rural Electric Power Grid by Ministry of Industry 57/2000/QĐ-BCN.
8) IEC 60038: Standard voltages.
9) IEC 60044: Instrument transformers
10) IEC 60076: Power Transformers
11) IEC 60228: Conductors of insulated cables.
12) IEC 60265: High-voltage switches
13) IEC 60269: Low-voltage fuses. Structure.
14) IEC 60282: High-voltage fuses
15) IEC 60287: Electric cables - Calculation of the current rating
16) IEC 60331: Test for electric cables under fire conditions – Circuit integrity.
17) IEC 60364: Low-voltage electrical installations
18) IEC 60439: Low-voltage switchgear and controlgear assemblies.
19) IEC 60502: Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um=1.2 kV) up to 30 kV (Um=36 kV).

20) IEC 60529: Degrees of protection provide by enclosure (IP code).

21) IEC 60715: Dimensions of low-voltage switchgear and controlgear. Standardized mounting on rails for mechanical support of electrical devices in switchgear and controlgear installations.

22) IEC 60724: Short-circuit temperature limits of electric cables with rated voltages of 1 kV (Um = 1, 2 kV) and 3 kV (Um = 3, 6 kV)

23) IEC 60787: Application Guide for the Selection of Fuse-Links of High-Voltage Fuses for Transformer Circuit Applications

24) IEC 60811: Common test methods for insulating and sheathing materials of electric cables and optical cables.

25) IEC 60840: Power cables with extruded insulation and their accessories for rated voltages above 30 kV (Um = 36 kV) up to 150 kV (Um = 170 kV) Test methods and requirements.

26) IEC 60947: Low-voltage switchgear and controlgear.

27) IEC 61557: Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. - Equipment for testing, measuring or monitoring of protective measures.

28) IEC 61558: Safety of transformers, reactors, power supply units and similar products for supply voltages up to 1 100 V

29) IEC 62271: High-voltage switchgear and controlgear

9.3 Design conditions

9.3.1 Service conditions

The project area has a hot, humid and tropical atmosphere. Moreover, the surrounding environment has a high degree of salinity.

All electrical equipment, cables, accessories and fittings which form part of the electrical installation shall be fully suitable for use in the following specified service conditions:

1)	Altitude above mean sea level (approx.)		: 2.0 m
2)	Ambient temperature	- Maximum	: 45 ^{o}C
		- Minimum	: 5 ^{o}C
3)	Relative humidity	- Maximum	: 100%
4)	Climatic atmosphere		: Tropical
5)	Wind pressure		: This value shall be followed the design criteria of Road and Bridge in this Project.
6)	Earthquake		: This value shall be followed the design criteria of Road and Bridge in this Project.
7)	Salt contamination		: This value shall be followed the design criteria of Road and Bridge in this Project.

9.3.2 Design criteria

(1) Electrical system

It is connected with Network of the following electric power company, and the electric power is supplied to substation in four places.

These substations shall be connected by 35kV or 22kV underground transmission line and equipped 35(22) kV/400-220V or 22 kV/400-220V receiving transformer, lighting distribution panel and associated accessory

Table 9.3.2-1 Technical parameters of power receiving and distribution system

Power Supply Substation (Power company)	Power Receiving Substation		
	Name	Location	Transformer
Tan Vu Power Station (Hai An Power Company)	SUBSTATION "A"	Around Tan Vu Interchange	3ph/4w-31.5kVA-**22**/0.4 kV
	SUBSTATION "B"	Around Dinh Vu Intersection	3ph/4w-31.5kVA-**22**/0.4 kV
	SUBSTATION "C"	At the West Side of Bridge	3ph/4w-50 kVA-**22**/0.4 kV
Ninh Tiep Power Station (Cat Hai Power Company)	SUBSTATION "D"	At the Eest Side of Bridge	3ph/4w-31.5 kVA-**35**/0.4kV

Source : Study Team

(2) Allowable Voltage Drop

The maximum allowable voltage drops between distribution transformer and the furthest fixture shall not exceed 5%.

(3) Cable sizing

The cables shall be covered to the maximum current demand.

The voltage drop was calculated, and the size of the cable for the wiring to each substation and the illuminator confirmed and selected the tolerance.

To refer to the Calculation sheets.: Attachment 9.3.2. (3)

(4) Lighting Arrangement

The lighting fixture shall be designed and arranged for each area so as to meet the following illumination level:

The acceptable value has been shown in the Chapter 4.2 of TCXDVN 259-2001 as below.

- Interchange and Intersection : $\geq$ 1.2 Cd/m^2 (Minimum luminance on ground)
- Bridge : $\geq$ 1.2 Cd/m^2 (Minimum luminance on ground)

The arrangement of the illuminator was designed as follows.;

1) At the Tan Vu intersection, arrangement shall be made for 2 poles of polygonal beacon light, 17m in height, each pole holds 4 beacon lights of HPS-400W.
2) At the road section on HN-HP expressway, arrangement shall be made for 2 lights poles of 12m illuminating the road from opposite
3) On the road sections of Tan Vu-Lach Huyen at the Tan Vu intersection, No.1 intersection and the residential area, lighting poles of 11m in height are arranged at the distance of 30m to 33m from pole to pole.
4) In the middle of the intersection No.1, one polygonal light (mast lamp) which could be lowered and raised to the height of 25m in the center of the roundabout.
5) On the bridge, two lines of lighting poles with the height of 11m are arranged in alternate lines with the 40m distance from pole to pole on the same line.
6) Inside the box girders, to serve the purposes of routine maintenance during the operation, fluorescent lights are arranged for lighting.

(5) Earthing system

The exposed metal frames of all electrical apparatus and machinery not forming parts of the electric circuits, neutral of transformers, etc., shall be earthed.

1) Earthing conductor, plate and rods

The following materials shall be used for earthing systems;

a) Earthing conductor: Annealed copper stranded conductor.
b) Earthing plate: 90 cm square, 1.5 mm thickness copper plate or equivalent.
c) Earthing rods: 16 mm diameter, 3 m length copper clad steel rod with coupling.
d) Connectors: Compression type connectors which shall be able to connect the annealed copper stranded conductors each other, earthing plate and rod.

2) Earthing works

a) Earthing rods, plate and conductors shall be buried deeper than 0.6 M or more from the ground surface.
b) The connection between earthing conductor and ground rod, plate and equipment connection conductor shall be electrically and mechanically rigid.
c) Earthing systems of the instruments equipment shall be done by separately from common ground.
d) The earthing for transformer neutrals and lightning arresters, earthing rod shall be installed in additionally for interconnections with earthing mesh.
e) Boundary fences shall be earthed by means of earthing rods, separately from the main earthing mesh.

(6) Lightning Protection

Structures which are made of metal and be electrically continuous do not require a separate down conductors for lightning connection.

Structures and equipment outside the protection zones shall be directly earthed as close to the base as possible.

(7) Wiring design

1) Medium voltage wiring:

Medium voltage wire line supply between transformers and supply from connection power which is using underground cable, will has anti-proof and anti-corrosion, it will pass in HDPE pipe and bury underground with minimum depth 0.7 m along side walk.

2) Low voltage wiring:

- Low voltage wiring for electric supplying on the road will pass in HDPE pipe and bury underground with minimum depth 0.7 m to lighting poles.
- Lighting axial cable low voltage wiring on the bridge will pass on cable support bar inside box girder to the lighting control box.
- Low voltage wiring for lighting supply on the bridge will pass in HDPE pipe inside parapet concrete of the bridge.

9.4 Equipment and Material

9.4.1 General

(1) The design shall be based on suitable protection of personnel and equipment during operation and maintenance, reliability of service, ease of maintenance, the provision of future loads, and convenience of operation.

(2) It is necessary to select the design considered enough to reduce it to the salt damage and the equipment.

(3) All equipment and materials to be furnished shall be commercially well known, proven for use in plant applications and designed and manufactured according to good engineering practice.

(4) The standardization of equipment shall be stressed.

(5) All equipment and materials to be supplied shall be new, and within 3(three) years after manufactured.

9.4.2 Equipment

(1) Type of structure for transformer (Substation)

Transformer, supplying electricity for lighting, is in saline area. Therefore, beside requirement of equipment property is anti-corrosion, the equipment is also put in closed area in order to mitigate impact of onshore wind to the equipment.

Figure 9.7-4 shows two type of transformer: synchronized type and hanging type for study and comparison;

Based on comparison results and in order to satisfy the above requirement, JICA Study Team recommends a synchronized transformer for lighting supply.

(2) Lighting distribution board

1) The lighting distribution board installed in the area shall be of outdoor use, metal enclosed cubicle type, and self-standing type, corrosion resistant, vermin-proof.

2) The distribution board shall be enclosed the distribution transformer and shall include necessary protection devices, circuit breakers and accessories be mounted on steel base channels.

3) The distribution transformer shall be enclosed into the distribution board to be the following specifications in consideration of a surrounding environment;

a) Type : ONAN

b) Rating :

- Substation “A” & “B” : 31.5kVA-22/0.4kV-50Hz, Un%=4%, Δ/Y_0 -11, Udc ± 2x2.5%
- Substation “C” : 50kVA-22/0.4kV-50Hz, Un%=4%, ∆/Y0 -11, Udc ± 2x2.5%
- Substation “D” : 50kVA-35(22)/0.4kV-50Hz, Un%=4%, ∆/Y0 -11, Udc ±2 x2.5%

4) The degree of protection provided by an enclosed shall be IP54 in accordance with IEC 60529, as a minimum.

5) The road lighting of each area shall preferably be automatically controlled by photo-electric cell devices.

(3) Structural and architectural lighting pole

As the project runs through area of aerodynamic lad, with great impact of wind, it is necessary to design the architectural structure in harmony with the total architecture of the Project, to ensure the phototropism, without causing the confused eyesight, and particularly, the wind-facing area must be made smallest for resistance against tremendous typhoons in the Eastern Sea. Upon the requirements, JICA Study Team proposes that:

1) The light poles have no extension arm but only one pole、directly fixed on the top of the pole.

   After having studied and compared three types of light poles as shown on Figure 9.7-1, alternative 1-Pole without extension arm is recommended.

2) The 17m high polygonal beacon light pole is installed with 4 beacon lights attached directly to tube beams. These two poles are located at the Tan Vu intersection. To refer to Figure 9.7-7.

3) The 25m high polygonal beacon light pole is installed with 8 beacon lights attached to the ring holder of the movable set. To refer to Figure 9.7-8.

4) The traffic lights set it installed on the 6.2m pole which can be raised at 7m, positioned in the center of roundabout lighting the lanes.

5) Lighting pole material is also studied and compared with two alternative: steel pole and moulded aluminum. Result of the comparison and recommended alternative of steel -pole are shown on the drawing Figure 9.7-2

(4) Selection type of lights

The lights should be corrosion proof when they are operated in saline environment.

Moreover, the lights shall be designed to perform automatically the electricity economization function.

Therefore, JICA Study Team proposed the following alternatives:

1) The road lights are of two-compartment optical lighting, in full operation of both compartments during the peak time, and one light is operative during the low time alternatively to ensure the lasting long life of the equipment.

2) The beacon light for street lighting at Tan Vu intersection is operated with 2 levels of capacity; running at full capacity during the peak time and automatically retuning to lower capacity during the low demand time to ensure economical consumption of electricity.

3) Beacon light for Intersection No.1 is the light of twin power mains, with 2 bulbs and one optical set. During the peak time, the mains operate at maximum capacity, and during the low time, the mains will automatically return to half capacity with one light off for economical purpose.

4) Two types with different shape are compared as shown on the drawing Figure 9.7-3.

   Result shows the alternative 1 although is more expensive than alternative 1 but it has much predominant advantages which are very suitable to apply for Works locating in maritime area of which salty moistures corrosion and erosion is high, as follows:

   - Control gear tightness level of IP65 to prevent from erosion of electrical detail due to sea condition;
   - Aerodynamic resistance area = 0.048 m^2 of luminaire unit is small;
   - Optical compartment tightness level of IP66 is followed by seal safe technology.
   - Service life of the luminaire is durable.

(5) Road Lighting fixture

In the selection of lamps and fittings consideration should be given to ensure the maximum lamp life, the minimum likelihood of internal moisture accumulation, and also effects of vibration, operating temperature, and breathing.

Types of road lighting fixture and pole shall be shown on the alternative comparison sheet which shall be issued for the decision of TAC and/or PMU2.

Lamps of lighting fixture shall be shown on the alternative comparison sheet which shall be issued for the decision of TAC and/or PMU2.

Materials of lighting pole shall be shown on the alternative comparison sheet which shall be issued for the decision of TAC and/or PMU2.

Types of road lighting fixture shall be of high power factor suitable for stable operation in tropical climate and weatherproof type.

Lighting supports for outdoor lighting shall be of base plate type steel poles painted with suitable colour. Ballast, fuse and terminals shall be equipped in the pole and other attachments necessary for wiring and fixing of the lighting fixtures shall also be provided with the pole.

(6) Navigation lighting unit

1) Navigation lighting design should be followed below mentioned standard.

   * 22 TCN 269-2000 Regulations on Navigation Signals Equipped for Domestic Waterways in Vietnam.

2) Lighting unit shall be bracket mounted type and minimum class of degree protection shall be IP65 for entire optical unit and suitable for humid and tropical atmosphere.

3) The type:BH-140A proposes though there are the type:BH-140A and the type:BH-998P/

   To refer to Figure 9.7-5.

(7) Lighting System inside Box Girders

Lighting System inside Box Girders contains following equipments,

1) Unamour Electric Cable (Cu/XLPE?PVC-0.6/1KV-4C),
2) Electric wire (Cu/PVC-0.6KV-1C),
3) Flexible Conduit Pipe (HDPE),
4) Luminaries (Fluorescent 40W and 20W),
5) Electrical Panel (Board Distribution),
6) Cable Connection (Pull Box).

The typical drawing of the lighting system is shown in Figure 9.7-8.

9.4.3 Material

(1) Cable

1) Cable sizing

   Conductor size for cables shall be adequate for the load requirements, voltage drop, short circuit current, and diversity factor for individual circuit application.

2) Type of lighting cable

   Lighting cables shall be of 600V cross-linked polyethylene insulated PVC sheathed (XLPE/PVC), steel wire armored or steel tape armored PVC outer-sheathed power cable (XLPE/SWA/PVC or XLPE/DSTA/PVC) type with suitable cable heads with terminals.

(2) Steel conduits and flexible conduits

1) Steel conduits

(a) Steel conduits shall be steel, hot-dipped galvanized and equipped with couplings and thread protector caps. All surfaces and threads shall be coated with zinc. The sectional areas of a steel conduit shall be, at least, 2.5 times the total cross sectional area of cables to be pulled in.

(b) Rigid steel conduits shall be installed for all exposed cable route.

(c) PVC coated conduits shall be installed for corrosive area cable route.

(d) Couplings and elbows shall be of the same materials as conduit pipes.

2) Flexible conduits

(a) Flexible metal conduits shall be used for flexible cable connection route. Flexible metal conduits shall have an interlocked flexible galvanized steel core with a permanently bonded outer polyvinyl chloride jacket.

(b) Flexible conduits to be installed inside concrete and below ground shall be HDPE or equivalent.

(3) Boxes and Fittings

The pull boxes, outlet boxes, fittings and covers shall be of mild steel and/or cast iron alloy with adequate strength and have sufficient size to provide free space for all conductors enclosed.

Pull boxes shall be of hot dip galvanized steel and sufficient size to accommodate the connected conduits and enclosed conductors.

Boxes and fittings shall be plated by melting zinc or coated with rust-preventive paint and tow or more finish coatings.

Outlet boxes shall be of hot dip galvanized steel, square and of sufficient size to accommodate all the required conductors enclosed in the box.

(4) Supporting Steel Materials

The supporting steel materials shall be of hot-dipped galvanized steel with adequate strength for support conduits, cable tray and/or wiring duct.

9.5 Inspection and Test

(1) Major electrical equipment shall be tested and inspected at manufacturer’s shop before shipping in accordance with the requirements of the applicable code and standard.

(2) All equipment and materials shall be performed in process and/or upon completion of construction activities on all the equipment and/or installation.

9.6 Drawings

(1) Shop drawings for the electrical equipment shall at least include: Dimensional outline drawings, floor plans, including anchor bolt locations and cable entrance locations.

1) Equipment weight.

2) Schematic (wiring) diagrams.

3) Bill of material describing components of multi-component equipment.

(2) Installation working drawings shall at least include.

1) Complete one line diagrams showing power distribution with necessary ratings, specification, cable size, and so on.

2) Lighting distribution board layout with necessary detail for installation.

3) Cabling layout for lighting cabling work.

(3) Road Lighting fixture layout and cabling layout.

(4) Layout plans showing all earthing wires.

(5) Typical installation method of the electrical equipment, local equipment, junction and pull boxes, cables, etc,

(6) Cable schedule showing:

1) Cable number, number of conductor, conductor size, and length.

2) Type of insulation, shielding, armor and jacket if applicable.

(7) Lighting panel and fixture schedules.

(8) Other information and drawings necessary for construction work.

9.7 Figures

Several typical drawings listed below are shown in the next pages for illustration of the works.

Figure 9.7-1: Typical Lighting Pole and High Mast

Figure 9.7-2: Lighting Pole Material

Figure 9.7-3: Street luminaries

Figure 9.7-4: Lighting transformer Station

Figure 9.7-5: Navigation Light

Figure 9.7-6: 17m High Mast

Figure 9.7-7: 25m High Mast

Figure 9.7-8: Plan of Lighting Inside Box Girder

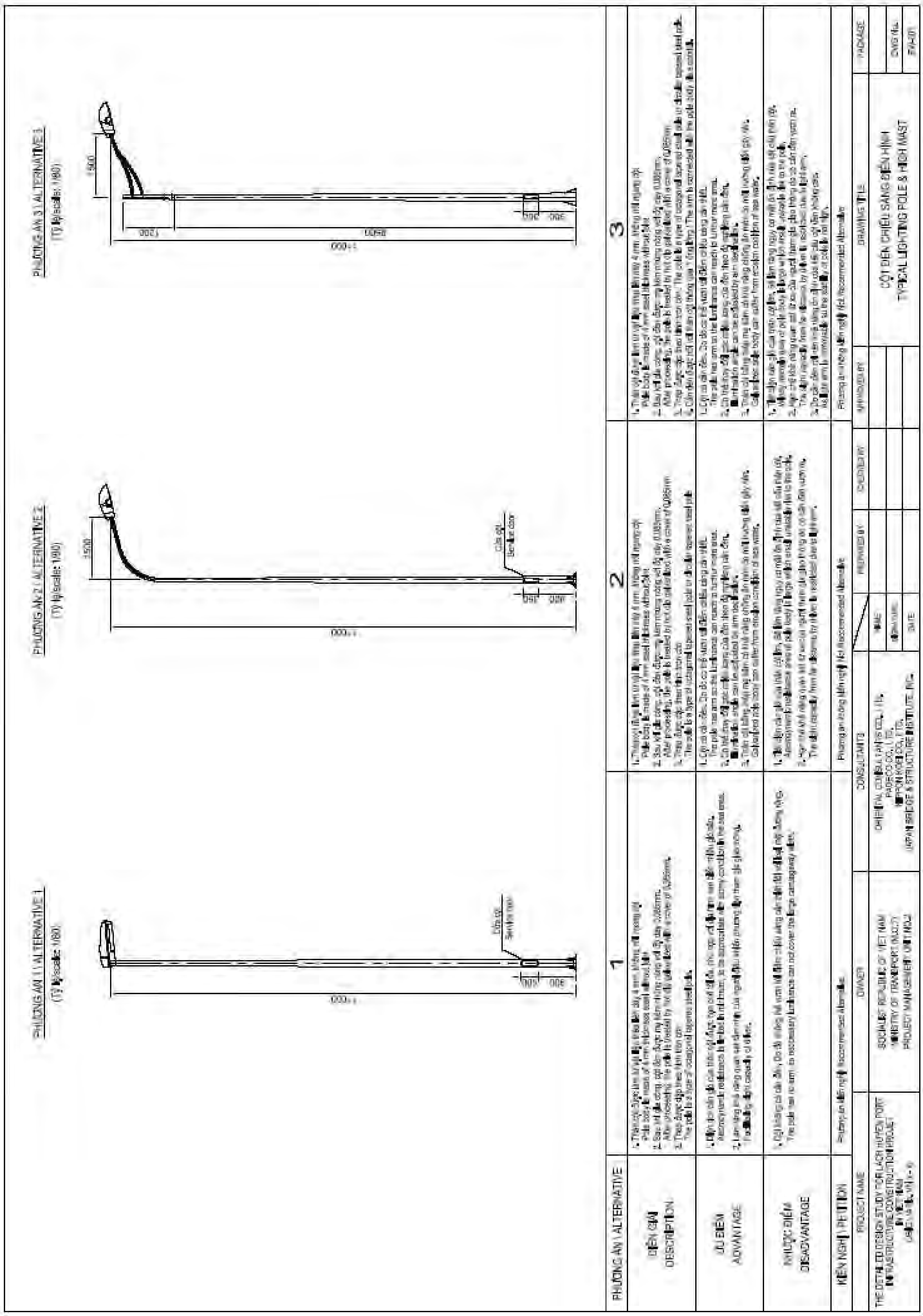


Figure 9.7-1 TYPICAL LIGHTING POLE & HIGH MAST

Source : Study Team

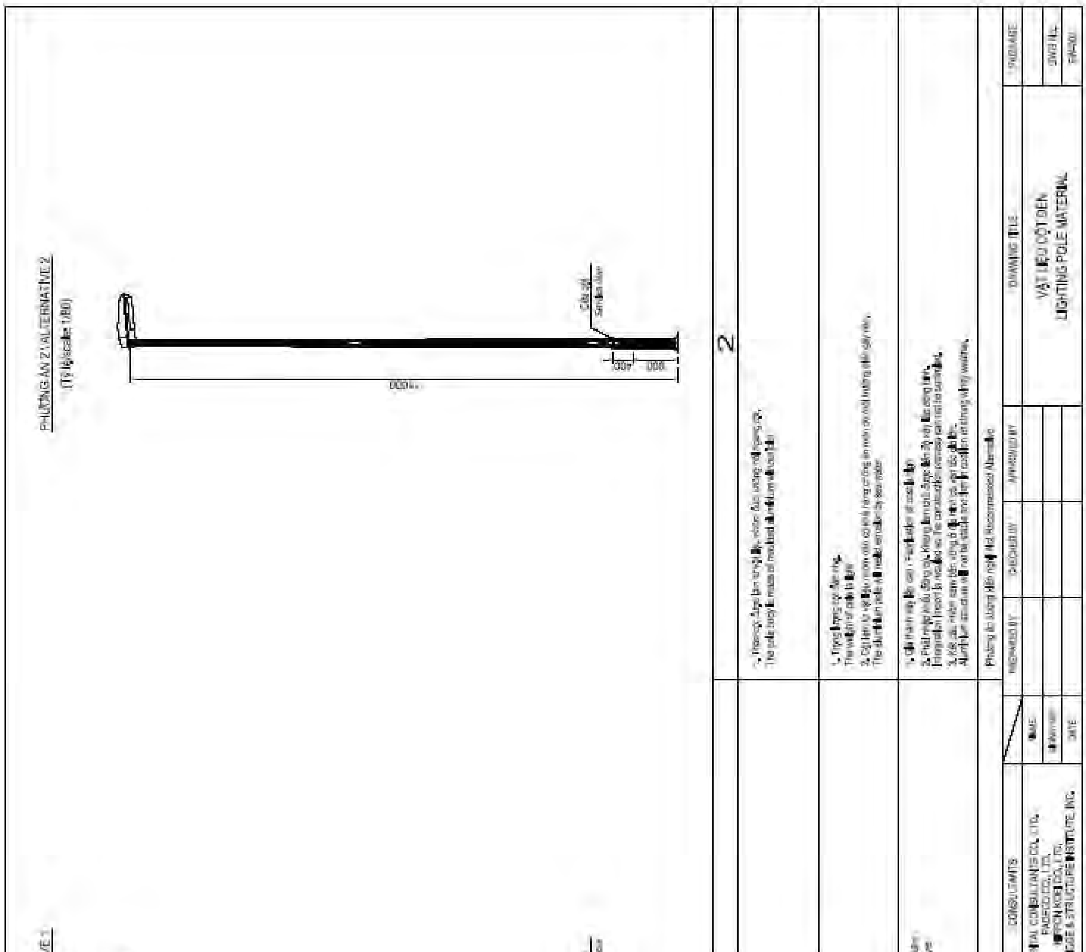


Figure 9.7-2 LIGHTING POLE MATERIAL

Source : Study Team

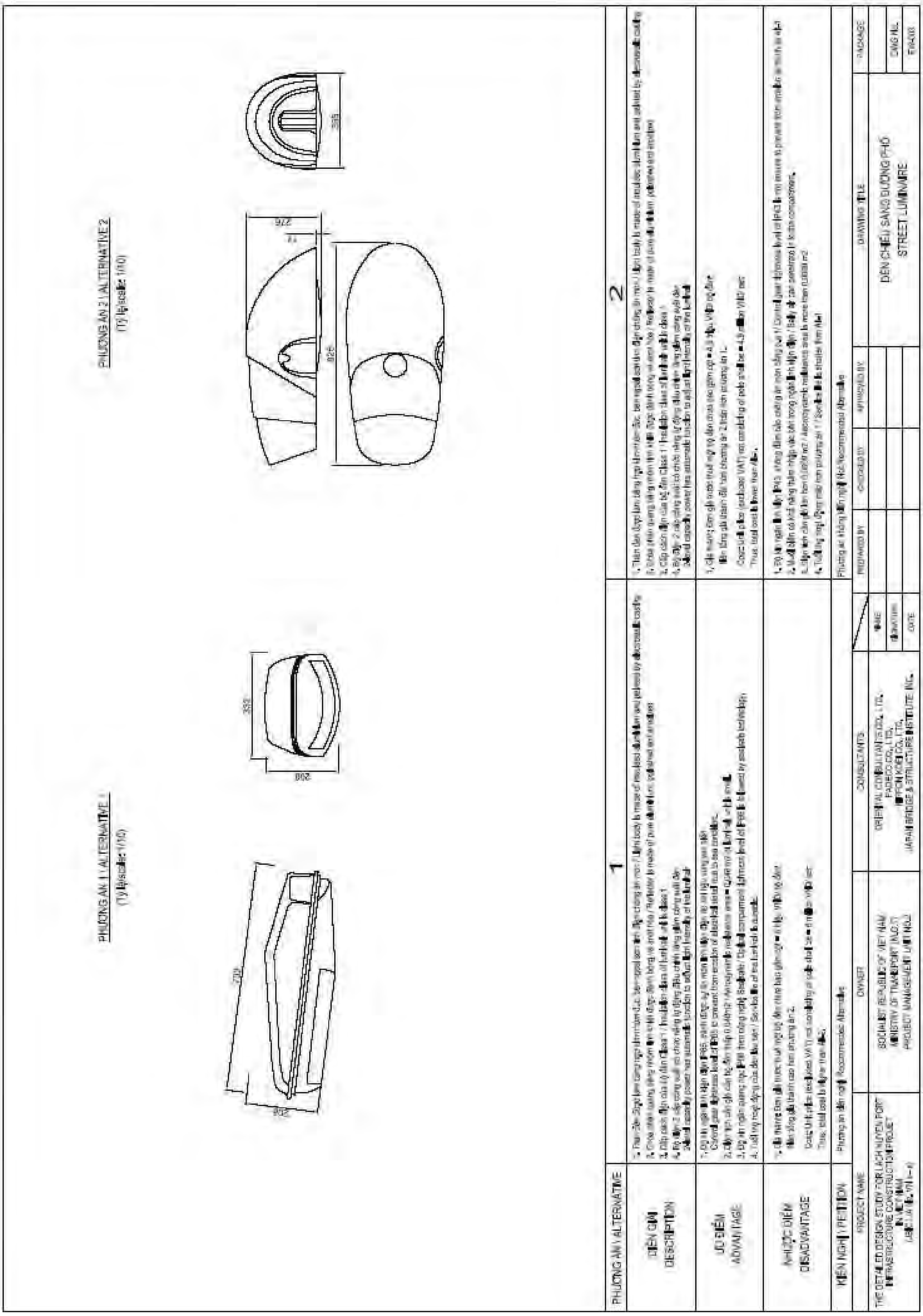


Figure 9.7-3 STREET LUMINAIRE

Source : Study Team

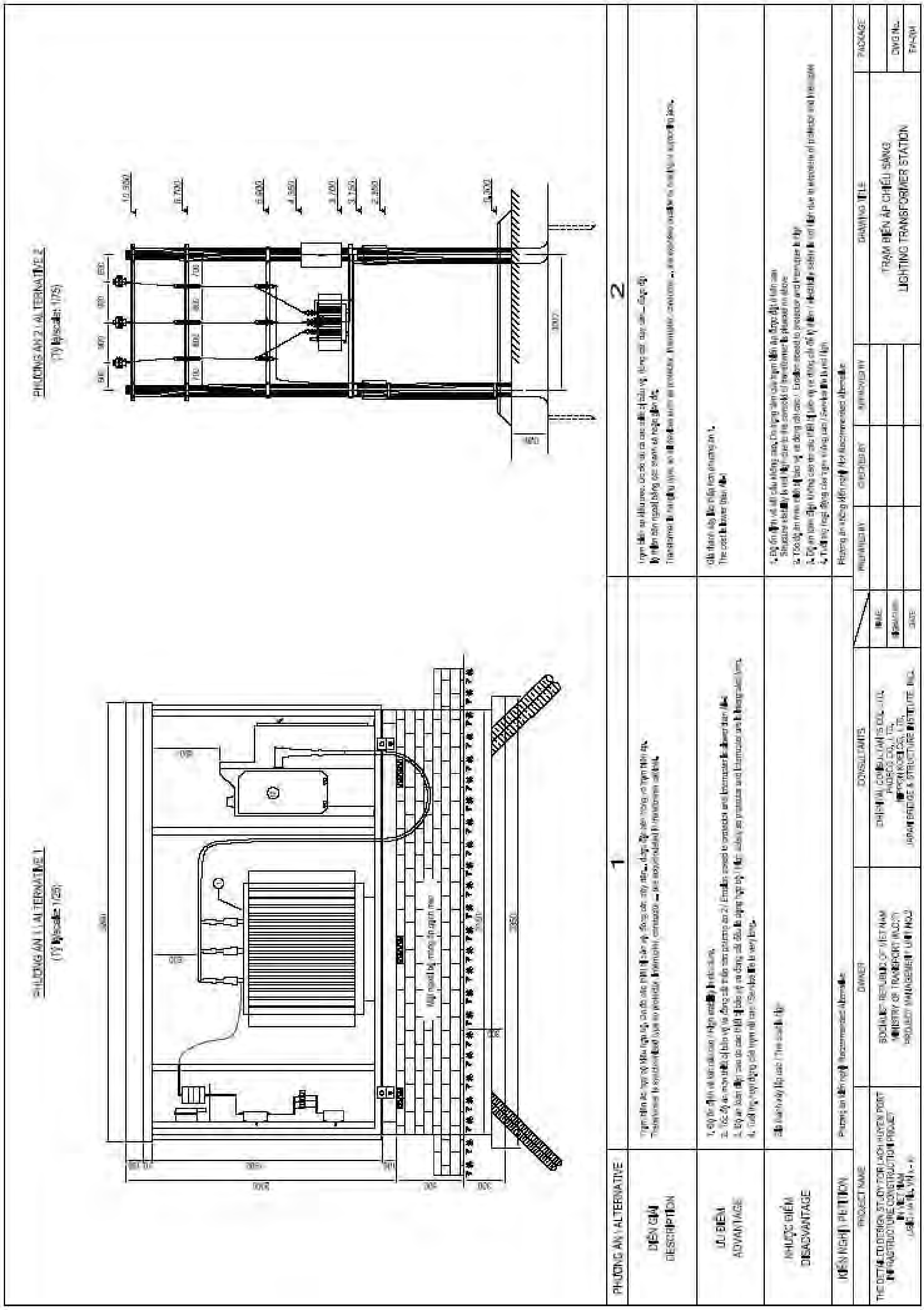


Figure 9.7-4 LIGHTING TRANSFORMER STATION

Source : Study Team

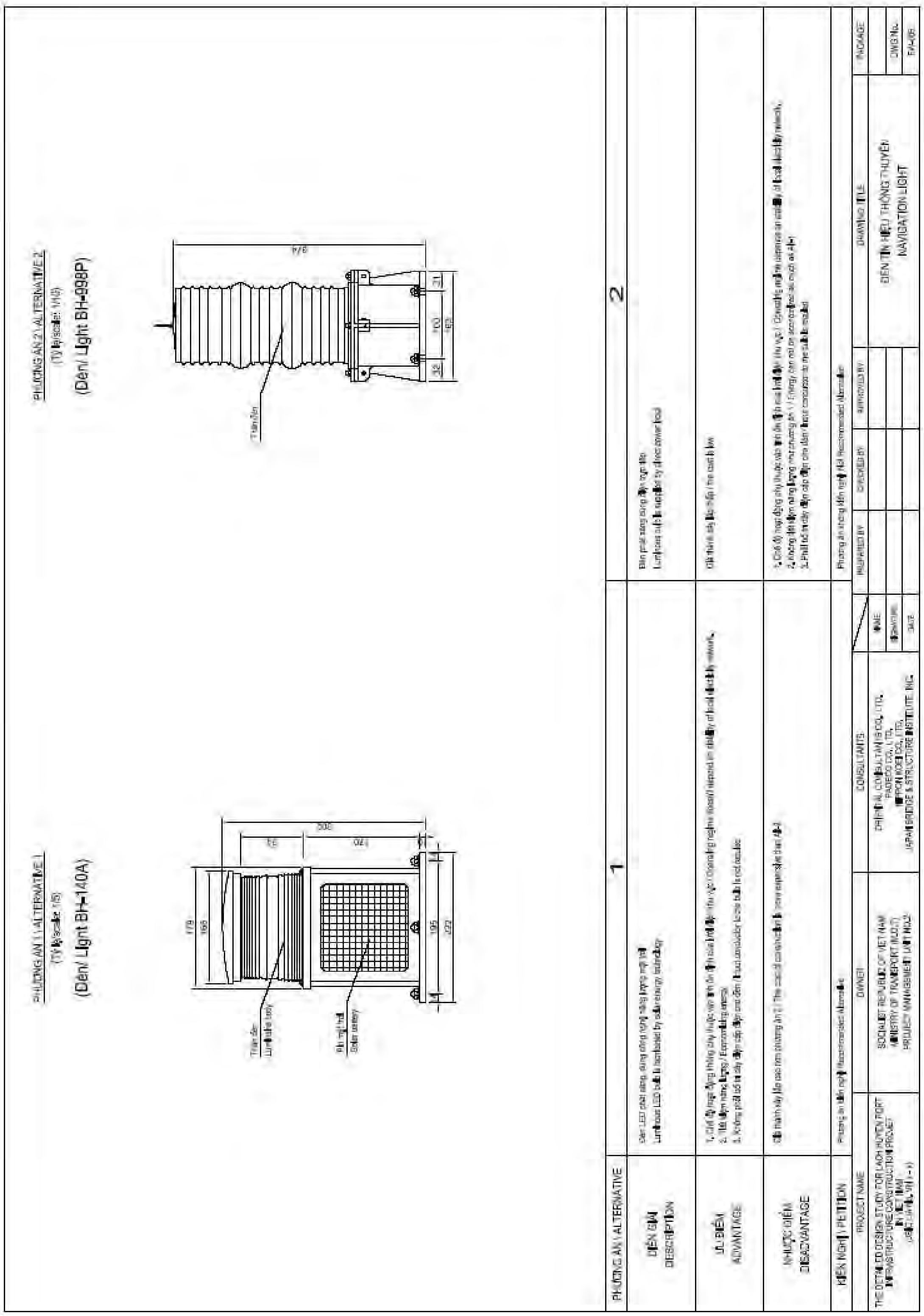


Figure 9.7-5 NAVIGATION LIGHT

Source : Study Team

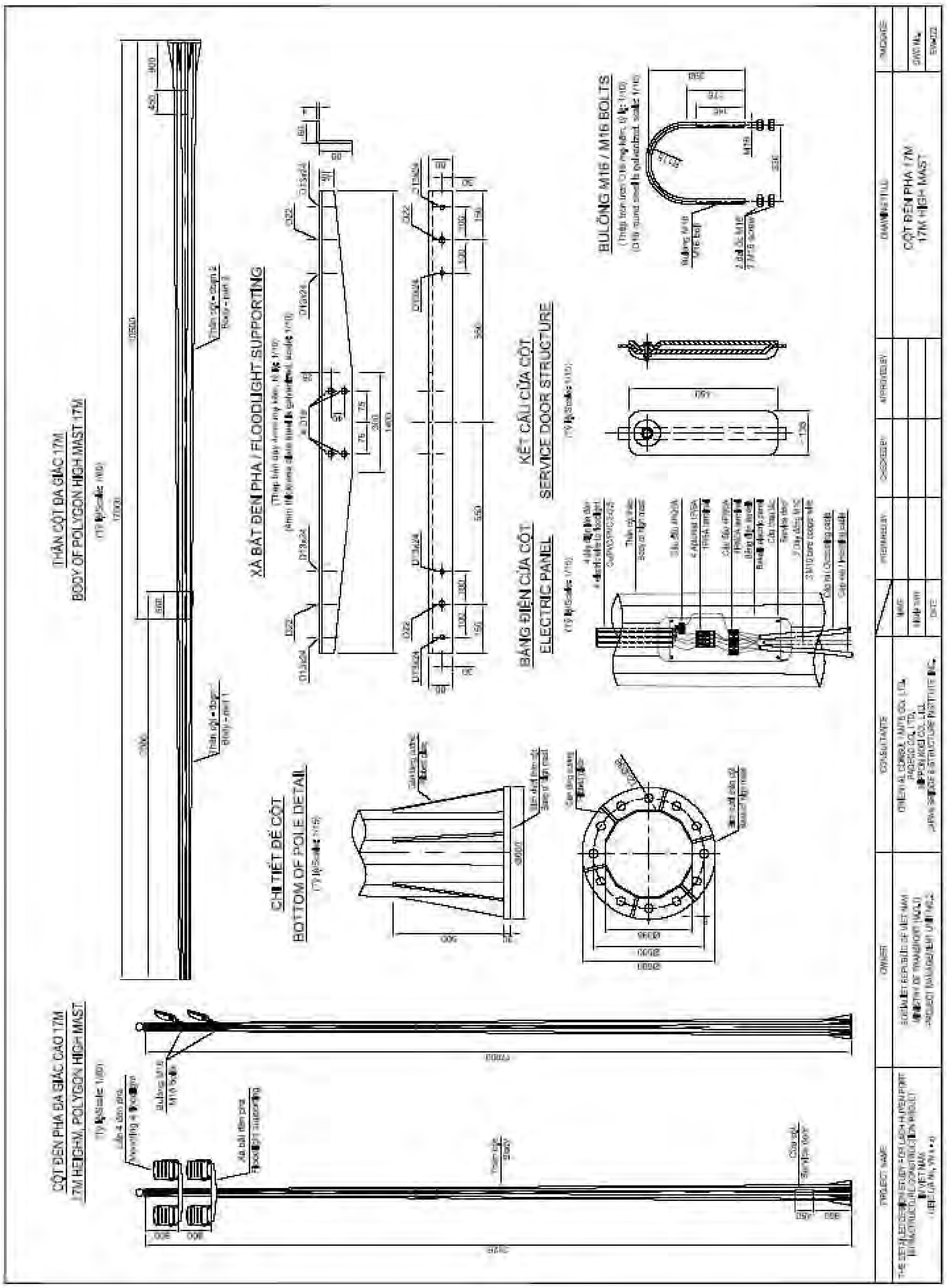


Figure 9.7-6 17M HIGH MAST

Source : Study Team

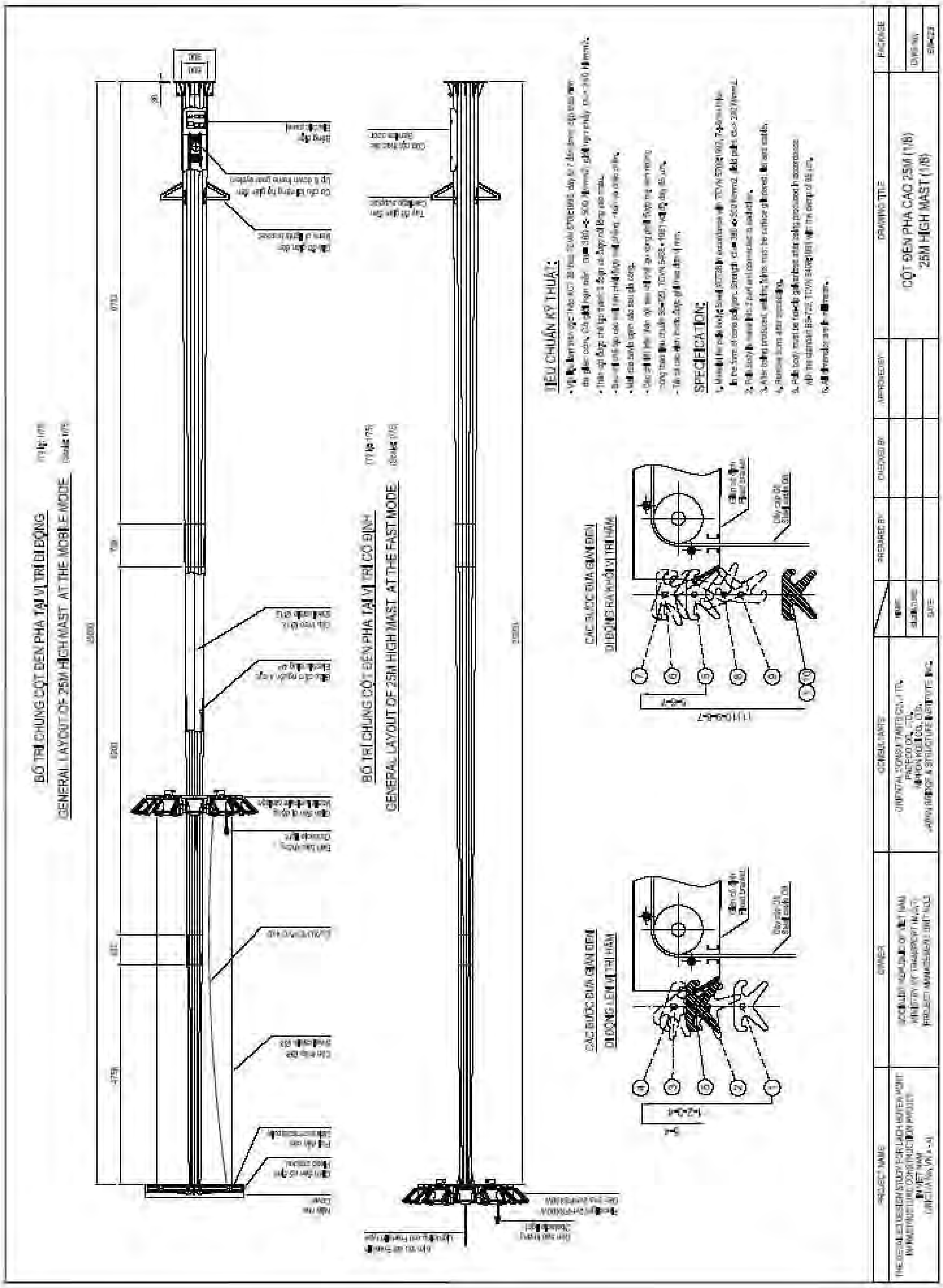


Figure 9.7-7 25M HIGH MAST

Source : Study Team

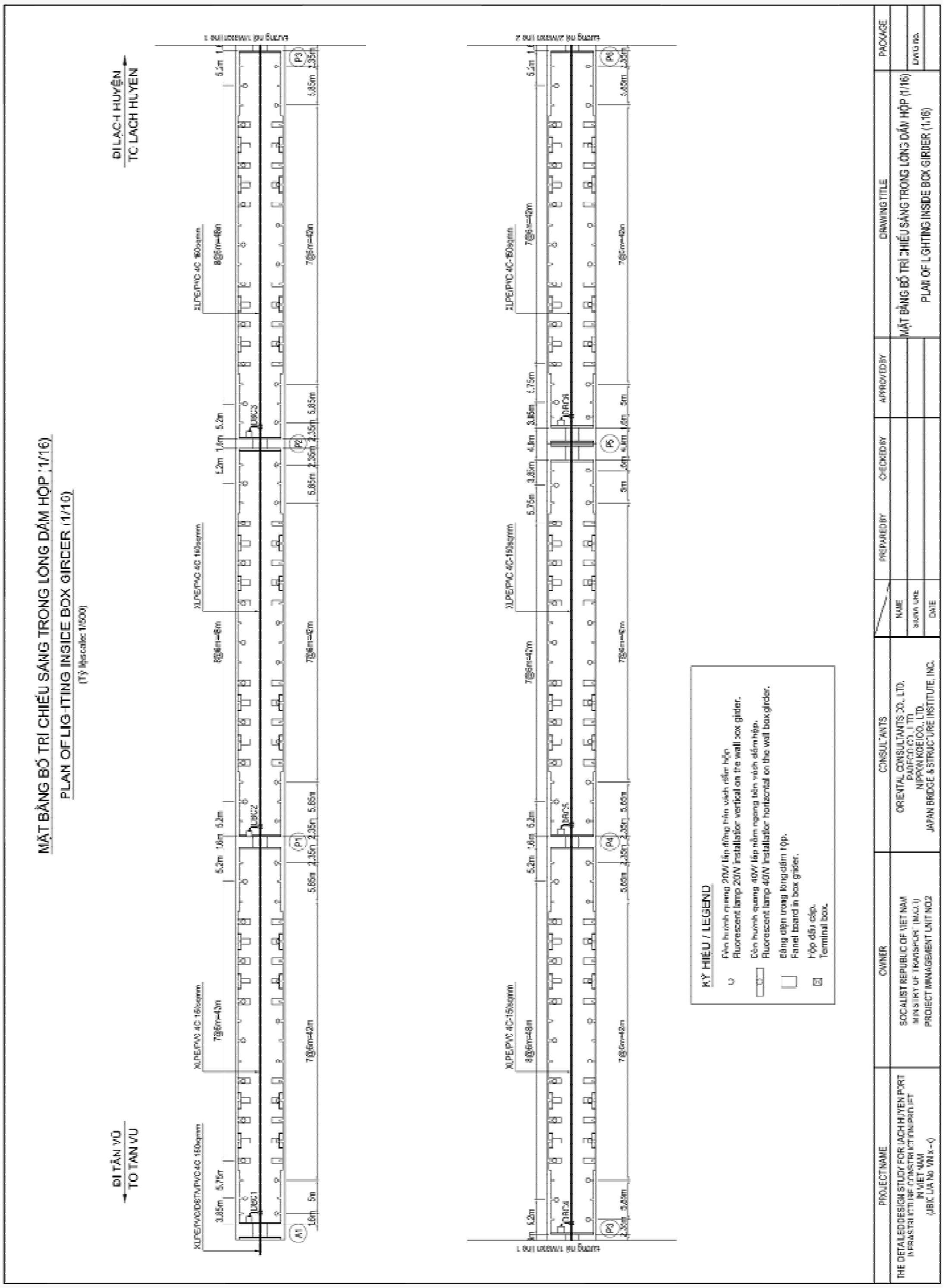


Figure 9.7-8 Plan of Lighting Inside Box Girder

Source : Study Team

CHAPTER 10 CONSTRUCTION PLANNING

10.1 PROJECT OUTLINE

10.1.1 Work Content

10.1.1.1 Work Content

The Works contain following major items.

1) Temporary Works
2) Hai An side works
   - (1) Soft soil treatment works
   - (2) Road works
   - (3) Approach Bridge works
   - (4) Box culvert and pipe culvert works
   - (5) Cam river bridge works

3) Main bridge works
4) Cat Hai side works
   - (1) Soft soil treatment works
   - (2) Road works
   - (3) Approach bridge works
   - (4) Box culvert and pipe culvert work

10.1.1.2 Bridge type and working method

Bridge type and working method are as follows.

1) Approach Bridge
   - Foundation Steel Pipe Pile and Bored Pile
   - Superstructure PC Segment Span-By-Span Method (SBS Method)-Hai An side
     Cast in-place Cantilever Method -Cat Hai side

2) Main Bridge
   - Foundation Steel Pipe Sheet Pile (SPSP) serving for temporary cofferdam as well
   - Superstructure Cast in-place cantilever method

10.1.2 Major Work Quantity

Major work quantity is shown below table.

Table 10.1.2-1 Major Work Quantity

	Description	Unit	Quantity
I	Bridge	m	
I-1	Approach Bridge Section-1	m	
	Steel Pipe Pile D=1.1m	t	
	Bored Pile D=1.5m	m	
	RC Pile 350x350	m	
	Concrete 50Mpa	m3	
	Concrete 28Mpa	m3	
	Reinforcement Bars	t	
	PC Tendon 19S15.2	t	
	PC Tendon 12S15.2	t	
	PC Tendon 1S28.6	t	
	Embankment	m3	
	Geotextile	m2	
	Sub-base Course	m3	
	Base Course	m3	
	Asphalt Concrete Binder Course t=70mm	m2	
	Asphalt Concrete Surface Course t=50mm	m2	
	Asphalt Concrete Surface Course t=75mm	m2	
I-2	Main Bridge section	m	
	Steel Pipe Sheet Pile D=1.2m	t	
	Concrete 40Mpa	m3	
	Concrete 28Mpa	m3	
	Reinforcement Bars	t	
	PC Tendon 19S15.2	t	
	PC Tendon 1S28.6	t	

	Asphalt Concrete Surface Course t=75mm	m2	
I-3	Approach Bridge Section-2	m	
	Steel Pipe Pile D=1.1m	t	
	Bored Pile D=1.5m	m	
	RC Pile 350x350	m	
	Concrete 40Mpa	m3	
	Concrete 28Mpa	m3	
	Reinforcement Bars	t	
	PC Tendon 19S15.2	t	
	PC Tendon 12S15.2	t	
	PC Tendon 1S28.6	t	
	Embankment	m3	
	Geotextile	m2	
	Sub-base Course	m3	
	Base Course	m3	
	Asphalt Concrete Binder Course t=70mm	m2	
	Asphalt Concrete Surface Course t=50mm	m2	
	Asphalt Concrete Surface Course t=75mm	m2	
II	Road		
II-1	Hai An Side		
	Embankment	m3	
	Slope Protection	m3	
	Soft Soil Treatment-Sand Drain Pile	m	
	Geotextile	m2	
	Sand Blanket	m3	
	RC Pile 350x350mm	m	
	Structural Concrete 28Mpa	m3	
	Reinforcement Bars	t	
	Sub-base Course	m3	
	Base Course	m3	
	Asphalt Concrete Binder Course t=70mm	m2	
	Asphalt Concrete Surface Course t=50mm	m2	

II-2	Cat Hai Side		
	Embankment	m3	
	Slope Protection	m3	
	Soft Soil Treatment-Sand Drain Pile	m	
	Geotextile	m2	
	Sand Blanket	m3	
	RC Pile 350x350mm	m	
	Structural Concrete 28Mpa	m3	
	Reinforcement Bars	t	
	Sub-base Course	m23	
	Base Course	m3	
	Asphalt Concrete Binder Course t=70mm	m2	
	Asphalt Concrete Surface Course t=50mm	m	

Source: Study Team

10.1.3 Major Materials to be incorporated in the works

Major materials to be incorporated in the works are shown on the table below.

Table 10.1.3-1 Major Materials

Major Material	Procurement From		
	Vietnam	Japanese Firm in Vietnam	Japan
Embankment Material	○		
Crushed Stone for Road	○		
Sand for Sand Drain Pile	○		
Material for Geotextyle	○		
RC Square Pile	○		
Asphalt Concrete	○		
Guard Rail, Lighting Post etc	○		
Water Pipe	○		
Cement		○	
Coase Aggregate for Concrete	○		
Fine Aggregate for Concrete	○		
Steel Bar		○	
PC Wire		○	
Steel Pipe Pile		(○)	○
Steel Pipe Sheet Pile		○	○
Shoe		(○)	○
Expansion Joint		(○)	○
SBS Erection Girder			○

Source: Study Team

10.2 TEMPORARY FACILITIES

10.2.1 Temporary Facilities Outline

Temporary facilities contains following major items.

1) Temporary offices and plant yard.

a) - Temporary office for contractor with contractors' accommodation.

b) - Concrete batching plant- 1set x 90m3/hr

c) - Asphalt plant-2set x 200t/hr (one in Cat Hai)

d) - PC Segment fabrication yard-5 casting beds

e) - Material stockyard

f) - Machinery work shop

2) Temporary access road

a) - Entrance Access Road from public road

b) - Site Access Road

- Mound type road
- Mound type with sand/soil filled tube
- Steel staging type road
- Temporary bridges

3) Temporary jetty (Hai An side and Cat Hai side)

Marine Concrete Batching Plant-2x 60m3/hr

4) Dredging work

5) Navigation channel safety measures

6) Existing utilities and connection

Temporary facilities are shown on Appendix Fig. No. CP-10-1 and CP-10-2.

10.2.2 Summary of Temporary Facilities

Summary of temporary facilities are shown on the table below.

Table 10.2.2-1 Summary of Temporary Facilities

Description	Location	Code Name	Length or Area	Top width	Controlled By		Note
1. Temp. Road							
1-1 Entrance Acces sRoad							
Hai An side	KM 0	A-1		3m	Hai An PC	VIDIFI	Access from public road to KM0 (Existing Road)
		A-2		3m	Hai An PC		Access from A-1 to KM0.4 (Existing Road)
	KM 2.4	B	1.5km	6m	Hai An PC	DVIZ	Access from DVIZ internal road to
	KM 3.2	C	2.3km	6m	Hai An PC	DVIZ	Access from DVIZ internal road to Compound-2
	KM 8.1	Temp Jetty					Access to marine vessel and Cat Hai
Cat Hai side	KM 9.6	Temp Jetty					Access to marine vessel and Hai An
1-2 Site Accsee Road and Bridge	KM 0-KM4.1	Type-A	4.1km	5m x 2	Hai An PC		Including temporary bridge at KM1.7
	KM4.1-KM8.1	Type-B	4.0km	5m x 2			
	KM10.5-KM10.9	Type-C	6.0km	6m	CatHai PC		
2. Site Compound							
	KM 1.8	Compound-1	50,731m2		Hai An PC		Road material stockpile
	KM3.4 North	Compound-2	91,800m2		Hai An PC	DVIZ	Concrete, Asphalt, Segment Plant Contractor's office
	KM 7.9	Compound-3	40,171m2			NAMDV	Stockpile for piling, Erection girder
	KM 9.8	Compound-4	28,019m2		CatHai PC		Stockpile for piling,
	KM 10.0	Compound-5	45,295m2		CatHai PC		Road material stockpile, Traveller, (asphalt plant-altanative)
		Compound-6	16,028m2		CatHai PC		Stockpile for unsuitable material
	KM 15.5	Compound-7	40,448m2		CatHai PC		Road material stockpile, Asphalt Plant
3. Dredging Area	KM8.1-KM9.0						
4. Dumping Area	KM7.5-KM8.1	CX2A, CX3A				NAMDV	
5. Ferry Terminals	Hai An and Cat Hai Ferry Terminals				Hai Phong One Member Waterway Traffic Protection Company		Equipment and material loading and unloading

Source: Study Team

10.2.2.1 Site Compound

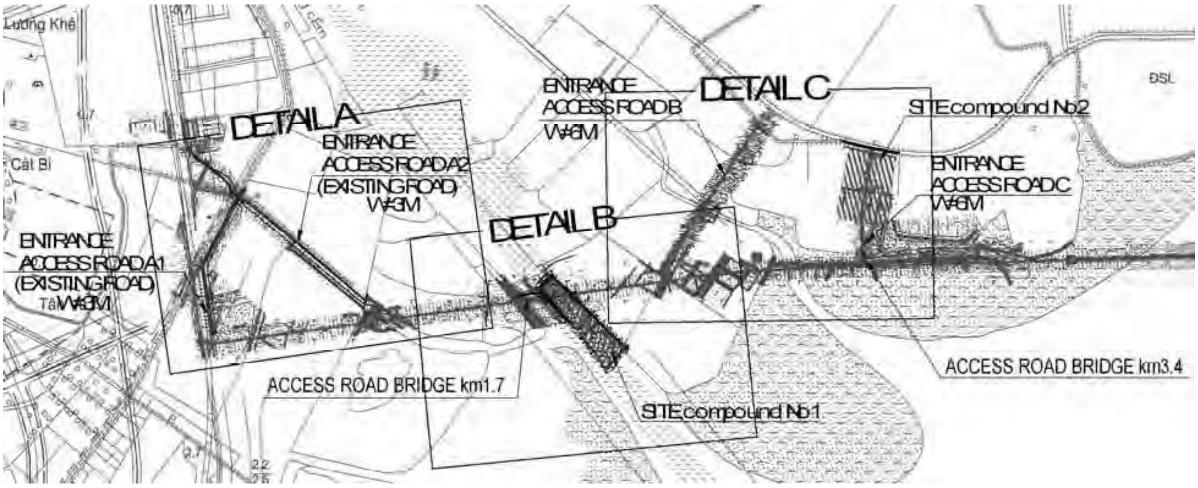
Site Compound-2 is a property of Dinh Vu Industrial Zone JSC and their conditions are to be strictly observed.

Site Compoud-3 is a property of Nam Dinh Vu Industrial Park and until now no detail discussion was made.

10.2.3 Temporary Access Road

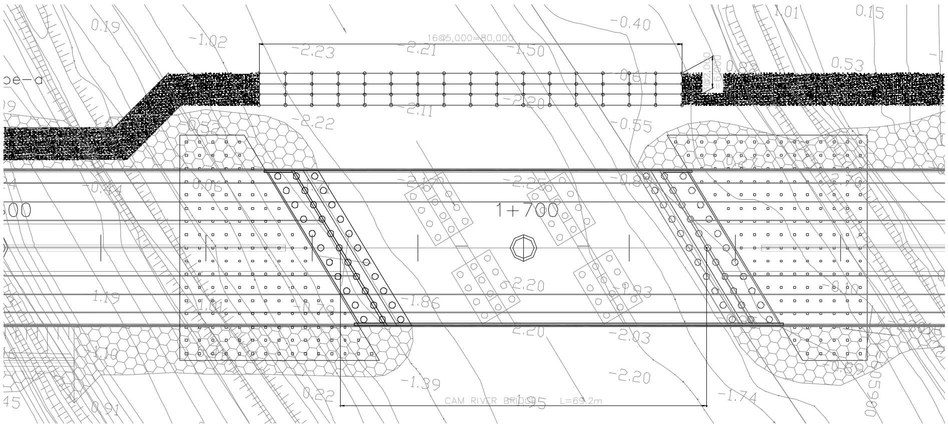
10.2.3.1 Entrance access road

As the site in Hai An side is isolated, entrance access roads from existing public road are essential. For this purpose three entrance access roads were selected. Entrance access road A be a direct access to Km0.0 point. However, the underpass has been planned with the new expressway. Therefore, Entrance access road A will be limited use for emergency vehicles, etc. Entrance access road B be a direct access to Km2.4 and Entrance access road C be a direct access through Site Compound-2. Other than those land access a marine access to Km1.7 Cam River for sand, aggregate material delivery and temporary jetty at Km8.1 be provided. At Cat Hai side a temporary jetty at Km9.65 be an access point, however existing ferry facility be alSourceful subject to detailed negotiation with Hai Phong One Member Waterway Traffic Protection Company.



Source: Study Team

Figure 10.2.3-1 Plan for Entrance Access Road and Site compound No1 and No2



Source: Study Team

Figure 10.2.3-2 Plan of Access Road Bridge km 1.7 (near Cam River)

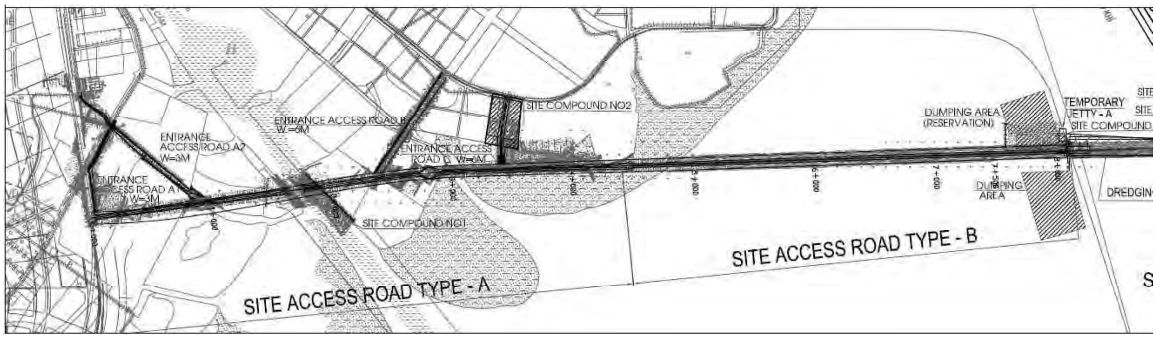
10.2.3.2 Site access road

Along the permanent road line site access road is also essential to work at several working spots.

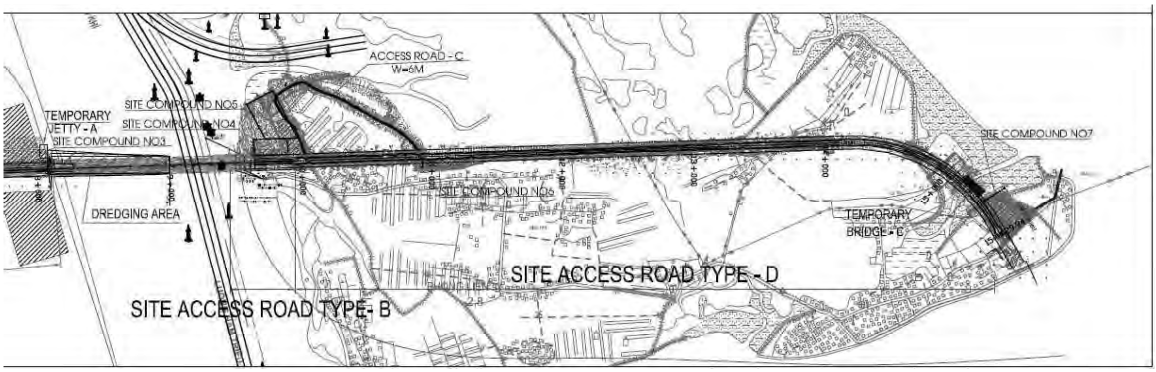
For this purpose, mound type roads, Site Access Road A and Site Access Road D, are assumed to be constructed along the section between Km 0.0 and Km 4.1 in Hai An side and between Km10.0 and Km16.6 in Cat Hai side except for except Cam River diversion bridge and box culvert locations.

Mound type roads with sand/soil filled tube, Site Access Road B, are assumed to be constructed for the area affected by sea water, between Km 4.1 and Km8.1 and between Km 9.7 and Km10.0, including mainly the bridge section.

A mound type road widened from the existing dike, Site Access Road C, is for temporary access for the period until the land acquisition and clearance is completed in the residential area between Km 10.0 and Km10.9 in Cat Hai Island.



(a) Hai An Side



(b) Cat Hai Side

Figure 10.2.3-3 Plan View of Site Access Roads

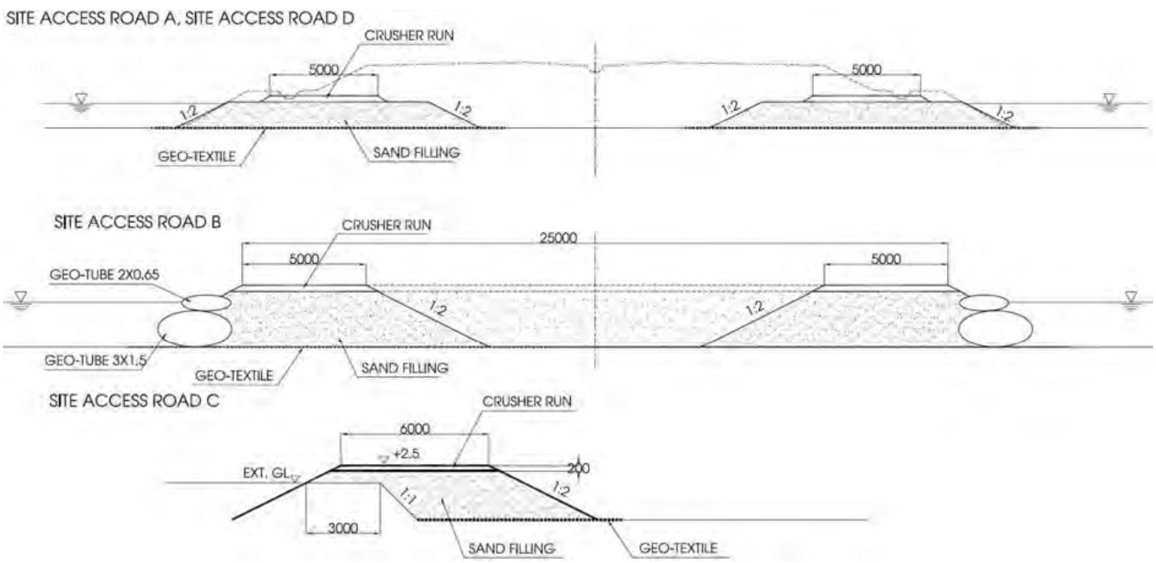
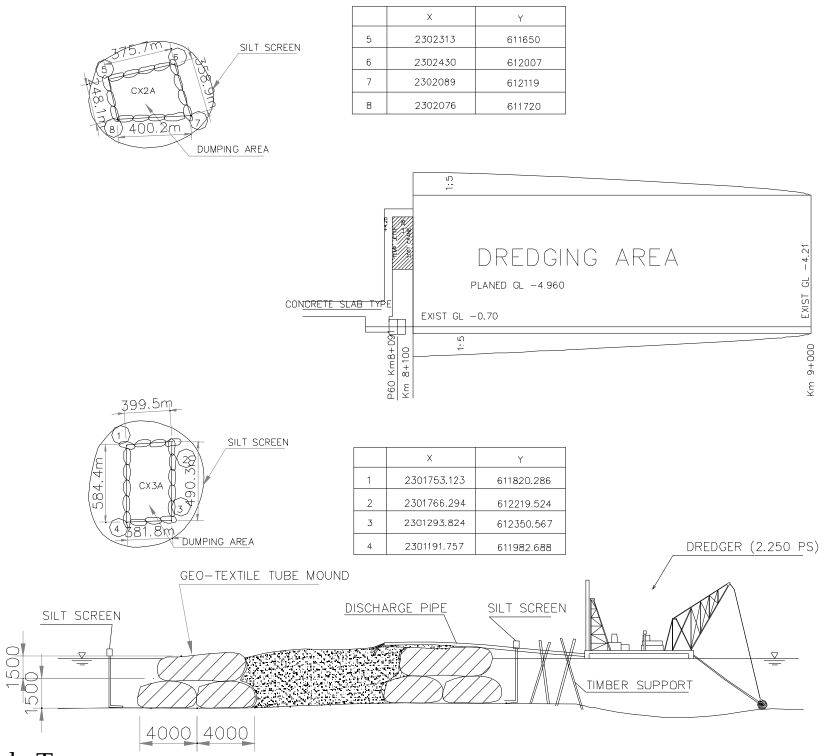


Figure 10.2.3-4 Typical Cross Sections of Site Access Roads

10.2.3.3 Dredging work

Dredging work is selected in between Km8.1 and Km9.0 in order to allow marine activities instead of steel staging construction. Dumping areas are designed at the locations indicated on the figure below. The dumping area is controlled by Nam Dinh Vu Industrial Park. Therefore close discussion with them be essential in prior to commencement the dredging work.

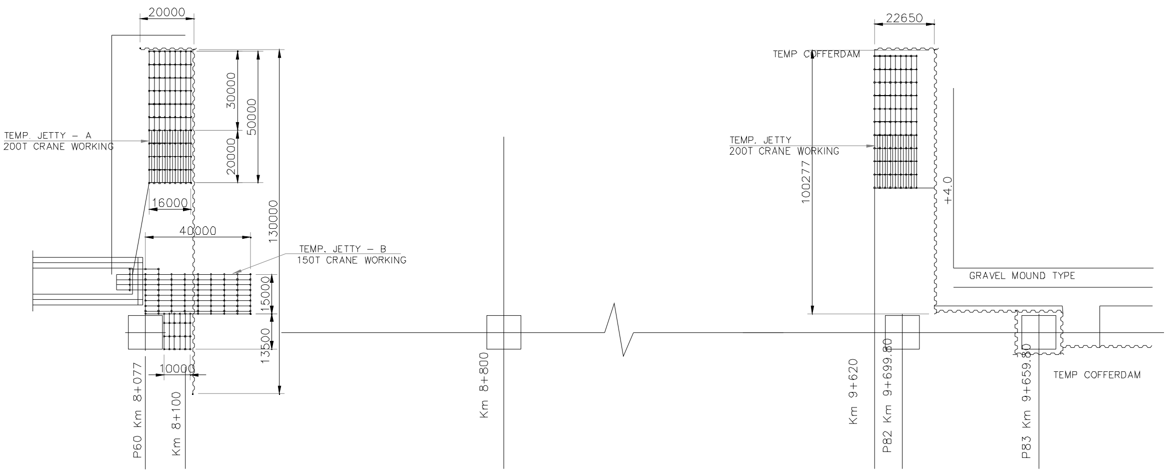


Source: Study Team

Figure 10.2.3-5 Dredging Area and Dumping Area

10.2.3.4 Temporary Jetty

Two temporary jetties be constructed at Km8.1 and Km9.62 in order to supply material and equipment to marine activities and transport the same to Cat Hai area as shown below.



Source: Study Team

Figure 10.2.3-6 Temporary Jetty

10.2.4 Navigation Channel Safety

There exists navigation channel (Nam Trieu Channel) between Hai An side and Cat Hai island, also there exist Dinh Vu-Cat Hai Ferry operation. The study team made series of discussion with Maritime Administration of Hai Phong and Nothern Vietnam Maritime Safety. The conclusion is for safety purpose two temporary navigation channels having a width of 80m each be established by means of installing additional buoys indicating limited temporary navigation channel and the construction working areas. In addition two monitoring stations are to be established with a speed boat each in order to monitor and communicate with any vessels passing the area and the controller always keep contact with marine police.

After completion of the bridge permanent navigation system be installed on the bridge.

Navigation system to be employed for construction purpose and permanent system are shown on Appendix Fig. No. CP-10-3, CP-10-4 & CP-10-5 and summary of equipment to be employed is shown on the table below.

Table 10.2.4-1 Navigation Safety Equipment

1. Main Bridge Foundation and Girder construction stage

Description of equipment	Number
Signal Buoys for waterway	4
Signal Buoys in construction area	6
Monitoring station	2
Speed boat	2

2. Bridge surface work stage and after completion of the bridge

All buoys, monitoring stations and speed boats are same as stage 1	
Star Board Hand Mark	4
Port Hand Mark	4
Pier Light	6

Source: Study Team

10.2.5 Existing Utilities and Connection

Existing utilities were surveyed near the site. Followings are findings.

1) Electricity

Hai An side : 750kva supply is available at Site Compound-2 with 2.2kv.
Supply conditions are to be agreed with DVIZ.

Cat Hai side: 250kva supply is available from existing overhead line near Site compound-7 and step down transformer of pole mounting type was recommended by Hai Phong Power One Member Liability Company.

2) Water

Hai An side: Daily 500m3 supply is available at Site Compound-2.

Supply conditions are to be agreed with DVIZ.

Cat Hai side: No tap water supply is expected.

10.2.6 Access to and Possession of Site

Due consideration of the provisions of the official documents, a letter , PMU2/110923-2 dated 23th of September, 2011, was submitted to PMU2 in order to draw their attention to the responsibility of the Employer under the Contract as follows;

(1) The Contract binding the Employer and the Contractor

1) Minutes of Discussion dated 18th June 2010 states that Guidelines for Procurement under Japanese ODA Loans (March 2009) shall be adopted for the Contract document.

2) Accordingly, FIDIC (MDB Harmonised Edition) shall be the basis of the Conditions of Contract.

3) In accordance with the latest version of FIDIC Red Book (MDB Harmonised Edition) Clause 2.1

> "the Employer should give the Contractor right of access to, and possession of, all parts of the Sitewithin the time (or times) stated in the Contract Data. The right and possession may not be exclusive of the Contractor."

4) FIDIC Red Book defines "Site" in Clause 1.1.6.7 that" means the places where the Permanent Works are to be executed and to which Plant and Materials are to be delivered, and any other places as may be specified in the Contract as forming part of the Site."

(2) Suggestions

It is very clear from agreed contract mechanism that access roads and plant yards for the Contractor's use are to be prepared by the Employer. If those land arrangement and land acquisition are left to the Contractor, it will obviously cause delay to the contract period which is estimated as 36 months without any spare time for land arrangement.

Also such situation may cause unnecessary dispute procedure based on the Contract.

The Detailed Design documents are made with an assumption that the Employer will fulfill his obligation under the Contract in respect of Site availability.

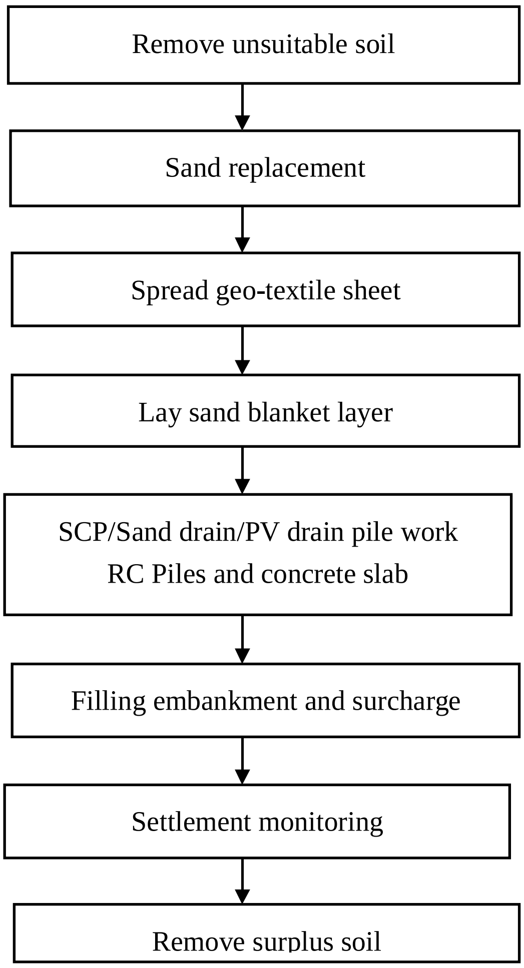
In order to avoid any future troubles, it will be necessary for the Employer to complete site arrangement including land acquisition for the Contractor's use without any hindrance before the Contractor will enter into the Contract.

10.3 SOFT SOIL TREATMENT AND EMBANKMENT WORK

10.3.1 Soft Soil Treatment Works

Road embankment design is controlled by residual settlement value of 30cm for embankment and 10cm for behind bridge abutment. In order to achieve those requirement accelerated settlement measures using Sand Compaction Piles(SCP), Sand Piles, PV Piles together with surcharge embankment are selected for embank section. For behind bridge abutment piled slab is selected.

Following shows construction sequences for sand drain pile and embankment works.



Source: Study Team

Table 10.3.1-1 Soft Soil Treatment and Embankment Work Procedure

Construction outline is shown on Appendix Fig .No. CP-10-6.

10.3.2 Geo-textile Sheet Spreading Works

Surface unsuitable material be removed or pushed away using either swamp type bulldozer or backhoe and the surface be replaced by sand layer. Geo-textile sheet be spread over the replace sand layer with utmost care for sheet jointing. On top of Geo-textile layer sand blanket be laid for ground water discharge purpose coming through PV drain and Sand drain piles.

10.3.2.1 SCP, PV Drain and Sand Drain Piling Works

SCP, Sand drain/PV drain piling rig sit on the sand blanket layer and drive steel tube into the ground and form sand column by means of vibration or insert drain sheet. Utmost care be paid for stability of the rig as heavy vibration equipment held by the rig at height.

Supply of sand be made by dump trucks and sand be loaded into the hopper either by shovel car or manually.

10.3.2.2 Soil Embankment Works

Embankment material be selected from existing borrow pits or any other sources after confirming volume and quality tests.

Material be transported by dump trucks or ships and laid using bulldozers with required thickness at each layer.

Compaction machines compact material to ensure required density.

10.3.2.3 Box Culvert and Pipe Culvert Works

In order to maintain existing water flow crossing the road embankment pipe culverts and box culverts are designed. Before embankment work commence temporary pipes are to be installed after PV Drain or Sand Drain works to allow water flow. Permanent pipe culvert or box culvert are to be constructed after designed settlement has been achieved.

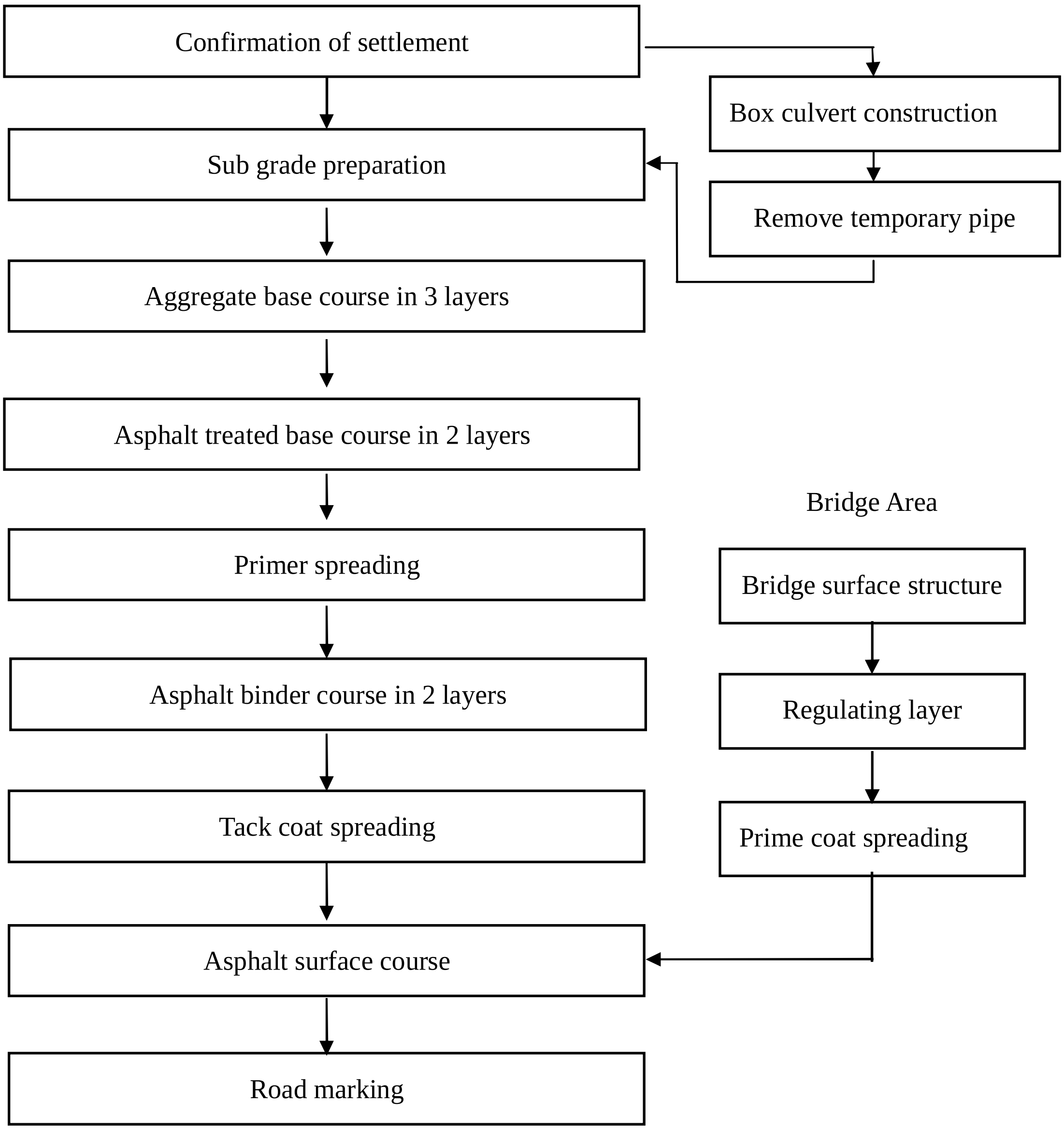
10.4 ROAD WORKS

10.4.1 Road Works Outline

After completion of consolidation settlement box culvert and pipe culvert work commence. Any temporarily installed pipes are to be removed and subgrade preparation work follows. Aggregate base course material and asphalt treated base course material be well compacted with tire roller, vibration roller and grader. Where working space is narrow small tandem roller or hand roller be used.

Following asphalt treated base course compaction and testing, primer be spread and asphalt binding course be laid using asphalt finisher and compacted using tire roller, macadam roller.

Asphalt treated base course, asphalt binding course and asphalt surface course be produced by site batching plants. Road work procedure is shown below.



Source: Study Team

Figure 10.4.1-1 Road Work Procedure

10.4.2 Sub grade, Sub -base course and Base- course Works

10.4.2.1 Sub grade

Sub-grade surface be well graded using motor grader. Any foreign materials be removed and soaked materials be replaced by good material. After preparation works sub-grade surface be well compacted using tier roller and macadam roller to receive selected Subgrade material.

In order to achieve smoothness motor grader and manual grading be repeated.

10.4.2.2 Aggregate base course

Material for aggregate base course be selected from borrow pits and tested. Selected material be transported using dump trucks and unloaded at working spot, spread using bulldozer and backhoe and compacted using tier roller and macadam roller to the thickness required.

Surface be well graded using motor grader and manual operation to achieve required thickness and smoothness.

10.4.3 Asphalt Treated Base Course and Pavement Works

10.4.3.1 Asphalt plant

In order to meet quality requirement and delivery requirement two 200t/hr capacity asphalt batching plant be established on site. One is to be at Hai An side and another one is to be at Cat Hai side.

10.4.3.2 Asphalt treated base course, asphalt binder course and surface course

Material be transported from site asphalt plants using dump truck.

Asphalt treated base course, asphalt binder course and asphalt surface course material be received by finisher and laid controlling thickness with a sensor system.

Laid asphalt concrete be immediately compacted using tire roller, macadam roller and tandem roller before temperature exceeding specified limit.

10.5 APPROACH BRIDGE

10.5.1 Approach Bridge Works Outline

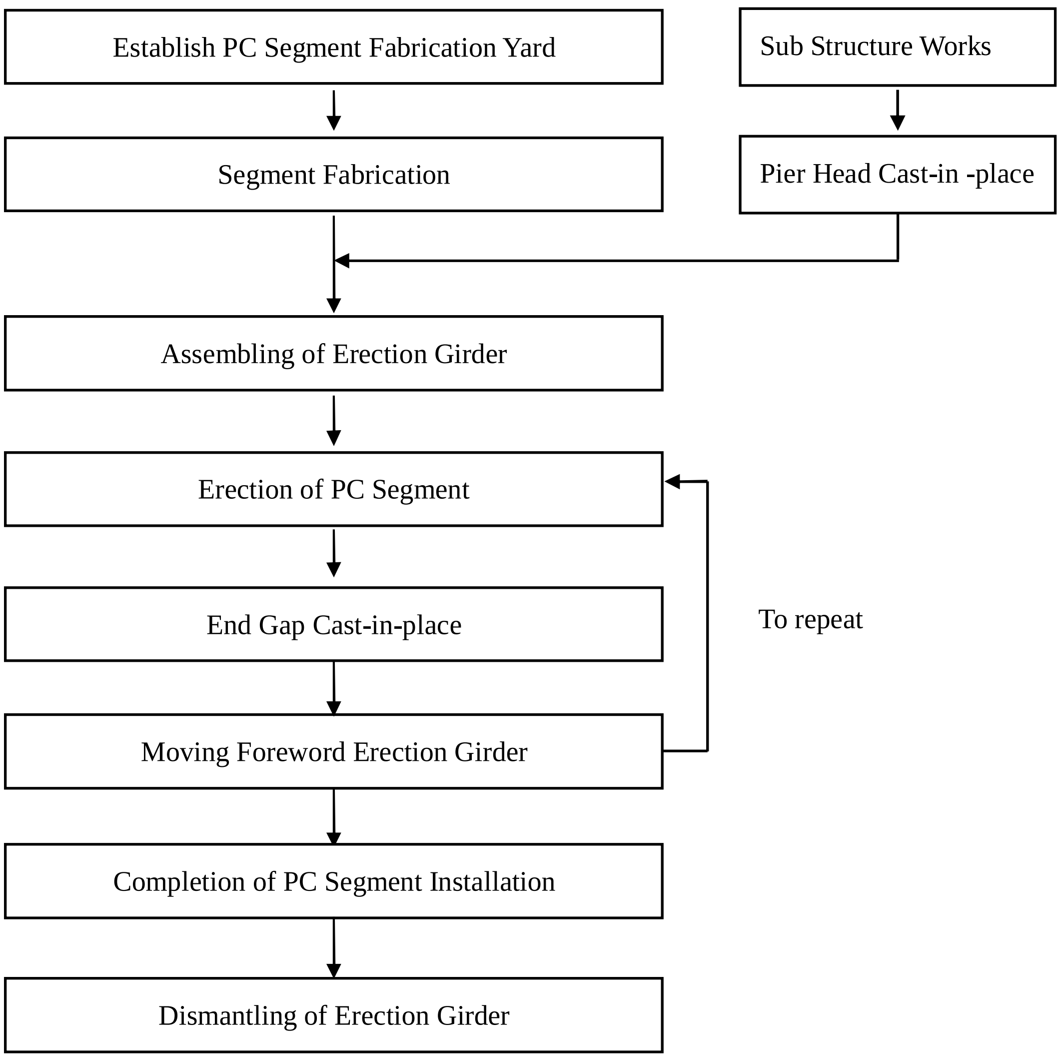
Two different types of superstructure design for Approach Bridge are selected, namely PC Segment Span By Span (SBS) Method for Hai An side and Cast-in-place Cantilever Method for Cat Hai side.

Foundation pile design has also two different types, namely Steel Pipe Pile and Bored Pile .

Working platform has three different types, namely Filled Ground, Steel Staging and off-shore.

10.5.2 Approach Bridge (SBS Method) Working Sequence

Construction sequence is shown below.



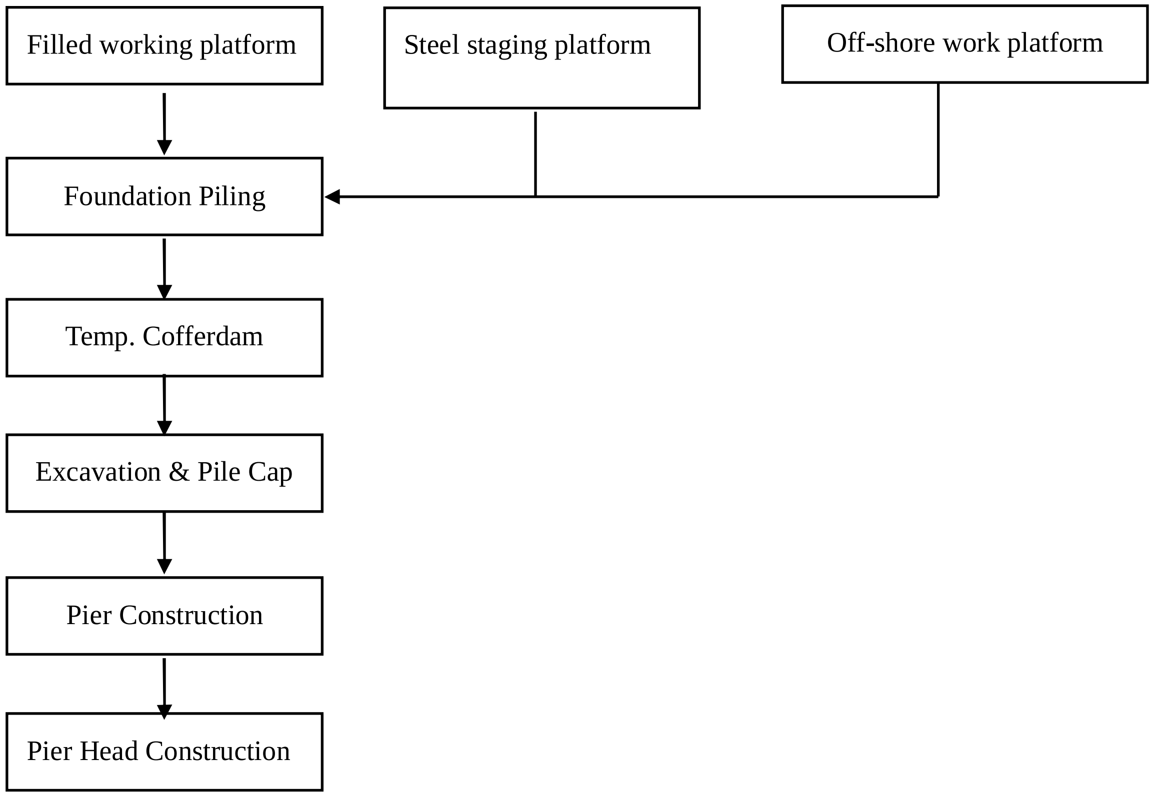
Source: Study Team

Figure 10.5.2-1 Approach Bridge (SBS Method) Working Sequence

10.5.3 Sub Structure Works

10.5.3.1 Construction sequence for substructure

Construction sequence for sub structure is shown below.



Source: Study Team

Figure 10.5.3-1 Construction sequence for Approach Bridge sub structure

10.5.3.2 Construction of working platform and piling works

During the time of construction of the temporary access road the working platforms be constructed.

Due to several different types of working platform piling activity require different type of machineries. Following table shows relation in between type of platform and piling machinery.

Table 10.5.3-1 Approach Bridge Piling Machinery and Working Platform

Pier Nr.	A1	P1-P50	P51-P60	P61-P75	P79-P82	P83-P87,A2
Foundation Pile Type	Steel Pipe Pile	Steel Pipe Pile	Steel Pipe Pile	Bored Pile	Bored Pile	Steel Pipe Pile
Platform Type	Filled Ground	Steel platform	Off shore	Off shore	Off shore	Filled Ground
Piling Method	Hydraulic Hammer 12.5t	Hydraulic Hammer 12.5t	Hydraulic Hammer 12.5t	Bored Pile Machine	Bored Pile Machine	Hydraulic Hammer 12.5t
Piling Machine	Crawler Crane 150t	Crawler Crane 150t	Crawler Crane 200t Barge 1000t	Crawler Crane 120t Barge 1000t	Crawler Crane 120t Barge 1000t	Crawler Crane 150t

Source: Study Team

Construction outline for piling work is shown on Appendix Fig. No. CP-10-7.

(1) Works on the filled platform (for A1, P83-A2)

a) In prior to the piling works guide piles and frame installation works be taken place.

b) Crawler Crane 150t be used for steel pipe pile driving with 12.5t capacity hydraulic hammer, and 100t crawler crane with 60Kw hydraulic vibration hammer be used for steel sheet pile driving

(2) Works on the steel platform (P1-P50)

Woks are same as item 1) above.

(3) Works off-shore (P51-P82)

a) Temporary .cofferdam sheet pile driving is carried out utilizing 150t crawler crane with 60 Kw hydraulic piling hammer on 1000t barge. Following temporary cofferdam steel pipes piles are driven utilizing 200t crawler crane for P51-P60. For P61-P82 bored pile stand pipe and also steel staging be installed for bored pile driving working platform.

b) Bored pile be formed using reverse-circulation method with roller bit. For hole wall stability bentonite liquid be used and fresh liquid be maintained with bentonite circulation method in order to prevent sedimentation.

c) Steel cage be installed in the hole using 120t crawler crane and concreting work follow using marine concrete batching plant (60m3/ hr).

10.5.3.3 Excavation, pile cap and pier construction works

(1) Works on the filled platform (for A1, P83-A2)

For excavation works a backhoe (0.8m3) be used and 10t dump truck be used for hauling.

After excavation truck crane (20t) be used for strut and walling works and structure concrete works follow.

(2) Works on the steel platform (P1-P50)

The works be carried out by the same procedure as described in (1) above.

(3) Works off shore (P51-P75)

The works be carried out by the marine equipment and concrete be supplied by a marine batching plant of the capacity 60m3/hr.

(4) Works off-shore (P79-P82)

After bored pile construction all procedures for pile cap and pier construction be carried out marine equipment.

After bored piles complete steel staging to receive pile cap structure be installed on those steel stand pipe for bored pile. This working platform be used for pile cap & pier form work, steel work and concrete work.

All concrete work be carried out using off shore equipment and where pier height be more than 4m one pour be limited to 4m to avoid concrete segregation.

10.5.3.4 Pier head construction work

(1) P1-P75

After pier work complete pier head work follow and pier head structure be constructed by means of cast in-place method.

For those pier head construction in between P1-P75 temporary support system be either bracket system or frame support sitting on the pile cap concrete.

(2) P79-A2

In between P79 and A2 super structure is designed as cast in-place cantilever type pier head length is 15m long in order to accommodate 2sets of traveler form on it. Pier head structure be constructed on the steel staging. Due to cast in-place cantilever method pier head structure need to be strengthen by introducing temporary shoe and temporary tie-in method into pier structure using pc bars.

Detail is stated in Section 10.5.6 hereinafter.

10.5.4 Fabrication of PC Segments

For the purpose of PC segment production a fabrication yard be established in the plant yard with an area of approximate 40,000m2.

Plan for segment fabrication yard is shown on Appendix Fig. No. CP-10-8.

10.5.4.1 PC segment fabrication outline

All PC segments be fabricated with short-line match casting method, and 5 sets of casting bed be established.

Form-

Form Facility composed from edge form, side form, inner form, and bottom form.

The edge form be equipped with sliding mechanism in order to satisfy with change in length of segments.

The side form be equipped with open and close mechanism by the jacks.

The inner form be equipped with the shifting mechanism.

The bottom form for old segment be supported by the mobile platform equipped with the vertical jacks enable to adjust vertical alignment.

Steel bar-

Steel bar cages are prepared at adjacent steel bar fabrication yard and pre-arranged steel bar cage be shifted using tower crane (180t/m) on the bottom form at the fabrication platform and fixed.

Following steel bar cage and sheath installation inner form be slide and fixed.

Concrete-

Concreting work be carried out after confirmation of survey check for form position, height, and angle and concrete be supplied from adjacent land concrete batching plant(90m3/hr.) with concrete pump car (60m3/hr.).

Old segment to be used for next segment-

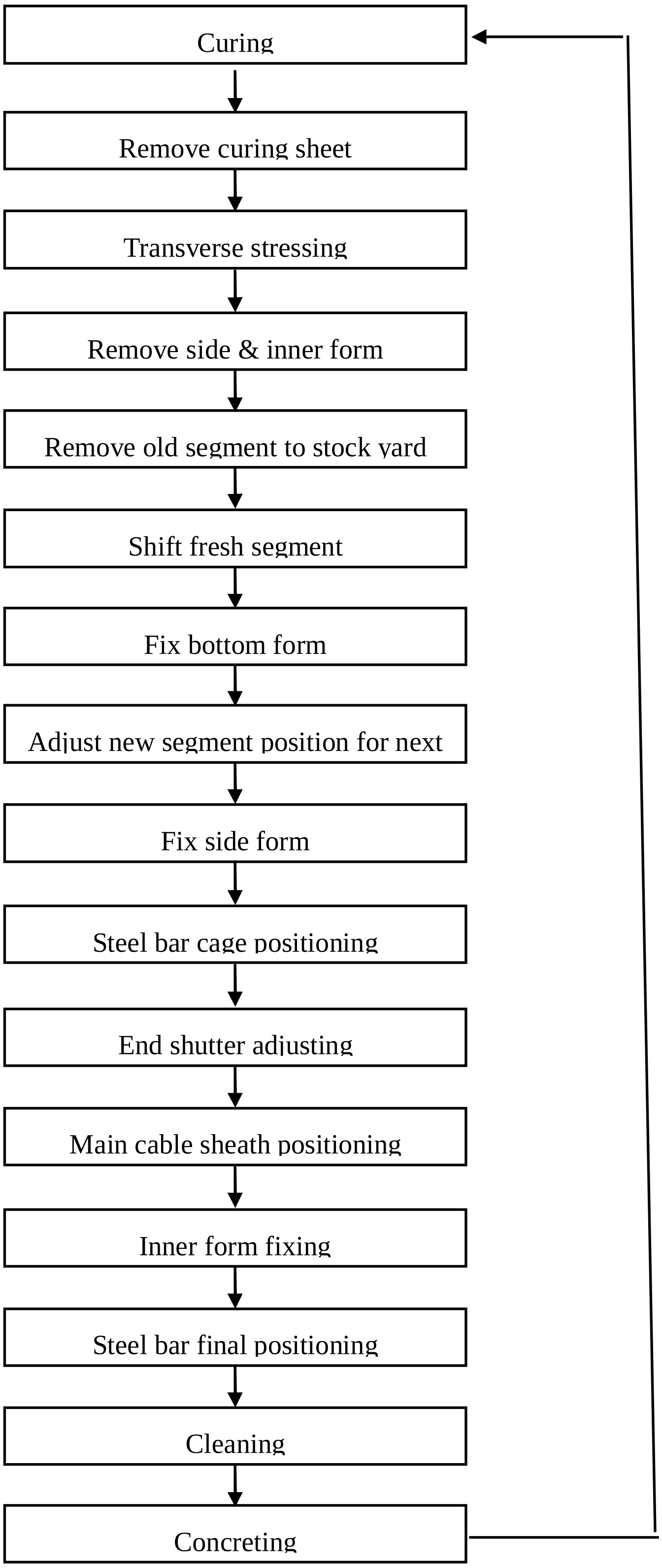
Freshly complete segment be removed and set back from the casting bed by means of sliding on the rail and be used as a external end shutter for new segment.

Stock yard-

The old segment used as a external form be removed after new segment concrete work and transferred to stock yard using gantry crane (30mx80t)

10.5.4.2 Fabrication Sequence

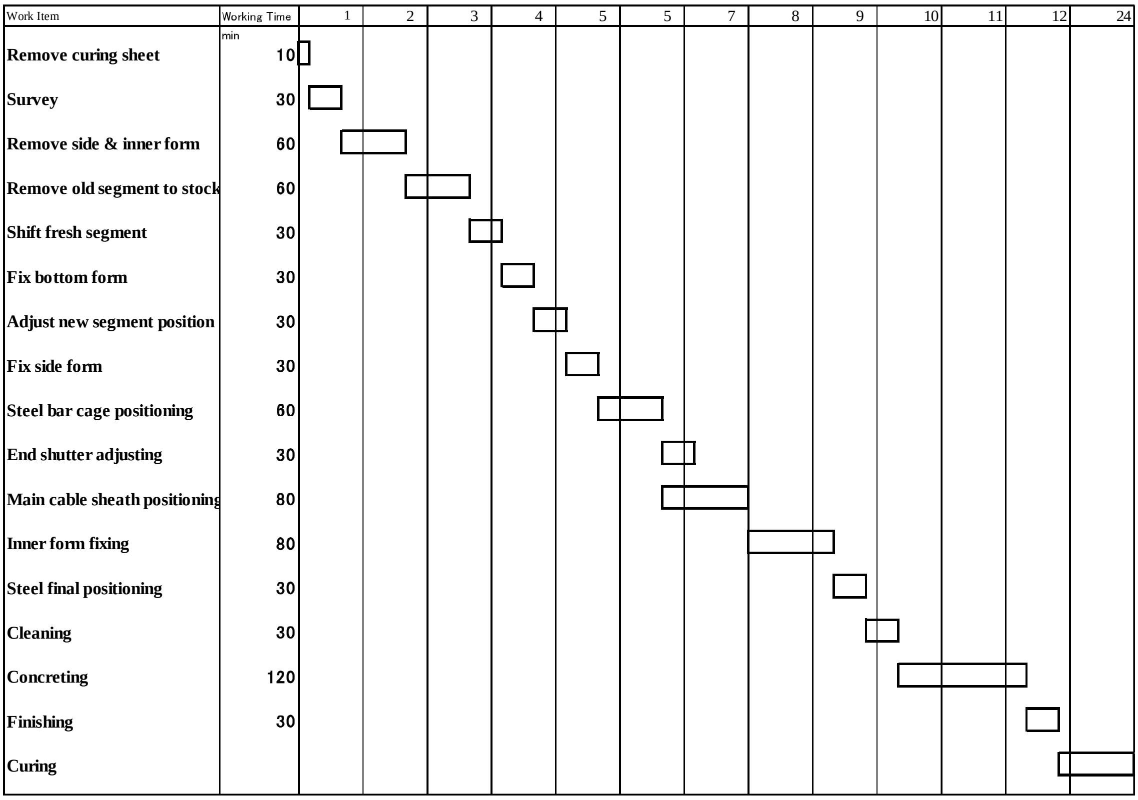
PC segment fabrication sequence is shown below.



Source: Study Team Figure 10.5.4-1 PC segment fabrication sequence

10.5.4.3 PC segment fabrication cycle time

PC segment fabrication cycle time is sown below.



Source: Study Team

Figure 10.5.4-2 Segment Fabrication Cycle Time

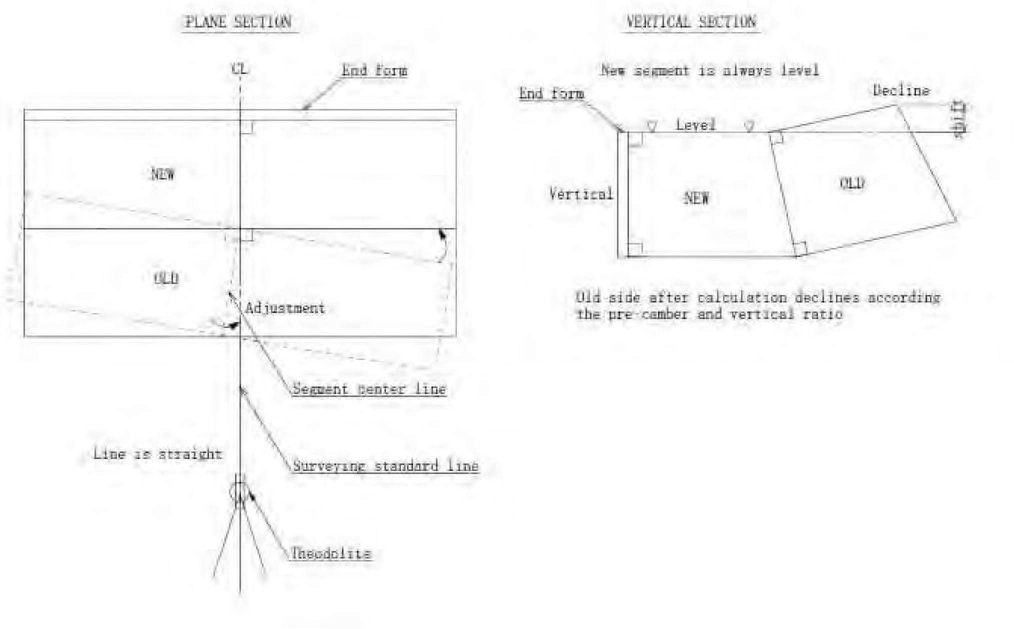
10.5.4.4 Geometry control

In order to satisfy vertical and horizontal alignment geometry control be assured using survey tower and bottom form adjusting for the old segment. The new segment be always kept level and straight alignment.

The survey tower be kept on the center line of the fabrication platform.

The old segment horizontal and vertical adjustment be made by hydraulic bottom form jacks and controlled by the survey work.

Geometry control system is shown below.



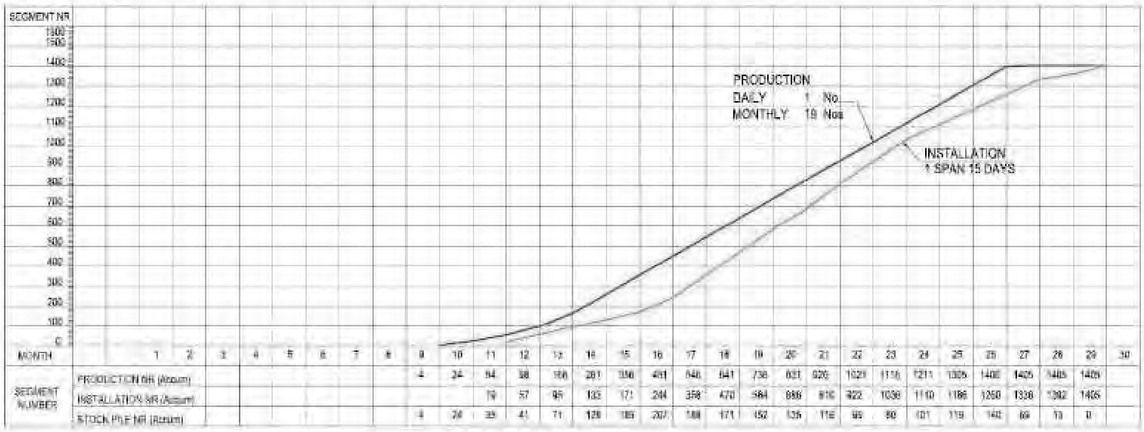
Source: Study Team

Figure 10.5.4-3 Geometry control outline

10.5.4.5 Segment stockpile

Fabricated segments be transferred to stockpile yard using gantry crane.
Segments are stacked in the stockpile yard in two layers .

PC segment stockpile number is shown below.



Source: Study Team

Figure 10.5.4-4 Segment fabrication and installation program showing stockpile number

.

10.5.4.6 Segment transport

All segments be loaded on the low bed trailer (80t) using gantry crane(30m 80t) established in the segment stock pile yard and segments be transported to the desired position and lifted using the erection girder which be elected and sit on the pier heads. Only for P50-P75 all segments be lifted

Transport distance be 2.3km in average and all segments be transported through temporary access road.

10.5.5 Segment Erection Work (Span By Span Method)

10.5.5.1 Outline

Segments erection be carried out using three erection girders simultaneously.

Each erection girder be assembled on temporary supports frame by frame and finally sit on the supporting columns which sit on the pier head after adjusting.

Each PC segment be lifted by lifting devices on the erection girder and rolled to the position from one end toward other end. When new segment comes to close to adjacent segment installed already , contact surface be pasted using chemical bonding glue and temporarily stressed. This process be repeated until all segments be positioned.

Finally small gap in between be filled using cement mortar with external hanging form and whole segments be stressed.

After those works complete the erection girder be rolled forward to next pier position and finally be dismantled on the bridge.

For erection work at P50-P75 the erection girder is designed purposely to receive segment at rear portal on the deck and the erection girder carry segment through foot support, by which all segments are to be delivered on the complete deck surface from P50.

Segment erection outline is shown on Appendix Fig. No. CP-10-9 and CP-10-10.

10.5.5.2 Assembling of Erection Girder

Assembling works of three erection girder be taken place at A1-P1-P2, P25-P26-P27 and P50-P51-P52.

For assembling at A1-P2 and P25-P27 temporary girder support be established at 7.5m spacing to meet 150t crawler crane lifting capacity. All girder pieces are to be lifted and positioned on the temporary supports and joined, finally foot supports sitting on the piers receive the girder weight.

For assembling at P50-P52, girder support be erected first at 15m spacing. 15m long girder piece be pre-assembled on the land works compound-3 and transferred by barge and lifted and positioned by using floating crane of 300t.

10.5.5.3 Erection of PC Segment

(1) A1-P50

In between A1-P50 each pc segment be delivered by mulch axle trailer to the lifting position which be designated for every span and lifted by the lifting gear on the erection girder and rolled to the final position. Contact surface glue application and temporary stressing follow.

(2) P50-P75

In between P51-P75 all segments are to be once lifted at P50 by lifting gantry crane and unloaded on the trailer sitting on the complete bridge surface, then transferred to the erection girder rear end and lifted by the lifting gear on the girder. The segment passes through the girder foot to the position and rotated 90 degree to meet adjacent segment. Due to necessity of segment rotation 6 pieces of segment be temporarily stocked on the temporary store platform adjacent to the younger pier in prior to erection work for the concerned section. Those stocked segments are to be erected at last.

10.5.5.4 Shifting of Erection Girder

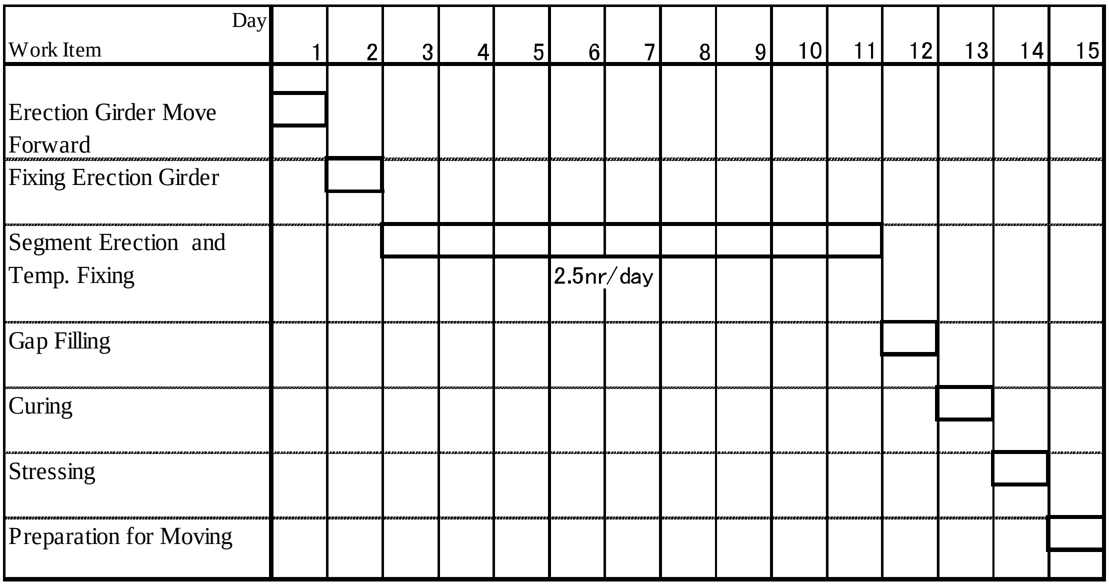
Erection girder be shifted to the next position by means of sliding using rolling gears sitting on the supporting towers and the girder be received by new supporting tower sitting on the next pier head.

10.5.5.5 Dismantling of Erection Girder

After completion of all segment erection the girder be dismantled using 100 t cranes and temporary supports on the bridge surface.

10.5.5.6 Segment erection cycle time

Segment erection work cycle time is shown below.



Source: Study Team

Figure 10.5.5-1 Segment Erection Work Cycle Time

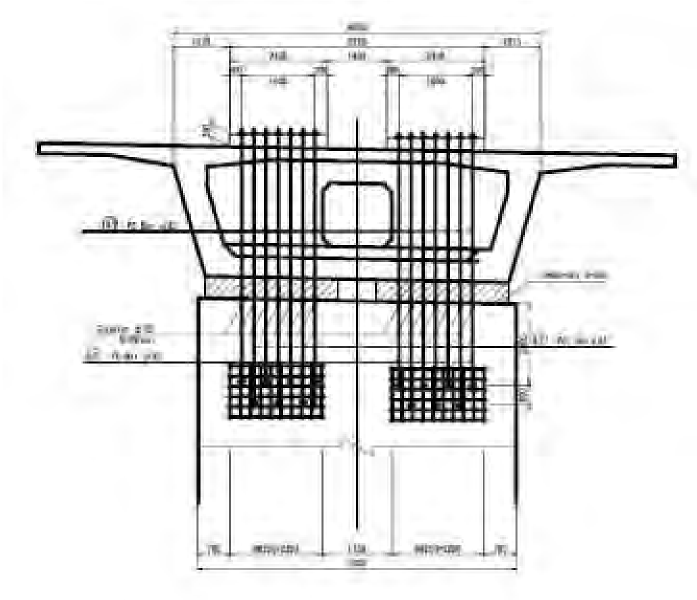
10.5.6 Cast in-place Cantilever Method

In between P79 to A2 Cast-in-place Cantilever Method be applied for super structure construction.

After completion of pier structure pier head be constructed by cast in-place method of which length be 15m at P80, P81, P82, P83, P85, P86 and P87. At P79, P84 and A2 the girder be constructed independently by cast-in place method as on those piers no form travelers will be used.

In addition at P80, P81, P82, P83, P85, P86 and P87 pier head be sit on the temporary shoes and tightened with pier structure by PC bars in order to stabilize the structure to meet additional load introduced by cantilever method.

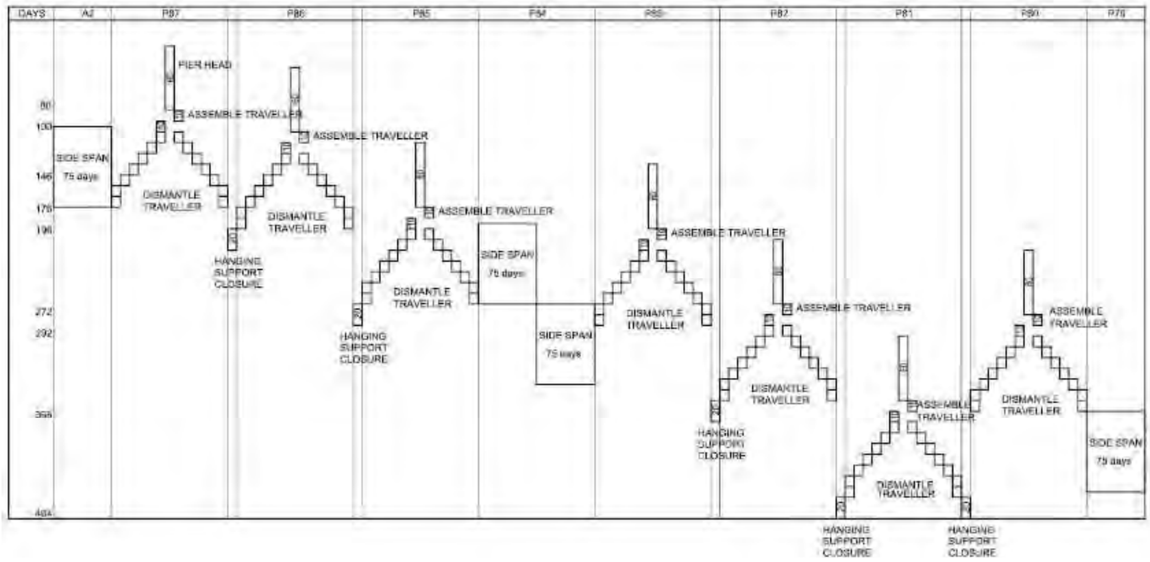
Pier head temporary measure is shown below.



Source: Study Team

Figure 10.5.6-1 Pier Head Temporary Shoe Detail

Working program is shown below.



Source: Study Team

Figure 10.5.6-2 A2-P79 Cantilever Method Working Program

10.6 MAIN BRIDGE

10.6.1 MAIN BRIDGE WORK OUTLINE

In between P76 to P78 the bridge cross existing navigation channel, therefor long span bridge is designed and Cast-in-place Cantilever Method is selected. For foundation structure Steel Pipe Sheet Piles (SPSP) Foundation is selected which serves temporary cofferdam and part of the permanent structure.

Navigation requirement and the main bridge construction activities are shown on Appendix Fig. No. CP-10-3,4 & 5.

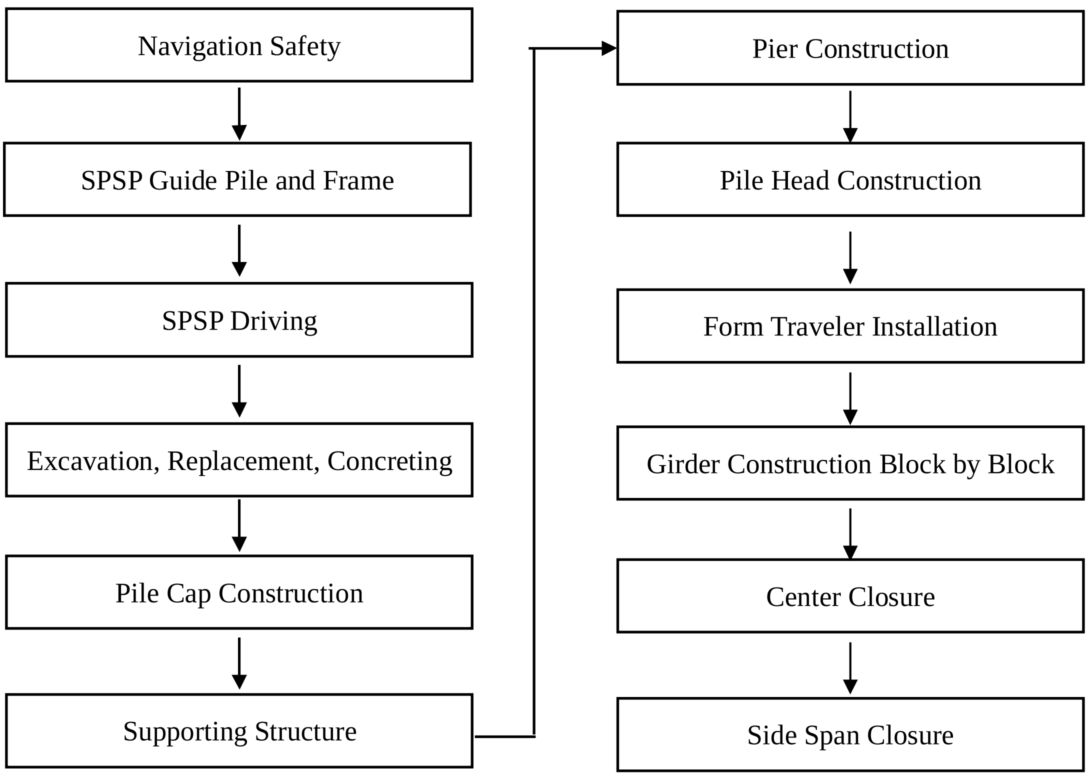
In prior to commencement of any marine activities, all necessary safety measures be taken place such as installation of demarcation buoys, provision of monitoring stations and speed boats as described in 10.2.4 before.

After piling works sea bed excavation, replacement of soft layer by rock and concrete, pile cap be constructed in dry condition and pier structure will follow. As pier structure is inclined and pier head structure is with height steel supporting system be installed before formwork.

Following pier head structure construction two sets of form traveler be installed at both pier head end. Main bridge girder structure be constructed block by block and one side by other with 3m to 5m length each.

Upon reaching final block small gap between the structure extended from one pier and adjacent pier be filled by concrete using the form traveler. Then final stressing work takes palace and the form traveller be dismantled.

Construction sequence is shown below

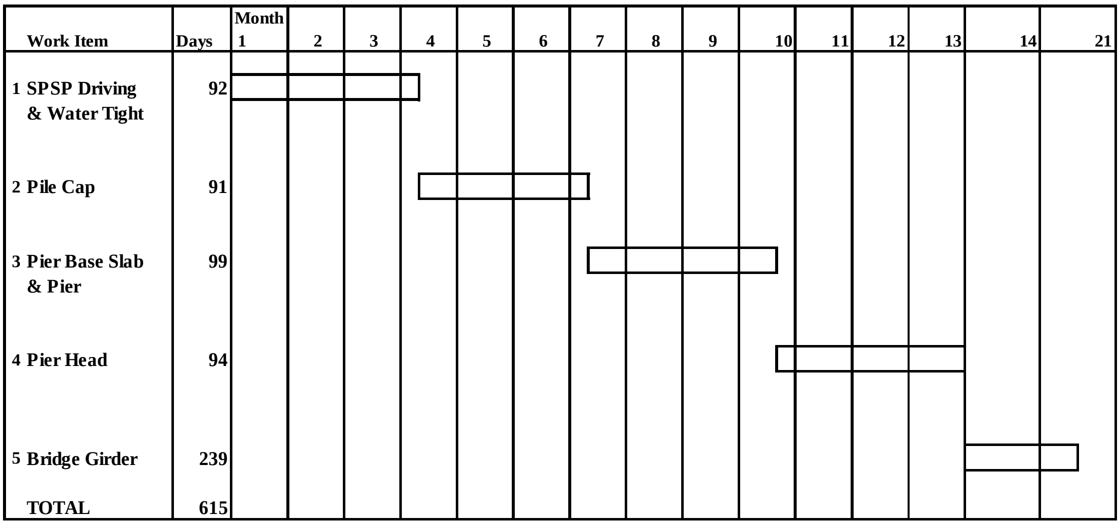


Source: Study Team

Figure 10.6.1-1 Construction sequence

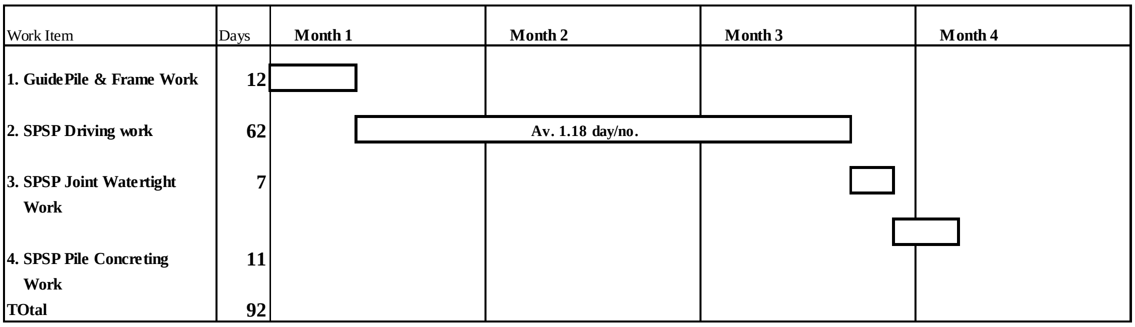
10.6.2 Main Bridge Overall Working Program

Overall working program for Main Bridge is shown below.



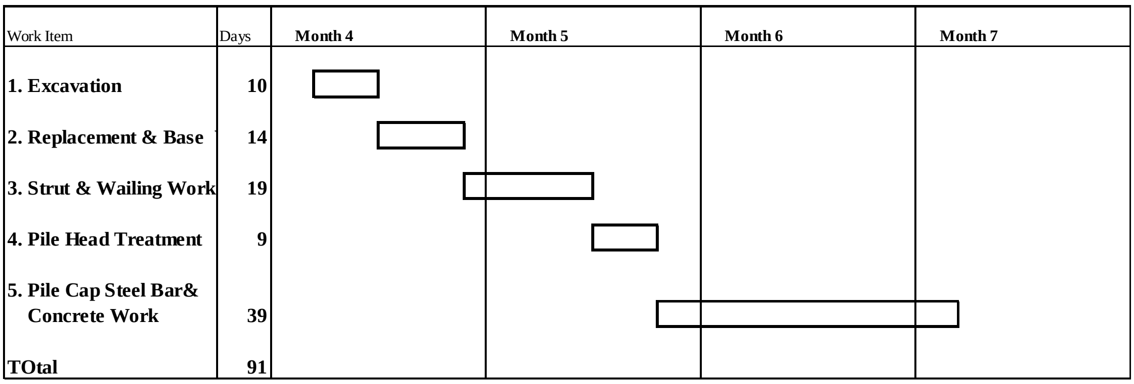
Source: Study Team

Figure 10.6.2-1 Main Bridge Overall Program



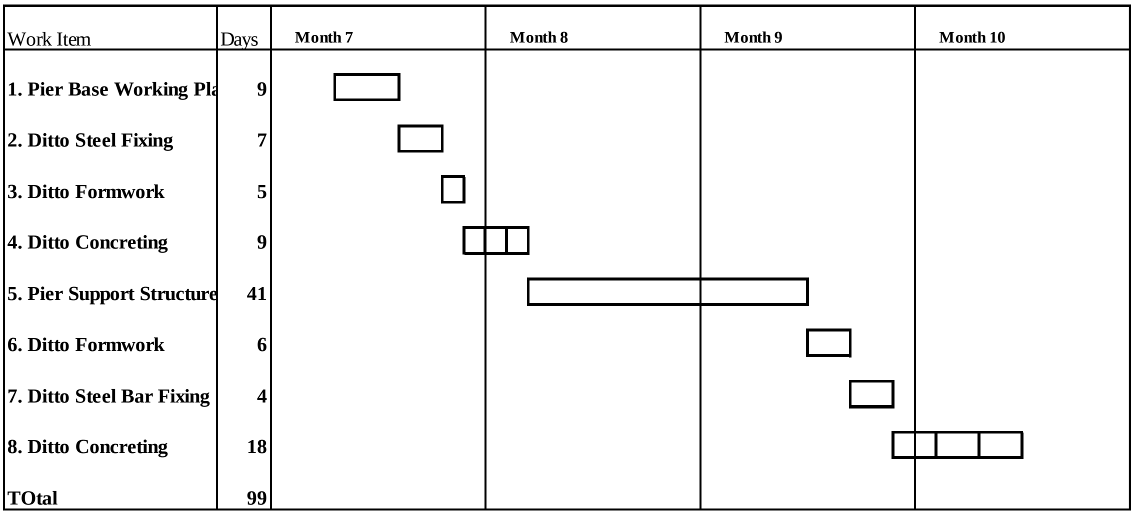
Source: Study Team

Figure 10.6.2-2 Main Bridge Foundation Work Program



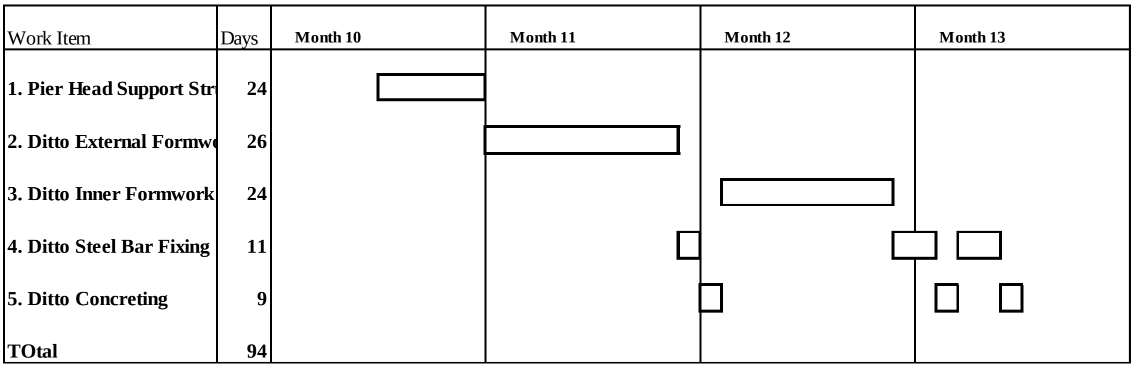
Source: Study Team

Figure 10.6.2-3 Main Bridge Pile Cap Work Program



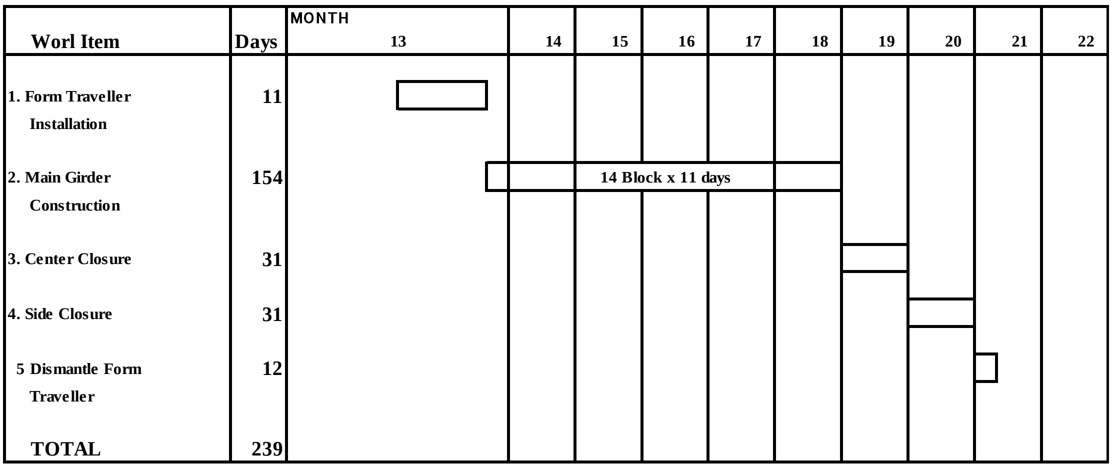
Source: Study Team

Figure 10.6.2-4 Main Bridge Pier Construction Program



Source: Study Team

Figure 10.6.2-5 Main Bridge Pier Head Construction Program



Source: Study Team

Figure 10.6.2-6 Main Bridge Girder Construction Program

10.6.3 Main Bridge Sub-structure Construction Method

10.6.3.1 SPSP Driving Work

In prior to commencement of SPSP driving, guide piles and frame be installed. In order to make sure proper positioning 2 lines of frame be installed and guide gear be used for positioning.

SPSP be positioned using vibration hammer and piles be driven down to reach refusing strata and hydraulic driving hammer together with high pressure water jet system be used for final penetration.

For 1st stage driving vibration hammer of 240kw capacity with 250t crawler crane sitting on 2000t barge be used and for 2nd stage driving 15t capacity hydraulic driving hammer with 300t crawler crane sitting on 2000t barge be used. In order to maximize working distance a hanging driving method be applied.

SPSP driving working method is shown on the Appendix Fig. No. CP-10-11.

10.6.3.2 To prevent water seepage through SPSP joint

All SPSP has been driven down to the required depth and closed, mud inside joint pipe be removed using high washer system and replaced by mortar grout to be pumped to prevent water seepage through joint.

Soil inside of SPSP itself also be removed using clamshell bucket and replaced by concrete.

10.6.3.3 Excavation and replacement of soil for foundation

After securing water tightness at SPSP joint and concreting inside pipes, excavation work proceed using clamshell bucket and rock material be dropped and leveled. On top of rock material base slab concrete be poured using floating type batching plant and concrete pump. Concrete surface level and smoothness be confirmed by divers.

10.6.3.4 Dewatering, strut & wailing and pile cap concrete

Following base slab concrete dewatering inside of the shell proceed together with strut & wailing installation work. Pile cap construction be carried out under dry condition and form work and steel bar fixing work proceed using 50t crane sitting on 1000t barge and material supply barge.

Considering size and height of pile cap be concreted in 2 stages.

10.6.3.5 Pier construction

Pier base structure be constructed after pile cap concrete complete.

As pier is designed inclined shape steel supporting stage be constructed to support both pier and pier head structure.

Both Pier Base and Pier Colum be constructed in 3 stages of concreting.

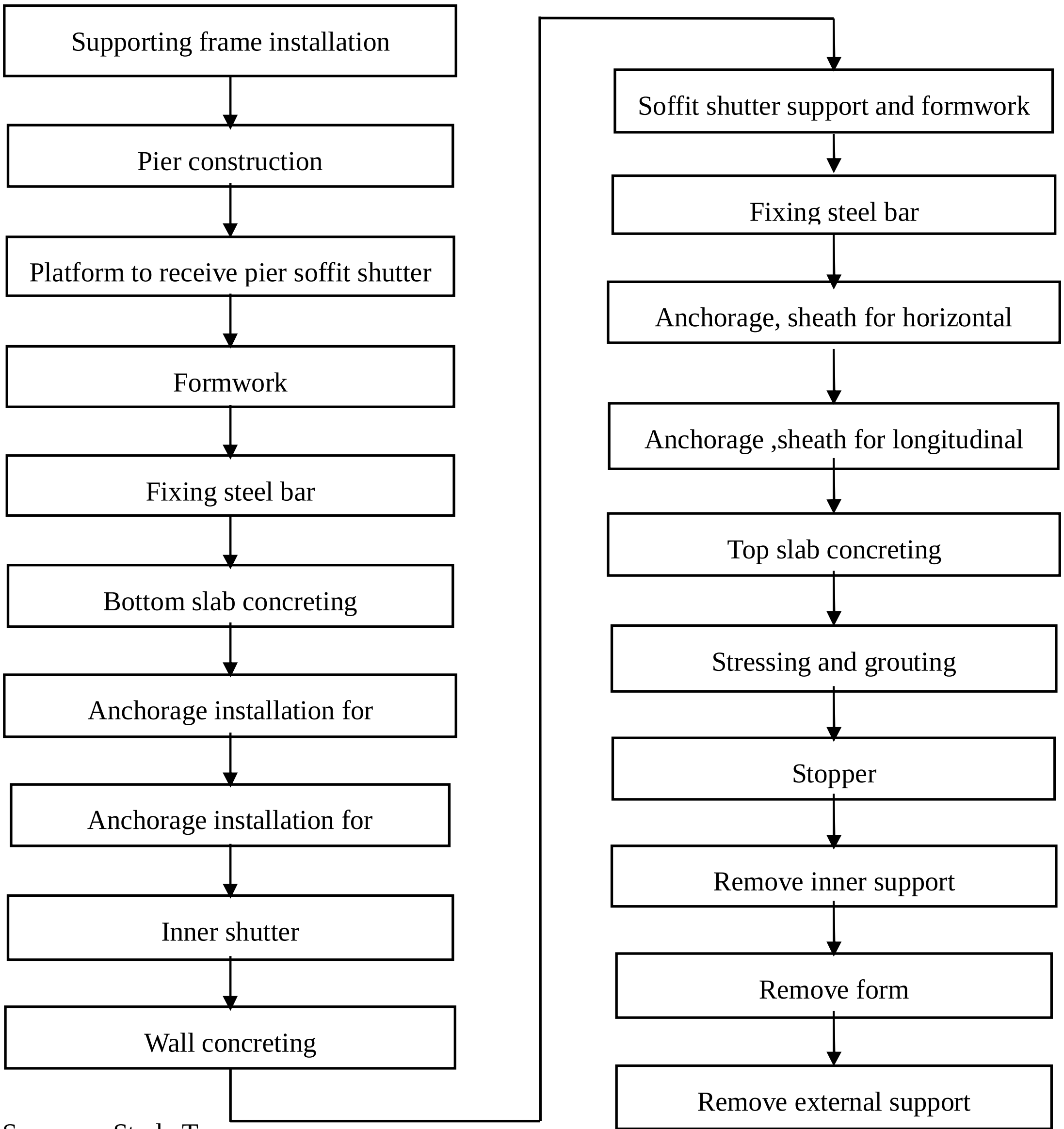
Pier column and pier head construction method outline is shown on Appendix Fig. No. CP-10-12.

10.6.4 Pier Head construction

10.6.4.1 Pier Head construction outline

Main bridge pier head having 30m long be supported by steel supporting system sitting on pile cap and SPSP piles. Concreting procedure be divided into 3 pours. 1st be bottom slab, 2nd be web wall and 3rd be top slab.

Working sequence is shown below.



Source: Study Team

Figure 10.6.4-1 Working sequence of Pier head construction

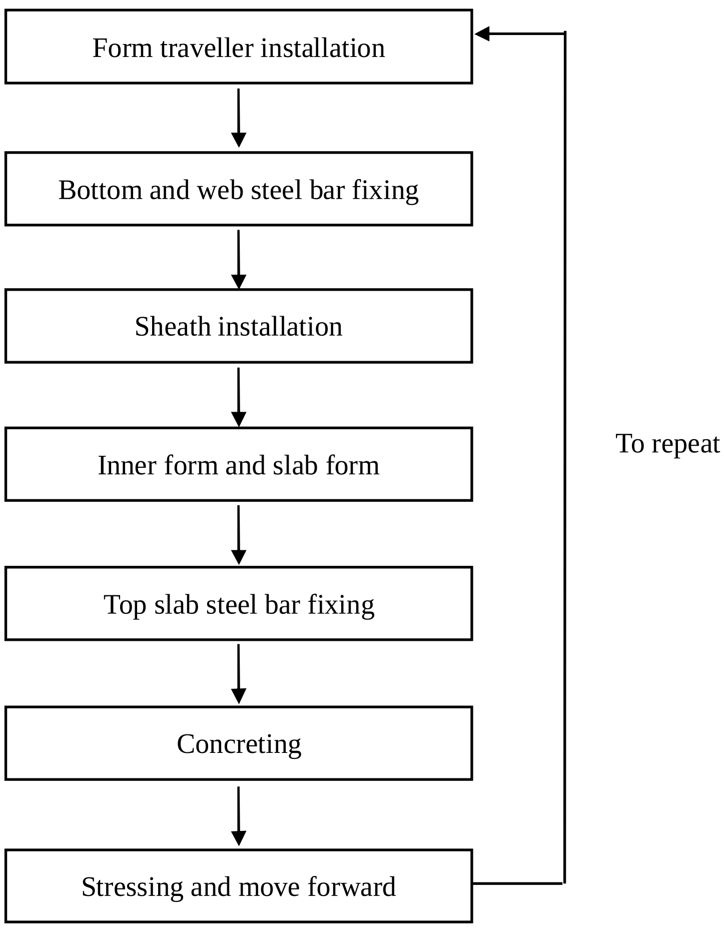
10.6.5 Main Bridge Girder Construction Method

10.6.5.1 Main Bridge girder construction outline

Main bridge girder be constructed using two sets of form traveler sitting on both end of pier head.

Form traveler be anchored on completed concrete structure and every span length be varied to suit equal weight as section of the girder vary(3m to 5m in length) so that external wall shutter be cut out after every pour. One form traveller serves for 14 blocks.

Construction sequence is shown below.



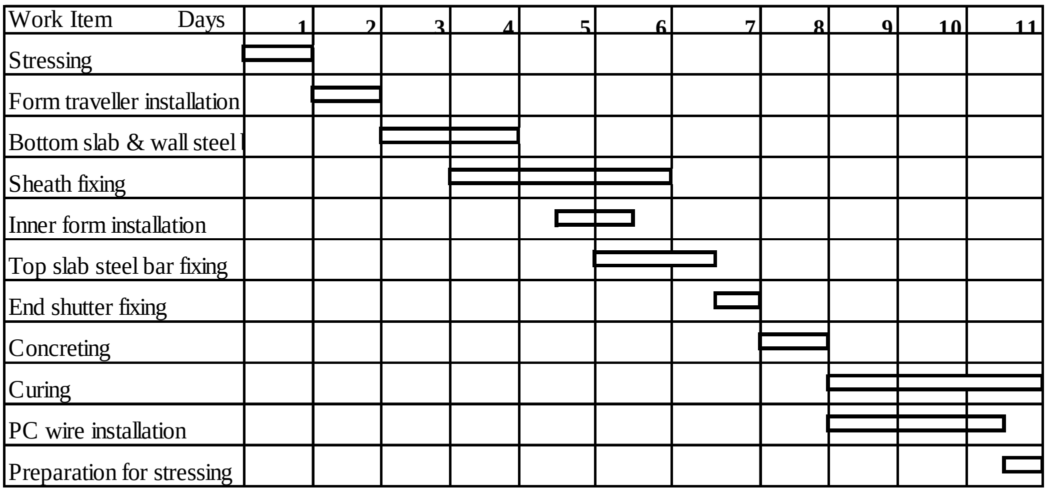
Source: Study Team

Figure 10.6.5-1 Construction sequence of Main bridge girder

Main Bridge girder construction method and form traveler are shown on Appendix Fig. No. CP-10-13 and CP-10-14.

10.6.5.2 Main Bridge Girder 1 block standard cycle time

Main Bridge construction cycle time is shown below.



Source: Study Team

Figure 10.6.5-2 Main Girder Construction Cycle Time

10.7 PROGRAM

10.7.1 Total construction period

Total construction period in this report is 36 months.

In comparison with 32 months construction period in Basic Design Report following additional requirement and time impact are taken.

Reasons	Time Impact
1.No site access road outside embankment structure is allowed	
Consequence-1 Road access road need to be replaced	2 months
Consequence-2 Drainage work is to be after pavement work	
2.Pavement structure design changed from Cement Treated Base Course to Asphalt Treated Base Course	2 months
Total	4 months

10.7.2 Basis of program

10.7.2.1 Documents referred

Program is made in accordance with the guide book published for estimation work for works under Ministry of Land, Infrastructure and Transport in Japan, similar guide book and JICA guide line.

Where items are not specified in the book working rate is established using available items with reasonable adjustment or work experiences under similar nature either in Japan or Vietnam.

10.7.2.2 Working efficiency

(1) Land work

In accordance with JICA guide line published for works under international cooperation project gross working time factor is specified as 1.35.

Hence gross working time be 1.35 x net working time.

(2) Marine work

a) The above guide line allows exceptional case such as wind or wave effect.

For this project wave height controls work efficiency and gross working factor of 2.26 is chosen.

Gross working time is 2.26 x net working time.

$$(1 \div 0.4428 = 2.26)$$

b) In accordance with the report issued by JICA study team in July 2010 Sec.7 Natural Conditions, 7.2.3 Meteorological Feature is described.

Occurrence factor of wave height less than 0.5m is 44.28%

c) Japanese published book for Marine work construction indicates limit of meteorological condition for marine work activities.

Recommended working condition for marine activities such as driving piles, concreting and transporting is under wave height of 0.5m

For reference extract of those books are shown below.

Table 10.7.2-1 Frequency in Occurrence of Normal Wave Height by Direction

Wave Direction	Wave Height (m)										Total	
	0 – 0.25		0.25 – 0.5		0.5 – 1.0		1.0 – 1.5		> 1.5			
	Nr	%	Nr	%	Nr	%	Nr	%	Nr	%	Nr	%
N	—	—	3	0.09	57	1.74	8	0.24	1	0.03	—	—
NE	—	—	0	0.00	47	1.43	16	0.49	0	0.00	—	—
E	—	—	104	3.60	844	25.71	63	1.92	5	0.15	—	—
SE	—	—	37	1.13	429	13.07	89	2.71	6	0.18	—	—
S	—	—	4	0.12	145	4.34	75	2.28	13	0.4	—	—
SW	—	—	0	0.00	10	0.30	5	0.15	1	0.03	—	—
W	—	—	0	0.00	1	0.03	0	0.00	0	0.00	—	—
NW	—	—	0	0.00	10	0.30	0	0.00	0	0.00	—	—
Total	1,226	37.34	228	6.94	1,547	47.12	256	7.80	26	0.79	3,283	100

Source: Report on Port Capacity [illegible] Plan in Northern Vietnam, September [illegible], Nippon Koei Co., Ltd. & Associates

Source: Study Team

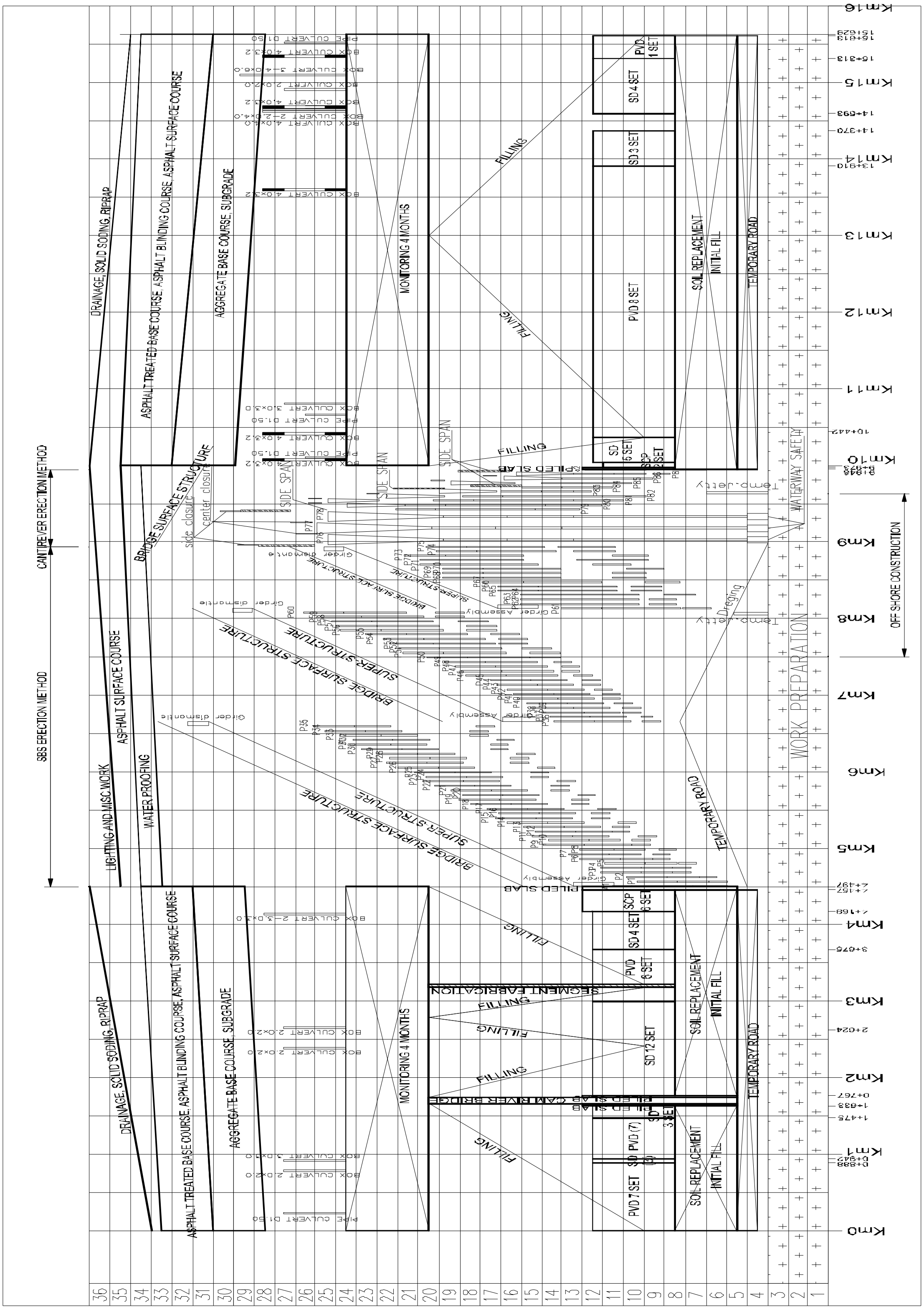
Table 10.7.2-2T Work Limit natural conditions for marine activity

Work Item \ Sea Condition		Wave height (m)	Wind Speed (m/s)	Max. Current (kt)	Rainfall (mm/day)
Transport	Self Propel	1.0	12	2	-
	Non self	0.6	10	2.5	9
Dredging	Pump	0.6	11	2	10
	Grab	0.6	11	2	10
Other Works	Anchoring	0.5	10	2	8
	Immersing Work	0.4	6	1	2
	Lifting	0.5	7	1	5
	Piling	0.4	8	1	4
	Filling	0.7	10	2	10
	Concreting	0.5	9	2	5
	Diving	0.5	8	1	10
SEP	SEP Operation	1.3	12	2	9
	SEP Moving	0.5	10	1	7

Source: Marine Construction Work

10.7.3 Construction Program

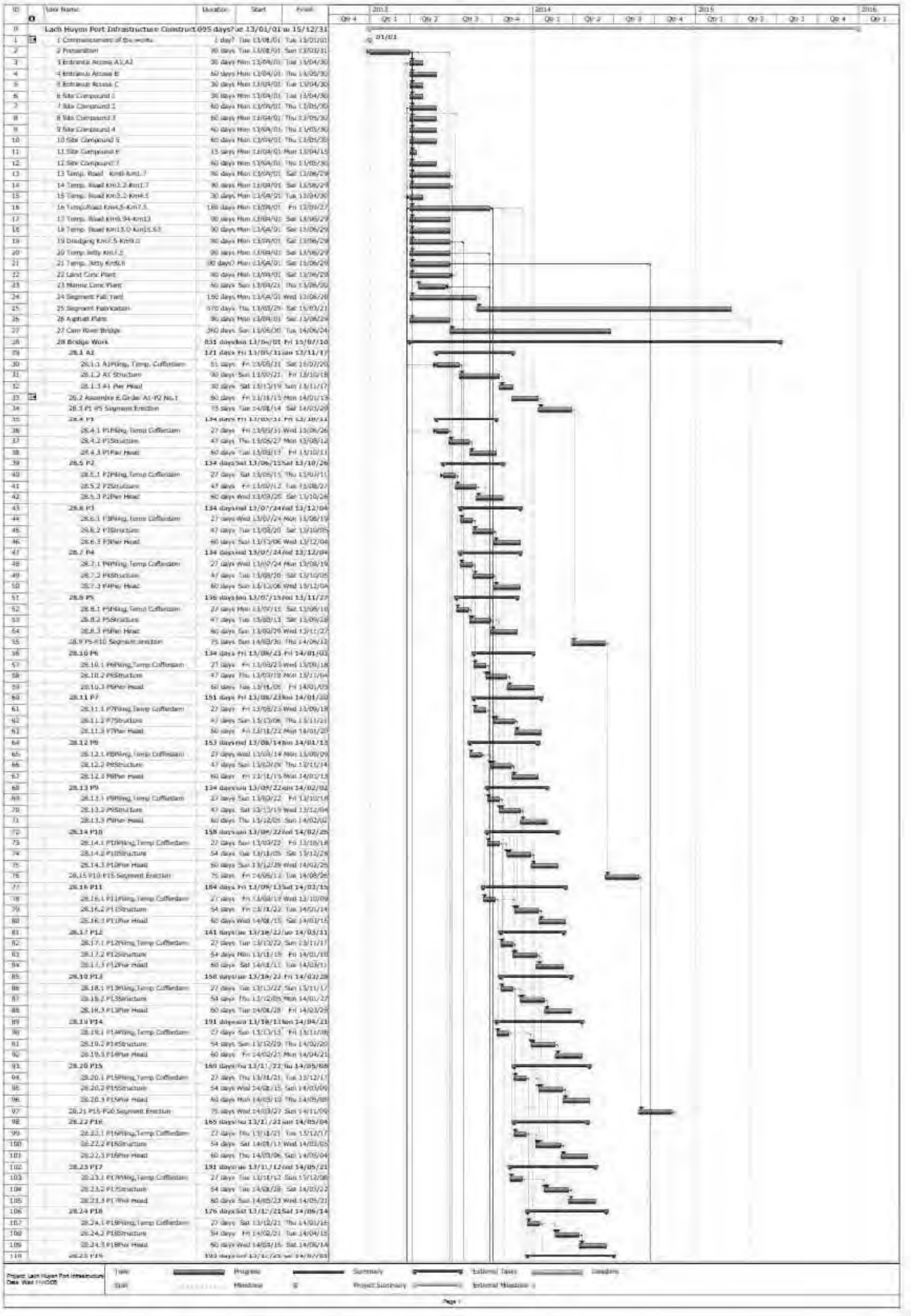
Time Space Diagram (Appendix CP10-15) attached shows overall construction sequence and major critical activities.

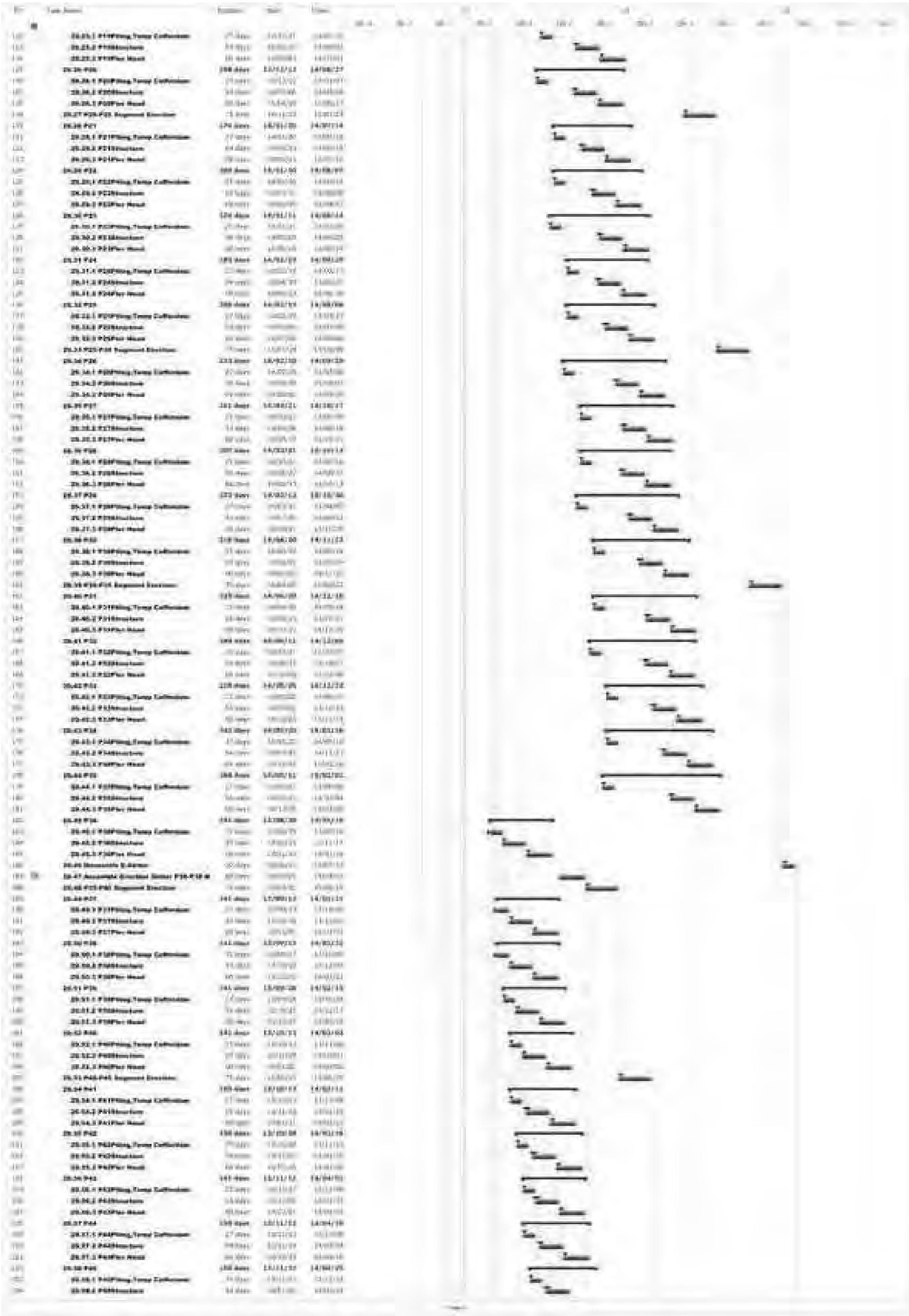


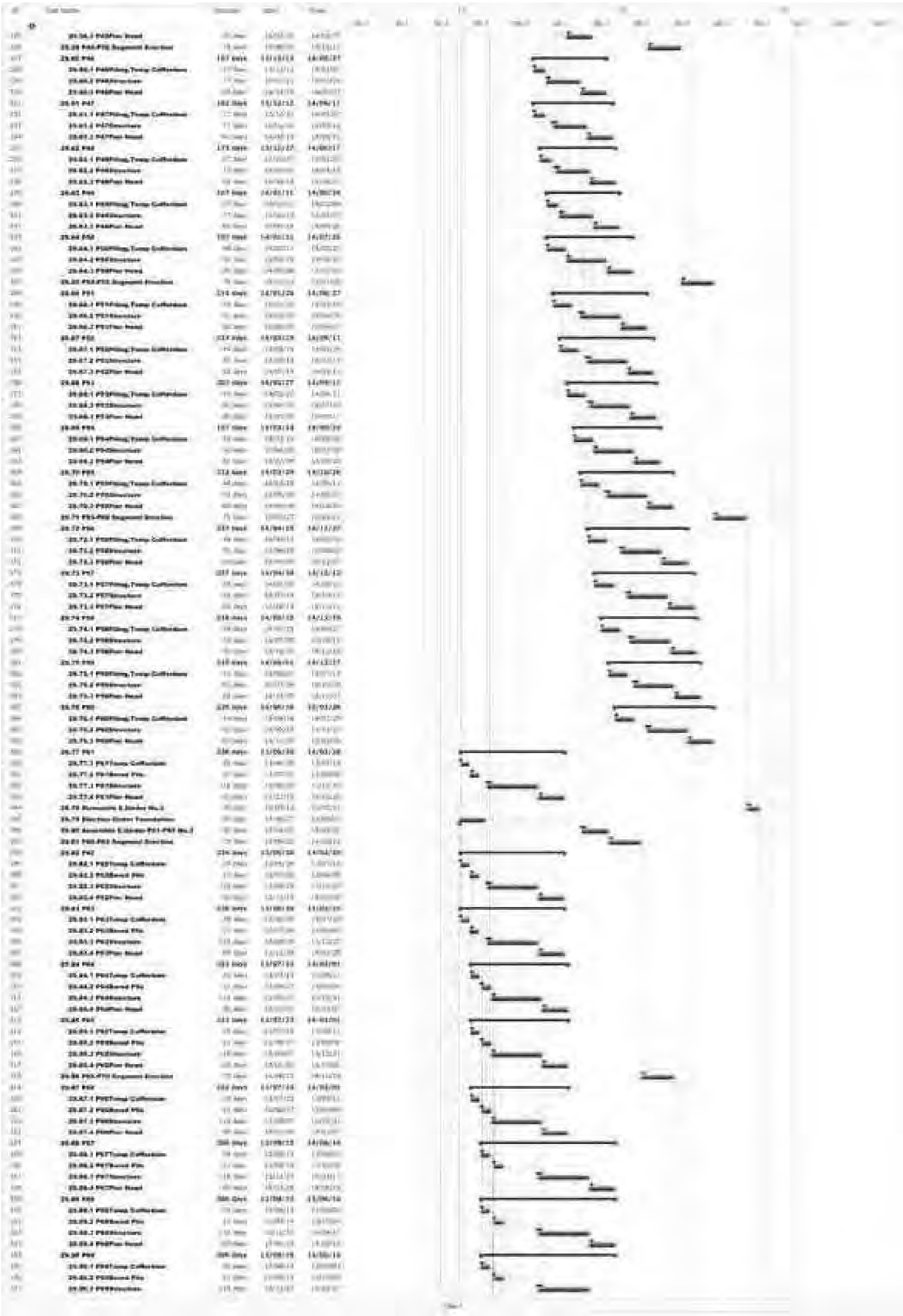
Source: Study Team Appendix CP10-15 Time Space Diagram

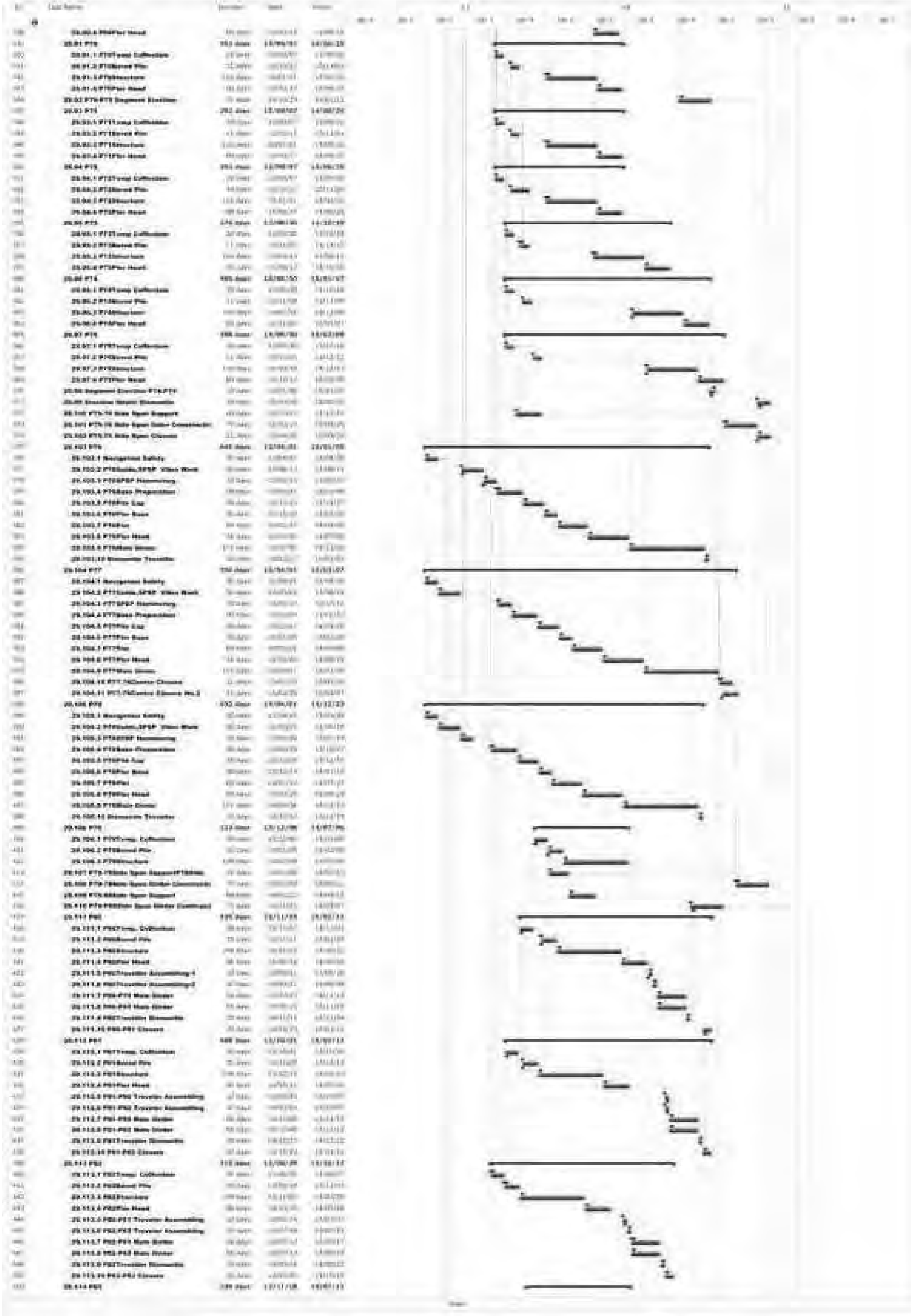
10.7.4 Network Program

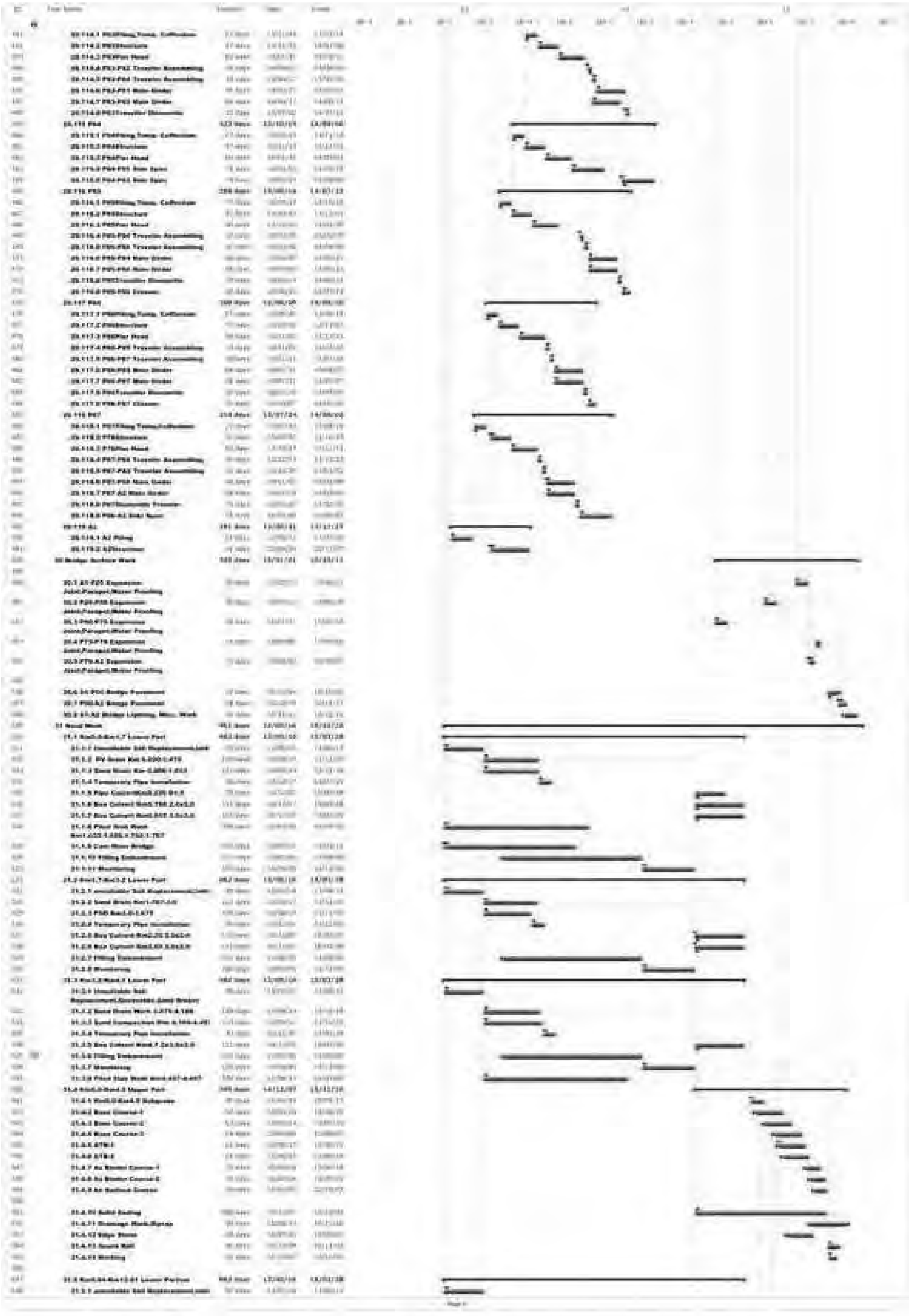
Detailed network program is shown below

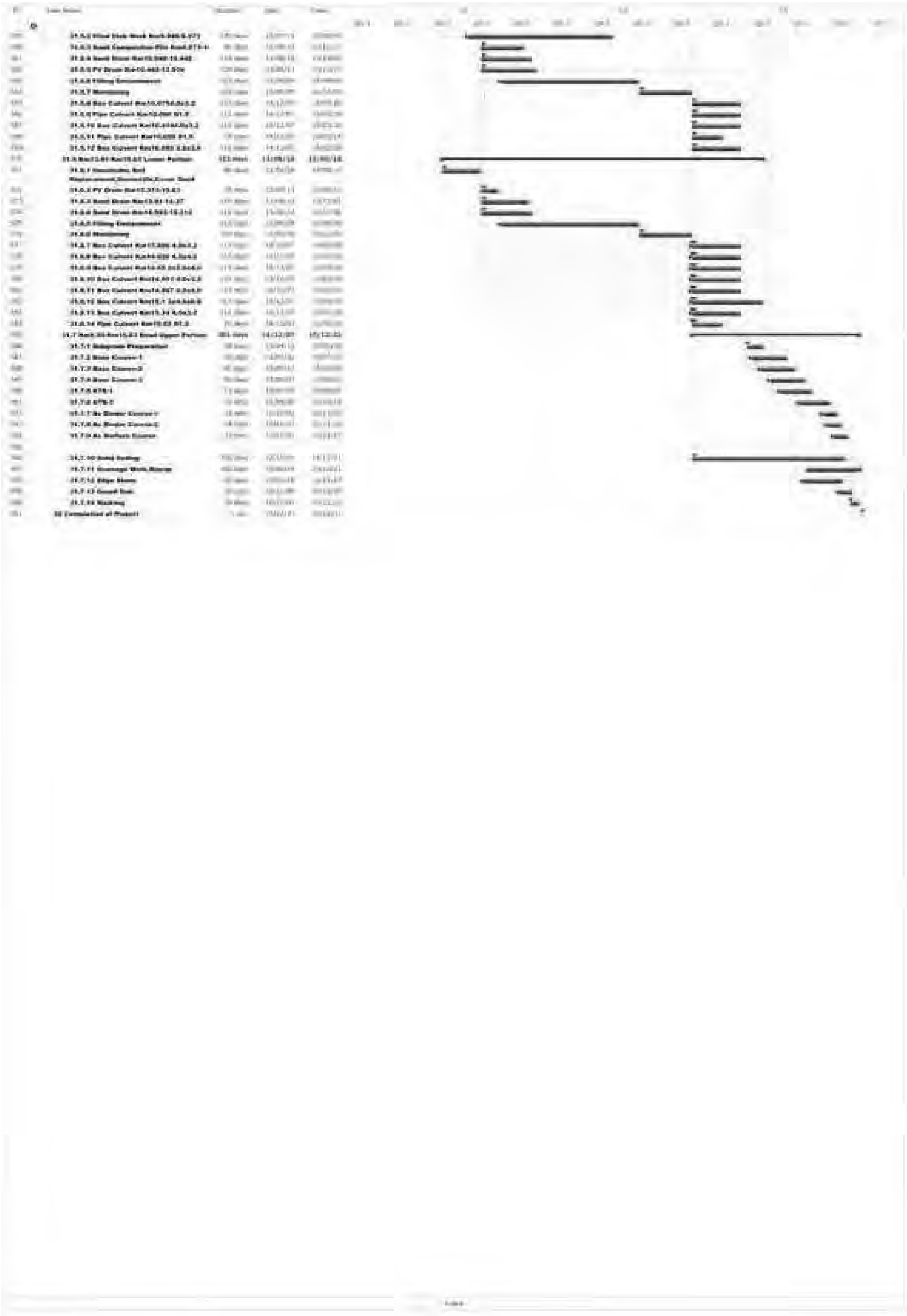












Source: Study Team.

Figure 10.7.4-1 Network Program

10.7.5 Work Days Calculation

Work days calculation for Pier 30, Pier 75, Pier 77 and road pavement work are shown on the following figures.

Place: P30 — Remark: Land Work

	Work Item	Q'ty	Unit	Working Rate	Unit	Net Working Day (8 Hr Work)	Net Working Day (10Hr Work)	Gross Woking Days X1.35	Party Nr.
1	Guide Pile Driving H400x15mx27nr	27	nr	12	nr/day	2.3	1.8	2.4	
2	Ditto Extraction	27	nr	43	nr/day	0.6	0.5	0.7	
3	Guide Frame Installation H300x160.6m	15.1	t	1.7	Days/10t	2.6	2.1	2.8	
4	Ditto Removal	15.1	t	1	Days/10t	1.0	0.8	1.1	
5	Steel Pipe Pile DrivingD1100,t12 L=46+3.25m, Top +2.35 α=1.22, β=1.24,Ta=5.1 T=7.71	16	nr	7.7	Days/10nr	12.3	9.9	13.3	
6	Steel Sheet Pile Driving Type III 10mx146nr	146	nr	25	nr/day	5.8	4.7	6.3	
7	Excavation 13X13X(+2.35+0.7)	515.5	m3	180	m3/day	2.9	2.3	3.1	
8	Strut & wailing	13.5	t	1.7	Days/10t	2.3	1.8	2.5	
9	Ditto Removal	13.5	t	1	Days/10t	1.4	1.1	1.5	
10	Pile Head Treatment	16	本	1	day/nr	16.0	12.8	4.3	4.0
11	Preparation for Pile Cap & Blinding C	1		1	sum		1.0	1.0	
12	Pile Cap Formwork	110	m2	3.2	day/100m2	3.5	2.8	3.8	
13	Pile Cap Steel Bar Fixing	30.2	t	0.2	day/t	6.0	4.8	6.5	
14	Pile Cap Concreting	302.5	m3						
	Casting	1	times	1	day/time	1.0	1.0	1.0	
	Curing	1	times	2	day/time	2.0	2.0	2.0	
15	Pier Working Platform	320	m2	2.5	day/100m2	8.0	6.4	8.6	
16	Pier Steel Bar Fixing	10.1	t	0.2	day/t	2.0	1.6	2.2	
17	Pier Formwork	147	m2	3.1	day/100m2	4.6	3.6	4.9	
18	Pier Concreting	102	m3						
	Casting	2	times	1	day/time	2.0	2.0	2.0	
	Curing	2	times	2	day/time	4.0	4.0	4.0	
19	Backfilling	120	m3	37	m3/day	3.2	2.6	3.5	
20	Sheet Pile Extraction	146	nr	43	nr/day	3.4	2.7	3.7	
	Total Working Days						72.3	**81.2**	

Source: Study Team

Figure 10.7.5-1 Work Days Calculation for Pier 30 Substructure Works

Working Days Calculation Sheet

Place: P75 — Remark: Marine Work

	Work Item	Q'ty	Unit	Working Rate	Unit	Net Working Day (8 Hr Work)	Net Working Day (12Hr Work)	Gross Woking Days X2.26	Party Nr.
1	Guide Pile Driving H400x15mx14nr	14	nr	12	nr/day	1.2	0.8	1.8	
2	Ditto Extraction	14	nr	43	nr/day	0.3	0.2	0.5	
3	Guide Frame Instaalation H300x96m	16.45	t	1.7	Days/10t	2.8	1.9	4.2	
4	Ditto Removal	16.45	t	1	Days/10t	1.0	0.7	1.5	
5	Working Platform Pile H400x15mx	6	nr	12	nr/day	0.5	0.3	0.8	
6	Ditto Extraction	6	nr	43	nr/day	0.1	0.1	0.2	
7	Working Platform Pile H300x300x12.5x8本 H150x150x12.5x12本	14.1	t	1.7	Days/10t	2.4	1.6	3.6	
8	Ditto Removal	14.1	t	1	Days/10t	1.0	0.7	1.5	
9	Steel Sheet Pile Driving Type III 40m	160	nr	25	nr/day	6.4	4.3	9.6	
10	Bored Pile D1500, 42m	12.0	nr	1.96	day/nr	23.5	15.7	21.2	
11	Excavation	156.3	m3	180	m3/day	0.9	0.6	1.3	
12	Strut&Wailing	45.3	t	1.7	日/10t	3.9	2.6	5.8	2.0
13	Ditto Removal	45.3	t	1	Days/10t	4.5	3.0	6.8	
14	Pile Head Treatment	21.195	m3	0.5	m3/day	8.0	5.3	12.1	4.0
15	Preparation for Pile Cap & Blinding C	1		1	sum		1.0	1.0	
16	Pile Cap Formwork	124	m2	3.2	day/100m2	4.0	3.2	7.2	
17	Pile Cap Steel Bar Fixing	37.4	t	0.2	day/t	7.5	6.0	13.5	
18	Pile Cap Concreting	374	m3						
	Casting	2	time	1	day/time	2.0	2.0	2.0	
	Curing	2	time	2	day/time	4.0	4.0	4.0	
19	Pier Working Platform	504	m2	2.5	day/100m2	6.3	5.0	11.4	2.0
20	Pier Steel Bar Fixing	31.1	t	0.2	day/t	6.2	5.0	11.2	
21	Pier Formwork	306	m2	3.1	day/100m2	9.5	7.6	17.2	
22	Pier Concreting	311.6	m3						
	Casting	4	time	1	day/time	4.0	4.0	4.0	
	Curing	4	time	2	day/time	8.0	8.0	8.0	
23	Backfill	57.5	m3	37	m3/day	1.6	1.0	2.3	
24	Sheet Pile Extraction	160	nr	43	nr/day	3.7	3.0	6.7	
	Total Working Days						87.4	**159.4**	

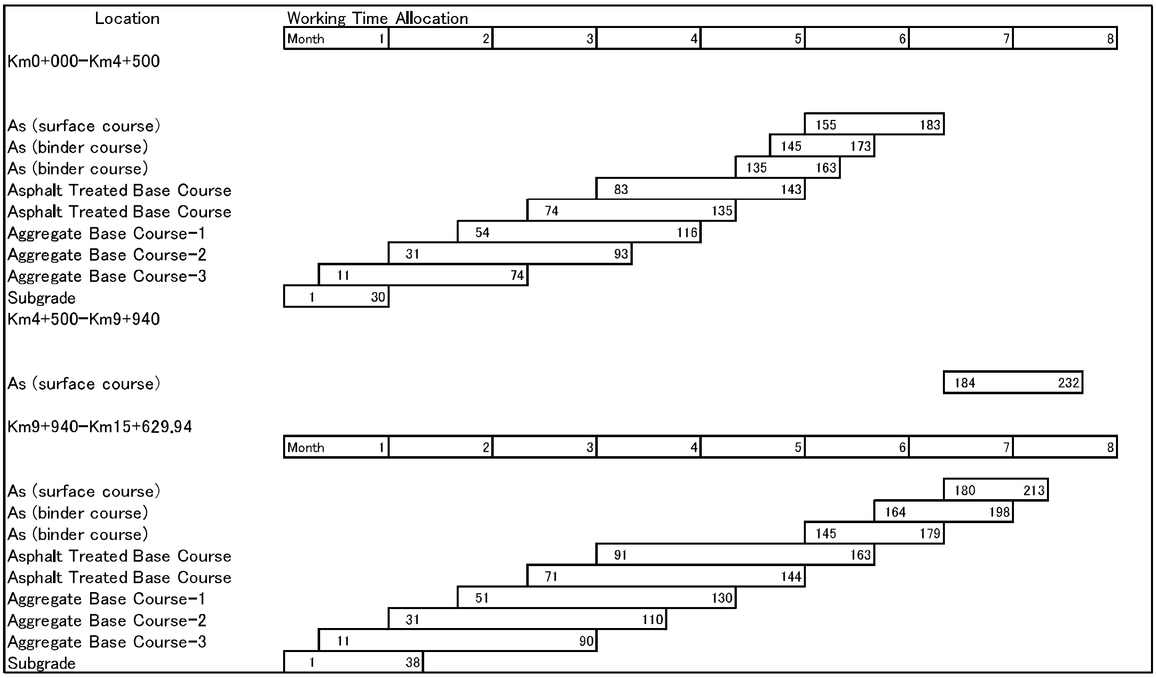
Source: Study Team

Figure 10.7.5-2 Work Days Calculation Sheet for Pier 75

Place: P77						Remark: Marine Work			
	Work Item	Q'ty	Unit	Working Rate	Unit	Net Working Day (8 Hr Work)	Net Working Day (20 Hr Work)	Gross Woking Days X2.26	Party Nr.
1	Guide Pile Driving H400x35mx52nr	52	nr	7	nr/day	7.4	3.0	6.7	
2	Ditto Extraction	52	nr	30	nr/day	1.7	0.7	1.6	
3	Guide Frame Instalation H300x156m	14.7	t	1.7	Days/10t	2.5	1.0	2.3	
4	Ditto Removal	14.7	t	1	Days/10t	1.5	0.6	1.3	
5	SPSP Driving-1 L=49.8m	44	nr	11.82	day/10nr	52.0	20.8	47.0	
6	SPSP Driving-1 L=48.8m	14	nr	11.82	day/10nr	16.5	6.6	15.0	
7	SPSP JOINT Removal of Soil	1696.2	m	250	m／day	3.4	1.4	3.1	2 Parties
8	SPSP Joint Grouting	2191.2	m	250	m／day	4.4	1.8	4.0	2 Parties
9	Excavation Inside Pipe	452.2	m3	53	m3／day	8.5	3.4	7.7	
10	Concreting Inside Pipe	497.4	m3	125	m3／day	4.0	1.6	3.6	
11	Excavation Inside Shell	1587	m3	143	m3/day	11.1	4.4	10.0	
12	Strut & Wailing Installation	68.4	t	4	t/day	17.1	6.8	15.5	
13	Concreting for Strut & Wailing	44.9	m3	11	m3/day	4.1	1.6	3.7	
14	Stone Replacement	198	m3	19	m3/day	10.4	4.2	9.4	
15	Base Concrete in water	595	m3	125	m3/day	4.8	1.9	4.3	
16	Stud	700	nr	200	nr/day	3.5	1.4	3.2	
17	Pile Head Treatment	14	nr	1	nr/day	7.0	2.8	6.3	2 Parties
18	Pile Cap Steel Bar	65.9	t	0.2	day/t	13.2	10.5	14.2	
19	Pile Cap Concreting	659	m3						
	concreting	3	time	1	day/time	8.0	8.0	8.0	
	curing	3	time	2	day/time	16.0	16.0	16.0	
20	Pier Base Working Platform	387	m2	2.5	day/100m2	9.7	3.9	8.7	
21	Pier Base Steel Bar Fixing	66	t	0.2	day/t	13.2	5.3	7.1	
22	Pier Base Formwork	315	m2	3.1	day/100m2	9.8	3.9	5.3	
23	Pier Base Concreting	660	m3						
	concreting	3	time	1	day/time	3.0	3.0	3.0	
	curing	3	time	2	day/time	6.0	6.0	6.0	
24	Pier Support Structure	166.7		1.7	Days/10t	28.3	11.3	25.6	
25	Ditto Remove	166.7		1	Days/10t	16.7	6.7	15.1	
26	Pier Form Work	437	m2	3.1	day/100m2	6.8	2.7	6.1	2 Parties
27	Pier Steel Bar Fixing	44	t	0.2	day/t	4.4	1.8	4.0	2 Parties
28	Pier Concreting	442	m3						
	concreting	6	time	1	day/time	6.0	6.0	6.0	
	curing	6	time	2	day/time	12.0	12.0	12.0	
29	Pier Head Supporting Structure	196		1.7	Days/10t	16.7	6.7	15.1	2 Parties
	Ditto Remove	196		1	Days/10t	9.8	3.9	8.9	2 Parties
30	Pier Head Formwork External	928.2	m2	3.1	day/100m2	28.8	11.5	26.0	
31	Pier Head Formwork Internal	707.58		3.7	day/100m2	26.2	10.5	23.7	
31	Pier Head Steel Bar Fixing	64	t	0.2	day/t	12.8	5.1	11.6	
32	Pier Head Concreting	636	m3						
	concreting	3	time	1	day/time	3.0	3.0	3.0	
	curing	3	time	2	day/time	6.0	6.0	6.0	
33	SPSP Cut & Remove	40	nr	2.3	day/10nr	9.2	3.7	0.0	
34	Form Traveller Installation	1	LS	11.0	Day	11.0	11.0	11.0	
	Ditto Removal	1	LS	6.0	Day	6.0	6.0	6.0	
35	Main Span Girder Construction	14	BLK	11.0	day／BLK	154.0	154.0	154.0	
36	Center Closure	1	LS	31.0	day	31.0	31.0	31.0	
37	Side Span Closure	1	LS	31.0	day	31.0	31.0	31.0	
38	Form Traveller Removal	1	LS	6.0	Day	6.0	6.0	6.0	
	Total Working Days						450.4	**614.9**	

Source: Study Team

Figure 10.7.5-3 Time Calculation for Pier 77 Works



Location	Pavement Structure				Daily Work Rate		Working Days	
1 Km0+000−Km4+500								
	W=9.75x2 L=4500	incl. 5% waste	Thickness	Daily Output			NET Working	Gross W
	m2	ton	mm	m2/set	t/set	t/2set	Days	Days
As (surface course)	88830	12,983.4	60	2300	320.2	640.3	20.3	27.4
As (binder course)	90090	15,362.1	70	2300	373.5	747.0	20.6	27.8
As (binder course)	91350	15,577.0	70	2300	373.5	747.0	20.9	28.1
Asphalt Treated Base Course	92430	27,019.1	120	1100	306.2	612.5	44.1	59.6
Asphalt Treated Base Course	93510	27,334.8	120	1100	306.2	612.5	44.6	60.3
Aggregate Base Course−1	102510		150	1100			46.6	62.9
Aggregate Base Course−2	102510		180	1100			46.6	62.9
Aggregate Base Course−3	102510		180	1100			46.6	62.9
Subgrade	102510		300	2300			22.3	30.1
2 Km4+500−Km9+940								
	m2	ton						
As (surface course)	165000	22968	60	2300	336.168	672.336	35.9	48.4
3 Km9+940−Km15+629.94								
As (surface course)	112320.6	15635.0	60	2300	320.2	640.32	24.4	33.0
As (binder course)	113913.8	18499.6	70	2300	373.5	747.04	24.8	33.4
As (binder course)	115507	18758.3	70	2300	373.5	747.04	25.1	33.9
Asphalt Treated Base Course	116872.6	32537.3	120	1100	306.2	612.48	53.1	71.7
Asphalt Treated Base Course	118238.2	32917.5	120	1100	306.2	612.48	53.7	72.6
Aggregate Base Course−1	129618.2		150	1100	334.4		58.9	79.5
Aggregate Base Course−2	129618.2		180	1100	355.3		58.9	79.5
Aggregate Base Course−3	129618.2		180	1100	355.3		58.9	79.5
Subgrade	129618.2		300	2300			28.2	38.0

Source: Study Team

Figure 10.7.5-4 Time Calculation for Road Pavement Works

10.8 Machine List

In accordance with the working method and site condition suitable type and capacity of machineries are selected.

10.8.1 Machinery selection study

Selection study is shown on the table below.

Table 10.8.1-1 Machine Selection Study

	Plant and Machine	Selection Study
1	Concrete Plant	
1-1	Land Concrete Plant	90m3/hr plant is selected. (Study) Total concrete volume for land batching plant is 73,000m3 and detail as below. Approach Bridge 22000 m3 Segment 46000 Box Culvert 2000 Others 3000 Total 73000 1) Average supply is 7000m3/month which is daily 320m3 av 2) Most critical demand is 5 segments +pier pile cap concrete 180+310=490m3 per day Therefore 81m3/hr supply is required.
1-2	Marine Concrete Plant	2 no. 60m3/hr are selected. (Study) Total concrete volume for marine batching plant is 60,000m3 Bored Pile 18,500 Pier Structure 38,500 Super Structure 13,000 Box Culvert etc 10,000 Total 80,000 1) In average 6500m3/month 296m3/day 2) Most critical demand is 980 times concreting in 13months. Daily demand is 3.4 locations for marine batching plant to move. Therefore 2 marine batching plant is required. Most critical volume demand is 310m3 in one day. Therefore 52m3/hr supply is required.
2	Asphalt Plant	200t/hr plant each for Hai An and Cat Hai work is selected. (Study) Most critical demand is asphalt binder coursea and sourface course works in six locations Daily demand is 3x2300m2x(0.07+0.06)x1.05x2.32=t Considering supply situation daily output is controled to 2185t/day Therefore 200t/hr supply is required.

3 Crawler Crane

Working Location Work Item		Lifting Weight	Hanging Height	Boom Length	Distance	Required Capacity	Land or Marine	Selected Capacity
A1-P50 Steel Pile Driving		41.2+1.2=42.4t	25+11+5+1 =42m	51m	14m	150t-43t	Land	150t
P50-P75, P79-P82 Bored Pile		12t	45+5+1 =51m	60m	20m	120t-18.6t	Marine	120t
P50-P75, P79-P82 Sheet Pile Driving		8.3t	30+5+1 =36m	40m	20m	120t-19.5t	Marine	120t
P76-P78 SPSP Driving		41.2+1.2=42.4t	42m	51m	20m	200t-43t Referred to NHAT TAN BRIDGE	Marine	300t
Temp. Jetty		42.4t	42m	51m	12m	150t-43t	Land	150t

Source: Study Team

10.8.2 Machine list

In accordance with machine selection study and the construction schedule machine allocation is shown on the table below.

Table 10.8.2-1 Machine allocation plan

No.	Work Item	Work Description	Plant Item	Plant Capacity	No.
1	Land Plant Area				
1-1	Concrete Plant	Hai An	Concrete Batching Plant	90m3/hr	1
			Truck Mixer	5.5m3	10
			Wheel Loader	3m3	2
			Generator	250kva	2
			Compressor	5.5m3	1
			Concrete Pump Car	90m3/hr	5
1-2	Asphalt Plant	Hai An. Cat Hai	Asphalt Plant	200t/hr	2
			Dump Truck	10t	24
			Generator	250kva	2
			Compressor	5.5m3	2
			Wheel Loader	3m3	2
1-3	Segment Fabrication Plant		Segment Fabrication Bed		5
		Hai An	Gantry Crane	30mx80t	2
			Gantry Crane	12mx7.5t	2
			Tower Crane	180tm	3
			Steam Curing Facility		1
			Mulch Axle Trailer	80t	5
			Folk Lift		3
			Generator	250kva	2
			Compressor	5.5m3	3
		Segment Lifting Place(P50)			
			Gantry Crane	30mx80t	1
1-4	Machine Yard		Crawler Crane	80t	1
			Generator	100kva	1
			Compressor	5.5.m3	2
			Welding Machine		4
			Folk Lift		2
			Diesel Lorry	2000L	2
			Flat Lorry	20t	5
			Water Tanker	2000L	5
1-5	Temp. Jetty		Crawler Crane	200t	2
			Passenger Boat		10
2	Marine Concrete Plant		Concrete Batching Plant	60m3/hr	2
			Wheel Loade	2m3	2
			Back Hoe	0.3m3	2
			Generator	250kva	2
			Compressor	5.5m3	2
			Barge	2000t	2
			Barge	1000t	2
			Concrete Pump	90m3/hr	2
3	Temporary Work				
3-1	Ent. Access Road		Bull Dozer(swamp type)	21t	5
			Back Hoe	0.8m3	5
			Dump Truck	10t	12
			Tire Roller	10t	5
			Vibration Roller	5t	5

No.	Work Item	Work Description	Plant Item	Plant Capacity	No.
3-2	Temp. Compund		Bull Dozer(swamp type)	21t	9
			Back Hoe	0.8m3	9
			Dump Truck	10t	10
			Tire Roller	10t	8
			Vibration Roller	5t	4
			Crawler Crane	70t	2
			Vibration Hammer	160kw	2
			Barge	1000t	4
			Sand Pump	6 inch	19
			Water Pump	3 inch	13
3-3	Site Access Road	Km0.0-Km4.5 & Km9.94-Km15	Bull Dozer(swamp type)	21t	8
			Back Hoe	0.8m3	8
			Dump Truck	10t	30
			Tire Roller	10t	8
			Vibration Roller	5t	8
			Sand Pump	6 inch	20
			Backhoe	0.5m3	40
			Generator	30kva	20
			Air Compressor	3.5m3	20
			Barge	100t	20
			TagBoat		8
			Anchor Boat		8
			Non-staging piler		10
			Crawler Crane	35t	10
			Welding set		10
			Generator	30kva	10
		Km4.5-Km7.5	Sand Pump	6 inch	10
			Backhoe	0.5m3	16
			Generator	100kva	8
			Generator	30kva	5
			Air Compressor	3.5m3	8
3-4			Crawler crane	30t	8
			Crawler crane	120t	7
			Crawler crane	150t	4
			Diesel Pile Hamma	4.5t	4
			Vibro Hamma	240kva	4
			welding set		8
			Barge	500t	15
			Barge	100t	13
			Tag boat		5
			Anchor boat		5
	Temporary Jetty Construction		Crawler Crane	150t	4
			Crawler Crane	150t	4
			Haydraulic VibHammer	160kw	2
			Barge	1000t	4
			Barge	1000t	4
			Tug Boat	250hp	1
			Anchor Boat		1
			Generator	200kva	2
			Compressor	5m3	2
			Welding Set		8

No.	Work Item	Work Description	Plant Item	Plant Capacity	Nos.		Location					
					A1-P50	P51-P60	P61-P75	P76-P78	P79-P82	P83-A2		
4	Pier Piling Work											
			Crawler Crane	300t				2				
			Crawler Crane	250t				2				
			Crawler Crane	150t	6					1		
			Crawler Crane	120t		6	6		4	1		
			Crawler Crane	100t						1		
			Vibration Hammer	240kw				2				
			Vibration Hammer	120kw	6					1		
			Vibration Hammer	60Kw		3						
			Hydraulic Hammer	15t				2				
			Hydraulic Hammer	12t	6	3				1		
			Hammer Sleeve		6	3		2		1		
			Flat Truck	10t	6					1		
			Trailer Truck	150t	6					1		
			Generator	200kva				2		1		
			Generator	100KVA	6	3	3		2			
			Compressor	5m3	6	3	3	2	2	1		
			Welding set		6	3	3	2	2	1		
			Bored Pile Reverse Circulation	D1500			3		2			
			Bentnite Mixing Plant				3		2			
			Barge	2000t				2				
			Barge	2000t				2				
			Barge	1000t		3	3		2			
			Barge	1000t		3	3		2			
			Tug Boat			1	1	1	1			
			Anchor Boat			1	1	1	1			
			Grout Pump					2				
			Grout Mixer					2				
5	Pier Structure				Nos.		Location					
					A1-P49	P50-P60	P61-P75	P76-P78	P79-P82	P83-A2		
			Hydraulic Crane	25t	9					2		
			Crawler Crane	150t	9	2	6	3	5			
			Crawler Crane	100t	9							
			Generator	50kva	9	2	6	3	5	2		
			Compressor	5m3	9	2	6	3	5	2		
			Welding Set		9	2	6	3	5	2		
			Concrete Vibrator		9	12	36	18	30	12		
			Flat Truck	20t	9					2		
			Lifting Truck	10t	9					2		
			Backhoe	0.8m3	9					2		
			Dump Truck	10t	16					4		
			Grab Hammer			2	6	3	5			
			Barge	1000t		2	6	3	5			
			Tug Boat	250hp		1	1	1	1			
			Anchor Boat			1	1	1	1			

No.	Work Item	Work Description	Plant Item	Plant Capacity	Nos./Loacation		
					A1-P25	P25-P50	P50-P75
6	Super Structure Approach BridgeA1-P75						
6-1	Girder Construction		Erection Girder Type-1		1	1	
			Erection Girder Type-2				1
6-2	Erection Girder Assebling Foundation and Assembling		Crawler Crane	150t	1	1	
			Vibration Hammer	160kw	1	1	1
			Generator	200kva	1	1	1
			Welding Set		1	1	1
			Flat Truck	20t	1	1	1
			Floating Crane	300t			1
			Crawler Crane	200t			1
			Barge	1000t			1
			Barge	1000t			1
			Tug Boat	250hp			1
			Anchor Boat				1
6-3	Erection Girder Temporary Stock Foundation		Crawler Crane	200t			1
			Vibration Hammer	160kw			1
			Generator	200kva			1
			Welding Set				1
			Crawler Crane	150t			1
			Barge	1000t			1
			Barge	1000t			1
			Tug Boat	250hp			1
			Anchor Boat				1
6-4	Segment Erection		Crawler Crane	100t	1	1	
			Generator		1	1	1
			Compressor		1	1	1
			Cable Pusher		1	1	1
			Grout Mixer		1	1	1
			Grout Pump		1	1	1
			Crawler Crane	150t			1
			Barge	1000t			1
6-5	Erection Girder Dismantling		Crawler Crane	150t	2	2	2
			Crawler Crane	100t	2	2	
			Trailer	50t	4	4	
			Welding Set		4	4	
			Crawler Crane	200t			2
			Barge	1000t			2
			Tug Boat	250hp			1
			Anchor Boat				1
			Floating Crane	300t			1

No.	Work Item	Work Description	Plant Item	Plant Capacity	Nos./Loacation		
					P75-P79	P79-A2	
7	Super Structure P75-A2						
7-1	Girder Construction		Form Traveller Type-1		4		
			Form Traveller Type-2			4	
			Crawler Crane	150t	2	1	
			Crawler Crane	100t		1	
			Generator	100kva	2	2	
			Compressor	5m3	2	2	
			Cable Pusher		4	4	
			Grout Pump		4	4	
			Grout Mixer		4	4	
			Barge	1000t	1	1	
			Tug Boat	250hp	1	1	
			Anchor Boat		1	1	
					P75,P79	P84,A2	
7-2	Side Span Foundation Construction						
			Crawler Crane	200t	1		
			Crawler Crane	150t		1	
			Vibration Hammer	160kw	1	1	
			Generator	100kva	1	1	
			Compressor	5m3	1	1	
			Welding Set		1	1	
			Barge	1000t	1		
			Barge	1000t	1		
			Tug Boat	250hp	1		
			Anchor Boat		1		
			Trailer	50t		2	
7-3	Segment Temporary Stock Platform						P50-P75
			Crawler Crane	200t			1
			Vibration Hammer	160kw			1
			Generator	100kva			1
			Compressor	5m3			1
			Welding Set				1
			Barge	1000t			1
			Barge	1000t			1
			Tug Boat	250hp			1
			Anchor Boat				1

No.	Work Item	Work Description	Plant Item	Plant Capacity	Nos./Loacation		
					Km0.0-Km4.5	Km10.0-Km15.63	
8	Unsuitable Soil Replacement						
			Bulldozer(swampy type)	D60	10	10	
			Buckhoe	0.8m3	10	10	
			Dump Truck	10t	5	5	
			Sand Pump	6inch	4	4	
			Generator		4	4	
			Backhoe	1.4m3	1	1	
			Dump Truck	10t	15	15	
			Bulldozer	21t	2	2	
9	Geo-textile and Cover sand						
			Backfoe	1.4m3	1	1	
			Dump Truck	10t	15	15	
			Bulldozer	D60	2	2	
			Flat Lorry	20t	2	2	
10	PV Drain		PV Drain machine		13	9	
			Bulldozer	D60	4	3	
			Flat Lorry	20t	6	4	
11	Sand Drain		Sand Drain Machine		19	12	
			Bulldozer	D60	19	12	
			Dump Truck	10t	10	6	
			Backhoe	1.4m3	1	1	
12	Sand Compaction Pile		Sand Compaction Pile Machine		6	2	
			Bulldozer	D60	6	2	
			Dump Truck	10t	4	2	
			Backhoe	1.4m3	1	1	
					Km1.7	A1	A2
13	Piled Slab Piling		Piling Rig	120t	4	3	2
			Hydraulic Piling Hamma	3.5t	4	3	2
			Crawler Crane	50t	4	3	2
			Truck Crane	20t	2	2	2
			Flat Lorry	20t	2	2	2
			Generator	100kva	4	3	2
			Compressor	3.5m3	2	2	2
			Welding Set		4	3	2
14	CAM River Bridge						Km1.7
			Crawler Crane	150t			1
			Vibration Hammer	160kw			1
			Hydrulic Hammer	12t			1
			Generator	100kva			1
			Compressor	5m3			1
			Welding Set				1
			Barge	1000t			1
			Tug Boat	250hp			1
			Anchor Boat				1
			Crawler Crane	100t			1
			Backhoe	0.8m3			1
			Cable Pusher				1
			Grout Mixer				1
			Grout Pump				1

No.	Work Item	Work Description	Plant Item	Plant Capacity	Nos./Loacation		
					Km0.0-4.5	Km10-15	
15	Temporary Bridge				Km1.7&3.2	Km15.1	
			Crawler Crane	150t	1	1	
			Crawler Crane	100t	1	1	
			Vibration Hammer	160kw	1	1	
			Generator	100kva	1	1	
			Compressor	5m3	1	1	
			Welding Set		1	1	
			Barge	1000t	1	1	
			Tug Boat	250hp	1	1	
			Anchor Boat		1	1	
			Crawler Crane	100t	1	1	
16	Box Culvert Construction						
			Backhoe	0.8m3	5	5	
			Crawler Crane	50t	5	5	
			Dump Truck	10t	5	5	
			Water Pump	6inch	5	5	
			Generator	50kva	5	5	
			Compressor	5m3	5	5	
			Flat Truck	20t	5	5	
17	Embankment Filling Work						
			Backhoe	1.4m3	8	8	
			Dump Truck	10t	100	100	
			Bulldozer	D6	6	6	
			Tire Roller	20t	6	6	
			Vibration Roller	5t	6	6	
18	Subgrade						
			Motor Grader	3.1m	2	2	
			Tire Roller	20t	2	2	
			Vibration Roller	3t	2	2	
19	Aggregate Base Course-1st layer						
			Motor Grader	3.1m	2	2	
			Macadam Roller	12t	2	2	
			Tire Roller	20t	2	2	
			Vibration Roller	3t	2	2	
			Backhoe	0.8m3	1	1	
			Dump Truck	10t	8	10	

No.	Work Item	Work Description	Plant Item	Plant Capacity	Nos./Loacation		
					Km0.0-Km4.5	Km10.0-Km15.63	
20	Aggregate Base Course-2nd layer						
			Motor Grader	3.1m	2	2	
			Macadam Roller	12t	2	2	
			Tire Roller	20t	2	2	
			Vibration Roller	3t	2	2	
			Backhoe	0.8m3	1	1	
			Dump Truck	10t	8	10	
21	Aggregate Base Course-3rd layer						
			Motor Grader	3.1m	2	2	
			Macadam Roller	12t	2	2	
			Tire Roller	20t	2	2	
			Vibration Roller	3t	2	2	
			Backhoe	0.8m3	1	1	
			Dump Truck	10t	8	10	
22	Asphalt Treated Base Course-1						
			Finisher	3.5m	2	2	
			Macadam Roller	12t	2	2	
			Tire Roller	20t	2	2	
			Vibration Roller	3t	2	2	
			Dump Truck	10t	8	10	
23	Asphalt Treated Base Course-2						
			Finisher	3.5m	2	2	
			Macadam Roller	12t	2	2	
			Tire Roller	20t	2	2	
			Vibration Roller	3t	2	2	
			Dump Truck	10t	8	10	
24	Asphalt Binder Course						
			Asphalt Finisher	3.5m	2	2	
			Tire Roller	20t	2	2	
			Macadam Roller	12t	2	2	
			Vibration Roller	3t	2	2	
			Dump Truck	10t	12	12	
25	Asphalt Surface Course						Km4.5-10
			Asphalt Finisher	3.5m	2	2	2
			Tire Roller	20t	2	2	2
			Macadam Roller	12t	2	2	2
			Vibration Roller	3t	2	2	2
			Dump Truck	10t	12	12	14

No.	Work Item	Work Description	Plant Item	Plant Capacity	Nos./Loacation		
					Km0.0-4.5	Km10-15	Km4.5-Km10
26	Drainage						
			Backhoe	0.3m3	2	2	
			Dump Truck	10t	4	4	
			Soil Compactor	500kg	10	4	
			Flat Truck	20t	1	1	
27	Solid Soding & Riprap						
			Backhoe	0.3m3	10	10	
			Bulldozer	D3	10	10	
			Dump Truck	10t	10	10	
			Soil Compactor	500kg	4	4	
28	Gurdrail						
			Gurdrail Piler		1	1	
			Flat Truck	20t	1	1	
29	Curve Stone						
			Flat Truck	20t	1	1	
30	Parapet Wall						
			Flat Truck	20t	1	1	1
			Truck Crane	20t	1	1	1
31	Lighting		Flat Truck	20t	1	1	1
			Truck Crane	20t	1	1	1
32	Navigation Safety						
			Monitaring Station Barge				2
			Speed Boat				2
			Tug Boat				1

Source: Study Team