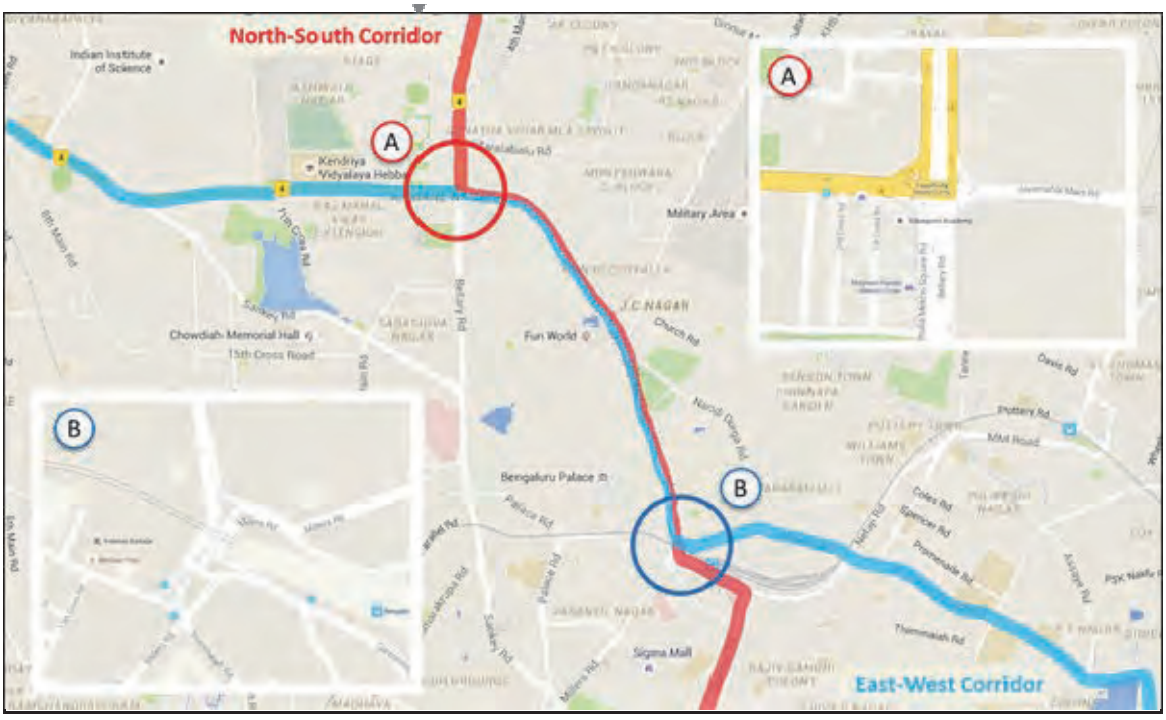
9 STUDY ON VIADUCT CONSTRUCTION PROJECT IN BANGALORE

9.1 Introduction

In this chapter, it is mentioned about proposed structures, result of economic analysis and environmental assessment of the viaduct construction project in Bangalore based on “Chapter 4 Environmental and Social Impact”, “Chapter 6 Japanese Advanced Technology can be Apply” and “Chapter 7 Traffic Forecast Demand and Economic Analysis”.

The target area of this project is as follows.



Source: JICA Study Team

Figure 9.1.1 Location Map of Target Area

9.2 Natural and Social Features

9.2.1 Social Aspect

Population in Karnataka which is the project site of the viaduct construction project in Bangalore and its capital city are shown in Table 9.2.1.

Table 9.2.1 Population of Karnataka State and Bangalore

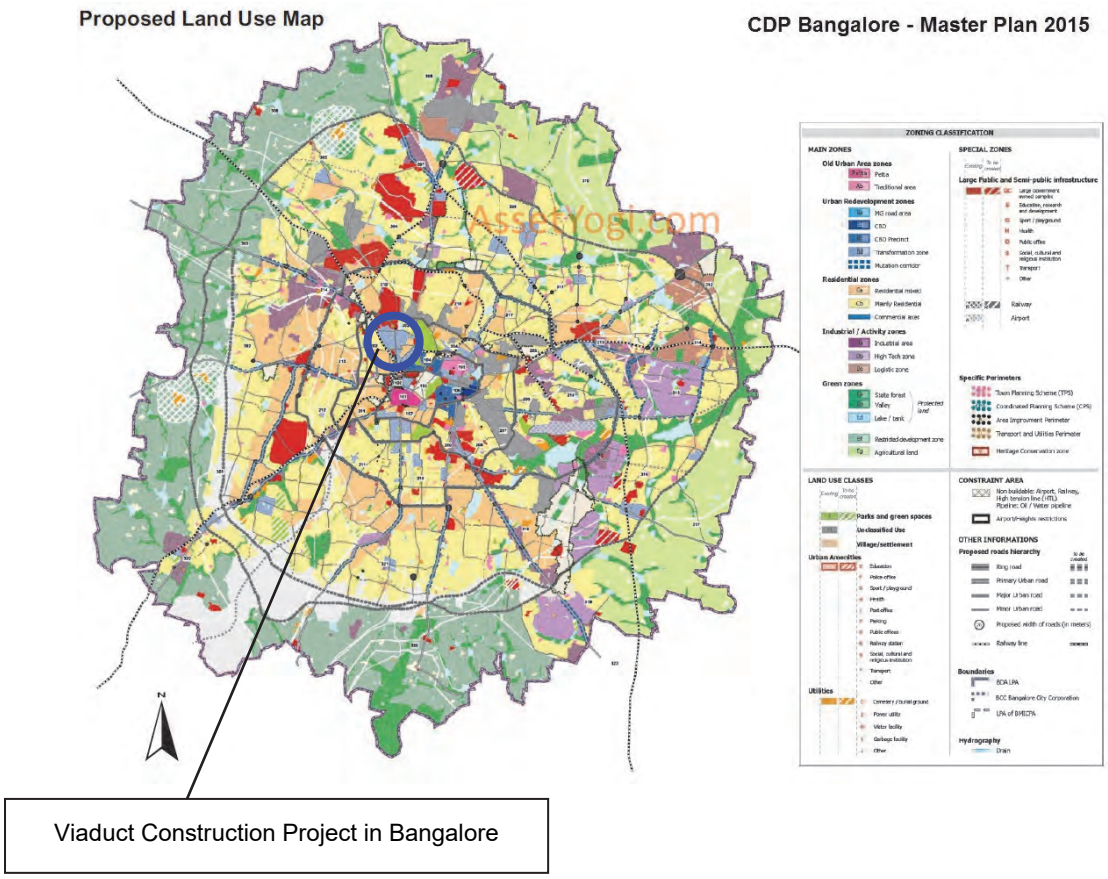
State	Population (2011)	Capital city	Population (2011)
Karnataka	61,095,297	Bangalore	9,621,551

Source: 2011 Census Data, Government of India, Ministry of Home Affairs

9.2.2 Natural Aspect

The land use map of the project sites are shown in Figure 9.2.1.

The situation of land use of the project sites is mainly urban and commercial areas for the project. And there are a lot of buildings in the project site.



Source: CDP Bangalore Master Plan

Figure 9.2.1 Land Use Map and the Location of the Project Site in Bangalore (Viaduct Construction Project in Bangalore)

9.3 Proposed Structure for Viaduct Construction Project in Bangalore

9.3.1 Introduction

The study on structure is being carried out for the two Junctions connecting between the East-West Corridor and North-South Corridor and a normal section is overlapped for both the East-West Corridor and North-South Corridor as shown in Figure 9.1.1. The study on structure is carried out in consideration of Japanese Advanced Technology which is explained in Chapter 6.

9.3.2 Study on Overlapped Section for Both the East-West and North-South Corridors

Since the surrounding environment (construction along congested road, same number of lanes and so on) and geological condition (depth of expected bearing layer) are the same as the construction site in Delhi, the study result can be expected to be the same as in Delhi as explained in chapter 8.3.2

9.3.3 Study on Junction Structure

(1) Introduction

As mentioned in a previous chapter, 2 Junctions are studied. Locations of the Junctions are shown in Figure 3.3.2. Due to issuance of the New Land Act 2013, land acquisition work became very difficult. Therefore, land use status is carefully considered during the study of the Junction Structure.

Design speed: 50km/h and minimum curve radius: 50m are applied for study of Junction alignment.

(2) Study of Junction A

1) Policy of Study

This Junction is to connect between the North-South Corridor and the East-West Corridor. Both the North-South Corridor and East-West Corridor will be double deck structures and connect with the intersection from the east side. After the intersection the North-South Corridor runs toward the north, on the other side, the East-West Corridor runs toward the west.

According to information from Local Consultant, another viaduct is planned for construction from the southern side to this intersection, therefore, this third viaduct is also considered in this Junction Structure study.

Two alternatives are studied for Junction A as follows, and land status of Junction A is shown in Figure 3.3.3.

Alternative 1: No consideration of surrounding land status, and a compact size of Junction
Alternative 2: Consideration of surrounding and status

2) Study of Alternative 1

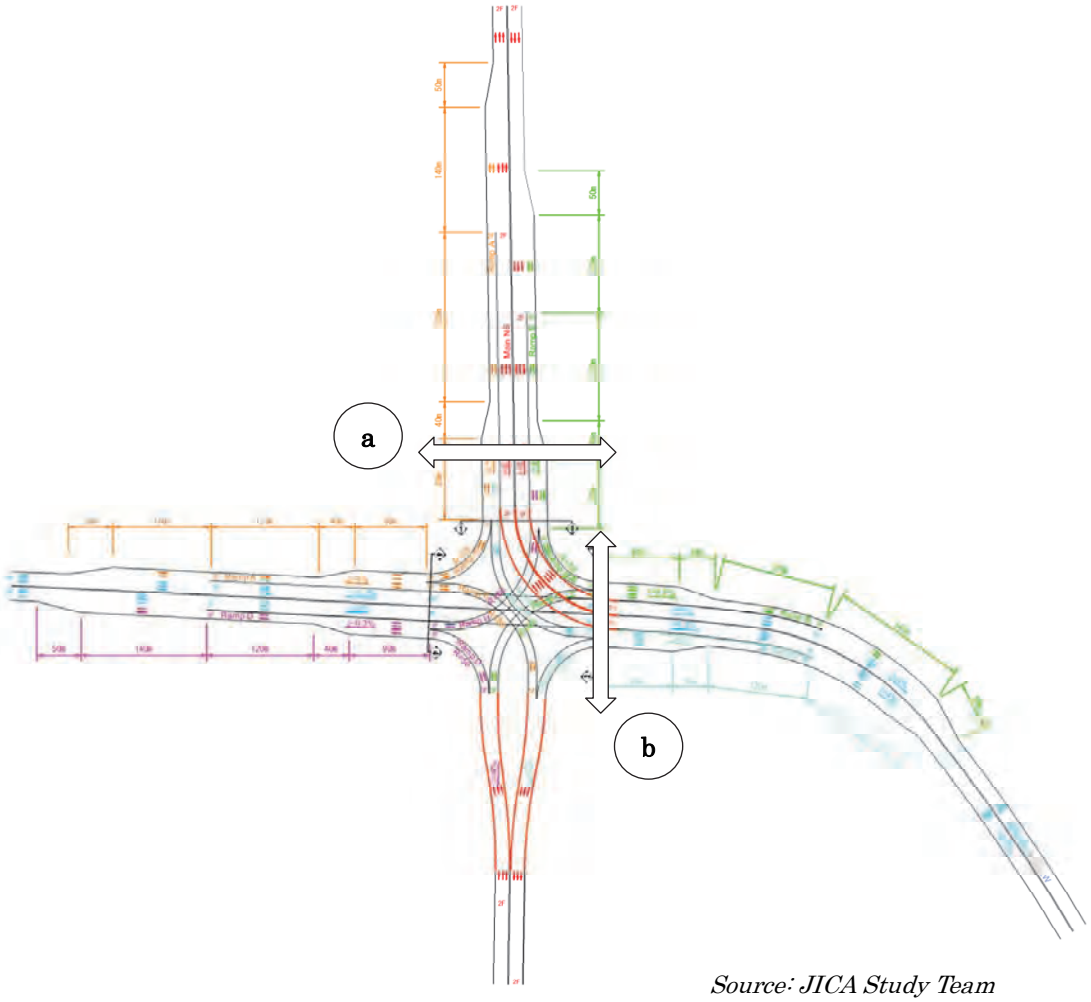
A plan of Alternative 1 is shown in Figure 9.3.1. This is almost the same Junction type as the "Hokko Junction" in the Hanshin Expressway, Japan. A photograph of Hokko Junction is shown in Figure 9.3.2.

Source: JICA Study Team/Google

Figure 9.3.1 Plan of Alternative 1

Source: Wikipedia

Figure 9.3.2 Photograph of Hokko Junction (Reference)



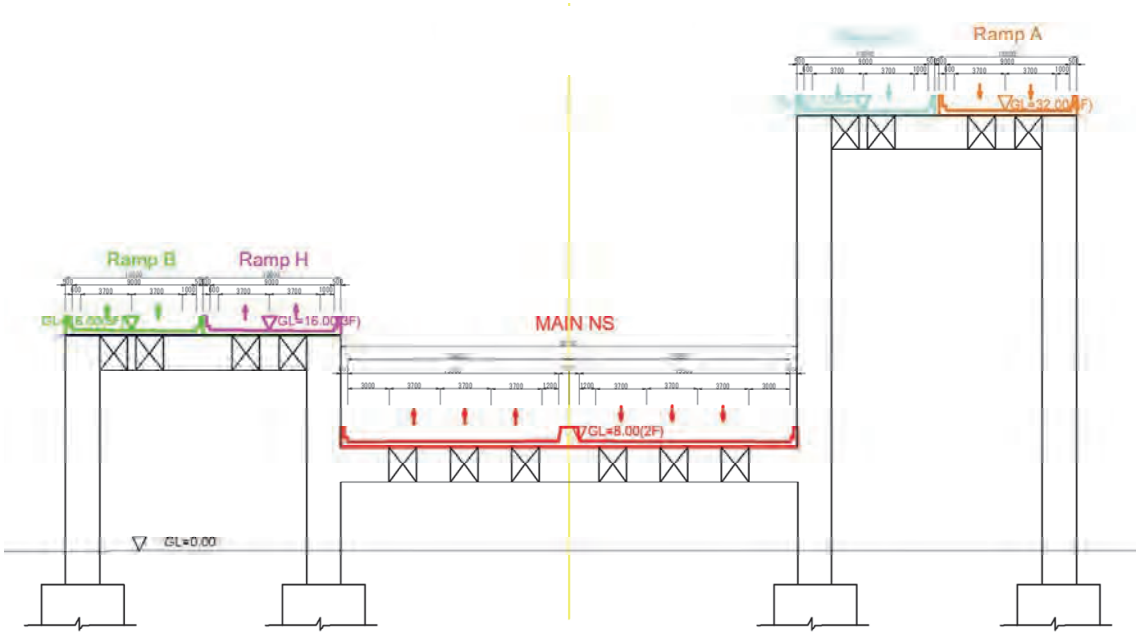
Source: JICA Study Team

Figure 9.3.3 Alignment of Alternative 1

Alignment of Alternative 1 is shown in Figure 9.3.3.

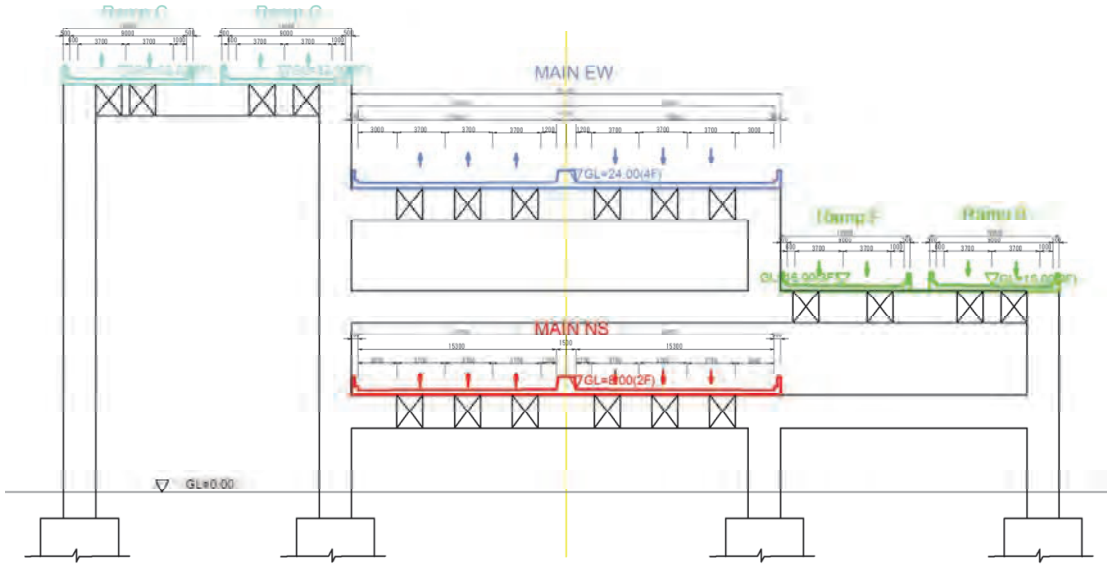
There is no access between the north direction (North-South Corridor) and the south direction (to be implemented by a different project) in this alternative. It means 10 access directions can be achieved by this alternative out of a total 12 access directions. Currently, the Junction structure composes 5 layers, however, if a 6 or 7 layer structure is applied, it is possible to achieve all 12 access directions.

Due to the very complicated alignment of the Junction, the bridge structure, especially the pier column structure, becomes very complicated also. Cross section of a and b are shown in Figure 9.3.4 and Figure 9.3.5, respectively. Width of both cross sections become wider than existing width, therefore, additional land acquisition will be necessary unless necessary number of lanes is reviewed.



Source: JICA Study Team

Figure 9.3.4 Cross Section a



Source: JICA Study Team

Figure 9.3.5 Cross Section b

3) Study of Alternative 2

A plan of Alternative 2 is shown in Figure 9.3.6. This alternative is studied giving consideration to the land status as shown in Figure 3.3.3.

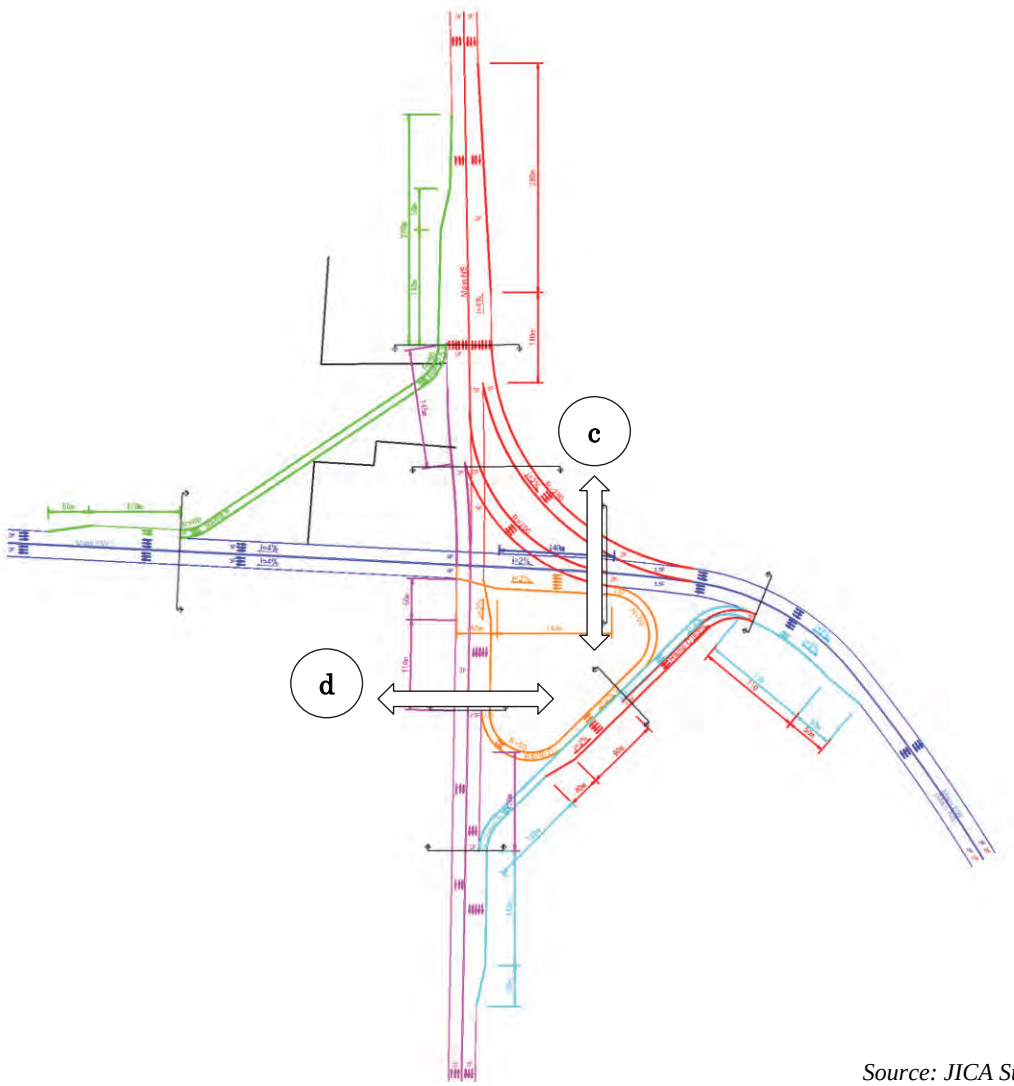
Source: JICA Study Team/Google

Figure 9.3.6 Plan of Alternative 2

Alignment of Alternative 2 is shown in Figure 9.3.7.

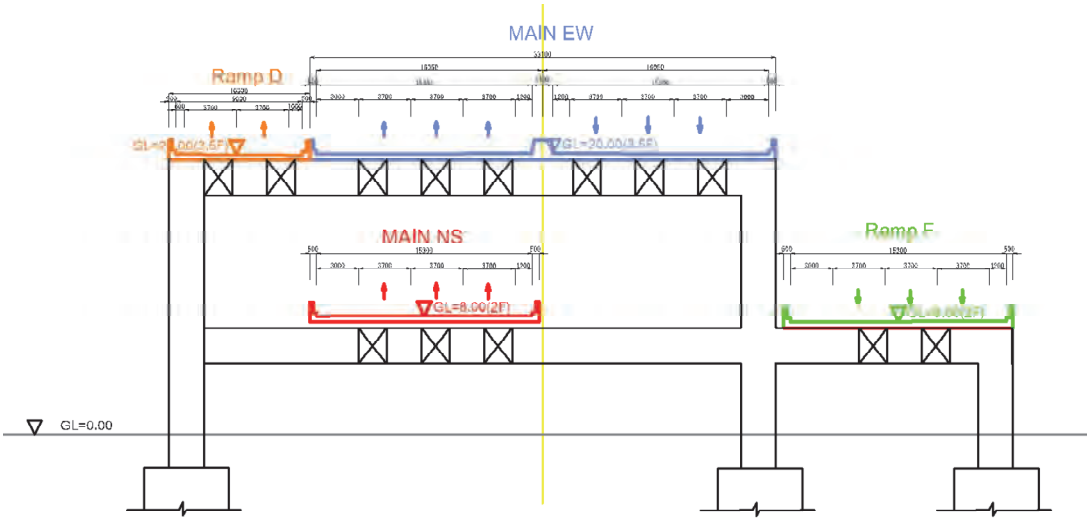
Due to restrictions on land use in the south western area, 3 access directions (South to East, South to West and West to South) cannot be available in this alternative, thus, the available number of access directions is 9 out of 12.

Due to the very complicated alignment of the Junction, the bridge structure, especially the pier column structure, becomes very complicated also. Cross section of c and d are shown in Figure 9.3.8 and Figure 9.3.9, respectively. Width of both cross sections become wider than existing width, therefore, additional land acquisition will be necessary unless necessary number of lanes is reviewed.



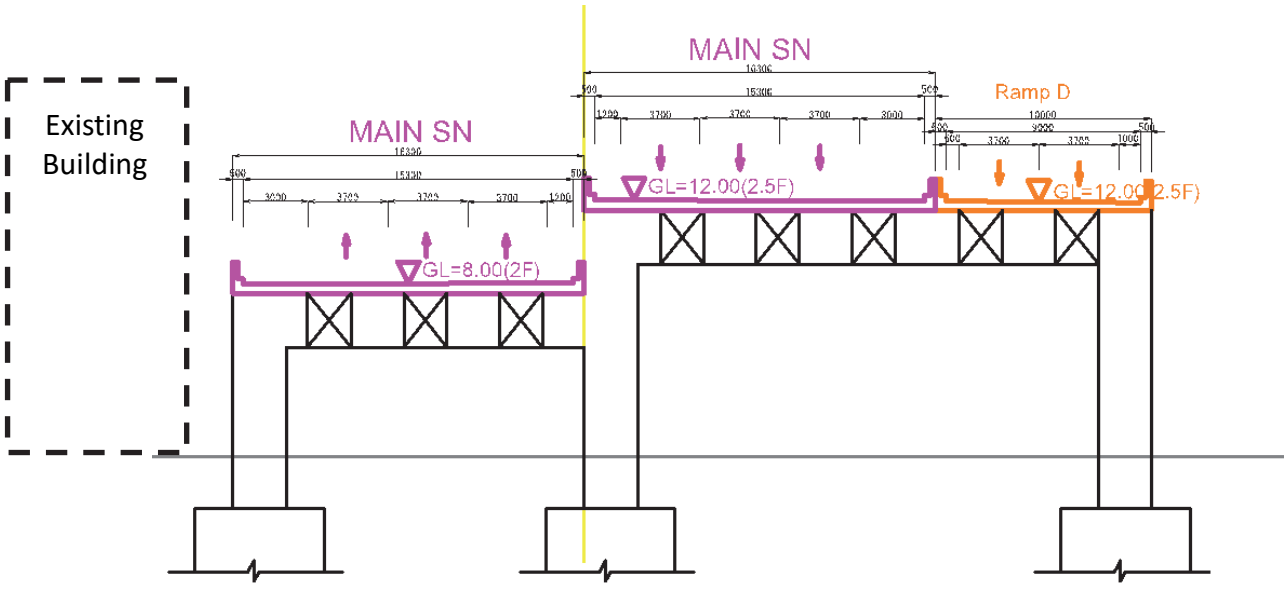
Source: JICA Study Team

Figure 9.3.7 Alignment of Alternative 2



Source: JICA Study Team

Figure 9.3.8 Cross Section c



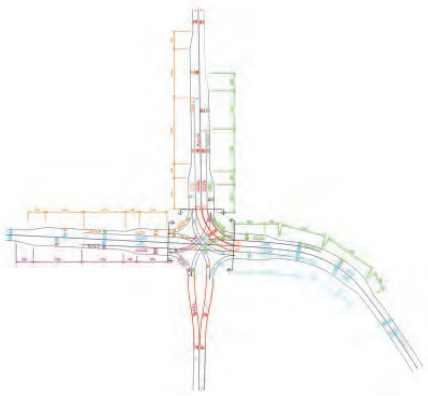
Source: JICA Study Team

Figure 9.3.9 Cross Section d

4) Comparison of Alternatives for Junction Structure

Comparison table for alternatives of Junction Structure is shown in Table 9.3.1.

Table 9.3.1 Comparison of Junction Structure

	Alternative 1	Alternative 2
Plan View		
Feature	✓ No restriction on land use, to be compact size of junction	✓ Consideration is given to actual land use situation, to be larger size of junction
Access	✓ 10 accesses out of 12 accesses can be accommodated. (2 more accesses can be accommodated, if number of layers increases)	✓ 9 accesses out of 12 accesses can be accommodated. (South - East, South - West and West - South direction cannot be accommodated)
Advantage	✓ Size of junction becomes small.	✓ There are not many points to be overlapped. ✓ Possible to apply simpler structure compared with Alternative 1.
Disadvantage	✓ Due to 5 story junction, pier column shape becomes very complicated.	✓ Required land area becomes large.

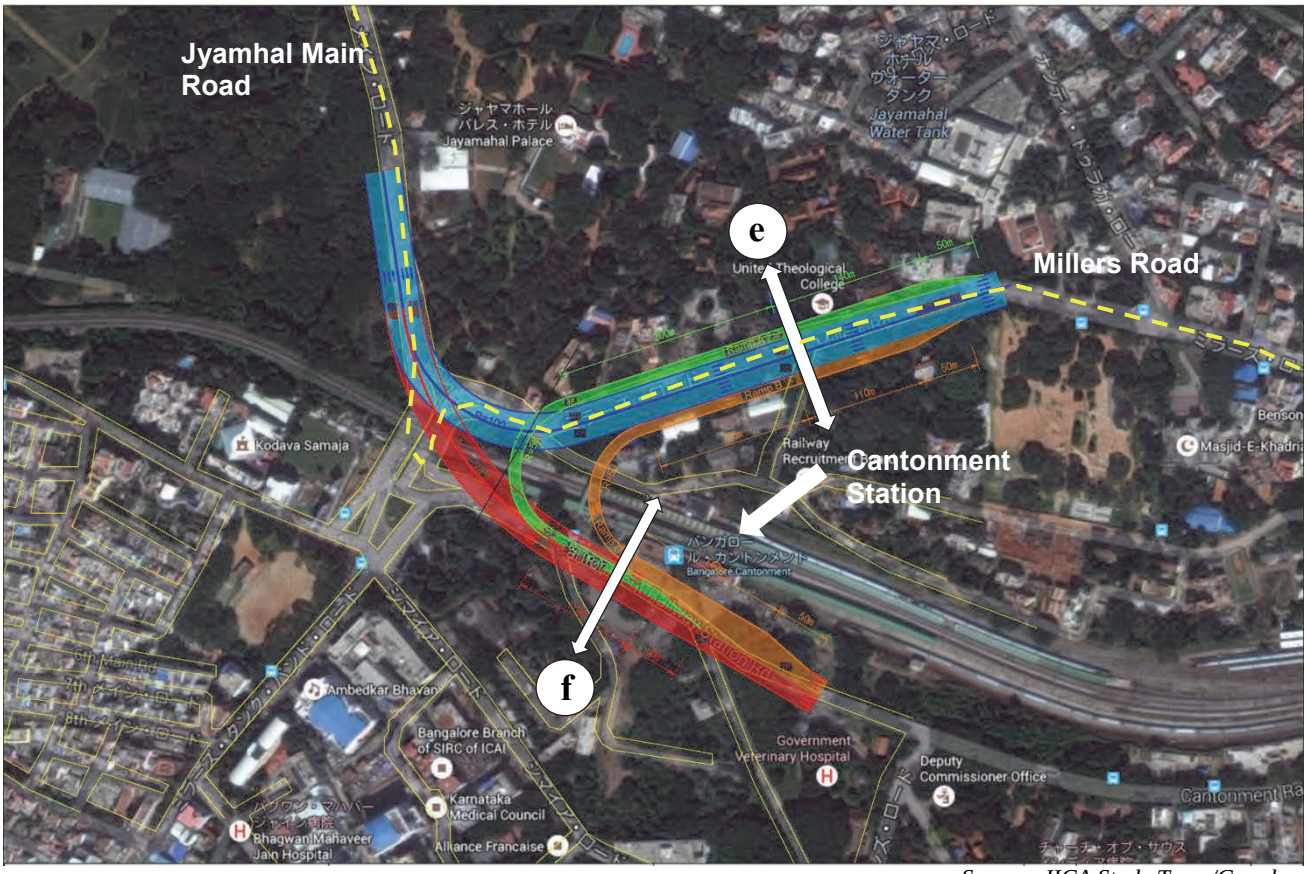
Both alternatives have advantage and disadvantage. Ramp structure becomes very complicated. It is considered to become more reality in planning by applying steel pier column and new foundation type (PC Well or Rotary Penetration Steel Pile) which can minimize negative impact surrounding environment.

Currently, 6 lanes carriageway is required, however, width of viaduct is wider than the existing road width. Therefore, it is required to review necessary number of lanes based on traffic volume analysis result in consideration of total road network at next stage.

(3) Study of Junction B

This Junction is to connect between the North-South Corridor and the East-West Corridor. Both the North-South Corridor and the East-West Corridor are double deck structures and connect to the intersection from the north side. After the intersection, the North-South Corridor runs toward the south direction, on the other side, the East-West Corridor runs toward the east direction.

Plan of Junction B is shown in Figure 9.3.10.



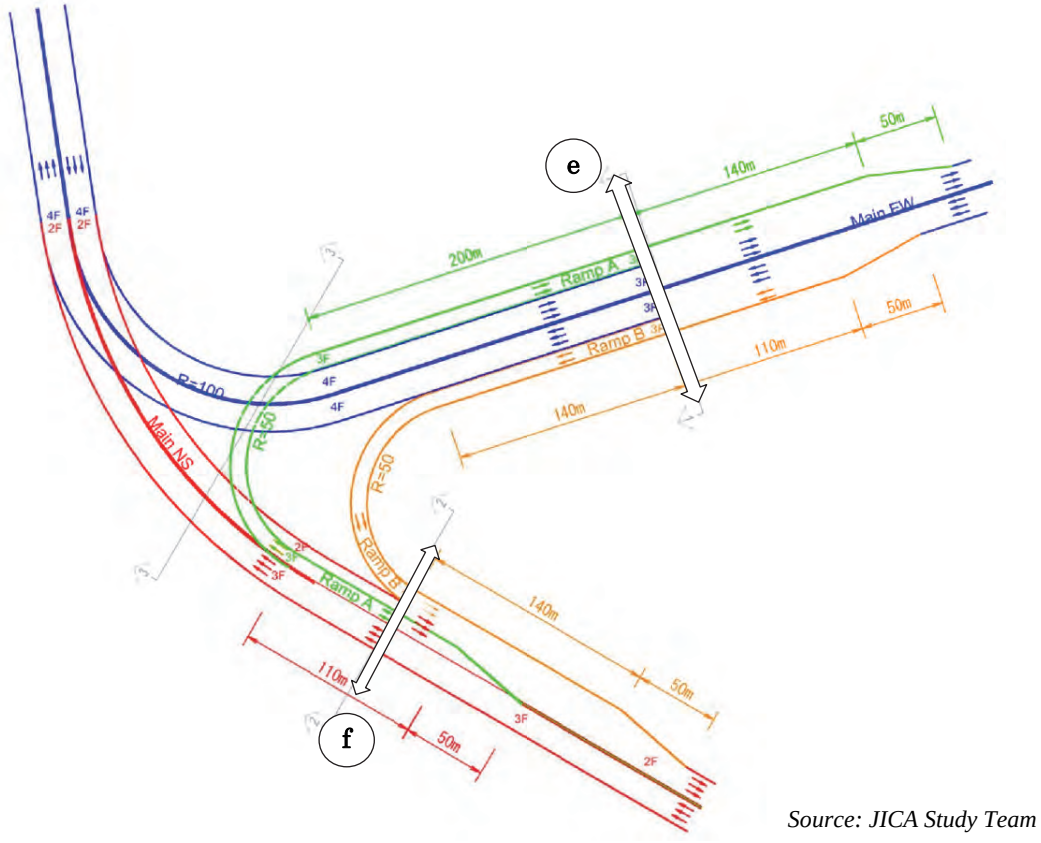
Source: JICA Study Team/Google

Figure 9.3.10 Plan of Junction B

Alignment of Junction B is shown in Figure 9.3.11.

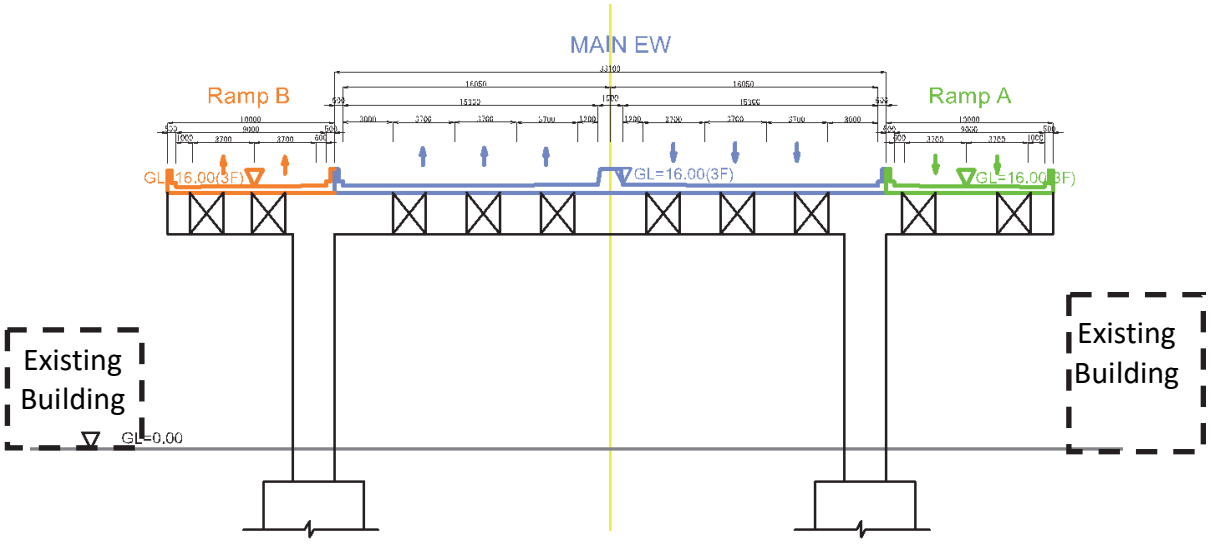
In Junction B, full accessibility can be achieved for all 6 directions.

Due to the very complicated alignment of the Junction, the bridge structure, especially the pier column structure, becomes very complicated also. Cross section of e and f are shown in Figure 9.3.12 and Figure 9.3.13, respectively. Width of both cross sections become wider than existing width, therefore, additional land acquisition will be necessary unless necessary number of lanes is reviewed.



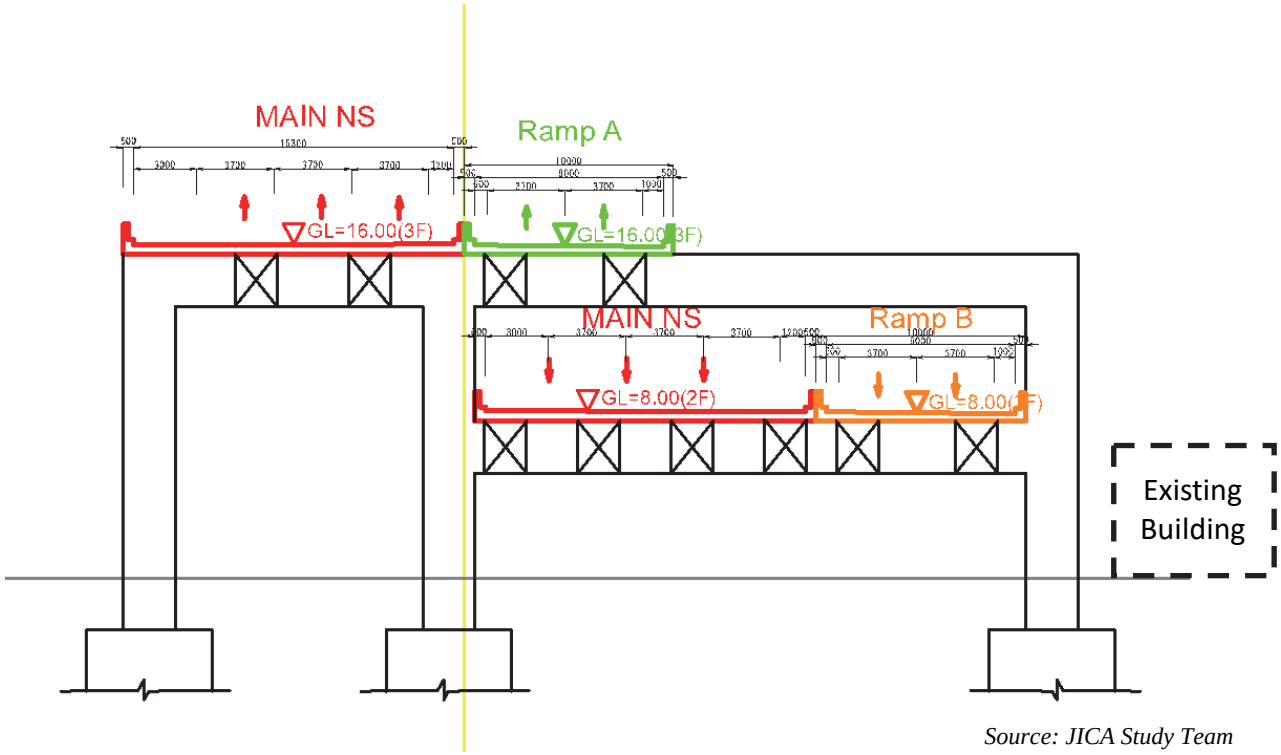
Source: JICA Study Team

Figure 9.3.11 Alignment of Junction B



Source: JICA Study Team

Figure 9.3.12 Cross Section e



Source: JICA Study Team

Figure 9.3.13 Cross Section f

9.3.4 Advanced Technologies can be Applied to Projects

The advanced technologies can be applied to viaduct construction project in Bangalore is shown in Table 9.3.2. According to apply these technologies, the construction of viaduct in narrow area in the city becomes more realistic and it is possible to be environment – friendly construction in more short term compared with construction by existing technology.

For details of the technologies are shown in chapter 6.

Table 9.3.2 List of Advanced Technology

Name of Technology	Feature
Cast-in-place Concrete Pile under low clearance	Construction Equipment can construct cast-in-place concrete pile under low clearance and narrow space
Rotary Penetration Steel Pile	New type of steel pile which can be constructed in a narrow space and utilize a smaller size of pile cap due to large load carrying capacity compared with Cast-in-place Concrete Pile. In addition, due to no generation of excavated soil, low vibration and low noise, this pile type is very eco-friendly type.
PC Well	New type of foundation which can be constructed in a narrow space and utilize a smaller size of foundation because no pile cap is required
Steel Pipe Socket Connection Method	New connection method between steel pier column and pile cap/pile by omitting anchor frame which can achieve shorter construction time and possible to apply PC Well foundation.
Composite Slab	New deck slab type which has high durability and safe for construction, especially, underneath of deck slab

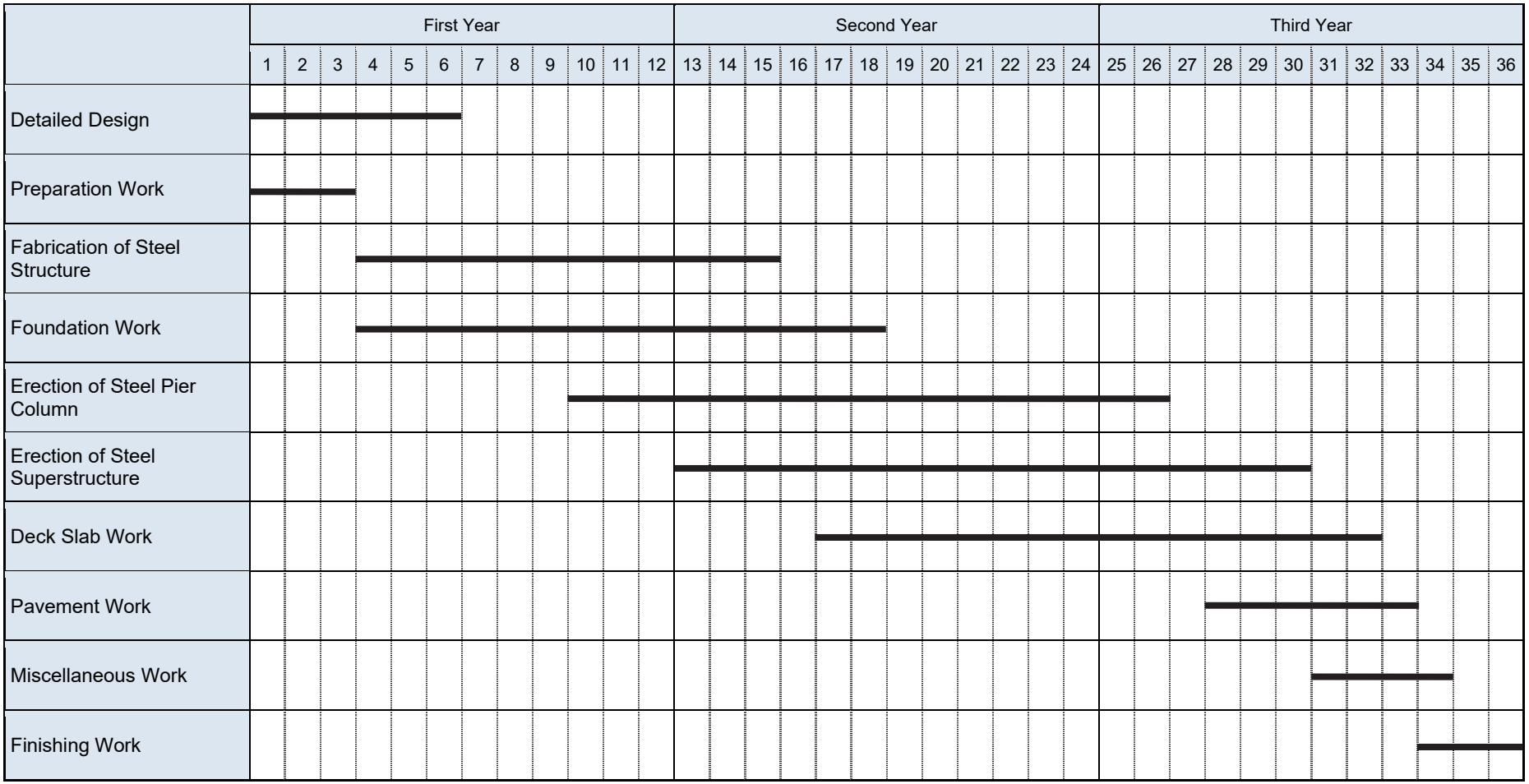
9.3.5 Overall Construction Schedule

Overall construction schedule for viaduct construction is shown in Table 9.3.3. It is possible to complete construction work by applying of Steel Pier Column, PC Well or Rotary Penetration Steel Pile and Steel Superstructure.

On the other hand, expected construction schedule is about 5 years in case conventional structure type is applied. However, it is impossible to estimate precise construction schedule since construction schedule is affected by number of construction teams and construction package.

In addition, it is recommended to establish construction planning to distinguish sections applied either Japanese advanced technology or conventional method, since application of Japanese advanced technology causes significant increment of construction cost.

Table 9.3.3 Overall Construction Schedule for Viaduct Construction Project in Bangalore



9.3.6 Cost Estimation

(1) Exchange Rate

Exchange rate used for calculation of cost estimation is average value for 2 weeks from the end of August 2016 to the beginning of September 2016. Applied exchange rate is shown as below;

- 1 USD = 101.80 [Yen]
- 1 INR = 1.52 [Yen]

(2) Estimated Project Cost

Estimated project costs in case of Japanese support are shown in Table 9.3.4 . The estimated total project cost (including construction costs, design costs and supervision costs) is approximately 114.9 billion Yen (75.6 billion INR).

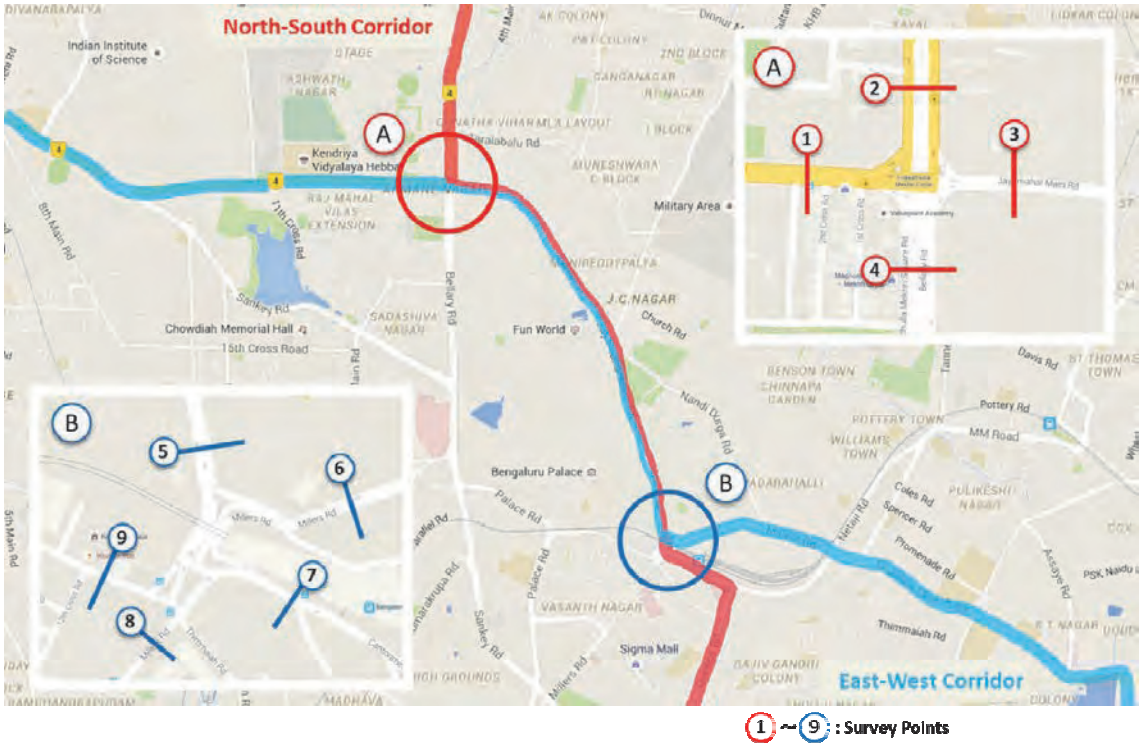
Table 9.3.4 Estimated Project Cost

Project Location	Contents	Unit	Quantity	Unit [100 Yen]	Project Cost [Million Yen]				Project Cost [Million INR]			
					Construction	Design	Supervision	Total	Construction	Design	Supervision	Total
Bangalore	- Length of Viaduct2.75km - Steel Box Girder （6Lanes×2） - Steel Pier Column (Double Deck)	m^2	121,000	334.9	40,528	1,622	3,648	45,798	26,663	1,067	2,400	30,130
	Junction A (Alternative 2)	m^2	102,769	388.6	39,935	1,598	3,595	45,128	26,273	1,051	2,365	29,689
	Junction B	m^2	54,732	388.6	21,268	851	1,914	24,033	13,992	560	1,259	15,811
	Total				101,731	4,071	9,157	114,959	66,928	2,678	6,024	75,630

9.4 Traffic Demand Forecast

9.4.1 Traffic Count Survey

As part of the work of the Data Collection Survey on Bridge Sector, the traffic count survey was carried out in Bangalore from 24th June 2016 to 15th August 2016. The locations of the survey are shown in Figure 9.4.1.



Source: JICA Study Team/Google

Figure 9.4.1 Location Map of Traffic Survey (Bangalore)

9.4.2 Traffic Characteristics

The following traffic characteristics have been presented in the following sections:

- Total Traffic Count and PCUs
- Hourly variation and Peak Hour Factor (PHF)
- Traffic composition

(1) Total Traffic Count

The traffic volume data collected during the surveys is shown in Table 9.4.1.

Table 9.4.1 Traffic Volume Count

Traffic Volume Count at Bangalore																			
S.No	Station Name	Direction from Junction	Traffic Volume																
			Car/Jeep (private)	Two Wheeler	Auto Rickshaw	Mini Bus	Bus	Passenger van	2 Axle Truck	3 Axle Truck	MAV	LCV/Pick Up	Tractor	Tractor with Trolley	Cycle	Cycle Rickshaw	Others	Total (In Vehicle)	Total (In PCUs)
1	Bellary Road (Ganganagar Side)	Away	13864	9819	3567	972	4845	198	1303	103	0	0	2	9	13	0	0	34695	42954
		Towards	12929	9594	2844	733	2656	622	1331	120	16	2	10	18	248	0	1	31124	35092
2	Bellary Road (Guttahalli side)	Away	13745	11753	3918	961	2400	420	579	18	1	1	14	0	34	0	0	33844	34463
		Towards	10291	8342	1976	590	2130	299	601	72	2	0	9	0	58	0	0	24370	26191
3	CV Raman Road	Away	8810	10796	2121	499	430	171	61	3	0	0	0	0	125	0	1	23017	18801
		Towards	9700	8773	3474	588	538	157	125	56	0	0	1	2	254	0	0	23668	20978
4	Jayamahal Main Road	Away	9007	9989	3066	162	484	173	583	384	10	0	4	0	47	0	0	23909	22487
		Towards	9799	9026	4067	337	674	39	1517	95	11	0	3	3	98	1	0	25670	26043
5	Cantonment Road Miller One way	Away	2700	2683	2592	231	732	113	486	9	0	0	51	8	41	0	0	9646	10921
		Towards	7384	6898	5566	864	2741	235	662	158	195	0	19	18	338	4	45	25127	30149
6	Jayamahal Main Road	Away	4808	7204	4123	181	774	82	333	95	23	0	3	0	178	9	2	18025	17801
		Towards	5097	8802	2489	265	980	87	715	17	1	0	4	2	190	2	0	18651	17752
7	Miller Two way	Away	4045	4451	2503	163	169	12	134	9	1	0	0	0	89	0	0	11576	10029
		Towards	3772	4135	3285	82	84	313	58	3	0	0	0	0	13	4	0	11567	9832.5
8	MV Jayram Road	Away	4587	5908	2791	154	79	78	290	72	33	7	0	0	72	9	14	14094	12348
		Towards	4570	5783	3979	259	230	13	249	90	11	11	2	0	106	23	2	15328	13861

Source: JICA Study Team

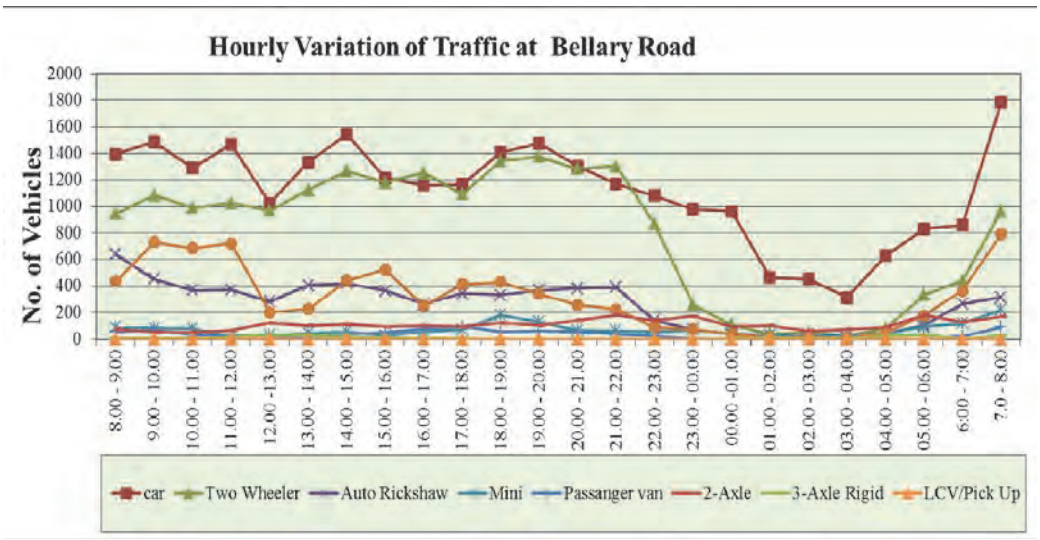
(2) Peak Hour Factor (PHF) and Hourly Variation

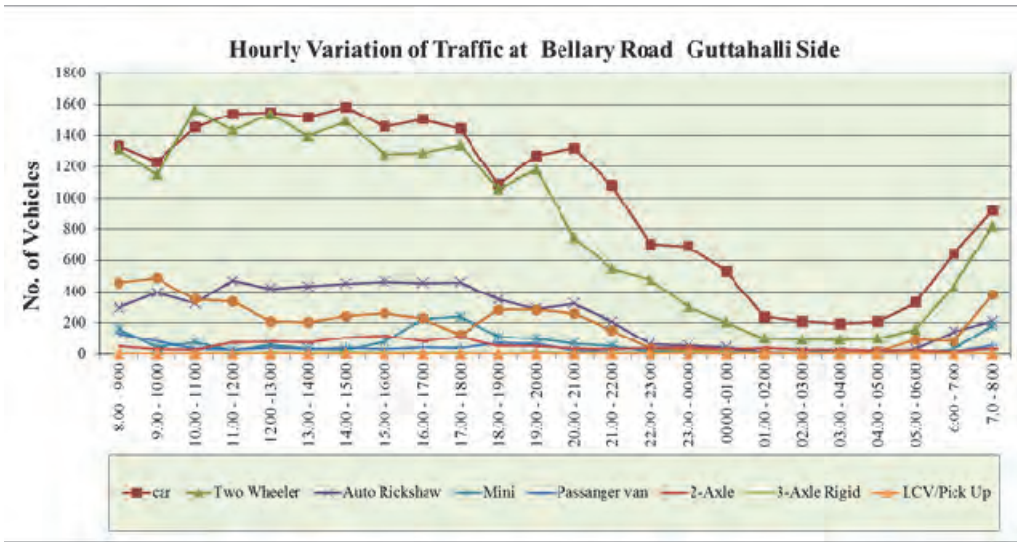
The hourly variation of traffic illustrates the distribution of traffic over the day with respect to time and the Peak Hour Factor (PHF) is the maximum percentage of the total traffic that uses the project highway in a single hour of the day. The peak hour factors observed at the count stations are summarized in Table 9.4.2. According to Table 9.4.2, it is confirmed peak hour traffic is generated at rush hour in morning and evening. In addition, PHF shows about 5-9% in Table 9.4.2. According to PHF in Japan, average PHF is about 7% (at National Highway by 24 hours measurement), therefore, PHF ranged from 5-9% is appropriate value.

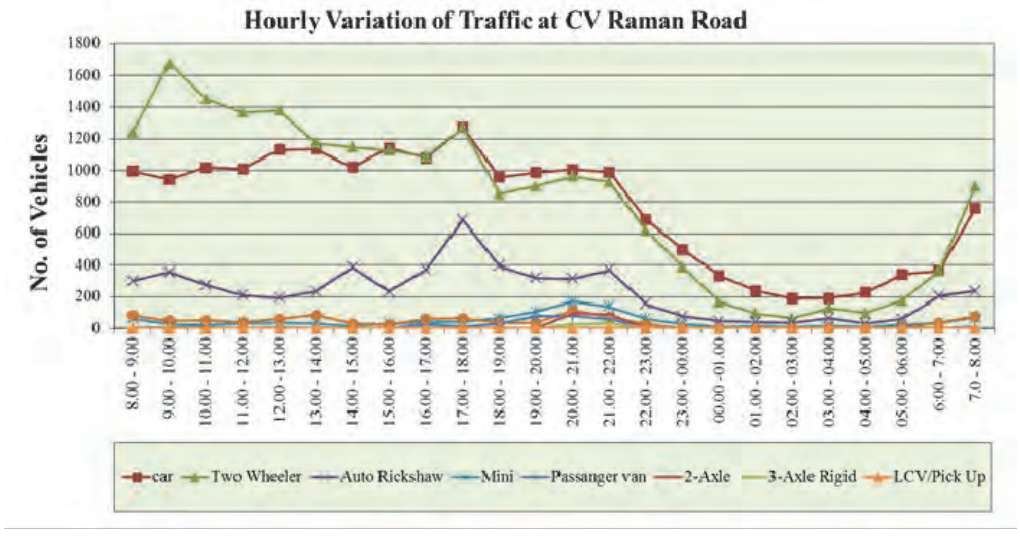
Table 9.4.2 Per Hour Traffic

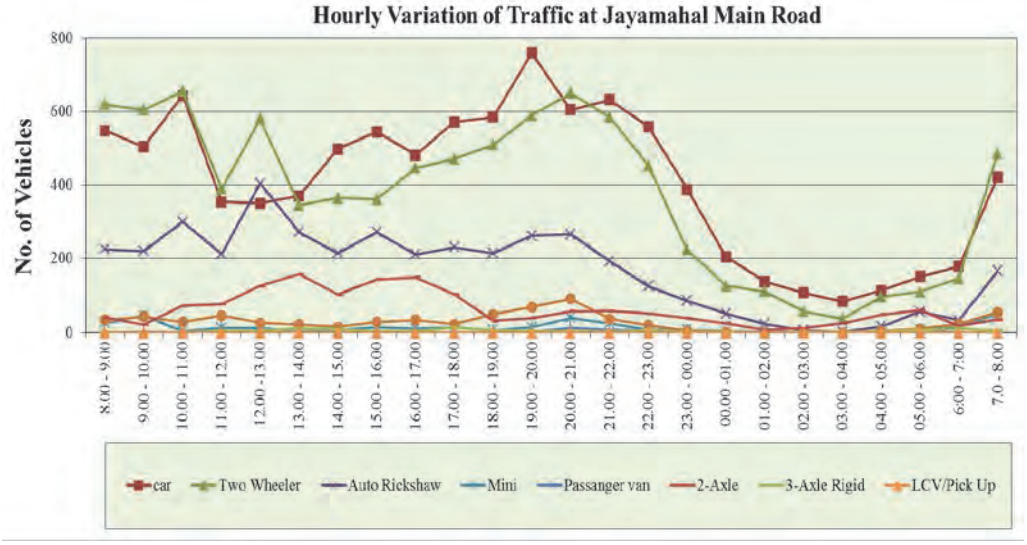
Traffic Count at Bangalore							
	Survey Locations	Traffic Peak Hour in Morning (Nos)	Peak Hour Percentage (Morning)	Observed Peak Hour	Traffic Peak hour in Evening (Nos)	Peak Hour Percentage (Evening)	Observed Peak Hour
Mekhri Circle (Junction A)	Bellary Road (Ganganagar Side)	4357	6.65	7:00 to 8:00	3870	5.91	18:00 to 19:00
	Bellary Road (Guttahalli side)	3898	6.71	11:00 to 12:00	3824	6.58	16:00 to 17:00
	CV Raman Road	3057	6.6	9:00 to 10:00	3344	7.23	17:00 to 18:00
	Jayamahal main Road	3035	6.14	8:00 to 9:00	3668	7.42	20:00 to 21:00
Cantonment Station (Junction B)	MV Jayram Raod	1880	7.09	9:00 to 10:00	2489	9.39	16:00 to 17:00
	Miller Two Way	1851	8.04	9:00 to 10:00	1531	6.65	15:00 to 16:00
	Cantonment Road	707	7.41	10:00 to 11:00	623	6.53	16:00 to17:00
	Millar One Way	1184	4.79	10:00 to 11:00	1930	7.81	18:00 to 19:00
	Jayamahal main Road	3124	8.66	9:00 to 10:00	2454	6.8	18:00 to 19:00

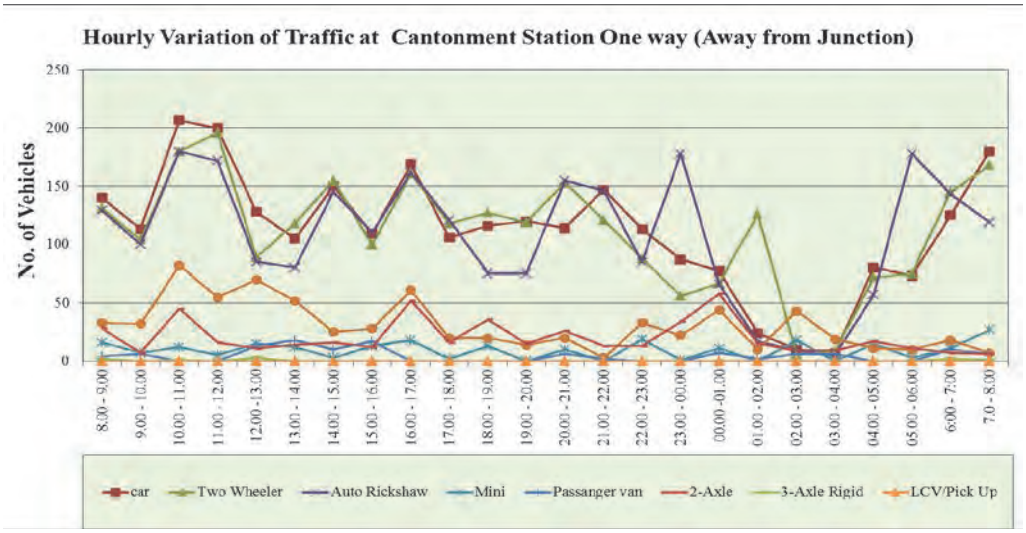
Source: JICA Study Team

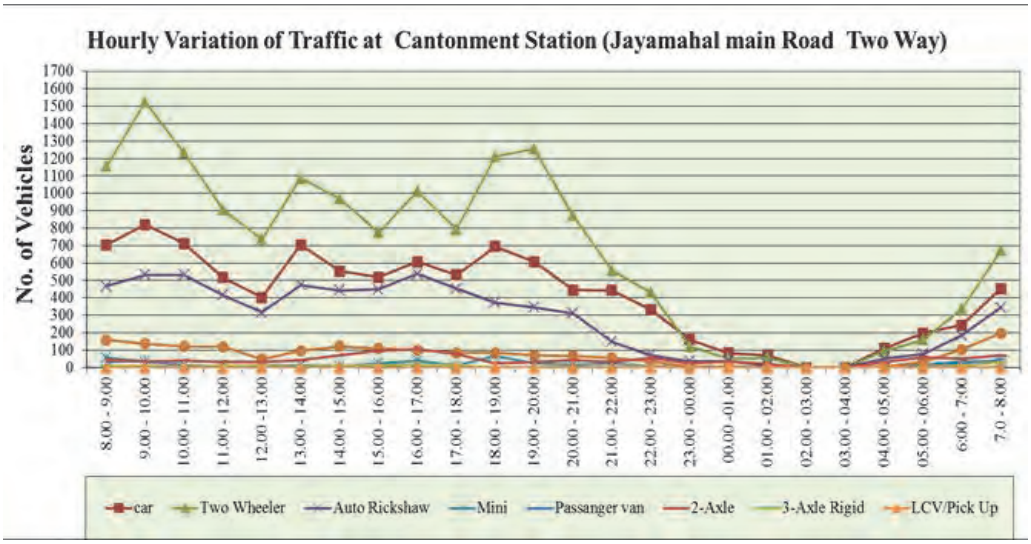

Hourly Variation of Traffic at Bellary Road
No. of Vehicles
car
Two Wheeler
Auto Rickshaw
Mini
Passanger van
2-Axle
3-Axle Rigid
LCV/Pick Up

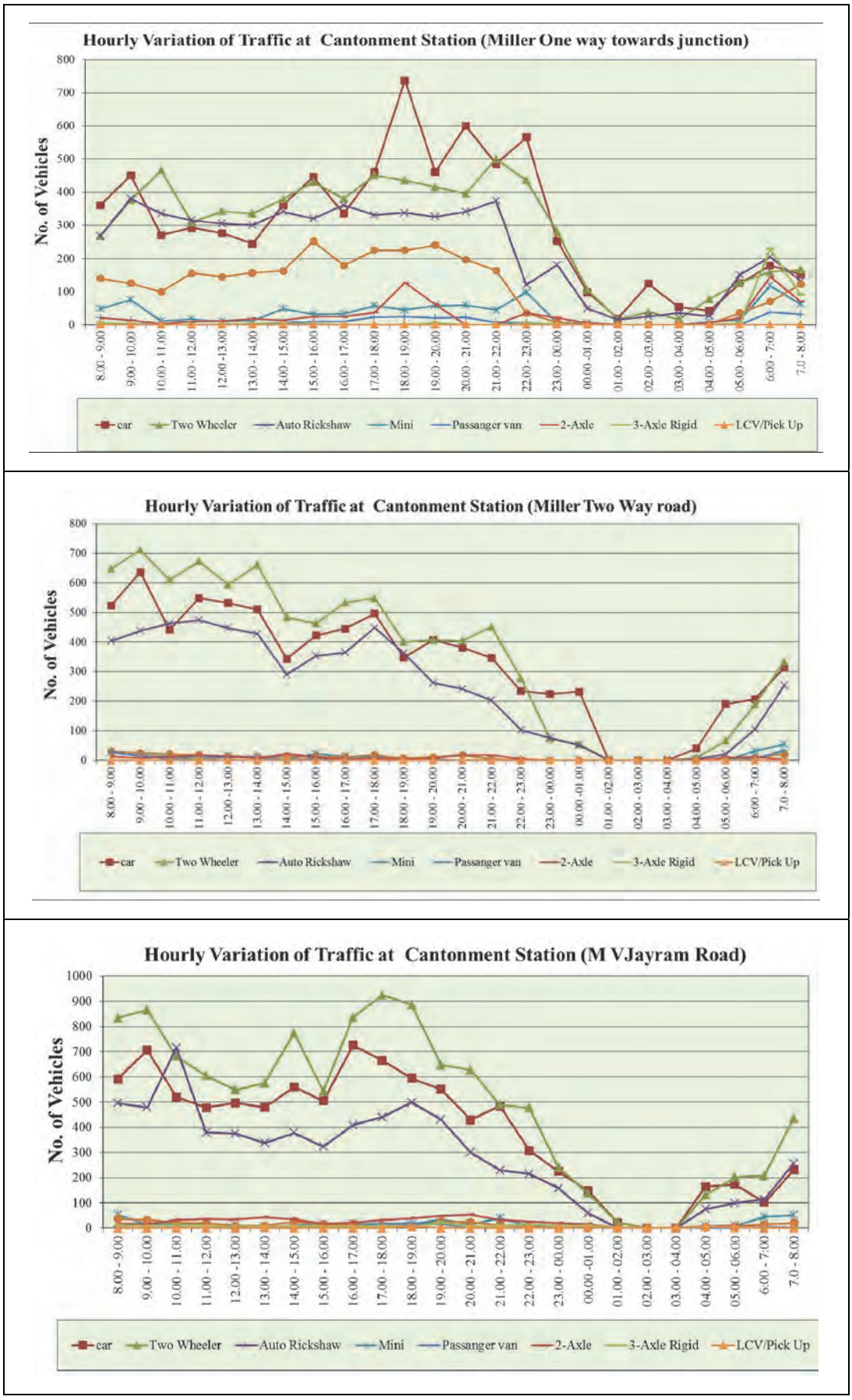

Hourly Variation of Traffic at Bellary Road Guttahalli Side
No. of Vehicles
car
Two Wheeler
Auto Rickshaw
Mini
Passanger van
2-Axle
3-Axle Rigid
LCV/Pick Up


Hourly Variation of Traffic at CV Raman Road
No. of Vehicles
car
Two Wheeler
Auto Rickshaw
Mini
Passanger van
2-Axle
3-Axle Rigid
LCV/Pick Up


Hourly Variation of Traffic at Jayamahal Main Road
No. of Vehicles
800
600
400
200
0
8.00 - 9.00
9.00 - 10.00
10.00 - 11.00
11.00 - 12.00
12.00 -13.00
13.00 - 14.00
14.00 - 15.00
15.00 - 16.00
16.00 - 17.00
17.00 - 18.00
18.00 - 19.00
19.00 - 20.00
20.00 - 21.00
21.00 - 22.00
22.00 - 23.00
23.00 - 00.00
00.00 -01.00
01.00 - 02.00
02.00 - 03.00
03.00 - 04.00
04.00 - 05.00
05.00 - 06.00
6:00 - 7:00
7.0 - 8.00
car
Two Wheeler
Auto Rickshaw
Mini
Passanger van
2-Axle
3-Axle Rigid
LCV/Pick Up


Hourly Variation of Traffic at Cantonment Station One way (Away from Junction)
No. of Vehicles
250
200
150
100
50
0
8.00 - 9.00
9.00 - 10.00
10.00 - 11.00
11.00 - 12.00
12.00 -13.00
13.00 - 14.00
14.00 - 15.00
15.00 - 16.00
16.00 - 17.00
17.00 - 18.00
18.00 - 19.00
19.00 - 20.00
20.00 - 21.00
21.00 - 22.00
22.00 - 23.00
23.00 - 00.00
00.00 -01.00
01.00 - 02.00
02.00 - 03.00
03.00 - 04.00
04.00 - 05.00
05.00 - 06.00
6:00 - 7:00
7.0 - 8.00
car
Two Wheeler
Auto Rickshaw
Mini
Passanger van
2-Axle
3-Axle Rigid
LCV/Pick Up


Hourly Variation of Traffic at Cantonment Station (Jayamahal main Road Two Way)
No. of Vehicles
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
8.00 - 9.00
9.00 - 10.00
10.00 - 11.00
11.00 - 12.00
12.00 -13.00
13.00 - 14.00
14.00 - 15.00
15.00 - 16.00
16.00 - 17.00
17.00 - 18.00
18.00 - 19.00
19.00 - 20.00
20.00 - 21.00
21.00 - 22.00
22.00 - 23.00
23.00 - 00.00
00.00 -01.00
01.00 - 02.00
02.00 - 03.00
03.00 - 04.00
04.00 - 05.00
05.00 - 06.00
6:00 - 7:00
7.0 - 8.00
car
Two Wheeler
Auto Rickshaw
Mini
Passanger van
2-Axle
3-Axle Rigid
LCV/Pick Up

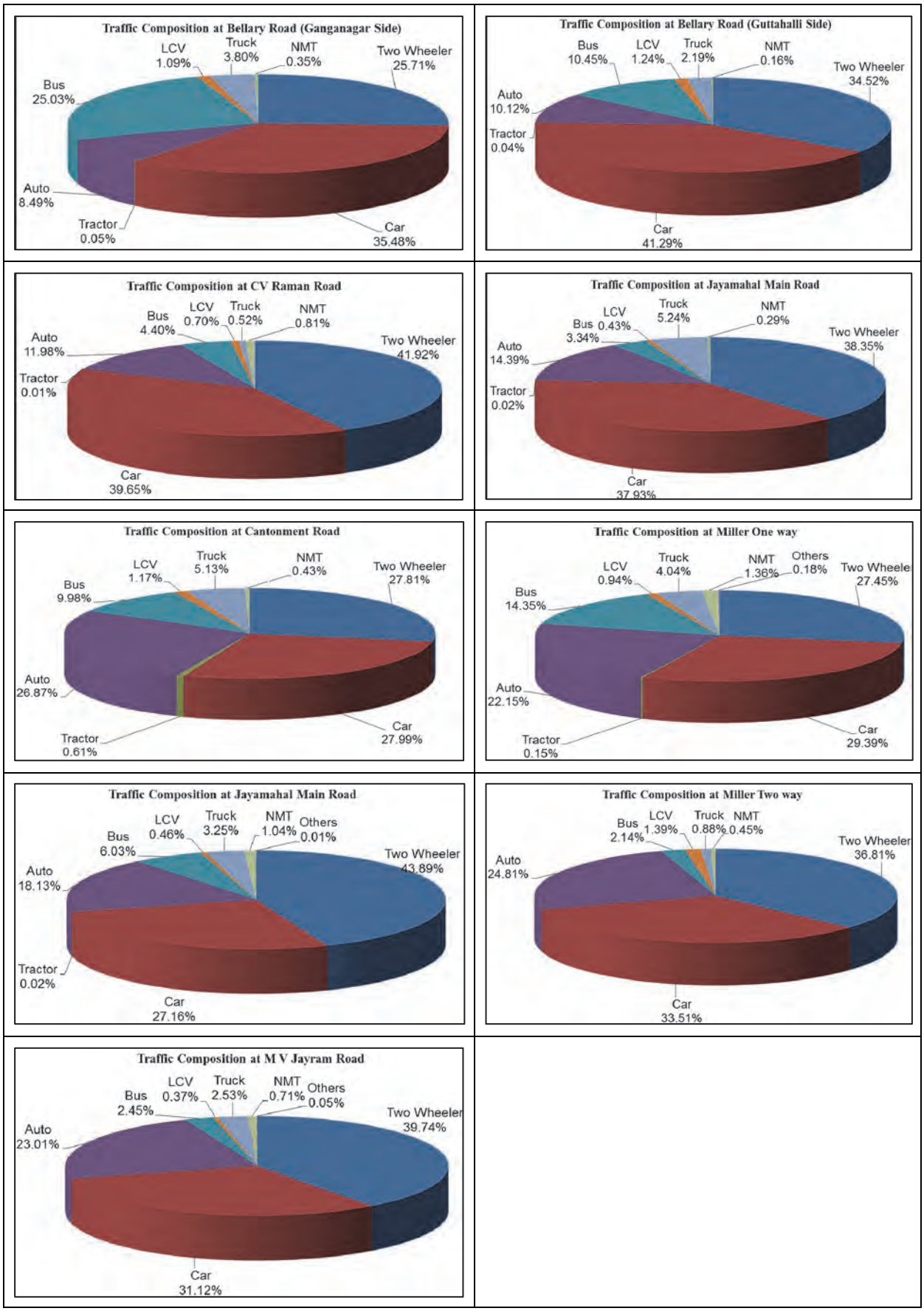


Source: JICA Study Team

Figure 9.4.2 Hourly Variation of Traffic at Bangalore

(3) Traffic Composition

Traffic composition for Bangalore based on traffic count survey result. Based on the Figure 9.4.3, 70-90% of traffic composition is Passenger Car, 2 wheelers and Auto rickshaw (3-wheeler), therefore, it is confirmed target road is served mainly for residents.



Source: JICA Study Team

Figure 9.4.3 Traffic Composition at Bangalore

9.4.3 Existing Traffic Volume at Study Area

The Viaduct Construction Project in Bangalore use the results of traffic survey which is implemented in this survey. The existing traffic volume of the study area is shown in Table 9.4.3.

Table 9.4.3 The Existing Traffic Volume (Viaduct Construction Project in Bangalore, 2016)

Location	east bound		west bound		Total	
unit	Vehicle	PCU	Vehicle	PCU	Vehicle	PCU
Passenger car	6,142	6,142	8,430	8,430	14,572	14,572
Bus	863	2,590	1,929	5,788	2,793	8,379
Truck	994	4,472	1,209	5,441	2,203	9,912
Total	7,999	13,204	11,569	19,659	19,568	32,863

Source: JICA Study Team

9.4.4 Traffic Demand Forecast of the Study Area

Annual Average Daily Traffic (AADT) of the study area is estimated in consideration with the existing traffic volume at the study area shown in Table 9.4.3 and estimated growth rate for future traffic volume described in Chapter 7.3.2. Estimated result of AADT is shown in Table 9.4.4.

Since traffic volume forecast has not been carried out by Local Consultants for Viaduct Construction Project in Bangalore, therefore, same percentage as Viaduct Construction Project in Delhi is applied. The rate of vehicles which will use the elevated viaducts, which are planned in the Survey, is fixed as 60%.

Table 9.4.4 Traffic Demand Forecast (Viaduct Construction Project in Bangalore, 2017)

(Unit: PCU)

	Car	Bus	Truck	Total
2020	12,297	7,070	8,364	27,731
2021	13,391	7,700	9,109	30,199
2022	14,583	8,385	9,919	32,887
2023	15,881	9,131	10,802	35,814
2024	17,294	9,944	11,764	39,001
2025	18,833	10,829	12,810	42,473
2026	20,509	11,792	13,951	46,253
2027	22,335	12,842	15,192	50,369
2028	24,323	13,985	16,544	54,852
2029	26,487	15,230	18,017	59,734
2030	28,845	16,585	19,620	65,050
2031	31,412	18,061	21,366	70,839
2032	34,208	19,669	23,268	77,144
2033	37,252	21,419	25,339	84,010
2034	40,567	23,325	27,594	91,487
2035	44,178	25,401	30,050	99,629
2036	48,110	27,662	32,724	108,496
2037	52,392	30,124	35,637	118,152
2038	57,054	32,805	38,809	128,668
2039	62,132	35,725	42,263	140,119
2040	67,662	38,904	46,024	152,590

Source: JICA Study Team

9.5 Economic Analysis

9.5.1 Introduction

In this section, social economic benefit is calculated for Viaduct Construction Project in Bangalore used for traffic demand forecast result as explained in Chapter 9.4. Social economic benefit is defined as the savings of social cost by implementing each project mentioned above, which is the difference of social cost between With Case (with implementing the project) and Without Case (without implementing the project).

9.5.2 Cases to be Studied

Steel double deck viaduct is planned for the section in which the North-South corridor and the East-West corridor overlap. The "With Case" is the one in which the steel double deck is implemented, the "Without Case" is the one in which a PC superstructure and RC substructure is implemented instead.

Table 9.5.1 "With Case" and "Without Case" (Viaduct Construction Project in Bangalore)

With Case	Without Case
Construct elevated viaduct from Mekhri Circle (intersection of Bellary Road and CV Raman Road) to the intersection of six roads on the west side of Cantonment Station.. The Elevated viaduct is double deck steel bridge constructed by Japanese advanced construction technology and methods that minimize the congestion of the existing traffic. Both the starting and ending points will be connected to the N-S corridor and E-W corridor by junctions. The implementation will start from 2020 when the viaduct will be opened	PC superstructure and RC substructure is constructed in the same location as the "With Case". The existing traffic will be congested due to wide construction field and be forced to make detours. Construction Period will be longer than "With Case".

Source: JICA Study Team

9.5.3 Implementation Schedule for Economic Analysis

Elevated viaduct will be implemented along the existing road both in the project in Bangalore. When the project is implemented by rapid construction with steel, "With case" is set, when the project by existing method with concrete, "Without case" is set. Therefore the implementation schedule is as follows.

Table 9.5.2 Implementation Schedule for Economic Analysis (Viaduct Construction Project in Bangalore)

	With Case	Without Case	Remarks
2019	D/D	D/D	
2020	Construction	Construction	With case: with Japanese advanced construction method Without Case: with conventional construction method
2021	Construction	Construction	
2022	New viaduct open	Construction	
2023	↓	Construction	
2024	↓	New viaduct open	
2025	↓	↓	
↓	↓	↓	
2048	End of analysis period	End of analysis period	

Source: JICA Study Team

9.5.4 Project Cost

The following table shows project cost for the economic analysis in the study area. (Refer to 6.7 for the details)

Table 9.5.3 Project Cost by Study Area

(Unit: Million Indian Rupees)

	With Case				Without Case			
Location	Construction	D/D	C/S	Total	Construction	D/D	C/S	Total
Bangalore	66,928	2,678	6,024	75,630	51,483	2,060	4,634	58,177

Source: JICA Study Team

9.5.5 Cost Benefit Analysis

The result of cost benefit analysis under the condition shown in Chapter 7.3.4 is shown in following table.

Table 9.5.4 Cost Benefit Analysis Result

Evaluation Indicator	Bangalore
Economic Internal Rate of Return (EIRR, %)	14.0%
Economic Net Present Value (ENPV, Million Indian Rupee)	8995
Benefit/Cost (B/C)	1.05

- Economic Internal Rate of Return (EIRR) = (Discount rate value which makes ENPV = 0)
- Economic Net Present Value (ENPV)
  = (Net present benefit of project benefit) – (Net present cost of project benefit)
- Benefit/Cost (B/C) = (Net present benefit of project benefit)/(Net present cost of project benefit)
  where,
  benefit of project = benefit reducing VOC + benefit reducing TTC
  cost of project = Implementing Cost + Operation & Maintenance Cost

Source: JICA Study Team

As shown is Table 9.5.4, the numerical of EIRR of the target four projects are over 12%, the validity of these projects are confirmed. For the projects of Delhi and Bangalore use the conventional flyover construction method as Without Case. The construction cost will be increased with using proposal structures; however the social convenient will be improved such as shortening of construction period and ensuring the traffic of existing roads. Therefore, it will be possible to improve the numerical of EIRR.

9.6 Environmental Evaluations

9.6.1 Screening Result based on JICA Guideline

The target for screening is the surrounding areas of North-South Corridor and East-West corridor. The location map is shown in Figure 3.3.2 in Chapter 3.

I. Pollution, the evaluation was A in Rating of Noise/Vibration and Air pollution (Dust) During and After Const. II. Social, it was the evaluation A in Rating of Involuntary Resettlement. III. Natural, little impact is assumed. In the JICA Category, it was the evaluation A in Rating of the Result of Screening based on JICA Guideline for Environmental and Social Considerations (2010).

Table 9.6.1 List of Target Bridge (Viaduct Construction Project in Bangalore)

Type of Bridge	Location	Junction	Name
Viaduct	Viaduct Construction Project in Bangalore	A	Mekhri Circle
		B	Cantonment Station

Source: JICA Study Team

Table 9.6.2 Preliminary Environmental Evaluation and Screening based on JICA Guideline (as of October 5th, 2016) – Viaduct Construction Project in Bangalore

Type of Bridge	Location	St. No	Br. No	Affected Item: Name	Affected Item: Repair /Reconstruction	Ⅰ.Pollution: Noise/ Vibration and Air pollution (Dust) During and After Const. Rating	Ⅰ.Pollution: Noise/ Vibration and Air pollution (Dust) During and After Const. Description	Ⅰ.Pollution: Water Quality (Turbid Water) During Const. Rating	Ⅰ.Pollution: Water Quality (Turbid Water) During Const. Description	Ⅱ.Social Environment: Involuntary Resettlement Rating	Ⅱ.Social Environment: Involuntary Resettlement Description	Ⅱ.Social Environment: Culture (Sacred place and Facility) Rating	Ⅱ.Social Environment: Culture (Sacred place and Facility) Description	Ⅲ.Natural Environment: Mangrove Trees Rating	Ⅲ.Natural Environment: Mangrove Trees Description	JICA Category: Result of **Screening** based on JICA Guideline for Environmental and Social Considerations (2010)		Expected clearances to be acquired: EC	Expected clearances to be acquired: Clearance for CRZ
Viaduct	Bangalore	1	1	A/B	New Construction	A	Residential area is observed and might be affected.	C	No river by the bridge.	A	Residential area and commercial area is observed and might be affected.	C	Mosque is located in the south west side but not directly affected.	C	No mangrove observed.	**A**	Many resettlements are expected and land acquisition might be required	✓	-

Impact Rating: (A): Serious impact is expected. (B): Some impact is expected. (C): Few impacts are expected. (D): Impact is unknown (serious impacts are not expected, but detailed survey is required on preparatory survey stage)
Screening definition: (A) serious (B) A degree of impact, but not serious (C) Few impacts are expected (refer to Table 3.5.3 Definition of Category on JICA Guideline)

Source: JICA Study Team

9.6.2 Recommended Environmental Mitigation Measures

Recommended major mitigation measures are shown below;

Table 9.6.3 Environmental Management Plan (Expected Mitigation Measures)

Category	No.	Item JICA Guidelines	Recommended Mitigation Measures	
			Pre and During Construction phase	Operation phase
Pollution	1	Air pollution	- Dust Water sprinkling near residential area	Appropriate land use management on roadside roads
	2	Water pollution	- Turbid water Sheet pile method is adopted to minimize turbid water during foundation repair works	-
	3	Waste	- Construction waste (waste concrete) Construction waste such as waste concrete is disposed at designated disposal site	-
	4	Soil contamination	-	-
	5	Noise and vibration	- Construction noise near residential area Installing noise barrier and selecting low-noise equipment. Avoiding works of heavy equipment during night time. Informing the construction schedule to surrounding communities to obtain their consensus.	Setting of noise barriers depending on need Appropriate land use management on roadside roads
	6	Sediment quality	-	-
Natural environment	9	Protected Area	CRZ permission shall be requested from environmental authorization agency (Ministry of Environment and Forest), if the reconstruction bridge with new approach road is in CRZ	-
	11	Hydrology	Designing of bridges with sufficient capacity	-
	12	Topography and geology	-	-
Social environment	13	Involuntary resettlement	Appropriate compensation shall be implemented in accordance with JICA Guidelines	-
	14	The poor		-
	15	Indigenous and ethnic people		-
	16	Local economy such as employment and livelihood		-
	17	Land use and utilization of local resources		
	18	Water usage	Installation of alternative water distribution system when unexpected situation such as reduction of water level of wells, if any	
	19	Existing social infrastructures and services	Appropriate compensation and displacement shall be implemented in accordance with JICA Guidelines	-
	22	Local conflict of interests	Local workforce is prioritized for construction of the bridge.	-
	23	Cultural heritage	If the project effect on the community temple, sacred places and monument, appropriate consultation and agreement shall be concluded with local stakeholders	-
	27	Infectious diseases such as HIV/AIDS	In order to prevent spread of infectious diseases such as HIV/AIDS, awareness of the laborers is promoted.	-

Category	No.	Item JICA Guidelines	Recommended Mitigation Measures	
			Pre and During Construction phase	Operation phase
Others	29	Accidents	- Installing gate structure at the entrance of the construction site to set up restricted area - Deploying flagman at the gate and crossing points of the construction vehicles - Installing fence around the construction site to keep out local people such as children - Restricting mobilization speed in the construction site - Safety training for the workers - Safety patrol at the construction site by supervisors - Monthly safety meeting	Traffic safety control and management should be done on the bridges without sidewalk (Excluding motor vehicle exclusive road)
	30	Cross boundary impacts and climate change	-	-

(-): Not required mitigation measures since negative impacts are negligible

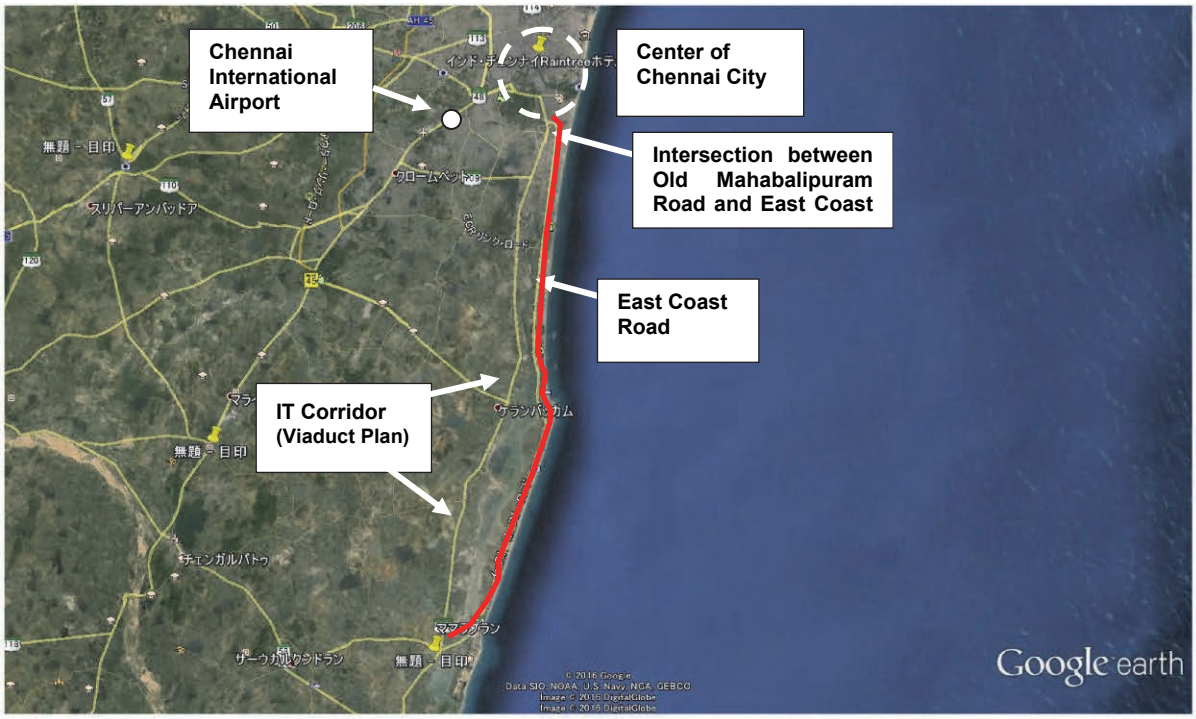
Source: JICA Study Team

10 STUDY ON VIADUCT CONSTRUCTION PROJECT ALONG EAST COAST ROAD IN CHENNAI

10.1 Introduction

In this chapter, it is mentioned about proposed structures, result of economic analysis and environmental assessment of the viaduct construction project along East Coast Road in Chennai based on "Chapter 4 Environmental and Social Impact", "Chapter 6 Japanese Advanced Technology can be apply" and "Chapter 7 Traffic Forecast Demand and Economic Analysis".

The target area of this project is as follows.



Source: JICA Study Team

Figure 10.1.1 Location Map of East Road

10.2 Natural and Social Features

10.2.1 Social Aspect

Population in Tamil Nadu which is the project site of the Viaduct Construction Project along East Coast Road in Chennai and its capital city are shown in Table 10.2.1.

Table 10.2.1 Population of Tamil Nadu State and Chennai

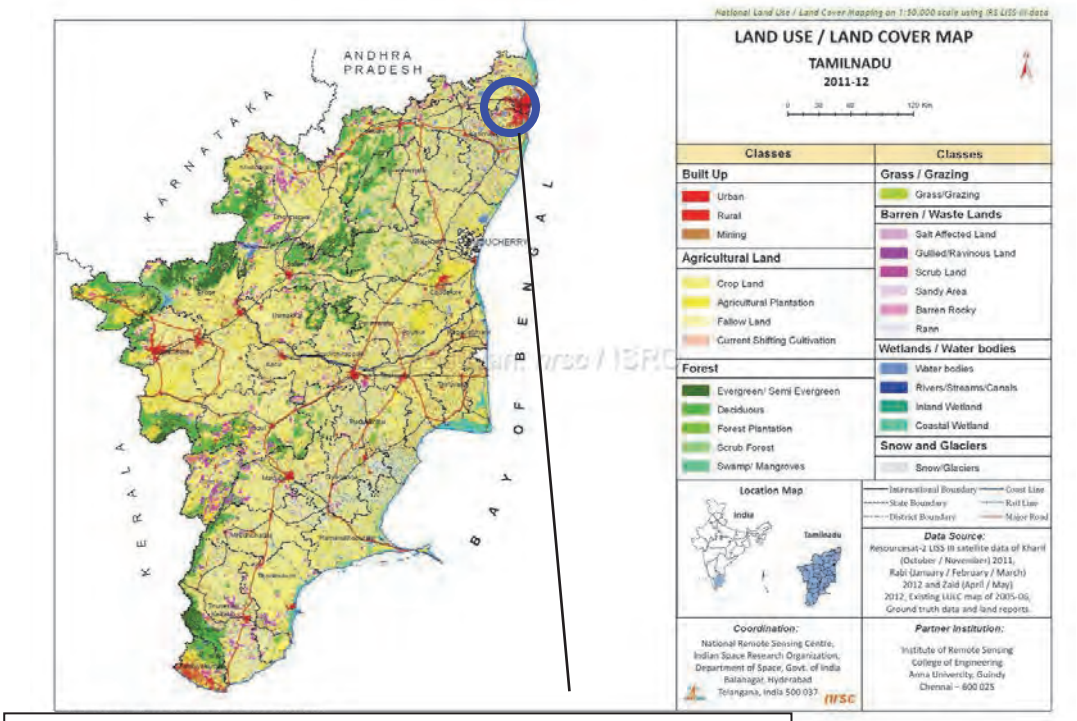
State	Population (2011)	Capital city	Population (2011)
Tamil Nadu	19,252,630	Chennai	570,851

Source: 2011 Census Data, Government of India, Ministry of Home Affairs

10.2.2 Natural Aspect

The land use map of the project sites are shown in Figure 10.2.1.

The situation of land use of the project site is mainly urban and commercial areas project. And there are a lot of houses and buildings along the east road.



Source: National Remote Sensing Center

Figure 10.2.1 Land Use Map and the Location of the Project Sites in Tamil Nadu (Viaduct Construction Project along East Coast Road in Chennai)

10.3 Proposed Structure for Viaduct Construction Project along East Coast Road in Chennai

10.3.1 Introduction

The study on structures has been carried out along the normal section length of 7.55 km from center of Chennai city as shown in Figure 10.1.1. Based on the site inspection, the width of existing road is not enough with 6-lanes viaduct as shown in Figure 10.3.1.

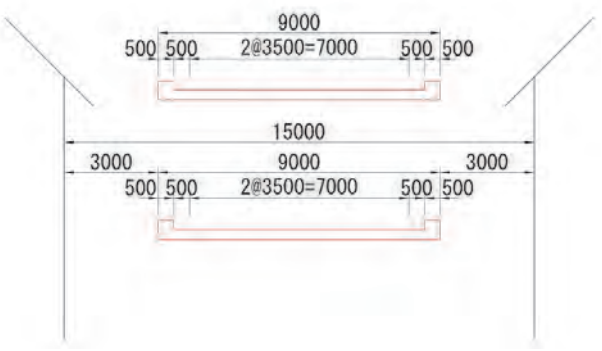
Source: JICA Study Team/Google

Figure 10.3.1 Location and Width of Existing Road

According to Tamil Nadu State Government, there is a plan to expand the existing road through land acquisition, however, consideration of the difficulty of land acquisition work, a viaduct structure and construction method with no land acquisition work is proposed in this chapter.

10.3.2 Superstructure Type

Since the width of existing road is only 15m houses located at both side of road will be affected in case 4 lanes viaduct is constructed within this 15m width. Therefore, 2-lane road built on a double deck structure can be accommodated inside the existing road as shown in Figure 10.3.2. And steel structures will be applied for both the Superstructure and Substructure.



Source: JICA Study Team

Figure 10.3.2 Arrangement of Carriageway

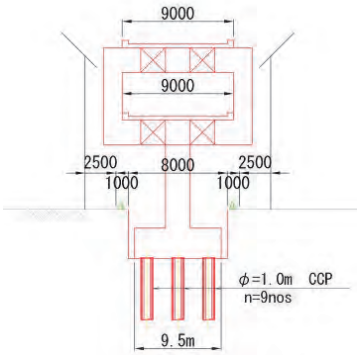
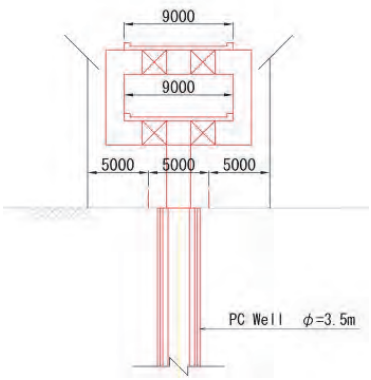
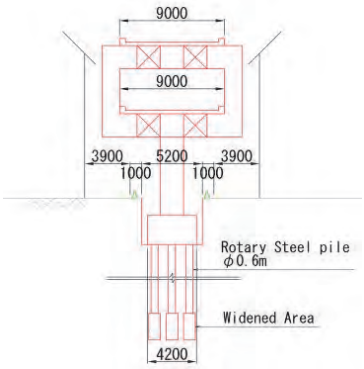
10.3.3 Study of Foundation Types

Because construction work needs to be carried out along a very congested road, it is recommended to minimize the negative impact during construction work. Therefore, construction yard and period should be minimized. The following foundation types were studied and the result of comparison is shown in Table 10.3.1 .

- Cast-in-place Concrete Pile (conventional type)
- PC Well
- Rotary Penetration Steel Pile

Although construction cost becomes higher than cast-in-place concrete pile (conventional type), it is recommended to apply PC Well foundation type since only this type can secure enough width for existing traffic.

Table 10.3.1 Comparison of Foundation Types

	Cast-in-place Concrete Pile (Conventional Type)	PC Well	Rotary Penetration Steel Pile
General View			
Comment	✓ Common foundation type has many past records and is the most economical ✓ Widest width of pile cap, would cause negative impact to existing traffic during construction	✓ Width of foundation is narrow and will not cause negative impact to existing traffic during construction. ✓ Shortest construction period due to structure unified with pier column	✓ Narrower width of pile cap than Type-1 will have a better impact on existing traffic during construction. ✓ Due to no excavation required, less impact to residents during construction.
Construction Cost	Superior	Inferior	Moderate
Cost Considering Social Effects	Inferior	Superior	Superior
Estimate		Recommended	Recommended

10.3.4 Advanced Technologies can be Applied to Projects

The advanced technologies can be applied to the project in Chennai is shown in Table 9.3.2. According to apply these technologies, the construction of viaduct in narrow area in the city becomes more realistic and it is possible to be environment - friendly construction in more short term compared with construction by existing technology.

For details of the technologies are shown in chapter 6.

Table 10.3.2 List of Advanced Technology

Name of Technology	Feature
Cast-in-place Concrete Pile under low clearance	Construction Equipment can construct cast-in-place concrete pile under low clearance and narrow space
Rotary Penetration Steel Pile	New type of steel pile which can be constructed in a narrow space and utilize a smaller size of pile cap due to large load carrying capacity compared with Cast-in-place Concrete Pile. In addition, due to no generation of excavated soil, low vibration and low noise, this pile type is very eco-friendly type.
PC Well	New type of foundation which can be constructed in a narrow space and utilize a smaller size of foundation because no pile cap is required
Steel Pipe Socket Connection Method	New connection method between steel pier column and pile cap/pile by omitting anchor frame which can achieve shorter construction time and possible to apply PC Well foundation.
Composite Slab	New deck slab type which has high durability and safe for construction, especially, underneath of deck slab

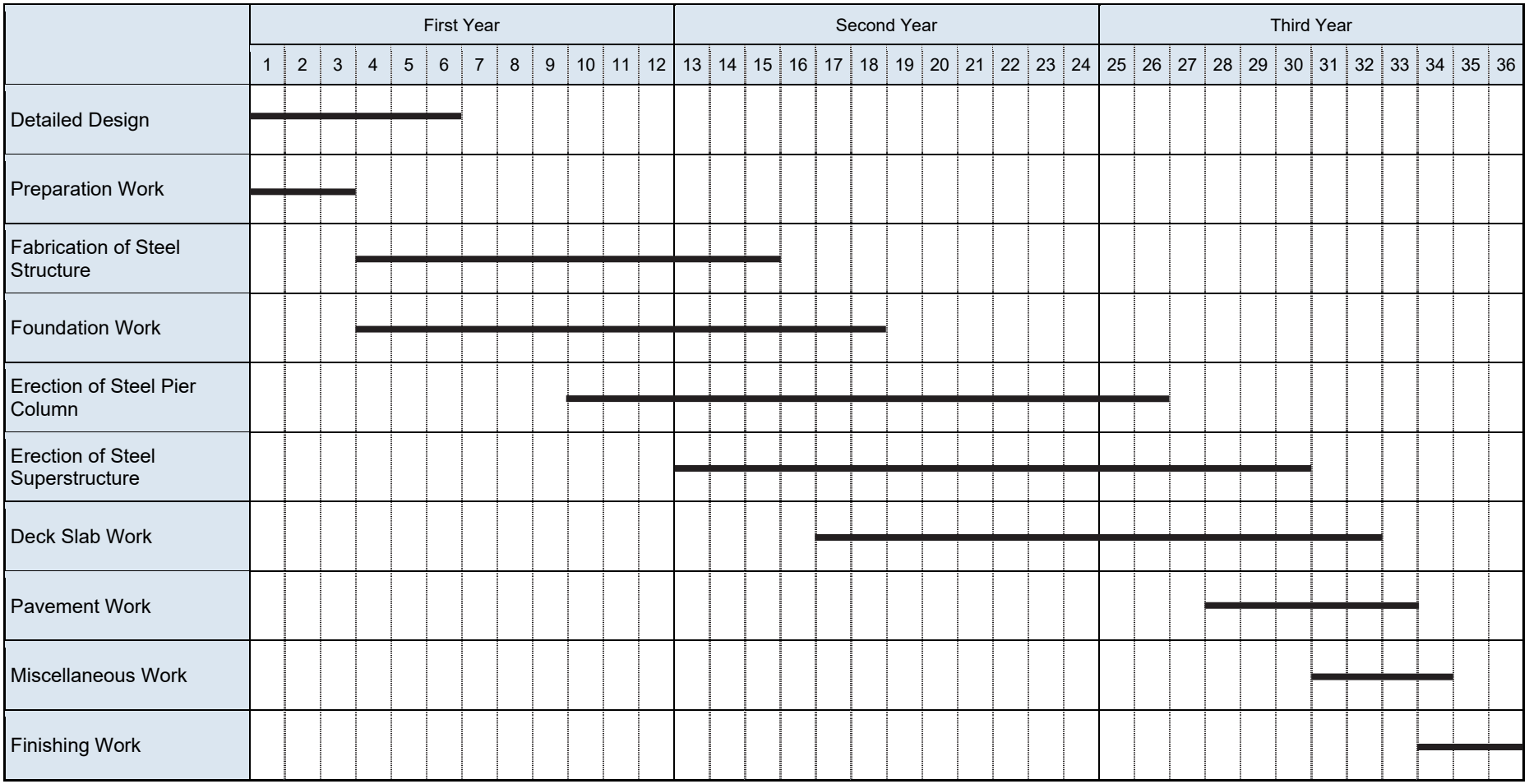
10.3.5 Overall Construction Schedule

Overall construction schedule for viaduct construction (scope of this study: 7.5km length) is shown in Table 10.3.3. It is possible to complete construction work by applying of Steel Pier Column, PC Well or Rotary Penetration Steel Pile and Steel Superstructure.

On the other hand, expected construction schedule is about 5 years in case conventional structure type is applied. However, it is impossible to estimate precise construction schedule since construction schedule is affected by number of construction teams and construction package.

In addition, it is recommended to establish construction planning to distinguish sections applied either Japanese advanced technology or conventional method, since application of Japanese advanced technology causes significant increment of construction cost.

Table 10.3.3 Overall Construction Schedule for Viaduct Construction Project along East Coast Road in Chennai



10.3.6 Cost Estimation

(1) Exchange Rate

Exchange rate used for calculation of cost estimation is average value for 2 weeks from the end of August 2016 to the beginning of September 2016. Applied exchange rate is shown as below;

- 1 USD = 101.80 [Yen]
- 1 INR = 1.52 [Yen]

(2) Estimated Project Cost

Estimated project cost in case of Japanese support is shown in Table 10.3.4 . The estimated total project cost (including construction costs, design costs and supervision costs) is approximately 54.4 billion Yen (35.8 billion INR).

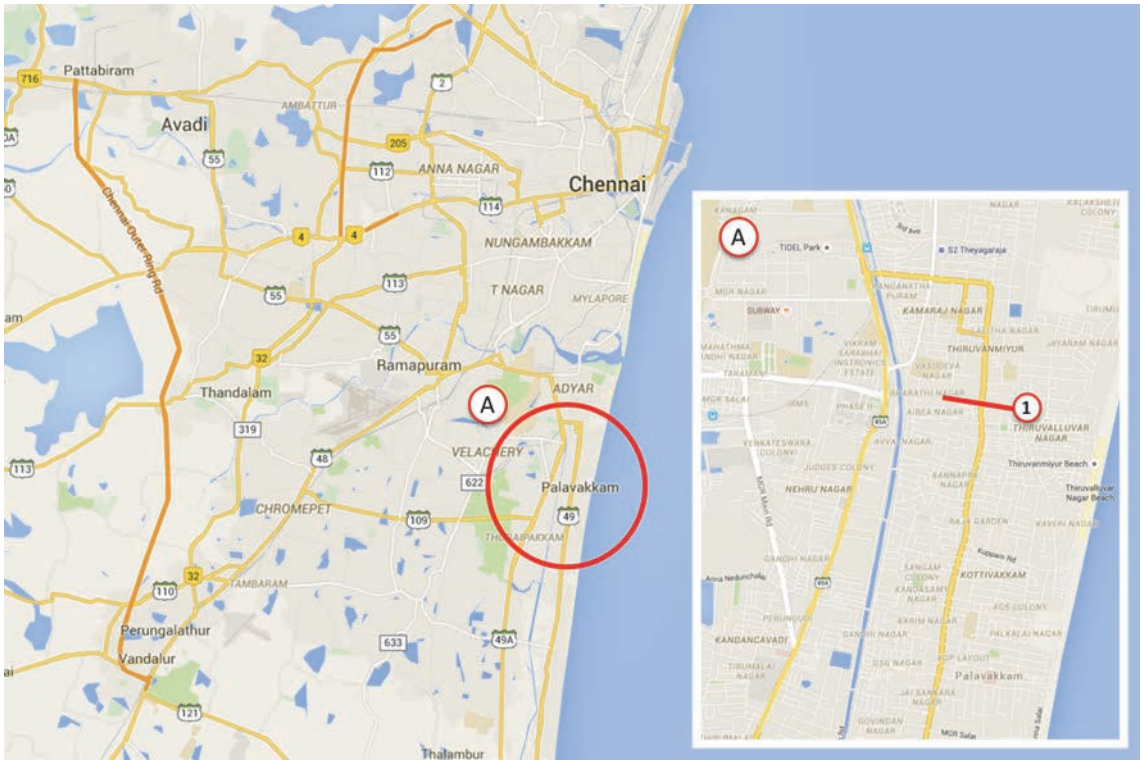
Table 10.3.4 Estimated project Cost

Project Location	Contents	Unit	Quantity	Unit [100 Yen]	Project Cost [Million Yen]				Project Cost [Million INR]			
					Construction	Design	Supervision	Total	Construction	Design	Supervision	Total
Chennai	- Length of Viaduct7.55km - Steel Box Girder （2Lanes×2） - Steel Pier Column (Double Deck)	m^2	135,900	354.1	48,128	1,926	4,332	54,386	31,663	1,267	2,850	35,780

10.4 Traffic Demand Forecast

10.4.1 Traffic Count Survey

As part of the work of the Data Collection Survey on Bridge Sector, the traffic count survey was carried out in Chennai from 24th June 2016 to 15th August 2016. The locations of the survey are shown in Table 10.4.1.



Source: JICA Study Team/Google

Figure 10.4.1 Location Map of Traffic Survey (Chennai)

10.4.2 Traffic Characteristics

The following traffic characteristics have been presented in the following sections:

- Total Traffic Count and PCUs
- Hourly variation and Peak Hour Factor (PHF)
- Traffic composition

(1) Total Traffic Count

The traffic volume data collected during the surveys is shown in Table 10.4.1.

Table 10.4.1 Traffic Volume Count

Traffic Volume Count at Chennai																			
S.No	LocationName	Direction from Junction	Traffic Volume																
			Car/Jeep (private)	Two Wheeler	Auto Rickshaw	Mini Bus	Bus	Passenger van	2 Axle Truck	3 Axle Truck	MAV	LCV/Pick Up	Tractor	Tractor with Trolley	Cycle	Cycle Rickshaw	Others	Total (In Vehicle)	Total (In PCUs)
1	Chhenai	North To South	13016	19030	5920	492	997	481	338	59	13	1036	0	0	163	44	0	41589	35723
		South To North	12484	18788	5654	471	941	451	185	25	15	1135	0	0	101	18	0	40274	34055

Source: JICA Study Team

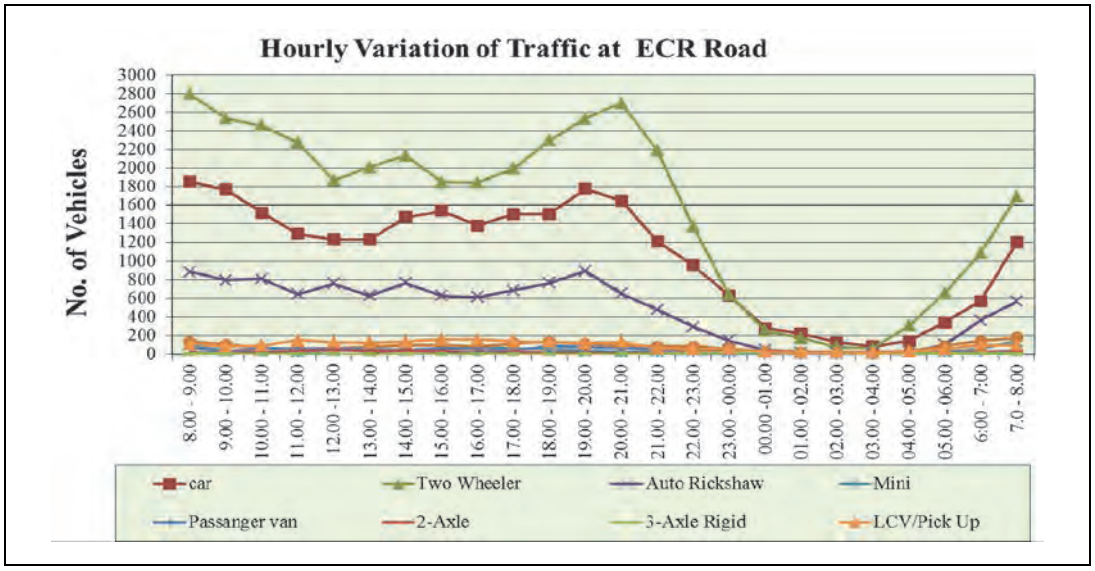
(2) Peak Hour Factor (PHF) and Hourly Variation

The hourly variation of traffic illustrates the distribution of traffic over the day with respect to time and the Peak Hour Factor (PHF) is the maximum percentage of the total traffic that uses the project highway in a single hour of the day. The peak hour factors observed at the count stations are summarized in Table 10.4.2. According to Table 10.4.2, it is confirmed peak hour traffic is generated at rush hour in morning and evening. In addition, PHF shows about 7% in Table 10.4.2. According to PHF in Japan, average PHF is about 7% (at National Highway by 24 hours measurement), therefore, PHF ranged from 7% is appropriate value.

Table 10.4.2 Per Hour Traffic

Traffic Count at Chennai							
	Survey Locations	Traffic Peak Hour in Morning (Nos)	Peak Hour Percentage (Morning)	Observed Peak Hour	Traffic Peak hour in Evening (Nos)	Peak Hour Percentage (Evening)	Observed Peak Hour
Chennai	Bellary Road (Ganganagar Side)	5956	7.3	8:00 to 9:00	5547	6.8	19:00 to 20:00

Source: JICA Study Team

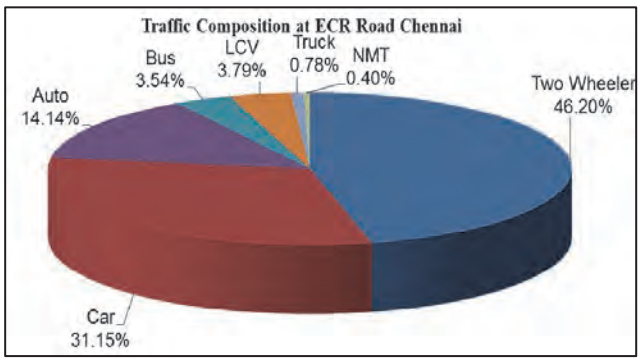


Source: JICA Study Team

Figure 10.4.2 Hourly Variation of Traffic at Chennai

(3) Traffic Composition

Traffic composition for Bangalore based on traffic count survey result. Based on the Figure 10.4.3, 70-90% of traffic composition is Passenger Car, 2 wheelers and Auto rickshaw (3-wheeler), therefore, it is confirmed target road is served mainly for residents.



Source: JICA Study Team

Figure 10.4.3 Traffic Composition at Chennai

10.4.3 Existing Traffic Volume

The following tables show Annual Average Daily Traffic (AADT) of the study areas. It represents traffic demand forecast for Viaduct Construction Project along East Coast Road in Chennai.

Table 10.4.3 The existing Traffic Volume
(Viaduct Construction Project along East Coast Road in Chennai, 2016)

Location	south bound		north bound		Total	
unit	Vehicle	PCU	Vehicle	PCU	Vehicle	PCU
Passenger car	14,533	14,533	14,070	14,070	28,603	28,603
Bus	1,489	4,467	1,412	4,236	2,901	8,703
Truck	410	1,845	225	1,013	635	2,858
Total	16,432	15,707	15,707	19,319	32,139	40,164

Source: JICA Study Team

10.4.4 Traffic Demand Forecast of the Study Area

Annual Average Daily Traffic (AADT) of the study area is estimated in consideration with the existing traffic volume at the study area shown in Table 10.4.3 and estimated growth rate for future traffic volume described in Chapter 7.3.2. Estimated result of AADT is shown in Table 10.4.4.

The results are to deduct 1,500pcu per one lane of existing road based on the traffic demand forecast of the traffic volume on the study area.

Table 10.4.4 Traffic Demand Forecast (Viaduct Construction Project along East Coast Road in Chennai, 2017)

(Unit: PCU)

	Car	Bus	Truck	Total
2020	24,137	7,344	2,411	33,892
2021	26,285	7,998	2,626	36,908
2022	28,624	8,709	2,860	40,193
2023	31,172	9,485	3,114	43,770
2024	33,946	10,329	3,391	47,666
2025	36,967	11,248	3,693	51,908
2026	40,257	12,249	4,022	56,528
2027	43,840	13,339	4,380	61,559
2028	47,742	14,526	4,769	67,037
2029	51,991	15,819	5,194	73,004
2030	56,618	17,227	5,656	79,501
2031	61,657	18,760	6,160	86,577
2032	67,144	20,430	6,708	94,282
2033	73,120	22,248	7,305	102,673
2034	79,628	24,228	7,955	111,811
2035	86,715	26,385	8,663	121,762
2036	94,432	28,733	9,434	132,599
2037	102,837	31,290	10,274	144,400
2038	111,989	34,075	11,188	157,252
2039	121,956	37,107	12,184	171,247
2040	132,810	40,410	13,268	186,488

Source: JICA Study Team

10.5 Economic Analysis

10.5.1 Introduction

In this section, social economic benefit is calculated for Viaduct Construction Project along East Coast Road in Chennai used for traffic demand forecast result as explained in Chapter 10.4. Social economic benefit is defined as the savings of social cost by implementing each project mentioned above, which is the difference of social cost between With Case (with implementing the project) and Without Case (without implementing the project).

10.5.2 Cases to be Studied

There is a viaduct planned in the southern part of Chennai. There are narrow sections in the planned existing road. These sections provide critical conditions for typical cross sections. Steel double deck viaduct is planned to overcome the critical condition. Implementing the viaduct is the "With Case" and the "Without Case" is no implementation at all.

Table 10.5.1 "With Case" and "Without Case"
(Viaduct Construction Project along East Coast Road in Chennai)

With Case	Without Case
Steel double deck viaduct planned along the State highway 49 (East Coast Road). The length is around 7.55km from beginning point east coarse road from center of Chennai city side to Injanbakkam. Steel double deck viaduct. Japanese advanced construction method is applied to shorten the construction period, and minimize the congestion of the existing traffic during construction.	No implementation is done at all and the road network will not have any improvement.

Source: JICA Study Team

10.5.3 Implementation Schedule for Economic Analysis

Elevated viaduct will be implemented along the existing road in Viaduct Construction Project along East Coast Road in Chennai. No implementation plan apart from steel viaduct. Therefore, when the project is implemented, "With Case" is set, when not, "Without Case" is set and set the implementation schedule as follows.

Table 10.5.2 Implementation Schedule for Economic Analysis
("With Case", Viaduct Construction Project along East Coast Road in Chennai)

Phase	Year	Remarks
D/D	2019	1 year
Construction	2020-21	2 years
Operation	2022-48	27 years

Source: JICA Study Team

10.5.4 Project Cost

The following table shows project cost for the economic analysis in the study areas. (Refer to 10.3.6 for the details)

Table 10.5.3 Project Cost by Study Area

(Unit: Million Indian Rupees)

	With Case				Without Case			
Location	Construction	D/D	C/S	Total	Construction	D/D	C/S	Total
Chennai	31,663	1,267	2,850	35,780	–	–	–	–

Source: JICA Study Team

10.5.5 Cost Benefit Analysis

The result of cost benefit analysis under the condition shown in Chapter 7.4.3 is shown in following table.

Table 10.5.4 Cost Benefit Analysis Result

Evaluation Indicator	Chennai
Economic Internal Rate of Return (EIRR, %)	28.1%
Economic Net Present Value (ENPV, Million Indian Rupee)	126,869
Benefit/Cost (B/C)	5.44

- Economic Internal Rate of Return (EIRR) = (Discount rate value which makes ENPV = 0)
- Economic Net Present Value (ENPV)
  = (Net present benefit of project benefit) – (Net present cost of project benefit)
- Benefit/Cost (B/C) = (Net present benefit of project benefit)/(Net present cost of project benefit)
  where,
  benefit of project = benefit reducing VOC + benefit reducing TTC
  cost of project = Implementing Cost + Operation & Maintenance Cost

Source: JICA Study Team

As shown is Table 10.5.4, the numerical of EIRR of the target four projects are over 12%, the validity of these projects are confirmed.

10.6 Environmental Evaluations

10.6.1 Screening Result based on JICA Guideline

The target for screening is the surrounding areas of East Coast Road which is shown in Figure 3.4.1 of Chapter 3.

The result of preliminary study and screening based on JICA Guideline is shown in Table 10.6.1.

I. Pollution, the evaluation was A in Rating of Noise/Vibration and Air pollution (Dust) During and After Const. II. Social, it was the evaluation A in Rating of Involuntary Resettlement. III. Natural, little impact is assumed. In the JICA Category, it was the evaluation A in Rating of the Result of Screening based on JICA Guideline for Environmental and Social Considerations (2010).

Table 10.6.1 Preliminary Environmental Evaluation and Screening based on JICA Guideline (as of October 5th, 2016) – Viaduct Construction Project along East Coast Road in Chennai

Type of Bridge	Location	St. No	Br. No	Affected Item: Name	Affected Item: Repair /Reconstruction	Ⅰ.Pollution: Noise/Vibration and Air pollution (Dust) During and After Const. Rating	Ⅰ.Pollution: Noise/Vibration and Air pollution (Dust) During and After Const. Description	Ⅰ.Pollution: Water Quality (Turbid Water) During Const. Rating	Ⅰ.Pollution: Water Quality (Turbid Water) During Const. Description	Ⅱ.Social Environment: Involuntary Resettlement Rating	Ⅱ.Social Environment: Involuntary Resettlement Description	Ⅱ.Social Environment: Culture (Sacred place and Facility) Rating	Ⅱ.Social Environment: Culture (Sacred place and Facility) Description	Ⅲ.Natural Environment: Mangrove Trees Rating	Ⅲ.Natural Environment: Mangrove Trees Description	JICA Category: Result of **Screening** based on JICA Guideline for Environmental and Social Considerations (2010)		Expected clearances to be acquired: EC	Expected clearances to be acquired: Clearance for CRZ
Viaduct	Chennai	1	1	-	New Construction	A	Residential area is observed and might be affected.	C	No river by the bridge.	A	Residential area and commercial area is observed and might be affected.	C	Mosque is located in the south west side but not directly affected.	C	No mangrove observed.	**A**	Many resettlements are expected and land acquisition might be required	✓	-

Impact Rating: (A): Serious impact is expected. (B): Some impact is expected. (C): Few impacts are expected. (D): Impact is unknown (serious impacts are not expected, but detailed survey is required on preparatory survey stage)

Screening definition: (A) serious (B) A degree of impact, but not serious (C) Few impacts are expected (refer to Table 3.5.3 Definition of Category on JICA Guideline)

Source: JICA Study Team

10.6.2 Recommended Environmental Mitigation Measures

Recommended major mitigation measures are shown below;

Table 10.6.2 Environmental Management Plan (Expected Mitigation Measures)

Category	No.	Item JICA Guidelines	Recommended Mitigation Measures	
			Pre and During Construction phase	Operation phase
Pollution	1	Air pollution	- Dust Water sprinkling near residential area	Appropriate land use management on roadside roads
	2	Water pollution	- Turbid water Sheet pile method is adopted to minimize turbid water during foundation repair works	-
	3	Waste	- Construction waste (waste concrete) Construction waste such as waste concrete is disposed at designated disposal site	-
	4	Soil contamination	-	-
	5	Noise and vibration	- Construction noise near residential area Installing noise barrier and selecting low-noise equipment. Avoiding works of heavy equipment during night time. Informing the construction schedule to surrounding communities to obtain their consensus.	Setting of noise barriers depending on need Appropriate land use management on roadside roads
	6	Sediment quality	-	-
Natural environment	9	Protected Area	CRZ permission shall be requested from environmental authorization agency (Ministry of Environment and Forest), if the reconstruction bridge with new approach road is in CRZ	-
	11	Hydrology	Designing of bridges with sufficient capacity	-
	12	Topography and geology	-	-
Social environment	13	Involuntary resettlement	Appropriate compensation shall be implemented in accordance with JICA Guidelines	-
	14	The poor		-
	15	Indigenous and ethnic people		-
	16	Local economy such as employment and livelihood		-
	17	Land use and utilization of local resources		
	18	Water usage	Installation of alternative water distribution system when unexpected situation such as reduction of water level of wells, if any	
	19	Existing social infrastructures and services	Appropriate compensation and displacement shall be implemented in accordance with JICA Guidelines	-
	22	Local conflict of interests	Local workforce is prioritized for construction of the bridge.	-
	23	Cultural heritage	If the project effect on the community temple, sacred places and monument, appropriate consultation and agreement shall be concluded with local stakeholders	-
	27	Infectious diseases such as HIV/AIDS	In order to prevent spread of infectious diseases such as HIV/AIDS, awareness of the laborers is promoted.	-

Category	No.	Item JICA Guidelines	Recommended Mitigation Measures	
			Pre and During Construction phase	Operation phase
Others	29	Accidents	- Installing gate structure at the entrance of the construction site to set up restricted area - Deploying flagman at the gate and crossing points of the construction vehicles - Installing fence around the construction site to keep out local people such as children - Restricting mobilization speed in the construction site - Safety training for the workers - Safety patrol at the construction site by supervisors - Monthly safety meeting	Traffic safety control and management should be done on the bridges without sidewalk (Excluding motor vehicle exclusive road)
	30	Cross boundary impacts and climate change	-	-

(-): Not required mitigation measures since negative impacts are negligible

Source: JICA Study Team

11. RECONSTRUCTION PROJECT OF ROBS IN MUMBAI

11.1 Introduction

In this chapter, it is mentioned about proposed structures, result of economic analysis and environmental assessment of the reconstruction project of ROBs in Mumbai based on "Chapter 4 Environmental and Social Impact", "Chapter 6 Japanese Advanced Technology can be Apply" and "Chapter 7 Traffic Forecast Demand and Economic Analysis".

The target area of this project is as follows.

Source: JICA Study Team

Figure 11.1.1 Location Map for Damaged Bridges (Mumbai)

11.2 Natural and Social Features

11.2.1 Social Aspect

Population in Maharashtra which is the project site of the project in Mumbai and its capital city are shown in Table 11.2.1.

Table 11.2.1 Population of Maharashtra state and Mumbai

State	Population (2011)	Capital city	Population (2011)
Maharashtra	112,374,333	Mumbai	3,085,411

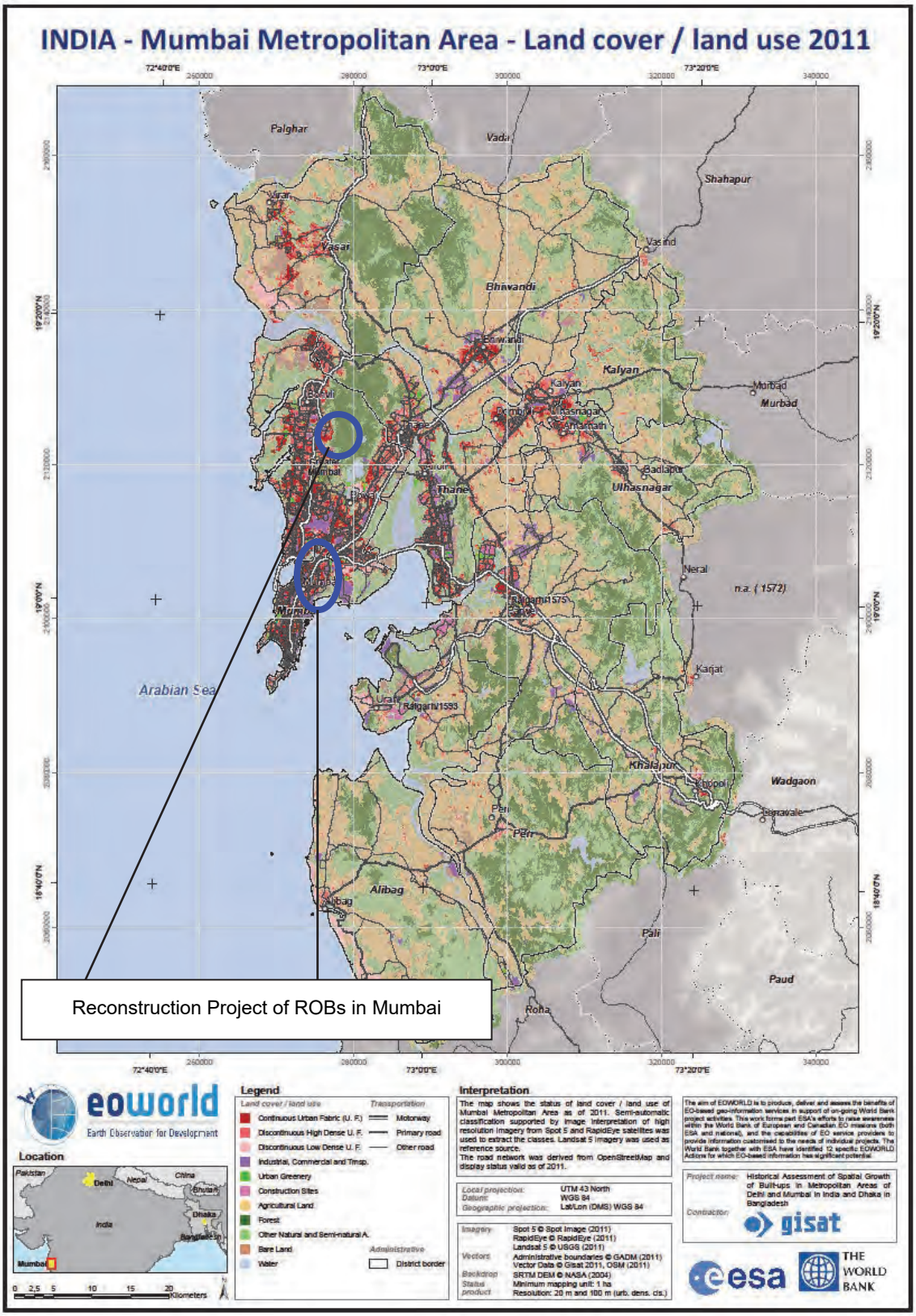
Source: 2011 Census Data, Government of India, Ministry of Home Affairs

11.2.2 Natural Aspect

The land use map of the project site is shown in Figure 11.2.1.

The situation of land use of the project sites are mainly urban and commercial areas for the project.

And it is high population density.



Source: World Bank

Figure 11.2.1 Land Use Map and the Location of the Project Site in Mumbai (Reconstruction Project of ROBs in Mumbai)

11.3 Proposed Structure for Reconstruction Project for ROBs in Mumbai

11.3.1 Introduction

The following 7 ROBs are required to reconstruct. The study on structure is carried out in consideration of Japanese Advanced Technology which is explained in Chapter 6.

Table 11.3.1 List of ROBs required reconstructing in Mumbai

No.	Bridge Name	Length [m]	Construction Year	Superstructure Type
1	Ferere ROB	25.36	1921	2 Main Steel I-Girders with Cross Girders
2	Balasis ROB	31.50	1893	Steel I-Girder
3	Mahalaxmi ROB	77.00	1920	Steel I-Girder
4	Delise ROB	63.20	1921	2 Main Steel I-Girders with Cross Girders
5	Tilak ROB	226.20	1925	2 Main Steel I-Girders with Cross Girders
6	Mahim ROB	80.00	1993	PC I-Shaped Girder
7	Goregaon ROB	79.00	1993	PC I-Shaped Girder

Based on the survey result of existing bridge, the superstructures of these existing bridges are classified in two types.

【Type 1】

- 2- Main Girders Type (1. Ferere ROB, 4. Delise ROB and 5. Tilak ROB)

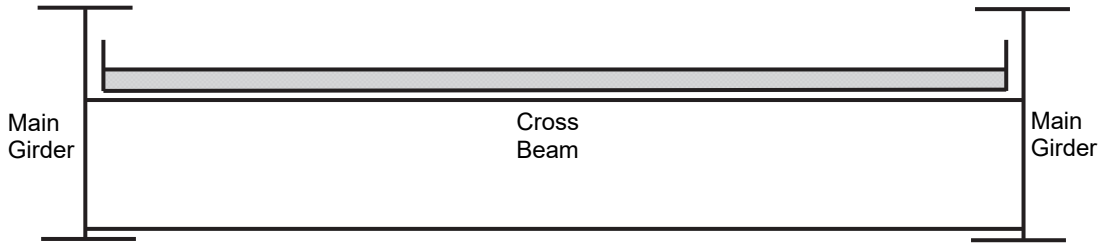


Figure 11.3.1 Cross Section of 2-Main Girders Type

Only 2 main girders connect between both abutments. The carriageway is supported by many cross beams connected to both main girders. Therefore, it is difficult to remove half of the girders (step construction).

【Type 2】

- Conventional I/T-Girder Type (2. Balasis ROB, 3. Mahalaxmi ROB, 6. Mahim ROB and 7. Goregaon ROB)

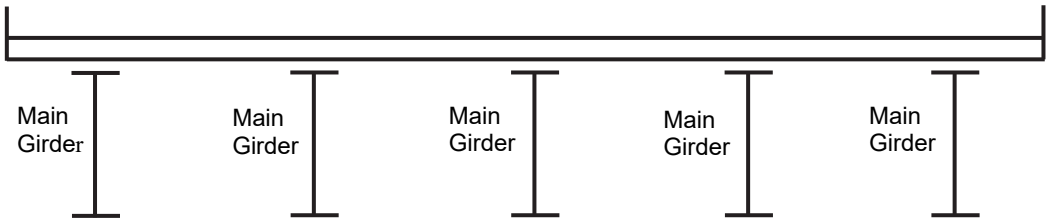


Figure 11.3.2 Cross Section of Conventional I/T-Girder Type

Many girders are supported by abutments. Therefore, it is easy to remove some part of the bridge and reconstruct by a step construction method.

The reconstruction method shall be different between Type-1 bridges and Type-2 bridges. Therefore, reconstruction methods were studied on each type.

Study on Reconstruction Method and Sequence on each Type.

11.3.2 Study on Reconstruction Method and Sequence on each Type

(1) Introduction

Targeted ROBs are located inside a busy city area in Mumbai. Therefore, it is required to maintain the flow of existing traffic as much as possible in order to avoid heavy traffic congestion by this reconstruction work.

In common, when reconstruction work of existing bridge is executed, temporary bridge is constructed beside existing bridge in order to secure existing traffic during reconstruction work. However, since there are a lot of houses on both side of existing bridge, it is impossible to construct temporary bridge besides existing bridge.

And it is impossible to carry out of step construction. Therefore, existing traffic needs to be stopped during reconstruction work for Type-1 Bridge. Construction method to minimize social impact is proposed in following chapter.

In case of Type-2 Bridge, it is possible to apply step construction. Construction method to minimize social impact is proposed in following chapter, also.

(2) Study on Reconstruction Method and Sequence for Type-1 Bridges

Step 1: Install Cofferdam and Temporary Bridge and Construction of Abutment (Secure existing traffic flow)

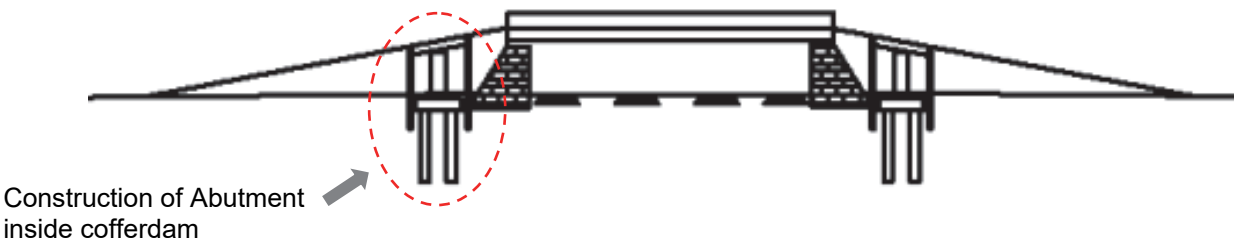


Figure 11.3.3 Reconstruction Procedure of Step 1 for Type-1 Bridge

In order to construct the abutments for the new superstructure and maintain existing traffic flow during construction of the abutment, temporary cofferdams will be installed behind the existing abutments. By installing the temporary cofferdams at night time there will be limited impact to the existing traffic.

Moreover, it is possible to handle the existing traffic by installing a temporary bridge inside the cofferdam area. However, it is required to construct new Abutment in a very restricted space. Therefore, "Cast-in-place Concrete Pile under low clearance" technology shown in Chapter 6.2.3 can be applied.

Estimated construction period for this work is 6-7 months.

Step 2: Demolition of Deck Slab (Closed to existing traffic)

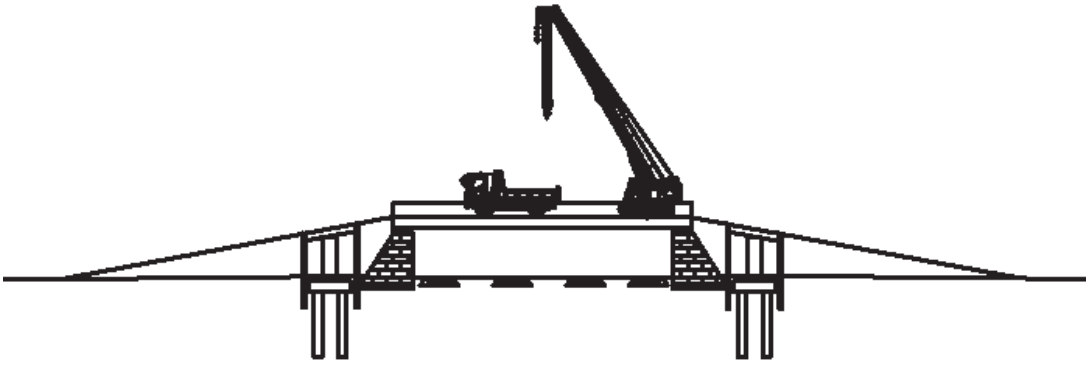


Figure 11.3.4 Reconstruction Procedure of Step 2 for Type-1 Bridge

After completion of construction of the new abutments, the deck slab for the existing superstructure will be removed. During this period, the existing traffic flow will be closed.

Estimated construction period for this work is about 1 week.

Step 3: Removal of Steel Girder (Closed to existing traffic)

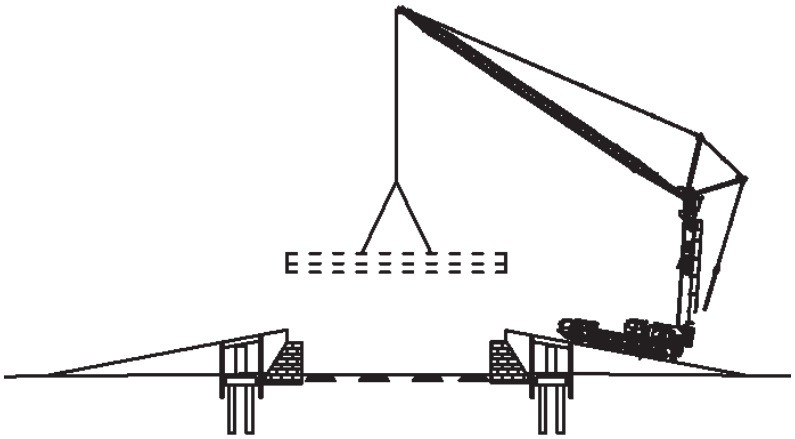


Figure 11.3.5 Reconstruction Procedure of Step 3 for Type-1 Bridge

After demolition of the deck slab for the existing Superstructure, the steel girders of the existing superstructure will be removed. During this period, the existing traffic flow will be closed.

Estimated construction period for this work is about 1.5 months.

Step 4: Construction of New Superstructure (Closed to existing traffic)

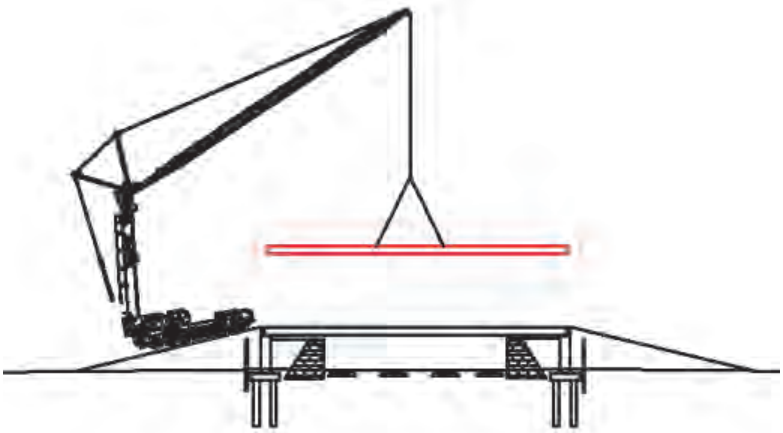


Figure 11.3.6 Reconstruction Procedure of Step 4 for Type-1 Bridge

After removal of the steel girders for slab for the existing superstructure, the new superstructure will be constructed. During this period, the existing traffic flow will be closed.

Estimated construction period for this work is about 1.5 months.

In order to reduce girder depth for reconstructed superstructure, study result of superstructure type is shown in Chapter 11.3.2. (4).

(3) Study on Reconstruction Method and Sequence for Type-2 Bridges

Step 1: Removal of HALF of Superstructure (Only a limited amount of the existing traffic can be handled due to the reduction in width)

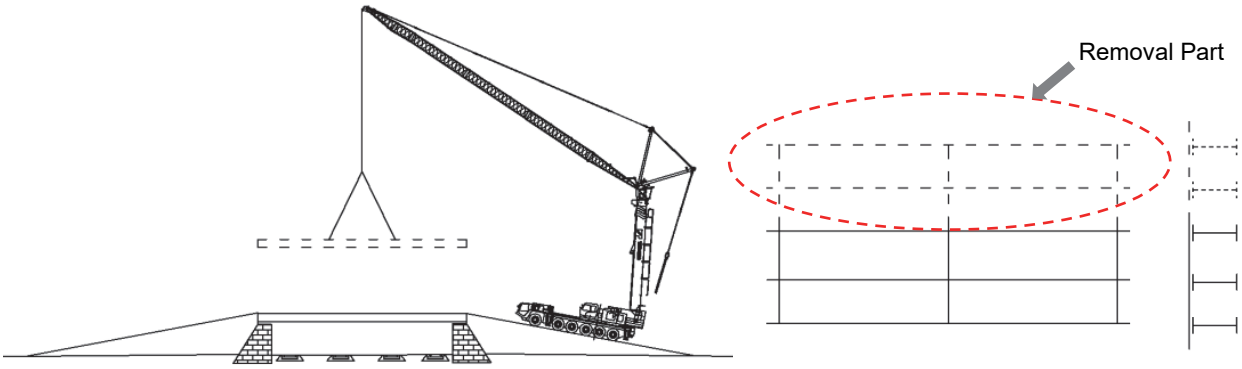
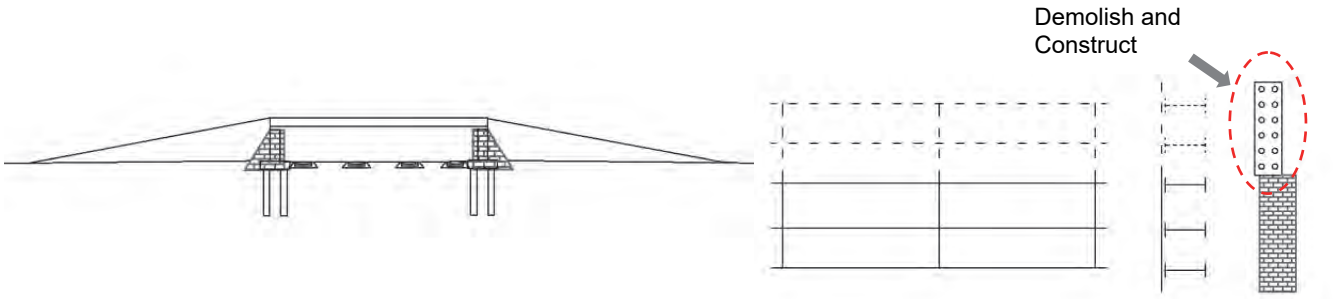


Figure 11.3.7 Reconstruction Procedure of Step 1 for Type-2 Bridge

Because of the structural characteristics, it is possible to demolish half of the existing superstructure. Therefore, half of the existing superstructure will be removed. During removal of that half of the existing superstructure, traffic can use the remaining part of the existing superstructure.

Estimated construction period for this work is 1-2 weeks.

Step 2: Demolition of HALF of the existing Abutment and Construction of HALF of the New Abutment.



(Only a limited amount of the existing traffic can be handled due to the reduction in width)

Figure 11.3.8 Reconstruction Procedure of Step 2 for Type-2 Bridge

After removal of half of the existing superstructure, demolition work on the existing abutments will be commenced. And, half of the new abutments will be constructed.

Estimated construction period of this work is 3-4 months.

Step 3: Construction of HALF of New Superstructure. (Only a limited amount of the existing traffic can be handled due to the reduction in width)

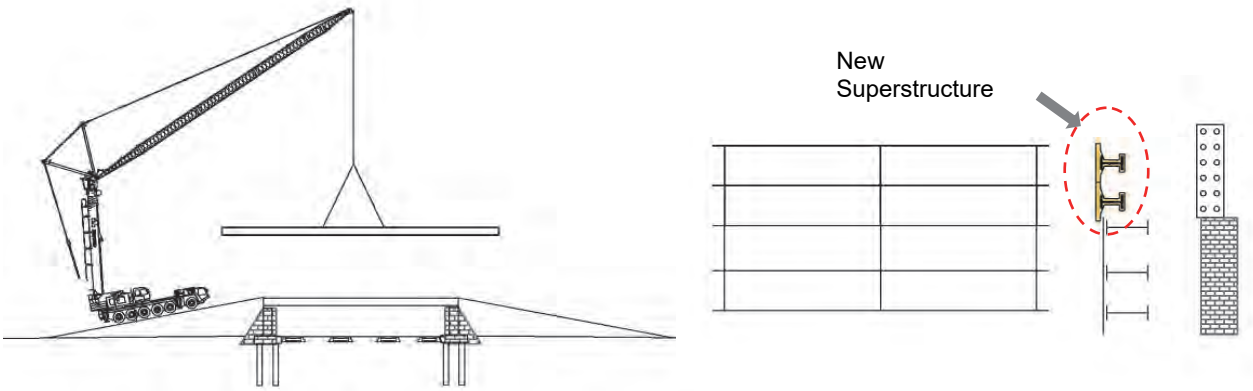


Figure 11.3.9 Reconstruction Procedure of Step 3 for Type-2 Bridge

After completion of construction for half of the new abutments, half of the new superstructure will be constructed.

Estimated construction period of this work is about 1.5-2 months.

Step 4: Removal of remaining Superstructure (Only a limited amount of the existing traffic can be handled due to the reduction in width of the New Superstructure part)

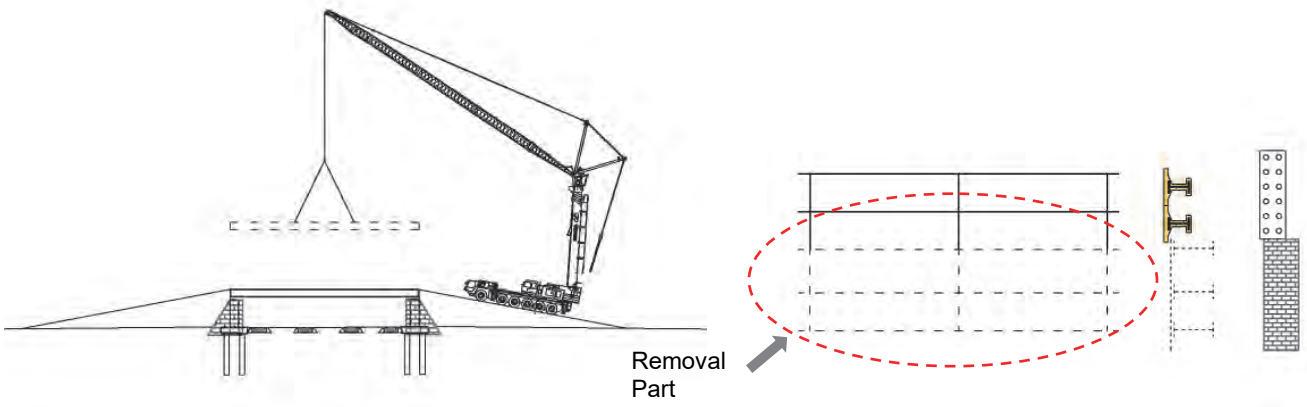


Figure 11.3.10 Reconstruction Procedure of Step 4 for Type-2 Bridge

After completion of construction for half of the new superstructure, the traffic will be shifted from the existing superstructure to the new. Then, removal work of the remaining existing superstructure will be commenced.

Estimated construction period of this work is 1-2 weeks.

Step 5: Demolition of Remaining existing Abutments and construction of HALF of New Abutments (Only a limited amount of the existing traffic can be handled due to the reduction in width)

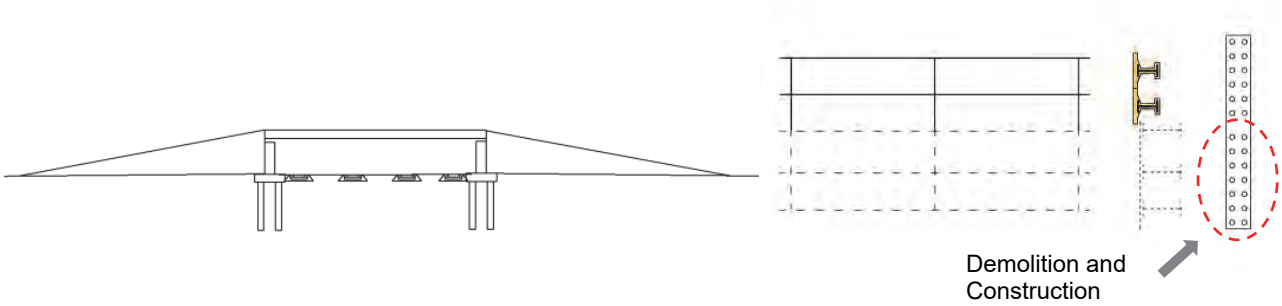


Figure 11.3.11 Reconstruction Procedure of Step 5 for Type-2 Bridge

After removal of the remaining existing superstructure, demolition work of the existing abutments will be commenced. And, the remaining new abutment will be constructed.

Estimated construction period of this work is 3-4 months.

Step 6: Erection of Remaining New Superstructure. (Only a limited amount of the existing traffic can be handled due to the reduction in width)

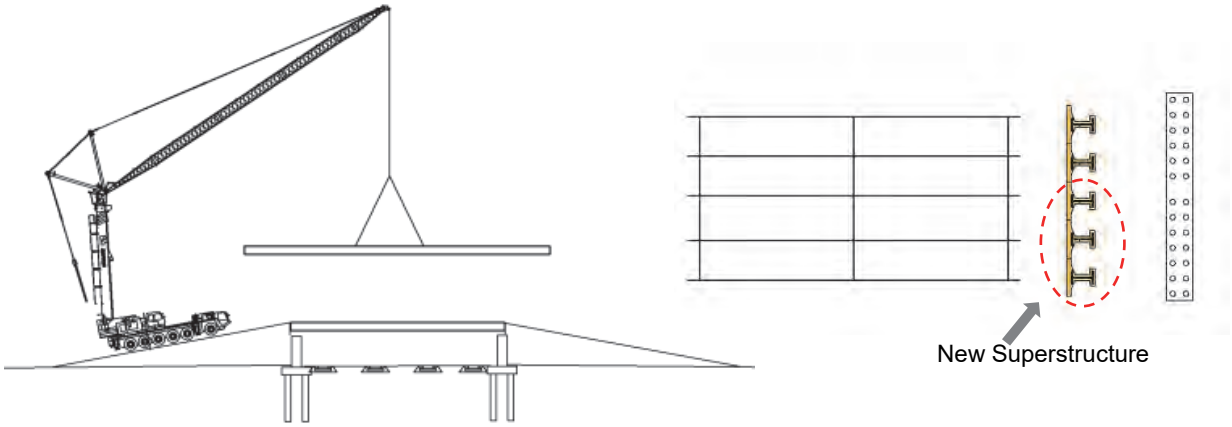


Figure 11.3.12 Reconstruction Procedure of Step 6 for Type-2 Bridge

After completion of construction for the remaining new abutments, the remaining new superstructure will be constructed.

Estimated construction period of this work is about 1.5-2 months.

In order to reduce girder depth for reconstructed superstructure, study result of superstructure type is shown in Chapter 11.3.2. (4).

(4) Study on Superstructure Type

Due to change electricity supply system from DC to AC, clearance under the ROBs is required to increase from 5.0m to 6.5m. Therefore, it is required to apply low girder depth superstructures in order to avoid negative impact to the surrounding environment by increasing the elevation of the vertical alignment.

For this purpose, the following superstructure types which can reduce girder depth are selected and comparison study is carried out. Features of each superstructure are shown in Chapter 6.2.2.

- Bi-Prestressing PC Beam
- Pre-fixed PC Beam
- Composite Floor Slab
- Steel I Girder with Steel Deck Plate (not advanced technology)
- Pony Truss (not advanced technology)

For reference, the relationships between span length and girder depth are shown in Figure 11.3.13.

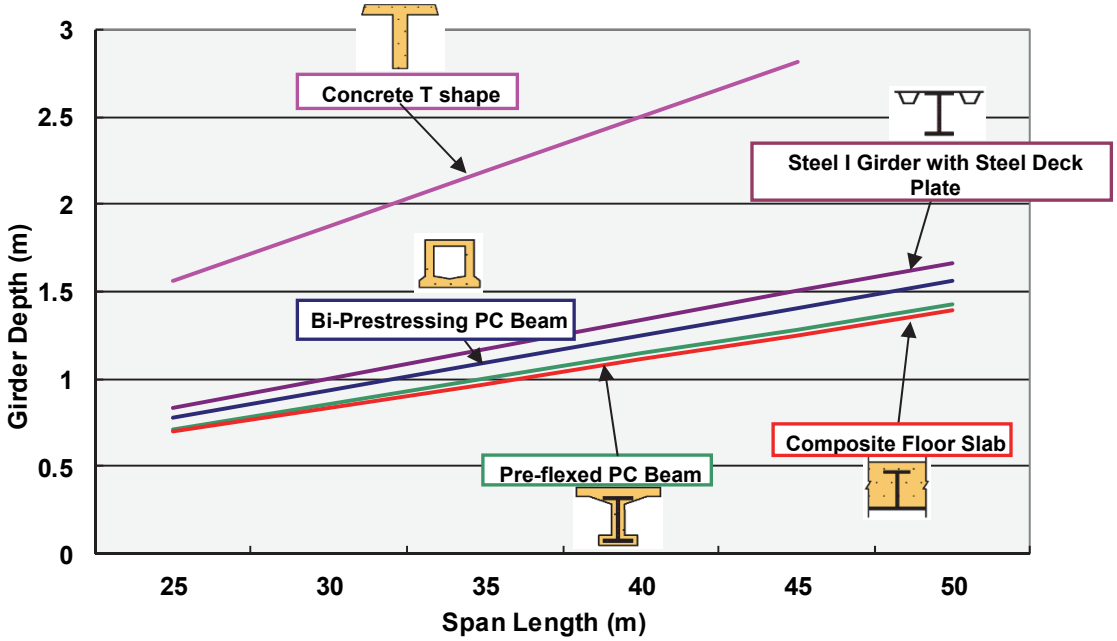


Figure 11.3.13 Graph for Relationship between Span Length and Girder Depth

Comparison table of superstructure types is shown in Table 11.3.2

Table 11.3.2 Comparison of Superstructure Types (1/2)

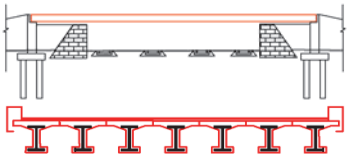
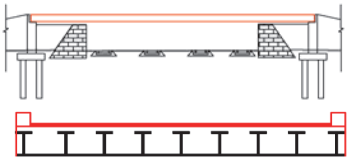
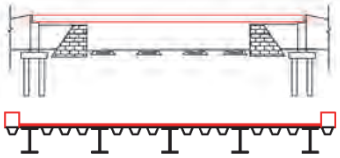
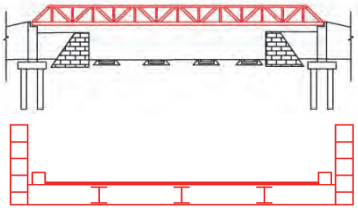
	Plan – 1 Bi - Prestressing PC Beam	**Plan - 2** Pre-fixed PC Beam	**Plan - 3** Composite Floor Slab
Side View & Cross Section			
Cost (Super Structure)	1.17	1.06	1.03
Comment	✓ Transversal Prestressing is necessary, Step Construction is difficult. (Moderate) ✓ Maintenance for re-coating is unnecessary. (Good) ✓ Due to requirement of high-strength concrete, fabrication shall be done at specialized factory (Bad).	✓ Step Construction is possible. (Good) ✓ Maintenance for re-coating is unnecessary. (Good) ✓ Easy for erection of girder, however, construction of cross beam and deck slab shall be done at site (Moderate).	✓ Step Construction is possible. (Good) ✓ Re-coating is necessary only for Lower Deck Slab. (Moderate), but, by applying weathering Steel, no maintenance work is required (Good) ✓ Due to all fabricating in Factory, easy for erection at site (Good)

Table 11.3.3 Comparison of Superstructure Types (2/2)

	Plan – 4 Steel I Girder with Steel Deck Plate	**Plan - 5** Pony Truss	-
Side View & Cross Section			-
Cost (Super Structure)	1.22	1.00	-
Comment	✓ Step Construction is possible. (Good) ✓ Re-coating is necessary for Main Girder and lower face of deck slab. (Moderate), but, by applying of weathering Steel, no maintenance work is required (Good) ✓ Due to all fabricating in Factory, easy for erection at site (Good)	✓ Step Construction is impossible. (Bad) ✓ Re-coating is necessary for Truss structure. (Moderate) , but, by applying of weathering Steel, no maintenance work is required (Good) ✓ Due to large number of members, period of work at site will be longer than other types. (Bad)	-

For Type-1 Bridge

Due to an economic advantage and easy work at site is preferable for Type 1 ⇒ Plan-3 (Composite Floor Slab) are recommended.

For Type-2 Bridge

Due to an economic advantage and requirement of Step Construction for Type 2 ⇒ Plan-3 (Composite Floor Slab) are recommended.

11.3.3 Advanced Technologies can be Applied to Projects

The advanced technologies can be applied to the project in Mumbai is shown in Table 11.3.4. According to apply these technologies, it is possible to be environment - friendly construction in more short term compared with construction by existing technology.

For details of the technologies are shown in chapter 6.

Table 11.3.4 List of Advanced Technology

Name of Technology	Feature
Bi-Prestressing PC System	New Superstructure type which can utilize a thinner Girder Height than the conventional type
Pre-flexed PC Beam	New Superstructure type which can make thinner the Girder Height than conventional type
Composite Floor Slab	New Superstructure type which can utilize a thinner the Girder Height than the conventional type
Composite Slab	New deck slab type which has high durability and safe for construction, especially, underneath of deck slab

11.3.4 Overall Construction Schedule

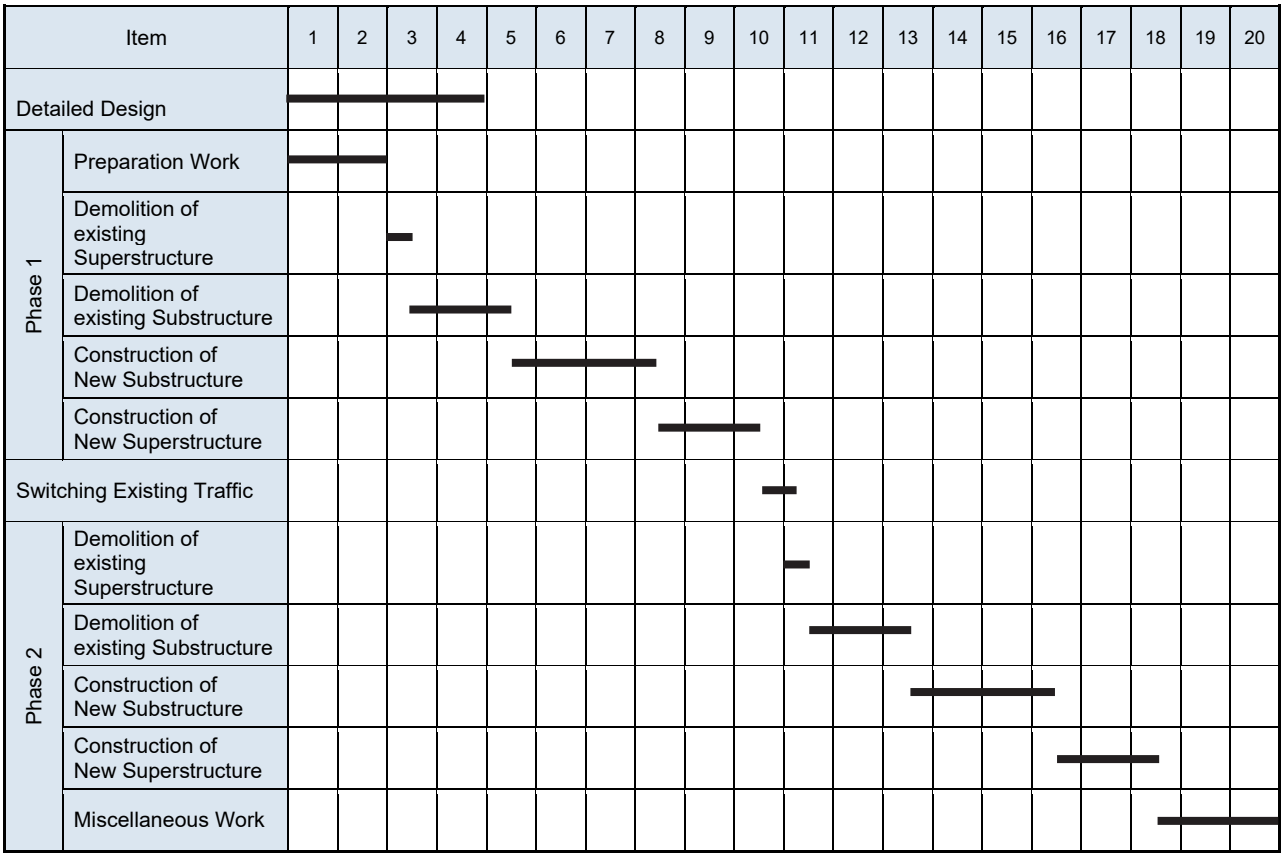
Based on above study result, overall construction schedules for both Type-1 Bridge and Type-2 Bridge are shown in Table 11.3.5 and Table 11.3.6.

Table 11.3.5 Overall Construction Schedule for Type-1 Bridge

Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Detailed Design															
Preparation Work															
Construction of New Abutment															
Demolition of Existing SS															
Construction of New SS															
Miscellaneous Work															
Restriction of Existing Traffic										Restriction of Existing Traffic					

Note: This schedule is prepared as for typical type of bridge which has 30m single span with 2 Abutments

Table 11.3.6 Overall Construction Schedule for Type-2 Bridge



Note: This schedule is prepared as for typical type of bridge which has 30m single span
During the construction, the existing traffic is affected by the step construction.

11.3.5 Cost Estimation

(1) Exchange Rate

Exchange rate used for calculation of cost estimation is average value for 2 weeks from the end of August 2016 to the beginning of September 2016. Applied exchange rate is shown as below;

- 1 USD = 101.80 [Yen]
- 1 INR = 1.52 [Yen]

(2) Estimated Project Cost

Estimated project costs in case of Japanese support are shown in Table 11.3.7 . The estimated total project cost (including construction costs, design costs and supervision costs) is approximately 9.5 billion Yen (6.2 billion INR).

Table 11.3.7 Estimated project Cost

Project Location	Contents	Unit	Quantity	Unit [100 Yen]	Project Cost [Million Yen]				Project Cost [Million INR]			
					Construction	Design	Supervision	Total	Construction	Design	Supervision	Total
Mumbai	Reconstruction of 7 ROBs	m^2	15,185	551.5	8,375	334	754	9,463	5,510	220	496	6,226

11.4 Traffic Demand Forecast

11.4.1 Traffic Count Survey

As part of the work of the Data Collection Survey on Bridge Sector, the traffic count survey was carried out in Mumbai from 24th June 2016 to 15th August 2016. The survey was conducted on the existing bridges.

11.4.2 Traffic Characteristics

The following traffic characteristics have been presented in the following sections:

- Total Traffic Count and PCUs
- Hourly variation and Peak Hour Factor (PHF)
- Traffic composition

(1) Total Traffic Count

The traffic volume data collected during the surveys is shown in Table 11.4.1.

Table 11.4.1 Traffic Volume Count

Traffic Volume Count at Mumbai																		
			Traffic Volume															
S.No	Location Name	ROB	Car/Jeep /Van (private)	Two Wheeler	Auto Rickshaw	Mini Bus	Bus	2 Axle Truck	3 Axle Truck	MAV	LCV/ Pick up	Tractor	Tractor with Trolley	Cycle	Cycle Rickshaw	Hand Cart	Animal /Hand Drawn	Total	PCUs
1	Mumbai	Frerere	12330	6974	53	64	839	69	1	0	557	4	0	431	20	51	12	21405	20029
2		Belasis	18047	8625	55	86	1011	332	37	5	919	0	0	245	14	36	2	29414	28419
3		Mahalaxmi	35187	15006	104	168	1215	648	78	12	1943	0	0	107	19	4	1	54492	49509
4		Delise	10463	8265	0	363	1129	1136	530	83	4908	0	0	527	24	159	18	27605	31516
5		Tilak	12940	10412	13	916	2772	891	17	0	2662	1	0	669	8	10	6	31317	34417
6		Mahim	9198	8390	0	256	382	1230	472	16	2337	2	0	369	62	123	25	22862	24720
7		Goregaon	15378	12660	12557	677	632	1734	124	14	5896	1	28	558	52	23	3	50337	49422

Source: JICA Study Team

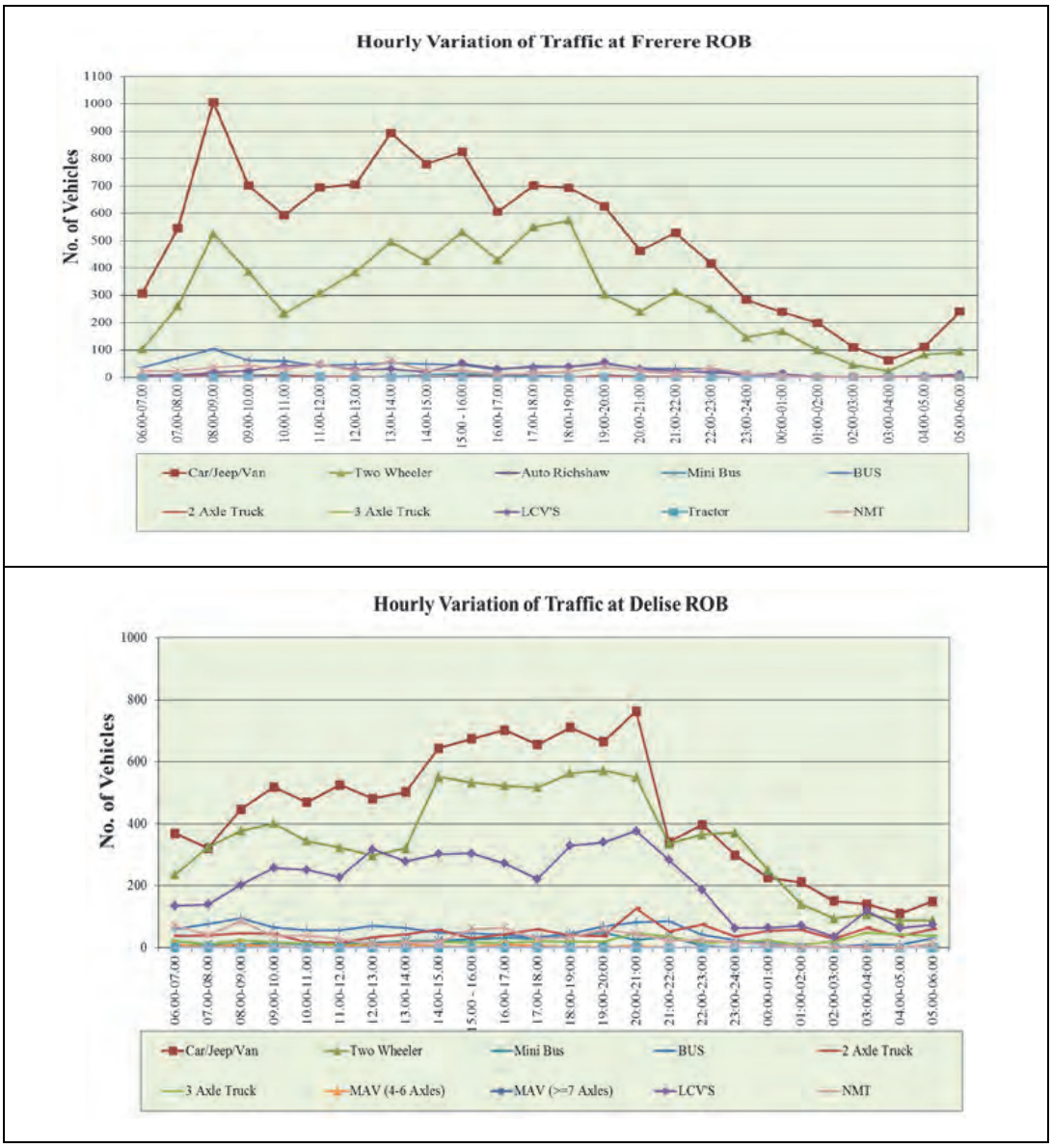
(2) Peak Hour Factor (PHF) and Hourly Variation

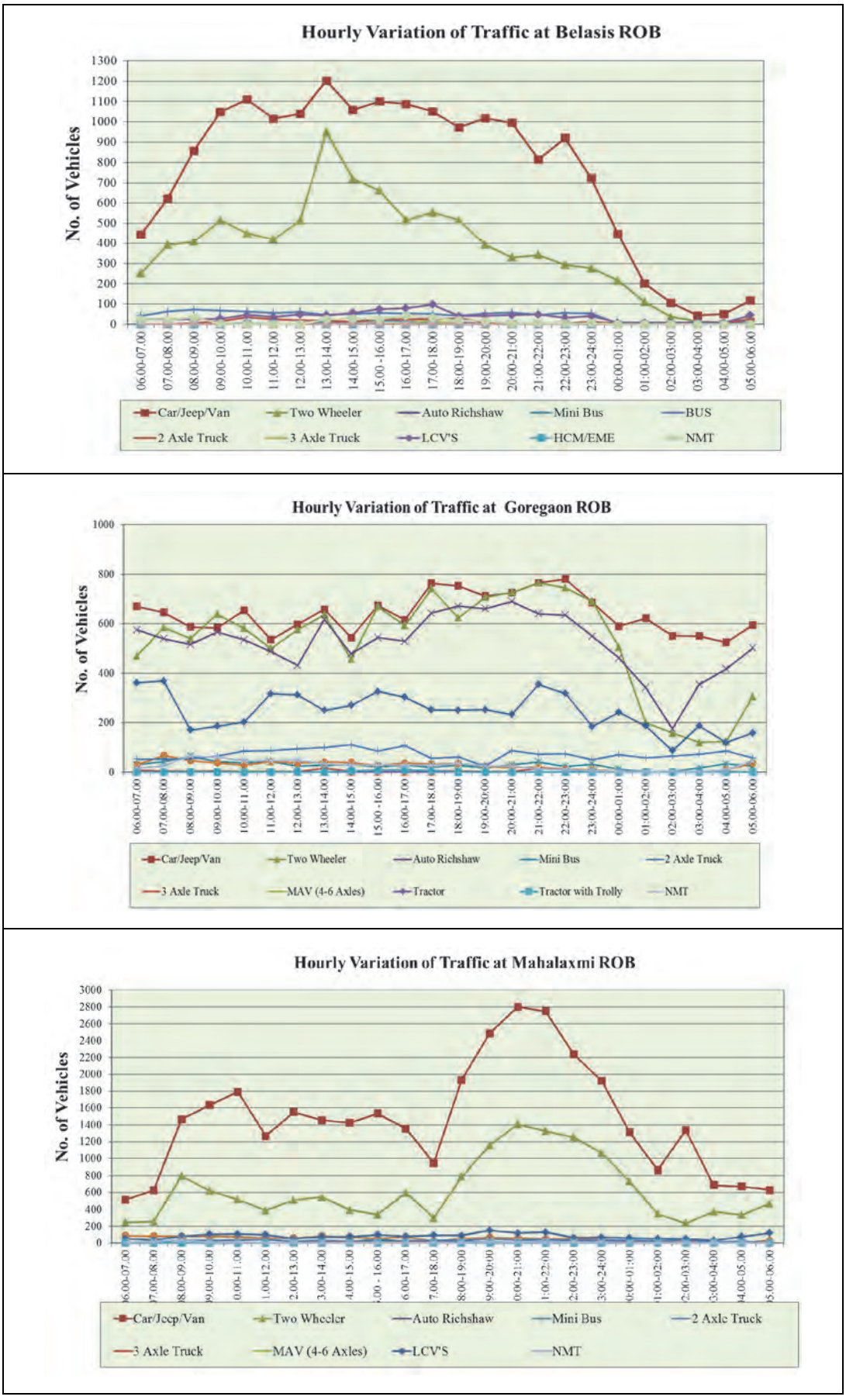
The hourly variation of traffic illustrates the distribution of traffic over the day with respect to time and the Peak Hour Factor (PHF) is the maximum percentage of the total traffic that uses the project highway in a single hour of the day. The peak hour factors observed at the count stations are summarized in Table 11.4.2. According to Table 11.4.2, it is confirmed peak hour traffic is generated at rush hour in morning and evening. In addition, PHF shows about 5-9% in Table 11.4.2. According to PHF in Japan, average PHF is about 7% (at National Highway by 24 hours measurement), therefore, PHF ranged from 5-9% is appropriate value.

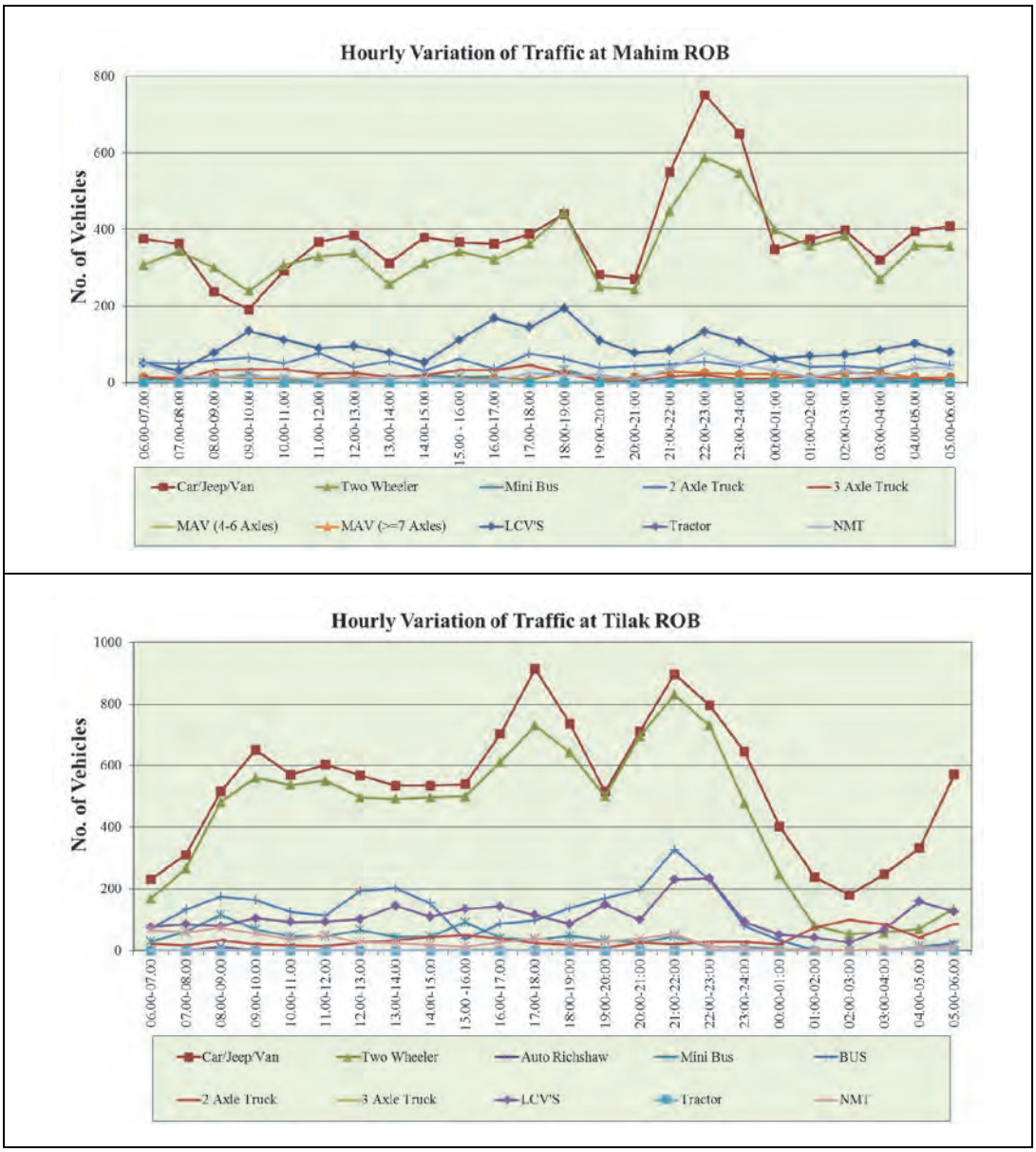
Table 11.4.2 Per Hour Traffic

Traffic Count at Mumbai							
	Survey Locations	Traffic Peak Hour in Morning (Nos)	Peak Hour Percentage (Morning)	Observed Peak Hour	Traffic Peak hour in Evening (Nos)	Peak Hour Percentage (Evening)	Observed Peak Hour
Mumbai	Frerere ROB	1718	8.59	08:00 to 09:00	1221	6.11	18:15 to 19:15
	Belasis ROB	1959	9.64	13:00 to 14:00	1650	5.84	18:15 to 19:15
	Malalaxmi ROB	2514	4.93	09:30 to 10:30	4117	8.07	19:30 to 20:30
	Delise ROB	1713	5.62	08:15 to 09:15	2358	7.73	19:30 to 20:30
	Tilak ROB	1944	5.77	08:30 to 09:30	2706	8.03	21:00 to 22:00
	Mahim ROB	1134	4.74	05:15 to 06:15	1761	7.36	21:45 to 22:45
	Goregaon ROB	2431	4.92	06:45 to 07:45	2542	5.14	21:15 to 22:15

Source: JICA Study Team




Hourly Variation of Traffic at Belasis ROB
No. of Vehicles
Car/Jeep/Van
Two Wheeler
Auto Richshaw
Mini Bus
BUS
2 Axle Truck
3 Axle Truck
LCV'S
HCM/EME
NMT
Hourly Variation of Traffic at Goregaon ROB
No. of Vehicles
Car/Jeep/Van
Two Wheeler
Auto Richshaw
Mini Bus
2 Axle Truck
3 Axle Truck
MAV (4-6 Axles)
Tractor
Tractor with Trolly
NMT
Hourly Variation of Traffic at Mahalaxmi ROB
No. of Vehicles
Car/Jeep/Van
Two Wheeler
Auto Richshaw
Mini Bus
2 Axle Truck
3 Axle Truck
MAV (4-6 Axles)
LCV'S
NMT

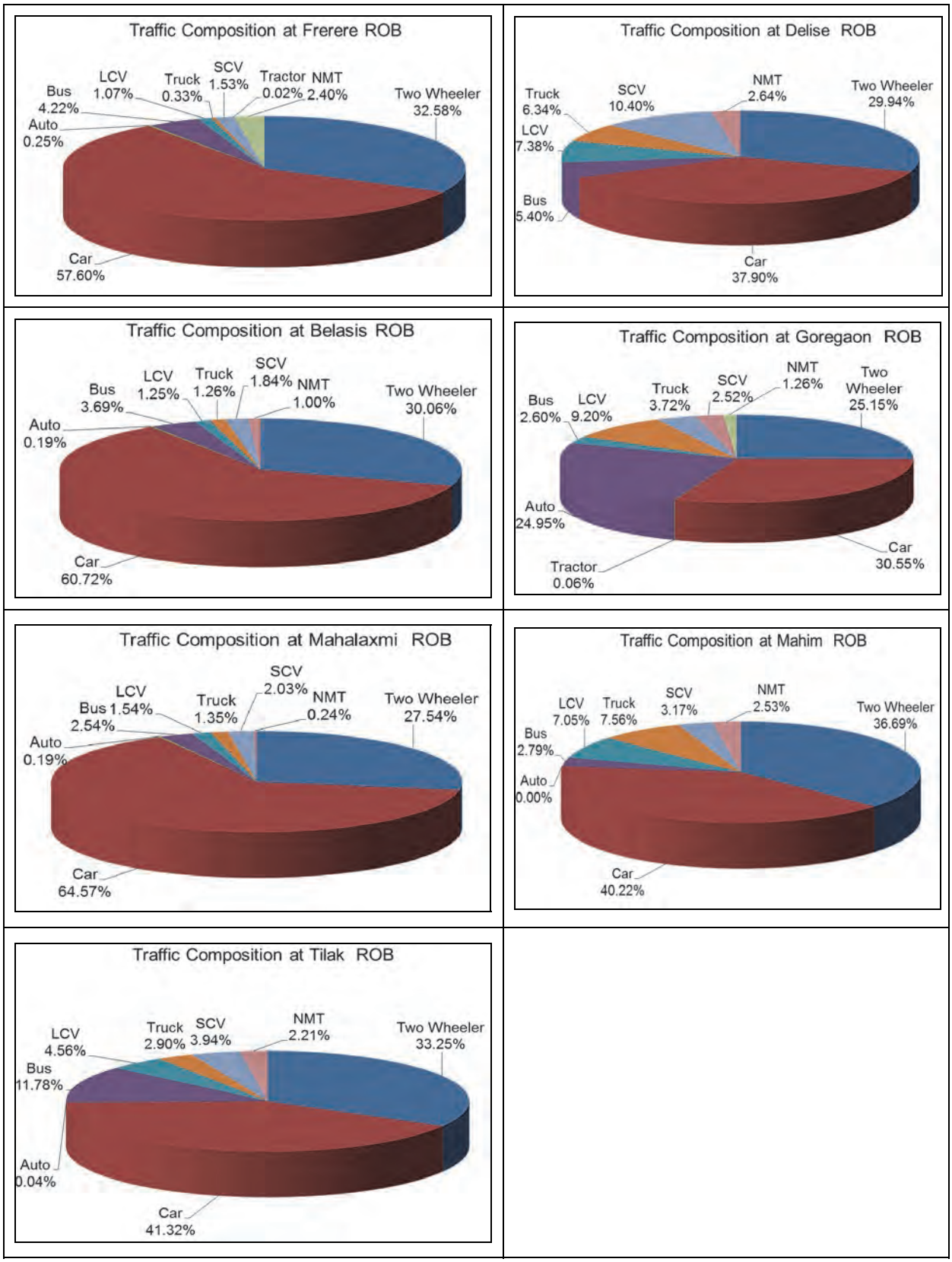


Source: JICA Study Team

Figure 11.4.1 Hourly Variation of Traffic at Mumbai

(3) Traffic Composition

Based on traffic volume survey, the traffic compositions of the each survey point in Mumbai are shown in Figure 11.4.2. Based on the result, 70-9% of traffic composition is Passenger Car, 2 wheelers and Auto Rickshaw (3-wheeler), therefore, it is confirmed target road is served mainly for residents.



Source: JICA Study Team

Figure 11.4.2 Traffic Composition at Mumbai

11.4.3 Existing Traffic Volume

The following tables show Annual Average Daily Traffic (AADT) of the study areas. It represents traffic demand forecast for Reconstruction Project of ROBs in Mumbai.

Table 11.4.3 The existing Traffic Volume (Reconstruction Project of ROBs in Mumbai, 2016)

(Unit: vehicle)

Location	Ferere ROB	Belasis ROB	Mahalaxmi ROB	Delise ROB	Tilak ROB	Mahim ROB	Goregaon ROB
Passenger car	12,887	18,966	37,130	15,371	15,602	11,535	21,274
Bus	903	1,097	1,383	1,492	3,688	638	1,309
Truck	74	374	738	1,749	909	1,720	1,901
Total	13,864	20,437	39,251	18,612	20,199	13,893	24,484

(Unit PCU)

Location	Ferere ROB	Belasis ROB	Mahalaxmi ROB	Delise ROB	Tilak ROB	Mahim ROB	Goregaon ROB
Passenger car	12,887	18,966	37,130	15,371	15,602	11,535	21,274
Bus	2,709	3,291	4,149	4,476	11,064	1,914	3,927
Truck	333	1,683	3,321	7,871	4,091	7,740	8,555
Total	15,929	23,940	44,600	27,718	30,757	21,189	33,756

Source: JICA Study Team

11.4.4 Traffic Demand Forecast of the Study Area

Annual Average Daily Traffic (AADT) of the study area is estimated in consideration with the existing traffic volume at the study area shown in Table 11.4.3 and estimated growth rate for future traffic volume described in Chapter 7.3.2.

The results of traffic demand forecast of ROBs in the study area is shown in follows.

Table 11.4.4 Traffic Demand Forecast (Reconstruction Project of ROBs in Mumbai 1, 2017)

(Unit: PCU)

	Ferere ROB				Belasis ROB			
	Car	Bus	Truck	Total	Car	Bus	Truck	Total
2020	18,124	3,810	468	22,403	26,674	4,628	2,367	33,669
2021	19,737	4,149	510	24,397	29,048	5,040	2,578	36,666
2022	21,494	4,518	555	26,568	31,633	5,489	2,807	39,929
2023	23,407	4,920	605	28,932	34,449	5,978	3,057	43,483
2024	25,490	5,358	659	31,507	37,514	6,510	3,329	47,353
2025	27,759	5,835	717	34,311	40,853	7,089	3,625	51,567
2026	30,229	6,355	781	37,365	44,489	7,720	3,948	56,157
2027	32,920	6,920	851	40,691	48,449	8,407	4,299	61,155
2028	35,850	7,536	926	44,312	52,761	9,155	4,682	66,598
2029	39,040	8,207	1,009	48,256	57,456	9,970	5,099	72,525
2030	42,515	8,937	1,099	52,551	62,570	10,857	5,552	78,980
2031	46,299	9,733	1,196	57,228	68,139	11,824	6,046	86,009
2032	50,419	10,599	1,303	62,321	74,203	12,876	6,585	93,663
2033	54,907	11,542	1,419	67,868	80,807	14,022	7,171	102,000
2034	59,793	12,569	1,545	73,908	87,999	15,270	7,809	111,077
2035	65,115	13,688	1,683	80,486	95,831	16,629	8,504	120,963
2036	70,910	14,906	1,832	87,649	104,360	18,109	9,261	131,729
2037	77,221	16,233	1,995	95,450	113,648	19,720	10,085	143,453
2038	84,094	17,678	2,173	103,945	123,763	21,475	10,982	156,220
2039	91,578	19,251	2,366	113,196	134,777	23,387	11,960	170,124
2040	99,729	20,964	2,577	123,270	146,773	25,468	13,024	185,265

Source: JICA Study Team

Table 11.4.5 Traffic Demand Forecast (Reconstruction Project of ROBs in Mumbai 2, 2017)

(Unit: PCU)

	Mahalaxmi ROB				Delise ROB			
	Car	Bus	Truck	Total	Car	Bus	Truck	Total
2020	52,220	5,835	4,671	62,726	21,618	6,295	11,069	38,982
2021	56,868	6,355	5,086	68,308	23,542	6,855	12,054	42,452
2022	61,929	6,920	5,539	74,388	25,637	7,465	13,127	46,230
2023	67,440	7,536	6,032	81,008	27,919	8,130	14,295	50,344
2024	73,443	8,207	6,569	88,218	30,404	8,853	15,568	54,825
2025	79,979	8,937	7,154	96,070	33,110	9,641	16,953	59,704
2026	87,097	9,732	7,790	104,620	36,056	10,500	18,462	65,018
2027	94,849	10,599	8,484	113,931	39,265	11,434	20,105	70,804
2028	103,290	11,542	9,239	124,071	42,760	12,452	21,895	77,106
2029	112,483	12,569	10,061	135,113	46,566	13,560	23,843	83,969
2030	122,494	13,688	10,956	147,138	50,710	14,767	25,965	91,442
2031	133,396	14,906	11,931	160,233	55,223	16,081	28,276	99,580
2032	145,268	16,233	12,993	174,494	60,138	17,512	30,793	108,443
2033	158,197	17,677	14,150	190,024	65,490	19,071	33,533	118,094
2034	172,277	19,251	15,409	206,936	71,319	20,768	36,518	128,604
2035	187,609	20,964	16,780	225,354	77,666	22,616	39,768	140,050
2036	204,307	22,830	18,274	245,410	84,578	24,629	43,307	152,515
2037	222,490	24,862	19,900	267,252	92,106	26,821	47,162	166,088
2038	242,292	27,074	21,671	291,037	100,303	29,208	51,359	180,870
2039	263,856	29,484	23,600	316,939	109,230	31,808	55,930	196,968
2040	287,339	32,108	25,700	345,147	118,952	34,639	60,908	214,498

Source: JICA Study Team

Table 11.4.6 Traffic Demand Forecast (Reconstruction Project of ROBs in Mumbai 3, 2017)

(Unit: PCU)

	Tilak ROB				Mahim ROB			
	Car	Bus	Truck	Total	Car	Bus	Truck	Total
2020	21,943	15,561	5,753	43,256	16,223	2,692	10,886	29,800
2021	23,896	16,945	6,265	47,106	17,667	2,931	11,854	32,453
2022	26,022	18,454	6,823	51,298	19,239	3,192	12,909	35,341
2023	28,338	20,096	7,430	55,864	20,951	3,476	14,058	38,486
2024	30,861	21,884	8,091	60,836	22,816	3,786	15,310	41,912
2025	33,607	23,832	8,811	66,250	24,847	4,123	16,672	45,642
2026	36,598	25,953	9,595	72,147	27,058	4,490	18,156	49,704
2027	39,855	28,263	10,449	78,568	29,466	4,889	19,772	54,127
2028	43,403	30,778	11,379	85,560	32,089	5,324	21,532	58,945
2029	47,265	33,518	12,392	93,175	34,945	5,798	23,448	64,191
2030	51,472	36,501	13,495	101,468	38,055	6,314	25,535	69,904
2031	56,053	39,749	14,696	110,498	41,442	6,876	27,807	76,125
2032	61,042	43,287	16,004	120,333	45,130	7,488	30,282	82,900
2033	66,474	47,140	17,428	131,042	49,146	8,155	32,977	90,279
2034	72,391	51,335	18,979	142,705	53,520	8,881	35,912	98,313
2035	78,833	55,904	20,668	155,406	58,284	9,671	39,108	107,063
2036	85,850	60,879	22,508	169,237	63,471	10,532	42,589	116,592
2037	93,490	66,298	24,511	184,299	69,120	11,469	46,380	126,968
2038	101,811	72,198	26,693	200,701	75,272	12,490	50,507	138,269
2039	110,872	78,624	29,068	218,564	81,971	13,601	55,002	150,575
2040	120,740	85,621	31,655	238,016	89,266	14,812	59,898	163,976

Source: JICA Study Team

Table 11.4.7 Traffic Demand Forecast (Reconstruction Project of ROBs in Mumbai 4, 2017)

(Unit: PCU)

	Goregaon ROB			
	Car	Bus	Truck	Total
2020	29,920	5,523	12,031	47,474
2021	32,583	6,015	13,102	51,699
2022	35,483	6,550	14,268	56,300
2023	38,641	7,133	15,538	61,311
2024	42,080	7,768	16,921	66,768
2025	45,825	8,459	18,427	72,710
2026	49,903	9,212	20,067	79,181
2027	54,345	10,032	21,853	86,229
2028	59,181	10,924	23,797	93,903
2029	64,448	11,897	25,915	102,260
2030	70,184	12,955	28,222	111,361
2031	76,431	14,108	30,734	121,273
2032	83,233	15,364	33,469	132,066
2033	90,641	16,731	36,448	143,820
2034	98,708	18,221	39,691	156,620
2035	107,493	19,842	43,224	170,559
2036	117,060	21,608	47,071	185,739
2037	127,478	23,531	51,260	202,269
2038	138,823	25,626	55,822	220,271
2039	151,179	27,906	60,791	239,875
2040	164,634	30,390	66,201	261,224

Source: JICA Study Team

11.5 Economic Analysis

11.5.1 Introduction

In this section, social economic benefit is calculated for Reconstruction Project of ROBs in Mumbai used for traffic demand forecast result as explained in Chapter 11.4. Social economic benefit is defined as the savings of social cost by implementing each project mentioned above, which is the difference of social cost between With Case (with implementing the project) and Without Case (without implementing the project).

11.5.2 Cases to be studied

A total of 7 ROBs (Railway over Bridge) of Western Railway, which has its origin in Mumbai Central Station, are planned to be replaced in this project. Immediate replacement with Japanese advanced construction method is the "With Case" and the "Without Case" is leaving the deteriorated bridges in a dangerous condition and replaces them some time later.

Table 11.5.1 "With Case" and "Without Case" (Reconstruction Project of ROBs in Mumbai)

With Case	Without Case
Replacing immediately the 7 ROBs of Western Railway in the north of Mumbai. Japanese advanced construction method is applied to shorten the construction period, and minimize the congestion of the existing traffic during construction.	Leaving the deteriorated bridges in a dangerous condition and replacing the 7 ROBs at some later date with conventional construction method. The existing traffic is forced to make a detour and will be congested heavily with long construction period.

Source: JICA Study Team

11.5.3 Implementation Schedule for Economic Analysis

A total of 7 deteriorated ROBs are planned to be replaced in this project. Immediate replacement applying Japanese advanced construction method is performed in the "With Case". The 7 ROBs are severely damaged and will have to be closed by 2026 due to the increase in the traffic volume and vehicle weight and emergency work will have to be executed in the "Without Case". The existing traffic will be forced to make a detour during an emergency in the "Without Case" but no traffic needs to make a detour in the "With Case".

Table 11.5.2 Implementation Schedule for Economic Analysis (Reconstruction Project of ROBs in Mumbai)

	With Case	Without Case	Remarks
2019	D/D	Leave as it is	
2020	Construction	↓	With Case: no detour for the existing traffic, a half section construction
2021	Construction	↓	
2022	New ROB open	↓	
↓	↓	↓	
2026	↓	ROB closed, D/D and construction	Without Case: emergency works, detour for the existing traffic
2027	↓	Construction	
2029	↓	New ROB open	
2030	↓	↓	
↓	↓	↓	
2048	End of analysis period	End of analysis period	

Source: JICA Study Team

11.5.4 Project Cost

The following tables show project cost for the economic analysis in the study areas. (Refer to 11.3.5 for the details)

Table 11.5.3 Project Cost by Study Area

(Unit: Million Indian Rupees)

	With Case				Without Case			
Location	Construction	D/D	C/S	Total	Construction	D/D	C/S	Total
Mumbai	5,510	220	496	6,226	3,673	147	331	4,151

Source: JICA Study Team

11.5.5 Cost Benefit Analysis

The result of cost benefit analysis under the condition shown in Chapter 7.4.3 is shown in following table.

Table 11.5.4 Cost Benefit Analysis Result

Evaluation Indicator	Mumbai
Economic Internal Rate of Return (EIRR, %)	20.9%
Economic Net Present Value (ENPV, Million Indian Rupee)	2,211
Benefit/Cost (B/C)	1.72

- Economic Internal Rate of Return (EIRR) = (Discount rate value which makes ENPV = 0)
- Economic Net Present Value (ENPV)
  = (Net present benefit of project benefit) – (Net present cost of project benefit)
- Benefit/Cost (B/C) = (Net present benefit of project benefit)/(Net present cost of project benefit)
  where,
  benefit of project = benefit reducing VOC + benefit reducing TTC
  cost of project = Implementing Cost + Operation & Maintenance Cost

Source: JICA Study Team

As shown is Table 11.5.4, the numerical of EIRR of the target four projects are over 12%, the validity of these projects are confirmed.

11.6 Environmental Evaluations

11.6.1 Screening Result based on JICA Guideline

The target bridges in reconstruction of ROB in Mumbai Section for screening are shown in Table 11.6.1. The locations are shown in Figure 3.7.1 of Chapter 3.

The result of preliminary study and screening based on JICA Guideline is shown in Table 11.6.2.

I. Pollution, the evaluation was A in Rating of Noise/Vibration and Air pollution (Dust) During and After Const. II. Social, it was the evaluation A in Rating of Involuntary Resettlement. III. Natural, it was mangrove forest B in the Rating of the Mahim ROB (No. 6). In the JICA Category, it was the evaluation A in Rating of the Result of Screening based on JICA Guideline for Environmental and Social Considerations (2010).

Table 11.6.1 List of Target Bridge (Reconstruction Project of ROBs in Mumbai)

Type of Bridge	Location	Bridge Name
ROB	Reconstruction Project of ROBs in Mumbai	(1) Ferere ROB (No. 1) (2) Balasis ROB (No. 2) (3) Mahalaxmi ROB (No. 3) (4) Delise ROB (No. 4) (5) Tilak ROB (No. 5) (6) Mahim ROB (No. 6) (7) Goregaon ROB (No. 7)

Source: List by Western Railway

Table 11.6.2 Preliminary Environmental Evaluation and Screening based on JICA Guideline (as of October 5th, 2016) – Reconstruction Project of ROBs in Mumbai

Type of Bridge	Location	St. No	Br. No	Affected Item / Bridge Name	Repair /Reconstruction	Ⅰ.Pollution: Noise/Vibration and Air pollution (Dust) During and After Const. Rating	Description	Ⅰ.Pollution: Water Quality (Turbid Water) During Const. Rating	Description	Ⅱ.Social Environment: Involuntary Resettlement Rating	Description	Ⅱ.Social Environment: Culture (Sacred place and Facility) Rating	Description	Ⅲ.Natural Environment: Mangrove Trees Rating	Description	JICA Category: Result of **Screening** based on JICA Guideline for Environmental and Social Considerations (2010)		Expected clearances to be acquired: EC	Clearance for CRZ
ROB	Mumbai	1	1	Ferere ROB	New Bridge Construction	A	Residential area is observed and might be affected.	C	No river by the bridge.	A	Residential area and commercial area is observed and might be affected.	C	Mosque is located in the south west side but not directly affected.	C	No mangrove observed.	**A**	Many resettlements are expected and land acquisition might be required	✓	-
	Mumbai	2	2	Balasis ROB	New Bridge Construction	A	Residential area is observed and might be affected.	C	No river by the bridge.	A	Residential area and commercial area is observed and might be affected.	C	No sacred facility is observed.	C	No mangrove observed.	**A**	Many resettlements are expected and land acquisition might be required	✓	-
	Mumbai	3	3	Mahalaxmi ROB	New Bridge Construction	A	Residential area is observed and might be affected.	C	No river by the bridge.	A	Residential area and commercial area is observed and might be affected.	C	No sacred facility is observed.	C	No mangrove observed.	**A**	Many resettlements are expected and land acquisition might be required	✓	-
	Mumbai	4	4	Delise ROB	New Bridge Construction	A	Residential area is observed and might be affected.	C	No river by the bridge.	A	Residential area and commercial area is observed and might be affected.	B	Temple is located on the south east side.	C	No mangrove observed.	**A**	Many resettlements are expected and land acquisition might be required	✓	-

Type of Bridge	Location	St. No	Br. No	Affected Item: Bridge Name	Affected Item: Repair /Reconstruction	Ⅰ.Pollution: Noise/Vibration and Air pollution (Dust) During and After Const. Rating	Ⅰ.Pollution: Noise/Vibration and Air pollution (Dust) During and After Const. Description	Ⅰ.Pollution: Water Quality (Turbid Water) During Const. Rating	Ⅰ.Pollution: Water Quality (Turbid Water) During Const. Description	Ⅱ.Social Environment: Involuntary Resettlement Rating	Ⅱ.Social Environment: Involuntary Resettlement Description	Ⅱ.Social Environment: Culture (Sacred place and Facility) Rating	Ⅱ.Social Environment: Culture (Sacred place and Facility) Description	Ⅲ.Natural Environment: Mangrove Trees Rating	Ⅲ.Natural Environment: Mangrove Trees Description	JICA Category: Result of **Screening** based on JICA Guideline for Environmental and Social Considerations (2010)		Expected clearances to be acquired: EC	Expected clearances to be acquired: Clearance for CRZ
	Mumbai	5	5	Tilak ROB	New Bridge Construction	A	Residential area is observed and might be affected.	C	No river by the bridge.	A	Residential area and commercial area is observed and might be affected.	C	No sacred facility is observed.	C	No mangrove observed.	**A**	Many resettlements are expected and land acquisition might be required	✓	-
	Mumbai	6	6	Mahim ROB	New Bridge Construction	A	Residential area is observed and might be affected.	C	No river by the bridge.	A	Residential area and commercial area is observed and might be affected.	C	No sacred facility is observed.	B	Cutting mangrove is expected on the north east by the bridge.	**A**	Many resettlements are expected and land acquisition might be required	✓	✓ -
ROB	Mumbai	7	7	Goregaon ROB	New Bridge Construction	A	Residential area is observed and might be affected.	C	No river by the bridge.	A	Residential area and commercial area is observed and might be affected.	C	No sacred facility is observed.	C	No mangrove observed.	**A**	Many resettlements are expected and land acquisition might be required	✓	-

Impact Rating: (A): Serious impact is expected. (B): Some impact is expected. (C): Few impacts are expected. (D): Impact is unknown (serious impacts are not expected, but detailed survey is required in preparatory survey stage)
Screening definition: (A) serious (B) A degree of impact, but not serious (C) Few impacts are expected (refer to Table 3.5.3 Definition of Category on JICA Guideline)

Source: JICA Study Team

11.6.2 Recommended Environmental Mitigation Measures

Recommended major mitigation measures are shown below;

Table 11.6.3 Environmental Management Plan (Expected Mitigation Measures)

Category	No.	Item JICA Guidelines	Recommended Mitigation Measures	
			Pre and During Construction phase	Operation phase
Pollution	1	Air pollution	- Dust Water sprinkling near residential area	-
	2	Water pollution	- Turbid water Sheet pile method is adopted to minimize turbid water during foundation repair works	-
	3	Waste	- Construction waste (waste concrete) Construction waste such as waste concrete is disposed at designated disposal site	-
	4	Soil contamination	-	-
	5	Noise and vibration	- Construction noise near residential area Installing noise barrier and selecting low-noise equipment. Avoiding works of heavy equipment during night time. Informing the construction schedule to surrounding communities to obtain their consensus.	Setting of noise barriers depending on need.
	6	Sediment quality	-	-
Natural environment	9	Protected Area	CRZ permission shall be requested from environmental authorization agency (Ministry of Environment and Forest), if the reconstruction bridge with new approach road is in CRZ	-
	11	Hydrology	Designing of bridges with sufficient capacity	-
	12	Topography and geology	-	-
Social environment	13	Involuntary resettlement	Appropriate compensation shall be implemented in accordance with JICA Guidelines	-
	14	The poor		-
	15	Indigenous and ethnic people		-
	16	Local economy such as employment and livelihood		-
	17	Land use and utilization of local resources		
	18	Water usage	Installation of alternative water distribution system when unexpected situation such as reduction of water level of wells, if any	
	19	Existing social infrastructures and services	Appropriate compensation and displacement shall be implemented in accordance with JICA Guidelines	-
	22	Local conflict of interests	Local workforce is prioritized for construction of the bridge.	-
	23	Cultural heritage	If the project effect on the community temple, sacred places and monument, appropriate consultation and agreement shall be concluded with local stakeholders	-
	27	Infectious diseases such as HIV/AIDS	In order to prevent spread of infectious diseases such as HIV/AIDS, awareness of the laborers is promoted.	-

Category	No.	Item JICA Guidelines	Recommended Mitigation Measures	
			Pre and During Construction phase	Operation phase
Others	29	Accidents	- Installing gate structure at the entrance of the construction site to set up restricted area - Deploying flagman at the gate and crossing points of the construction vehicles - Installing fence around the construction site to keep out local people such as children - Restricting mobilization speed in the construction site - Safety training for the workers - Safety patrol at the construction site by supervisors - Monthly safety meeting	Traffic safety control and management should be done on the bridges without sidewalk (Excluding motor vehicle exclusive road)
	30	Cross boundary impacts and climate change	-	-

(-): Not required mitigation measures since negative impacts are negligible

Source: JICA Study Team

12. PROPOSAL OF FUTURE JAPANESE SUPPORT

12.1 Outline of the Support Scheme

12.1.1 Proposed Structure and Justification of Proposal

As mentioned in a previous chapter, a structure type using Japanese Advanced Technology is proposed for each project as summarized in Table 12.1.1.

Table 12.1.1 Proposed Structure for each project

Project Name	Proposed Structure		
	Superstructure	Substructure	Foundation
Viaduct Construction Project in Delhi	**Steel Box Girder with Composite Deck Slab**	Steel Pier Colum	**PC Well or Steel Rotation Pile**
Viaduct Construction Project in Bangalore	**Steel Box Girder with Composite Deck Slab**	Steel Pier Colum	**PC Well or Steel Rotation Pile**
Viaduct Construction Project along East Coast Road in Chennai	**Steel Box Girder with Composite Deck Slab**	Steel Pier Colum	**PC Well**
Reconstruction Project for ROBs in Mumbai			
Type 1: - Ferere ROB, - Delise ROB - Tilak ROB	**Composite Floor Slab**	RC Structure	**Cast-in-place Concrete Pile under low clearance**
Type 2: - Balasis ROB - Mahalaxmi ROB - Mahim ROB - Goregaon ROB	**Composite Floor Slab**	RC Structure	Cast-in-place Concrete Pile

Note: Bald structure type is considered as technology/structure type by Japanese Advanced Technology

Although most of the proposed structure types are not the same structure types that are applied in India conventionally and construction cost becomes higher, EIRR values are higher compared with construction by conventional structure type, because proposed structure type can shorten construction period and minimize social impact.

Therefore, it is considered that the proposed structure type is worth applying in these projects.

As for these proposed structure, explanation and discussion of the draft final report to each related organization were carried out on the forth field survey. As a result, the agreement was basically obtained for the proposed structures, and its advantage was confirmed especially proposed foundation type in urban area. However, It was also pointed out the proposed construction cost is more expensive than the construction cost which is usually implemented in India. Therefore, the site condition and surrounding environmental conditions shall be studied carefully and it is necessary to distinguish section where proposed structure should be applied and section where conventional construction method can be applied when the detailed design is carried out.

12.1.2 Special consideration about Steel Structures

As shown in Chapter 8~10, it is necessary to construction of viaduct at very congested area in city and above existing traffic, and at pier columns having very restricted features. Since structure of pier column at Junction will be very complicated and having many corner point in the pier column, stress concentration is due to take place at the corner point. Hence, advanced technologies shall be applied to alleviate the stresses concentration as far as possible to the normal level.

Apart from technologies required for design and fabrication of steel structure, the technologies for erection work are also very important. Due to the erection work taking place inside city area and with many levels of structure, it is recommended that the erection work is to be carried out by experienced contractor who has vast experience in viaduct and erection at junction in city. The contractor with appropriate erection method and procedure and securement of existing traffic and safety measure during erection is an important point of consideration.

- Apply thick steel (more than 50mm) and high tension steel (σy=700 N/mm^2) : necessary to apply corner point which stress will be concentrate
- Consideration of details for prevention of fatigue damage, such as welding and shape of scallop: necessary to apply design method and know-how developed by Japan and other developed country in order to solve problem of “Fatigue” which is recently introduced.
- Experience of erection method for complicated structure in congested areas: necessary to select the Contractor having vast experience to carry out erection work in city. The most crucial consideration are the erection method and procedure and securing the safety of the existing traffic during erection work, since the candidate projects require complex erection work of steel structure having many levels.

12.2 Financial Support

12.2.1 Introduction

There are various types of financial schemes such as ODA (Official Development Assistance), PPP (Public Private Partnership) and BOT (Built-Operate-Transfer) to support economic development in developing countries. In India, the BOT scheme (concessioner) is commonly used for road construction/maintenance projects. On the other hand, the most common schemes with the Japanese government are ODA Loan in these days and there is little investment by Japanese companies on BOT or PPP which private companies invest in. And also, PPP is now being introduced for the infrastructure projects in developing countries through public-private cooperation in public projects.

The outlines of each scheme regarding Japanese support are shown in the following chapters.

12.2.2 Outline of the Japanese Support Scheme

(1) ODA

The financial and technical assistance that the Japanese government provides to developing countries as part of this economic cooperation are called Official Development Assistance (ODA).

ODA is broadly classified into two types: bilateral aid and multilateral aid. Multilateral aid consists of financing and financial contributions to international organizations, while bilateral aid is provided in three forms: Technical Cooperation, Loan Aid and Grant Aid.

- **Technical Cooperation**

  Technical Cooperation supports the development and improvement of technologies that are appropriate for the actual circumstances of these countries, while also contributing to raising their overall technology levels and setting up new institutional frameworks and organizations.

- **Load Aid**

  Loan Aid supports the efforts of developing countries to advance by providing these countries with the capital necessary for development for the long-term at substantially lower interest rates than commercial rates. The primary types of Loan Aid are ODA Loans to supply developing countries and Private-Sector Investment Finance to supply private sector. ODA Loans in particular enable the provision of finance in larger amounts compared with Technical Cooperation or Grant Aid, and therefore this form of aid has been well utilized for building large-scale basic infrastructure in developing countries.

- **Grand Aid**

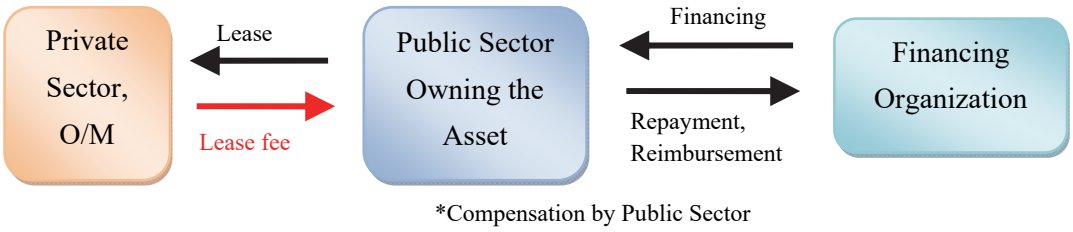
  Grant Aid, which is an assistance method that provides necessary funds to promote socioeconomic development, is financial cooperation with developing countries with no obligation for repayment.

12.2.3 Outline of Private-Sector Investment Finance

There is a possibility of applying two major schemes, which are Public Private Partnership (PPP) and Private Finance Initiative (PFI). It is said that in utilizing the private finance, it can reduce the entire cost, both initial and O/M, by private firms' cost reduction know-how. On the other hand, it is considered that there is difficulty of quality control due to private sector's initiative in project operation. And also, there is a risk of the private sector terminating the project suddenly, which can end up in contract default.

12.2.4 Public Private Partnership (PPP)

(1) Two-tiered System with Public Sector Implementing the Construction

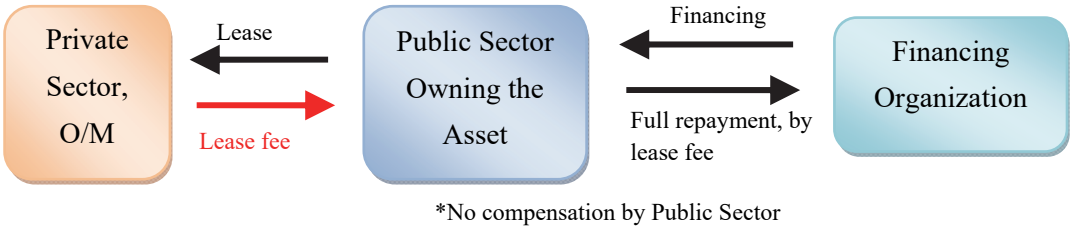


Source: JICA Study Team

Figure 12.2.1 Two-tiered System with Public Sector Implementing the Construction

It is said that this scheme is favourable in projects which do not have sufficient cash-flow in the operation stage and the public sector has difficulty in obligating the private sector to pay high enough rent to fulfil the repayment.

(2) Two-tiered System with Public Sector Implementing the Construction



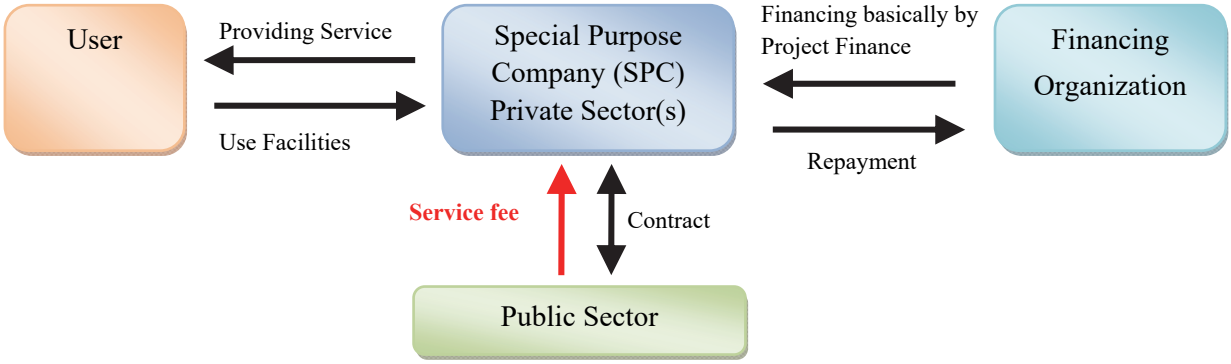
Source: JICA Study Team

Figure 12.2.2 Two-tiered System with Full Repayment

This scheme is considered applicable to the projects which have sufficient cash-flow in the operation stage and are able to repay the full fund by the lease fee. The lease contract can be modified to be in the form of a concession contract to improve the flexibility in procurement of finance for expanding the project or business of the private sector. If a concession contract is signed, the private sector may place a mortgage on the concession contract and procure additional finance.

(3) Private Finance Initiative (PFI)

1) Service Sold to the Public Sector (BTO)



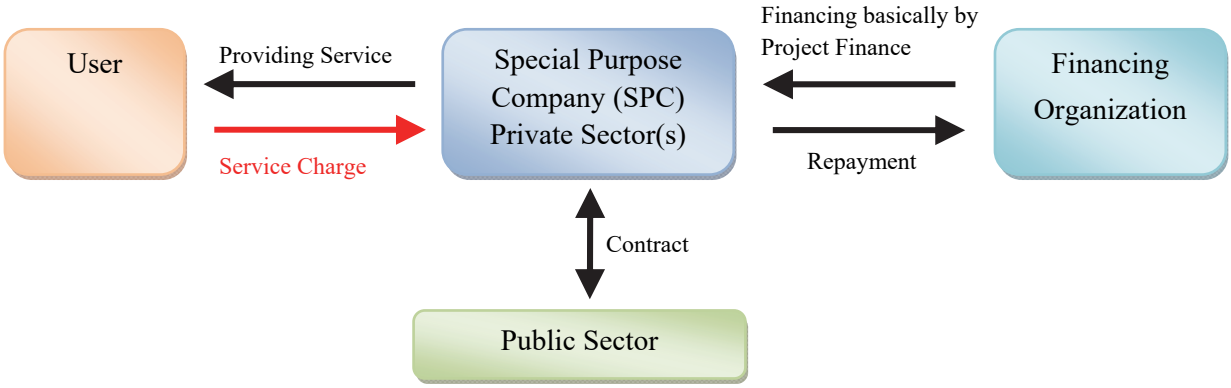
Source: JICA Study Team

Figure 12.2.3 Project Implementing Scheme "Services Sold to the Public Sector" (BTO)

In this scheme of "Services Sold to the Public Sector" of PFI, the private sector(s) is to procure the fund from a financing organization or directly procure from the financial market. The procured fund is invested to implement the facility and service is provided to users. Providing safe use for viaduct and junction is the service to be provided in this project. Private sector(s) regularly receive payment as the compensation for providing public service to users from the public sector. This payment is the source of repayment to the creditors, which are the financing organization/investors. There is no need to collect toll fee/service charge from users; therefore this scheme is applied to the facilities without sufficient cash flow, such as city hall, etc.

The ownership of the facilities is usually transferred to the public sector after construction in order to avoid paying real property tax. The private sector(s) continues operation of the facility including the maintenance during the contract period. And it is common to establish a Special Purpose Company (SPC) so as to make the project's financial condition off-balanced from investors' balance sheet.

2) Financially Free-standing Projects (BTO)



Source: JICA Study Team

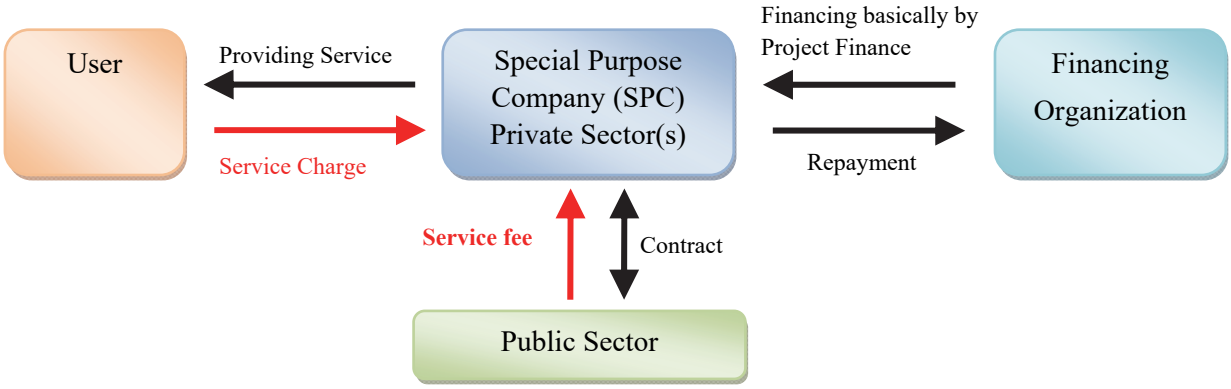
Figure 12.2.4 Project Implementing Scheme "Financially Free-standing Projects" (BTO)

In this scheme of "Financially Free-standing Projects" of PFI, the private sector(s) is to procure the fund from a financing organization or directly procure from the financial market. The procured fund is invested to implement the facility and a service is provided to users. Providing safe use for viaduct and junction is the service to be provided in this project.

The difference with the other PPP scheme 'Services Sold to the Public Sector' is that the private sector needs to collect the service charge directly from the users, and there is no compensation from the public sector. This scheme is usually applied to a project with sufficient cash flow not only for operating/maintaining the facility but also for repaying the financial organization/investors, such as MRT, Toll road, or container terminal, etc.

The ownership of the facilities is usually transferred to the public sector after construction in order to avoid paying real property tax. The private sector(s) continues operation of the facility including the maintenance during the contract period. And it is common to establish a Special Purpose Company (SPC) so as to make the project's financial condition off-balanced from investors' balance sheet.

3) Hybrid Scheme of "Services Sold to the Public Sector" and "Financially Free-standing Projects" (BTO)



Source: JICA Study Team

Figure 12.2.5 Project Implementing with Hybrid Scheme

This scheme is hybrid of two schemes which are mentioned above. Private sector(s), as the operating entity, directly collects service charge from users and also receives compensation from the public sector. This could be applied to a project with insufficient service charge to cover repayment.

The advantage is that the private sector(s) is able to maximize the profit by adjusting the service price or improving the service, or the public sector is able to keep the service charge at a low price by enhancing the compensation.

12.3 Method of Japanese Support

12.3.1 Recommendations of Support Scheme

Based on the discussion with each organization which is undertaking the projects, some sub-projects have been selected and proposed the structures as shown in Chapter 6. The summary of the financial scheme which is considered by each organization and the appropriate support scheme which is recommended by JICA study team for each project are shown in the Table 12.3.1.

Table 12.3.1 Summary of Financial Support Scheme to be adopted

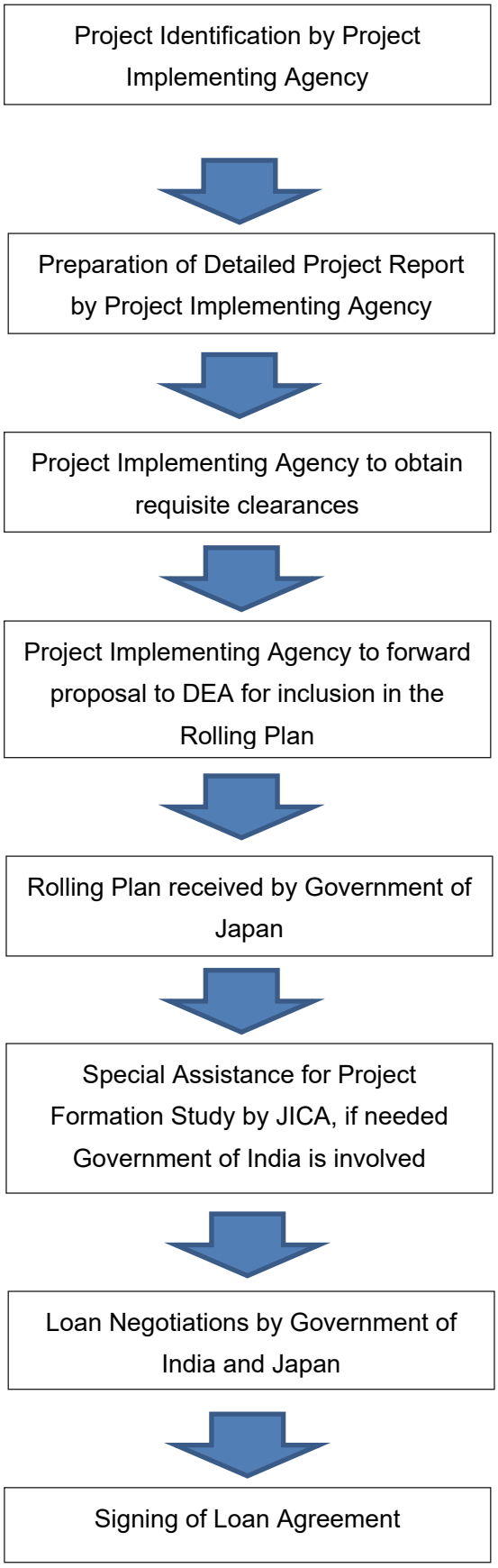
No.	Project Name	Considered Scheme	Recommended Scheme
1	Viaduct Construction Project at Delhi	ODA Loan is considered.	ODA Loan Aid is recommended. Because the project will be large-scale (the total construction fee will be quite high) and India is not the least developed country
2	Viaduct Construction Project in Bangalore	The scheme is under consideration. However the BOT scheme is a high priority.	
3	Viaduct Construction Project along East Coast Road in Chennai	The scheme is under consideration.	
4	Reconstruction Project for ROBs in Mumbai - Ferere ROB - Balasis ROB - Mahalaxmi ROB - Delise ROB - Tilak ROB - Mahim ROB - Goregaon ROB	The scheme is under consideration	

12.3.2 Acquisition Processes in ODA Loan

The processes of acquiring ODA Loan in India are shown in Figure 12.3.1 and the schedule of it is shown in Table 12.3.2. The schedule is for "Viaduct Construction Project in Delhi" which is considered as acquiring ODA Loan.

Table 12.3.2 Schedule of acquiring ODA Loan

	First Year				Second Year				Third Year
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
Preparation of Detailed Project Report	━								
Proposal and Publication to Rolling Plan		━	━						
Selection of project supported by Japanese government and study of the project by Japanese government				━	━	━	━		
Discussion between Japan and India							━	━	
Signing of Loan Agreement									★



Source: "Bilateral Development Assistance", Department of Economic Affairs

Figure 12.3.1 Processes in ODA Loan

12.3.3 Recommendations of Other Support Scheme

(1) Urban Transportation Master Plan

The road development projects are implemented by a state government and development authority in each city. However, due to the information is not exchanged enough between both of them, most of the construction projects such as highway, improvement of intersection and Metro are implemented in a disorderly. Therefore, it is necessary to organize the whole public transportation development plan such as highway construction in urban area, improvement of intersection, construction of Metro and BRT (Bus Rapid Transit system) under implementation of the Urban Transportation Master Plan. And it is possible to organize urban traffic systematically with assigning priority of the each project.

(2) Technical Cooperation Project of Highway in Urban Area

Since, there is no metropolitan highway constructed in city in India, government officials and engineers of local consultant company lack of knowledge about planning, designing, constructing and maintaining of metropolitan highway in urban area. Therefore, regarding to the Viaduct Construction Project in Delhi and Bangalore, their plans are only to construct viaduct on the existing road with enough width. The plan to install Interchange and Junction which can make highway in urban area more effective is not sufficient. To improve these situations, the Technical Cooperation Project of the planning, designing, operation and maintenance of highway in urban area is recommended.

(3) Grant Aid of Application of High-Elasticity CFRP

Application of CFRP for repair and rehabilitation work of bridges has become very common, even in India. Currently, High-Elasticity CFRP has become common in Japan. The advantage of High-Elasticity CFRP is to reduce the number of CFRP compared with the conventional type of CFRP (for example, two sheets are required by conventional CFRP, but only one sheet can be satisfactory when using High-Elasticity CFRP). This makes installation easier and more economical. However, India doesn't have enough results of using High-Elasticity CFRP, and a merit of it is not widely known. If the Grant Ai Project is organized for repair and rehabilitation work of existing bridges with usage of High-Elasticity CFRP in India, it becomes possible to confirm the advantages of the technology by the person concerned through this Grant Aid Project, as a result, dissemination of the technology in India is expected. In addition, implementation of repair and reinforcement of existing bridges is also recommended as another scope of the Technology Cooperation Project of Highway in Urban Area as shown above.

(4) Entering Indian Market of Japanese Company

As mentioned above, the bridge construction technology in India reaches a constant level. It is difficult to enter Indian market of Japanese company because of especially price competition. However, Japanese Company may enter Indian Market easier by applying Japanese Advanced Technology which has advantage to Japanese Construction Company and mentioned in Chapter 6 into Technical Specification of the Project and applying "Specialist Subcontractor" and "Nominated Subcontractor" into the Bid Document.

APPENDIX

APPENDIX 1

Explanatory Material of

Viaduct Construction Project in Delhi

Data Collection Survey on Road/Railway Bridge Sector

Explanatory Material of Viaduct Construction Project in Delhi

October 2016
Delhi

JAPAN INTERNATIONAL COOPERATION AGENCY
Oriental Consultants Global Co., Ltd.

Contents

1. Introduction

Objectives of the Survey

1. To grasp current situation of Road / Railway bridges and Viaducts in India.
2. To identify bridge / Viaducts wherein consideration of the application of the Japanese advanced technologies such as rapid construction method in urban area and latest bridge rehabilitation and reinforcement method could be explored.

Further development on bridge construction and rehabilitation field in India will be achieved by incorporating advanced technology.

Ⅰ. Introduction

Based on discussion with PWD, Delhi, on April 14, June 2-3 and August 16
Study on Planned Elevated Corridor and JCT were proposed.

Structure of Planned Elevated Corridor and JCT were studied by JICA Study Team

Draft Final Study Result is presented by this meeting.

Ⅱ. Scope of Study

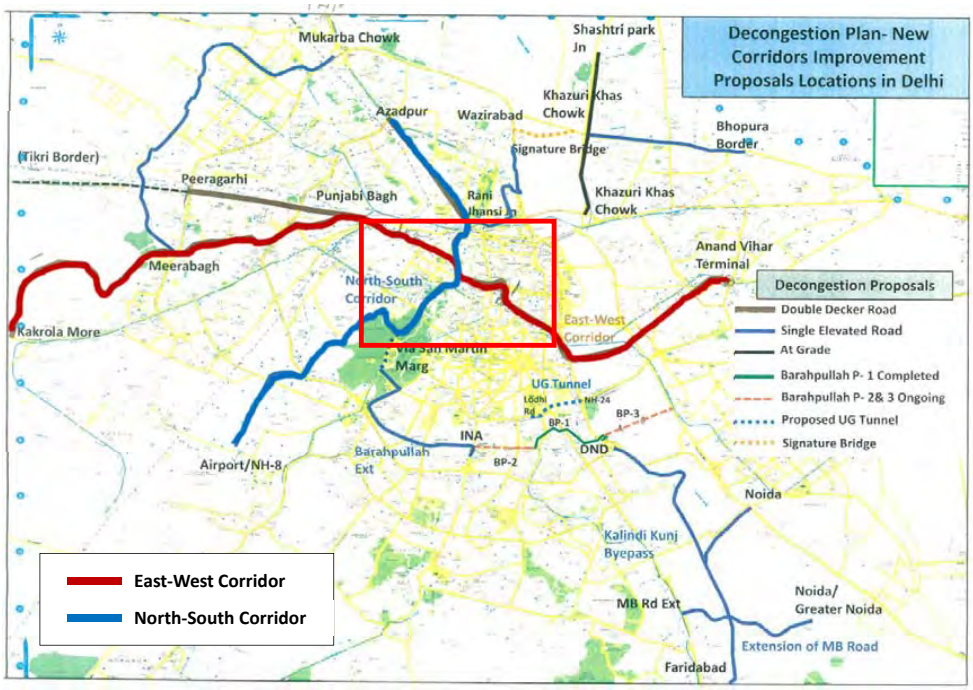
1. List of Planned Elevated Corridors

No	Name of Planned Corridor	Length	No. of Lanes	Type
1	Elevated Road along Najafgarh Nallah	16.4km	-	Elevated
2	Elevated Road along supplementary drain (Nangloi Drain)	16.0km	-	Elevated
3	East – West Corridor	29.0km	6	Elevated
	East – West Corridor Extension	13.0km	6	Elevated
4	North – South Corridor	24.0km	6	Elevated
5	Barahpullah Extension	10.0km	-	Elevated
6	U-G Tunnel	3.0km	-	Tunnel
7	Mehrauli Badarpur Road Extension	7.0km	-	Elevated
8	Khazuri Khas to Bhopura Border	3.2km	-	Elevated
9	Kalindi Kunj Byepass	13.2km	-	Elevated
10	Azadpur to Rani Jhansi Road	6.0km	-	Elevated
11	Marginal Bundh Road	7.5km	-	At Grade

Source: Presentation documents by Delhi PWD

Ⅱ. Scope of Study

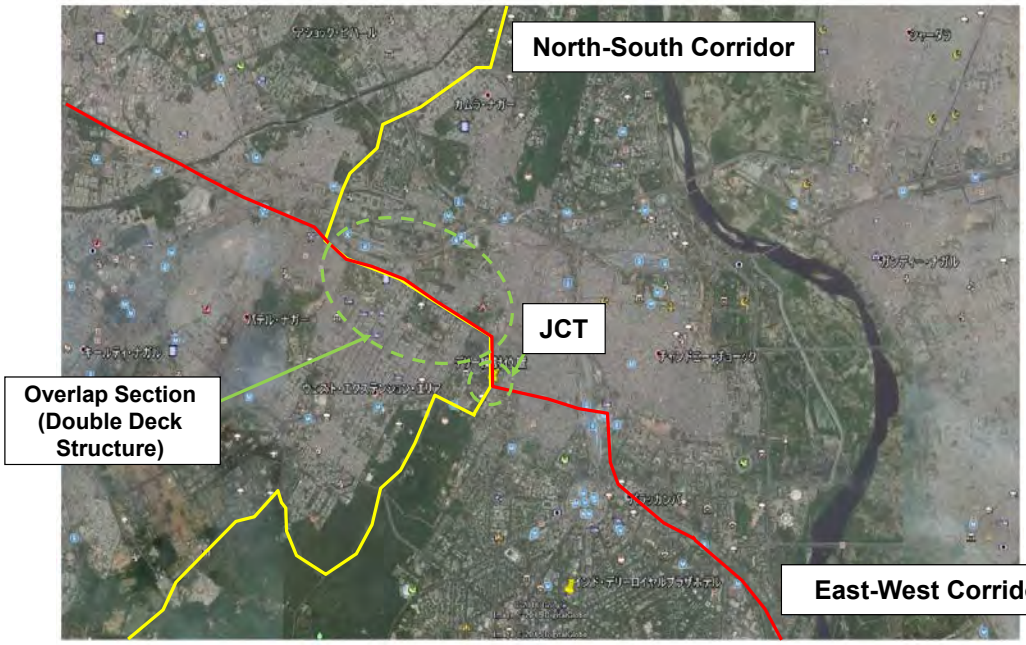
2. Location of Planned Elevated Corridors



Source: Presentation documents by Delhi PWD

Ⅱ. Scope of Study

3. Location of Studied Elevated Corridors and JCT



Ⅲ. Study on Standard Section

1. Feature of Standard Section

Precondition	Required
Bridges is in the congested area	Construction period needs to be shorten.
	Minimum negative impact on social environment. (Construction in the minimum space)

Ⅲ. Study on Standard Section

2. Bridge Foundation

Construction

- ✓ To reduce the space
- ✓ To save the time

Advanced Technology to be considered

① PC Well

② Rotary Penetration Steel Pile

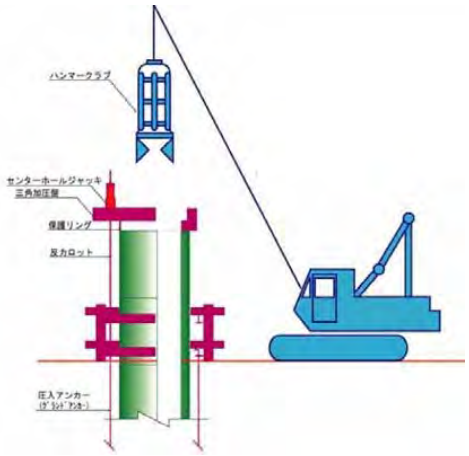
③ Steel Pipe Socket Connection Method

Ⅲ. Study on Standard Section

ORIENTAL CONSULTANTS GLOBAL CO., LTD.

2. Bridge Foundation

2.1 PC Well

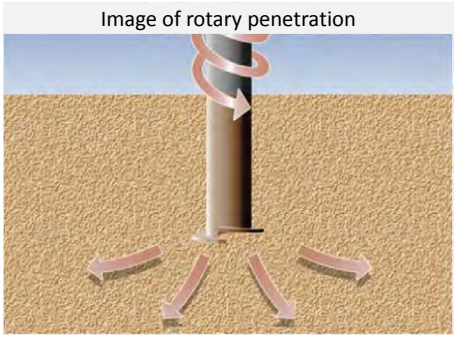


PC Well foundation is comprised of precast concrete block (Circular or Oval shape). Each precast concrete blocks is connected by Post-tension method after they placed at site. After placing precast concrete block and connection each other, excavation work is carried out and compressed into ground.

2. Bridge Foundation

2.2 Rotary Penetration Steel Pile

Image of rotary penetration

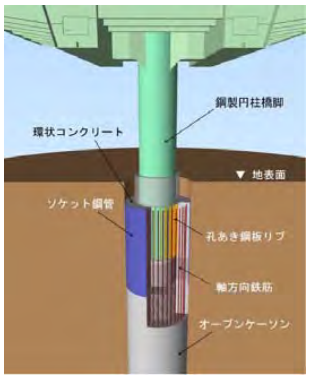


It is Steel Pipe Foundation which is welded a spiral processed steel plate (Wing) to the tip of steel pipe together. The pile penetrates/screws into the ground with propulsion of wing.

It is obtained large bearing force by the base enlarging effect of Wing. And, due to penetration method, there is no excavated soil at site. Therefore, it will be possible to be eco-friendly construction with non-emission, low-vibration and reducing pile number.

2. Bridge Foundation

2.3 Steel Pipe Socket Connection Method



Connection part at tip of pier column

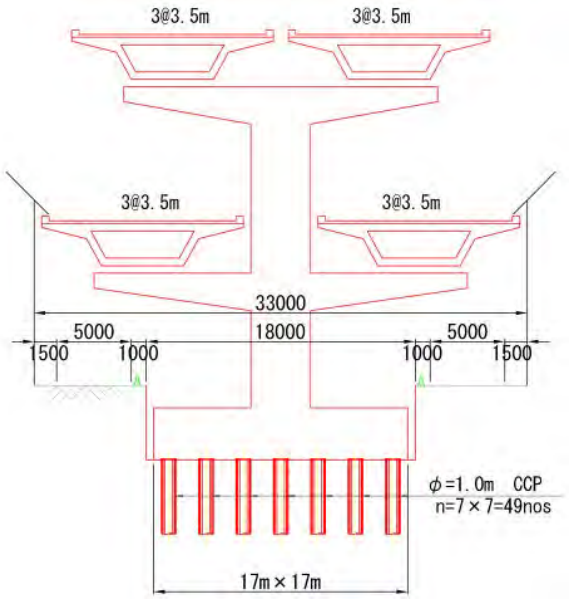
Construction of Caison Structure

Steel Pipe Socket Connection Method is the jointing technique of inserting a Steel Column into Steel Pipe Socket which is constructed at the top of foundation, and filling up a concrete inside the gap of it. It is possible to reduce construction period by omitting Pile Cap and Anchor Frame used in conventional method.

Ⅲ. Study on Standard Section

3. Bridge Pier Column

3.1 Concrete Type (Conventional)



Ⅲ. Study on Standard Section

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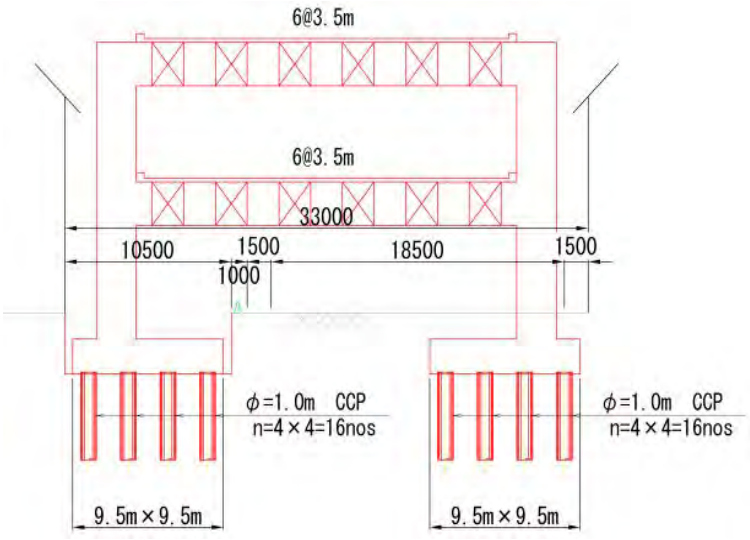
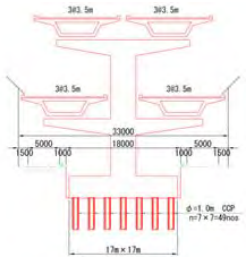
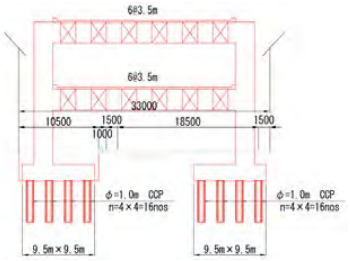
3. Bridge Pier Column

3.2 Steel Type



Ⅲ. Study on Standard Section

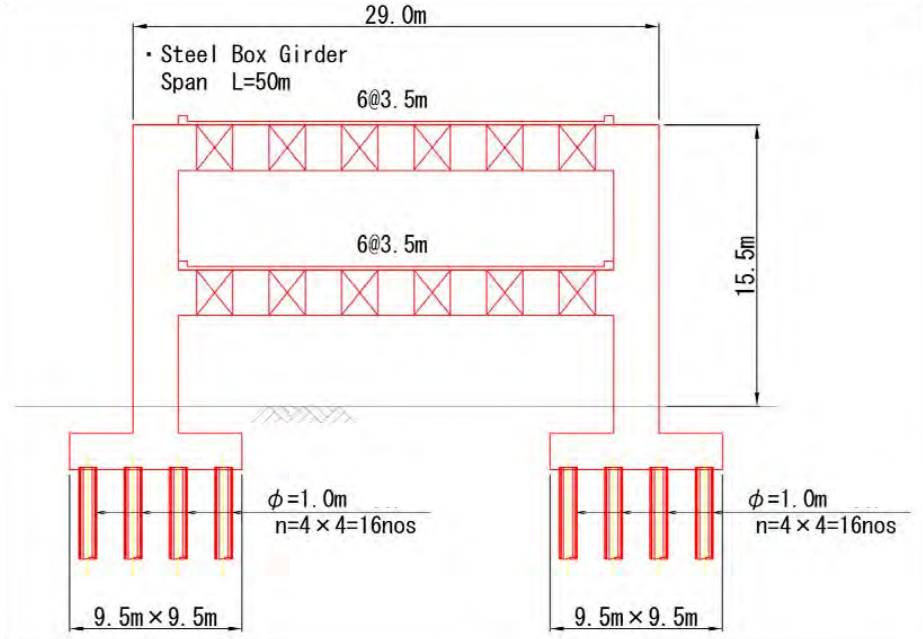
3. Bridge Pier Column

	Concrete Type	Steel Type
General View		
Comment	✓ Due to heavy weight structure, cross section of column and foundation becomes much larger than Steel Type. ✓ Difficult to secure enough carriageway width during pile cap construction (2x5m only.	✓ There are a lot of steel pier column applied in urban area in Japan, despite of high cost. ✓ Easy to apply steel pier column for complicated structure. ✓ Possible to secure enough carriageway width (18.5m)
Construction Cost	Superior	Inferior
Cost Considered Social Effect	Inferior (Due to large width of foundation and longer construction period by cast in-site)	Superior (Due to narrow width of foundation and shorter construction period by prefabrication)
Estimate		**Recommended**

Ⅲ. Study on Standard Section

4. Comparison of Foundation Type

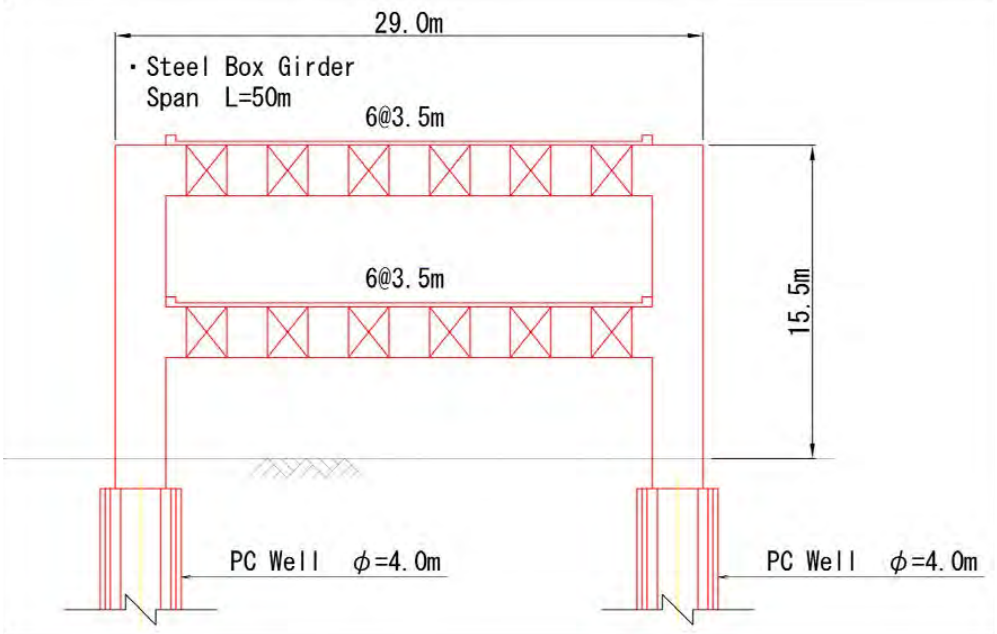
4.1 (Type-1) Cast-in-place Concrete Pile



Ⅲ. Study on Standard Section

4. Comparison of Foundation Type

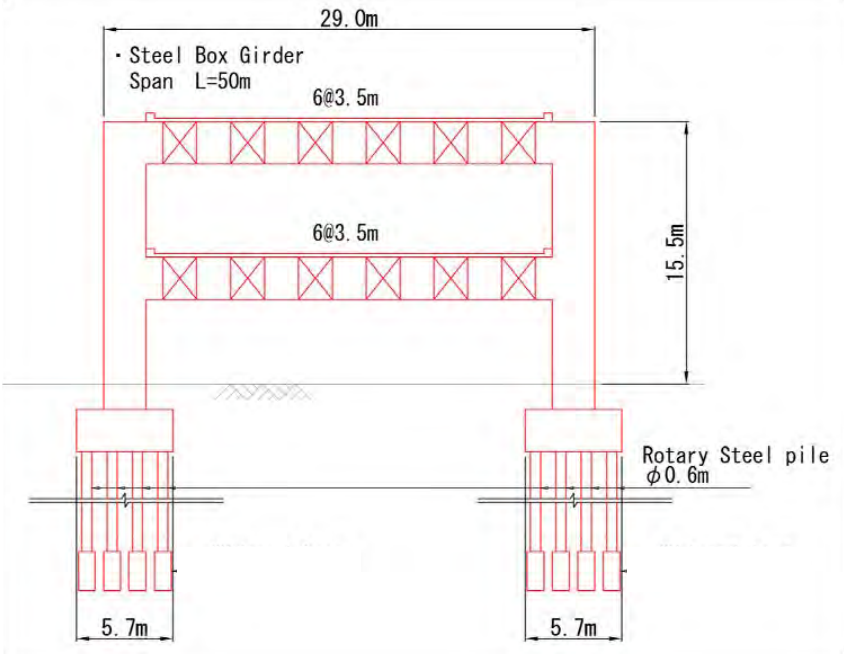
4.2 (Type-2) PC Well



Ⅲ. Study on Standard Section

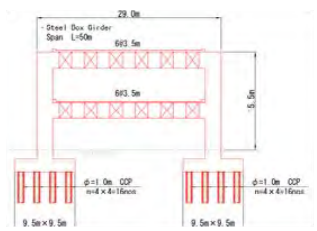
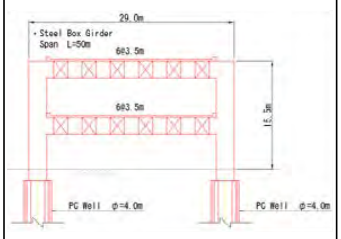
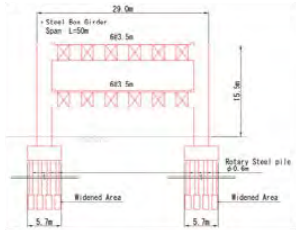
4. Comparison of Foundation Type

4.3 (Type-3) Rotary Penetration Steel Pile



Ⅲ. Study on Standard Section

4. Comparison of Foundation Type

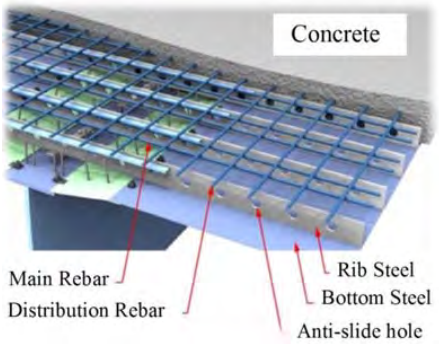
	Type-1 Cast-in-place Concrete Pile	**Type-2** PC Well	**Type-3** Rotary Penetration Steel Pile
General View			
Comment	✓ Common foundation type has many past records and most economical ✓ Widest width of pile cap, cause negative impact to existing traffic during construction	✓ Width of foundation is narrow not cause negative impact to existing traffic during construction. ✓ Shortest construction period due to unified structure with pier column	✓ Narrower width of pile cap than Type-1 cause better impact to existing traffic during construction. ✓ Due to no excavation required, less impact to residence during construction.
Construction Period	Long	Very Short	Short
Construction Cost	Superior	Inferior	Moderate
Cost Considered Social Effect	Inferior	Moderate	Superior
Estimate		**Recommended**	**Recommended**

Ⅲ. Study on Standard Section

5. Type of Superstructure

Due to construction work in very congested area, steel superstructure with composite slab is recommended since this type can minimize social impact.

What is Composite Slab??



Bottom steel plate serves as rebar, formwork, working platform and scaffoldings

1. Higher durability (more than double for conventional RC slab)
2. Shorter construction period by 2months due to less rebar arrangements, form works and scaffoldings.
3. Better working conditions on site
4. No fear of leak of wet concrete and cement milk to the existing traffic

Ⅳ. Study on JCT Structure

1. Alternatives

Following 2 alternatives are studying.

Alternative A

- **WITHOUT consideration of Land Constraints**
- **High Service Level**

Alternative B

- **With consideration of Land Constraints**
- **Realistic (Lower Service Level)**

Ⅳ. Study on JCT Structure

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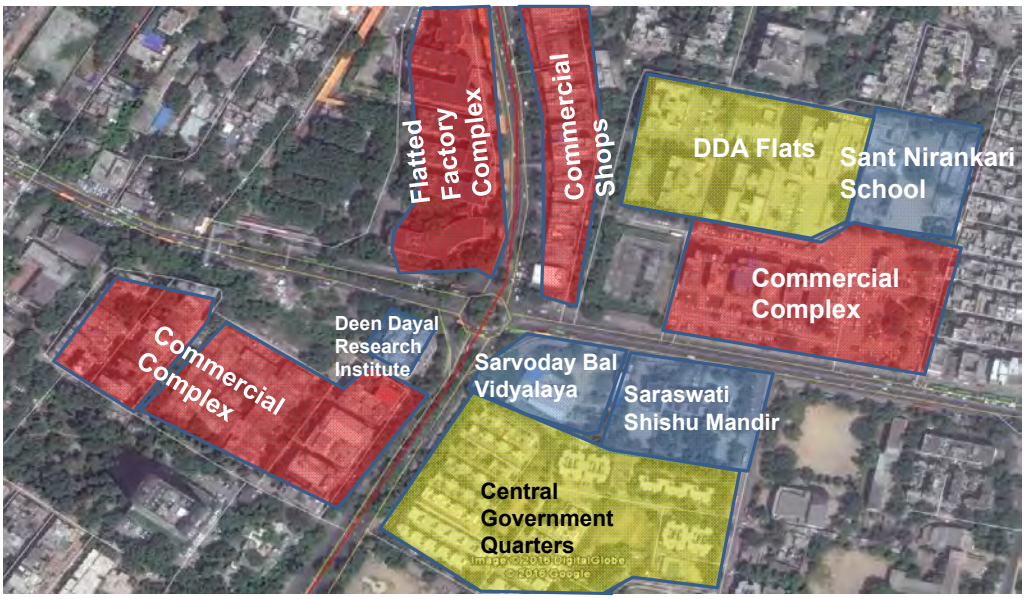
2. Land Use Status around JCT Point



Red Color: Private Land (Difficult for Land Acquisition)
Blue Color: School Land (Possible for Land Acquisition, but, take long time for procedure)
Yellow Color: Government Land (Possible for Land Acquisition)

Ⅳ. Study on JCT Structure

3. Study Result of Alternative (A)

3.1 Plan View

Ⅳ. Study on JCT Structure

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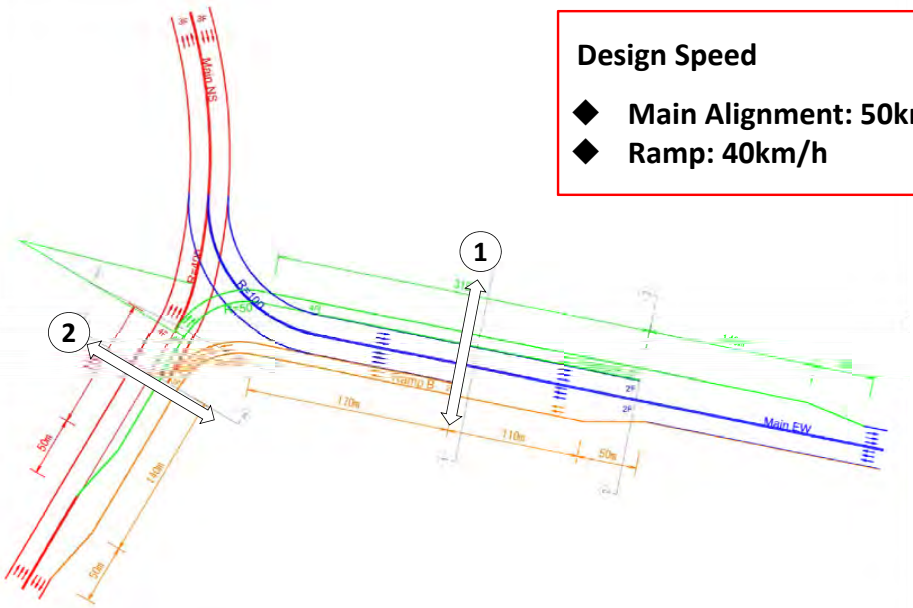
3. Study Result of Alternative (A)

3.2 Structure of JCT

Design Speed

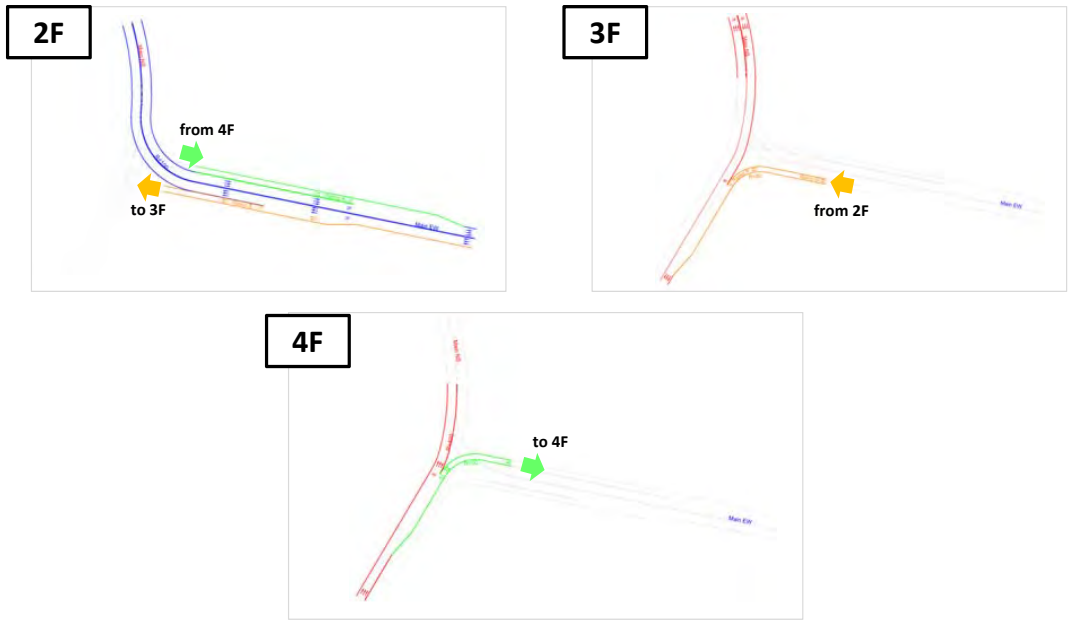
- **Main Alignment: 50km/h**
- **Ramp: 40km/h**



Ⅳ. Study on JCT Structure

3. Study Result of Alternative (A)

3.2 Structure of JCT (Explanation)



Ⅳ. Study on JCT Structure

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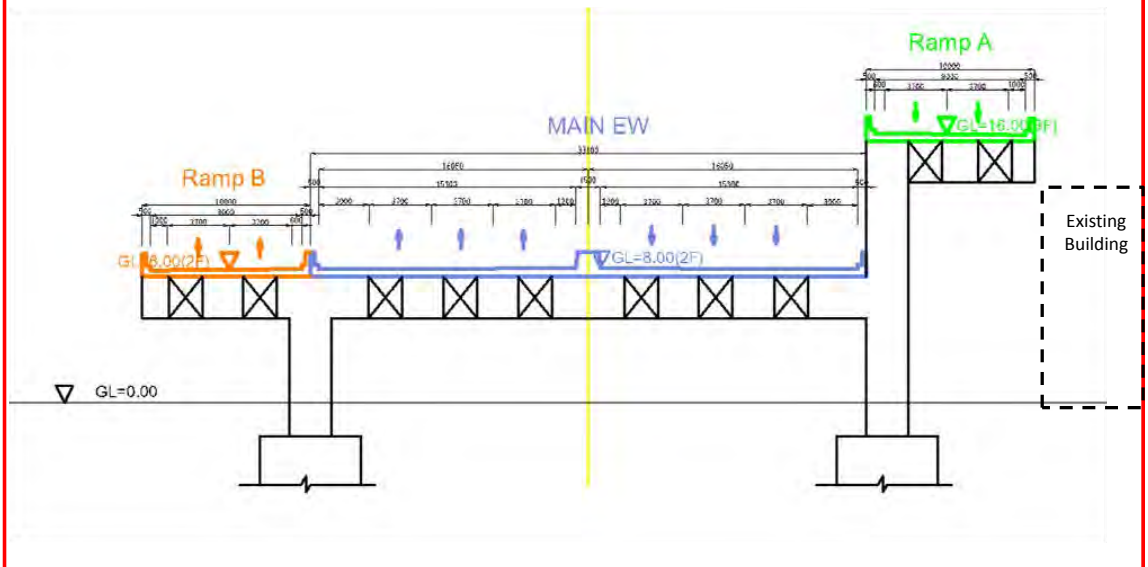
3. Study Result of Alternative (A)

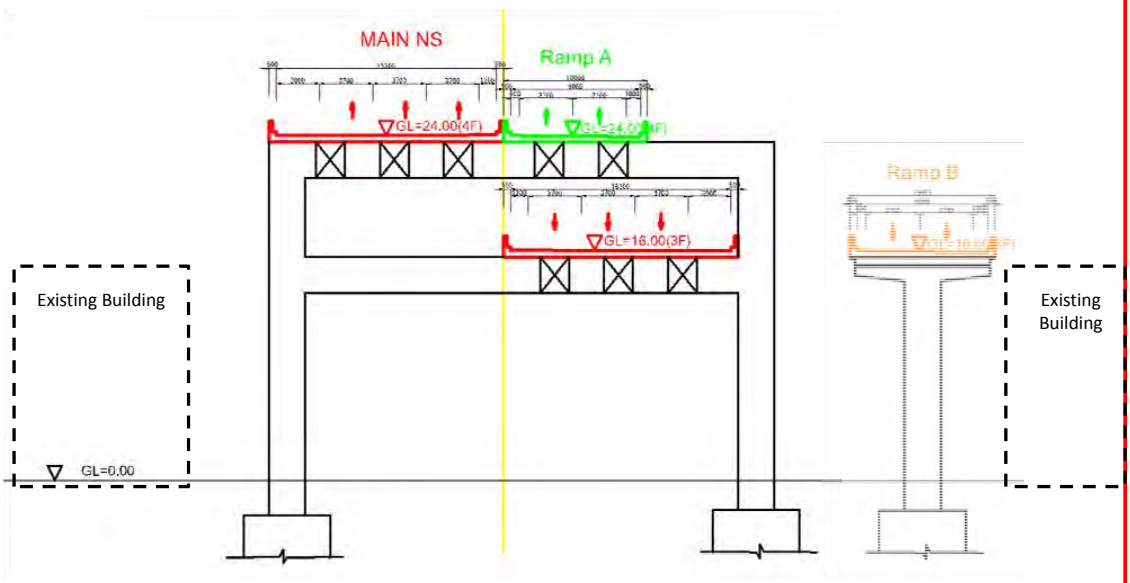
3.3 Cross Section for ①



Ⅳ. Study on JCT Structure

3. Study Result of Alternative (A)

3.3 Cross Section for ②



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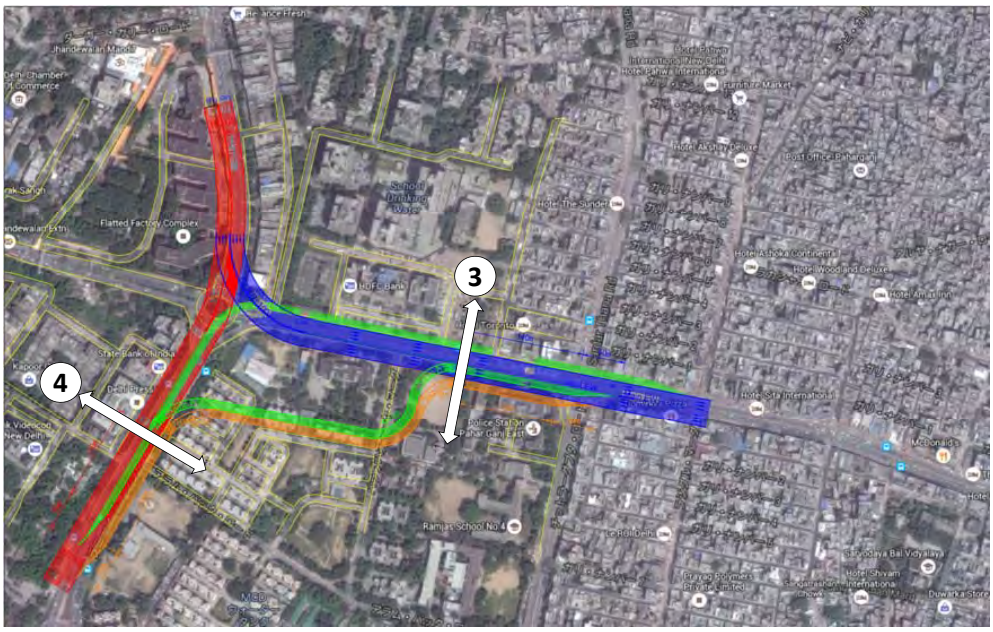
Ⅳ. Study on JCT Structure

4. Study Result of Alternative (B)

4.1 Plan View



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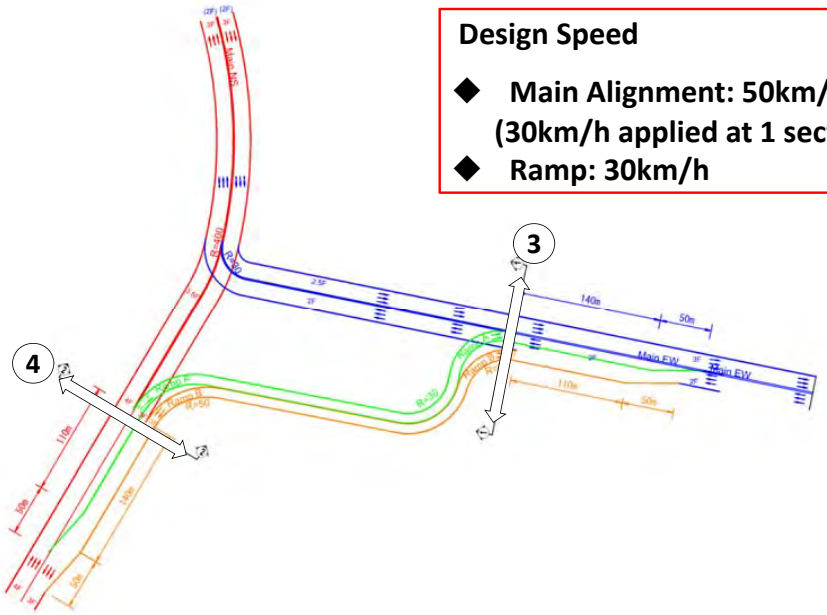
Ⅳ. Study on JCT Structure

4. Study Result of Alternative (B)

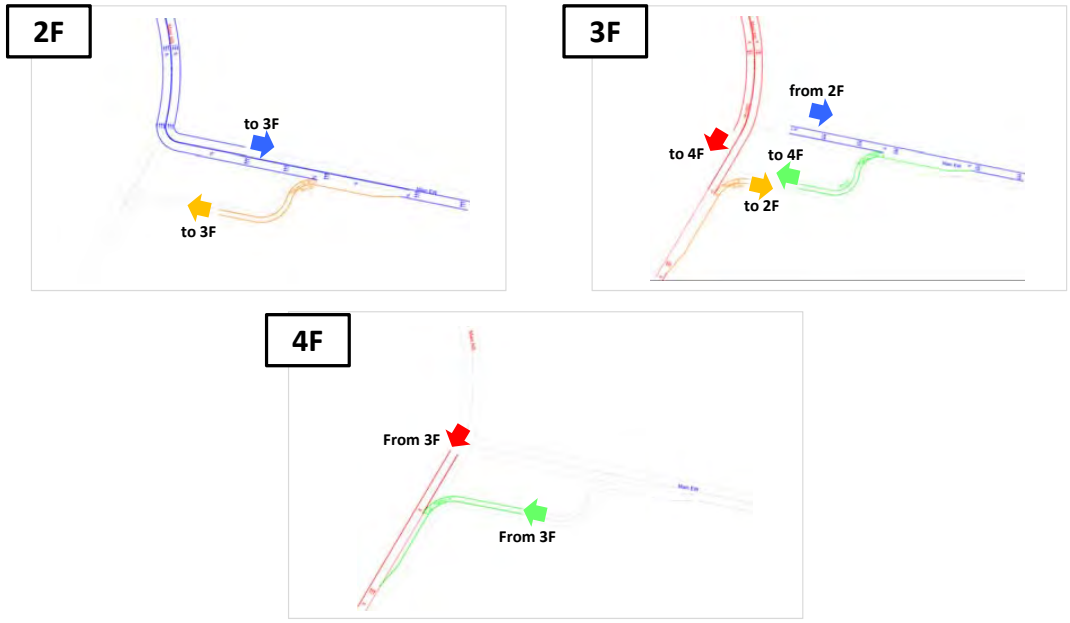
4.2 Structure of JCT



Ⅳ. Study on JCT Structure

4. Study Result of Alternative (B)

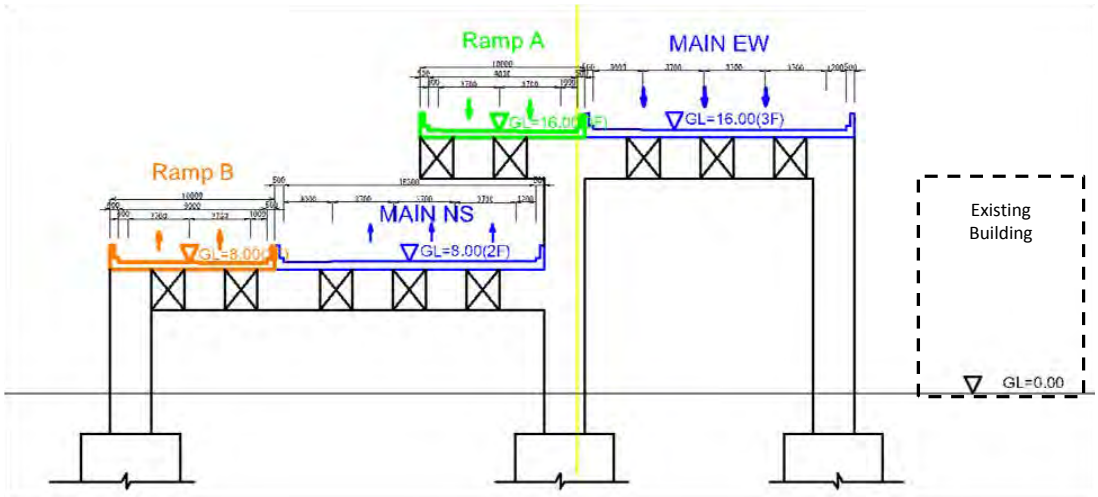
4.2 Structure of JCT (Explanation)



Ⅳ. Study on JCT Structure

4. Study Result of Alternative B

4.3 Cross Section for ③



Ⅳ. Study on JCT Structure

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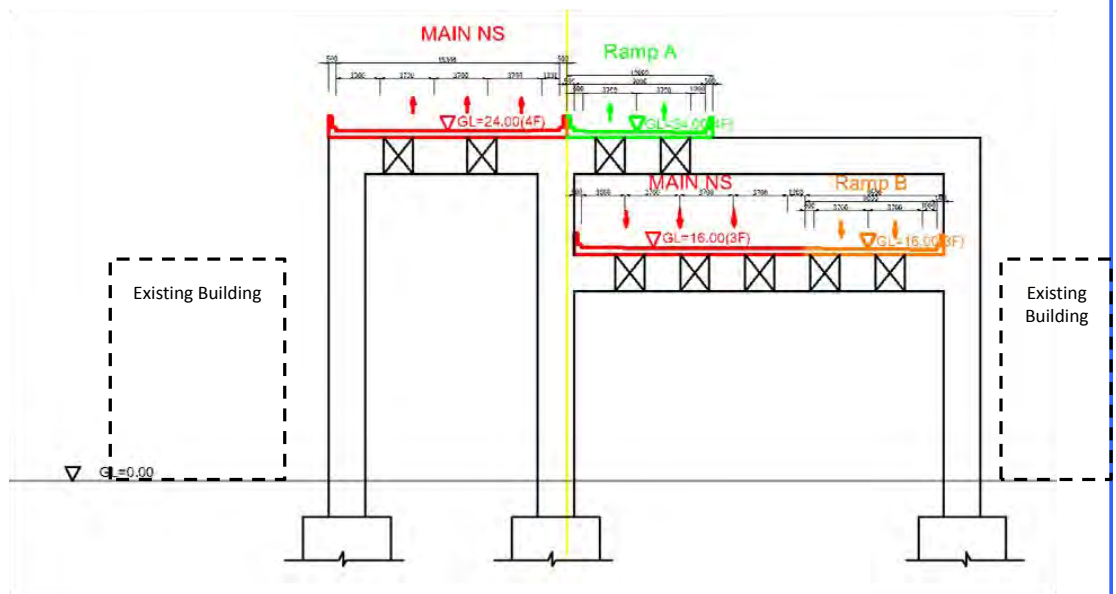
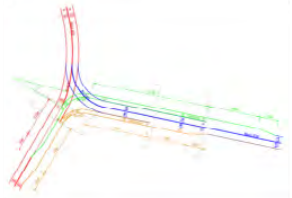
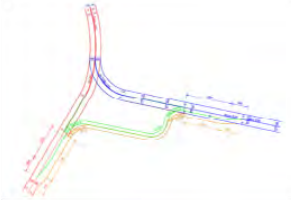
4. Study Result of Alternative B

4.3 Cross Section for ④



Ⅳ. Study on JCT Structure

5. Comparison of JCT

	Alternative (A)	Alternative (B)
Plan View		
Feature	✓ No restriction of land use, to be compact size of JCT	✓ Consideration of actual land use situation, to be larger size of JCT
Access	✓ Possible to access for all direction (6 number)	✓ Possible to access for all direction (6 number)
Advantage	✓ Due to most compact size of JCT, length of ramp becomes shortest.	✓ No land acquisition in “Red Color” area
Disadvantage	✓ Additional land acquisition will be necessary at “Red Color” area.	✓ In order to avoid land acquisition in “Red Color” area, very steep curve is applied. (R=30m) ✓ Problem of usage of land where surrounded by Ramp and E-W line.

Ⅳ. Study on JCT Structure

6. Recommendation of Steel Structure

In order to achieve these complicated structure, followings advanced technologies will be required.

- **Application of thick steel (more than 50mm)**
- **Application of high tension steel (σy=700 N/mm2)**
- **Consideration of details for prevention of fatigue damage, such as welding and shape of scallop.**
- **Experience of erection method for complicated structure at congested area.**

Ⅴ. Summary of Structural Study

1. Rough Cost Estimation

◆ **Condition for Estimation**

- **Length of Viaduct = 1.55km (JCT to JCT, excluding JCT)**
- **Superstructure: Steel Box Girder with Composite Deck Slab**
- **Substructure: Steel Pier Column (double deck)**
- **Foundation: PC Well**

Construction Cost	Design Cost	Supervision Cost	Total
15,122	605	1,361	17,088

Unit : Million Rs

Ⅴ. Summary of Structural Study

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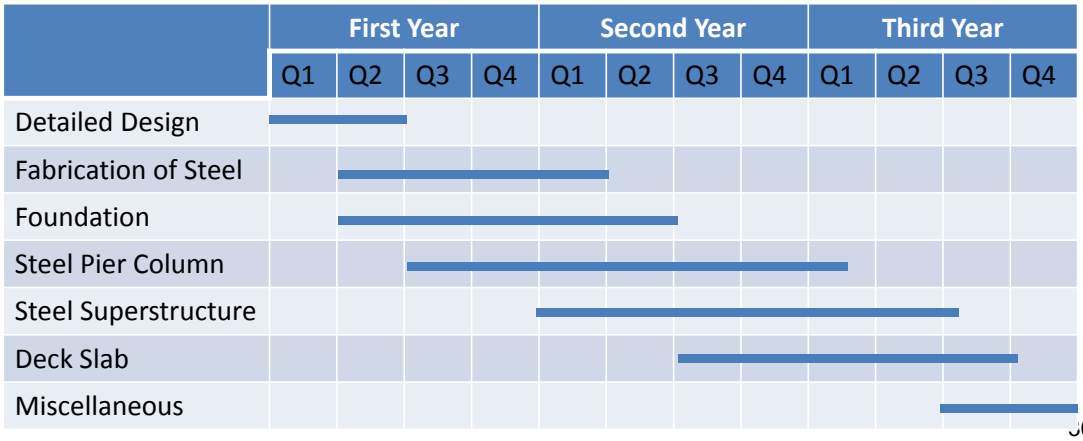
2. Construction Schedule

Since no critical path, construction schedule will be decided by number of construction team.

Appropriate Construction Schedule (total 3 years)



Ⅴ. Summary of Structural Study

3. Economic Analysis Result

With Case => Construction by Steel Superstructure and Steel Pier Column

Without Case => Construction by PC Superstructure and RC Pier Column (partially, PC)

Although construction cost becomes higher, but, social benefit can increase

EIRR => 20.7% > 12.0%

Because of enough number of EIRR, implementation by Steel Structure will have better EIRR number than PC Structure

Ⅵ. Introduction of Japanese Support

★ Risk of BOT Scheme

✓ <u>Reliability of Project Implementation</u>

⇒ Risk for suspension of the project, depending on their financial status

Recommend to handle the Project by the Government

Since, the Project is implemented inside Delhi Center and acts very important role for decongestion of Delhi City.

Japanese Government can support by YEN Loan

Ⅶ. Recommendation

After studying of Proposed Elevated Corridor and JCT, following structures are recommended.

- ✓ **Superstructure**
  ⇒ Steel Box Girder with Composite Deck Slab
- ✓ **Substructure**
  ⇒ Steel Pier Column
- ✓ **Foundation**
  ⇒ PC Well or Rotary Steel Penetration Pile

Although construction cost becomes higher, but, due to increment of social benefit, EIRR value becomes higher.

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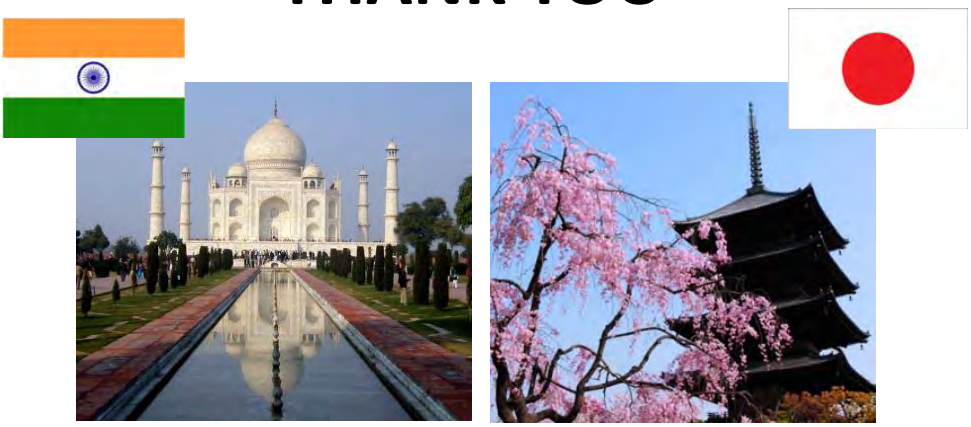
Tokyo Metropolitan Expressway

THANK YOU



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APPENDIX 2

Explanatory Material of

Viaduct Construction Project in Bangalore

Data Collection Survey on Road/Railway Bridge Sector

Explanatory Material of Viaduct Construction Project in Bangalore

October 2016
Bangalore

JAPAN INTERNATIONAL COOPERATION AGENCY
Oriental Consultants Global Co., Ltd.

Contents

Ⅰ. Introduction

Based on discussion with KRDA and AECOM, on April 13, May 31 and August 24
Study on Planned Elevated Corridor and 2 JCTs were proposed.

Structure of Planned Elevated Corridor and JCTs were studied by JICA Study Team

Draft Final Study Result is presented by this meeting.

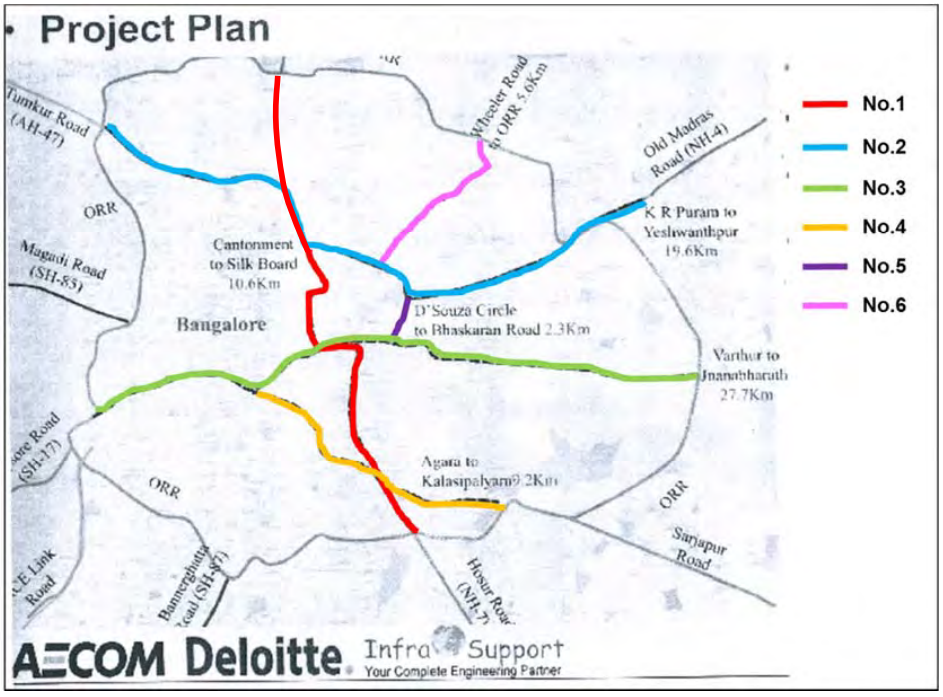
Ⅱ. Scope of Study

1. List of Planned Elevated Corridors

No	Name of Proposed Corridor	Length	No. of Lanes	Type
1	North-South Corridor connecting central Silk Board to Cantonment (i.e., NH7 towards Hosur to NH towards Bellary)	10.60km	6	Elevated
2	East-West Corridor-1 connecting K.R.Puram to Gorguntepalya (i.e., NH-4 towards old Madras Road and NH-4 Bangalore – Pune Road)	19.70km	6	Elevated
3	East-West Corridor-2 connecting SH-17 to SH-35 from Jnanagharathi on SH-17 to Varthur Kodi on SH-35.	27.70km	6	Elevated
4	Connecting Corridor-1; Connecting North-South Corridor & East –West Corridor-2 from Agra to Kalasipalya.	9.20km	4	Elevated
5	Connectiong Corridor-2; Connecting East-West Corridor-1 & East-West Corridor-2 from Richmond Road to Ulsoor.	2.30km	4	Elevated
6	Connecting Corridor-3; Connecting Corridor from Kalyan Nagar Junection at Outer Rind Road to St. Johns Church Road and Wheelers Road Junection.	5.70km	4	Elevated

Ⅱ. Scope of Study

2. List Map of Planned Elevated Corridors



Ⅲ. Study on Standard Section

1. Feature of Standard Section

Precondition	Required
Bridges is in the congested area	Construction period needs to be shorten.
	Minimum negative impact on social environment. (Construction in the minimum space)

Ⅲ. Study on Standard Section

2. Bridge Foundation

Construction

- ✓ To reduce the space
- ✓ To save the time

Advanced Technology can be considered

① PC Well

② Rotary Penetration Steel Pile

③ Steel Pipe Socket Connection Method

Ⅲ. Study on Standard Section

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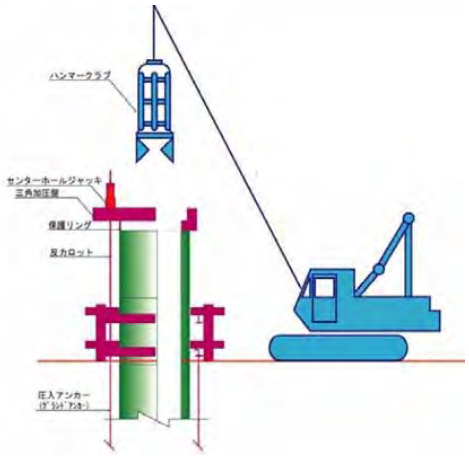
2. Bridge Foundation

2.1 PC Well

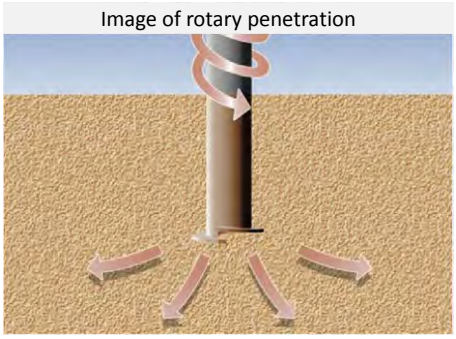


PC Well foundation is comprised of precast concrete block (Circular or Oval shape). Each precast concrete blocks is connected by Post-tension method after they placed at site. After placing precast concrete block and connection each other, excavation work is carried out and compressed into ground.

2. Bridge Foundation

2.2 Rotary Penetration Steel Pile

Image of rotary penetration

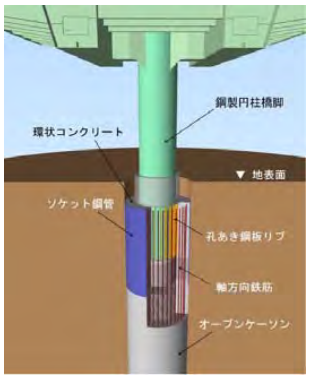


It is Steel Pipe Foundation which is welded a spiral processed steel plate (Wing) to the tip of steel pipe together. The pile penetrates/screws into the ground with propulsion of wing.

It is obtained large bearing force by the base enlarging effect of Wing. And, due to penetration method, there is no excavated soil at site. Therefore, it will be possible to be eco-friendly construction with non-emission, low-vibration and reducing pile number.

2. Bridge Foundation

2.3 Steel Pipe Socket Connection Method



Connection part at tip of pier column

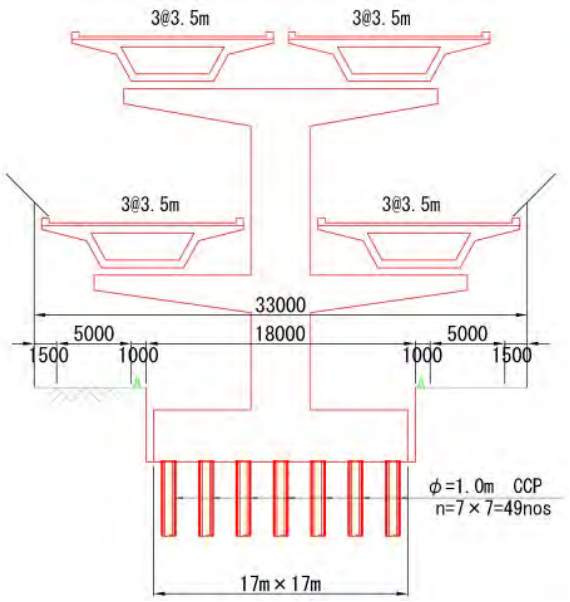
Construction of Caison Structure

Steel Pipe Socket Connection Method is the jointing technique of inserting a Steel Column into Steel Pipe Socket which is constructed at the top of foundation, and filling up a concrete inside the gap of it. It is possible to reduce construction period by omitting Pile Cap and Anchor Frame used in conventional method.

Ⅲ. Study on Standard Section

3. Bridge Pier Column

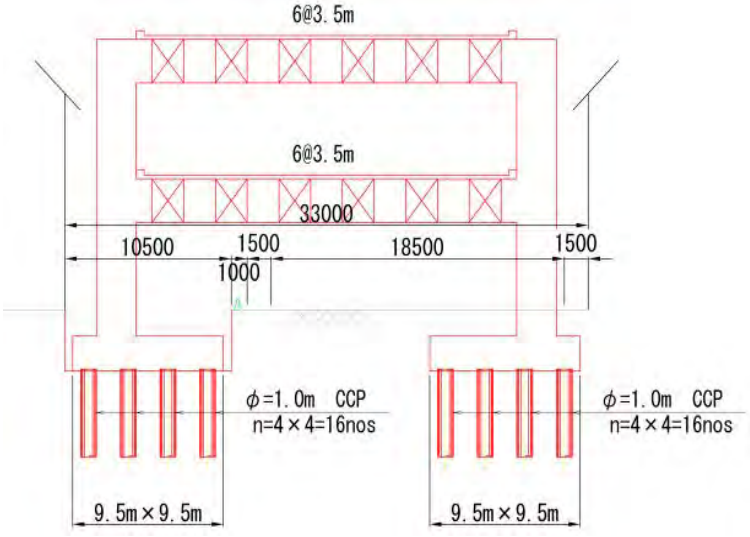
3.1 Concrete Type (Conventional)



Ⅲ. Study on Standard Section

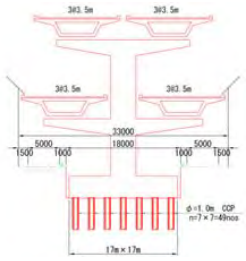
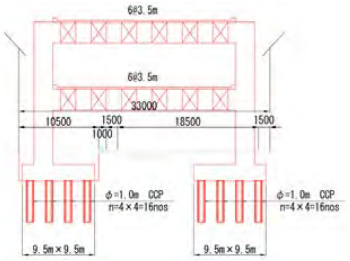
3. Bridge Pier Column

3.2 Steel Type



Ⅲ. Study on Standard Section

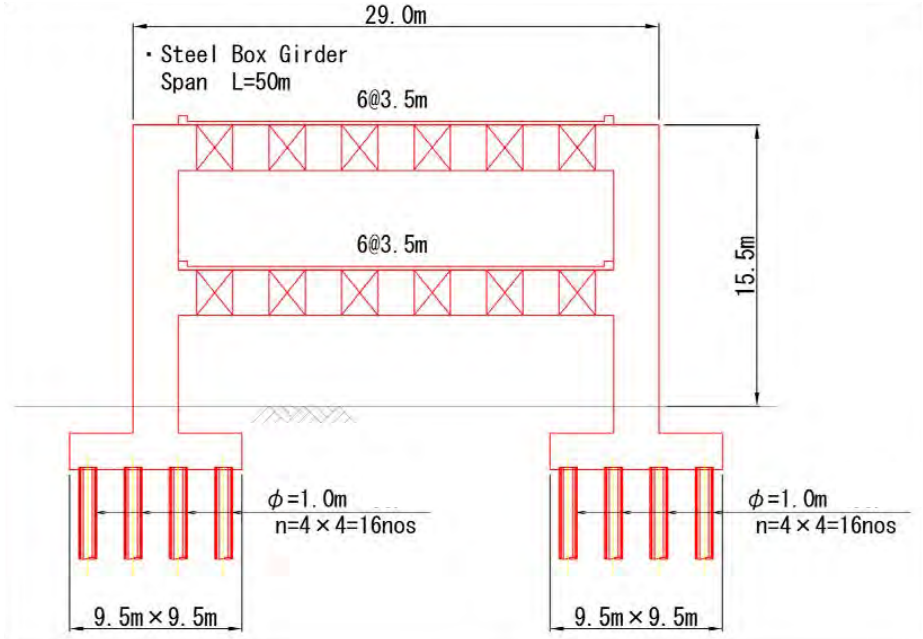
3. Bridge Pier Column

	Concrete Type	Steel Type
General View		
Comment	✓ Due to heavy weight structure, cross section of column and foundation becomes much larger than Steel Type. ✓ Difficult to secure enough carriageway width during pile cap construction (2x5m only.	✓ There are a lot of steel pier column applied in urban area in Japan, despite of high cost. ✓ Easy to apply steel pier column for complicated structure. ✓ Possible to secure enough carriageway width (18.5m)
Construction Cost	Superior	Inferior
Cost Considered Social Effect	Inferior (Due to large width of foundation and longer construction period by cast in-site)	Superior (Due to narrow width of foundation and shorter construction period by prefabrication)
Estimate		**Recommended**

Ⅲ. Study on Standard Section

4. Comparison of Foundation Type

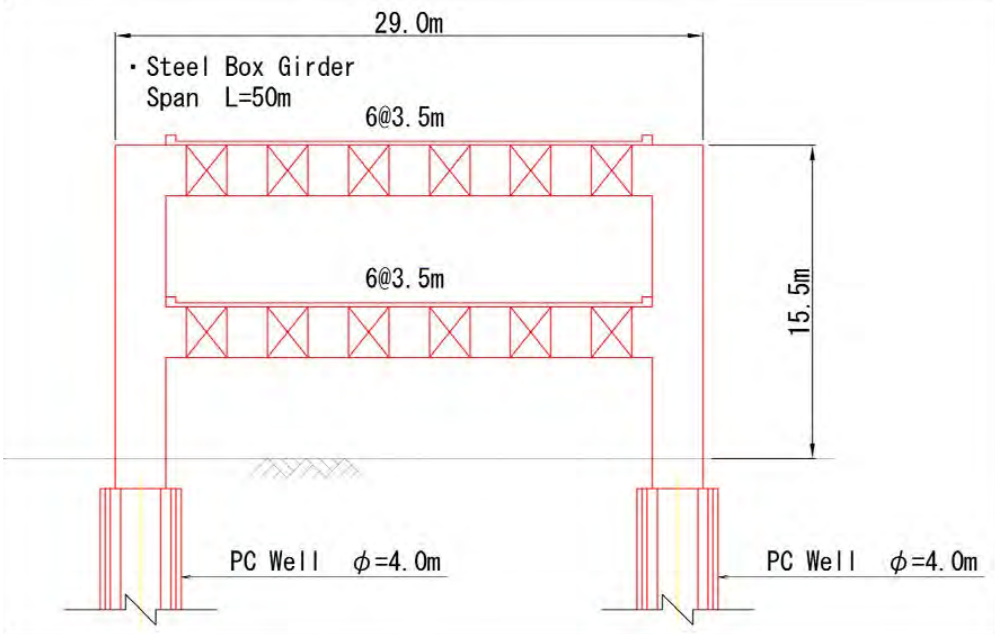
4.1 (Type-1) Cast-in-place Concrete Pile



Ⅲ. Study on Standard Section

4. Comparison of Foundation Type

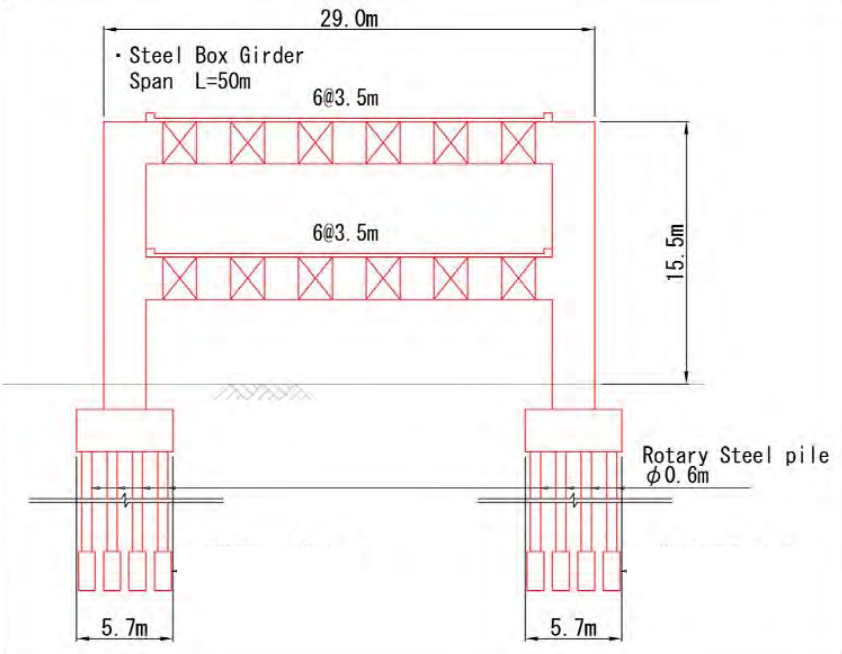
4.2 (Type-2) PC Well



Ⅲ. Study on Standard Section

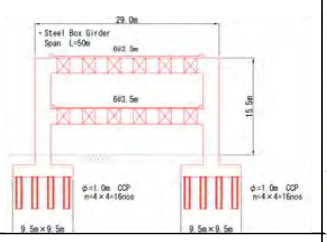
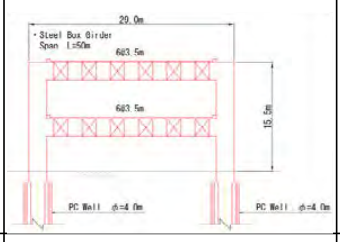
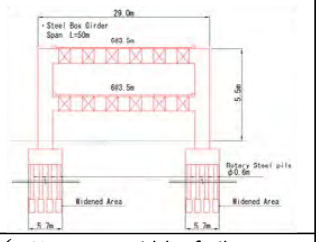
4. Comparison of Foundation Type

4.3 (Type-3) Rotary Penetration Steel Pile



Ⅲ. Study on Standard Section

4. Comparison of Foundation

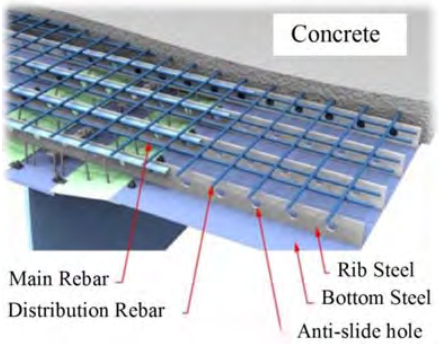
	Type-1 Cast-in-place Concrete Pile	**Type-2** PC Well	**Type-3** Rotary Penetration Steel Pile
General View			
Comment	✓ Common foundation type has many past records and most economical ✓ Widest width of pile cap, cause negative impact to existing traffic during construction	✓ Width of foundation is narrow not cause negative impact to existing traffic during construction. ✓ Shortest construction period due to unified structure with pier column	✓ Narrower width of pile cap than Type-1 cause better impact to existing traffic during construction. ✓ Due to no excavation required, less impact to residence during construction.
Construction Period	Long	Very Short	Short
Construction Cost	Superior	Inferior	Moderate
Cost Considered Social Effect	Inferior	Moderate	Superior
Estimate		**Recommended**	**Recommended**

Ⅲ. Study on Standard Section

5. Type of Superstructure

Due to construction work in very congested area, steel superstructure with composite slab is recommended since this type can minimize social impact.

What is Composite Slab??



Bottom steel plate serves as rebar, formwork, working platform and scaffoldings

1. Higher durability (more than double for conventional RC slab)
2. Shorter construction period by 2months due to less rebar arrangements, form works and scaffoldings.
3. Better working conditions on site
4. No fear of leak of wet concrete and cement milk to the existing traffic

Ⅳ. Study Result of JCT

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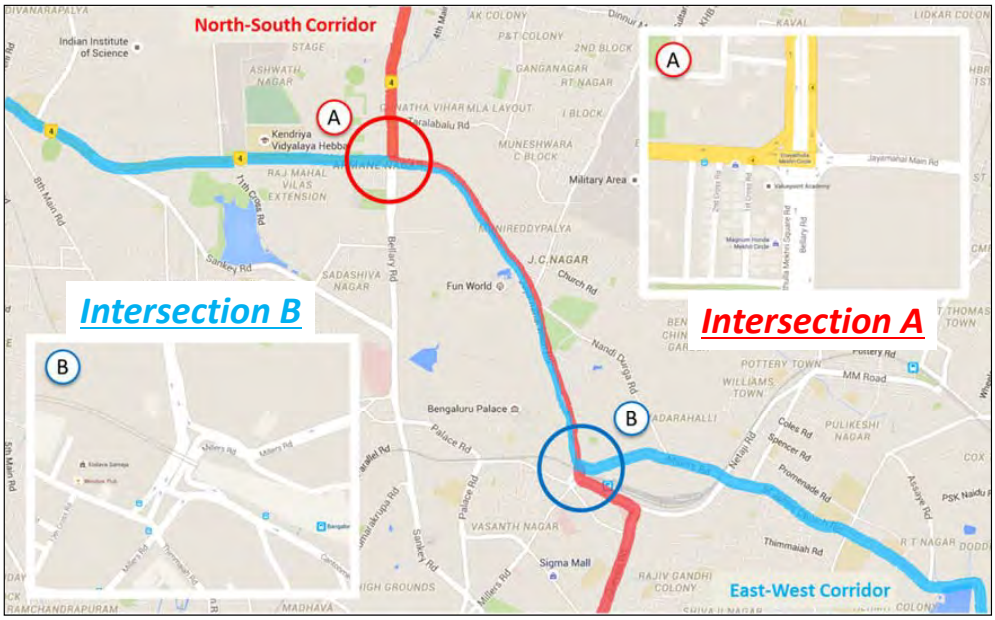
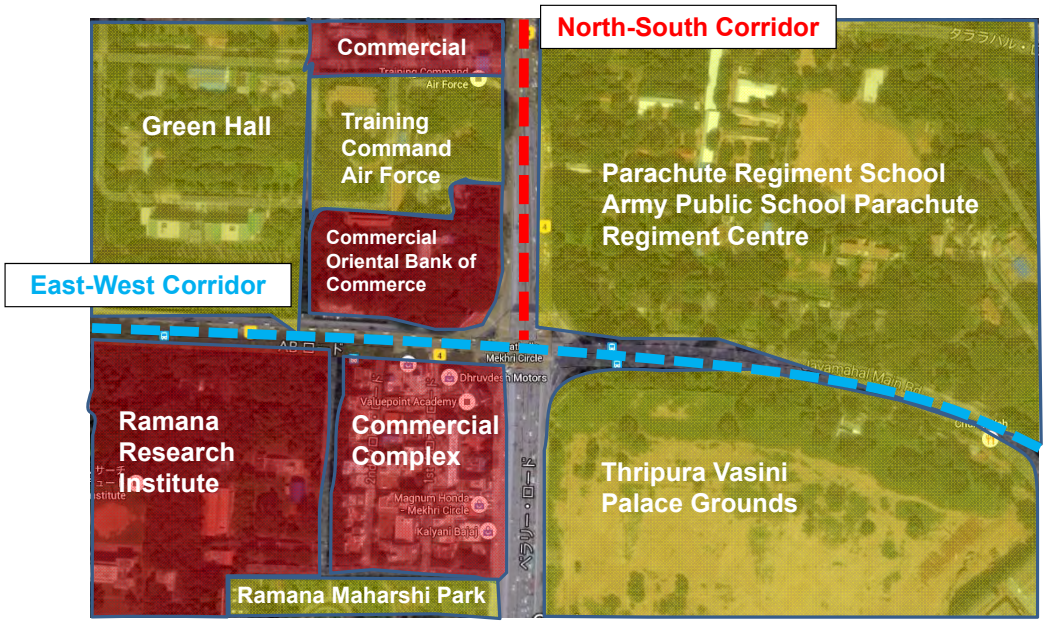
1. Location of Studied Elevated Corridors



Ⅳ. Study on JCT Structure

ORIENTAL CONSULTANTS GLOBAL CO., LTD.

2. Land Use Status around Intersection A



Red Color: Private Land (Difficult for Land Acquisition)
Yellow Color: Government Land (Possible for Land Acquisition)

Ⅳ. Study on JCT Structure

ORIENTAL CONSULTANTS GLOBAL CO., LTD.

3. Alternatives

Intersection A

Following 2 alternatives are studying.

Alternatives 1

- **<u>WITHOUT</u> consideration of Land Acquisition**
- **High Service Level**

Alternatives 2

- **With consideration of Land Acquisition**
- **Realistic (Lower Service Level)**

Ⅳ. Study on JCT Structure

ORIENTAL CONSULTANTS GLOBAL CO., LTD.

4. Study Result of Alternative 1

Intersection A

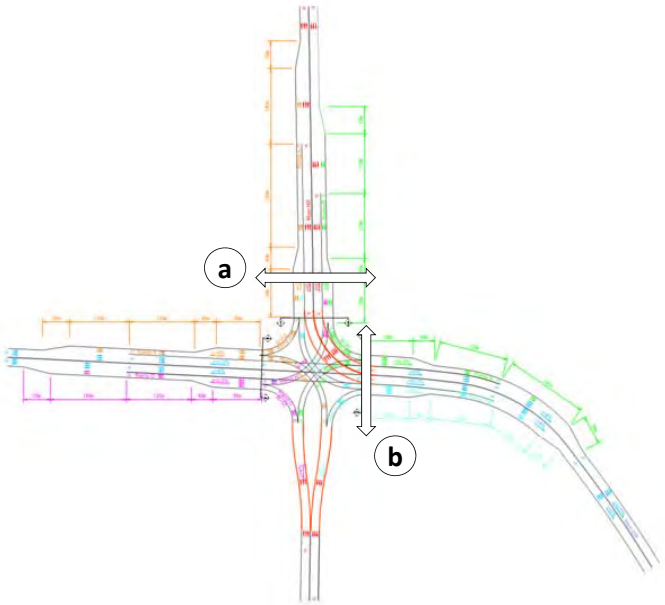
<u>4.1 Plan View</u>

Ⅳ. Study on JCT Structure

4. Study Result of Alternative (1)

Intersection A

4.2 Structure of JCT



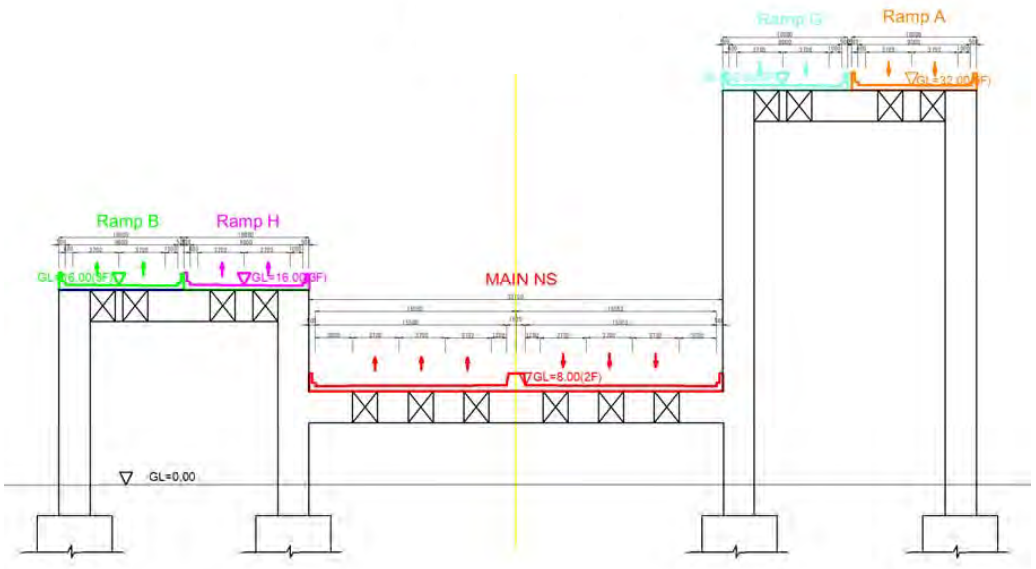
Ⅳ. Study on JCT Structure

ORIENTAL CONSULTANTS GLOBAL CO., LTD.

4. Study Result of Alternative (1)

Intersection A

4.3 Cross Section for (a)

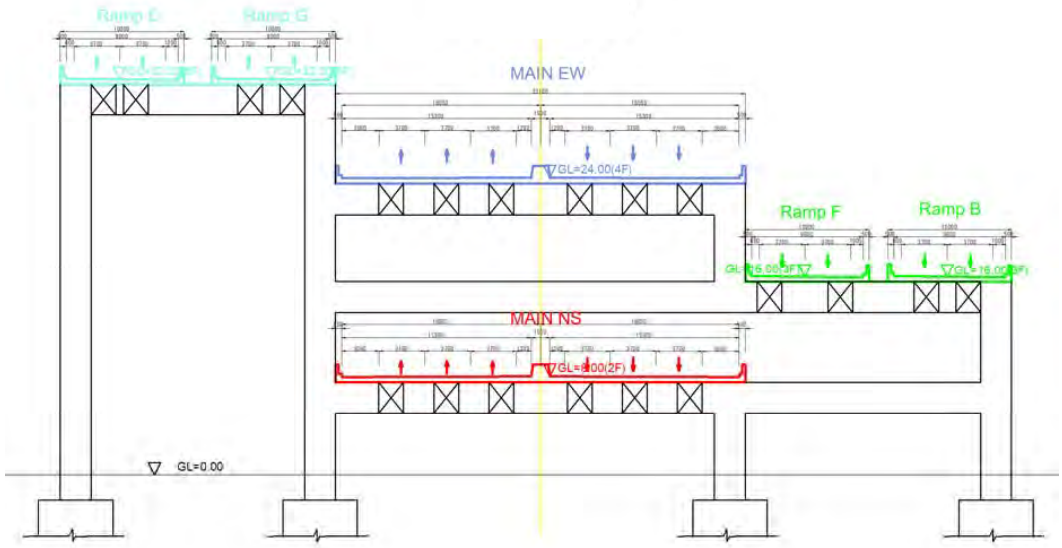


Ⅳ. Study on JCT Structure

4. Study Result of Alternative (1)

Intersection A

4.4 Cross Section for (b)



Ⅳ. Study on JCT Structure

5. Study Result of Alternative (2)

Intersection A

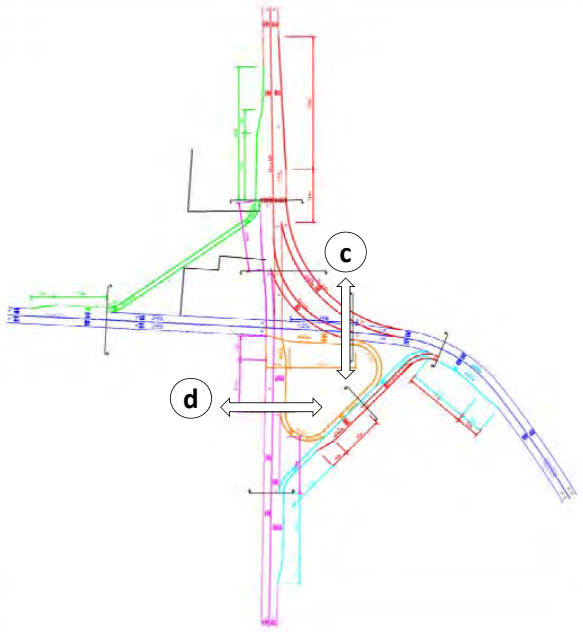
5.1 Plan View

Ⅳ. Study on JCT Structure

5. Study Result of Alternative (2)

Intersection A

5.2 Structure of JCT

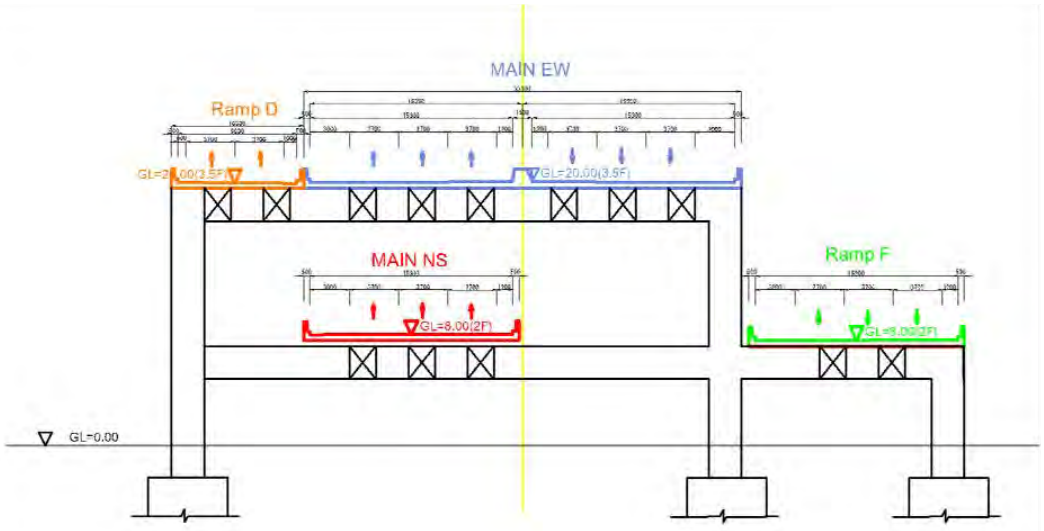


Ⅳ. Study on JCT Structure

5. Study Result of Alternative (2)

Intersection A

5.3 Cross Section for (c)

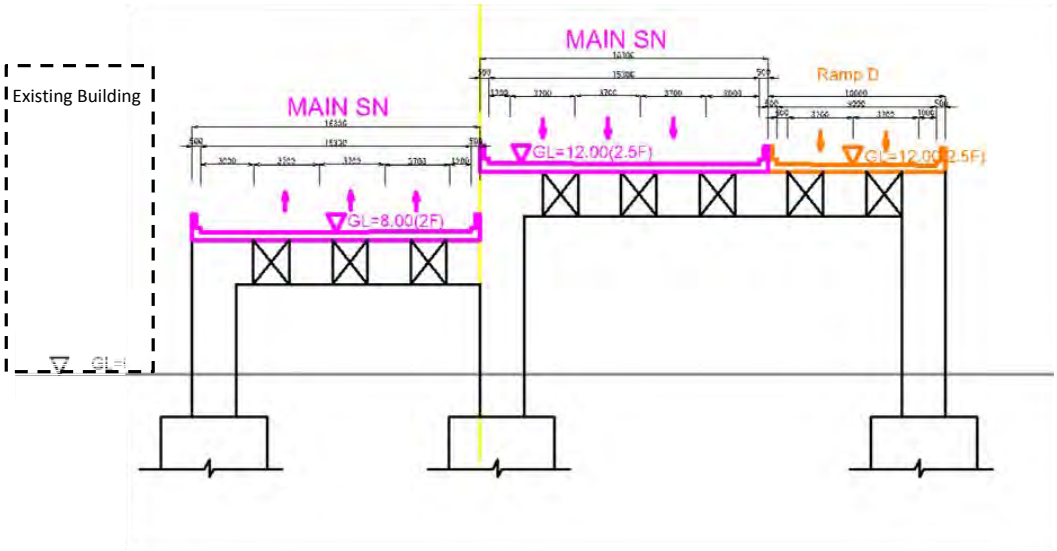


Ⅳ. Study on JCT Structure

5. Study Result of Alternative (2)

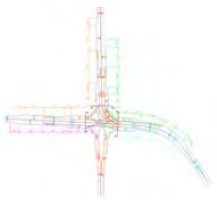
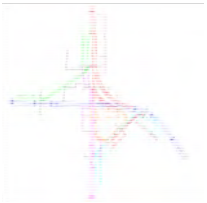
Intersection A

5.4 Cross Section for (d)



Ⅳ. Study on JCT Structure

6. Comparison of JCT for Intersection A

	Alternative (1)	Alternative (2)
Plan View		
Feature	✓ No restriction of land use, to be compact size of JCT	✓ Consideration of actual land use situation, to be larger size of JCT
Access	✓ 10 accesses out of 12 accesses can be accommodated. (2 more accesses can be accommodated, if layer number increase)	✓ 9 accesses out of 12 accesses can be accommodated. (South – East, South – West and West – South direction cannot be accommodated)
Advantage	✓ Size of JCT becomes small.	✓ There are not many points to be overlapped. ✓ Possible to apply simple structure compared with Alternative 1.
Disadvantage	✓ Due to 5 stories JCT, pier column shape becomes very complicated.	✓ Required land area becomes large.

Ⅳ. Study on JCT Structure

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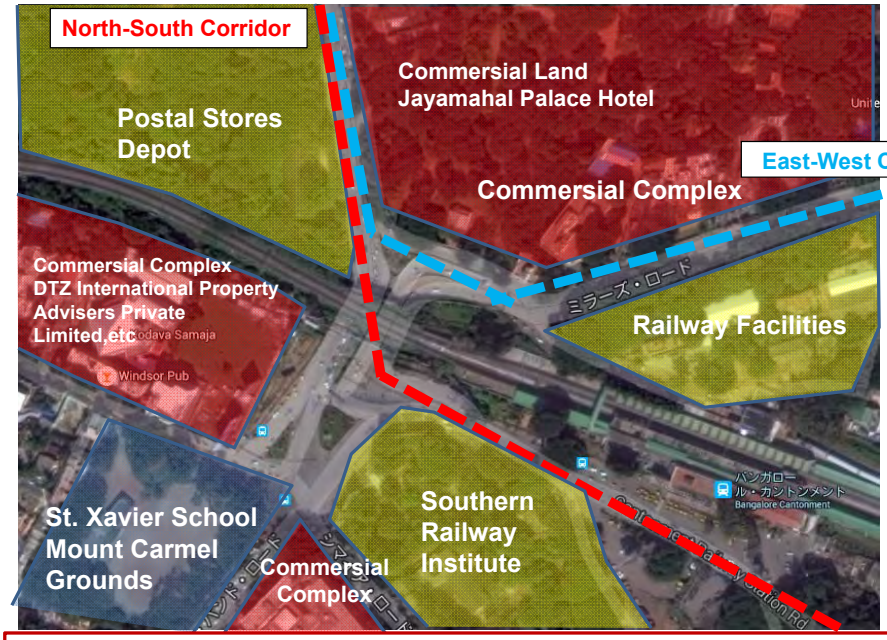
7. Land Use Status around Intersection B



Red Color: Private Land (Difficult for Land Acquisition)
Blue Color: School Land (Possible for Land Acquisition, but, take long time for procedure)
Yellow Color: Government Land (Possible for Land Acquisition)

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Ⅳ. Study on JCT Structure

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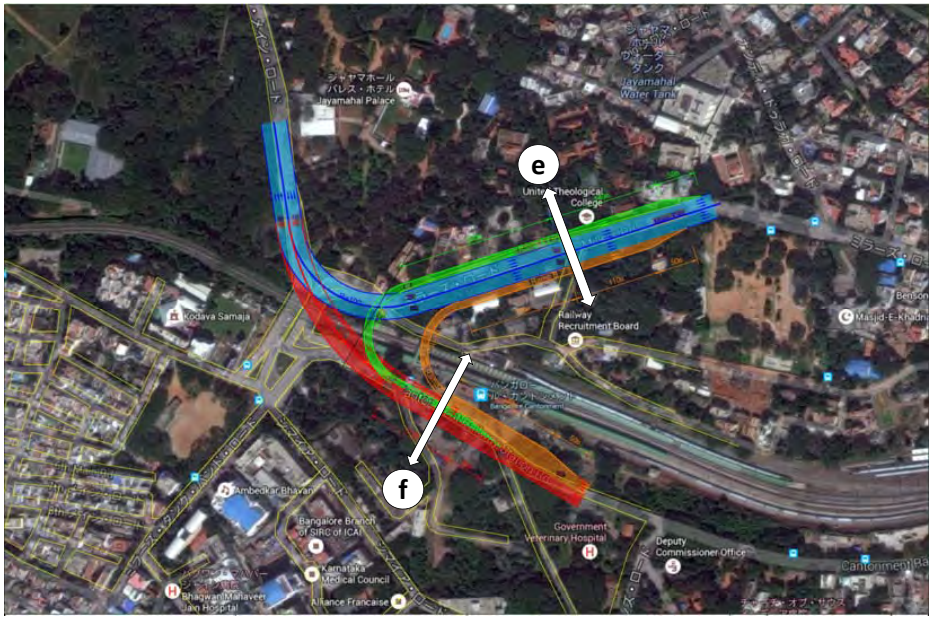
8. Study Result

Intersection B

8.1 Plan View



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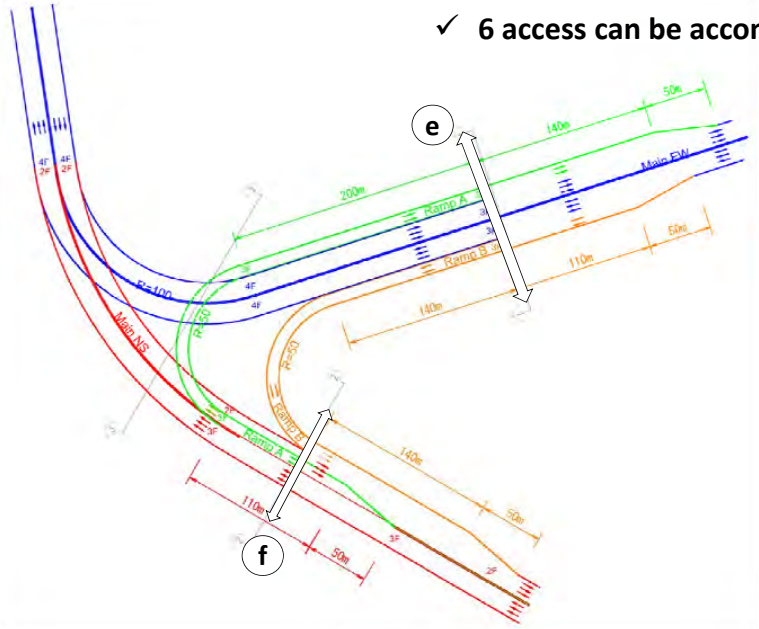
Ⅳ. Study on JCT Structure

8. Study Result

Intersection B

8.2 Structure of JCT

✓ 6 access can be accommodated

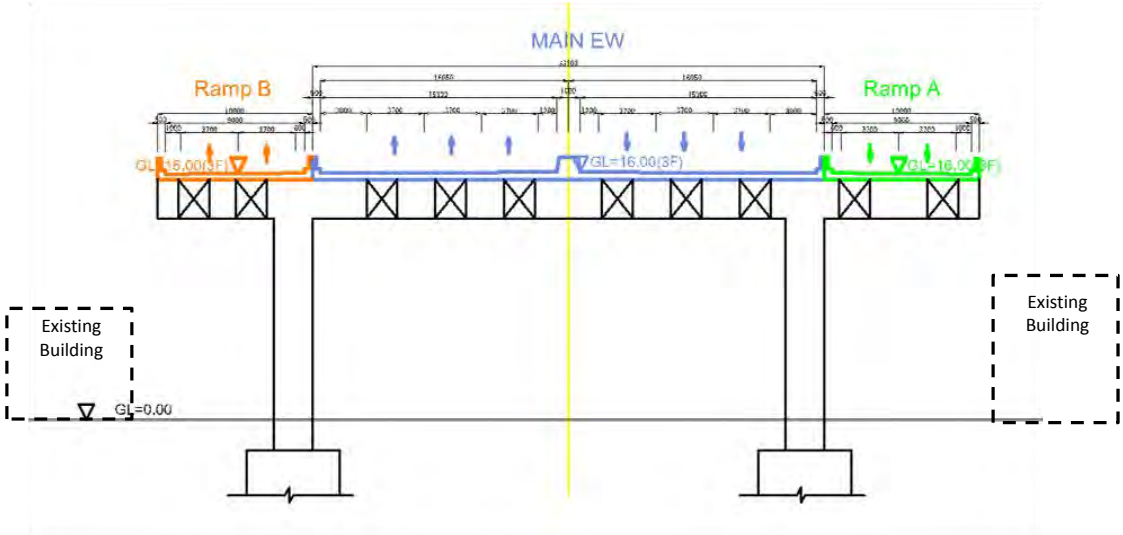


Ⅳ. Study on JCT Structure

8. Study Result

Intersection B

8.3 Cross Section for (e)

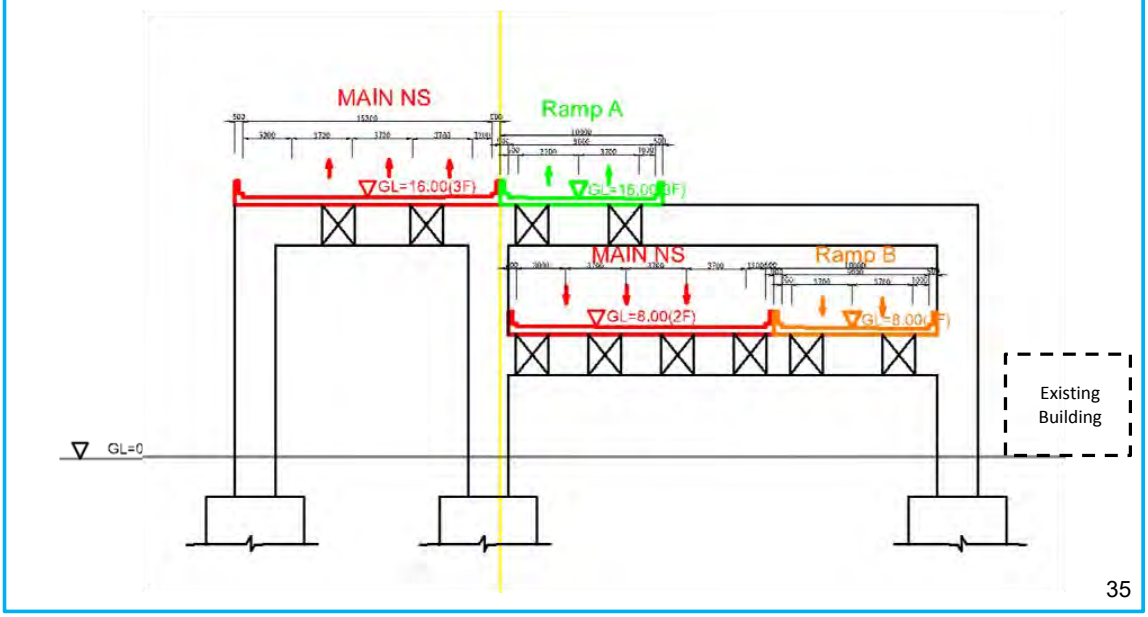


Ⅳ. Study on JCT Structure

8. Study Result

Intersection B

8.4 Cross Section for ⓕ



Ⅳ. Study on JCT Structure

9. Recommendation of Steel Structure

In order to achieve these complicated structure, followings advanced technologies will be required.

- **Application of thick steel (more than 50mm)**
- **Application of high tension steel (σy=700 N/mm2)**
- **Consideration of details for prevention of fatigue damage, such as welding and shape of scallop.**
- **Experience of erection method for complicated structure at congested area.**

Ⅴ. Summary of Structural Study

1. Rough Cost Estimation

◆ **Condition for Estimation**

- **Length of Viaduct = 2.75km (JCT to JCT, excluding JCT)**
- **Superstructure: Steel Box Girder with Composite Deck Slab**
- **Substructure: Steel Pier Column (double deck)**
- **Foundation: PC Well**

Construction Cost	Design Cost	Supervision Cost	Total
26,663	1,067	2,400	30,130

Unit : Million Rs

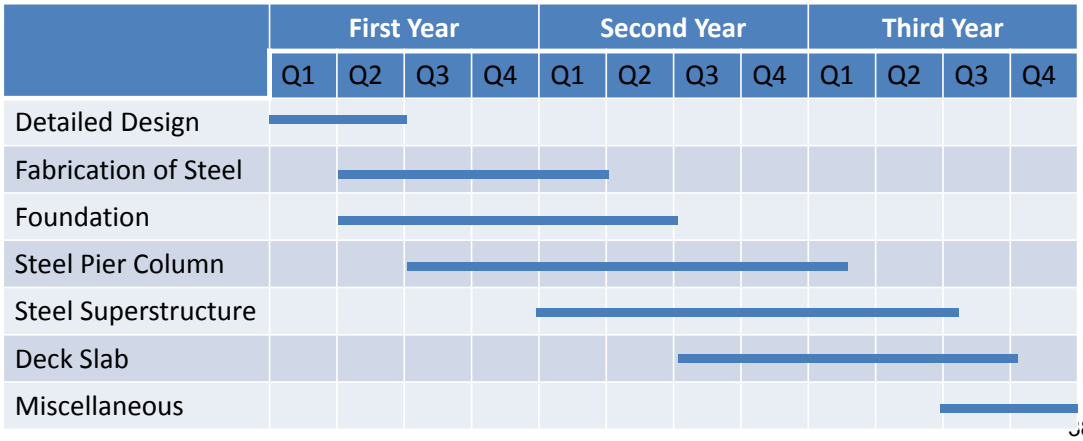
Ⅴ. Summary of Structural Study

ORIENTAL CONSULTANTS GLOBAL CO., LTD.

2. Construction Schedule

Since no critical path, construction schedule will be decided by number of construction team.

Appropriate Construction Schedule (total 3 years)



Ⅴ. Summary of Structural Study

3. Economic Analysis Result

With Case => Construction by Steel Superstructure and Steel Pier Column

Without Case => Construction by PC Superstructure and RC Pier Column (partially, PC)

Although construction cost becomes higher, but, social benefit can increase

EIRR => 14.0% > 12.0%

Because of enough number of EIRR, implementation by Steel Structure will have better EIRR number than PC Structure

Ⅵ. Recommendation

After studying of Proposed Elevated Corridor and JCT, following structures are recommended.

- ✓ **Superstructure**
  ⇒ **Steel Box Girder with Composite Deck Slab**
- ✓ **Substructure**
  ⇒ **Steel Pier Column**
- ✓ **Foundation**
  ⇒ **PC Well or Rotary Steel Penetration Pile**

Although construction cost becomes higher, but, due to increment of social benefit, EIRR value becomes higher.

Tokyo Metropolitan Expressway

THANK YOU

Oriental Consultants Global Co., Ltd.

APPENDIX 3

Explanatory Material of

Viaduct Construction Project in Chennai

Data Collection Survey on Road/Railway Bridge Sector

Explanatory Material of Viaduct Construction Project in Chennai

October 2016
Chennai

JAPAN INTERNATIONAL COOPERATION AGENCY
Oriental Consultants Global Co., Ltd.

Contents

1. Introduction

Objectives of the Survey

1. To grasp current situation of Road / Railway bridges and Viaducts in India.
2. To identify bridge / Viaducts wherein consideration of the application of the Japanese advanced technologies such as rapid construction method in urban area and latest bridge rehabilitation and reinforcement method could be explored.

Further development on bridge construction and rehabilitation field in India will be achieved by incorporating advanced technology.

Ⅰ. Introduction

Based on discussion with Highway & Minor Ports Department, Tamil Nadu Government, on June 21
Study on Planned Elevated Corridor
were proposed.

Structure of Planned Elevated Corridor was studied by JICA Study Team

Draft Final Study Result is presented by this meeting.

Ⅱ. Results of Site Inspection

1. Location of Proposed IT Corridors

Ⅱ. Results of Site Inspection

2. Width of Existing Road

Ⅲ. Study on Standard Section

1. Feature of Standard Section

Precondition	Required
Viaduct is in the congested area. (Existing road width is only 15m, including sidewalk)	Construction period needs to be shorten.
	Minimum negative impact on social environment. (Construction in the minimum space)

Ⅲ. Study Result on East Coast Road Viaduct

2. Advanced Technology can be Adopted

Construction

- ✓ To reduce the space
- ✓ To save the time

Type of Viaduct Foundation

① PC Well

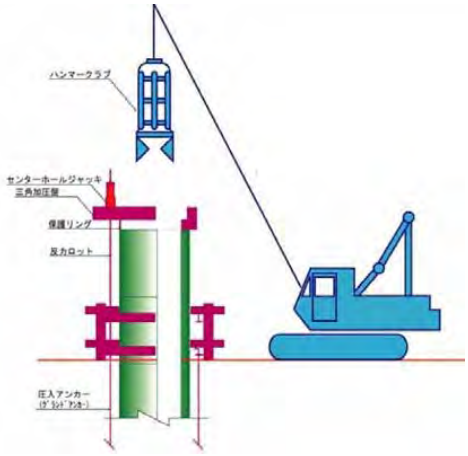
② Rotary Penetration Steel Pile

③ Steel Pipe Socket Connection Method

Ⅲ. Study Result on East Coast Road Viaduct

3. Viaduct Foundation

3.1 PC Well



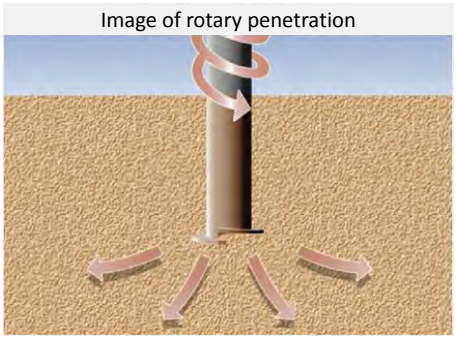
PC Well foundation is comprised of precast concrete block (Circular or Oval shape). Each precast concrete blocks is connected by Post-tension method after they placed at site. After placing precast concrete block and connection each other, excavation work is carried out and compressed into ground.

Ⅲ. Study Result on East Coast Road Viaduct

3. Viaduct Foundation

3.2 Rotary Penetration Steel Pile

Image of rotary penetration



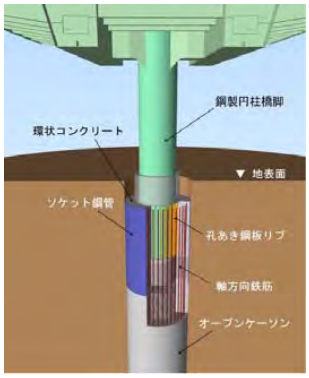
It is Steel Pipe Foundation which is welded a spiral processed steel plate (Wing) to the tip of steel pipe together. The pile penetrates/screws into the ground with propulsion of wing.

It is obtained large bearing force by the base enlarging effect of Wing. And, due to penetration method, there is no excavated soil at site. Therefore, it will be possible to be eco-friendly construction with non-emission, low-vibration and reducing pile number.

Ⅲ. Study Result on East Coast Road Viaduct

3. Viaduct Foundation

3.3 Steel Pipe Socket Connection Method



Connection part at tip of pier column

Construction of Caison Structure

Steel Pipe Socket Connection Method is the jointing technique of inserting a Steel Column into Steel Pipe Socket which is constructed at the top of foundation, and filling up a concrete inside the gap of it. It is possible to reduce construction period by omitting Pile Cap and Anchor Frame used in conventional method.

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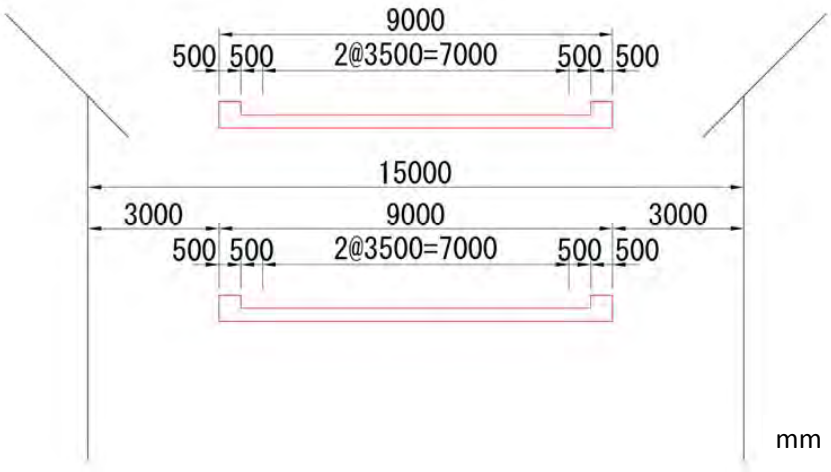
Ⅲ. Study Result of East Coast Road Viaduct

4. Proposed Carriageway Width

In consideration of existing road width (15m), following cross section is proposed if land acquisition is not considered.



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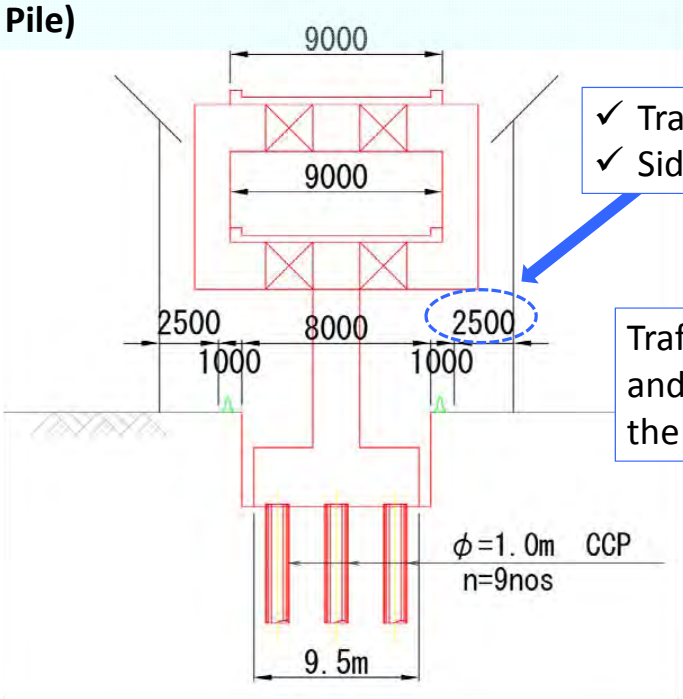
Ⅲ. Study Result on East Coast Road Viaduct

5. Comparison of Viaduct Foundation (Cast in Site Concrete Pile)



- ✓ Traffic Lane: only 2500mm
- ✓ Side Walk: Not secured

Traffic lane will be narrow and no space to construct the side walk.

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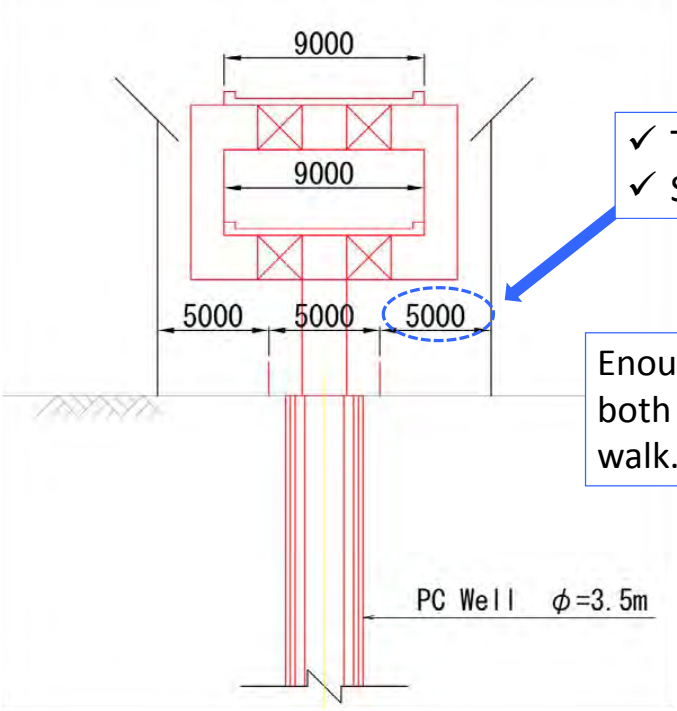
Ⅲ. Study Result on East Coast Road Viaduct

5. Comparison of Foundation (PC Well)



- ✓ Traffic Lane: 3500mm
- ✓ Side Walk: 1500mm

Enough space to construct both of traffic lane and side walk.

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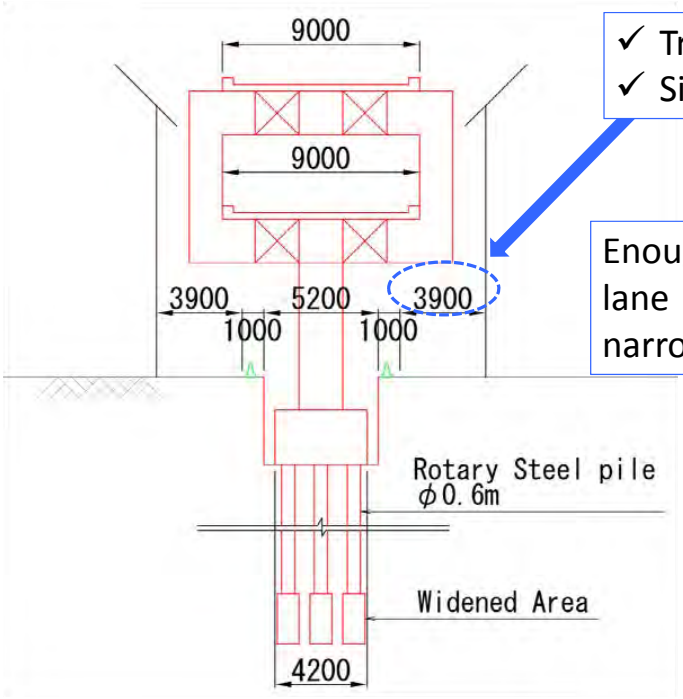
Ⅲ. Study Result on East Coast Road Viaduct

5. Comparison of Foundation (Rotary Penetration Steel Pile)



- ✓ Traffic Lane: 3000mm
- ✓ Side Walk: 900mm

Enough space for traffic lane but side walk will be narrow.

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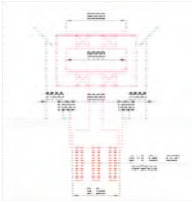
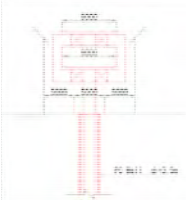
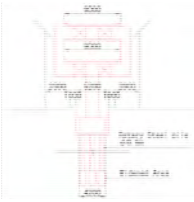
Ⅲ. Study Result on East Coast Road Viaduct

6. Comparison of Foundation

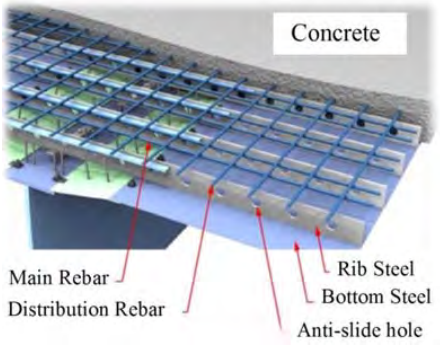
	Type-1 CCP Pile	**Type-2** PC Well	**Type C-1** Rotary Penetration Steel Pile
General View			
Comment	✓ Common foundation type has many past records and most economical ✓ Widest width of pile cap, cause negative impact to existing traffic during construction	✓ Width of foundation is narrow not cause negative impact to existing traffic during construction. ✓ Shortest construction period due to unified structure with pier column	✓ Narrower width of pile cap than Type-1 cause better impact to existing traffic during construction. ✓ Due to no excavation required, less impact to residence during construction.
Construction Cost	Superior	Inferior	Moderate
Cost Considered Social Effect	Inferior	Superior	Superior
Estimate		**Recommended**	**Recommended**

Ⅲ. Study Result on East Coast Road Viaduct

7. Type of Superstructure

Due to construction work in very congested area, steel superstructure with composite slab is recommended since this type can minimize social impact.

What is Composite Slab??



Bottom steel plate serves as rebar, formwork, working platform and scaffoldings

1. Higher durability (more than double for conventional RC slab)
2. Shorter construction period by 2months due to less rebar arrangements, form works and scaffoldings.
3. Better working conditions on site
4. No fear of leak of wet concrete and cement milk to the existing traffic

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Ⅲ. Study Result on East Coast Road Viaduct

8. Recommendation of Steel Structure

In order to achieve these complicated structure, followings advanced technologies will be required.

- **Application of thick steel (more than 50mm)**
- **Application of high tension steel (σy=700 N/mm2)**
- **Consideration of details for prevention of fatigue damage, such as welding and shape of scallop.**
- **Experience of erection method for complicated structure at congested area.**

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Ⅳ. Summary of Structural Study

1. Rough Cost Estimation

◆ **Condition for Estimation**

- **Length of Viaduct = 7.55km (B. P from Center of Chennai City side to Injanbakkam)**
- **Superstructure: Steel Box Girder with Composite Deck Slab**
- **Substructure: Steel Pier Column (double deck)**
- **Foundation: PC Well**

Construction Cost	Design Cost	Supervision Cost	Total
31,663	1,267	2,850	35,780

Unit : Million Rs

Ⅳ. Summary of Structural Study

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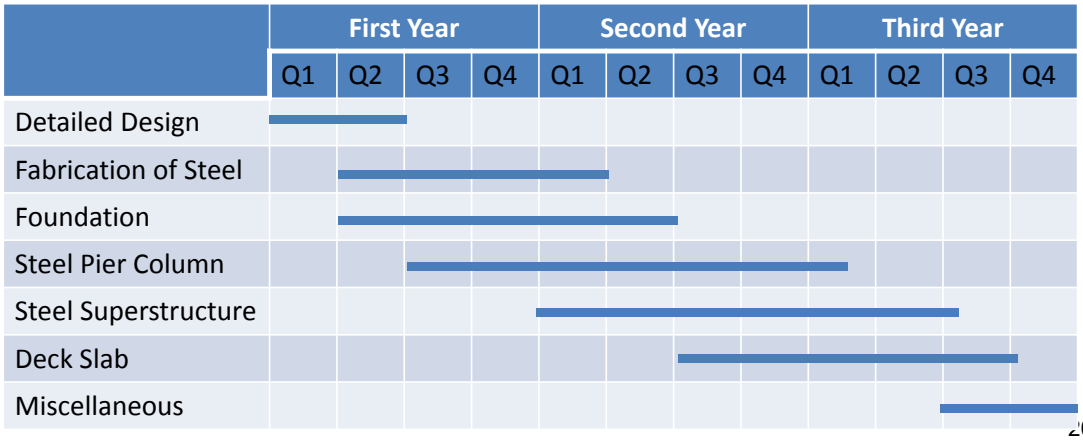
2. Construction Schedule

Since no critical path, construction schedule will be decided by number of construction team.

Appropriate Construction Schedule (total 3 years)



Ⅳ. Summary of Structural Study

3. Economic Analysis Result

With Case => Construction by Steel Superstructure and Steel Pier Column

Without Case => No Construction of Viaduct

Although construction cost is high, but, due to large social benefit

EIRR => 28.1% > 12.0%

Ⅵ. Introduction of Japanese Support

★ Risk of BOT Scheme

✓ <u>Reliability of Project Implementation</u>

⇒ Risk for suspension of the project, depending on their financial status

Recommend to handle the Project by the Government

Since, the Project is implemented inside Chennai and acts very important role for decongestion of Chennai.

Japanese Government can support by YEN Loan

Ⅵ. Recommendation

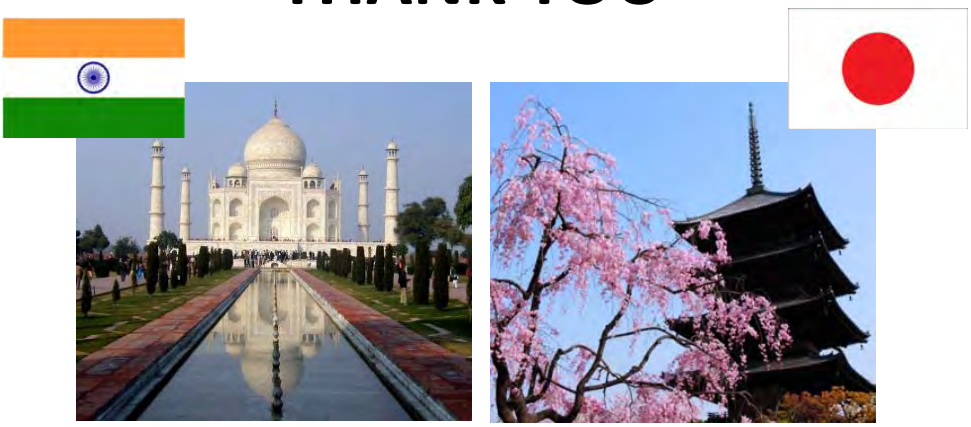
After studying of Proposed Elevated Corridor, following structures are recommended.

- ✓ **Superstructure**
  ⇒ **Steel Box Girder with Composite Deck Slab**
- ✓ **Substructure**
  ⇒ **Steel Pier Column**
- ✓ **Foundation**
  ⇒ **PC Well**

Although construction cost becomes high, but, due to increment of social benefit, EIRR value becomes higher.

Tokyo Metropolitan Expressway

THANK YOU



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APPENDIX 4

Explanatory Material of Construction of New Mahtma Gandhi Bridge in Patna

Data Collection Survey on Road / Railway Bridge Sector

Explanatory Material of Construction of New Mahatma Gandhi Bridge in Patna

August 30, 2016

JAPAN International Cooperation Agency

Oriental Consultants Global Co., Ltd.

1

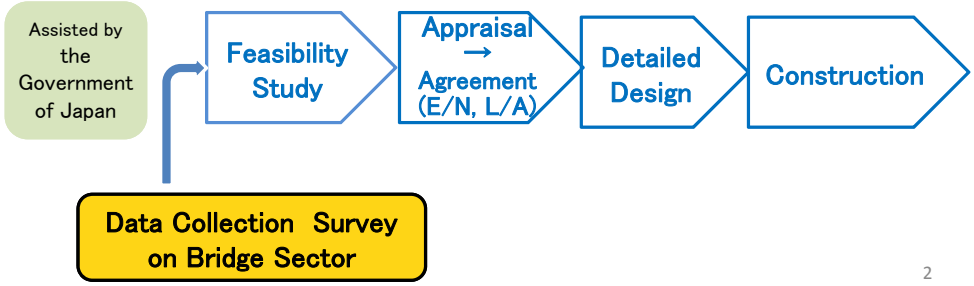
1. General

(1) Objective

- To propose most feasible structure for New Mahatma Gandhi Setu
- For the future JICA feasibility study

(2) Positioning of the Study

Flow of Japanese ODA Loan Project



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1. General

(3) Study Schedule

- Duration: from April to November 2016
- Interim Meeting: Aug. 2016
- Draft Final Meeting: Oct. 2016
- Submission of Final Report: Nov. 2016

2. Significance and Necessity of New MG Setu

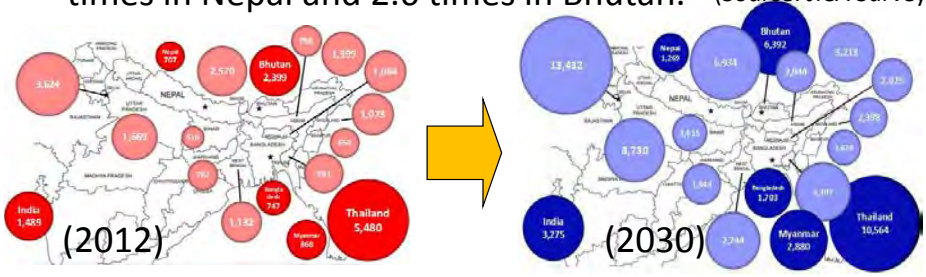
(1) Connectivity of Roads to Outside the Bihar State

Export

- Nepal: 69% of exports to India in 2012
- Bhutan: 76% of exports to India in 2012

GDP

Prediction of GDP increasing about 3 times in Bihar State, 1.8 times in Nepal and 2.6 times in Bhutan. (Source: JICA Survey in2014)



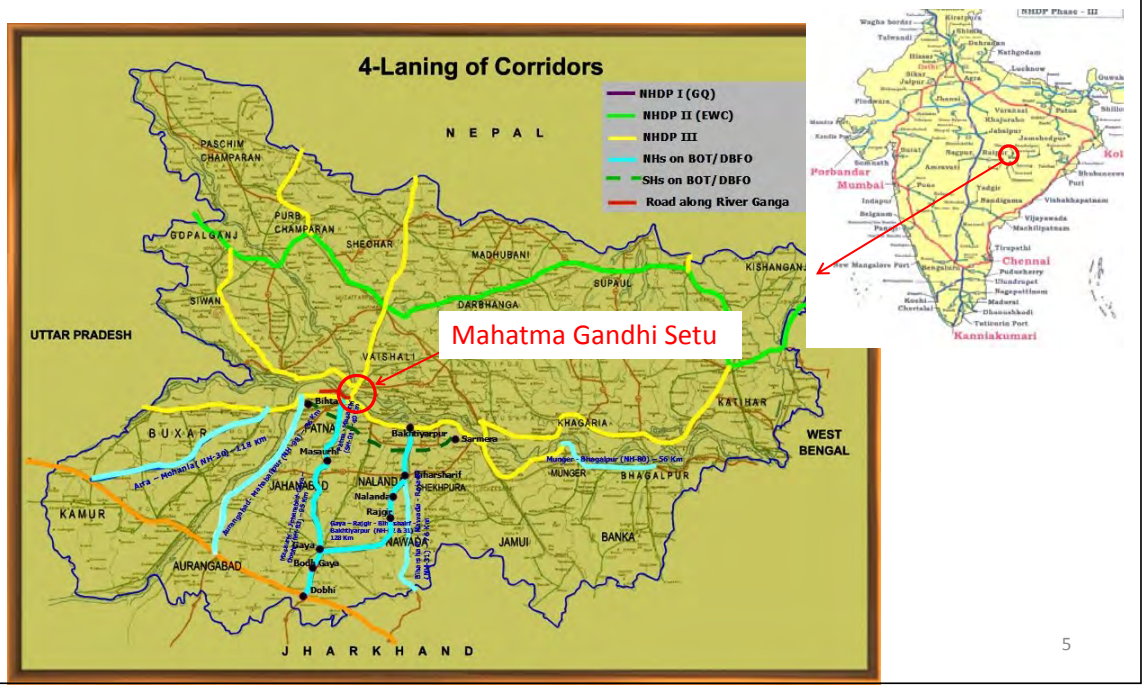
When inter-regional logistics networks will be further developed,

- More than 150% economic growth
- More than 350% growth of inter-regional logistics

(Predicted by JICA Survey in2014)

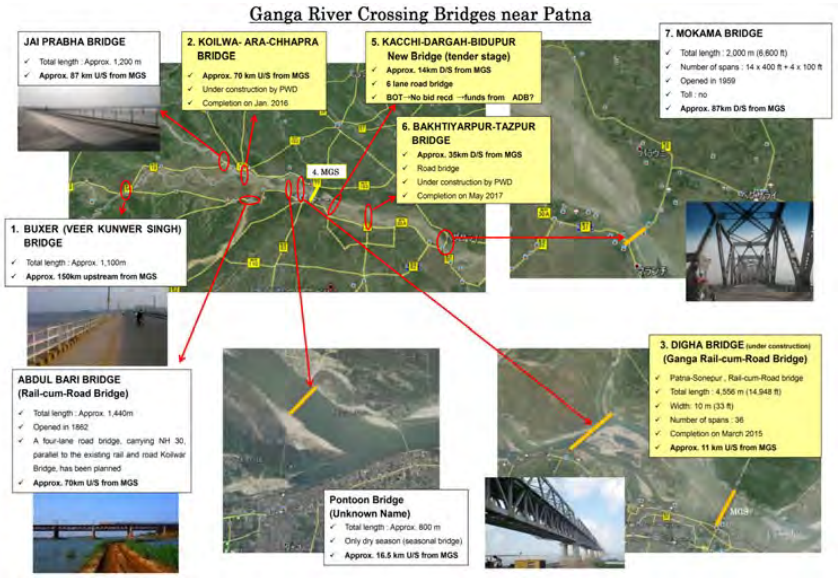
2. Significance and Necessity of New MG Setu

(1) Connectivity of Roads to Outside the Bihar State



2. Significance and Necessity of New MG Setu

(2) Roles in Local Traffic



- Rapidly increasing traffic volume.
- Expansion of trade with Nepal and Bhutan.

Continue to play an important role as before.

2. Significance and Necessity of New MG Setu

(3) Traffic assignment after completion of 4 new Bridge

	Scheduled completion Year	Traffic Assignment		
		2016	2017	2018
Mahatma Gandhi Setu	–	50.8 %	35.5 %	28.7 %
Koilwa– Ara-Chhapra Bridge	2016		17.1 %	14.4 %
Digha Bridge (Railway cum)	2015	49.2 %	33.6 %	27.3 %
Kacchi- Dargah Bidupur Bridge	2017			18.6 %
Bakhtiyarpur-Bidupur Bridge	2016		13.8 %	11.0 %

(4) Future traffic demand forecast of MG Setu (2014-2052)

	Car/Taxi/Jeep etc.	Bus	LCV	Truck	Total	2-W	3-W	Tractor	Others	Grand Total Veh. / day	Grand Total PCU / day
2013	11,890	2,161	3,268	11,982	29,301	11,576	6,306	850	508	48,541	80,107
2014	13,079	2,377	3,627	13,300	32,383	12,734	6,937	850	508	53,412	88,177
2015	14,387	2,615	4,026	14,763	35,791	14,007	7,631	850	508	58,787	97,104
2016	8,090	1,472	2,260	8,287	20,109	15,408	8,394	850	508	45,269	64,167
2017	6,233	1,224	1,726	6,327	15,510	16,949	9,233	850	508	43,050	55,702
2018	5,499	1,106	1,557	5,707	13,869	18,644	10,156	850	508	44,027	54,022
2022	7,905	1,589	2,321	8,508	20,323	26,800	14,599	850	508	63,080	77,072
2027	11,615	2,335	3,572	13,091	30,613	39,379	21,450	850	508	92,800	113,627
2032	15,544	3,125	5,010	18,363	42,042	52,699	28,705	850	508	124,804	153,937
2037	20,803	4,183	7,028	25,757	57,771	70,524	38,413	850	508	168,066	209,176
2042	27,839	5,597	9,857	36,126	79,419	94,376	51,406	850	508	226,559	284,906
2047	37,255	7,490	13,824	50,669	109,238	126,296	68,793	850	508	305,685	388,799
2052	49,855	10,023	19,388	71,066	150,332	169,012	92,061	850	508	412,763	531,402

Note: Traffic Volume is from "Development of Six Lane Suspension Cable Green Field Bridge over river Ganga from Kacchi Dargah on NH-30 to Bidupur in Dist Vaishali on NH-103, 2013" and forecasted in METI Study in 2014.

2. Significance and Necessity of New MG Setu

(5) Necessity of New MG Setu

According to Highway Capacity Manual (AASHTO)

2 Lanes < 20,000

20,000 < 4 Lanes < 80,000

80,000 < 6 Lanes

unit [PCU/DAY]

According to Traffic Demand Forecast,

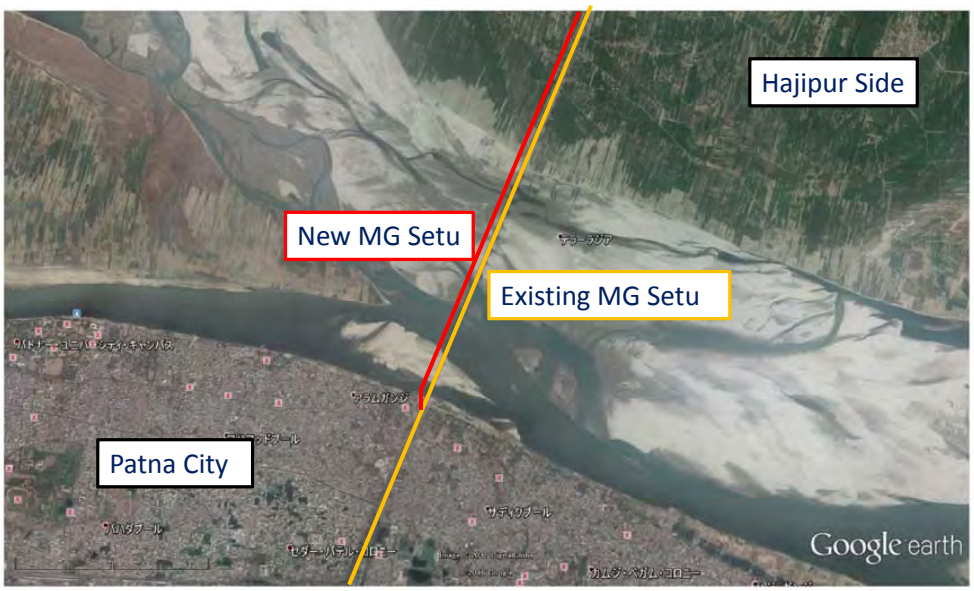
Year 2022 => 4 Lanes Required

Year 2027 => 8 Lanes Required

New MG Setu is required

3. Location of New MG Setu and Connection to existing road

(1) Location of New MG Setu



Location of New MG Setu will be decided by Scouring and Construction near existing bridge => 50~100 m

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3. Location of New MG Setu and Connection to existing road

(2) Land Status at Patna City Side

Some space for New MG Setu is secured

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3. Location of New MG Setu and Connection to existing road

(3) Land Status at Hajipur Side

Most of area is for farm land, but, there is some houses beside existing road.

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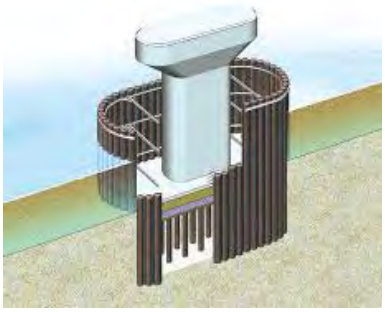
4. Introduction of Applicable Bridge Types for New MG Setu

(1) Foundation

<u>Steel Pipe Sheet Pile (SPSP) Foundation</u>

SPSP foundation can be adopted for New MG Setu.

- Not required Temporary Cofferdam separately
- Large bearing capacity and compact foundation
- Fast and safe construction after driving steel pipes
- Advantageous for scouring and seismic force



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4. Introduction of Applicable Bridge Types for New MG Setu

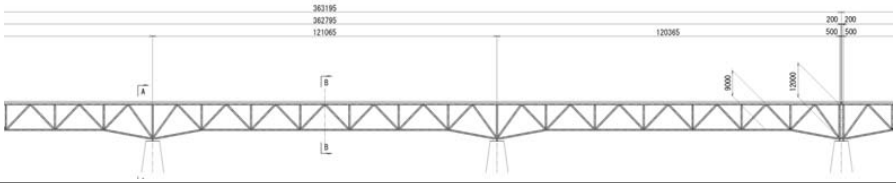
(2) Superstructure

Span length of Existing MG Setu ： 121m (47 spans)

1) In case of same span length (121m),

Continuous Steel Truss with Composite Slab

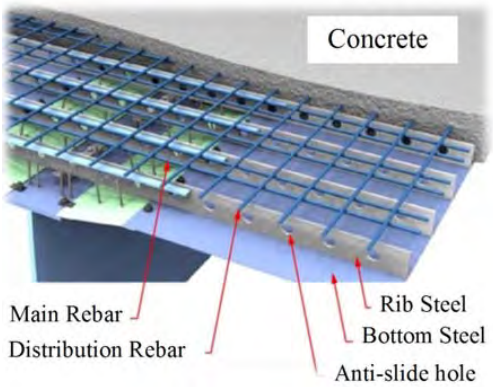
- Existing MG Setu will be replaced by Steel Truss
  → Unify of Bridge Type (Steel Truss Bridge)
- Passing of many overloaded trucks
  → Required high durability → Composite slab
- Required shorter construction period
  → Steel Truss + Composite slab



4. Introduction of Applicable Bridge Types for New MG Setu

Composite Slab

Steel-concrete composite slab is applied to steel truss bridge



Bottom steel plate serves as rebar, formwork, working platform and scaffoldings

1. Higher durability (more than double for conventional RC slab)
2. Shorter construction period by 2months due to less rebar arrangements, form works and scaffoldings.
3. Better working conditions on site
4. No fear of leak of wet concrete and cement milk to the river

4. Introduction of Applicable Bridge Types for New MG Setu

(2) Superstructure

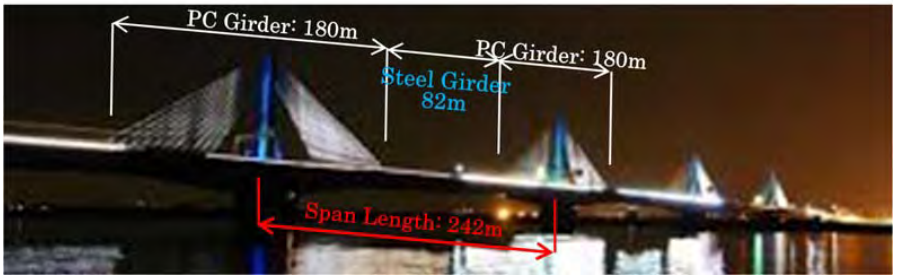
2) In case of double span, Span Length will be 242m

Hybrid Extra-dosed Bridge

Conventional PC ED Bridge : 100-200m (max. 220m)

→ Hybrid ED Bridge 200-270 (max. 275m)

Image of New ED Bridge (Span Length : 242m)

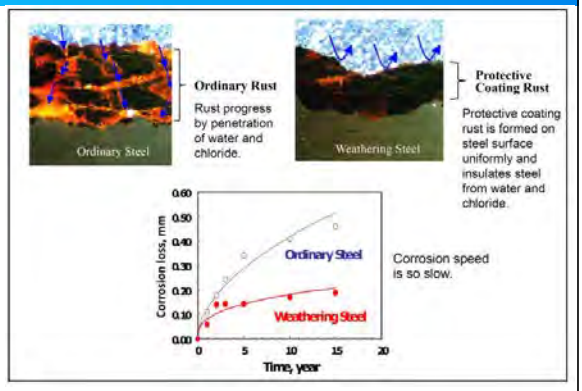


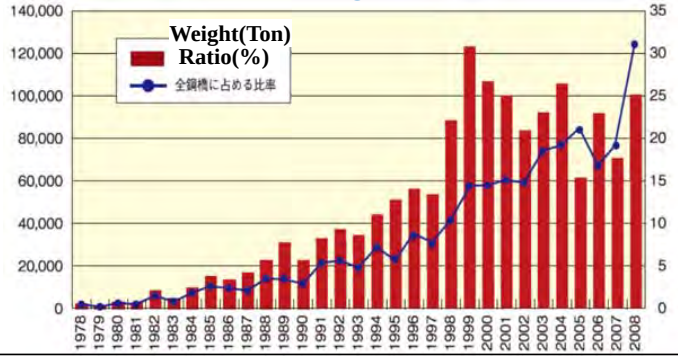
4. Introduction of Applicable Bridge Types for New MG Setu

Weathering Steel

Weathering steel is a high strength steel to resist corrosion.

- Initial Cost is almost same as Ordinary Painting Steel
- It can reduce a Life Cycle Cost
  ⇒ painting material and works and scaffolding etc.





It is adopted in approximately 25-30% and 40-50% of all steel bridges in Japan and United States respectively.

5. Next Step

Recommended Bridge Type of New MG Setu will be proposed in October.

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APPENDIX 5

Explanatory Material of

Reconstruction Project of ROBs in Mumbai

Data Collection Survey on Road/Railway Bridge Sector

Explanatory Material of Reconstruction Project of ROBs in Mumbai

August 2016
Mumbai

JAPAN INTERNATIONAL COOPERATION AGENCY
Oriental Consultants Global Co., Ltd.

Contents

Ⅰ. Introduction

Based on discussion with Western Railway, MOR,
Reconstruction of several Railway Bridges
were requested.

Interim Study Result is presented by this meeting.

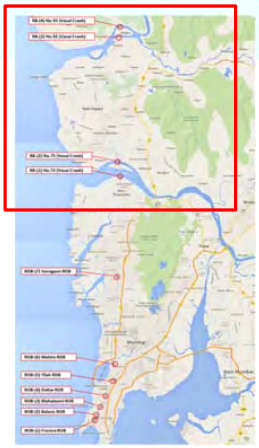
Ⅱ. Results of Site Inspection

1. List of Target Damaged Bridges

Type of Bridge	Location	Number (18 Bri.)	Bridge Name
ROB	Mumbai	7	(1) Ferere ROB (No. 1) (2) Belasis ROB (No. 2) (3) Mahalaxmi ROB (No. 3) (4) Delise ROB (No. 4) (5) Tilak ROB (No. 5) (6) Mahim ROB (No. 6) (7) Goregaon ROB (No. 7)
	Vadodara	2	(8) LC No. 5/A (No. 8) (9) LC No. 2/X (No. 9)
Railway Bridge	Mumbai	4	(1)No.73 (Vasai Creek) (2)No.75(Vasai Creek) (3)No.92 (Vasai Creek) (4)No.93 (Vasai Creek)
	Ratlam	5	(5) No. 114 (6) No. 129 (7) No. 132 (8) No. R5 (9) No. R8

Ⅱ. Results of Site Inspection

2. Location of Target Damaged Bridges



Ⅱ. Results of Site Inspection

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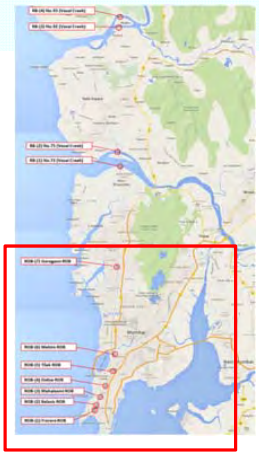
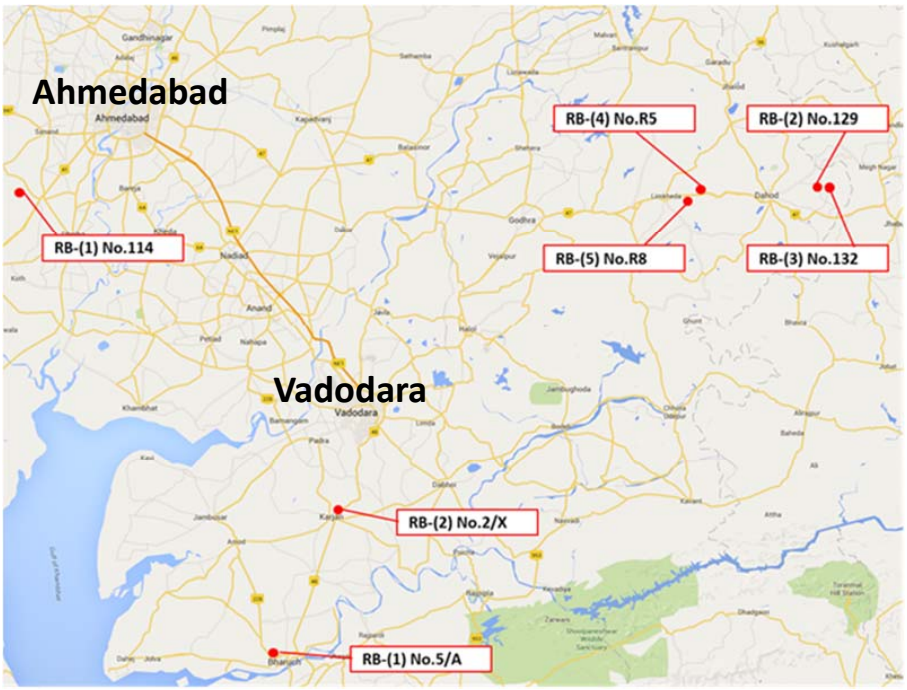
2. Location of Target Damaged Bridges



Ⅱ. Results of Site Inspection

2. Location of Target Damaged Bridges



Ⅱ. Results of Site Inspection

3. Summary of Inspection Results (ROB)

No.	Bridge Name	Length [m]	Span No.	Const. Year	Superstructure Type	Comments/ Next Step
Road over Bridge (ROB)						
1	**Ferere ROB**	25.36	1	1921	2 Main Steel I-Girder with cross girders	Most of bridges were constructed nearly 100 years ago ⇩ Reconstruction
2	**Balasis ROB**	31.50	5	1893	Steel I-Girder	
3	**Mahalaxmi ROB**	77.00	5	1920	Steel I-Girder	
4	**Delise ROB**	63.20	3	1921	2 Main Steel I-Girder with cross girders	
5	**Tilak ROB**	226.20	3	1925	2 Main Steel I-Girder with cross girders	
6	**Mahim ROB**	80.00	3	1993	PC I-Shaped Girder	
7	**Goregaon ROB**	79.00	2	1993	PC I-Shaped Girder	
8	**LC No. 5/A**	85.00	2	2012	PC Box Girder	Non-Destructive Survey
9	**LC No. 2/A**	35.08	1	2008	PC Box Girder	

9 ROBs are selected for next step

Ⅱ. Results of Site Inspection

3. Summary of Inspection Results (Railway Bridge)

No.	Bridge Name	Length [m]	Span No.	Const. Year	Superstructure Type	Comments/ Next Step
Railway Bridge						
1	**No. 73**	1,450	29	1993	PC Box Girder	NO Next step Because of minor damage
2	**No. 75**	550	11	1993	PC Box Girder	
3	**No. 92**	380	20	1963	Steel I-Girder	
4	**No. 93**	410	22	1963	Steel I-Girder	
5	**No. 114**	80	4	1960	PC I-Shaped Girder	NO Next step Because, repaired by CFRP already
6	**No. 129**	60	3	1960	PC I-Shaped Girder	
7	**No. 132**	20	1	1960	PC I-Shaped Girder	
8	**No. R5**	20	1	1960	PC I-Shaped Girder	
9	**No. R8**	20	1	1960	PC I-Shaped Girder	

Ⅲ. Proposal for Reconstruction

1. Feature of this Project

Precondition	Required
Bridges is in the congested area and No space for diversion road	**Construction period needs to be shorten.** **Minimum negative impact on social environment.** **(Construction in the minimum space)**
Revision of Electric Supply System (DC → AC) **Clearance needs to be changed to 6.25m from 5m**	**The height of Girder need to be lower due to prevent the influence of surroundings.** **⇒ New girder height shall be as thin as possible.**

Ⅲ. Proposal for Reconstruction

2. Advanced Technology can be Adopted

Construction

- ✓ To reduce the Height of Road Surface
- ✓ To make thin the Girder Height

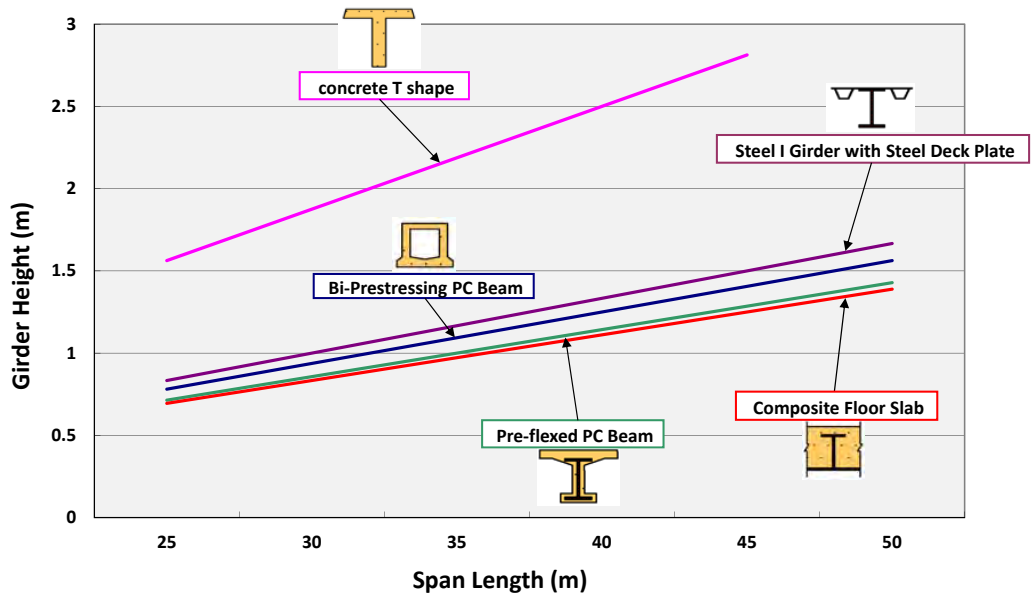
Applicable Superstructure Type

① Bi-Prestressing PC System
② Pre-flexed PC Beam
③ Composite Floor Slab
④ Steel I Girder with Steel Deck Plate
⑤ Pony Truss

Ⅲ. Proposal for Reconstruction

2. Advanced Technology can be Adopted

Type of Superstructure

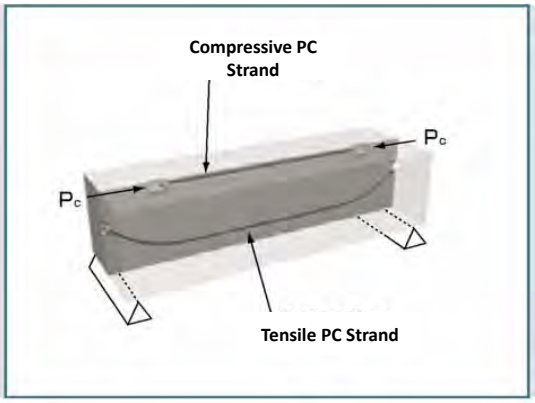


Type of Superstructure

① Bi-Prestressing PC System

This construction method is to combine a conventional prestressed method (give compressive force to concrete by pulling PC Strand) with a Post-compression method (give tension force to concrete by pushing PC strand).
It is possible to reduce girder height and extend span length.

◆ Ratio of Span Length and Girder Height
= approx. 1/32



Ⅲ. Proposal for Reconstruction
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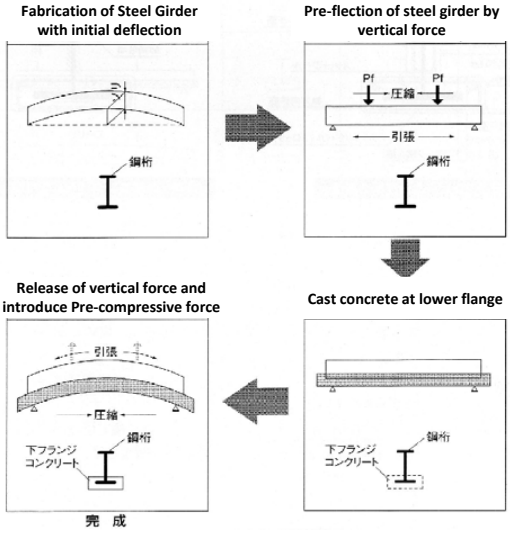
2. Advanced Technology to be Adopted

Type of Superstructure

② Pre-flexed PC Beam

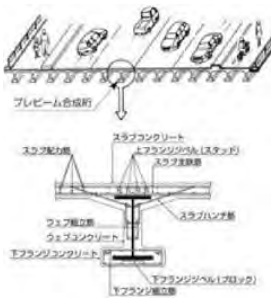


This is composite girder of steel girder and concrete.

Steel girder is added pre-flection in advance by vertical force and introduce pre-stress by release after casting concrete at lower flange.

It is possible to construct under very low girder height compared to other method.

◆ Ratio of Span Length and Girder Height
= Approx. 1/35



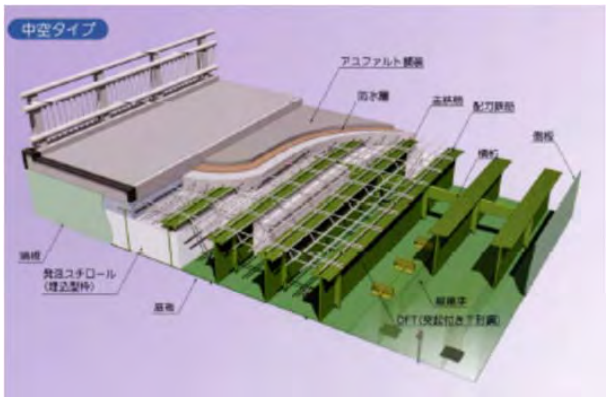
Type of Superstructure

③ Composite Floor Slab

Main girder is simple structure that comprises of T-shape steel, bottom plate and filling concrete as main cross section.

To suppress an increase in girder height by using T-shaped steel with projections as shear key.

◆ Ratio of Span Length and Girder Height = Approx. 1/30 ～ 1/42 (extremely thin structure)



Type of Superstructure

④ Steel I Girder with Steel Deck Plate

It is possible to reduce the self weight of deck slab by using steel deck plate to Steel I girder. And longitudinal reinforcing member is installed at steel deck plate. Steel deck plate bears the role as a upper flange of main girder reinforced with reinforcing member, therefore the girder height is suppressed.

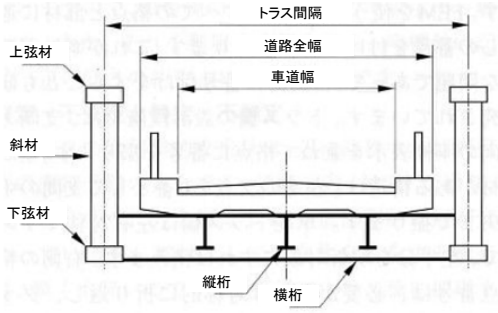
◆ Ratio of Span Length and Girder Height = Approx. 1/30

Ⅲ. Proposal for Reconstruction

2. Advanced Technology to be Adopted

Type of Superstructure

⑤ Pony Truss



This method is to reduce a structure height under road by applying pony truss type.

Only reinforcing member is installed under deck slab, therefore, regardless of span length, structure height under road is about 1m.

◆ Ratio of Span Length and Girder Height = Approx. over 75m

Ⅲ. Proposal for Reconstruction

2. Advanced Technology can be Adopted

Construction

- ✓ To reduce the space
- ✓ To save the time

Applicable Foundation Type

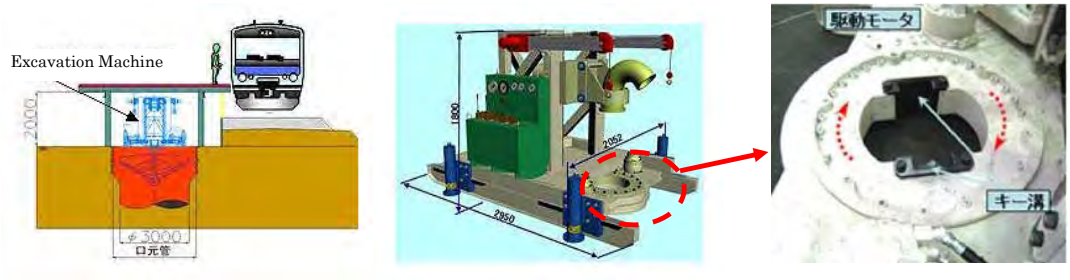
① Cast-in-place Concrete Pile under low clearance
② Rotary Penetration Steel Pile
③ Steel Pipe Socket Connection Method

Ⅲ. Proposal for Reconstruction

2. Advanced Technology to be Adopted

Applicable Foundation Type

① Cast-in-place Concrete Pile under low clearance



This technique employs turntable type for driving system of excavation rod. It is possible to construct at the height under 2m by combining a special type of kelly rod.

Construction of Cast-in-situ pile under low clearance (under existing bridge) becomes possible used by this special type of equipment.

Ⅲ. Proposal for Reconstruction

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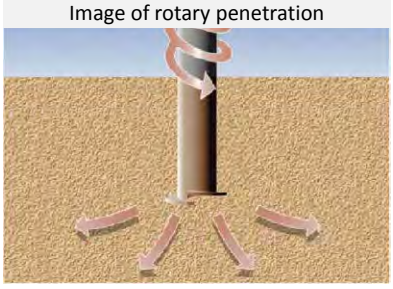
2. Advanced Technology to be Adopted

Applicable Foundation Type

② Rotary Penetration Steel Pile

Image of rotary penetration



It is Steel Pipe Foundation which is welded a spiral processed steel plate (Wing) to the tip of steel pipe together. The pile penetrates/screws into the ground with propulsion of wing.

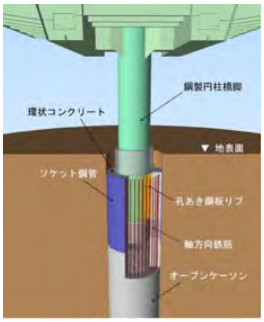
It is obtained large bearing force by the base enlarging effect of Wing. And, due to penetration method, there is no excavated soil at site. Therefore, it will be possible to be eco-friendly construction with non-emission, low-vibration and reducing pile number.

Ⅲ. Proposal for Reconstruction

2. Advanced Technology to be Adopted

Applicable Foundation Type

③ Steel Pipe Socket Connection Method



Connection part at tip of pier column

Construction of Caison Structure

Steel Pipe Socket Connection Method is the jointing technique of inserting a Steel Column into Steel Pipe Socket which is constructed at the top of foundation, and filling up a concrete inside the gap of it. It is possible to reduce construction period by omitting Pile Cap and Anchor Frame used in conventional method.

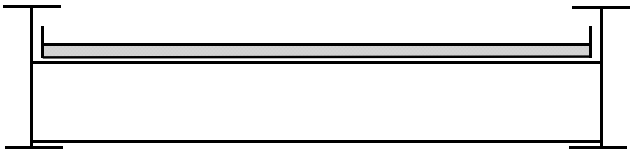
21

Ⅲ. Proposal for Reconstruction

3. Construction Process

3.1 Type of Existing Superstructure

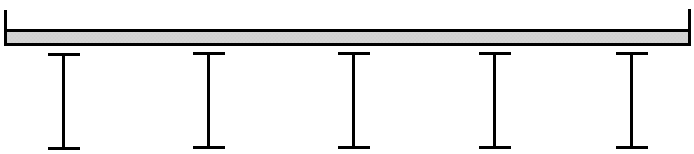
Ⓐ 2-Main Girder Type



1. Ferere ROB
4. Delise ROB
5. Tilak ROB

※ Impossible for Step Construction ⇒ Quick Construction is Required

Ⓑ Conventional I/T-Girder Type



2. Balasis ROB
3. Mahalaxmi ROB
6. Mahim ROB
7. Goregaon ROB

※ Possible for Step Construction

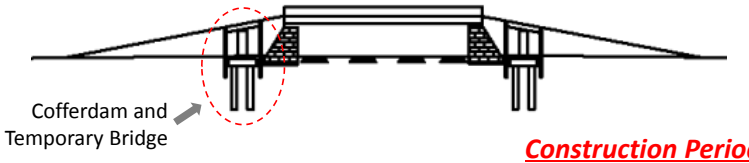
22

Ⅲ. Proposal for Reconstruction

3. Construction Process

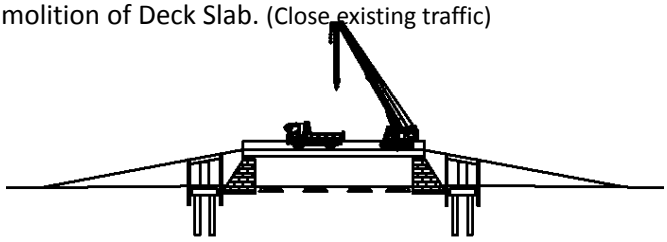
3.2 Proposal for Construction Steps for (A)

Step-1 Install Cofferdam and Temporary Bridge and Construction of Abutment. (Secure existents traffic)



Construction Period: 2 – 3 months

Step-2 Demolition of Deck Slab. (Close existing traffic)



Construction Period: 1 week

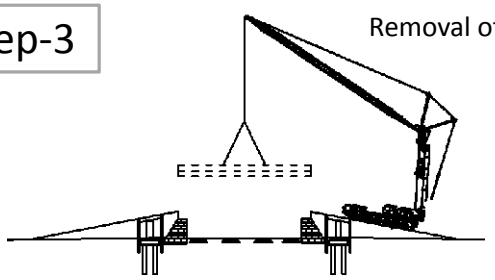
Ⅲ. Proposal for Reconstruction

ORIENTAL CONSULTANTS GLOBAL CO., LTD.

3. Construction Process

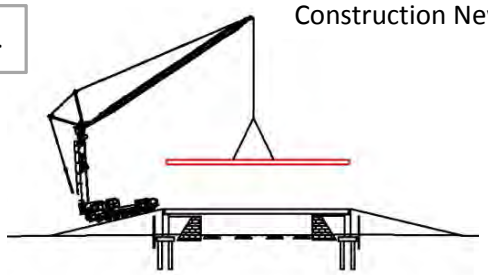
3.2 Proposal for Construction Steps for (A)

Step-3 Removal of Steel Girder. (Close existing traffic)



Construction Period: 3 days

Step-4 Construction New Superstructure. (Close existing traffic)



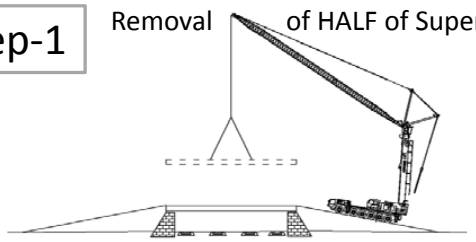
Construction Period: 10 days

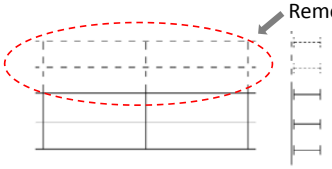
Ⅲ. Proposal for Reconstruction

3. Construction Process

3.3 Proposal for Construction Steps for (B)

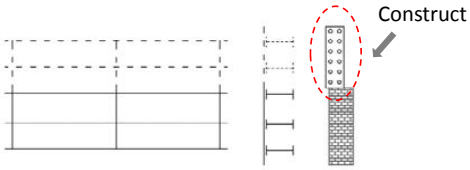
Step-1 Removal of HALF of Superstructure (Secure existing traffic, but by limited width)





Construction Period: 1 week

Step-2 Demolition of HALF of existing Abutment and Construction of HALF of New Abutment. (secure existing traffic but by limited width)



Construction Period: 2 – 3 months

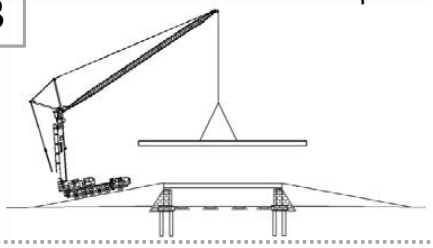
Ⅲ. Proposal for Reconstruction

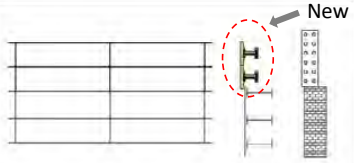
ORIENTAL CONSULTANTS GLOBAL CO., LTD.

3. Construction Process

3.3 Proposal for Construction Steps for (B)

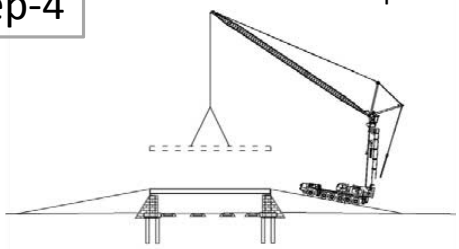
Step-3 Erection of HALF of New Superstructure. (Secure existing traffic, but by limited width)

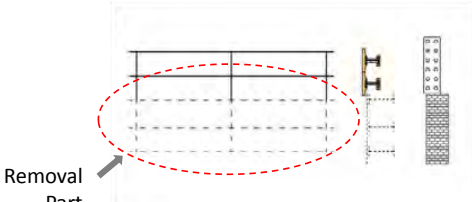




Construction Period: 3 days

Step-4 Removal of remained Superstructure. (Secure existing traffic at New Superstructure part)





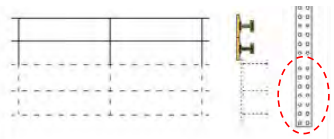
Construction Period: 10 days

Ⅲ. Proposal for Reconstruction

3. Construction Process

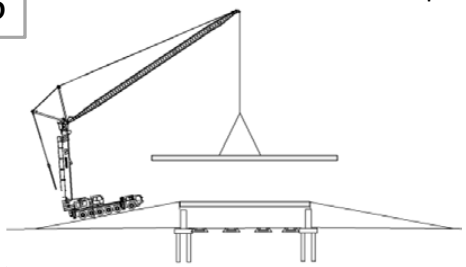
3.3 Proposal for Construction Steps for (B)

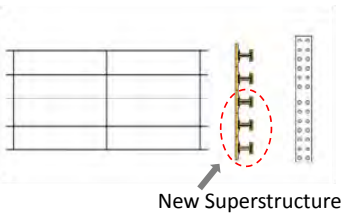
Step-5 Demolition of Remained of existing Abutment and construction of HALF of New Abutment. (Secure existing traffic but by limited width)



Construction Period: 1 week

Step-6 Erection of Remained of New Superstructure. (Secure existing traffic, but by limited width)



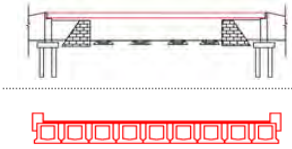
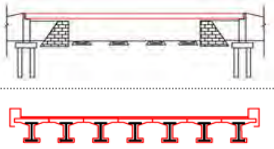
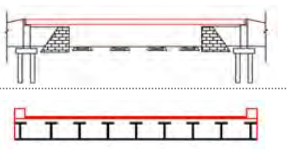


Construction Period: 2 – 3 months

Ⅲ. Proposal for Reconstruction

3. Construction Process

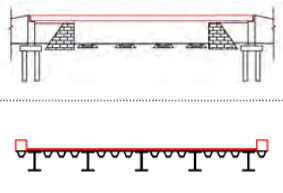
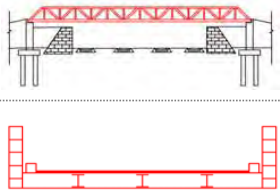
3.4 Comparison of Bridge Type

	Plan – 1 Bi - Prestressing PC Beam	**Plan - 2** Pre-fixed PC Beam	**Plan - 3** Composite Floor Slab
Side View & Cross Section			
Cost (Super Structure)	**1.17**	**1.06**	**1.03**
Comment	・Transversal Prestressing is necessary, **Step Construction is difficult. (Moderate)** ・Maintenance for re-coating is unnecessary. (Good) **・Due to requirement of high-strength concrete, fabrication shall be done at specialized factory (Bad).**	**・ Step Construction is possible. (Good)** ・ Maintenance for re-coating is unnecessary. (Good) **・ Easy for erection of girder, however, construction of cross beam and deck slab shall be done at site (Moderate).**	**・ Step Construction is possible. (Good)** ・ Re-coating is necessary only for Lower Deck Slab. (Moderate), but, by applying of weathering Steel, no maintenance work is required (Good) **・ Due to all fabricate in Factory, easy for erection at site (Good)**

Ⅲ. Proposal for Reconstruction

3. Construction Process

3.4 Comparison of Bridge Type

	Plan – 4 Steel I Girder with Steel Deck Plate	**Plan - 5** Pony Truss
Side View & Cross Section		
Cost (Super Structure)	**1.22**	**1.00**
Comment	▪ **Step Construction is possible. (Good)** ・ Re-coating is necessary for Main Girder and lower face of deck slab. (Moderate), but, by applying of weathering Steel, no maintenance work is required (Good) ▪ **Due to all fabricate in Factory, easy for erection at site (Good)**	▪ **Step Construction is impossible. (Bad)** ・ Re-coating is necessary for Truss structure. (Moderate) , but, by applying of weathering Steel, no maintenance work is required (Good) ▪ **Due to large number of members, period of work at site will be longer than other types. (Bad)**

Ⅲ. Proposal for Reconstruction

3. Construction Process

3.5 Recommendation

◆ For Bridge Type (A)

Due to an economic advantage and easy work at site is preferable for type A, because short construction period at site is required.

⇒ **Plan-3 (Composite Floor Slab) are preferable.**

◆ For Bridge Type (B)

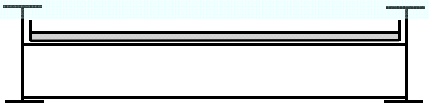
Due to an economic advantage and requirement of Step Construction for type B,

⇒ **Plan-3 (Composite Floor Slab) are preferable.**

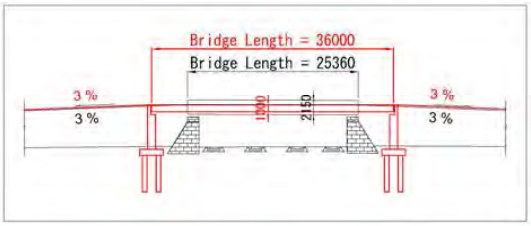
Ⅲ. Proposal for Reconstruction

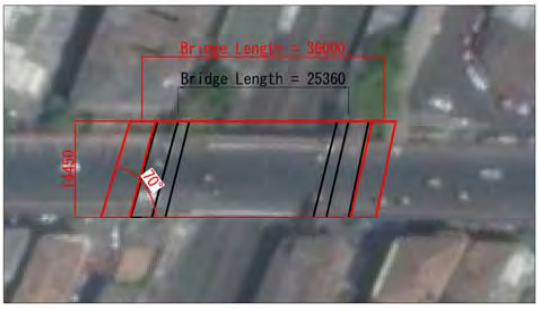
4. Case Study

4.1 For Type A

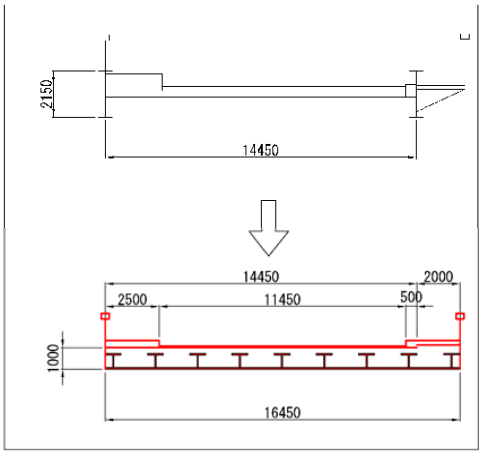


1. Ferere ROB
4. Delise ROB
5. Tilak ROB





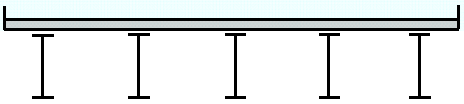
Ferere ROB : Bridge General



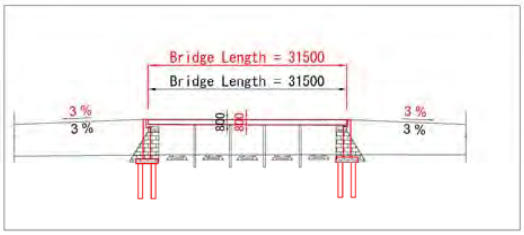
Ⅲ. Proposal for Reconstruction

4. Case Study

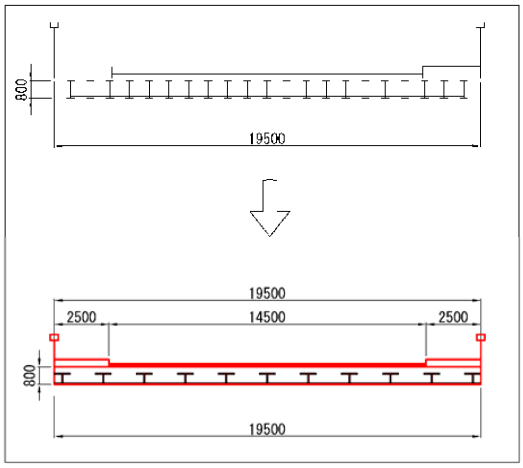
4.2 For Type B



2. Balasis ROB
3. Mahalaxmi ROB
6. Mahim ROB
7. Goregaon ROB



Balasis ROB : Bridge General



Ⅲ. Results of Site Inspection

5. Summary of Study Result

No.	Bridge Name	Proposed Plan					
		Length [m]	Width [m]	Span No.	Superstructure Type	Construction Method	Cost Estimation (Approx.)
Road over Bridge (ROB)							
1	**Ferere ROB**	36.00	19.50	1	Composite Floor Slab	One Time Construction	Rs. 260 million
2	**Balasis ROB**	31.50	19.50	5	Composite Floor Slab	Step Construction	Rs. 230 million
3	**Mahalaxmi ROB**	77.00	25.00	5	Composite Floor Slab	Step Construction	Rs. 700 million
4	**Delise ROB**	100.20	24.80	1	Composite Floor Slab	One Time Construction	Rs. 900 million
5	**Tilak ROB**	236.00	20.00	3	Composite Floor Slab	One Time Construction	Rs. 1,700 million
6	**Mahim ROB**	80.00	28.30	3	Composite Floor Slab	Step Construction	Rs. 820 million
7	**Goregaon ROB**	79.00	27.50	2	Composite Floor Slab	Step Construction	Rs. 900 million

Ⅳ. Study for Next Step

2. Non-Destructive Survey

Target Bridges for Non-Destructive Survey		
Type of Bridge	Location	Bridge Name
ROB (Concrete)	Mumbai	Mahim ROB (No.6)
	Vadodara	LC No. 5/A (No.8)
		LC No.2/X (No.9)

Ⅴ. Application of High-Elasticity CFRP

Recently, High-module CFRP is used in JAPAN.

Advantage of
High-module CFRP

↓

Can reduce
number of sheet

2 Num. (230 kN/mm2)

↓

1 Num. (640 kN/mm2)

Specification of Replakr

Elasticity

品名(品番)		目付量 (g/m²)	厚み (mm)	引張強度 (N/mm²)	引張弾性率 (KN/mm²)	含浸接着樹脂の標準使用量
リペラーク® 高強度グレード (1方向)	20タイプ(MRK-M2-20)	200	0.111	3,400	230(245)	0.6kg/m²
	30タイプ(MRK-M2-30)	300	0.167	3,400	230(245)	0.8kg/m²
	40タイプ(MRK-M2-40)	400	0.222	3,400	230(245)	1.0kg/m²
	45タイプ(MRK-M2-45)	450	0.250	3,400	230(245)	1.1kg/m²
	60タイプ(MRK-M2-60)	600	0.333	3,400	230(245)	1.2kg/m²
リペラーク® 中弾性グレード (1方向)	MMタイプ(MRK-M4-30)	300	0.165	2,900	390	0.8kg/m²
	MM2タイプ(MRK-M5-30)	300	0.163	2,400	440	0.8kg/m²
リペラーク® 高弾性グレード (1方向)	HMタイプ(MRK-M6-30)	300	0.143	1,900	640	0.8kg/m²
	HM40タイプ(MRK-M6-40)	400	0.190	1,900	640	1.0kg/m²
	HM45タイプ(MRK-M6-45)	450	0.214	1,900	640	1.1kg/m²
	HM60タイプ(MRK-M6-60)	600	0.286	1,900	640	1.4kg/m²
リペラーク® (2方向)	2方向 20タイプ(MRK-2D2-20)	200 (縦100／横100)	0.0556／0.0556	2,900	230	0.6kg/m²

High-module Type

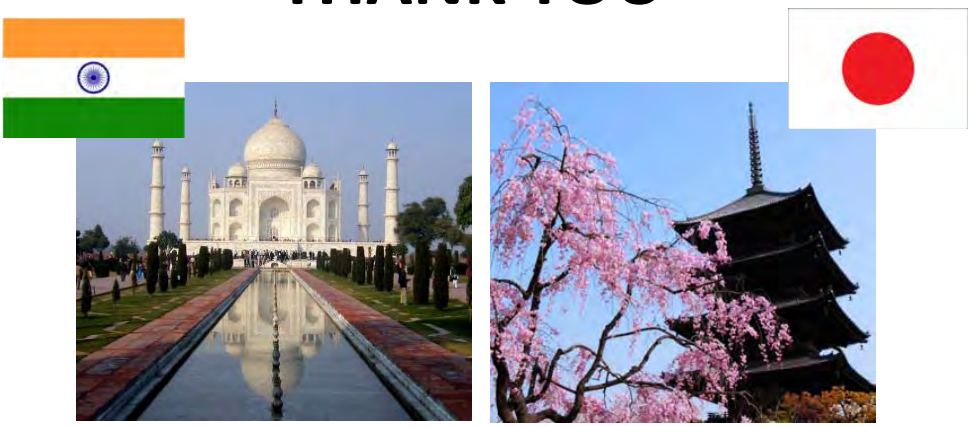
More Economical and Easy for installation.

Ⅵ. Schedule

1. Major Work Items and Schedule

Deliverables		Submission Date
Inception Report	Done	April, 2016
Interim Report	Done	July, 2016
Draft Final Report		Beginning of October, 2016
Final Report		End of November, 2016

THANK YOU



Oriental Consultants Global Co., Ltd.