3. JICA/DULTBDA-003-D
18 May 2015

JICA Experts on Bengaluru Peripheral Ring Road Project

(Work Office)
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To **Commissioner, DULT**
Engineer Member, BDA

Your Ref.: Our Ref.: JICA/DULTBDA-003-D Date: 18 May 2015

SUBJECT: Submission of Record of Discussion on 11 May

Dear Sirs,

We would like to submit herewith the record of the technical discussion held on 11 May regarding the project of BPRR.

All items in Record of Discussion were mutually discussed between JICA Experts and attendances (DULT/BDA/STUP) of the meeting. And some of the critical items have been mentioned in the Record of Discussion which needs to be confirmed by Engineer Member before the wrap-up meeting (scheduled on 20th May).

Thanking you for your kind attention on the above.

Urban Development Department * Directorate of Urban Land Transport *

Takaaki TANAKA
Team Leader, JICA Experts

Encl.: 1) Record of Discussion
2) Discussion Paper R02 (Road)
3) Discussion Paper R03 (Road)

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Record of Discussion

Number	RD-PRR-DP-005
Objection	Technical Discussion based on Discussion Paper No. R02 & R03
Date	11th May 2015 15:00~20:30
Venue	Meeting Room in DULT
Attendance	DULT : Mr. Shamanth K, Mr. Sivasubramaniam J BDA : Mr. Srinivask, Mr. H.C Ramendra, Mr. B Nagendra , Mr. Ajithkumar S.M STUP : Mr. T.V.Rajeev , Mr. Srivathsa B K JICA Experts: Mr. T. Tanaka, Mr. N. Kondo, Mr. S. Yamada
Handout	-Discussion Paper R02 (Road : Cross Sections, Vertical Alignment) -Discussion Paper R03 (Road : Junction/Toll Plaza/Rest Area)

Contents

"Overall regarding Land Acquisition"

Horizontal alignment will be reviewed based on the technical review by JICA Experts on DP R01 which technically required for fulfilling the design speed of 80km/h to accommodate within available ROW of BPRR. Final Decision will be taken by BDA after the revision in the detailed design.

(It has to be confirmed by engineer member)

"DISCUSSION PAPER R02 (Road: Cross Sections, Vertical Alignment)"

1. Cross Sections

1.1 General regarding Cross Sections

Typical cross sections were updated in Final DPR with outer shoulder and edge strip but JICA Experts found that some earlier version of the drawings in DPR still used the old cross sections. STUP informed that the updated cross sections will be applied in the detailed design.

1.2 Typical Cross Sections of Mainline

1.2.1 Lane Width

It was confirmed that 3.5m of the lane width of BPRR was fixed based on IRC 86 (urban road).

1.2.2 Width of Shoulder and Edge Strip

Width of outer shoulder (min.=2.0m) and edge strip (min.=0.5m) of BPRR was determined based on IRC SP-99 based on earlier discussions with JICA. JICA Experts understand the basis of the determination and 0.25m of the narrow edge strip is only at the section with gantry facility of ITS. Accordingly, no change will be required for the detailed design.

1.2.3 Cross Fall (Camber)

JICA Experts found differences regarding the cross fall between DPR Report (2.0%) and Drawings (2.5% in some drawings). It was agreed to apply 2.0% of the standard cross fall of BPRR with rigid pavement. At toll plaza section and its approaches, cross fall/camber can be reduced to 1.7% with provision of cross drain at toll plaza central location.

1.3 Typical Cross Sections of Service Road

1.3.1 Cross Sections of Service Road

The lane configuration (i.e. number of lanes) of the service road is not mentioned in DPR. It was confirmed that the current width of carriageway (W=9.0m) is derived based on available width of 75m ROW for development of formation with other cross section elements firmed up. In principle, the number of lanes of the service road is 2-lane with wider shoulder as proposed by JICA Experts in the Discussion Paper. The final lane configuration will be further discussed and determined during the detailed design stage with proper lane markings.

(It has to be confirmed by engineer member)

1.3.2 Unnecessary Cross Sectional Bottleneck of Service Road

In DPR, the width of service roads is getting narrower toward the entry/exit of VUP and PUP as pointed out in the Discussion Paper. It was confirmed by STUP that compliance is already given to JICA 3rd Mission comments that the end of underpass will be flared (6m x 6m at VUP and 3m x 3m at PUP) in the detailed design stage to get sight distance and also to avoid narrowing of road section at approaches. Planning appropriate structure considering the turning radius of large-sized vehicles will be incorporated in the detailed design.

(It has to be confirmed by engineer member)

2. Vertical Alignment of BPRR (Mainline)

2.1 Gradient

It was agreed that application of 4.0% for maximum gradient and 0.3% for minimum gradient would be considered in accordance with the requirement of IRC SP 23.

BDA/STUP explained the requirement of the railway-crossing which will be based on the results of discussions with railway authorities providing 2.5% of the maximum gradient.

(It has to be confirmed by engineer member)

2.2 Length of Curve

BDA/STUP explained the length was determined using an abbreviated application table (Table 6) in IRC SP 23 and JICA Experts confirmed there are not major differences between figures in the table and the calculated value by formula in IRCs. Accordingly, the length of curves is not necessary to be changed.

2.3 Clearance for Intersections

It was agreed to modify the drawings properly reflecting the required clearance height for the overpass locations.

2.4 Maximum Height of Retaining Wall

It was basically agreed it would be better to avoid such tall retaining wall concerning the following demerits.

- Stability and future deformation by tall height *need special analysis such as FEM, etc.
- Requirement of high-performance costly material such as steel reinforcement sheet, strictly selected backfill, etc)
- Less accessibility across BPRR under the retaining wall
- Construction difficulties

- Time for construction
- Operation and maintenance of huge fill

Limitation of the height and the span layout of bridges will be further discussed in the next structural meeting on 13 May 2015 (am11:00-).

(It has to be confirmed by engineer member)

2.5 Example of Modification for Vertical Alignment

2.5.1 Modification for VUP

Vertical alignment will be designed as mentioned in 2.3 above during the detailed design stage.

2.5.2 Modification for flat section

Vertical alignment will be designed as mentioned in 2.1 above during the detailed design stage.

2.5.3 Modification for filling (high embankment)

As mentioned in 2.4 above, the height limitation of the retaining wall will be further discussed.

2.5.4 Modification for Toll Plaza

It was agreed to apply 2.0% for the maximum vertical gradient for the toll plaza section.

"DISCUSSION PAPER R03 (Road : Junction/Toll Plaza/Rest Area)"

1. Design Concept of Ramp Terminal

1.1 Ramp Design Speed

It was agreed to apply 40km/h for the design speed of ramps.

1.2 Design Speed of Acceleration/Deceleration Lanes

Suggestions from JICA Experts will be considered in the detailed design.

1.3 Transition Section of Main Carriageway and Ramp

Suggestions from JICA Experts will be considered in the detailed design.

1.4 Measures enable minimize the accident at section which connecting main carriageway and ramp

Suggestions from JICA Experts will be considered in the detailed design.

STUP informed that the length of acceleration and deceleration lane lengths in the interchange layout drawings are more than those required for 40km/h. Rumble strip/speed breakers, raised pavement markers, chevron markings, luminous water barricades will be proposed during the detailed design stage.

2. Design Concept of Toll Plaza Area

2.1 Alignment of Toll Plaza Area

As discussed by Discussion Paper R02, 2% of the maximum vertical gradient was agreed. Other suggestions in this section will be considered in the detailed design.

2.2 Toll Island

DULT, BDA , STUP agreed following suggestions from JICA Experts regarding toll plaza area, subject to no change in centerline of the main road and increase in land requirement beyond what is envisaged by BDA in land acquisition plan.

- Minimum radius of horizontal curve shall be 200m.
- Minimum radius of vertical curve shall be 700m
- Vertical gradient shall be not more than 2.0%

- Cross fall shall be between 1.7% to 2.0%
- Crossing drainage system for both side of toll island will be considered in the detail design to protect toll lane from water immersion
- Unifying width of toll lane width (3.2m) were agreed for considering future increase of ETC usage ratio.
- Unifying length of toll island (35m) were agreed for the same reason above.

BDA/STUP informed that the toll plaza layout has been revised and the layout drawings at Tumkur end submitted based on earlier discussion with JICA.

3. Rest Area

JICA Experts enquired about provision of rest areas for the Project. BDA informed that the rest area is not envisaged in the present scope of work.

Directorate of Urban Land Transport, Government of Karnataka
Bangalore Development Authority

JICA Experts on
Bengaluru Peripheral Ring Road Project

DISCUSSION PAPER R02

regarding

- ✓ ***Cross Sections***
- ✓ ***Vertical Alignment of BPRR (Mainline)***

11 May 2015

JAPAN INTERNATIONAL COOPERATION AGENCY

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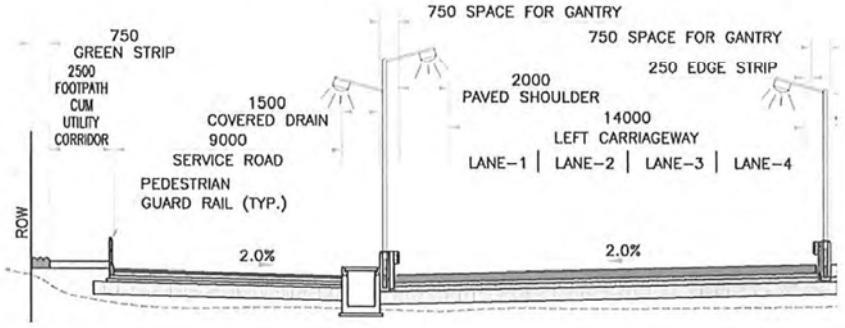
1 Cross Sections

1.1 General

Comments on DPR:
Cross sections on the junction drawings have not been updated. Old sections (without shoulders) are still used in these drawings.
Suggestion from JICA Experts:
Agreed cross sections shall be used properly in the detailed design.

Based on the review by JICA Experts in 2012/13, provision of the shoulders for the mainline was agreed. Figure 1.1 shows the updated cross section in the drawings of "Typical Cross Sections" in Final DPR. Main modifications from Draft DPR are listed below.

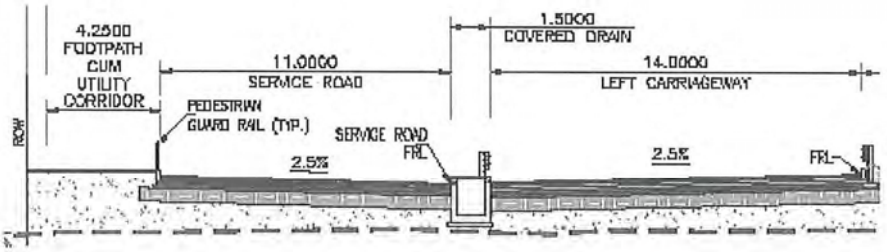
- Provision of "outer shoulder (2.0m)"
- Provision of "inner shoulder (0.25m) as an edge strip"
- Provision of 0.75m width at inner/outer carriageway for gantry's space
- Reduction of carriageway and footpath width of service road



Source: Final DPR, 2014

Figure 1.1 Cross Section in Final DPR

However JICA Experts found the old cross sections (without shoulders) in the drawings of interchanges and junctions.



Source: Final DPR, 2014

Figure 1.2 Old Cross Section in Draft DPR

JICA Experts would like to request BDA and STUP to conduct the detailed design using only the agreed cross sections.

1.2 Typical Cross Sections of Mainline

1.2.1 Lane Width

The lane width of BPRR is 3.5m based on IRC 86 (design standard of "urban road"). For reference, the lane width of "expressway" is 3.75m in plain and rolling terrains and 3.5m only in mountainous terrains.

JICA Experts has no objection on the above after the consensus to apply 80km/h of the design speed for BPRR (consensus based on DP R01 on 6 May 2015).

1.2.2 Shoulder and Edge Strip Width

Comments on DPR:
Width of the inner shoulder (edge strip) is too narrow for high speed traffic.
Suggestion from JICA Experts:
Provision of 1.5m width for "Outer Shoulder" and 0.75m width for "Edge Strip/Inner Shoulder"

BPRR is not designed as "expressway" but "urban road" allowing 80km/h high speeding. BPRR might be defined as "semi-expressway". Necessity of shoulders is not mentioned in IRC 86 which specify the design guideline of "urban road".

Necessity of shoulder was mutually agreed between DULT/BDA/STUP and JICA in 2012/2013. Therefore Guidelines for Expressway (hereinafter IRC-E) has been referred to finalize the dimension of the shoulders for BPRR.

Table 1.1 presents the required width of edge trips according to IRC-E.

Table 1.1 Width of Edge Strips in IRC

Terrain	Width of Edge Strip	
	Left (outer side)	Right (median side)
Plain	0.5m	0.75m
Rolling	0.5m	0.75m

Source: Guidelines for Expressways, IRC, 2010

According to IRC-E, *"edge strips should provide lateral support to the carriageway properly and will also accommodate the edge markings and edge strip shall provided so as to enhance the delineation effect to drivers and to constitute a part of lateral clearance for the safety of vehicles".*

The width of edge strip in Final DPR of BPRR is 0.25m only and not fulfill the above requirement. Provision of 0.75m width of edge strip (inner shoulder) is recommended by JICA Experts.

Table 1.2 presents the required width of shoulders (outer shoulder) according to IRC-E.

Table 1.2 Width of Shoulders in IRC

Terrain	Paved Shoulder
Plain	3.0m
Rolling	3.0m

Source: Guidelines for Expressways, IRC, 2010

Provision of the above width is actually quite difficult for BPRR due to the fixed available land. However the concept of the outer shoulder stipulated in IRC-E shall be considered as much as technically practical.

IRC-E stated the following important functions regarding the provision of shoulders.

i) Space is provided for stopping of vehicle and make the through traffic lane free from obstruction because of mechanical difficulty, a flat tyre, or othr emergency;

ii) Space is provided for the occasional driver who is required to stop, to decide road ramps, service areas, or for other reasons;

iii) Space is provided to escape potential accidents or reduce their severity;

iv) The sense of openness created by shoulders of adequate width contributes much to driving ease and freedom from strain;

v) Sight distance is improved in cut sections, thereby improving safety;

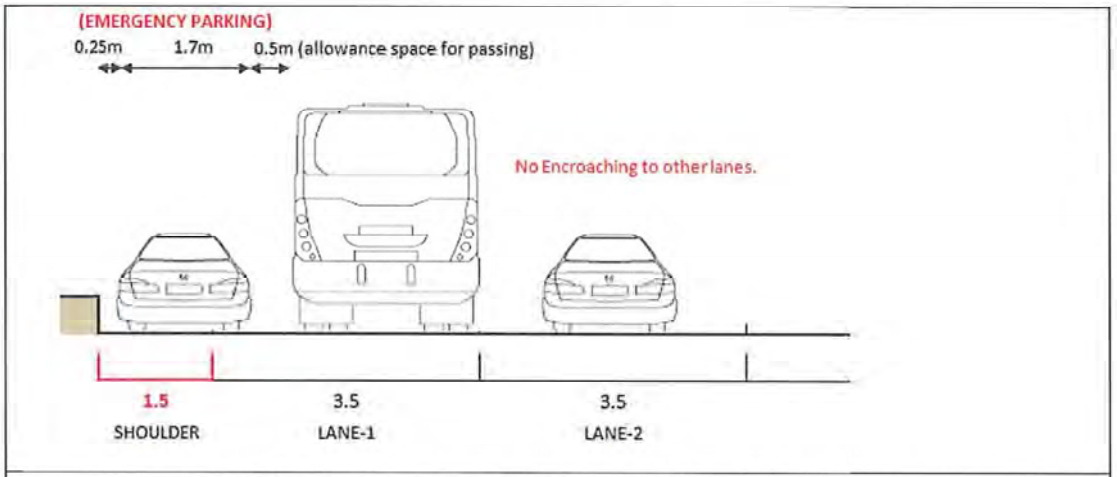
vi) Space is provided for road maintenance, operation and security.

Accordingly, JICA Experts introduces "Partial Shoulder" concept which is well-known in other developed countries' design guidelines (AASHTO, etc) and propose 1.5m width of the outer shoulder for BPRR.

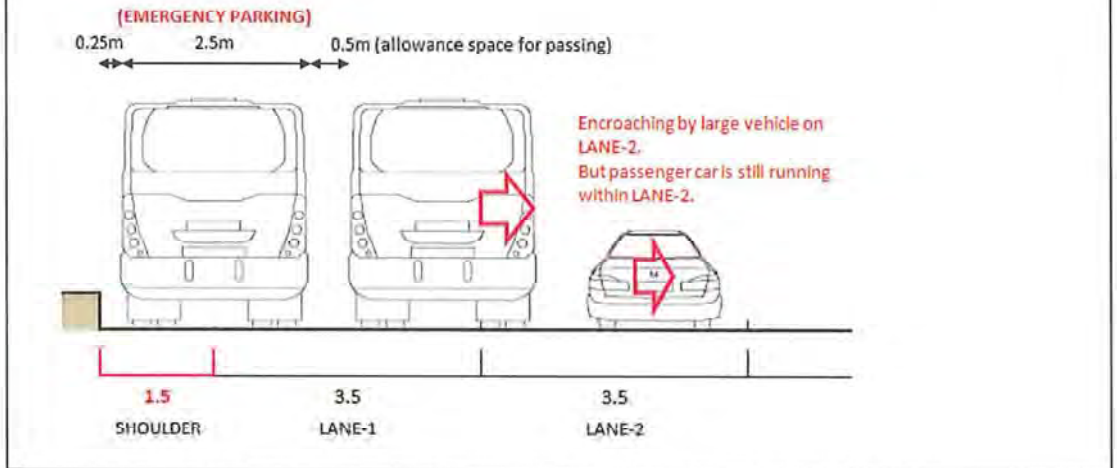
> Although it is desirable that a shoulder be wide enough for a vehicle to be driven completely off the traveled way, narrower shoulders are better than none at all. For example, when a vehicle making an emergency stop can pull over onto a narrow shoulder such that it occupies only 0.3 to 1.2 m [1 to 4 ft] of the traveled way, the remaining traveled way width can be used by passing vehicles. Partial shoulders are sometimes used where full shoulders are unduly costly, such as on long (over 60 m [200 ft]) bridges or in mountainous terrain.

Source: A Policy on Geometric Design of Highways and Streets, AASHTO

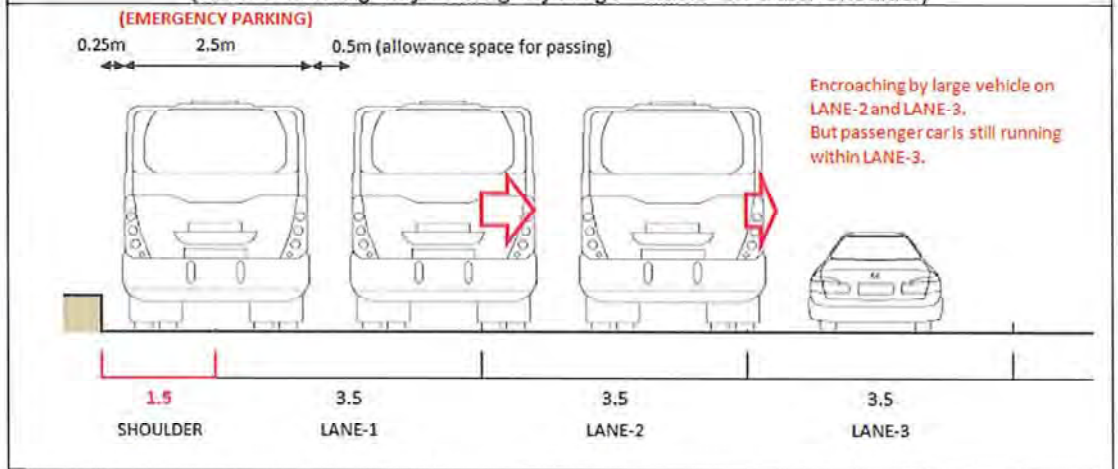
The concept of the proposal of JICA Experts is shown in Figure 1.3. JICA Experts propose 1.5m width of the partial outer shoulder.



(CASE-1: Emergency Parking "by Passenger Car" on Outer Shoulder)



(CASE-2: Emergency Parking "by Large Vehicle" on Outer Shoulder)

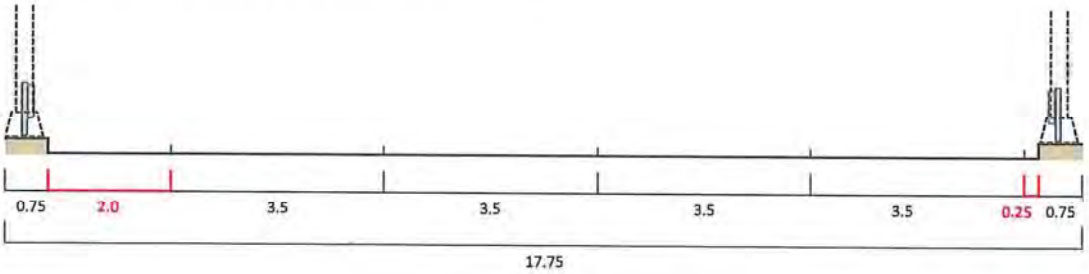


(CASE-2a: Emergency Parking "by Large Vehicle" on Outer Shoulder)

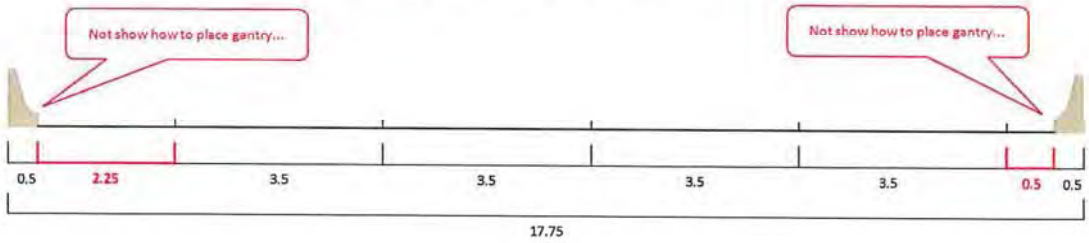
Source: JICA Experts

Figure 1.3 Proposed Concept of Partial Outer Shoulder for BPRR

Figure 1.4 shows the cross sections designed in DPR.



(Cross Section of At-grade Section)

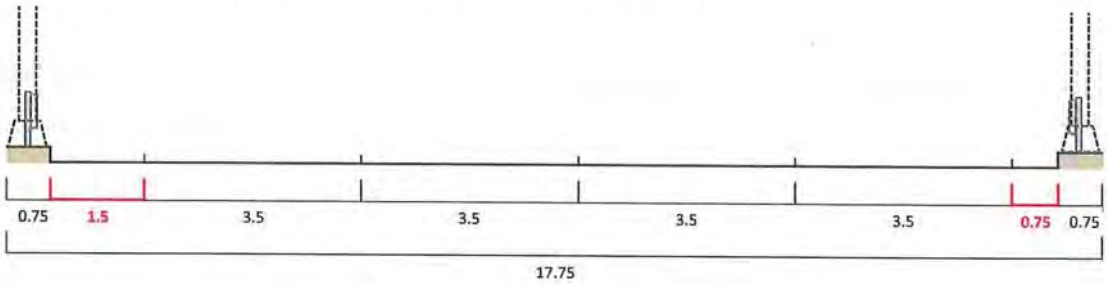


(Cross Section of Elevated Section)

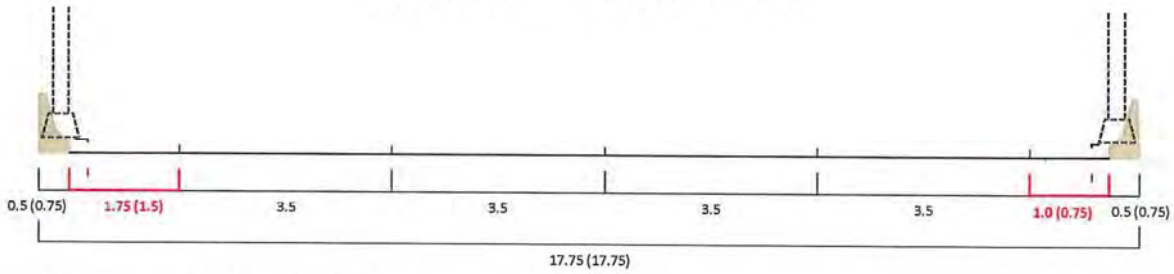
Source: Draft DPR

Figure 1.4 Cross Sections of Mainline of BPRR (Draft DPR)

JICA Experts propose the definitive cross sections as shown in Figure 1.5. It is noted that no change has been made to ROW fixed by DPR.



(Cross Section of At-grade Section)



Note: Figure in parentheses shows the width with gantry pole for ITS.

(Cross Section of Elevated Section)

Source: JICA Experts

Figure 1.5 Cross Sections of Mainline of BPRR (Proposed)

1.2.3 Cross fall (Camber)

Comments on DPR:
DPR modified the cross fall from 2.5% to 2.0%. However there are still descriptions of 2.5% in the drawings.
Suggestion from JICA Experts:
Need to be modified in the detailed design

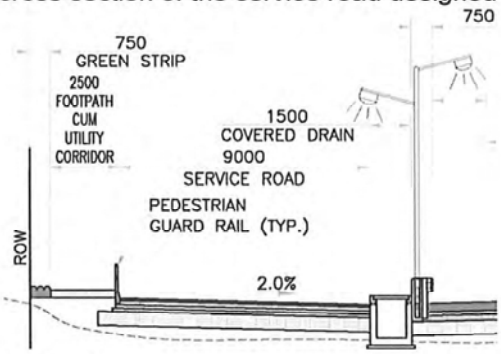
As stated above.

1.3 Typical Cross Sections of Service Road

1.3.1 Cross Section of Service Road

Comments on DPR:
Number of lanes for service road is not clearly mentioned in DPR.
Suggestion from JICA Experts:
Each direction of the service road can accommodate 2-lane with "partial shoulder" and "edge strip.

Figure 1.6 shows the cross section of the service road designed in DPR.



Source: Final DPR, 2014

Figure 1.6 Cross Section of Service Road in Final DPR

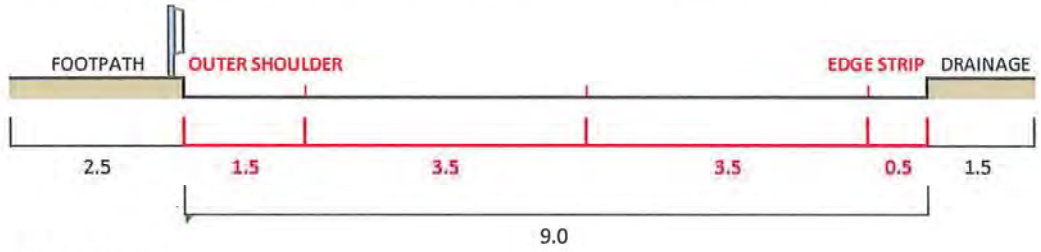
According to IRC-86, 3-lane roads require 10.5m of the carriageway width. Therefore 9.0m of the carriageway width for BPRR can accommodate only 2-lane.

Figure 1.7 shows the cross section of the service road designed in DPR. Lane configuration of the service road is not shown on the drawing.

Source: Draft DPR

Figure 1.7 Cross Sections of Mainline of BPRR (Draft DPR)

JICA Experts propose the lane configuration as shown in Figure 1.8.



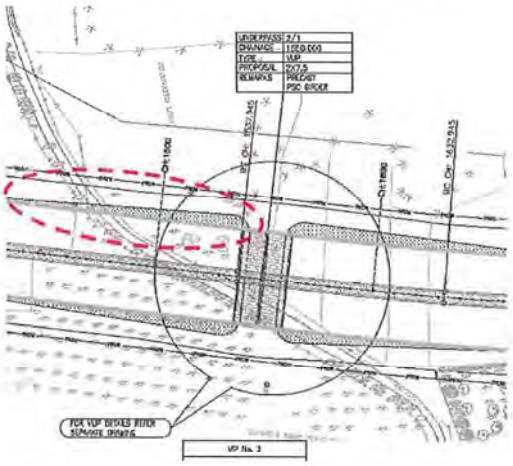
Source: JICA Experts

Figure 1.8 Cross Sections of Mainline of BPRR (Proposed)

1.3.2 Unnecessary Cross Sectional Bottleneck of Service Road

Comments on DPR:
Width of carriageway of the service road is narrowed at the approach to VUP and PUP.
Suggestion from JICA Experts:
Flyovers or bridges shall be studied instead of box-culverts.

Figure 1.9 shows the narrowed carriageway of the service roads.



(Bottleneck for VUP)

(Bottleneck for PUP)

Source: Final DPR

Figure 1.9 Bottleneck of Carriageway

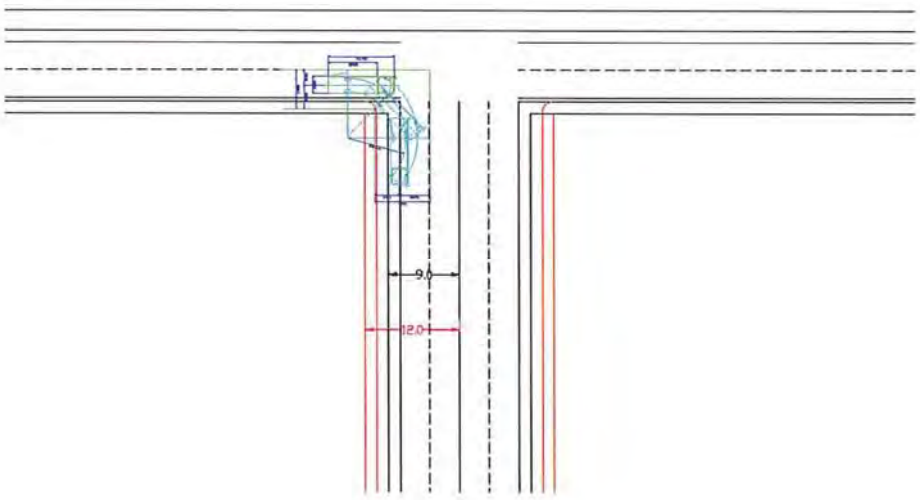
The narrowed carriageway will induce traffic congestion and the width of the carriageway shall keep the original width (9.0m).

Figure 1.10 present the vehicle motion path of 30 ton truck and semi-trailer on the proposed VUP of BPRR.

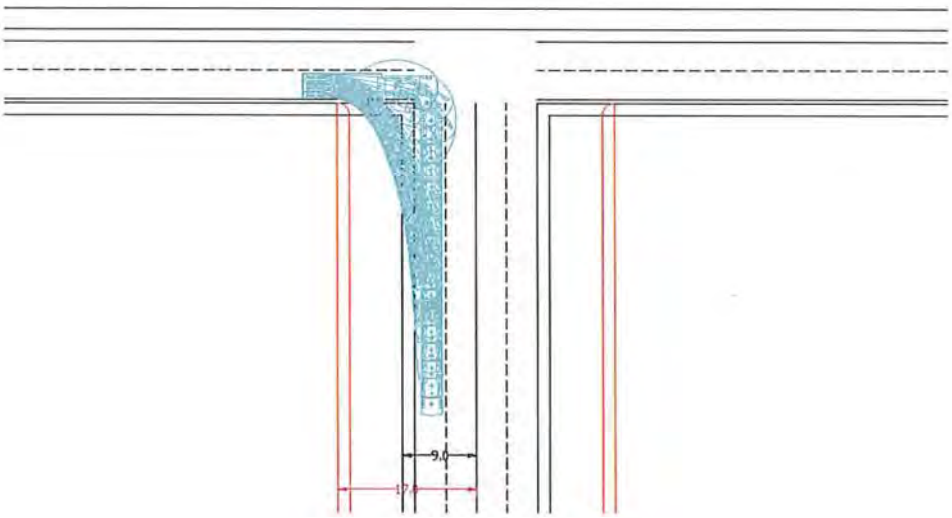
The proposed width of box-culvert cannot manage the traffic flow properly. In order to secure the minimum turning movement of these vehicle, width of the box culvert shall be much larger as suggested in Figure 1.10.

The development along the proposed BPRR will be rapidly accelerated after the completion of the road. Concurrently, traffic volume of heavy vehicles to/from the newly developed premises/enterprises will be increased.

It is quite essential to consider heavy vehicle's turning movement into the design of the VUP.



(30 ton Truck)



(Semi-trailer)

Source: JICA Experts

Figure 1.10 Vehicle Motion Path at VUP

According to the result of the motion path presented in above figure, size of box-culvert shall be changed to much larger one. JICA Experts recommend flyovers or bridges instead of box culvert for VUP.

2 Vertical Alignment of BPRR (Mainline)

2.1 Gradient

Comments on DPR:
Minimum gradient of the vertical alignment does not fulfill IRC 23.
Maximum gradient of the vertical alignment is set as 3.33% based on IRC 23.
Suggestion from JICA Experts:
Minimum gradient = 0.3%.
Maximum gradient = 4.0%

According to IRC SP 23-1983, the specified minimum gradient is 0.3% and 3.33% as maximum gradient. However the vertical alignment of DPR does not fulfill the requirement of IRC.

JICA Experts reviewed the vertical alignment of DPR based on "IRC 86-1983" and "IRC-SP 23-1983". IRC 86-1983 also specifies the absolute minimum gradient as 0.3% and 4.0% as a maximum gradient.

JICA Experts have pointed out there are many sections do not fulfill the requirement for minimum/maximum gradient as summarized in Table 2.1 in the next page.

The modifications of the vertical alignment shall be required at 19 curves as a respect of minimum gradient and 8 curves as a respect of maximum gradient.

However 8 curves required to modify regarding the maximum gradient might be canceled in case of applying IRC 86 (max gradient=4.0%).

Table 2.1 Review on Gradient of Vertical Alignment of BPRR (Mainline)

Elements on DPR											Check			
Tangent 1		VCR				Tangent 2		Gradient			Gradient (max)		Gradient (min)	Gradient (min)
		Start		End							IRC 86	IRC-sp23	IRC 86 (desirable)	IRC 86 (absolute)
Ch.	Elev	Ch.	Elev	Ch.	Elev	Ch.	Elev	i1	i2	i1-i2	(i1<4%)	(i1<3.3%)	(i1>0.5%)	(i1>0.3%)
0+100.000	859.528	0+470.000	850.045	0+570.000	849.885	1+400.000	868.504	-2.563%	2.243%	4.806%	OK	OK	OK	OK
0+570.000	849.885	1+400.000	868.504	1+700.000	869.876	2+165.000	859.597	2.243%	-1.995%	-4.239%	OK	OK	OK	OK
1+700.000	868.676	2+165.000	859.597	2+265.000	858.676	2+339.898	858.790	-1.995%	0.152%	2.146%	OK	OK	OK	OK
2+265.000	858.676	2+339.898	858.790	2+439.898	860.142	2+700.000	866.775	0.152%	2.550%	2.398%	OK	OK	[illegible]	[illegible]
2+439.898	860.142	2+700.000	866.775	3+000.000	871.282	3+079.087	871.642	2.550%	0.455%	-2.095%	OK	OK	OK	OK
3+000.000	871.282	3+079.087	871.642	3+179.087	872.301	3+510.000	875.161	0.455%	0.864%	0.409%	OK	OK	[illegible]	OK
3+179.087	872.301	3+510.000	875.161	3+610.000	875.495	4+245.000	874.253	0.864%	-0.196%	-1.060%	OK	OK	OK	OK
3+610.000	875.495	4+245.000	874.253	4+345.000	872.473	4+416.000	870.086	-0.196%	-3.362%	-3.166%	OK	OK	[illegible]	[illegible]
4+345.000	872.473	4+416.000	870.086	4+516.000	867.830	4+711.214	865.588	-3.362%	-1.148%	2.213%	OK	[illegible]	OK	OK
4+516.000	867.830	4+711.214	865.588	4+811.214	865.173	5+650.000	867.841	-1.148%	0.318%	1.467%	OK	OK	OK	OK
4+811.214	865.173	5+650.000	867.841	5+750.000	867.208	5+822.574	866.058	0.318%	-1.585%	-1.903%	OK	OK	[illegible]	OK
5+750.000	867.208	5+822.574	866.058	5+922.574	866.636	6+600.000	885.191	-1.585%	2.739%	4.324%	OK	OK	OK	OK
5+922.574	866.636	6+600.000	885.191	6+900.000	886.816	7+099.992	883.503	2.739%	-1.657%	-4.396%	OK	OK	OK	OK
6+900.000	886.816	7+099.992	883.503	7+199.992	882.319	7+413.975	880.795	-1.657%	-0.712%	0.944%	OK	OK	OK	OK
7+199.992	882.319	7+413.975	880.795	7+513.975	881.610	7+696.355	885.891	-0.712%	2.347%	3.060%	OK	OK	OK	OK
7+513.975	881.610	7+696.355	885.891	7+796.355	889.022	8+046.072	898.799	2.347%	3.915%	1.568%	OK	OK	OK	OK
7+796.355	889.022	8+046.072	898.799	8+246.072	899.558	8+602.202	888.321	3.915%	-3.155%	-7.071%	OK	[illegible]	OK	OK
8+246.072	899.558	8+602.202	888.321	8+752.202	887.239	8+760.000	887.323	-3.155%	1.077%	4.233%	OK	OK	OK	OK
8+752.202	887.239	8+760.000	887.323	8+960.000	885.538	9+110.000	880.216	1.077%	-3.548%	-4.625%	OK	OK	OK	OK
8+960.000	885.538	9+110.000	880.216	9+210.000	879.541	9+690.799	890.111	-3.548%	2.198%	5.746%	OK	[illegible]	OK	OK
9+210.000	879.541	9+690.799	890.111	9+890.799	889.063	9+919.287	888.138	2.198%	-3.247%	-5.445%	OK	OK	OK	OK
9+890.799	889.063	9+919.287	888.138	10+019.287	886.820	10+288.757	888.464	-3.247%	0.610%	3.857%	OK	OK	OK	OK
10+019.287	886.820	10+288.757	888.464	10+388.757	889.895	10+560.000	893.749	0.610%	2.251%	1.641%	OK	OK	OK	OK
10+388.757	889.895	10+560.000	893.749	10+760.000	898.641	11+128.000	906.359	2.251%	2.641%	0.390%	OK	OK	OK	OK
10+760.000	898.641	11+128.000	906.359	11+328.000	908.784	11+368.239	907.893	2.641%	-2.214%	-4.855%	OK	OK	OK	OK
11+328.000	908.784	11+368.239	907.893	11+518.239	908.535	11+735.000	915.193	-2.214%	3.072%	5.286%	OK	OK	OK	OK
11+518.239	908.535	11+735.000	915.193	12+035.000	922.749	12+435.000	930.612	3.072%	1.966%	-1.106%	OK	OK	OK	OK
12+035.000	922.749	12+435.000	930.612	12+635.000	930.278	12+864.224	925.005	1.966%	-2.300%	-4.266%	OK	OK	OK	OK
12+635.000	930.278	12+864.224	925.005	12+964.224	923.838	13+965.914	923.504	-2.300%	-0.033%	2.267%	OK	OK	OK	OK
12+864.224	923.838	13+965.914	923.504	14+125.914	920.773	14+230.000	917.254	-0.033%	-3.381%	-3.348%	OK	OK	[illegible]	[illegible]
14+125.914	920.773	14+230.000	917.254	14+390.000	913.480	15+570.000	897.694	-3.381%	-1.338%	2.043%	OK	[illegible]	OK	OK
14+390.000	913.480	15+570.000	897.694	15+730.000	895.196	16+100.000	888.594	-1.338%	-1.784%	-0.447%	OK	OK	OK	OK
15+730.000	895.196	16+100.000	888.594	16+260.000	889.845	16+505.000	898.050	-1.784%	3.349%	5.133%	OK	OK	OK	OK
16+260.000	889.845	16+505.000	898.050	16+665.000	901.752	17+260.000	909.361	3.349%	1.279%	-2.070%	OK	[illegible]	OK	OK
16+665.000	901.752	17+260.000	909.361	17+360.000	908.663	17+695.000	899.702	1.279%	-2.675%	-3.954%	OK	OK	OK	OK
17+360.000	908.663	17+695.000	899.702	17+795.000	899.371	18+296.223	909.455	-2.675%	2.012%	4.687%	OK	OK	OK	OK
17+795.000	899.371	18+296.223	909.455	18+496.223	909.472	18+520.000	908.998	2.012%	-1.994%	-4.005%	OK	OK	OK	OK

2.2 Length of Vertical Curve

Comments on DPR:
The minimum length of curve adopted in design is 100m.
Suggestion from JICA Experts:
Length of vertical curves shall be determined by formulae.

In DPR, the minimum length of curve adopted in design is 100m. In the drawings, all of the length is designed over 100m. But, to keep stopping site distance, JICA Experts recommend determining length of vertical curves based on formulae.

According to IRC SP 23-1983, length of vertical curves shall be determined as below.

Summit Curve

1) When the length of the curve exceeds the required sight distance

$$L = \frac{NS^2}{4.4}$$

S= stopping sight distance in metres (120m for the speed 80km/h)
N=deviation angle, i.e. the algebraic difference between the two grades

2) When the length of the curve is less than the required sight distance

$$L = 2S - \frac{4.4}{N}$$

Valley Curve

1) When the length of the curve exceeds the required sight distance

$$L = \frac{NS^2}{1.5 + 0.035S}$$

2) When the length of the curve is less than the required sight distance

$$L = 2S - \frac{1.50 + 0.035S}{N}$$

JICA Experts reviewed the drawings based on above formulae. JICA Experts have pointed out there are many sections do not fulfill the requirement for length of vertical curves as presented in Table 2.2 in the next page.

Table 2.2 Review on Vertical Curves of Vertical Alignment of BPRR (Mainline)

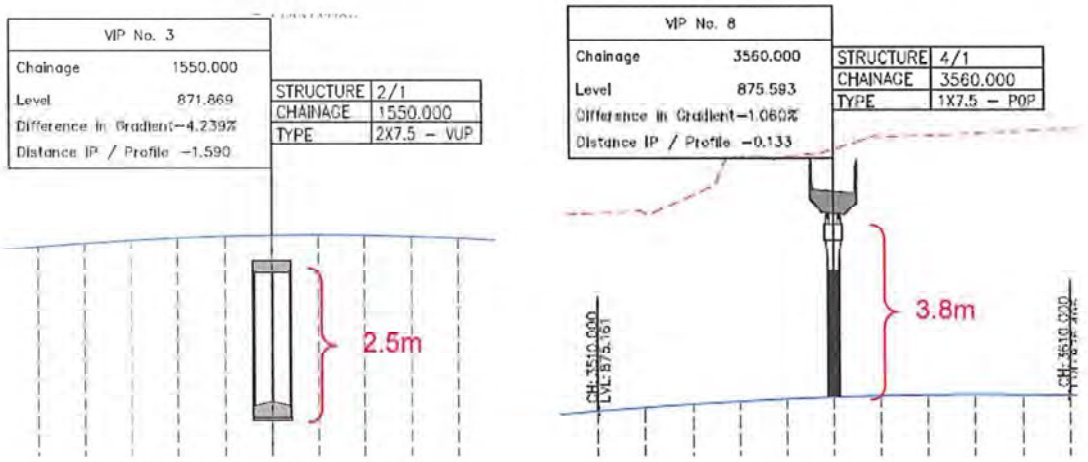
Elements on DPR													Check				
Tangent 1		VCR				Tangent 2		Tangent		VCR			Min. L	VCR			
		Start		End									IRC 86	Stopping Sight Distance			
														Required L by IRC 86		Check	
Ch.	Elev	Ch.	Elev	Ch.	Elev	Ch	Elev	L1	L2	L	R	K	(L>50m)	Summit VCR	Valley VCR	Summit VCR	Valley VCR
0+100.000	859.528	0+470.000	850.045	0+570.000	849.885	1+400.000	868.504	370	830	100.000	2,081	20.806	OK	-	121.404	-	[illegible]
0+570.000	849.885	1+400.000	868.504	1+700.000	868.875	2+165.000	859.597	830	465	300.000	7,075	70.776	OK	138.722	-	OK	-
1+700.000	868.876	2+165.000	859.597	2+265.000	858.678	2+339.898	858.790	465	75	100.000	4,655	46.562	OK	-	-25.401	-	OK
2+265.000	858.678	2+339.898	858.790	2+439.898	860.142	2+700.000	866.775	75	260	100.000	4,170	41.702	OK	-	2.297	-	OK
2+439.898	860.142	2+700.000	866.775	3+000.000	871.282	3+079.087	871.642	260	79	300.000	14,320	143.201	OK	68.562	-	OK	-
3+000.000	871.282	3+079.087	871.642	3+179.087	872.301	3+510.000	875.161	79	331	100.000	24,445	244.451	OK	-	-1153.368	-	OK
3+179.087	872.301	3+510.000	875.161	3+610.000	875.495	4+245.000	874.253	331	635	100.000	9,435	94.352	OK	-175.147	-	OK	-
3+610.000	875.495	4+245.000	874.253	4+345.000	872.473	4+416.000	870.086	635	71	100.000	3,158	31.582	OK	101.040	-	[illegible]	-
4+345.000	872.473	4+416.000	870.086	4+516.000	867.830	4+711.214	865.588	71	195	100.000	4,518	45.178	OK	-	-17.512	-	OK
4+516.000	867.830	4+711.214	865.588	4+811.214	865.173	5+650.000	867.841	195	839	100.000	5,819	58.187	OK	-	-148.664	-	OK
4+811.214	865.173	5+650.000	867.841	5+750.000	867.208	5+822.574	866.056	839	73	100.000	5,256	52.558	OK	8.746	-	OK	-
5+750.000	867.208	5+822.574	866.056	5+922.574	866.636	6+600.000	885.191	73	677	100.000	2,313	23.129	OK	-	108.166	-	[illegible]
5+922.574	866.636	6+600.000	885.191	6+900.000	886.816	7+099.992	883.503	677	200	300.000	6,625	68.250	OK	143.856	-	OK	-
6+900.000	886.816	7+099.992	883.503	7+199.992	882.319	7+413.975	880.795	200	214	100.000	10,589	105.892	OK	-	-363.583	-	OK
7+199.992	882.319	7+413.975	880.795	7+513.975	881.610	7+696.355	885.891	214	182	100.000	3,269	32.685	OK	-	53.695	-	OK
7+513.975	881.610	7+696.355	885.891	7+796.355	889.022	8+046.072	898.799	182	250	100.000	6,378	63.778	OK	-	-123.535	-	OK
7+796.355	889.022	8+046.072	898.799	8+246.072	899.558	8+602.202	888.321	250	356	200.000	2,629	28.286	OK	231.400	-	[illegible]	-
8+246.072	899.558	8+602.202	888.321	8+752.202	887.239	8+760.000	887.323	356	8	150.000	3,544	35.440	OK	-	106.927	-	OK
8+752.202	887.239	8+760.000	887.323	8+960.000	885.538	9+110.000	880.216	8	150	200.000	4,324	43.241	OK	151.370	-	OK	-
8+960.000	885.538	9+110.000	880.216	9+210.000	879.541	9+690.799	890.111	150	481	100.000	1,740	17.402	OK	-	140.808	-	[illegible]
9+210.000	879.541	9+690.799	890.111	9+890.799	889.063	9+919.287	888.138	481	28	200.000	3,673	36.728	OK	178.213	-	OK	-
9+890.799	889.063	9+919.287	888.138	10+019.287	886.820	10+288.757	888.464	28	269	100.000	2,593	25.926	OK	-	92.219	-	OK
10+019.287	886.820	10+288.757	888.464	10+388.757	889.895	10+560.000	893.749	269	171	100.000	6,096	60.956	OK	-	-107.452	-	OK
10+388.757	889.895	10+560.000	893.749	10+760.000	898.641	11+128.000	908.359	171	368	200.000	51,261	512.613	OK	-	9.857	-	OK
10+760.000	898.641	11+128.000	908.359	11+328.000	908.784	11+368.239	907.893	368	40	200.000	4,119	41.194	OK	158.892	-	OK	-
11+328.000	908.784	11+368.239	907.893	11+518.239	908.535	11+735.000	915.193	40	217	150.000	2,836	28.378	OK	-	133.537	-	OK
11+518.239	908.535	11+735.000	915.193	12+035.000	922.749	12+435.000	930.612	217	400	300.000	27,129	271.288	OK	36.191	-	OK	-
12+035.000	922.749	12+435.000	930.612	12+635.000	930.278	12+864.224	925.005	400	229	200.000	4,688	46.881	OK	139.618	-	OK	-
12+635.000	930.278	12+864.224	925.005	12+964.224	923.838	13+965.914	923.504	229	1002	100.000	4,411	44.111	OK	-	-11.431	-	OK
12+964.224	923.838	13+965.914	923.504	14+125.914	920.773	14+230.000	917.254	1002	104	160.000	4,780	47.797	OK	109.555	-	OK	-
14+125.914	920.773	14+230.000	917.254	14+390.000	913.480	15+570.000	897.694	104	1180	160.000	7,831	78.314	OK	-	51.614	-	OK
14+390.000	913.480	15+570.000	897.694	15+730.000	895.196	15+100.000	888.594	1180	370	160.000	35,832	358.320	OK	14.614	-	OK	-
15+730.000	895.196	16+100.000	888.594	16+260.000	889.845	15+505.000	898.050	370	245	160.000	3,117	31.169	OK	-	129.683	-	OK
16+260.000	889.845	16+505.000	898.050	16+565.000	901.752	17+260.000	909.361	245	595	160.000	7,729	77.289	OK	67.751	-	OK	-
16+665.000	901.752	17+260.000	909.361	17+360.000	908.663	17+695.000	899.702	595	335	100.000	2,529	25.292	OK	128.713	-	[illegible]	-
17+360.000	908.663	17+695.000	899.702	17+795.000	899.371	18+296.223	909.455	335	501	100.000	2,134	21.336	OK	-	118.382	-	[illegible]
17+795.000	899.371	18+290.223	909.165	18+496.223	909.472	18+520.000	908.998	501	24	200.000	4,993	49.933	OK	131.086	-	OK	-

2.3 Clearance for intersection

Comments on DPR:
Vertical clearance of 5.5m for vehicular underpasses, 4.5m for pedestrian underpasses
Suggestion from JICA Experts:
Vertical clearance of 5.5m for vehicular underpasses, 4.5m for pedestrian underpasses

Vertical clearance shall be determined as 5.5 m for vehicular underpasses and 4.5m for pedestrian underpasses in the final DPR. However, several underpasses in the drawing are not kept the clearance as written in final DPR.

JICA Experts reviewed the drawings based on above standard. JICA Experts have pointed out there are many sections do not fulfill the requirement for clearance as presented in the Table 2.3



Source: JICA Experts

Figure 2.1 Insufficient Lateral Clearance for VUP/POP

Table 2.3 Review on Vertical Clearance of VUP, VOP, PUP and POP (Mainline)

Chainage	Type	Clearance (m)	IRC86 5.5m vehicular road 4.5m pedestrian road
1+550.000	VUP	2.5	error
2+270.000	PUP	2.1	error
3+560.000	POP	3.8	error
4+950.000	PUP	4.0	error
5+700.000	PUP	3.5	error
6+750.000	VUP	4.5	error
8+860.000	VUP	5.5	OK
10+700.000	VUP	4.4	error
11+700.000	PUP	3.1	error
12+550.000	VUP	4.8	error
14+800.000	POP	3.9	error
15+600.000	POP	4.1	error
17+310.000	VUP	4.4	error
20+269.000	VUP	5.5	OK
21+200.000	PUP	3.0	error
23+400.000	VOP	5.3	error
27+145.000	POP	4.5	error
28+080.000	VUP	4.4	error
29+700.000	VOP	5.5	OK
31+500.000	VUP	5.5	OK
33+620.000	VUP	4.4	error
37+760.000	VOP	3.9	error
41+344.000	PUP	3.7	error
44+382.000	VUP	5.0	error
45+445.000	VUP	4.6	error
49+430.000	POP	2.1	error
50+360.000	VUP	5.0	error
51+430.000	VUP	5.5	OK
54+580.000	POP	3.7	error
61+370.000	PUP	3.5	error
62+900.000	VUP	3.8	error

2.4 Maximum Height of Retaining Wall

Comments on DPR:
Very tall MSE retaining wall is planned in DPR.
Suggestion from JICA Experts:
It is better to set the limitation of the height of MSE. Otherwise, detailed analysis, such as FEM analysis, will be required for the tall wall.

Mechanical Stabilized Earth (MSE) Wall is planned in the sections of embankment slope of mainline and service road including the following high embankment locations:

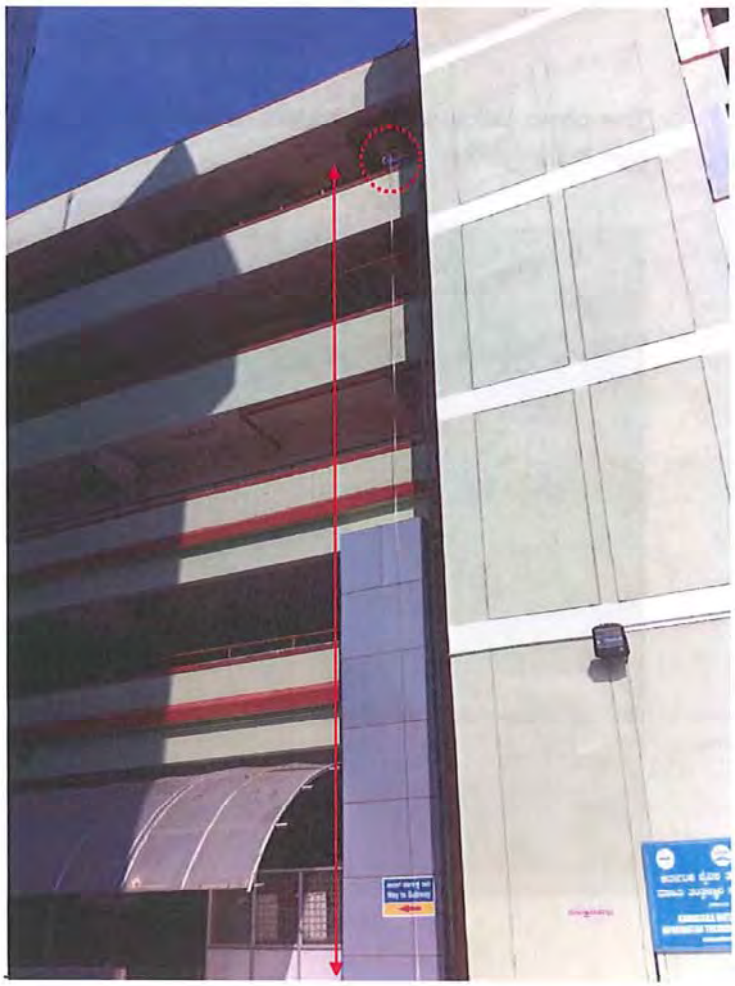
- KM43+100 (ROB at Chennai Railway Line): 16m on the centerline
- KM59+200 (ROB at Hosur Railway Line): 15m on the center line

It is noted that the above height is scaled on the centerline and actual maximum height of MSE at the both edges of the road might be <u>further increased such as 18m-20m height.</u>

(EXAMPLE OF H-18m)

This photo indicate 18m height at the office building of DULT.

18m will reach to 4th floor (actually 5-storey height) of DULT office.



Actually there are some cases in the world constructing tall MSE as listed below. However certain settlement of MSE was observed even using high- performance filling material (strictly selected granular or soil) and inextensible reinforcement (steel reinforcement).

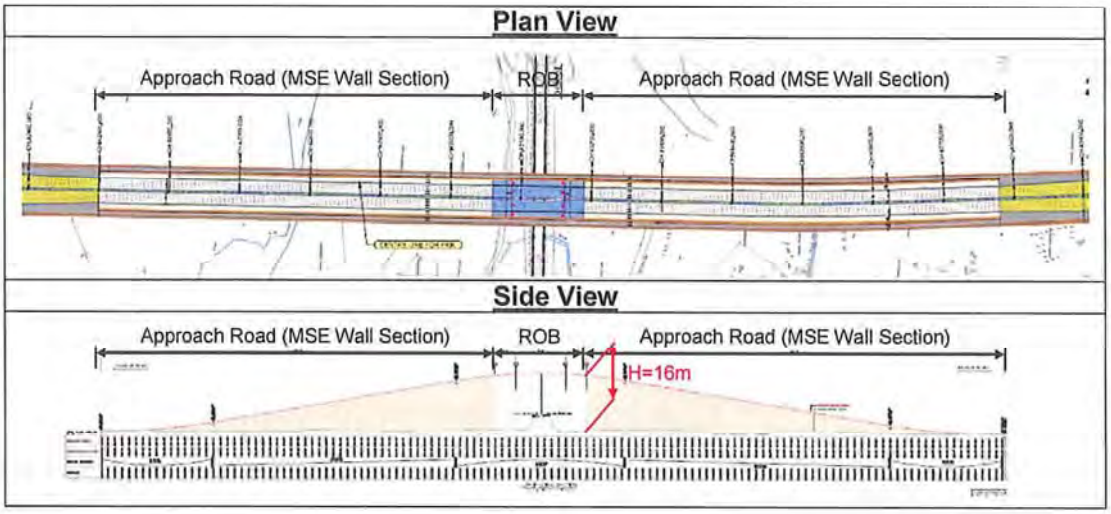
Location	*Max. Height(m)*	*No. of Tiers*	*Year Complete*	*Comments (Supplier)*
Crushing System Expansion, Victor, Colorado USA	32	1	2001	Mine wall supporting bridge crane. (Hilfiker)
Route 288, Richmond, Virginia USA	24	2	2002	High friction (gravel) backfill. (RECo)
Springfield Interchange, Virginia USA	20	1	2002	High friction (gravel) backfill. (RECo)
Hartsfield Airport Runway, Georgia USA	20	1	2003	Maximum total settlement of 600 mm during construction. (RECo)

Source: www.reinforcedearth.com

The photo below shows the actual deformation (settlement) of the 6m height MSE wall in Bangalore.

(Deformation at MSE Wall of NH-7 in Bangalore)

These exceed an experimental standard height (maximum 12m in general); therefore, structural measures or optional structure type are necessary to be considered.



Source: Final DPR

Figure 1.12 Height of MSE Wall at Chennai Railway Line (KM43+100)

JICA Experts recommend applying the standard height of MSE Wall by setting back the abutment locations (extending of ROB length) to assure structural aspects.

In case of applying tall MSE Wall, following technical measures are necessary to assure structural aspects during design life:

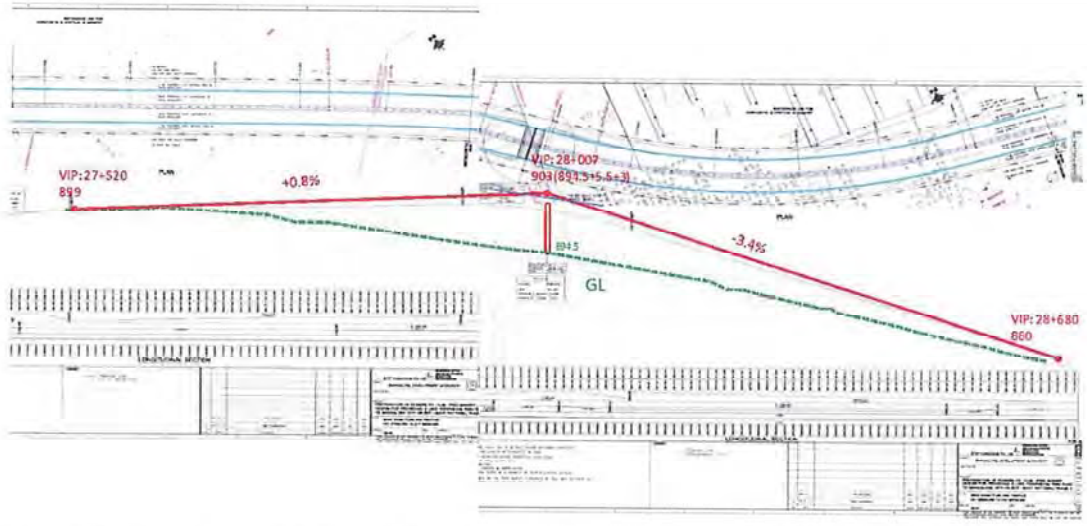
- Considering as critical structure during design life,
- Conducting detail geotechnical investigations at the planned locations,
- Conducting stability/deformation analyses by FEM in static/seismic conditions,
- Conducting consolidation analysis in detail,
- Using specific reinforcing such as metallic/geosynthetic reinforcing, etc.
- Conducting deformation and settlement monitoring during construction and operation periods.

Furthermore, in case of applying high MSE Wall, environmental and social conditions are significantly changed; therefore, it is necessary to agree with neighborhood.

2.5 Example of modification for vertical alignment

2.5.1 VUP

JICA Experts shows an example of modification for drawings including VUP. VUP shall be revised to keep minimum vertical clearance.

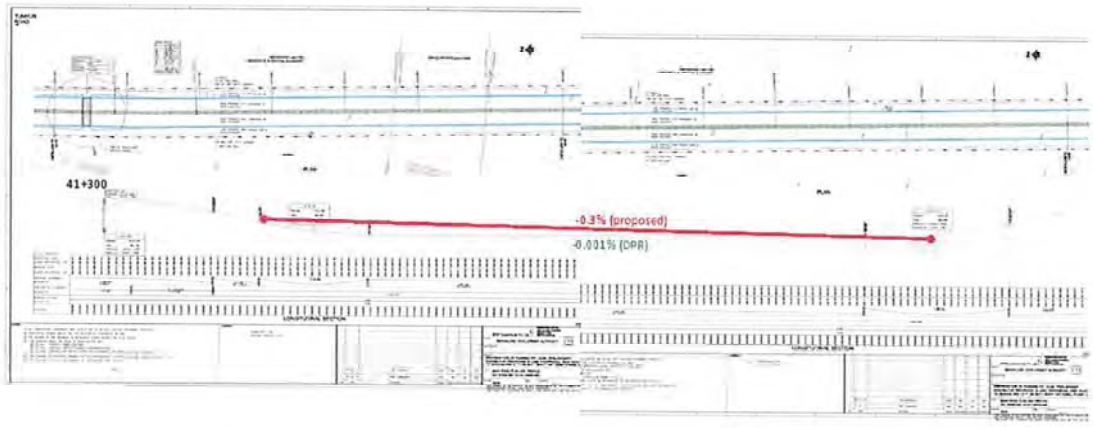


Source: JICA Experts based on Final DPR

Figure 1.13 Draft Modifications for Vertical Alignment (1)

2.5.2 Flat

Some drawings do not fulfill the requirement for minimum gradient. JICA Experts shows example of modification as below.



Source: JICA Experts based on Final DPR

Figure 1.14 Draft Modifications for Vertical Alignment (2)

2.5.3 Filling

Filling landscape shall be applied 4 per cent gradient. JICA Experts shows example that modified from 2.5 per cent to 4 per cent gradient. Therefore, filling can be minimize than existing drawing as below.

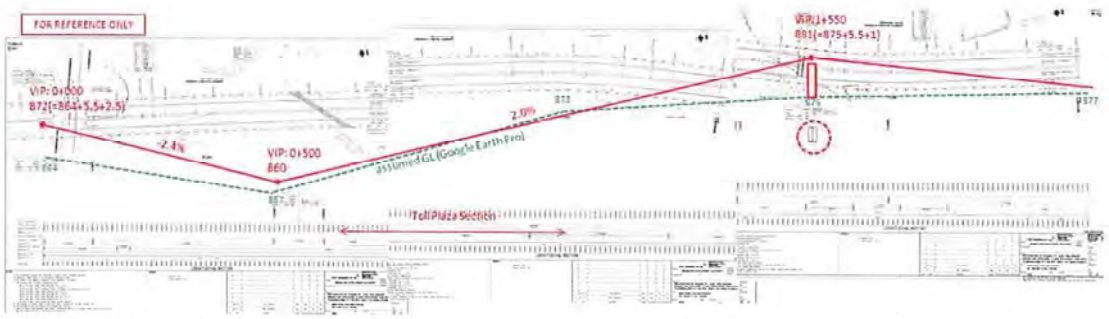
Source: JICA Experts based on Final DPR

Figure 1.15 Draft Modifications for Vertical Alignment (3)

2.5.4 Sections of Toll Plaza

IPC-86 does not specify about the limitation of vertical gradient around toll plaza. Queuing vehicles toward toll booths are sometime stopping on the toll plaza. To avoid minor accident "face to rear hitting" by stopping vehicle due to unintended releasing of brake, the vertical gradient on the toll plaza shall be smaller. Japanese Toll Road Guideline (NEXCO) specifies 2.0% for desirable maximum gradient to avoid the incidents mentioned above.

JICA Experts propose minor modification of the vertical alignment of BPRR as introduced below.



Source: JICA Experts based on Final DPR

Figure 1.16 Draft Modifications for Vertical Alignment (4)

Directorate of Urban Land Transport, Government of Karnataka
Bangalore Development Authority

JICA Experts on
Bengaluru Peripheral Ring Road Project

DISCUSSION PAPER R03

regarding

- ✓ *Design Concept of Ramp Terminal*
- ✓ *Design Concept of Toll Plaza Area*
- ✓ *Rest Area*

11 May 2015

JAPAN INTERNATIONAL COOPERATION AGENCY

TABLE OF CONTENTS

1 Design Concept of Ramp Terminal

1.1 Ramp Design Speed

Comments on DPR:
No description on DPR
Suggestion from JICA Experts:
Below suggestion need to be consider.

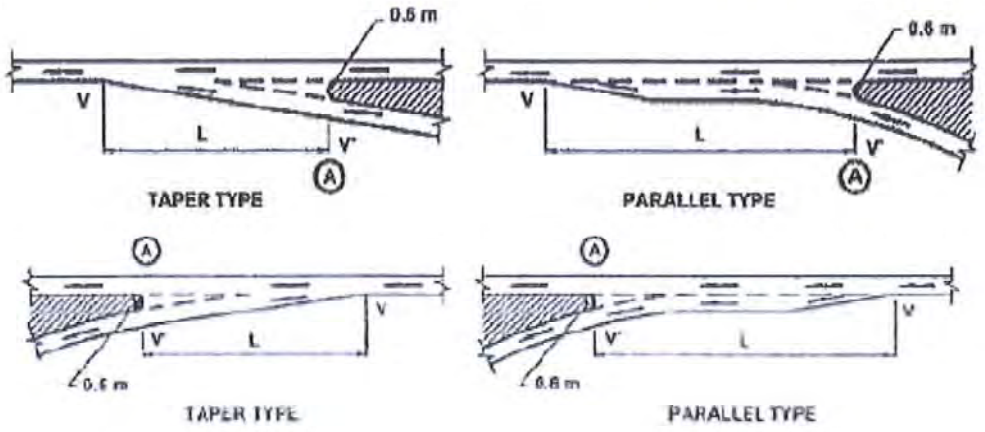
According to "Manual of Specification and Standard for Expressways" (IRC:SP:99-2013), ramp speed of BPRR is the range of 60-80 (km/h). JICA Experts recommend 60(km/h) for ramp speed since most of the car need to accelerate from stopping position at tool booth except ETC.

1.2 Design Speed of Acceleration/deceleration lanes

Comments on DPR Drawings:
No description on OPR drawings about taper Type and ramp speed
Suggestion from JICA Experts:
Acceleration lane length shall be 65m and deceleration lane length shall be 80m.
Structure type of acceleration and deceleration lane shall be taper type

In principle, parallel type is adopted for acceleration lane and taper type is adopted for deceleration lane. However, BPRR adopt the **taper type** for both accelerate and deceleration because of following reasons.

- Since the design speed of main carriageway is 80km/h, long length for acceleration lane is not requires.
- Vehicle can enter main carriageway without too much handling.



(Soure: IRC:SP:99-2013)

Minimum acceleration/deceleration lengths for exit by IRC:SP:99-2013.are shown below.(Under the condition of 80km/h for expressway design speed and 60km/h for ramp design speed.)

Acceleration Length: 65m (Minimum)

Deceleration Length: 80m (Minimum)

1.3 Transition Section of Main Carriageway and Ramp

Comments on DPR Drawings:
Alignment of connecting section of main carriageway with ramp is not considered visibility
Suggestion from JICA Experts:
Any possible measures shall be conducted

Even not description of IRC:SP:99-2013, alignment of connecting section of main carriageway with ramp, need to ensure the driver's visibility since this accident tends to occur in this section. To avoid accident in this section, driver need to recognize interchange from a long distance.

Descriptions below are shown alignment of main carriageway needed to be considered at connecting section of main carriageway and ramp as per Japanese manual.

- Radius of Horizontal Curve (shall be more than 1100m (800m※))
- Radius of Vertical Curve 凸 type (shall be more than 12,000m (6,000m※))
- Radius of Vertical Curve 凹 type (shall be more than 8,000m (4,000m※))
- Vertical Gradient (3% (4%※))

※This is the value shall be follow under any conditions.

Many sections of BPRR are violating above. Since additional land acquisition to follow above values, any possible measures shall be conducted as much as possible.

Besides, operational control for the vehicle speed and recognition of merging/diverging points toward interchanges shall be taken by proper road sign board system. DPR does not provide any drawings of traffic control devices including road signs. This shall be carefully considered in the detailed design.

1.4 Measures enable minimize the accident at section which connecting main carriageway and ramp

Comments on DPR Drawings:
No detail design

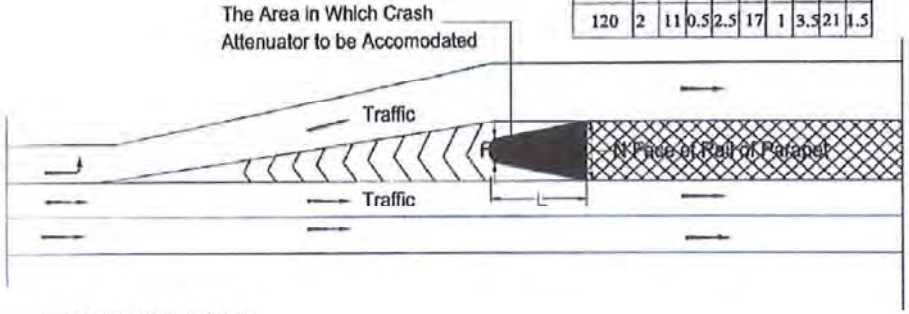
Suggestion from JICA Experts:
Some possible measures shall be considered in this stage

Every measure needs to focus on that improvement of recognition of interchanges for drivers coming from upstream from a long distance.

- Improvement of radius of vertical curve (especially at crest section)
- Expansion of margining/separating length
- Clear segregation between main carriageway and ramp

  (Wide dot marking, Arrow marking, Lettering marking, Colored pavement, Grooving pavement, Cat eye, etc.)
- Warning Signs (2km, 1km, 500m)
- Nose protection

Minimum Space Reoquired For Crash Attanuators i.e. Reserve Area (in meter									
Speed of Main Highway (kmph)	Minimum Space						Preferred Space		
	Restricted Conditions			Unrestricted Conditions					
	N	L	F	N	L	F	N	L	F
50	2	2.5	0.5	2.5	3.5	1	3.5	5	1.5
80	2	5	0.5	2.5	7.5	1	3.5	10	1.5
100	2	8.5	0.5	2.5	3.5	1	3.5	17	1.5
120	2	11	0.5	2.5	17	1	3.5	21	1.5



(Source:IRC:SP:99-2013)

2 Design Concept of Toll Plaza Area

2.1 Alignment of Toll Plaza Area

Comments on DPR Drawings:
No finalized drawings are submitted
Suggestion from JICA Experts:
Radius of horizontal curve should be more than 200m and gradient of tool plaza area should not be more than 2%

To design toll plaza area, followings shall be considered.

- Strait line is the best for toll plaza area but if horizontal curve is impossible to avoid, minimum radius of horizontal curve shall be 200m.
- Minimum radius of vertical curve shall be 700m
- Gradient of toll plaza area shall be not more than 2%.
- Crossfall of toll plaza area shall be not more than 2%

2.2 Toll Island

Comments on DPR Drawings:
No finalized drawings are submitted
Suggestion from JICA Experts:
Width of toll lane should be uniformed

As per IRC:SP:99-2013, width of ETC lane is 3.5m and others are 3.2m. However, considering increasing ETC users in future, width should be unformed as 3.2m.

IRC also described 25m for toll island length and not described about ETC lane length. ETC lane need longer island than manual lane since ETC lane requires communication zone between antenna and OBU. Therefore, all lane shall be 30m.(+5m for communication zone)

3 Rest Area

3.1 Recommendation of Rest Area

Comments on DPR/Drawings:
No description about rest area
Suggestion from JICA Experts:
Building rest area along the BPRR is recommended for releasing the call for nature and fatigue.

Total length of peripheral ring road (including NICE) will be 110 km. If some freight trucks drive from Mysore road to Old Madras road, it will drive about half of entire stretch. In order to consider driver's mental fatigue, call for nature and refueling petroleum, having a rest area along the BPRR can improve driver's convenience.

Facilities for rest area are shown below.

- Parking lots (minimum requirement)
- Toilet (minimum requirement)
- Petroleum stand
- Restaurant

- Food court
- Shopping area

Except parking lots and toilet, tenant fee for other facilities will be additional income for road administrator.