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Earthquake Reconstruction and Rehabilitation Authority (ERRA)

Urgent Rehabilitation Project: West Bank Bypass Design

Under the Urgent Development Study on

Rehabilitation and Reconstruction in Muzaffarabad City

In the Islamic Republic of Pakistan

FINAL REPORT

APPENDIX A

SUPPORTING DATA FOR ROAD DESIGN

March 2008

NIPPON KOEI CO., LTD.

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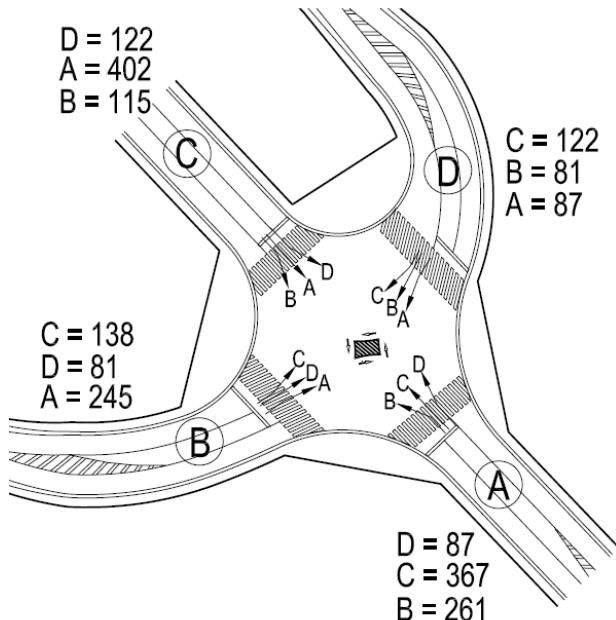
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Appendix A-1. Signal Phase Calculation

1.1 Intersection A: 4-leg signalized intersection

1.1.1 Condition and Assumption

(1) Peak Hour Traffic Volume estimated for 2019



(2) Geometric Design and Condition of Road

	A	B	C	D
Approach Speed (km/h)	40	40	40	40
Clearance (m)	40	40	40	40
Lane Width (m)	3	3	3	3
Vertical Gradient (%)	2.5	2.0	-2.5	-2.0
Heavy Vehicle Share (%)	7.4	7.4	7.4	7.4

(3) Signal Phase Pattern

	A	B	C	D
1φ	Green	Red	Green	Red
2φ	Red	Green	Red	Green

1.1.2 Ratio of Left and Right Turn Ratio

(1) Left-Turn Ratio

To calculate degree of saturation, it is required to derive left-turn ratio for the lane which through lane and left-turn lane are the same. It is derived from the following formula.

$$L = \frac{QL}{(QS + QLR) / N} \times 100$$

Where
 L: Left-turn ratio
 QL: Left-turn traffic volume
 QS: Through traffic volume
 QLR: Sum of left-turn and right-turn traffic volume. However, there is a lane only for right-turn, right-turn traffic is not included in QLR.
 N: Number of left-turn lanes including through traffic

The result of calculation is shown in the table below.

	A	B	C	D
QL	261	138	122	87
QS + QLR	628	219	524	168
N	1	1	1	1
Left-turn Ratio, L (%)	41.6	63.0	23.3	51.8

(2) Right-Turn Ratio

To calculate degree of saturation, it is required to derive right-turn ratio for the lane which through lane and right-turn lane are the same. It is derived from the following formula.

$$R = \frac{QR}{(QS + QLR) / N} \times 100$$

Where
 R: Right-turn ratio
 QR: Right-turn traffic volume
 QS: Through traffic volume
 QLR: Sum of left-turn and right-turn traffic volume. However, there is a lane only for left-turn, left-turn traffic is not included in QLR.
 N: Number of right-turn lanes including through traffic

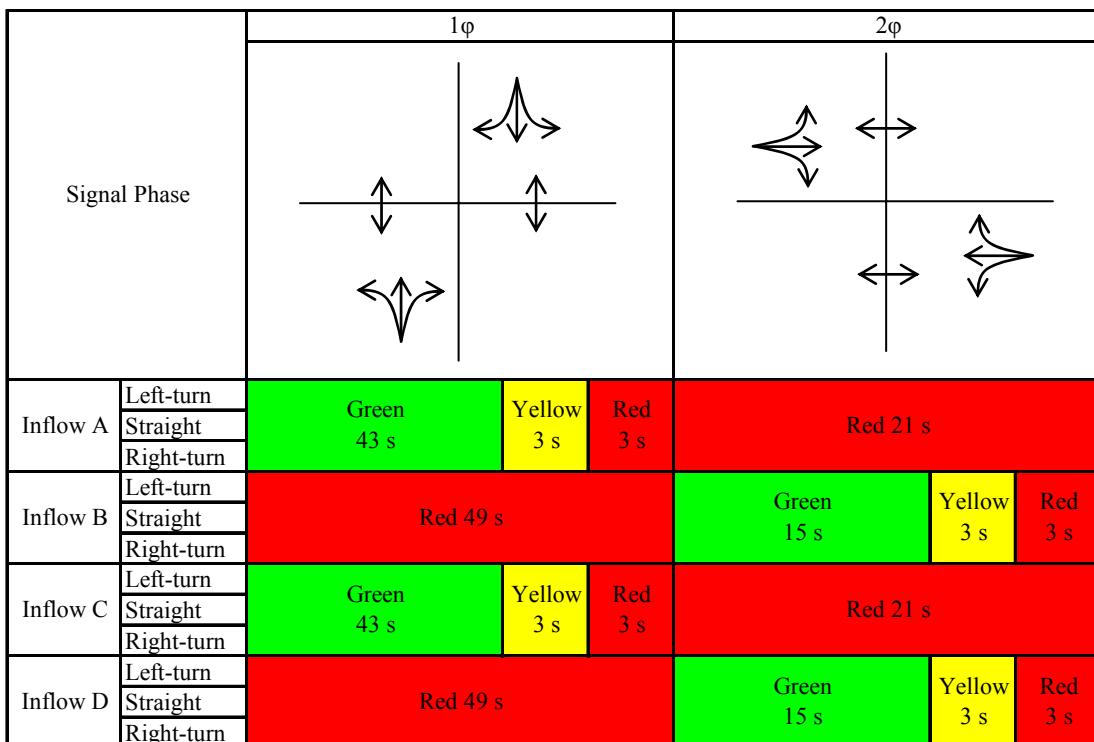
The result of calculation is shown in the table below.

	A	B	C	D
QR	0	0	0	0
QS + QLR	628	219	524	168
N	1	1	1	1
Left-turn Ratio, R (%)	0.0	0.0	0.0	0.0

1.1.3 Calculation on Signal Phase Time and Saturation Flow Rate

(1) Time of Signal Phase and Cycle Length

Phase	Green (s)	Yellow (s)	Red (s)	Clearance Time (s)	Loss Time (s)
1φ	43	3	3	6	5
2φ	15	3	3	6	5
Total	58	6	6	12	10
Cycle Length = 70s					



(2) Calculation of Saturation Flow Rate

Saturation flow rate is generally calculated using the following formula.

$$SA = SB \times \alpha W \times \alpha G \times \alpha T \times \alpha LT \times \alpha RT$$

- Where SA: Saturation flow rate (vehicle/effective-green-hour)
 SB: Base saturation flow rate (through traffic: 2000, left and right-turn: 1800)
 αW : Lane width coefficient
 αG : Vertical gradient coefficient
 αT : Heavy vehicle share coefficient
 αLT : Left-turn ratio coefficient
 αRT : Right turn ratio coefficient

Lane width coefficient, vertical gradient coefficient, and heavy vehicle share coefficient are selected from the following tables or calculated by a formula.

- Lane width coefficient, α_W

Lane Width (m)	α_W
2.50~3.00 (less than)	0.95
3.00~3.50	1.00

Lane Width of right-turn lane (m)	α_W
2.50~2.75 (less than)	0.95
2.75~	1.00

- Vertical gradient coefficient, α_G

Vertical Gradient (%)	α_G
-6	0.95
-5	0.96
-4	0.97
-3	0.98
-2	0.99
-1	1.00
0	1.00
1	1.00
2	0.95
3	0.90
4	0.85
5	0.80
6	0.75

- Heavy vehicle share coefficient, α_T

Heavy Vehicle Share (%)	α_T
0	1.00
5	0.97
10	0.93
15	0.90
20	0.88
25	0.85
30	0.83
35	0.80
40	0.78
45	0.76
50	0.74

Heavy vehicle share coefficient, αT can be calculated by using the following formula;

$$\alpha T = \frac{100}{(100 - T) + ET \times T}$$

Where αT : Heavy vehicle share coefficient
 ET: Conversion factor from heavy vehicle to passenger car (= 1.7)
 T: Heavy Vehicle Share (%)

➤ Left-turn ratio coefficient, αLT

- If no effect of crossing pedestrians is expected, αLT is calculated by the following formula assuming conversion factor from left-turn to through traffic, ELT, to be 1.11.

$$\alpha LT = \frac{100}{(100 - L) + ELT \times L}$$

Where αLT : Left-turn ratio coefficient
 ELT: Conversion factor from left-turn to through traffic
 L: Left-turn ratio

- If the effect of crossing pedestrians is not significant, αLT is selected from the following table.

Left-turn ratio (%)	αLT
5	0.99
10	0.97
15	0.96
20	0.94
25	0.93
30	0.91
35	0.90
40	0.88
45	0.87
50	0.85

- If the effect of crossing pedestrians is significant, αLT is calculated by using the following formula.

$$ELT = \frac{1.1 \times G}{(1 - fp) \times Gp + (G - Gp)}$$

$$\alpha LT = \frac{100}{(100 - L) + ELT \times L}$$

Where αLT : Left-turn ratio coefficient
 ELT: Conversion factor from left-turn to through traffic
 G: Effective green time
 Gp: Green time for pedestrian
 Fp: Reduction ratio
 L: Left-turn ratio

Inflow A (from Muree)

1. Left-turn and through lane

SB = 2000

Lane width: 3.00 m, Vertical gradient: 2.5%, Heavy vehicle share: 7.4%

$$\alpha_W = 1.000$$

$$\alpha_G = 0.925$$

$$\alpha_T = 0.951$$

$$\alpha_{LT} = \frac{100}{(100 - L) + ELT \times L} = \frac{100}{(100 - 41.6) + 1.11 \times 41.6} = 0.956$$

$$\alpha_{RT} = 1.000$$

Applying the coefficients above to formula for saturation flow rate;

$$SA = 2000 \times 1.000 \times 0.925 \times 0.951 \times 0.956 \times 1.000 = 1682$$

SA = 1682

2. Right-turn lane

SB = 1800

Lane width: 3.00 m, Vertical gradient: 2.5%, Heavy vehicle share: 7.4%

$$\alpha_W = 1.000$$

$$\alpha_G = 0.925$$

$$\alpha_T = 0.951$$

Since there is no signal phase for only right-turn, the following formula is used to derive its capacity.

$$Ci = Sro \times f \times \frac{(S \times G - q \times C)}{C \times (S - q)} + N$$

Where,

S: Saturation flow ratio basis of oncoming through traffic
(vehicle/effective-green-hour)

q: Oncoming through traffic volume(vehicle/hour)

f: Probability for right-turn traffic to pass the intersection crossing through traffic, q

q	0	200	400	600	800	1000
f	1.00	0.81	0.65	0.54	0.45	0.37

$$Sro = 1800 \times 1.000 \times 0.925 \times 0.951 = 1583$$

$$f = 0.649, S = 2000, q = 81, C = 70, G = 44, N = 0$$

$$Ci = 1583 \times 0.649 \times \frac{(2000 \times 44 - 402 \times 70)}{70 \times (2000 - 402)} + 0$$

Traffic Capacity, **Ci = 550**

Inflow B (from Lower Chatter)

1. Left-turn and through lane

SB = 2000

Lane width: 3.00 m, Vertical gradient: 2.0%, Heavy vehicle share: 7.4%

$$\alpha_W = 1.000$$

$$\alpha_G = 0.950$$

$$\alpha_T = 0.951$$

$$\alpha_{LT} = \frac{100}{(100 - L) + ELT \times L} = \frac{100}{(100 - 63.0) + 1.11 \times 63.0} = 0.935$$

$$\alpha_{RT} = 1.000$$

$$SA = 2000 \times 1.000 \times 0.950 \times 0.951 \times 0.935 \times 1.000 = 1689$$

$$SA = 1689$$

2. Right-turn lane

SB = 1800

Lane width: 3.00 m, Vertical gradient: 2.0%, Heavy vehicle share: 7.4%

$$\alpha_W = 1.000$$

$$\alpha_G = 0.950$$

$$\alpha_T = 0.951$$

Since there is no signal phase for only right-turn, the following formula is used to derive its capacity.

$$Ci = Sro \times f \times \frac{(S \times G - q \times C)}{C \times (S - q)} + N$$

Where, S: Saturation flow ratio basis of oncoming through traffic

(vehicle/effective-green-hour)

q: Oncoming through traffic volume(vehicle/hour)

f: Probability for right-turn traffic to pass the intersection crossing through traffic, q

q	0	200	400	600	800	1000
f	1.00	0.81	0.65	0.54	0.45	0.37

$$Sro = 1800 \times 1.000 \times 0.950 \times 0.951 = 1626$$

$$f = 0.923, S = 2000, q = 81, C = 70, G = 16, N = 0$$

$$Ci = 1626 \times 0.923 \times \frac{(2000 \times 16 - 81 \times 70)}{70 \times (2000 - 81)} + 0$$

Traffic Capacity, Ci = 294

Inflow C (from Naluchi Bridge)

1. Left-turn and through lane

SB = 2000

Lane width: 3.00 m, Vertical gradient: - 2.5%, Heavy vehicle share: 7.4%

$$\alpha_W = 1.000$$

$$\alpha_G = 0.985$$

$$\alpha_T = 0.951$$

$$\alpha_{LT} = \frac{100}{(100 - L) + ELT \times L} = \frac{100}{(100 - 23.3) + 1.11 \times 23.3} = 0.975$$

$$\alpha_{RT} = 1.000$$

$$SA = 2000 \times 1.000 \times 0.985 \times 0.951 \times 0.975 \times 1.000 = 1827$$

$$SA = 1827$$

2. Right-turn lane

SB = 1800

Lane width: 3.00 m, Vertical gradient: - 2.5%, Heavy vehicle share: 7.4%

$$\alpha_W = 1.000$$

$$\alpha_G = 0.985$$

$$\alpha_T = 0.951$$

Since there is no signal phase for only right-turn, the following formula is used to derive its capacity.

$$Ci = Sro \times f \times \frac{(S \times G - q \times C)}{C \times (S - q)} + N$$

Where,

S: Saturation flow ratio basis of oncoming through traffic
(vehicle/effective-green-hour)

q: Oncoming through traffic volume(vehicle/hour)

f: Probability for right-turn traffic to pass the intersection crossing through traffic, q

q	0	200	400	600	800	1000
f	1.00	0.81	0.65	0.54	0.45	0.37

$$Sro = 1800 \times 1.000 \times 0.985 \times 0.951 = 1686$$

$$f = 0.676, S = 2000, q = 367, C = 70, G = 44, N = 0$$

$$Ci = 1686 \times 0.676 \times \frac{(2000 \times 44 - 367 \times 70)}{70 \times (2000 - 367)} + 0$$

Traffic Capacity, Ci = 621

Inflow D (from Upper Chatter)

1. Left-turn and through lane

SB = 2000

Lane width: 3.00 m, Vertical gradient: - 2.0%, Heavy vehicle share: 7.4%

$$\alpha_W = 1.000$$

$$\alpha_G = 0.990$$

$$\alpha_T = 0.951$$

$$\alpha_{LT} = \frac{100}{(100 - L) + ELT \times L} = \frac{100}{(100 - 51.8) + 1.11 \times 51.8} = 0.946$$

$$\alpha_{RT} = 1.000$$

$$SA = 2000 \times 1.000 \times 0.990 \times 0.951 \times 0.946 \times 1.000 = 1781$$

$$SA = 1781$$

2. Right-turn lane

SB = 1800

Lane width: 3.00 m, Vertical gradient: - 2.0%, Heavy vehicle share: 7.4%

$$\alpha_W = 1.000$$

$$\alpha_G = 0.990$$

$$\alpha_T = 0.951$$

Since there is no signal phase for only right-turn, the following formula is used to derive its capacity.

$$Ci = Sro \times f \times \frac{(S \times G - q \times C)}{C \times (S - q)} + N$$

Where, S: Saturation flow ratio basis of oncoming through traffic

(vehicle/effective-green-hour)

q: Oncoming through traffic volume(vehicle/hour)

f: Probability for right-turn traffic to pass the intersection crossing through traffic, q

q	0	200	400	600	800	1000
f	1.00	0.81	0.65	0.54	0.45	0.37

$$Sro = 1800 \times 1.000 \times 0.990 \times 0.951 = 1695$$

$$f = 0.923, S = 2000, q = 81, C = 70, G = 16, N = 0$$

$$Ci = 1695 \times 0.923 \times \frac{(2000 \times 16 - 81 \times 70)}{70 \times (2000 - 81)} + 0$$

Traffic Capacity, Ci = 307

1.1.4 Summary of Calculation Results

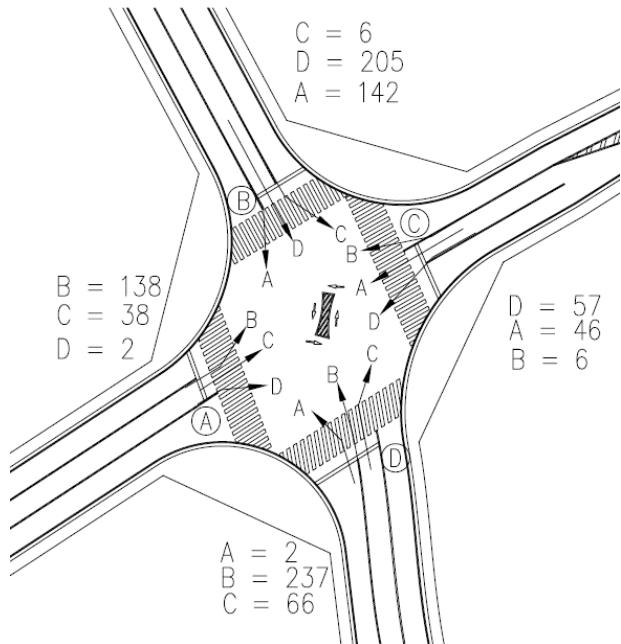
Inflow	Lane Type	A Left-turn & Straight	B Right-turn	C Left-turn & Straight	D Right-turn
No. of Lanes	1	1	1	1	1
Basis of Saturation Flow Rate, S B	2000	1800	2000	1800	2000
Lane Width Coefficient, α_w (Lane Width), m	1.000 (3.00)	1.000 (3.00)	1.000 (3.00)	1.000 (3.00)	1.000 (3.00)
Vertical Gradient Coefficient, α_G (Vertical Gradient), %	0.925 (2.50)	0.925 (2.50)	0.950 (2.00)	0.985 (2.50)	0.985 (2.50)
Heavy Vehicle Share Coefficient, α_T (Heavy Vehicle Share), %	0.951 (7.40)	0.951 (7.40)	0.951 (7.40)	0.951 (7.40)	0.951 (7.40)
Left-turn Ratio Coefficient, $\alpha_L T$ (Left-turn Ratio), %	0.956 (41.6)	0.935 (63.0)	0.975 (23.3)	0.975 (23.3)	0.946 (51.8)
Right-turn Ratio Coefficient, $\alpha_R T$ (Probability of right-turn), f (Effective-green time), s	0.649 44	0.649 16	0.923 16	0.676 44	0.923 16
Saturation Flow Rate, S A	1682	*550	1689	*294	1827
Design Traffic Volume, q	628 (261+367)	87	219 (138+81)	245 (122+402)	524 (87+81)
Degree of Saturation by leg	0.373	-	0.130	-	0.094
Degree of Saturation by Phase	1 φ 2 φ	0.373 -	0.130 -	0.287 -	0.094 -
Effective-green time, (s)	1 φ 2 φ	44	44	44	44
Green Time / Cycle Length, G / C	44/70	44/70	16/70	44/70	44/70
Traffic Capacity, C i	1057	550	386	294	1148
Design Traffic / Capacity, q / C i	0.594	0.158	0.567	0.833	0.456
Evaluation	OK	OK	OK	OK	OK
Storage Length, L s (m)	13.1		36.8		17.3
					18.3

Note: *: Traffic Capacity per actual hour

1.2 Intersection No.4: 4-leg signalized intersection

1.2.1 Condition and Assumption

(1) Peak Hour Traffic Volume estimated for 2019



	A	B	C	D
Left-turn	138	6	57	2
Straight	38	205	46	237
Right-turn	2	142	6	66
Total	178	353	109	305

(2) Geometric Design and Condition of Road

	A	B	C	D
Approach Speed (km/h)	40	40	30	40
Clearance (m)	33	36	33	36
Lane Width (m)	3	3	3	3
Vertical Gradient (%)	4.0	-2.0	-4.0	2.0
Heavy Vehicle Share (%)	7.4	7.4	7.4	7.4

(3) Signal Phase Pattern

	A	B	C	D
1φ	Green	Red	Green	Red
2φ	Red	Green	Red	Green
3φ	Red	Right-turn only	Red	Right-turn only

1.2.2 Ratio of Left and Right Turn Ratio

(1) Left-Turn Ratio

To calculate degree of saturation, it is required to derive left-turn ratio for the lane which through lane and left-turn lane are the same. It is derived from the following formula.

$$L = \frac{QL}{(QS + QLR) / N} \times 100$$

Where L: Left-turn ratio
 QL: Left-turn traffic volume
 QS: Through traffic volume
 QLR: Sum of left-turn and right-turn traffic volume. However, there is a lane only for right-turn, right-turn traffic is not included in QLR.
 N: Number of left-turn lanes including through traffic

The result of calculation is shown in the table below.

	A	B	C	D
QL	138	6	57	2
QS + QLR	176	211	103	239
N	1	1	1	1
Left-turn Ratio, L (%)	78.4	2.8	55.3	0.8

(2) Right-Turn Ratio

To calculate degree of saturation, it is required to derive right-turn ratio for the lane which through lane and right-turn lane are the same. It is derived from the following formula.

$$R = \frac{QR}{(QS + QLR) / N} \times 100$$

Where R: Right-turn ratio
 QR: Right-turn traffic volume
 QS: Through traffic volume
 QLR: Sum of left-turn and right-turn traffic volume. However, there is a lane only for left-turn, left-turn traffic is not included in QLR.
 N: Number of right-turn lanes including through traffic

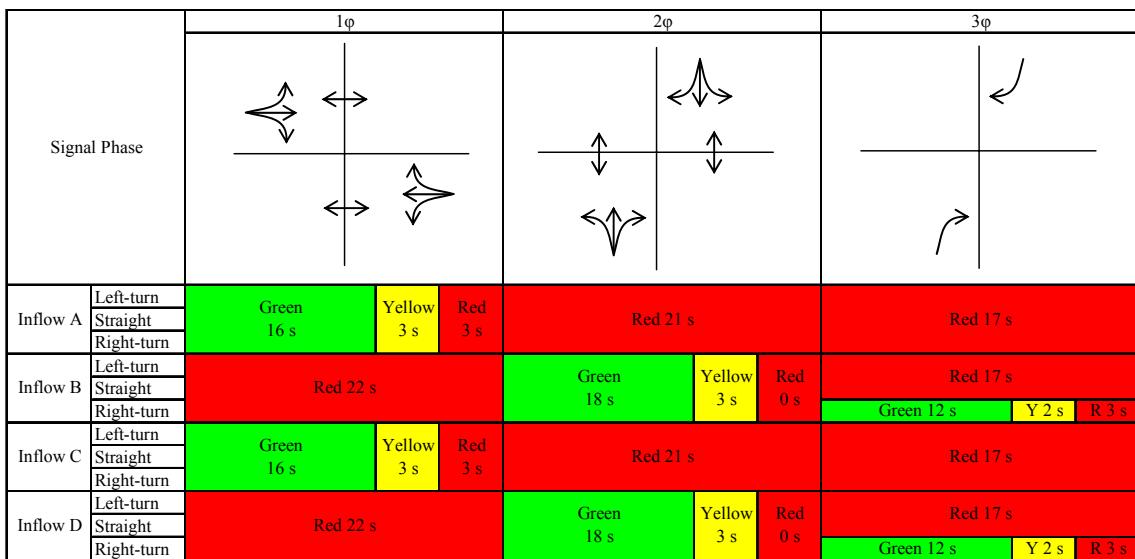
The result of calculation is shown in the table below.

	A	B	C	D
QR	0	0	0	0
QS + QLR	176	211	103	239
N	1	1	1	1
Left-turn Ratio, R (%)	0.0	0.0	0.0	0.0

1.2.3 Calculation on Signal Phase Time and Saturation Flow Rate

(1) Time of Signal Phase and Cycle Length

Phase	Green (s)	Yellow (s)	Red (s)	Clearance Time (s)	Loss Time (s)
1φ	16	3	3	6	5
2φ	18	3	0	3	2
3φ	12	2	3	5	4
Total	46	8	6	14	11
Cycle Length	= 60s				



(2) Calculation of Saturation Flow Rate

Saturation flow rate is generally calculated using the following formula.

$$SA = SB \times \alpha W \times \alpha G \times \alpha T \times \alpha LT \times \alpha RT$$

Where SA: Saturation flow rate (vehicle/effective-green-hour)
 SB: Base saturation flow rate (through traffic: 2000, left and right-turn: 1800)
 αW : Lane width coefficient
 αG : Vertical gradient coefficient
 αT : Heavy vehicle share coefficient
 αLT : Left-turn ratio coefficient
 αRT : Right turn ratio coefficient

Lane width coefficient, vertical gradient coefficient, and heavy vehicle share coefficient are selected from the following tables or calculated by a formula.

- Lane width coefficient, α_W

Lane Width (m)	α_W
2.50~3.00 (less than)	0.95
3.00~3.50	1.00

Lane Width of right-turn lane (m)	α_W
2.50~2.75 (less than)	0.95
2.75~	1.00

- Vertical gradient coefficient, α_G

Vertical Gradient (%)	α_G
-6	0.95
-5	0.96
-4	0.97
-3	0.98
-2	0.99
-1	1.00
0	1.00
1	1.00
2	0.95
3	0.90
4	0.85
5	0.80
6	0.75

- Heavy vehicle share coefficient, α_T

Heavy Vehicle Share (%)	α_T
0	1.00
5	0.97
10	0.93
15	0.90
20	0.88
25	0.85
30	0.83
35	0.80
40	0.78
45	0.76
50	0.74

Heavy vehicle share coefficient, αT can be calculated by using the following formula;

$$\alpha T = \frac{100}{(100 - T) + ET \times T}$$

Where αT : Heavy vehicle share coefficient
 ET: Conversion factor from heavy vehicle to passenger car (= 1.7)
 T: Heavy Vehicle Share (%)

➤ Left-turn ratio coefficient, αLT

- If no effect of crossing pedestrians is expected, αLT is calculated by the following formula assuming conversion factor from left-turn to through traffic, ELT, to be 1.11.

$$\alpha LT = \frac{100}{(100 - L) + ELT \times L}$$

Where αLT : Left-turn ratio coefficient
 ELT: Conversion factor from left-turn to through traffic
 L: Left-turn ratio

- If the effect of crossing pedestrians is not significant, αLT is selected from the following table.

Left-turn ratio (%)	αLT
5	0.99
10	0.97
15	0.96
20	0.94
25	0.93
30	0.91
35	0.90
40	0.88
45	0.87
50	0.85

- If the effect of crossing pedestrians is significant, αLT is calculated by using the following formula.

$$ELT = \frac{1.1 \times G}{(1 - fp) \times Gp + (G - Gp)}$$

$$\alpha LT = \frac{100}{(100 - L) + ELT \times L}$$

Where αLT : Left-turn ratio coefficient
 ELT: Conversion factor from left-turn to through traffic
 G: Effective green time
 Gp: Green time for pedestrian
 Fp: Reduction ratio
 L: Left-turn ratio

Inflow A (Bypass)

1. Left-turn and through lane

SB = 2000

Lane width: 3.00 m, Vertical gradient: 4.0%, Heavy vehicle share: 7.4%

$$\alpha_W = 1.000$$

$$\alpha_G = 0.850$$

$$\alpha_T = 0.951$$

$$\alpha_{LT} = \frac{100}{(100 - L) + ELT \times L} = \frac{100}{(100 - 78.4) + 1.11 \times 78.4} = 0.921$$

$$\alpha_{RT} = 1.000$$

Applying the coefficients above to formula for saturation flow rate;

$$SA = 2000 \times 1.000 \times 0.850 \times 0.951 \times 0.921 \times 1.000 = 1489$$

$$SA = 1489$$

2. Right-turn lane

SB = 1800

Lane width: 3.00 m, Vertical gradient: 4.0%, Heavy vehicle share: 7.4%

$$\alpha_W = 1.000$$

$$\alpha_G = 0.850$$

$$\alpha_T = 0.951$$

Since there is no signal phase for only right-turn, the following formula is used to derive its capacity.

$$Ci = Sro \times f \times \frac{(S \times G - q \times C)}{C \times (S - q)} + N$$

Where,

S: Saturation flow ratio basis of oncoming through traffic

(vehicle/effective-green-hour)

q: Oncoming through traffic volume(vehicle/hour)

f: Probability for right-turn traffic to pass the intersection crossing through traffic, q

q	0	200	400	600	800	1000
f	1.00	0.81	0.65	0.54	0.45	0.37

$$Sro = 1800 \times 1.000 \times 0.850 \times 0.951 = 1455$$

$$f = 0.956, S = 2000, q = 46, C = 60, G = 17, N = 0$$

$$Ci = 1455 \times 0.956 \times \frac{(2000 \times 17 - 46 \times 60)}{60 \times (2000 - 46)} + 0$$

Traffic Capacity, Ci = 371

Inflow B (Neelum Valley Road from North)

1. Left-turn and through lane

SB = 2000

Lane width: 3.00 m, Vertical gradient: -2.0%, Heavy vehicle share: 7.4%

$$\alpha_W = 1.000$$

$$\alpha_G = 0.990$$

$$\alpha_T = 0.951$$

$$\alpha_{LT} = \frac{100}{(100 - L) + ELT \times L} = \frac{100}{(100 - 2.8) + 1.11 \times 2.8} = 0.997$$

$$\alpha_{RT} = 1.000$$

$$SA = 2000 \times 1.000 \times 0.990 \times 0.951 \times 0.997 \times 1.000 = 1877$$

2. Right-turn lane

SB = 1800

Lane width: 3.00 m, Vertical gradient: -2.0%, Heavy vehicle share: 7.4%

$$\alpha_W = 1.000$$

$$\alpha_G = 0.990$$

$$\alpha_T = 0.951$$

Since there is a signal phase for only right-turn, left-turn and right-turn ratio does not affect on its capacity. Then,

$$\alpha_{LT} = 1.00$$

$$\alpha_{RT} = 1.00$$

$$SA = 1800 \times 1.000 \times 0.990 \times 0.951 \times 1.000 \times 1.000 = 1695$$

Inflow C (from University)

1. Left-turn and through lane

SB = 2000

Lane width: 3.00 m, Vertical gradient: - 4.0%, Heavy vehicle share: 7.4%

$$\alpha_W = 1.000$$

$$\alpha_G = 0.970$$

$$\alpha_T = 0.951$$

$$\alpha_{LT} = \frac{100}{(100 - L) + ELT \times L} = \frac{100}{(100 - 55.3) + 1.11 \times 55.3} = 0.943$$

$$\alpha_{RT} = 1.000$$

$$SA = 2000 \times 1.000 \times 0.970 \times 0.951 \times 0.943 \times 1.000 = 1740$$

$$SA = \mathbf{1740}$$

2. Right-turn lane

SB = 1800

Lane width: 3.00 m, Vertical gradient: - 4.0%, Heavy vehicle share: 7.4%

$$\alpha_W = 1.000$$

$$\alpha_G = 0.970$$

$$\alpha_T = 0.951$$

Since there is no signal phase for only right-turn, the following formula is used to derive its capacity.

$$Ci = Sro \times f \times \frac{(S \times G - q \times C)}{C \times (S - q)} + N$$

Where,

S: Saturation flow ratio basis of oncoming through traffic
(vehicle/effective-green-hour)

q: Oncoming through traffic volume(vehicle/hour)

f: Probability for right-turn traffic to pass the intersection crossing through traffic, q

q	0	200	400	600	800	1000
f	1.00	0.81	0.65	0.54	0.45	0.37

$$Sro = 1800 \times 1.000 \times 0.970 \times 0.951 = 1660$$

$$f = 0.964, S = 2000, q = 38, C = 60, G = 17, N = 0$$

$$Ci = 1660 \times 0.964 \times \frac{(2000 \times 17 - 38 \times 60)}{60 \times (2000 - 38)} + 0$$

Traffic Capacity, Ci = **431**

Inflow D (from Chela Bandi Bridge)

1. Left-turn and through lane

SB = 2000

Lane width: 3.00 m, Vertical gradient: 2.0%, Heavy vehicle share: 7.4%

$$\alpha_W = 1.000$$

$$\alpha_G = 0.950$$

$$\alpha_T = 0.951$$

$$\alpha_{LT} = \frac{100}{(100 - L) + ELT \times L} = \frac{100}{(100 - 0.8) + 1.11 \times 0.8} = 0.999$$

$$\alpha_{RT} = 1.000$$

$$SA = 2000 \times 1.000 \times 0.950 \times 0.951 \times 0.999 \times 1.000 = 1805$$

$$SA = 1805$$

2. Right-turn lane

SB = 1800

Lane width: 3.00 m, Vertical gradient: 2.0%, Heavy vehicle share: 7.4%

$$\alpha_W = 1.000$$

$$\alpha_G = 0.950$$

$$\alpha_T = 0.951$$

Since there is a signal phase for only right-turn, left-turn and right-turn ratio does not affect on its capacity. Then,

$$\alpha_{LT} = 1.00$$

$$\alpha_{RT} = 1.00$$

$$SA = 1800 \times 1.000 \times 0.950 \times 0.951 \times 1.000 \times 1.000 = 1626$$

$$SA = 1626$$

1.2.4 Summary of Calculation Results

Inflow	Lane Type	A	B	C	D
	Left-turn & Straight	Right-turn	Left-turn & Straight	Right-turn	Left-turn & Straight
No. of Lanes	1	1	1	1	1
Basis of Saturation Flow Rate, S B	2000	1800	2000	1800	2000
Lane Width Coefficient, α_w (Lane Width), m	1.000 (3.00)	1.000 (3.00)	1.000 (3.00)	1.000 (3.00)	1.000 (3.00)
Vertical Gradient Coefficient, α_G (Vertical Gradient), %	0.850 (4.00)	0.850 (4.00)	0.990 (-2.00)	0.990 (-2.00)	0.950 (-4.00)
Heavy Vehicle Share Coefficient, α_T (Heavy Vehicle Share), %	0.951 (7.40)	0.951 (7.40)	0.951 (7.40)	0.951 (7.40)	0.951 (7.40)
Left-turn Ratio Coefficient, α_{LT} (Left-turn Ratio), %	0.921 (78.4)		0.997 (2.8)	0.943 (55.3)	0.999 (0.8)
Right-turn Ratio Coefficient, α_{RT} (Probability of right-turn), f (Effective-green time), s	0.956 17		0.780 19	0.964 17	0.806 19
Saturation Flow Rate, S A	1489	*371	1877	1695	1740
Design Traffic Volume, q	176 (138+38)	2	211 (6+205)	142	103 (57+46)
Degree of Saturation by leg	0.118	-	0.112	0.084	0.059
Degree of Saturation by Phase	1φ 2φ	0.118 -	0.112	0.084	0.059
Effective-green time, (s)	1φ 2φ 3φ	17	17	17	17
Green Time / Cycle Length, G / C	17/60	17/60	19/60 13/60	17/60	17/60 13/60
Traffic Capacity, C i	422	371	594	367	493
Design Traffic / Capacity, q / C i	0.417	0.005	0.355	0.387	0.209
Evaluation	OK	OK	OK	OK	OK
Storage Length, L s (m)	0.3		18.3		0.8
					8.5
					60
					13
					13

Note: * : Traffic Capacity per actual hour

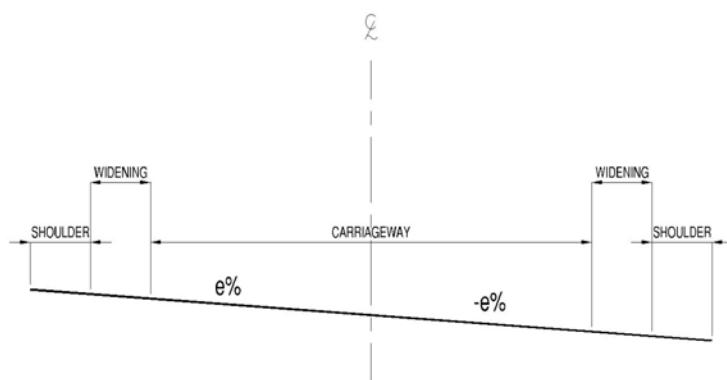
Appendix A-2. Supporting Data for Road Alignment

2.1 Super Elevation

Super elevations applied in curve section are listed below. They are applied according to its design speed, which are 50 km/h and 40 km/h in this Project. In straight line section, 2% of cross slope is applied to let surface water flow down in side ditch.

V= 50 km/h	
RADIUS (m)	e%
750 ~	2.0
668 ~ 749	2.2
599 ~ 667	2.4
540 ~ 598	2.6
488 ~ 539	2.8
443 ~ 487	3.0
402 ~ 442	3.2
364 ~ 401	3.4
329 ~ 363	3.6
294 ~ 328	3.8
261 ~ 293	4.0
234 ~ 260	4.2
210 ~ 233	4.4
190 ~ 209	4.6
172 ~ 189	4.8
156 ~ 171	5.0
142 ~ 155	5.2
128 ~ 141	5.4
115 ~ 127	5.6
102 ~ 114	5.8
79 101	6.0

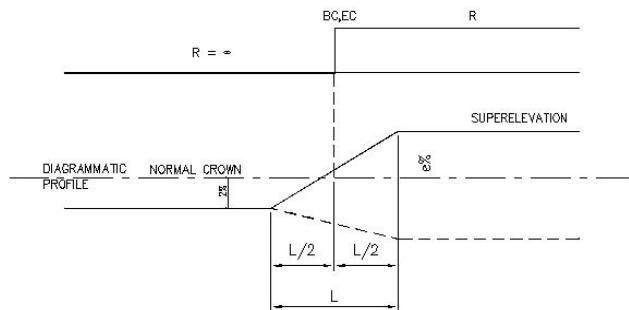
V= 40 km/h	
RADIUS (m)	e%
525	2.0
465 ~ 524	2.2
415 ~ 464	2.4
372 ~ 414	2.6
334 ~ 371	2.8
300 ~ 333	3.0
269 ~ 299	3.2
239 ~ 268	3.4
206 ~ 238	3.6
177 ~ 205	3.8
155 ~ 176	4.0
136 ~ 154	4.2
121 ~ 135	4.4
108 ~ 120	4.6
97 ~ 107	4.8
88 ~ 96	5.0
79 ~ 87	5.2
71 ~ 78	5.4
63 ~ 70	5.6
56 ~ 62	5.8
43 ~ 55	6.0



Three types of transition curves require in the horizontal alignment; tangent to curve, reverse curve and compound curve. Tangent to curve is the transition from a straight line to a curve. Reverse curve indicates a transition from curve to an opposite direction. Compound curve is a transition from curve to curve having a different radius. Each transition method is shown in figure below.

The transition ratio is set to be less than 1/154 for design speed of 50km/h and less than 1/143 for 40km/h.

TYPE-1 TANGENT TO CURVE ($R = \infty \sim R$)

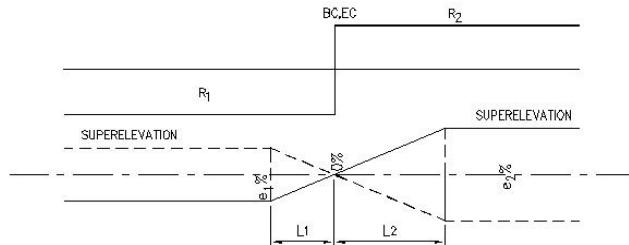


TYPE-2 REVERSE CURVE ($R_1 \sim R_2$)

WHERE:

L = SUPERELEVATION RUNOFF LENGTH (M)

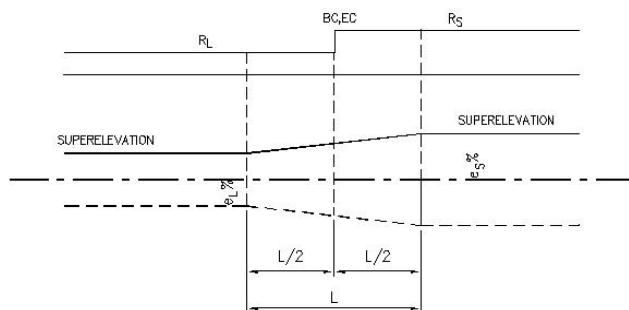
e = SUPERELEVATION (%)



TYPE-3 COMPOUND CURVE ($R_L \sim R_S$)

R_L = LARGE CURVE

R_S = SMALL CURVE



Super elevation applied are listed by station in the following.

No.	Station	Horizontal Alignment	Design Speed	Super Elevation (e%)		BC or EC	Type
				North-South	South-North		
1	0-120.000	R=∞	V=50km/h		-2.000%		
2	0-100.000	R=∞	V=50km/h	-2.000%	-2.000%		
3	0-080.000	R=∞	V=50km/h	-2.000%	-2.000%		
4	0-060.000	R=∞	V=50km/h	-2.000%	-2.000%		
5	0-040.000	R=∞	V=50km/h	-2.000%	-2.000%		
6	0-020.000	R=∞	V=50km/h	2.000%	-2.000%		
7	0+000.000	R=∞	V=50km/h	2.000%	-2.000%		
8	0+020.000	R=∞	V=50km/h	2.000%	-2.000%		
9	0+040.000	R=∞	V=50km/h	-2.000%	-2.000%		
10	0+060.000	R=∞	V=50km/h	-2.000%	-2.000%		
11	0+080.000	R=∞	V=50km/h	-2.000%	-2.000%		
12	0+100.000	R=∞	V=50km/h	-2.000%	-2.000%		
13	0+120.000	R=∞	V=50km/h	-2.000%	-2.000%		
14	0+140.000	R=∞	V=50km/h	-2.000%	-2.000%		
15	0+160.000	R=∞	V=50km/h	-2.000%	-2.000%		
16	0+180.000	R=∞	V=50km/h	-2.000%	-2.000%		
17	0+200.000	R=∞	V=50km/h	-2.000%	-2.000%		
18	0+220.000	R=∞	V=50km/h	-2.000%	-2.000%		
19	0+240.000	R=∞	V=50km/h	-2.000%	-2.000%		
20	0+260.000	R=∞	V=50km/h	-2.000%	-2.000%		
21	0+280.000	R=∞	V=50km/h	-2.000%	-2.000%		
22	0+300.000	R=∞	V=50km/h	-2.000%	-2.000%		
23	0+320.000	R=∞	V=50km/h	-2.000%	-2.000%		
24	0+340.000	R=∞	V=50km/h	-2.000%	-2.000%		
25	0+360.000	R=∞	V=50km/h	-2.000%	-2.000%		
26	0+380.000	R=∞	V=50km/h	-2.000%	-2.000%		
27	0+400.000	R=∞	V=50km/h	-2.000%	-2.000%		
28	0+415.000	R=∞	V=50km/h	-2.000%	-2.000%		
29	0+420.000	R=∞	V=50km/h	-2.355%	1.200%		
30	0+435.592	R=150	V=50km/h			BC	Type1
31	0+440.000	R=150	V=50km/h	-3.777%	2.000%		
32	0+460.000	R=150	V=50km/h	-5.200%	5.200%		
33	0+480.000	R=150	V=50km/h	-5.200%	5.200%		
34	0+500.000	R=150	V=50km/h	-5.200%	5.200%		
35	0+520.000	R=150	V=50km/h	-5.200%	5.200%		

				Super Elevation (e%)			
36	0+540.000	R=150	V=50km/h	-5.200%	5.200%		
37	0+560.000	R=150	V=50km/h	-5.200%	5.200%		
38	0+580.000	R=150	V=50km/h	-3.777%	2.000%		
39	0+585.801	R=150	V=50km/h			EC	Type1
40	0+600.000	R=∞	V=50km/h	-2.355%	-1.200%		
41	0+605.000	R=∞	V=50km/h	-2.000%	-2.000%		
42	0+620.000	R=∞	V=50km/h	-2.000%	-2.000%		
43	0+640.000	R=∞	V=50km/h	1.300%	-3.300%		
44	0+640.987	R=-200	V=50km/h			BC	Type1
45	0+660.000	R=-200	V=50km/h	4.600%	-4.600%		
46	0+680.000	R=-200	V=50km/h	4.600%	-4.600%		
47	0+700.000	R=-200	V=50km/h	4.600%	-4.600%		
48	0+716.497	R=-200	V=50km/h			EC	Type1
49	0+720.000	R=∞	V=50km/h	1.300%	-3.300%		
50	0+740.000	R=∞	V=50km/h	-2.000%	-2.000%		
51	0+760.000	R=∞	V=50km/h	-2.000%	-2.000%		
52	0+780.000	R=∞	V=50km/h	-2.000%	-2.000%		
53	0+800.000	R=∞	V=50km/h	-2.000%	-2.000%		
54	0+820.000	R=∞	V=50km/h	-2.000%	-2.000%		
55	0+835.000	R=∞	V=50km/h	-2.000%	-2.000%		
56	0+840.000	R=∞	V=50km/h	-1.171%	-2.257%		
57	0+854.887	R=-300	V=50km/h			BC	Type1
58	0+860.000	R=-300	V=50km/h	2.143%	-3.286%		
59	0+870.000	R=-300	V=50km/h	3.800%	-3.800%		
60	0+880.000	R=-300	V=50km/h	3.800%	-3.800%		
61	0+900.000	R=-300	V=50km/h	3.800%	-3.800%		
62	0+915.000	R=-300	V=50km/h	3.800%	-3.800%		
63	0+920.000	R=-300	V=50km/h	2.971%	-3.584%		
64	0+932.897	R=-300	V=50km/h			EC	Type1
65	0+940.000	R=∞	V=50km/h	-0.343%	-2.514%		
66	0+950.000	R=∞	V=50km/h	-2.000%	-2.000%		
67	0+960.000	R=∞	V=50km/h	-2.000%	-2.000%		
68	0+980.000	R=∞	V=50km/h	-2.000%	-2.000%		
69	1+000.000	R=∞	V=50km/h	-2.000%	-2.000%		
70	1+020.000	R=∞	V=50km/h	-2.000%	-2.000%		
71	1+040.000	R=∞	V=50km/h	-2.000%	-2.000%		
72	1+060.000	R=∞	V=50km/h	-2.000%	-2.000%		
73	1+080.000	R=∞	V=50km/h	-2.000%	-2.000%		
74	1+100.000	R=∞	V=50km/h	-2.000%	-2.000%		

				Super Elevation (e%)			
75	1+115.000	R=∞	V=50km/h	-2.000%	-2.000%		
76	1+120.000	R=∞	V=50km/h	-2.355%	-1.200%		
77	1+137.085	R=150	V=50km/h			BC	Type1
78	1+140.000	R=150	V=50km/h	-3.777%	2.000%		
79	1+160.000	R=150	V=50km/h	-5.200%	5.200%		
80	1+180.000	R=150	V=50km/h	-5.200%	5.200%		
81	1+200.000	R=150	V=50km/h	-5.200%	5.200%		
82	1+220.000	R=150	V=50km/h	-1.733%	1.733%		
83	1+227.881	R=150	V=50km/h			EC	
84	1+230.000			0.000%	0.000%		Type1
85	1+235.853	R=-150	V=50km/h			BC	
86	1+240.000	R=-150	V=50km/h	1.733%	-1.733%		
87	1+260.000	R=-150	V=50km/h	5.200%	-5.200%		
88	1+280.000	R=-150	V=50km/h	5.200%	-5.200%		
89	1+292.500	R=-150	V=50km/h	5.200%	-5.200%		
90	1+300.000	R=-150	V=50km/h	4.000%	-4.667%		
91	1+314.969	R=-150	V=50km/h			EC	Type1
92	1+320.000	R=∞	V=50km/h	0.800%	-3.244%		
93	1+337.500	R=∞	V=50km/h	-2.000%	-2.000%		
94	1+340.000	R=∞	V=50km/h	-2.000%	-2.000%		
95	1+360.000	R=∞	V=50km/h	-2.000%	-2.000%		
96	1+365.000	R=∞	V=50km/h	-2.000%	-2.000%		
97	1+379.549	R=500	V=50km/h			BC	Type1
98	1+380.000	R=500	V=50km/h	-2.400%	0.400%		
99	1+395.000	R=500	V=50km/h	-2.800%	2.800%		
100	1+400.000	R=500	V=50km/h	-2.800%	2.800%		
101	1+420.000	R=500	V=50km/h	-2.800%	2.800%		
102	1+440.000	R=500	V=50km/h	-2.800%	2.800%		
103	1+460.000	R=500	V=50km/h	-2.800%	2.800%		
104	1+480.000	R=500	V=50km/h	-2.800%	2.800%		
105	1+500.000	R=500	V=50km/h	-2.800%	2.800%		
106	1+520.000	R=500	V=50km/h	-2.800%	2.800%		
107	1+535.000	R=500	V=50km/h	-2.800%	2.800%		
108	1+540.000	R=500	V=50km/h	-2.667%	2.000%		
109	1+548.145	R=500	V=50km/h			EC	Type1
110	1+560.000	R=∞	V=50km/h	-2.133%	-1.200%		
111	1+565.000	R=∞	V=50km/h	-2.000%	-2.000%		
112	1+580.000	R=∞	V=50km/h	-2.000%	-2.000%		
113	1+600.000	R=∞	V=50km/h	-2.000%	-2.000%		

				Super Elevation (e%)			
114	1+620.000	R=∞	V=50km/h	-2.000%	-2.000%		
115	1+640.000	R=∞	V=50km/h	-2.000%	-2.000%		
116	1+660.000	R=∞	V=50km/h	-2.000%	-2.000%		
117	1+680.000	R=∞	V=50km/h	-2.000%	-2.000%		
118	1+700.000	R=∞	V=50km/h	-2.000%	-2.000%		
119	1+720.000	R=∞	V=50km/h	-2.000%	-2.000%		
120	1+740.000	R=∞	V=50km/h	-2.000%	-2.000%		
121	1+745.000	R=∞	V=50km/h	-2.000%	-2.000%		
122	1+758.238	R=500	V=50km/h			BC	Type1
123	1+760.000	R=500	V=50km/h	-2.400%	0.400%		
124	1+775.000	R=500	V=50km/h	-2.800%	2.800%		
125	1+780.000	R=500	V=50km/h	-2.800%	2.800%		
126	1+800.000	R=500	V=50km/h	-2.800%	2.800%		
127	1+820.000	R=500	V=50km/h	-2.800%	2.800%		
128	1+840.000	R=500	V=50km/h	-2.800%	2.800%		
129	1+860.000	R=500	V=50km/h	-2.800%	2.800%		
130	1+880.000	R=500	V=50km/h	-2.800%	2.800%		
131	1+900.000	R=500	V=50km/h	-2.800%	2.800%		
132	1+920.000	R=500	V=50km/h	-2.800%	2.800%		
133	1+935.000	R=500	V=50km/h	-2.800%	2.800%		
134	1+940.000	R=500	V=50km/h	-2.667%	2.000%		
135	1+951.155	R=500	V=50km/h			EC	Type1
136	1+960.000	R=∞	V=50km/h	-2.133%	-1.200%		
137	1+965.000	R=∞	V=40km/h	-2.000%	-2.000%		
138	1+980.000	R=∞	V=40km/h	-2.000%	-2.000%		
139	1+992.500	R=∞	V=40km/h	-2.000%	-2.000%		
140	2+000.000	R=∞	V=40km/h	-2.471%	-0.671%		
141	2+010.966	R=150	V=40km/h			BC	Type1
142	2+020.000	R=150	V=40km/h	3.729%	2.871%		
143	2+027.500	R=150	V=40km/h	-4.200%	4.200%		
144	2+040.000	R=150	V=40km/h	-4.200%	4.200%		
145	2+060.000	R=150	V=40km/h	-4.200%	4.200%		
146	2+080.000	R=150	V=40km/h	-4.200%	4.200%		
147	2+100.000	R=150	V=40km/h	-4.200%	4.200%		
148	2+120.000	R=150	V=40km/h	-4.200%	4.200%		
149	2+127.500	R=150	V=40km/h	-4.200%	4.200%		
150	2+140.000	R=150	V=40km/h	-3.414%	1.986%		
151	2+143.686	R=150	V=40km/h			EC	Type1
152	2+160.000	R=∞	V=40km/h	2.157%	-1.557%		

				Super Elevation (e%)			
153	2+162.500	R=∞	V=40km/h	-2.000%	-2.000%		
154	2+177.500	R=∞	V=40km/h	-2.000%	-2.000%		
155	2+180.000	R=∞	V=40km/h	-1.556%	-2.222%		
156	2+200.000	R=∞	V=40km/h	2.000%	-4.000%		
157	2+202.269	R=-50	V=40km/h			BC	Type1
158	2+220.000	R=-50	V=40km/h	5.556%	-5.778%		
159	2+222.500	R=-50	V=40km/h	6.000%	-6.000%		
160	2+240.000	R=-50	V=40km/h	6.000%	-6.000%		
161	2+260.000	R=-50	V=40km/h	6.000%	-6.000%		
162	2+262.500	R=-50	V=40km/h	6.000%	-6.000%		
163	2+280.000	R=-50	V=40km/h	2.889%	-4.444%		
164	2+283.169	R=-50	V=40km/h			EC	Type1
165	2+300.000	R=∞	V=40km/h	-0.667%	-2.667%		
166	2+307.500	R=∞	V=40km/h	-2.000%	-2.000%		
167	2+320.000	R=∞	V=40km/h	-2.000%	-2.000%		
168	2+340.000	R=∞	V=40km/h	-2.000%	-2.000%		
169	2+342.500	R=∞	V=40km/h	-2.000%	-2.000%		
170	2+360.000	R=∞	V=40km/h	-3.556%	1.111%		
171	2+363.987	R=55	V=40km/h			BC	Type1
172	2+380.000	R=55	V=40km/h	-5.333%	4.667%		
173	2+387.500	R=55	V=40km/h	-6.000%	6.000%		
174	2+400.000	R=55	V=40km/h	-4.889%	3.778%		
175	2+410.629	R=55	V=40km/h			EC	Type1
176	2+420.000	R=∞	V=40km/h	-3.111%	0.222%		
177	2+432.500	R=∞	V=40km/h	-2.000%	-2.000%		
178	2+440.000	R=∞	V=40km/h	-2.000%	-2.000%		
179	2+442.500	R=∞	V=40km/h	-2.000%	-2.000%		
180	2+460.000	R=∞	V=40km/h	1.111%	-3.556%		
181	2+466.939	R=-45	V=40km/h			BC	Type1
182	2+480.000	R=-45	V=40km/h	4.667%	-5.333%		
183	2+487.500	R=-45	V=40km/h	6.000%	-6.000%		
184	2+500.000	R=-45	V=40km/h	6.000%	-6.000%		
185	2+520.000	R=-45	V=40km/h	6.000%	-6.000%		
186	2+530.000	R=-45	V=40km/h	6.000%	-6.000%		
187	2+540.000	R=-45	V=40km/h	4.286%	-4.286%		
188	2+540.386	R=-45	V=40km/h			EC	
189	2+560.000	R=∞	V=40km/h	0.857%	-0.857%		Type1
190	2+565.000	R=∞	V=40km/h	0.000%	0.000%		
191	2+575.075	R=400	V=40km/h	-0.867%	0.867%	BC	

					Super Elevation (e%)		
193	2+580.000	R=400	V=40km/h	-2.600%	2.600%		
194	2+600.000	R=400	V=40km/h	-2.600%	2.600%		
195	2+620.000	R=400	V=40km/h	-2.600%	2.600%		
196	2+640.000	R=400	V=40km/h	-2.600%	2.600%		
197	2+660.000	R=400	V=40km/h	-2.600%	2.600%		
198	2+680.000	R=400	V=40km/h	-2.600%	2.600%		
199	2+700.000	R=400	V=40km/h	-2.600%	2.600%		
200	2+720.000	R=400	V=40km/h	-2.600%	2.600%		
200	2+727.500	R=400	V=40km/h	-2.600%	2.600%		
201	2+740.000	R=400	V=40km/h	-2.300%	0.300%		
202	2+742.124	R=400	V=40km/h			EC	Type1
203	2+752.500	R=400	V=40km/h	-2.000%	-2.000%		
204	2+760.000	R=∞	V=40km/h	-2.000%	-2.000%		
205	2+780.000	R=∞	V=40km/h	-2.000%	-2.000%		
206	2+800.000	R=∞	V=40km/h	-2.000%	-2.000%		
207	2+820.000	R=∞	V=40km/h	-2.000%	-2.000%		
208	2+840.000	R=∞	V=40km/h	-2.000%	-2.000%		
209	2+860.000	R=∞	V=40km/h	-2.000%	-2.000%		
210	2+880.000	R=∞	V=40km/h	-2.000%	-2.000%		
211	2+900.000	R=∞	V=40km/h	-2.000%	-2.000%		
212	2+920.000	R=∞	V=40km/h	-2.000%	-2.000%		
213	2+934.482	R=250	V=40km/h			BC	Type1
214	2+940.000	R=250	V=40km/h	-2.933%	1.600%		
215	2+950.000	R=250	V=40km/h	-3.400%	3.400%		
216	2+960.000	R=250	V=40km/h	-3.400%	3.400%		
217	2+980.000	R=250	V=40km/h	-3.400%	3.400%		
218	3+000.000	R=250	V=40km/h	-3.400%	3.400%		
219	3+020.000	R=250	V=40km/h	-3.400%	3.400%		
220	3+040.000	R=250	V=40km/h	-3.400%	3.400%		
221	3+060.000	R=250	V=40km/h	-3.400%	3.400%		
222	3+080.000	R=250	V=40km/h	-3.400%	3.400%		
223	3+095.000	R=250	V=40km/h	-3.400%	3.400%		
224	3+100.000	R=250	V=40km/h	-2.555%	2.555%		
225	3+102.966	R=250	V=50km/h			EC	
226	3+115.000	R=∞	V=50km/h	0.000%	0.000%		Type2
227	3+120.000	R=∞	V=50km/h	0.867%	-0.867%		
228	3+126.489	R=-150	V=50km/h			BC	
229	3+140.000	R=-150	V=50km/h	4.333%	-4.333%		
230	3+145.000	R=-150	V=50km/h	5.200%	-5.200%		

				Super Elevation (e%)			
231	3+160.000	R=-150	V=50km/h	5.200%	-5.200%		
232	3+180.000	R=-150	V=50km/h	5.200%	-5.200%		
233	3+200.000	R=-150	V=50km/h	5.200%	-5.200%		
234	3+220.000	R=-150	V=50km/h	5.200%	-5.200%		
235	3+235.000	R=-150	V=50km/h	5.200%	-5.200%		
236	3+240.000	R=-150	V=50km/h	4.333%	-4.333%		
237	3+260.000	R=-150	V=50km/h	0.867%	-0.866%		
238	3+265.000	R=-150	V=50km/h	0.000%	0.000%		
239	3+265.597	R=-150	V=50km/h			EC	Type2
240	3+279.289	R=150	V=50km/h			BC	
241	3+280.000	R=150	V=50km/h	2.600%	2.600%		
242	3+295.000	R=150	V=50km/h	-5.200%	5.200%		
243	3+300.000	R=150	V=50km/h	-5.200%	5.200%		
244	3+320.000	R=150	V=50km/h	-5.200%	5.200%		
245	3+340.000	R=150	V=50km/h	-5.200%	5.200%		
246	3+360.000	R=150	V=50km/h	-5.200%	5.200%		
247	3+380.000	R=150	V=50km/h	-5.200%	5.200%		
248	3+400.000	R=150	V=50km/h	-5.200%	5.200%		
249	3+407.500	R=150	V=50km/h	-5.200%	5.200%		
250	3+420.000	R=150	V=50km/h	-4.311%	3.200%		
251	3+428.868	R=150	V=50km/h			EC	Type1
252	3+440.000	R=∞	V=50km/h	-2.889%	0.000%		
253	3+452.500	R=∞	V=50km/h	-2.000%	-2.000%		
254	3+460.000	R=∞	V=50km/h	-2.000%	-2.000%		
255	3+480.000	R=∞	V=50km/h	-2.000%	-2.000%		
256	3+500.000	R=∞	V=50km/h	-2.000%	-2.000%		
257	3+502.500	R=∞	V=50km/h	-2.000%	-2.000%		
258	3+520.000	R=∞	V=50km/h	1.100%	-3.100%		
259	3+520.611	R=-250	V=50km/h			BC	Type1
260	3+537.500	R=-250	V=50km/h	4.200%	-4.200%		
261	3+540.000	R=-250	V=50km/h	4.200%	-4.200%		
262	3+557.500	R=-250	V=50km/h	4.200%	-4.200%		
263	3+560.000	R=-250	V=50km/h	3.757%	-4.043%		
264	3+575.394	R=-250	V=50km/h			EC	Type1
265	3+580.000	R=∞	V=50km/h	0.214%	-2.786%		
266	3+592.500	R=∞	V=50km/h	-2.000%	-2.000%		
267	3+600.000	R=∞	V=50km/h	-2.000%	-2.000%		
268	3+620.000	R=∞	V=50km/h	-2.000%	-2.000%		
269	3+640.000	R=∞	V=50km/h	-2.000%	-2.000%		

				Super Elevation (e%)		
270	3+660.000	R=∞	V=50km/h	-2.000%	-2.000%	
271	3+680.000	R=∞	V=50km/h	-2.000%	-2.000%	
272	3+700.000	R=∞	V=50km/h	-2.000%	-2.000%	
273	3+720.000	R=∞	V=50km/h	-2.000%	-2.000%	
274	3+740.000	R=∞	V=50km/h	-2.000%	-2.000%	
275	3+760.000	R=∞	V=50km/h	-2.000%	-2.000%	
276	3+777.500	R=∞	V=50km/h	-2.000%	-2.000%	
277	3+780.000	R=∞	V=50km/h	-2.129%	-1.586%	
278	3+793.856	R=300	V=50km/h			BC
279	3+800.000	R=300	V=50km/h	-3.157%	1.729%	
280	3+812.500	R=300	V=50km/h	-3.800%	3.800%	
281	3+820.000	R=300	V=50km/h	-3.800%	3.800%	
282	3+840.000	R=300	V=50km/h	-3.800%	3.800%	
283	3+842.500	R=300	V=50km/h	-3.800%	3.800%	
284	3+857.636	R=300	V=50km/h			EC
285	3+860.000	R=∞	V=50km/h	-2.900%	0.900%	
286	3+777.500	R=∞	V=50km/h	-2.000%	-2.000%	
287	3+880.000	R=∞	V=50km/h	-2.000%	-2.000%	
288	3+900.000	R=∞	V=50km/h	-2.000%	-2.000%	
289	3+920.000	R=∞	V=50km/h	-2.000%	-2.000%	
290	3+937.500	R=∞	V=50km/h	-2.000%	-2.000%	
291	3+940.000	R=∞	V=50km/h	-1.586%	-2.129%	
292	3+954.348	R=-300	V=50km/h			BC
293	3+960.000	R=-300	V=50km/h	1.729%	-3.157%	
294	3+972.500	R=-300	V=50km/h	3.800%	-3.800%	
295	3+980.000	R=-300	V=50km/h	3.800%	-3.800%	
296	3+995.000	R=-300	V=50km/h	3.800%	-3.800%	
297	4+000.000	R=-300	V=50km/h	3.040%	-3.040%	
298	4+020.000	R=-300	V=50km/h	0.000%	0.000%	
299	4+025.162	R=-300	V=50km/h			EC
300	4+028.903	R=180	V=50km/h			BC
301	4+040.000	R=180	V=50km/h	-3.200%	3.200%	
302	4+050.000	R=180	V=50km/h	-4.800%	4.800%	
303	4+060.000	R=180	V=50km/h	-4.800%	4.800%	
304	4+080.000	R=180	V=50km/h	-4.800%	4.800%	
305	4+090.000	R=180	V=50km/h	-4.800%	4.800%	
306	4+100.000	R=180	V=50km/h	-3.200%	3.200%	
307	4+106.673	R=180	V=50km/h			EC
308	4+120.000	R=∞	V=50km/h	0.000%	0.000%	Type2

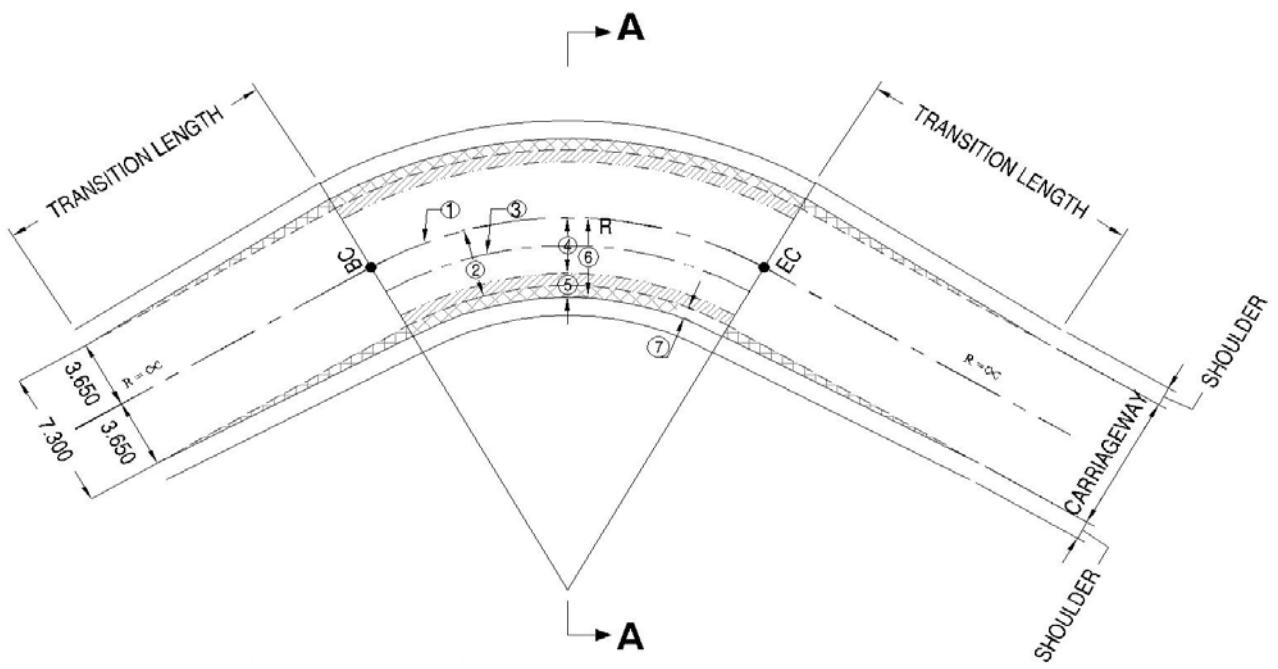
				Super Elevation (e%)			
309	4+134.365	R=-250	V=50km/h			BC	
310	4+140.000	R=-250	V=50km/h	3.360%	3.360%		
311	4+145.000	R=-250	V=50km/h	4.200%	-4.200%		
312	4+160.000	R=-250	V=50km/h	4.200%	-4.200%		
313	4+172.500	R=-250	V=50km/h	4.200%	-4.200%		
314	4+180.000	R=-250	V=50km/h	2.871%	-3.729%		
315	4+187.576	R=-250	V=50km/h			EC	Type1
316	4+200.000	R=∞	V=50km/h	0.671%	-2.471%		
317	4+207.500	R=∞	V=50km/h	-2.000%	-2.000%		
318	4+220.000	R=∞	V=50km/h	-2.000%	-2.000%		
319	4+240.000	R=∞	V=50km/h	-2.000%	-2.000%		
320	4+252.500	R=∞	V=50km/h	-2.000%	-2.000%		
321	4+260.000	R=∞	V=50km/h	-2.060%	0.740%		
322	4+266.506	R=680	V=50km/h			BC	Type1
323	4+277.500	R=680	V=50km/h	-2.200%	2.200%		
324	4+280.000	R=680	V=50km/h	-2.200%	2.200%		
325	4+300.000	R=680	V=50km/h	-2.200%	2.200%		
326	4+320.000	R=680	V=50km/h	-2.200%	2.200%		
327	4+340.000	R=680	V=50km/h	-2.200%	2.200%		
328	4+360.000	R=680	V=50km/h	-2.200%	2.200%		
329	4+380.000	R=680	V=50km/h	-2.200%	2.200%		
330	4+400.000	R=680	V=50km/h	-2.200%	2.200%		
331	4+420.000	R=680	V=50km/h	-2.200%	2.200%		
332	4+440.000	R=680	V=50km/h	-2.200%	2.200%		
333	4+460.000	R=680	V=50km/h	-2.200%	2.200%		
334	4+480.000	R=680	V=50km/h	-2.200%	2.200%		
335	4+490.000	R=680	V=50km/h	-2.200%	2.200%		
336	4+500.000	R=680	V=50km/h	-3.600%	3.600%		
337	4+500.443	R=680	V=50km/h			EC	
338	4+500.556	R=170	V=50km/h			BC	Type3
339	4+510.000	R=170	V=50km/h	-5.000%	5.000%		
340	4+520.000	R=170	V=50km/h	-5.000%	5.000%		
341	4+530.000	R=170	V=50km/h	-5.000%	5.000%		
342	4+540.000	R=170	V=50km/h	-4.250%	3.250%		
343	4+555.470	R=170	V=50km/h			EC	Type1
344	4+560.000	R=∞	V=50km/h	-2.750%	-0.250%		
345	4+570.000	R=∞	V=50km/h	-2.000%	-2.000%		
346	4+580.000	R=∞	V=50km/h	-0.300%	-2.700%		
347	4+585.815	R=-180	V=50km/h			BC	Type1

				Super Elevation (e%)			
348	4+600.000	R=-180	V=50km/h	3.100%	-4.100%		
349	4+610.000	R=-180	V=50km/h	4.800%	-4.800%		
350	4+620.000	R=-180	V=50km/h	4.800%	-4.800%		
351	4+640.000	R=-180	V=50km/h	4.800%	-4.800%		
352	4+645.000	R=-180	V=50km/h	4.800%	-4.800%		
353	4+660.000	R=-180	V=50km/h	2.400%	-2.400%		
354	4+672.869	R=-180	V=50km/h			EC	
355	4+675.000	R=∞	V=50km/h	0.000%	0.000%		Type2
356	4+676.266	R=250	V=50km/h			BC	
357	4+680.000	R=250	V=50km/h	-0.840%	0.840%		
358	4+700.000	R=250	V=50km/h	-4.200%	4.200%		
359	4+720.000	R=250	V=50km/h	-4.200%	4.200%		
360	4+740.000	R=250	V=50km/h	-4.200%	4.200%		
361	4+760.000	R=250	V=50km/h	-4.200%	4.200%		
362	4+780.000	R=250	V=50km/h	-4.200%	4.200%		
363	4+800.000	R=250	V=50km/h	-4.200%	4.200%		
364	4+820.000	R=250	V=50km/h	-4.200%	4.200%		
365	4+840.000	R=250	V=50km/h	-4.200%	4.200%		
366	4+852.500	R=250	V=40km/h	-4.200%	4.200%		
367	4+860.000	R=250	V=40km/h	-3.729%	2.871%		
368	4+870.815	R=250	V=40km/h			EC	Type1
369	4+880.000	R=∞	V=40km/h	-2.471%	-0.671%		
370	4+887.500	R=∞	V=40km/h	-2.000%	-2.000%		
371	4+900.000	R=∞	V=40km/h	-2.000%	-2.000%		
372	4+920.000	R=∞	V=40km/h	-2.000%	-2.000%		
373	4+940.000	R=∞	V=40km/h	-2.000%	2.000%		
374	4+940.283	R=400	V=40km/h			BC	
375	4+951.995	R=400	V=40km/h	-2.000%	2.000%		

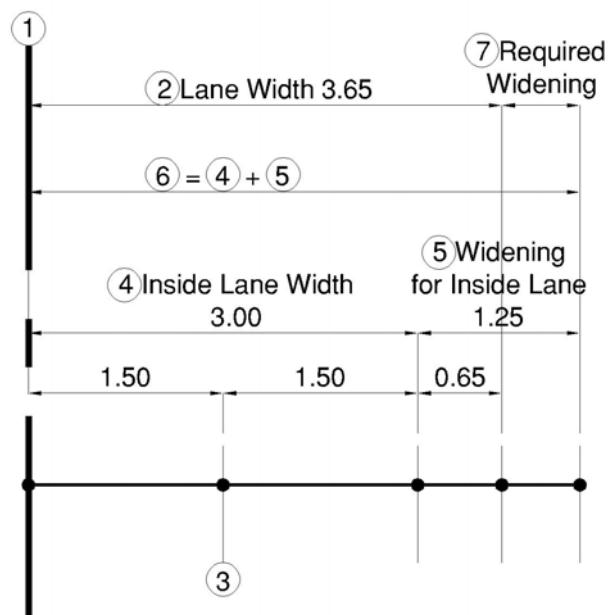
2.2 Widening

The Project road width is widened at curves to accommodate semi-trailer traffic. Since the design road width is 3.65 m, which is relatively large to vehicle width of 2.5 m, widening at curve is designed accounting the inside lane width of 3 m.

- | | |
|--------------------------------|----------------------------|
| ① Radius of Bypass Center Line | ⑤ Widening for Inside Lane |
| ② Lane Width | ⑥ ④ + ⑤ |
| ③ Radius of Inside Center line | ⑦ Required Widening |
| ④ Inside lane width | |



Section A-A



Widening requires for the section with a horizontal radius of curve of less than 99 m. The required widening widths are listed in the table below according to the size of radius as well as transition length required for design speed of 40 km/h.

Radius	Widening Width	Transition Length
45~49m	0.6m	60m
50~69m	0.35m	35m
70~99m	0.1m	10m

In section-5, there are three continuous curves: R = 50 m, 55 m and 45 m. The following table shows curve section and widening width of the section.

No.	Station	① Radius of Bypass Center line	② Lane width (m)	③ Radius of Inside Center line	④ Inside lane width (m)	⑤ Widening for Inside lane (m)	⑥=④+⑤ (m)	⑦=⑥-② Required Widening (m)	BC,EC
1	2+160.000	R=∞	3.000	Section for Adjustment of Widening	3.000	1.000	4.000	0.350	BC
2	2+180.000	R=∞	3.130		3.300	1.000	4.000	0.350	
3	2+200.000	R=∞	3.330		3.660	1.000	4.000	0.350	
4	2+202.269	R=-50	3.650	R=-48.5	3.000	1.000	4.000	0.350	
5	2+220.000	R=-50	3.650	R=-48.5	3.000	1.000	4.000	0.350	
6	2+240.000	R=-50	3.650	R=-48.5	3.000	1.000	4.000	0.350	
7	2+260.000	R=-50	3.650	R=-48.5	3.000	1.000	4.000	0.350	
8	2+280.000	R=-50	3.650	R=-48.5	3.000	1.000	4.000	0.350	
9	2+283.169	R=-50	3.650	R=-48.5	3.000	1.000	4.000	0.350	EC
10	2+300.000	R=∞	3.650	Section for Adjustment of Widening	3.850	0.200			
11	2+320.000	R=∞	3.650		3.680	0.003			
12	2+324.000	R=∞	3.650		3.650	0.000			
13	2+340.000	R=∞	3.650		3.790	0.140			
14	2+360.000	R=∞	3.650		3.970	0.320			
15	2+363.987	R=55	3.650	R=53.5	3.000	1.000	4.000	0.350	BC
16	2+380.000	R=55	3.650	R=53.5	3.000	1.000	4.000	0.350	
17	2+400.000	R=55	3.650	R=53.5	3.000	1.000	4.000	0.350	
18	2+410.629	R=55	3.650	R=53.5	3.000	1.000	4.000	0.350	EC
19	2+420.000	R=∞	3.650	Section for Adjustment of Widening	3.920	0.270			
20	2+427.000	R=∞	3.650		3.850	0.200			
21	2+440.000	R=∞	3.650		3.980	0.330			
22	2+460.000	R=∞	3.650		4.180	0.530			
23	2+466.939	R=-45	3.650	R=-43.5	3.000	1.250	4.250	0.600	BC

Appendix A-2

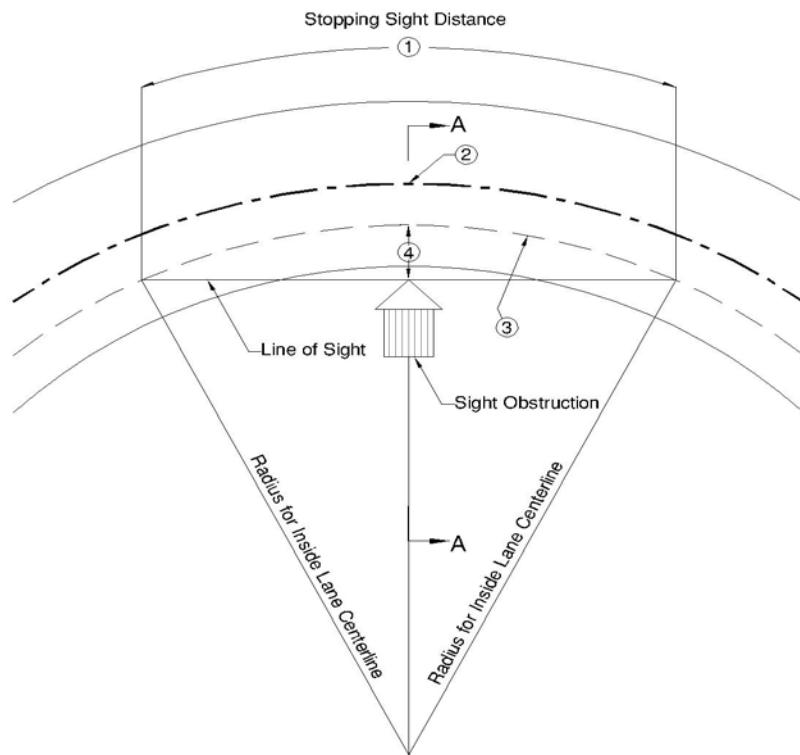
No.	Station	① Radius of Bypass Center line	② Lane width (m)	③ Radius of Inside Center line	④ Inside lane width (m)	⑤ Widening for Inside lane (m)	⑥=④+ ⑤ (m)	⑦=⑥− ② Require d Widenin g (m)	BC,EC
24	2+480.000	R=-45	3.650	R=-43.5	3.000	1.250	4.250	0.600	
25	2+500.000	R=-45	3.650	R=-43.5	3.000	1.250	4.250	0.600	
26	2+520.000	R=-45	3.650	R=-43.5	3.000	1.250	4.250	0.600	
27	2+540.000	R=-45	3.650	R=-43.5	3.000	1.250	4.250	0.600	
28	2+540.386	R=-45	3.650	R=-43.5	3.000	1.250	4.250	0.600	EC
29	2+560.000	R=∞	3.650	Section for Adjustment of Widening				4.060	0.410
30	2+575.075	R=400	3.650					3.900	0.250
31	2+580.000	R=400	3.650					3.850	0.200
32	2+600.000	R=400	3.650					3.650	0.000

2.3 Sight Distance

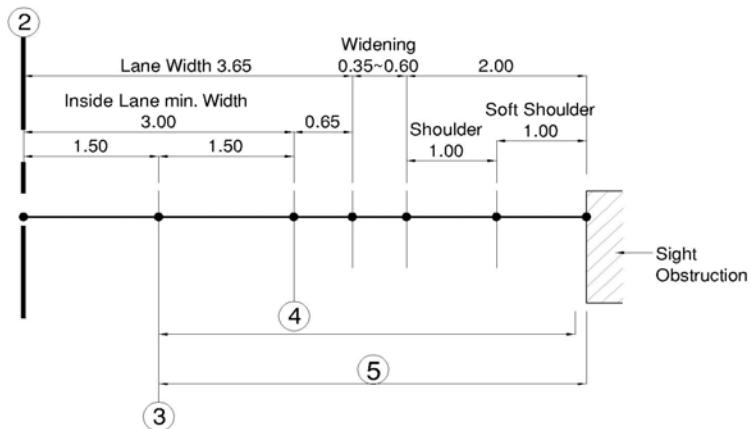
Stopping sight distance required for design speed of 40 km/h is 40 m.

Horizontal Sightline Offset, HOS, is ensured in the design as illustrated below.

- ① Stopping Sight Distance (D)
- ② Radius for Bypass Center Line
- ③ Radius for Inside lane Center line (R)
- ④ Horizontal Sightline Offset (HOS) * $HOS=D^2/8R$
- ⑤ Distance from Inside lane center line to Sight Obstruction



Section A-A



HOS is ensured for cutting section as well. HOS and Distance from centreline for inside lane to sight obstruction is listed in the table below.

No	Station		Design Speed	① Stopping Sight Distance	② Radius for Bypass Center line	③ Radius for Inside Lane Center line	④ Horizontal Sightline Offset (HOS)	⑤ Distance from centerline for inside lane to Sight Obstruction	⑤>④
	from	to							
1	2+160.000	2+283.169	V=40km/h	40m	R=50	R=48.5	4.124m	4.50m (1.5+0.65+0.35+2.0)	0.376m
2	2+363.987	2+410.629	V=40km/h	40m	R=55	R=53.5	3.739m	4.50m (1.5+0.65+0.35+2.0)	0.761m
3	2+466.939	2+466.939	V=40km/h	40m	R=45	R=43.5	4.598m	4.75m (1.5+0.65+0.60+2.0)	0.152m